Production matters
VTT in global trends

VTT

Production matters
VTT in global trends

Preface

The price of work in low-knowledge production is too high in many Western European countries. After the recession in 2008, structural change has speeded up, and many companies are moving their activities from Europe to low-salary countries, such as China and India. Mass production in particular is facing problems. Furthermore, in many countries the exodus of the manufacturing industry has led design and other industrial activities to relocate as well. All possible actions and means of research should be employed to avoid this.

The speed of globalisation is increasing and at the same time the economy has been highly uncertain. For several years the business environment has been struggling to avoid a new crisis instead of pursuing sustainable growth. These days have been exceptionally hard for the industry – companies have been waiting for better days, and have thus postponed ordinary investments and decisions for too long. That has prevented them from focusing on long-term business visions.

The best way to ensure that manufacturing remains a major part of industry in Europe is to specialise in types of production in which special skills are required and the price of the workforce is not a key factor. This is easiest with products that are highly innovative. Due to historical reasons, the industrial forms of manufacturing activities are quite different in different parts of Europe. The global factory of the future will comprise a company network that extends to countries where salaries are low, to countries where levels of competence are high, and to expanding market areas. It is vital to have effective business models.

We must have confidence that it is possible to create successful business in Europe also in the field of manufacturing, because production will still be a vital element in creating national welfare. To maintain and enhance the competitiveness of production, new innovative approaches and methods should be developed and implemented. Companies have taken a particular interest in investigating and developing new approaches, such as network manufacturing and broadranging implementation of industrial information technology.

Digital factory solutions that react quickly to unplanned events and challenges will ensure the economical and technical feasibility of individualised production. Unique and eco-efficient material design – including raw material selection, material performance and recycling aspects – is an essential part of manufacturing. In future, additive manufacturing may give the ability to produce highly complex designs. This will have a huge effect on resource use and logistics – and lead to radical changes in value networks and business models.

The great challenges facing the manufacturing industry are the transition from resource-oriented production to knowledge-oriented production and the transition from goods-oriented logic to service-oriented logic. This report describes VTT's research results that will help the manufacturing industry to deal with these challenges.

Production matters.

Risto Kuivanen
Rauno Heinonen

Contents

MANUFACTURING METHODS

FACTORY AND ENTERPRISE SYSTEMS

ENTERPRISE NETWORKS

Manufacturing methods

Augmented assembly (Augasse)

Tapio Salonen

One of the main challenges of introducing Augmented Reality technology into industrial applications is fast, reliable, low-cost authoring of animated AR content of product data created in 3D CAD systems. Here, a product data information pipeline from commercial CAD systems used in industry to a marker-based augmented reality system is presented. The pipeline uses the ISO 10303 (STEP) data protocol, Design for Assembly Tool and VTT's proprietary content-creation and augmenting software. The pipeline is verified with a real industrial application.
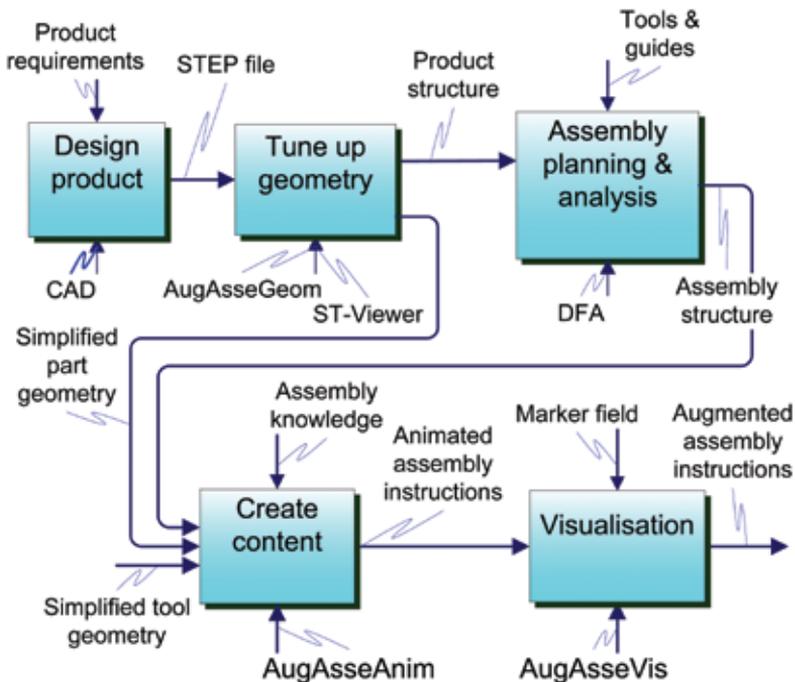
Figure 1. Overview of the method. A commercial CAD system is used in the 'Design prod-uct' phase. In the 'Tune up geometry' phase, commercial STEP software and an in-house software pro-gram are used. In the 'Assembly planning' phase and the 'Analysis' phase, DFA software is used to add assembly tools, guides and an assembly structure. In the 'Create content' phase, augmented assembly instructions are created and, in the end, the visualized instruction of the assembly work.
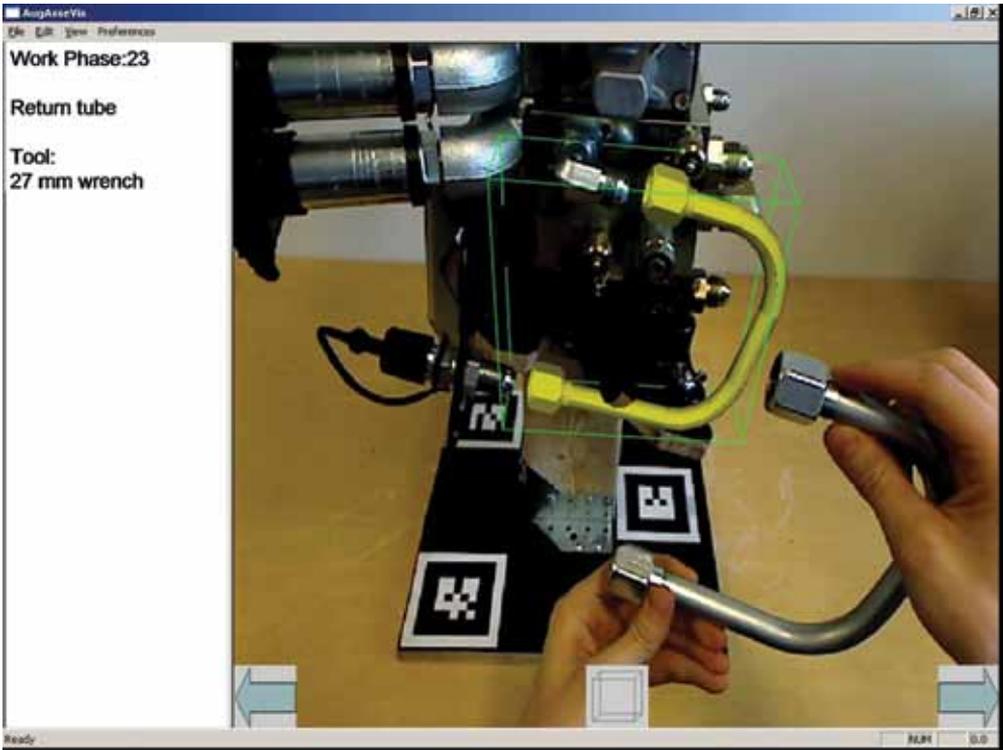
Figure 2. Animation example.

Introduction

The development of Augmented Reality (AR) technology was initiated in the 1990s as a parallel technology to Virtual Reality. In Augmented Reality, virtual objects are combined with the real surroundings seen with the human eye. The augmented view is projected onto, for example, a computer screen or miniature PC, or seen through data glasses. In Augmented Reality, VTT's main focus is on industrial applications in which augmenting is believed to have major potential and provide strong benefits.

Methodology

Figure 1 shows the proposed methodology for creating the AR instructions from the product's 3D model. First, the CAD model is exported to a standard STEP (ISO 10303 203) format file that includes the product structure and 3D geometry model of the product.

The 3D model is first triangulated to the appropriate coarseness level and the product structure extracted. The 3D model is split into 3D part models that refer to the product structure.

As a result of the designer's preferences for company-specific part libraries and features of typical CAD systems, the generated product structure usually does not conform to the real parts to be assembled in manufacturing. The assembly structure and order therefore have to be re-created from the product structure. The assembly tools, operations and guides also have to be added. As well as creating the right assembly structure and adding assembly instructions, the main purpose of the DFA Tool is to analyse the created assembly. The basic idea is to simplify the assembly and product structure.

In the 'Create content' phase, animations of the parts are created for the assembly

work. When the animations have been defined for each assembly phase, the whole assembly process can be simulated. The user can see any animated assembly work phase or the whole animated assembly work.

In the 'Visualization' phase, the user can see animations that demonstrate the assembly work of a device (Figure 2). The 3D model of each assembly part is in a separate file and the assembly order, animation definitions, assembly instructions and references to the part files are contained in another file.

In this project, a standard USB webcam and markers are used for tracking 3D models in the real environment.

Results

In this project, we have developed a methodology for applying 3D product data created in commercial CAD systems to AR applications and then to the AR instructions [1]. The data pipeline exploits the STEP data protocol available in practically all CAD systems. The data pipeline is tested in a real industry case, in the assembly of the power unit of a tractor accessory at the Finnish tractor factory Valtra Plc. The project also examined how modern smartphones could be used in augmented reality devices. Currently, the biggest lack of use of AR technology is on the hardware side. Head-mounted displays felt uncomfortable (weight, screen alignment of the eye, wires).

Students carried out the assembly work of the hydraulic block in spring 2008 at Tampere University of Technology. Eighty-nine persons (74 men and 15 women) participated in this experiment over three weeks. The assembly work of the hydraulic block was carried out using the paper instructions (assembly drawing, parts list, assembly instructions) and the AR-based instructions. In the test, the paper instructions were compared with the assembly AR instructions, including the assembly time and the number of errors. The results were significant. The assembly work was accelerated by 15% and the number of errors reduced by 84%.

Users generally admired that the AR technology was visual and easy to understand. The AR technology was considered excellent. Tough things were simple and clear with the help of the AR animations. In fact, the work seemed straightforward and fun. In summary, it could be said that the AR technology enhanced work, showing a part/component of the assembly in the right place. Unproductive contemplation will end. Showing the correct order of the work phase will also accelerate the work.

Discussion and conclusions

Future research should explore whether the described augmentation process for assembly instructions improves assembly planning and whether the process might reveal errors in the assembly process earlier than in the product design process when design changes are easier and less expensive to make.

Exploitation potential

AR technology is a new interactive way of man-machine interaction. Digital information can be displayed to the user, combined with the right environment. The information may be text data, images, 3D models or any other visualized material. With AR technology, the information can be direct in a real environment and just to the right point, for example, the information of the part shown on the part etc. AR systems will reduce assembly times, accelerate learning of the assembly tasks and provide more quality assurance on the factory floor.

Augmented reality may be used in many other fields, such as education, training, welding, service, packaging and maintenance. For example, the employee typically does certain maintenance work only once. The AR-based guidance would then really help him/her. Similarly, the AR instructions in the training are very visual and effective.

Publications

Pyykkö, T. Lisätyn todellisuuden hyödyntäminen kokoonpanossa, Master's thesis. Tampere University of Technology, Tampere, Finland, 2008. (In Finnish.)

Salonen, T., Sääski, J., Woodward, C., Hakkarainen, M., Korkalo, O. & Rainio, K. Augmented assembly – Ohjaava kokoonpano. VTT Working Papers 138. VTT, Espoo, Finland, 2008. 32 p. + app. 36 p. (In Finnish.)

Sääski, J., Salonen, T., Liinasuo, M. Kuution kokoaminen AR-teknologian avulla. VTT Working Papers 89. VTT, Espoo, Finland, 2008. 27 p. + app. 1 p. (In Finnish.)

References

[1]   Salonen, T., Sääski, J., Woodward, C., Korkalo, O., Marstio, I. & Rainio, K. Data Pipeline from Cad to AR Based Assembly Instructions. Proceedings of the 2009 World Conference of Innovative Virtual Reality, WINVR09. 25–26 February, 2009, Chaton-sur-Chaone, France.

Transferable and reconfigurable production systems (LIIKU)

Timo Salmi

Introduction

Today, production faces increasing require-ments for flexibility and productivity: product life cycles are shortening, variety is increasing and production volumes are fluctuating, while production costs should be reduced. The com-petition puts pressure on automation, while, at the same time, the flexibility needs make auto-mation more difficult. Transferable or mobile production machines have been suggested as a potential solution to flexible and cost-effective production with the following advantages:

- Enabling reconfiguring of production systems, lines and workshops, and fast ramp-ups of new lines.
- Automation can be used according to the current needs.
- In the case of a varying production load, the capacity can be transferred where it is needed.
- The investment risks are reduced when the capacity is easily transferred and used somewhere else.
- When processing big products, the nec-essary large movements are achieved by mobile devices and the production devices are transferred instead of the product.
- Transferable production systems offer possibilities to make the product on site or near the customer through tailoring with industrial methods.

The aim of our research was to develop meth-ods and tools that enable fast building and transfer of production capacity according to the changing production situations and to develop concept solutions for different application areas.

Our approach was to find practical, cost-efficient solutions to industrial environments and situations in which production volumes vary and the number of diverse products and variants is high. Our aim was to cover different types of flexibilities, from pure volume increase to one-of-a-kind type production [1].

Methods

This project has a mostly constructive research approach, a concept development with analytic reasoning. The project started with an analy-sis of different application areas in order to find the solutions with most potential for transfer-able robotic systems and their restrictions and to define the requirements. The second phase was a survey of potential enabling technolo-gies and the selection of the building blocks for the concept. The main focus has been on the development of the different technological solu-tions for the concept of the transferable robotic system. A practical touch of real industrial needs was obtained in case studies.

Results

Our research found the solutions with most potential for the transferable robotic systems to be:

- easily transferable ready-to-use produc-tion cells
- a transferable universal robotic mod-ule/platform for the material handling of machine tools; see Figure 1

Figure 1. A conceptual picture of a transferable universal robotic platform for the material handling of machine tools.

Figure 2. A conceptual picture of a freely transformable robot platform used in a welding application.

- welding or other processing tasks of big products with a transferable robot system; see Figure 2.

It seems that the requirements of the main application areas are quite congruent while the focus varies from case to case:
- well-functioning, fast calibration routines, adaptability to inac-curacies
- ability to produce different products – versatility
- non-part-specific mechanics – especially in material handling
- the ability to adapt new products
- easy programming of new products – especially in process applications
- transferability and compact design
- easily made interconnections, integration to other systems
- easily transferable safety arrangements
- reconfigurability.

According to our technology survey, the required functions can be achieved using a variety of advanced technologies:
- a robot is a basic system component
- calibration methods and different sensor technologies are essential components: 2D and 3D machine vision, seam-tracking and other types of intelligent sensors

- versatile technologies for material handling, e.g. servo grippers for a large variety of parts and sensor-based material handling methods
- advanced programming methods to achieve easier new product implementation, at least partly automated off-line programming, e.g. CAD or module-based or parametric programming or sensor-based program creation, task-oriented programming or guiding
- a compact, integrated, easy-to-transfer platform using a modular structure in the mechanics, control system hardware and software could achieve reconfigurability
- instead, the self-navigation or self-movement functions are not the preliminary needs
- new types of safety sensors, laser scanners or vision-based safety systems are able to be integrated into the transferable platform, and with the new safety robot controllers it is possible to build space-saving, fenceless, intelligent and dynamic safety areas.

Many of the building blocks have similarities with those of modular ultra-flexible production units presented as Automation Islands [2]. The development work focused on several areas, e.g. the safety design met complicated challenges.

As a result, the project introduced two conceptual solutions with several stages according to the needs of the applications.

Discussion, conclusions and exploitation potential

Transferable robotic systems offer new possibilities to minimize investment risks and to find a new type of cost-effective solution to change the production environment. There are also several challenges to be solved, but application areas were found where this type of solutions has special potential. As a result, some concept solutions have been presented. The development work also has meaning in a wider perspective: most results are relevant in production systems in which flexibility, changeability and reactability are favourable. The concept has combined the approaches of Reconfigurable Manufacturing Systems (RMS) and Flexible Manufacturing systems (FMS) [3].

The work is still in progress and the final results will be published during 2012.

Acknowledgements

References

[1] Salmi, T., Heikkilä, T., Leino, K. & Väätäinen, O. Transferable and reconfigurable robot-based production units. Proceedings of the 3rd International Conference on Changeable, Agile, Reconfigurable and Virtual Production, CARV 2009, Munich, Germany. 10 p.

[2] Salmi, T., Haataja, K., Sallinen, M., Göös, J. & Voho, P. Automation Islands – Requirements and solutions for a highly flexible concept of robotic systems. The 2nd International Conference on Changeable, Agile, Reconfigurable and Virtual Production, CARV 2007, Toronto, Canada. 10 p.

[3] ElMaraghy, H.A. Flexible and reconfigurable manufacturing systems paradigms. International Journal of Flexible Manufacturing Systems, Special Issue on Reconfigurable Manufacturing Systems 17, October 2005, pp. 261–276.

Picking of randomly oriented parts with machine vision (bin picking)

Ilari Marstio

Introduction

When automating short-run production, one of the greatest obstacles is the need for part-specific mechanical handling devices. One solution to this problem is to introduce an industrial robot with machine vision and flexible gripper for picking randomly oriented work parts from a bin with-out the need to organize the parts. Traditionally, parts have needed to be organized before they can be fed to the machining or the automated assembly line.

Random bin picking has been researched since computer vision started to gain ground in the 1980s. A lack of computation power, good algorithms and sensors has constricted the industrial applications of bin picking.

The project goal was to determine the current state of bin-picking technology and introduce this technology to Finnish companies.

Methods

The technology behind bin picking was researched. The suitability of different sensors including cameras and 3D sensors was investigated. Modern gripper technology was also researched. The software or algorithms that actually located the pickable part from the stack had a very important role.

All the commercial bin-picking systems to be reckoned with were benchmarked alongside the current research applications.

Different kinds of parts were classified according to the bin-picking method that was most suitable for the part. The shape and material of the part determine which method should be used.

Tests were conducted to compare different methods and products.

Results

There is no universal solution to bin picking, at least not yet. In many cases, bin picking is practicable, but all cases need a tailored solution. An analysis of the picked part is necessary. A camera or stereo camera can be used if the part has distinct features. If a camera is used, the lighting is crucial. Dynamic lighting is one option: several images can be made from the object with light coming from different angles. 3D sensors can be con-sidered if there are no reflective surfaces. The best 3D sensors for bin picking are the laser-line triangulation scanner and scanners based on structured light, unless the picked objects are very big. If large parts are picked, time of flight laser scanners and structured light scanners can be used. When using structured light, ambient light may be a problem. There are very effective algorithms for 3D point clouds but good solid scan data are needed.

The leading commercial bin-picking companies are Scape Technologies, Binar and IH Tech, which all provide complete solutions with sensors, robots and integration. Software for bin picking is provided by 3ideo and MVTec. Binar with its SensActive (Figure 1) and IH Tech in cooperation with PROFACTOR with its iRob-Feeder provide a system based on laser light triangulation, whereas Scape Technologies provides many different methods from dynamic lighting to 3D scanning. All the companies have

their own algorithms, which work nicely on certain workpieces. 3ideo's Pick3D provides tools for bin picking. The 3D data are fed into the Pick3D and it returns the place and orientation of the part to be picked. MVTec's Halcon is a machine vision library with many 3D algorithms. Two of the most interesting algorithms, which can be used in bin picking, are shape-based matching and surface-based matching. Shape-based matching will read the CAD model of the picked part and try to find such parts in the analysed image (Figure 2). Shape-based matching needs optimal lighting conditions and takes quite a long time. Accuracy-wise it is best if the camera is mounted on the robot to obtain images from as close a range as possible even though the cycle time will be reduced drastically. Surface-based matching is a robust algorithm to localize parts from a point cloud. It works in a similar manner to Pick3D. The cycle time is good but it needs good 3D data. Most of the time is taken by the actual scanning process.

In most cases, the most cost-effective way is to use standard grippers. Great attention should be paid to good gripper design. The accuracy is often no better than a couple of millimetres and the gripper should be able to cope with that. Different gripping positions in the workpiece should also be considered. If a vacuum gripper is an option, it should be used. It can pick from the top and will avoid collisions with siding parts. If there are different parts, the picked gripper should be designed accordingly.

Conclusions

As a rule of thumb: do not use bin picking if you do not have to. It is still quite laborious to realize bin picking and thus expensive. One step towards flexibility by dedicated feeders is the flexible feeder with which parts are fed to a lit surface and localized with machine vision.

Bin picking is a functional technology, but there are still some limitations part-wise and cycle-time-wise. In some cases, it can significantly reduce the need for manual labour.

Future research will continue in this area. Some research institutes are researching the possibilities of using cheap sensors like Micro-
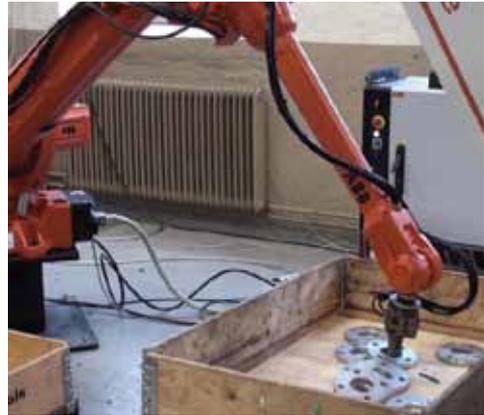
Figure 1. Tests in Binar, Sweden.

Figure 2. Halcon shape-based matching.

soft Kinect for bin picking. More and more industrial applications are popping up and speeding up the development in providing companies.

More information can be found in the final report of the project [1].

Publications

Final report of the project: Sekaisin olevien kappaleiden käsittely konenäön avustamana – Bin-Picking. (Picking of randomly oriented parts with machine vision – BinPicking.) Available on request. (In Finnish.)

References

[1] Sekaisin olevien kappaleiden käsittely konenäön avustamana – Bin-Picking. (Picking of randomly oriented parts with machine vision – BinPicking.) Available on request. (In Finnish.)

Direct colour marking of metals with fibre lasers (DIME)

Petri Laakso

Introduction

In most applications, laser marking is the fastest and cheapest method. The flexibility of laser marking is based on writing with a laser beam without the need for chemicals or tools. Laser marking has had its limitations producing graphics and colours. Colour marking on stainless steel and titanium has been available for some time but has not yet been used widely in consumer products. There have been some industrial applications however. New fibre lasers allow independent tuning of the pulse width, and the marking process can be optimized to produce colours with better quality and visual appearance. In this study, the visual appearance of laser-marked surfaces was optimized by varying the pulse width, laser power, pulse energy and scanning velocity. The aim was to create uniform oxide layers on the surface that would appear as high-quality colour markings.

Methods

In the beginning, the laser equipment used in the project was the IPG 20W pulsed fibre laser. A more tunable SPI-pulsed fibre laser was used in most of the tests. As a reference, a 20W Nd:YVO$_4$ laser was tested to see the difference between traditional and fibre lasers. The surface characterization included surface roughness, oxide thickness measurements and an elementary analysis.

The materials tested were AISI grade 304L. The surface quality was 2B and the thicknesses 1 and 2 mm. Another selected material was titanium of commercial purity 1 grade. The thickness was 0.5 mm. The actual grade was ASTM B265-99 G1/ASTM F67-00 G1.

Three different instruments were used to measure the colours of the laser-marked samples. First, the spectrophotometer was used to measure the total reflectance of the samples. Second, the fibre spectrometer was used to measure the reflectance in multiangle measurements. Third, the spectral camera was used to measure spectral images through a microscope.

Results

Laser colour marking of metals has been used for more than ten years with a variety of different laser sources [1, 2, 3, 4].

The typical laser of choice for marking is a q-switched crystal laser, which produces pulses in the nanosecond regime. These lasers do not allow independent adjustment of the processing parameters, but the pulse width is dependent on the repetition frequency and as the frequency changes so does the pulse width. Lasers that allow adjustment of the pulse width regardless of the frequency may therefore give an advantage in marking.

Some metals can be marked so that the surface appears coloured. This is based on oxidation and the following thin film effect. In order to create a uniform and high quality mark, the laser used must have good enough beam quality and stability. A high quality mark results in a smooth and uniform oxide layer. Oxide formation during the laser process involves, among other things, transport of oxygen from the medium to the solid surface, adsorption of

molecular oxygen and electric field-enhanced diffusion of species through the oxide layer [5]. The laser-induced temperature rise enhances the diffusion flux and the reaction rate within the scanned area.

From the look of the laser-marked samples (Figure 1), it is not possible to say whether they are good or bad in terms of corrosion. The smooth oxide surface may look good, but in the wear test, the oxide may be seriously damaged. Roughness measurements do not reveal any explanation of which surface may be good or bad. It is therefore not easy to predict which colour or parameter setup will lead to a good combination of all the properties.

When some colour is wanted on the surface, the laser parameter may have to be set to a particular parameter range and there may not be any alternative parameters for doing this if speed has to be maximized. If a slightly slower marking speed is used, it is easier to tune the parameters and different marking strategies to also keep wear and corrosion in mind.

During the project, a wide variety of different lasers were used. Commercially available lasers kept improving during the project.

Conclusions

In this project, laser colour marking was further developed and the marked areas were examined for wear, corrosion and colour. Before this project, colour marking was available but the colours could only be produced in a limited way with one laser system, and another laser might have been needed for other colours. Good beam properties and tunability of the laser make high quality marking with affordable equipment possible.

During the project, a wide variety of colours was found. Almost all colours can be marked on a stainless steel surface, though

Figure 1. Sample with different colours marked on it.

the different shades of a colour may be challenging. From the corrosion results, we can see that the marking speed has a big effect on corrosion resistance, even if the heat input remains the same. The wear tests clearly showed that the laser colour marking parameters have a significant influence on the wear behaviour of both the colour-marked stainless steel surface and the counterpart surface.

The colours of the surfaces can be explained by the thin film interference. The thickness of the film together with the illumination angle determines the visible colour. According to the results of the modelling, it can be concluded that the thin film is composed of chromium oxide, Cr_2O_3. Colours are best defined if they are measured spectrally under some CIE standard geometries.

Publications

Laakso, P., Pantsar, H., Leinonen, H. & Helle, A. Preliminary study on corrosion and wear properties of laser color marked stainless steel. Proceedings of the 27th International Congress on Applications of Lasers and Electro-Optics, ICALEO, Temecula, CA, USA, 20–23 October, 2008. The Laser Institute of America (LIA). Orlando, USA, pp. 212–221.

Laakso, P., Pantsar, H. & Mehtälä, V. Marking decorative features to stainless steel with fiber laser. Advanced Laser Applications Conference and Exposition, 1–3 October, 2008, Minneapolis, MN, USA. The International Laser Users Council (ILUC), Saline, Michigan, pp. 29–36.

Laakso, P., Ruotsalainen, S., Leinonen, H., Helle, A., Penttilä, R., Lehmuskero, A., Hiltunen, J. DIME project report. Research report; VTT-R-02403-09. VTT, Lappeenranta, Finland, 2009. 65 p.

Laakso, P., Ruotsalainen, S., Pantsar, H. & Penttilä, R. Relation of laser parameters in color marking of stainless steel. 12th NOLAMP Conference in Laser Processing of Materials, Copenhagen, Denmark, 24–26 August, 2009. ATV, SEMAPP, Copenhagen.

Westin, E.M., Laakso, P., Oliver, J. & Penttilä, R. Effect of laser color marking on the corrosion performance of stainless steel. Proceedings of the 28th International Congress on Applications of Lasers and Electro-Optics, ICALEO, Orlando USA, FL, 2–5 November, 2009. The Laser Institute of America (LIA), Vol. 102, pp. 1245–1250.

References

[1] Carey, A.M., Steen, W.M. & Watkins, D. Laser Surface Ornamentation. Proceedings of International Congress on Application of Lasers & Electro-Optics, ICALEO 1998, pp. 170–178.

[2] Hongyu, Z. Laser-induced colours on metal surfaces. SIMTech Technical Report PT/01/005/AM 2001.

[3] Ruston, R. & Gold, J. Color marking. Industrial Laser Solutions, December 2005, pp. 16–18.

[4] Ming, L., Hoult A. & TSE, A. Colour marking of metals with fiber lasers. Proceedings of the 3rd Pacific International Conference on Application of Lasers and Optics 2008.

[5] Bäuerle, D. Laser Processing and Chemistry. 3rd edition. Springer, Berlin-Heidelberg, 2000.

Nano structures and applications with fs laser technology (FinFem)

Petri Laakso, Raimo Penttilä and Ilkka Vanttaja

The aim of the FINFEM project is to create new nano- and microscale laser processing techniques using a femtosecond laser to map out the possible applications and specific advantages that ablation can bring to the industrial processes. The objectives defined by the industrial partners range from the traditional material removal to the generation of functional surfaces.

Introduction

Joensuu University conducted basic research on laser-matter interaction together with international partner Laser-Laboratorium Göttingen. The VTT Laser processing team assisted in the basic research and developed the micro- and nanomachining processes for the industrial applications. The industrial partners in the project were Okmetic, Thermo Fischer Scientific, Stora Enso, Modines and Cencorp.

The nanoscale features could be used when combining electronics and mechan-

ics (MEMS), and electronics and biotechnology (diagnostics), and when making medical implants and instruments, optical components and functional surfaces (lubrication, friction control, lotus effect, optical functional surfaces, chemical catalysts and bioactive surfaces). In Figure 1, these nanoscale features are used to make holographic marks on polished metal surfaces.

Methods

VTT's femtosecond laser is the Integra C2.0 with a maximum pulse energy of 2 mJ at a 1 kHz repetition rate. The pulse width is 130 fs. The wavelength of the laser is 790 nm. The pulse energy is attenuated with an external polarization-dependant cube and computer-controlled polarizing window. After the pulse energy is attenuated, the beam is divided into two beams. One part of the beam goes to the scan head and the other to the normal processing head. VTT implemented on-line vision for the fixed optics after delivery.

The x-y axes are used for sample positioning and movement in the plane together with the software. The beam focus was adjusted to the sample surface (z movement) by a manual axis. The scanhead is also controlled via software. Joensuu UEF also had a laboratory workstation with constantly changing setups.

Example of the results

The wetting properties of the material can be altered by changing the surface topography. The superhydrophobic surfaces can be obtained using surface topography combining

Figure 1. VTT logo made with grating-like structures.

Figure 2. Contact angle measurement of the stainless steel surface. The value of 80° is obtained for the smooth surface and 152° for the structured surface.

micro- and nanostructures. The reason for such enhancement of the hydrophobic properties is the reduced area fraction of the liquid-solid contact when changing the topography of the surface. These structures can be made using femtosecond laser ablation on a wide variety of materials. Femtosecond laser ablation can be used for the generation of both self-organized and directly written nano-, micro- and macrostructures. Two distinct types of surface structures were found during the project that made the surface superhydrophobic.

When ablating the target surface with consecutive high-fluence femto-second pulses, various self-organized structures start appearing on the sample surface. These structures are usually considered an undesired side-effect that degrades the surface finish when using the femtosecond laser for micromachining. The self-organized micro-structures consist of randomly distributed deep holes connected with ravine-type formations. The average feature size of the microstructure can be controlled by laser fluence and pulse number. Note that the microstructures can be covered with self-organized nanostructures. Similar structures can be made for a large selection of materials including metals, alloys and semiconductors.

The hydrophobic properties of the surface are usually determined with the static contact angle measurement by placing a droplet of water on a sample surface and by taking a photo from which the contact angle is calculated using a computer program. The surface is considered superhydrophobic if the contact angle is greater than 150°. The very low contact angle hysteresis and tilt angle indicates the self-cleaning properties of the surface. Figure 2 shows the contact angle measurement for the polished and structured stainless steel surface shown. The contact angle is 80° for the polished and 152° for the structured surface.

Conclusions

Functional surfaces were a big part of the project and the hydrophobic and hydrophilic properties, in particular, were pursued. The main principles for structurizing the surface were taken from the literature, as a starting point. Good results were obtained by laser structuring metallic surfaces. This effect could also be copied to injection moulded samples by making an inverse structure on a mould. Contact angles as high as 152° were measured. Hydrophilic surfaces were also made when the contact angle could not be measured due to the drop spread over a very large area. Metallic surfaces were noted to be hydrophilic just after processing, but this effect changed over time. Depending on the material, the sur-

face properties changed completely after a couple of, or even up to 30, days after processing. From the literature, it was found that if a sample was kept in an inert atmosphere the effect would not change. Injection moulded samples did retain similar properties days to weeks after moulding.

Novel optical means to enhance the processing speed with an fs laser were used successfully and, compared with the literature processing speed, the speed could be increased by several orders of magnitude. For industrial production, the fs laser had much to offer, but high processing speed is normally needed and a high repetition rate is then desirable for low intensities and high speeds. So, why use an fs laser if multiple times the average power can be achieved with a ps laser? There are some fs laser applications in which femtosecond pulses are needed and no compromise can be made.

To conclude all the results in this report, we could say that goals were met, but much still needs to be done if a full understanding is to be achieved. The femtosecond industry is still developing quite fast, and new things are continually opening up new possibilities that may make new applications possible next year.

Publications

Päiväsaari, K., Kaakkunen, J., Silvennoinen, M., Vahimaa, P., Laakso, P., Penttilä, R., Heimala, P Vanttaja, Ilkka & Lehtimäki, Matti. FinFem project report. 84 p. VTT Research report: VTT-R-08007-10 VTT, Lappeenranta, Finland, 2010. http://www.vtt.fi/inf/julkaisut/muut/2010/VTT-R-08007-10.pdf.

Flexible tailored serial production of 3D sheet metal products and new processes of automated manufacturing (Joyrem)

Timo Savinainen

Introduction

The wavelength, great power and good beam quality of new single mode lasers will revolutionize remote laser cutting and welding based on robotics. It is known that very little heat is transferred to the material when the material surface is removed by vaporizing. Material cutting with a single mode laser based on scanning works with almost no thermal effect on thin sheet metals, resulting in accurate and thin cutting grooves.

New powerful 2–5 kW single mode fibre lasers and high-power scan heads have entered the market. The production benefits of this new technology are obvious, though very few research results were available when the project started. The good beam quality of single mode lasers allows greater focal lengths and working distances. Easily programmed high-power scanner optics makes the beam more movable and allows the beam to be scanned flexibly on the workpiece. The working area can also be increased by moving the scanner with a robot or a workstation.

Material-vaporizing remote laser cutting of sheet metals, based on a single mode laser and scanning technique, was also studied in the project. The studied materials were carbon steel, coated carbon steel, stainless steel, electrical steel and aluminium.

The project was coordinated by VTT and associated with the Lappeenranta University of Technology (LUT). The industrial partners were ABB Oy Motors, Patricomp Oy, Pivatic Oy, Laserplus Oy and Prolaser Oy.

Methods

Remote laser cutting was tested with two laser systems. In Germany, the Mittweida University of Applied Sciences Laser Application Centre had a 3 kW IPG Photonics YLR-3000-SM laser with a Raylase Superscan-SS-LD 30 scan head and a 3D workstation. The scanner's focal length was 200 mm with max. speed 15 m/s, max. power density on workpiece surface 7.6×10^8 W/mm^2 and scanning field 50 x 50 mm.

The Lappeenranta LPC had a 2 kW IPG Photonics YLS-2000-SM laser with an Arges 3D-Elephant FE50 scan head in the KUKA robot. The scanner's focal length was 650 mm, work distance 350 mm, max. speed 2 m/s, max. power density on the workpiece 9.4×10^7 W/cm^2 and scanning field 300 x 300 mm. Both lasers had M2 =1.1 and wavelength 1070 nm.

An accurate figure, including straight lines, curves and straight an-gles, was cut in tests with different sheet metals. The groove widths, burrs on the upper and lower surfaces, surface roughness, cut angles and corner radius were measured in the grooves. The heat effects, the through-cut scanning repeat numbers and cut roundness as well as the effects of the focal position, repeat frequency and laser power were also studied. Comparison tests were conducted with identical materials and cutting figures using a 1.8 kW Bystronic Bysprint CO_2 laser (with nitrogen and oxygen) and an IPG Photonics YLR-5000-S 5 kW multi-mode fibre laser with a Precitec OT YW50 scanner (melt-

	1.4301 0,5mm	1.4301 0,88mm	M400-50A (1) 0,52mm	M400-50A (2) 0,52mm	S235 0,76mm	S235 1mm	DC01 1mm	DX51D+Z 1 40-M-C 1mm	Aluminium 1 1mm
■ Upper surface	85,4	82,9	70,2	78,3	83,3	85,5	65,8	62,8	90,4
■ Bottom surface	69,9	63,9	60,0	60,5	46,6	49,4	56,2	53,1	72,8
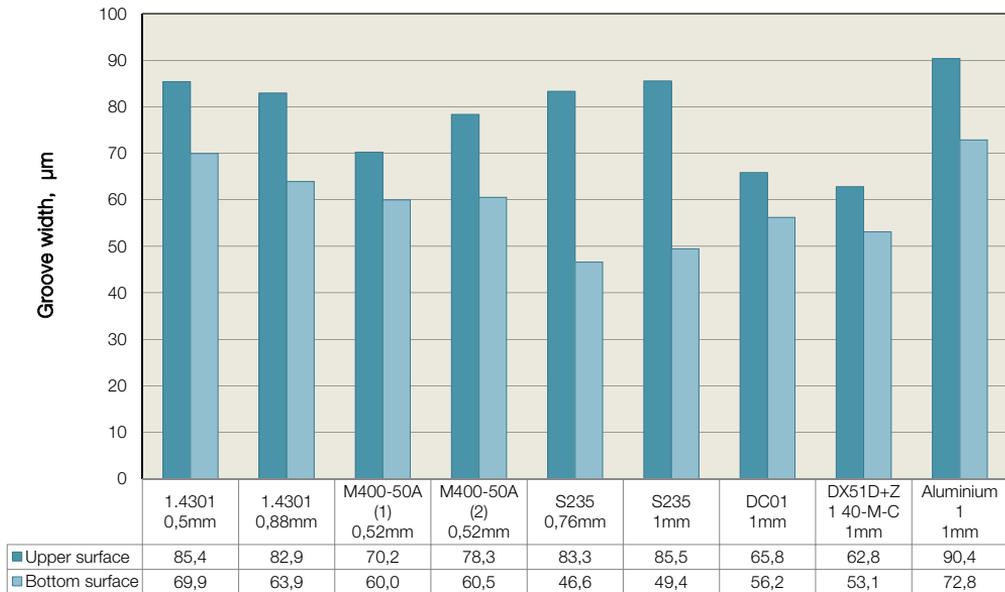
Figure 1. Groove widths in remote laser cutting with values in µm. Remote laser welding results in significantly smaller groove widths than traditional laser cutting methods. (CO_2N laser cutting groove widths: 1.4301 s = 0.5 mm – groove width 322 µm, S235 s = 0.76 mm – groove width 308 µm).

ing remote cutting). Optional comparison tests were also carried out with an IPG 400 W CV fibre laser, a 4 kW Trumpf Trucell 5020 disc laser and a 100 W pulsed Nd:YAG laser.

Examples of results

The remote laser cutting scanning removes material from the groove at 30–200 µm per scanning cycle, depending on the process parameters, material and thickness. Up to 1 mm thickness, the through-cut scanning number has an almost linear dependence on the thickness. On thicker materials, the number increases non-linearly as the laser beam intensity is smaller in deeper grooves and it is more difficult to remove the melted metal. Cutting of forms needs more through-cut scanning cycles than cutting of straight lines. All test materials except aluminium are similar to cut because the vaporizing temperatures and liquid metal viscosities are similar.

The scanning of repeat intervals has essential effects on the effective cutting speed and total cutting time, e.g. for a test piece, the cutting length was 325 mm, the material 1.4301 and s = 0.5 mm. A 5 ms repeat interval resulted in a cutting time of 3.5 s and a 200/400 ms repeat interval of 15.5 s. The effective cutting speeds were 5.6 m/min and 1.3 m/min.

The groove is wider on the upper surface than the lower surface, leading to non-perpendicular cutting surfaces. The groove width does not change significantly when the thickness increases. Aluminium, with a lower melting temperature than steel, has the biggest groove width. (See Figure 1.)

The surface roughness varied for different measurements and between measured locations. The cutting surface profiles are irregular because the liquid metal sticks in the groove surfaces when removed.

|	1.4301 0,5 mm	1.4301 0,88 mm	M400-50A (1) 0,52 mm	M400-50A (2) 0,52 mm	S235 0,76 mm	S235 1 mm	DC01 0,5 mm	DX51D+Z 1 40-M-C 0,64 mm	Aluminium 1 0,16 mm
Upper surface	137,5	156,25	150	100	131,25	137,5	137,5	162,5	208,33
Bottom surface	125	156,25	131,25	68,75	112,5	131,25	100	81,25	150
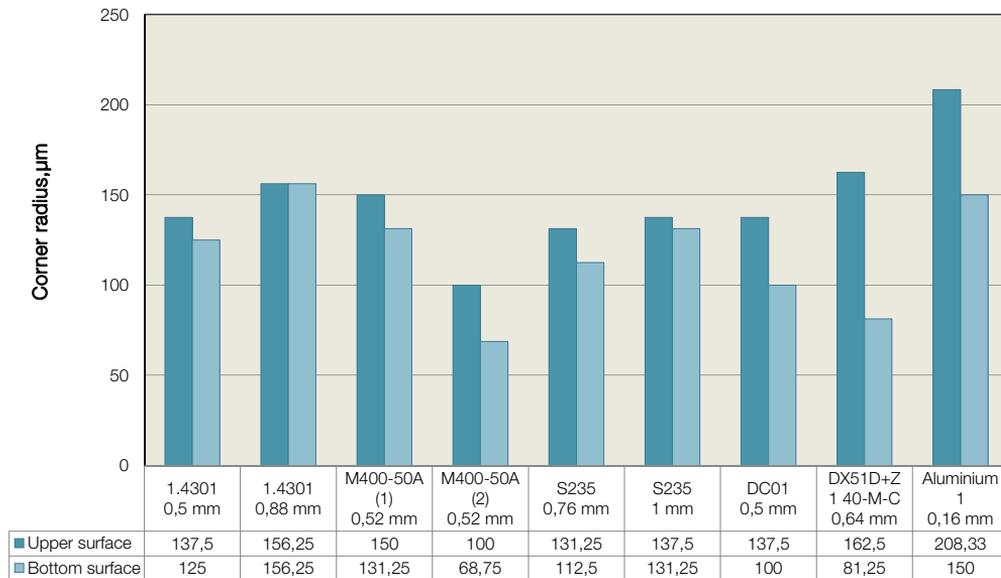
Figure 2. Corner radius of cutting surfaces with 90 degree corners on the upper and lower surfaces [μm]. (CO_2N laser cutting results in the corner radius 1.4301 s = 0.5 mm – r upper/lower surface = 175/162.5 μm).

Remote laser cutting results in good cutting groove surface perpendicularity, and the differences in perpendicularity are small.

The corner sharpness was determined by measuring the corner radius r [μm]. The corner radius was bigger on the upper surface than on lower surface. The corner sharpness quality was good. The smallest corner radius was 100 μm on the upper surfaces and 69 μm on the lower surfaces. (See Figure 2.)

Burr appears on both sides of the groove on the upper and lower surfaces, and the burr dimensions vary on different materials, e.g. material 1.4301 has wider burr than the other materials. [1]

Conclusions

Remote laser cutting demands good beam quality in single mode lasers as well as quality optics to reach a small focal spot and material-vaporizing power intensity. The process works very well on thin materials. Thicker materials cause lower power densities and difficulties removing liquid metal from the groove.

The laser beam power and quality, scanning speed, scanning sequence repeat number and scanning repeat interval are the most important remote laser cutting parameters. The effective cutting speed depends significantly on the time between scanning repeats.

In through-cut scanning, the repeat number of thin sheet metals depends more on the thickness than the material because the power intensity decreases when the groove becomes deeper.

The heat effects in the material depend on the number of scanning repeats (thickness) and scanning intervals. A shorter repeat interval reduces the scanning repeat number but has more heat effects and widens the groove.

The groove widths are very small in remote laser cutting because of the good beam quality. The groove is wider on the upper surface than the lower surface, but the thickness does

not have much effect on the groove width (on thin materials).

The surface roughness varies and is worse than, e.g., CO_2 N laser cutting.

Perpendicularity is good on low (> 1 mm) thicknesses and similar to CO_2 N laser cutting.

The remote laser-cut 90 degree corners are significantly sharper than in CO_2 N laser cutting. The corner radius depends more on the material than the thickness (in thin materials).

The burr layer appears on both sides of the groove on the upper surface while in CO_2 N laser cutting, the burr appears on the lower surface. The burr is thicker on thicker materials. [2]

References

[1] Pihlava, A. Remote laser welding of sheet metals. Master's thesis. Lappeenranta, University of Technology, Lappeenranta, 2010. 110 p. (In Finnish.)

[2] Savinainen, T., Kujanpää, V. & Salminen, A. Internal reports of Joyrem project. VTT and Lappeenranta University of Technology, Finland, 2009–2011. (In Finnish.)

An interactive 3D sensor system and its programming for target localizing in robotics applications (Luovi)

Tapio Heikkilä and Esa Viljamaa

Due to the cost level, the production of goods in developed countries favours shorter series over mass production. This sets strong demands for more flexible means of production. Interactive robotics introduces high flexibility to robotic task execution, relying on human intelligence and understanding.

Introduction

Due to the needs for flexibility in production by Western countries, new methods to leverage flexibility are needed.

An interactive sensor system for robotic applications with easy and flexible planning and programming enables flexible feedback from the process to the robot. This results in cost-effective, easy-to-use and accurate object localizing [1, 2].

The aim of the research has been to use human intelligence and skills to reduce hazardous manual work and introduce flexibility to robotic tasks. Flexible measurement technologies with optical sensors supervised by human operators are used to adapt to the variation in target object locations and robot paths. This is supported by CAD-based programming of sensory operations.

Methods

The full use of the measurement system is explained in Figure 1.

The localizing in the robot task execution is based on the initial estimate of the target object location, the set of programmed geometric reference features and the results from the interactive measurements. The interactive measurements (2D or 3D points) are fitted to the reference feature models and a Localizing algorithm calculates the position and orientation (pose) of the target object. This is then loaded into the robot controller and used to adapt the robot work paths to the real location of the target object.

The accuracy of the measurement system was verified with reference measurements by an industrial level tachometer and accurately calibrated robot.

Results

A main scientific result of the project was a new method and tested prototype system for interactive object localization for the needs of flexible manufacturing. The system was easy to use and worked as expected. The system reached 1–2 mm relative accuracy at a sensor (camera) distance of 5 m for the 4 m x 4 m measured workpiece.

The novelty of the work, especially the easy programming of the sensor tasks, lies in the use of standard CAD tools. The full application of the interactive sensor scheme with dynamic formation of the measurement model in a real experimental test environment is also new.

Discussion

The interactive sensor system has been implemented, is working and easy to use. It is based mostly on commercial HW and SW tools, with an extension to estimate planned feature parameters and an estimation of the target object location during task execution.

- Generate target 3D models for each process phase in the 3D modelling environment (Autodesk Inventor):
    - 1) fresh mould
    - 2) cut out 1/4 from fresh mould
    - 3) cut out 2/4 partly machined mould
    - 4) cut out 2/4 partly machined mould
- Preview models in each phase to capture reference surface data for interactive measurements

- Generate toolpaths in Cam environment (MasterCam)
    - Use 3D models for all machining phases

- Finalize the paths with a robot simulation/post-processing tool (RoboMaster, ConiferRob, …)
    - approach and departure points to robot program
    - details for variables such as workpiece positioning and tool data
    - simulation with reachability and singularity check
    - post-processing and downloading to the robot controller

- Interactive and iterative program execution
    - Set markers (manually)
    - Detect markers with robot vision and locate the target in robot space
    - Machine the target segment

Figure 1. Usage scenario of the interactive localization method.

The planning and programming of the sensor operations relied on general CAD tools, which are easy to implement and use and applicable to sensor programming for automatic task execution.

Interactive task execution takes additional time and extends the task execution time of the robot system in the range of several seconds to several tens of seconds. In many cases, especially in highly flexible and close to one-of-a-kind production, this can be acceptable. Due to the complexity of the environment and frequent changes, however, this may be the only feasible way to introduce robotic technologies to heavy-duty industrial applications, in many cases removing otherwise inevitable ergonomically problematic and hazardous working conditions.

Exploitation potential

The interactive sensor system can be exploited in many kinds of localization applications with the following prerequisites:

- The located workpiece should contain large enough regular reference features.
- A tool should be available to pick reference points from the features, e.g. in a CAD image.
- The localization time could reach several seconds or, for complicated shapes, tens of seconds.
- The accuracy requirement should be at the level of 1–2 mm at a measurement distance of 5 metres.

References

[1]   Heikkilä, T., Ahola, J.M., Viljamaa, E., Järvi-
       luoma, M. An interactive 3D sensor system
       and its programming for target localizing
       in robotics applications. In: Proceedings
       of the IASTED International Conference on
       Robotics, Robo 2010, Phuket, Thailand,
       24–26 November, 2010. Pp. 89–96.

[2]   Heikkilä, T., Ahola, J.M., Viljamaa, E.,
       Järviluoma, M. Vuorovaikutteisen 3D
       mittausjärjestelmän CAD-perusteinen
       ohjelmointi ja liittäminen robotin ohjauk-
       seen. Automaatio 2011, Helsinki, Finland,
       15–16 March, 2011. (In Finnish.)

Manufacturing low-cost miniaturized disposable 'Lab-on-a-Chip' plastic cartridges by injection moulding (RUISKUCHIP)

Antero Jokinen and Topi Kosonen

Introduction

The ageing of the population is leading to a huge increase in health care costs, and it has led to a special need for 'Point Of Care' (POC) testing, which means that people can monitor their health condition at home and even, in some cases, diagnose diseases automatically and quickly with low-cost devices.

In environmental control, e.g. water quality testing and many other areas like food, and the chemical and process industry, there is also a strong demand for automatic, fast, reliable and portable analysis of the composition and condition of raw materials, including the quality of the products.

The aim is 'sample in, answer out' with a low-cost disposable cartridge that automatically takes care of sampling, dosing, transferring and mixing the required liquids, analytes and reagents and also carries out the analysis so that the result can be read simply and quickly.

The main issue is to develop sample handling to be automatic and simple enough that no expertise is needed and practically everyone can carry out the analysis. This means that no pipetting or handling of test tubes is needed and that all the reagents and analytes are integrated into a disposable plastic cartridge.

To ensure commercial application, these kinds of disposable high-volume and high-technology products should be suitable for low-cost mass manufacturing, which means that the design of the functions and component inside the cartridge should be done carefully, and they should be integrated into the moulding process and the moulded parts so that the need for separate components and assembling steps is minimized.

VTT is conducting research in many areas of miniaturized systems and micro-manufacturing and has long experience of microfluidics and of developing low-cost disposable micro-total analysing products to meet the needs of medical diagnostic companies and the chemical and process industry. Figure 1 shows an example of a disposable plastic cartridge for handling liquids.

In the Ruiskuchip project, the aim was to develop the manufacturing of disposable plastic cartridges for automatic sampling, dosing, transferring and mixing of liquids.
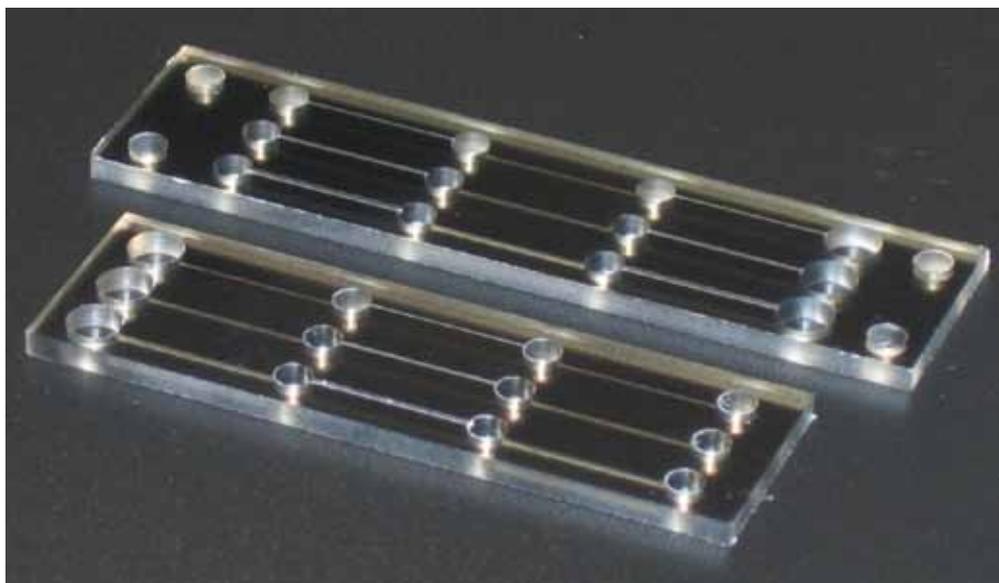
Figure 1. Disposable plastic cartridge for handling liquids.

Methods

The simplicity of the cartridge is an important point at the manufacturing stage and during use of the cartridge. It is important that the cartridge contains as few components as possible. Fewer separate components mean fewer moulds and mouldings and simpler final assembly. The cartridge should also be easy to use and, if necessary, the functions should be operated without external devices.

Commercial thermoplastics are an economical choice of raw material for the cartridge. In the Ruiskuchip project, polycarbonate (PC), polystyrene (PS), polypropylene (PP) and cyclic polyolefin (COC) were observed to be the most suitable materials due their processability and optimal mechanical, chemical and optical properties.

The functionality of the cartridges was based on the surface and gravity forces and simple ways to generate under- and over-pressure. The sampling and dosing were solved by special accurate containers and the use of innovative multi-use valves that can be manufactured by injection moulding. Several types of pumping components were developed and manufactured. They can all be made by injection moulding and easily integrated into a disposable plastic cartridge.

The sealing of the cartridge is also an essential manufacturing stage. It usually means bonding the cover to the cartridge. The thermal processes and use of adhesives easily destroy the reagents and analytes if they are integrated into the cartridge before sealing. The micro-features inside the product place special demands on the bonding process. In the project, an effective laser welding process was developed for the sealing step. The process made accurate positioning of the bonding area possible without destroying of the micro-features and analytes inside the cartridge. It is also suitable for low-cost mass manufacturing of the products.

Results

In the project, several demonstration cartridges were developed and manufactured for sampling, dosing, transferring and mixing the liquids.
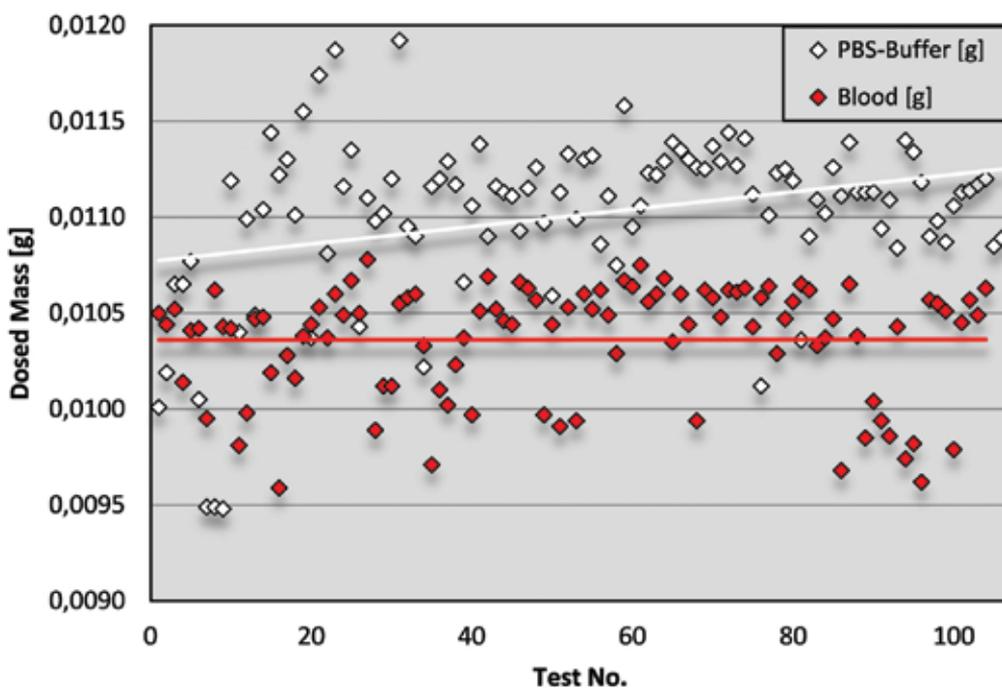
Figure 2. Results of the dosing experiments with a microfluidic cartridge. The liquid sample was PBS-buffer solution and human whole blood.

In the dosing experiments for 10 microlitre samples, the volume and repeatability of the samples were good (Figure 2) and comparable to the results of other disposable cartridges. The deviation of the sample size can be less than ±3%, depending of the liquid (PBS buffer solution or whole blood) and cartridge material.

Conclusion and exploitation potential

VTT has developed disposable plastic cartridges with automatic, quick and simple handling of liquids. The product is suitable for low-cost manufacturing by injection moulding. The sealing of the cartridge is carried out by laser welding the cover to the injection moulded parts.

The exploitation potential is great and covers areas of medical diagnostics, environmental control, food and nutrition as well as the chemical and process industry. The markets are growing fast and the technology will enable several new business areas and commercial applications.

Acknowledgements

Publications

Kosonen, T., Jokinen, A. Miniatyrisoitujen "Lab-on-Chip"-muovinäytekasettien edullinen valmistus ruiskuvalulla. VTT Research Report: VTT-R-00305-12. VTT, Espoo, Finland, 2007. (In Finnish.)

Exploitation of MIM production technology in Finland – project in the SISU 2010 Technology Programme by Tekes (SISU-MIM)

Jouko Virta

Introduction

Complicated metal components can be manufactured cost-effectively using metal injection moulding (MIM). The MIM process consists of injection moulding feedstock composed of metal powder and binder, debinding and sintering. The processing parameters of each phase depend on the binder and sintering characteristics of the metal powder alloy. The manufacturing technology is a typical mass production method suitable for a production series of about a few thousand to millions. The typical MIM components are small, from a micro size of 0.5 g to 100 g. The production costs of MIM are considerably lower than those of traditional manufacturing methods machining or casting. The reduction in costs can be as much as 70%.

The MIM markets have grown by 15–20% annually. The automotive industry has been one of the sectors with a high demand because of the many actuators needed in modern cars. Small metal components have beaten plastic components because they are stronger and more reliable. MIM has facilitated the complicated geometry and freedom of design of metal parts at low costs.

In Finland and other the Scandinavian countries, there is no industrial production of MIM components. In other European countries (France, Germany, Italy, Spain, Switzerland, etc.) there are several production lines. Globally, MIM components are mostly manufactured in Asia. Japan and the USA are also strong in MIM.

One manufacturer of technical plastic components, Plastoco Oy AB in Porvoo, saw the potential of the new technology and decided to investigate the possibility of starting MIM production. Plastoco is a joint VTT-MIM project to gain detailed knowledge of the processing, quality costs and experience.

Methods

In the project, the general boundary conditions of MIM production in Finland were clarified as well as the quality and cost structure of the MIM technology. The demonstration components were manufactured and tested at VTT. The three production phases of injection moulding, debinding and sintering were developed for the demonstration components. There was international cooperation with MIM feedstock producers in Germany. Supplementary processing experiments were performed at their premises.

Results, discussion and conclusion

The production costs of MIM components proved significantly lower than those of the same component machined. The quality of the MIM components met the requirements when the processing was carried out using the proper material-specific parameters. Sintering was the most demanding process phase considering quality and costs. Figure 1 presents closely charged MIM components in the sintering furnace.

The processing of the trial components demonstrated that very accurate and compli-

Figure 1. Sintered MIM components of stainless steel in the sintering fur-nace.

Figure 2. Moulded and sintered MIM counterparts. The male and female threads fit together perfectly.

cated shapes and measures are possible in MIM, for instance, male and female threads could be reproduced reliably. The threading ability is one of the most significant benefits of MIM. In Figure 2, threaded counterparts can be seen.

When starting MIM production it is reasonable to use ready-to-mould feedstock. The commercial feedstock is expensive however. Later in the steady-state production, the mixing of own feedstock may become a reasonable option.

The main result of the project was that Plastoco decided to establish a MIM production line in Porvoo. Plastoco has found several domestic clients. The export of MIM components has also taken its first steps.

Market potential

During the project, the domestic demand for MIM components proved to be large enough to allow MIM production in Finland. Later, markets abroad will become a reality.

Today's trend in component manufacturing is for production to move from Europe to low-cost countries. However, when production is highly automatic, such as in injection moulding, component manufacturing is also cost-effective in Europe. One driver of domestic production and demand is geographical vicinity. The communication, considering the product specification, is fast and easy when the component manufacturer and client are close to each other.

High-power laser welding for demanding applications (TriLaser)

Kalervo Leino and Miikka Karhu

Introduction

Laser welding has long been widely used in sheet metal product manufacturing, e.g. the automobile industry. Applications in heavier industries, however, have been much more limited. This is largely due to the strict accuracy requirements that laser welding places on the preparation of the parts to be welded.

The development of hybrid laser welding and the introduction of cost-effective high-power fibre and disc lasers have made laser welding a serious alternative to traditional high-quality welding pro-cesses in heavy metal industries and highly demanding applications.

Hybrid laser welding is a novel welding process in which a laser beam and an arc welding process are coupled together and directed to a single spot in the weld groove. The arc welding process in hybrid laser welding is usually gas metal arc (MIG/MAG) welding.

Hybrid laser welding combines the advantages of laser and arc welding. The welding speed equals that of laser welding, and the melting efficiency that of gas metal arc welding. The heat input and welding distortions are only slightly higher than with laser welding. The accuracy tolerance requirements of weld grooves are much more forgiving than in laser welding.

Methods

The welding tests are conducted when: a) preparing thick-walled (multi-pass) austenitic stainless steel joints representing demanding energy equipment applications, and b) fabricating multi-metal joints.

When welding thick sections, hybrid laser welding is challenging, e.g. narrow gap TIG welding, is the standard welding method in power plant engineering. The benefits of laser hybrid welding in-clude high cost-efficiency and minimal welding distortions.

At the first stage, moderate laser power of 3 kW was used, but the acquisition of a more powerful 10–15 kW fibre laser is under way. Plans also include combining the power of three 10+ kW laser power sources to conduct tests with laser power in excess of 30 kW.

In multi-metal joints, the attraction of laser welding derives from the narrow weld profile, which means minimal melting of the materials, and the possibility of positioning the weld accurately to control the composition of the weld metal much better than with arc welding processes. The use of hybrid welding further improves the possibilities of weld metal composition control.

Results

Welding tests, even with relatively low laser power, have shown that hybrid laser welding is very competitive with the traditional high-quality arc welding processes. Laser hybrid welding with a laser power of 3 kW is more than five times faster than narrow-gap TIG welding in the corresponding conditions.

With low laser power, hybrid laser welding has drawbacks however. Low laser power results in relatively small penetration depth, which leads to a substantial number of filling passes and the use of filler material. With a low laser power welding parameter, tolerances

are very small to guarantee high quality of the whole weld.

In multi-metal joining, the deep penetration profile and low and well-controlled dilution of the metals offer good possibilities of joining materials that are difficult to weld with traditional arc welding processes. The use of hybrid welding facilitates further weld metal composition control. Due to the low heat input of hybrid laser welding, the properties of the metals are less affected and the heat-affected zone much narrower than with arc welding processes.

Discussion

The project is still ongoing, and the results presented above are of a provisory nature. Increasing the laser power from 3 kW to 10+ kW (and further to 30+ kW) will most probably not only increase the performance and cost-efficiency of the process but also eliminate the drawbacks experienced with low laser power.

An increase in laser power may, however, introduce new development needs to hybrid laser welding. The laser power handling capacity of laser welding optics may prove insufficient to laser powers in excess of 10 kW. The development of optical materials and coatings will be needed to cope with the most recent high-power laser sources.

The high-power hybrid laser welding application range still needs to be determined. In principle, an increase in laser power results in increased penetration, which means improved productivity in thick-section welding. The behaviour of the weld pool may, however, set limits for the maximum penetration depth that can be used in workshop conditions. This will limit the application range somewhat as well as the investment costs of the hybrid laser welding equipment to a reasonable level.

Exploitation potential

Hybrid laser welding may be considered one of the developments with most potential in welding, especially in welding productivity during the last two decades. With arc welding processes, welding productivity can be maximized with automation, but, in spite of this, the cost level of industrializing countries is hard to achieve. The productivity of high-power hybrid laser welding is multifold compared with traditional welding processes and it provides the Finnish industry with much-improved competitiveness over countries with low labour costs.

Hybrid laser welding is most applicable to welding long and/or thick welds that have strict quality requirements. The manufacturing of machinery for the process and energy industry, mining and construction equipment, shipbuilding and pressure equipment manufacturing are potential uses of hybrid laser welding. It is a good alternative to the present welding methods in the manufacturing of semi-finished metal products such as welded profile beams and pipes.

Hybrid laser welding is still a relatively novel welding process that will involve a substantial amount of qualification and acceptance work. This will inevitably delay its exploitation in applications that are controlled or regulated by third parties. The benefits of the process are such, however, that the process qualification process will be very profitable.

Publications

Karhu, M. 2011. Narrow Gap Laser-Cold Wire and Laser-Arc Hybrid Welding Process Development for 60 mm Thick Austenitic Stainless Steel Joints. Tri-Laser Research Report. VTT, Lappeenranta, Espoo, Finland. 23 p.

Flexible and autonomous small batch welding production (Sisuhitsi)

Markku Hentula

Introduction

The aim of the project was to develop a model of means and possibilities for success in the Finnish welding industry: a) by which productivity can be increased to a level at which the performance of welding production will approach the automated production cells of machining, b) that will enable cost-efficient manufacturing of welded products, especially in small batch production, and c) by which the ability of companies to react to product and production changes will increase to a new level.

Methods

A questionnaire was conducted in the project with the purpose of collecting as much information as possible about the state-of-the-art and future expectations of the Finnish welding industry. The questionnaire was sent to 316 companies, and 105 replies from 87 companies were received. The questionnaire was aimed specifically at welding companies that represented the main suppliers, contract manufacturers and subcontractors.

Welding automation of big products made of heavy plate constructions was studied in a master thesis. In the case part of the master thesis, a welding concept was determined for one company. The most important aims of the concept were to decrease the throughput time, and increase welding productivity and profit by reducing the total work hours. The final goal was to implement mechanization and automation welding as far as possible.

A research exchange was carried out in cooperation between Aachen University (RWTH, ISF) and VTT. The aim of the exchange was to further the development of the welding simulation software, SimWeld, developed by RWTH (Figure 1).

Four case projects (that supported the research work) were also carried out for the following companies: TTP-Yhtiöt Oy, STX Finland Cruise Oy, Paramet Konepaja Oy and Halikko Works Oy. The most important aim of the case projects was study usability and restrictions of welding automation at different stages for use in small batch and one-off production. One essential challenge discovered was quick and simple programming of welding robots between product changes. The feasibility of the machine vision to increase robotic welding productivity was studied. Other research areas were hybrid laser welding, sheet metal material handling and forming before welding production, and welding and control of weld deformation in big steel structure welding.

Results, discussion and conclusion

In Finland, the essential competition factors of welded products and welding production are quality and features (performance) of products, delivery time and reliability, cost-effectiveness, productivity and manufacturing expertise. The price of the product is an important but not essential competition factor. No major changes in the competition factors are expected in the future, but the importance of delivery time is expected to increase.

The market areas of the Finnish welding companies are global. The biggest portion is still domestic deliveries (which may even be
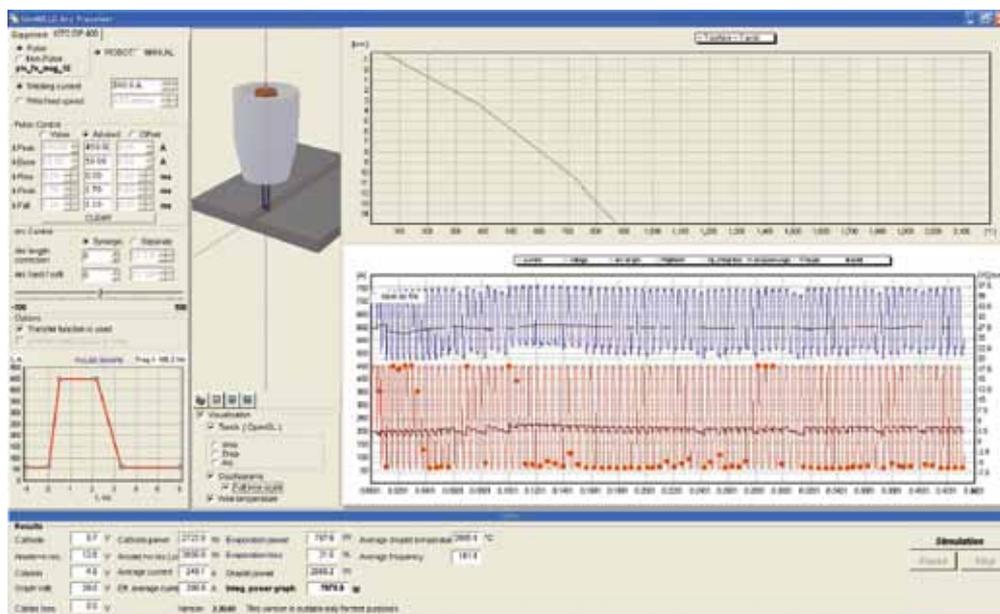
Figure 1. WeldSim software redeveloped by Aachen University and VTT.

highlighted by the fact that big main manufacturers have outsourced their production to SME-sized subcontractors and system suppliers, in which case the client of the welding companies is domestic, even though the product is exported), but Asia has risen after Europe and the Nordic Countries to the fourth most important market area ahead of North and South America.

The most important problems in the welding industry were discovered to be:
1. a large number of project products, which leads to small manufacturing series (typically < 5),
2. the dominant role of manual welding (degree of automation < 20%), which is partly due to R&D (products not suitable for automation) and faults in job planning (large portion of position welding),
3. low welding output (< 500 g/h) and
4. difficulties hiring welding manpower and shortages in basic welding education.

It was positively noted that welding quality management is in a good shape in Finland: a quality management system, a named and qualified welding coordinator and a welder qualification system are in use in most of the companies. The conditions of welding automation have also improved: welding companies are able to influence product design, the number of accurate component manufacturing methods has increased and the growth in production volume has enabled profitable automation.

The main development aims for the future are:
1. marketing
2. better manufacturing networks,
3. assembly (from welding component manufacturers to system deliverers of assemblies) and
4. the welding itself, especially increased automation. The development of welding technologies was not seen as that important.

The most important means to increase welding productivity are automation and products designed to be feasible for automation. Automated and robotized welding requires actions that are anomalous to the familiar equipment purchasing process because an optimized turnkey supply for a specific purpose is very limited. For large constructions and small batches of robotized case-specific welding, custommade system solutions have to be built. Commercial components and systems can be used in these but connecting them to a solution is more like a production development project than plain machine building.

Welding productivity can be increased in many and different size steps. A significant technology leap (e.g. from manual welding to robotized welding) can be made or smaller steps taken towards the same goal. The biggest outcome/input ratio can be achieved just by migrating from manual welding to simple mechanized welding. The cost-efficiency of welding can still be increased through a greater degree of automation and welding process optimization, but the additional outcome per input will not rise by the same ratio. The competitive situation of the company defines how much welding automation should be used.

The starting point of welding development is the decision to invest in welding in the long term. Increasing the rate of welding automation is a long-term and demanding process. It should be designed carefully, beginning with defining targets and ending with measuring the results and defining further development steps. Development work is a non-stop process, and it has to be carried out to maintain competitiveness.

Exploitation potential
The project results can be used by welding companies, welding automation system distributors and VTT.

Direct write techniques for competitiveness and increased product functionality (SUORA)

Helena Ronkainen

Introduction

Direct Write (DW) techniques belong to the Additive Manufacturing technologies and enable completely new solutions for electronic and mechanical components. The DW technique allows electronics to be integrated into mechanical components and systems, thus facilitating the fabrication of electronic components, such as sensors, wirings and antenna structures, during the machine and instrument manufacturing process. With DW techniques it is possible to deposit different material layers and structures directly onto straight, curved and three-dimensional component surfaces rapidly and efficiently. The process does not require masks or other complex tools either, which has a beneficial environmental impact. DW technology facilitates efficient production of tailor-made functional solutions and enhances the competitiveness and reliability of products. DW also lowers production costs and simplifies logistics chains. It can also improve the environmental friendliness of products and production methods.

In 2009, VTT invested in two different DW techniques, namely the Direct Write Thermal Spray (DWTS) and Direct Write Paste (DWP) techniques (Figure 1). The objective of the SUORA project is to facilitate the effective use of DW techniques in research and development and to study the feasibility of the DW techniques for different applications.

Methods of the projects

The basic process parameters affecting the performance of the two DW techniques were studied. The parameters, such as pumping pressure, speed, dispensing height and surface energy, affect the dispensing quality of the DWP technique. With the DWP, paste or ink-type materials are dispensed with high accuracy to create fine lines and features. One typical material studied in the project is the conductive silver paste that can be used to fabricate conductive lines and structures. Different conductive pastes have been demonstrated and the post-sintering processes developed. Different polymer-based materials have also been dispensed to create 2D and 3D structures. The DWTS is based on thermal spraying and, due to the melting of the powder material in the spray process, no post treatments are required. The DWTS spraying of different materials is studied in the project. The dielectrics, such as spinel ($Mg-Al_2O_3$), can be used for insulating layers on metal surfaces. Typical conductive materials are copper, which can be used for conductive lines, and different sensor materials, such as alumel and chromel used in thermocouples. The process parameters for different materials were tuned to obtain good material quality.

The feasibility of DW techniques for different application areas was evaluated by developing demos covering a wide technological field. The performance and quality of the demos were tested in a laboratory and in some cases in field tests.

Results

The conductive silver materials dispensed by DWP reached conductivities in the range

a)   b)

Figure 1. (a) The DWTS manufacturing cell with a 6-axis robot. (b) The DWP (nScrypt) CAD/CAM compatible facility with a two pump system.

of 5 to 50% of the bulk Cu conductivity with post-sintering temperatures in the range of 120 to 300ºC, and the DWTS copper had a conductivity of about 40% of the bulk copper conductivity. The DWTS spinel has good electrical insulating properties on metal surfaces thus providing the dielectric properties for different sensor structures.

To demonstrate the feasibility of DWP, silver paste was used to fabricate conductive structures on polymer substrates. The other demo consisted of both 2D and 3D polymer structures. A 3D structure dispensed for the polycaprolactone (PCL) polymer is presented in Figure 2.

Different sensor structures were fabricated and tested with the DWTS technique. Thermocouples (TC) sprayed on 2D samples were tested in the laboratory giving reasonable repeatability. Figure 2 shows TCs deposited on curved surfaces for temperature demonstration purposes. The strain gauges were fabricated on 2D samples and tested by MesoScribe Technologies Inc. The strain gauges performed in a similar way to those fabricated by MesoScribe. However, some needs for more tuning and material improvement were distinguished for more stable and repeatable measurement results. Strain gauges to meas-

ure torque were also fabricated on a cylindrical shaft. Since the spray gun is manipulated by a robot, it is possible to make deposits on complicated component structures. The sensors were evaluated with a repeated pulsating load. The results showed good performance for the sensors compared with the reference sensors and proved the feasibility of using DWTS technology to fabricate stain gauges for, e.g., torque measurement [1].

Discussion and conclusions
The results and demo evaluations showed good performance by DW materials and structures. Several demonstrations provided good insights into the capability of techniques and proved the huge potential the DW techniques have for future manufacturing. However, more research and development of the material used is needed in order to improve the material performance.

Exploitation potential
As Direct Write (DW) technology enables new production techniques and solutions for electronics and the integration of electronics onto mechanical components it has a wide application field and huge potential in the future. The DWP technique enables miniaturization in elec-

a)
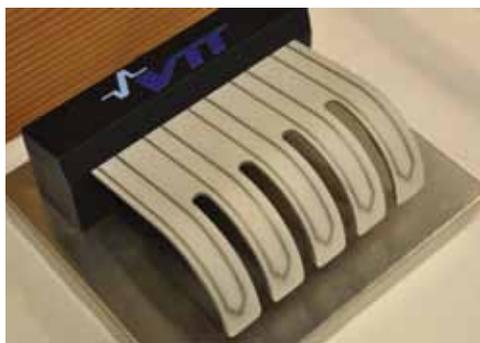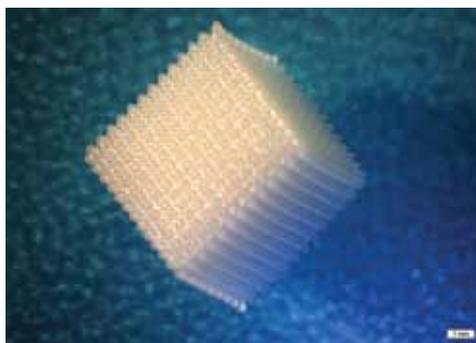
b)

Figure 2. (a) Thermocouples fabricated on curved surfaces by the DWTS technique. (b) 3D structures dispensed from PCL with the DWP technique.

tronics as well as a generation of 3D electronics. The new technique can also shorten the production chain and provide savings in component production. With DW, electronic components, such as sensors, wirings and antenna structures, can be fabricated directly onto surfaces during machine and instrument manufacture. It is also possible to integrate the DWTS facility as one part of the production chain. The sensors and other electric components fabricated with DWTS are robust and can thus provide sensoring solutions for harsh conditions.

Acknowledgements

References

[1] Tervo, J., Paro, J., Ruusuvuori, K. & Ronkainen, H., Plasmaruiskutus sulautettujen antureiden valmistusmenetelmänä. Promaint 1, 2012, pp. 52–45. (In Finnish.)

Factory and enterprise systems

More intelligence for laser processes (ÄLLI)

Jouko Viitanen

Introduction

The ÄLLI project ran during 2009–2010. It was funded by Tekes in the SISU 2010 Technology Programme and by five laser technology companies: Corelase Oy (www.corelase.fi), TH-Tools Oy (www.th-tools .fi), Nanofoot Finland Oy (www.nanofoot.fi), Cavitar Oy (www.cavitar.com) and Technology Center Hermia Oy (www.hermia.fi, http://lccfinland.nettisivut.fi). The research partners were VTT and Tampere University of Technology. The objectives included:

- Development of laser processes and their automation software, including measurement and control, and modular software for 3D laser beam steering.
- Four selected laser processes were developed as demonstrators of the developed technology:
  - accurate surface coating
  - glass-to-silicon or glass-to-glass joining and welding
  - direct writing of thin films
  - two photon polymerization.

Methods

The software development work used industrystandard visual programming tools and a hard real time kernel to implement synchronized motion control for beam steering and workpiece motion platforms. The modular implementation allows fast configuration of optomechanical setups that consist of scanned mirrors, stepper or servomotor stages, laser shutters, and electrical control of

lasers. The methods also included experimental process development for high-speed pulse lasers in selected material processing tasks.

Results

The modular software development approach was demonstrated by building a workstation for a two-photon polymerization (2PP) laser process. It included databases and visualization of 3D CAD designs (left side in Figure 1) and real time process monitoring through microscope optics of the polymerized structures (right side). 2PP allows additive manufacturing in a microscale rapid prototyping or '3D printing' device: arbitrary objects designed in a 3D CAD can be formed using 2PP in a sub-micron resolution. Common photoresists or even biomaterials can be polymerized with a high-speed pulse laser. At VTT, there are various alternative pulse lasers within the femtosecond-picosecond ranges that can concentrate high optical intensity in a small volume that initiates multiphoton excitation of monomers.

The SEM picture in Figure 2 shows one precision polymerized structure. This work was commercialized by Nanofoot Oy. In addition to 2PP, other laser processes were also developed. In the project, thin film patterning was also performed, as seen in Figure 3.

In the work packages coordinated by TUT, an axially symmetric high-power diode laser by Cavitar Oy was tested in the tasks of welding and high accuracy powder deposition, and high-speed pulse lasers by Corelase Oy were
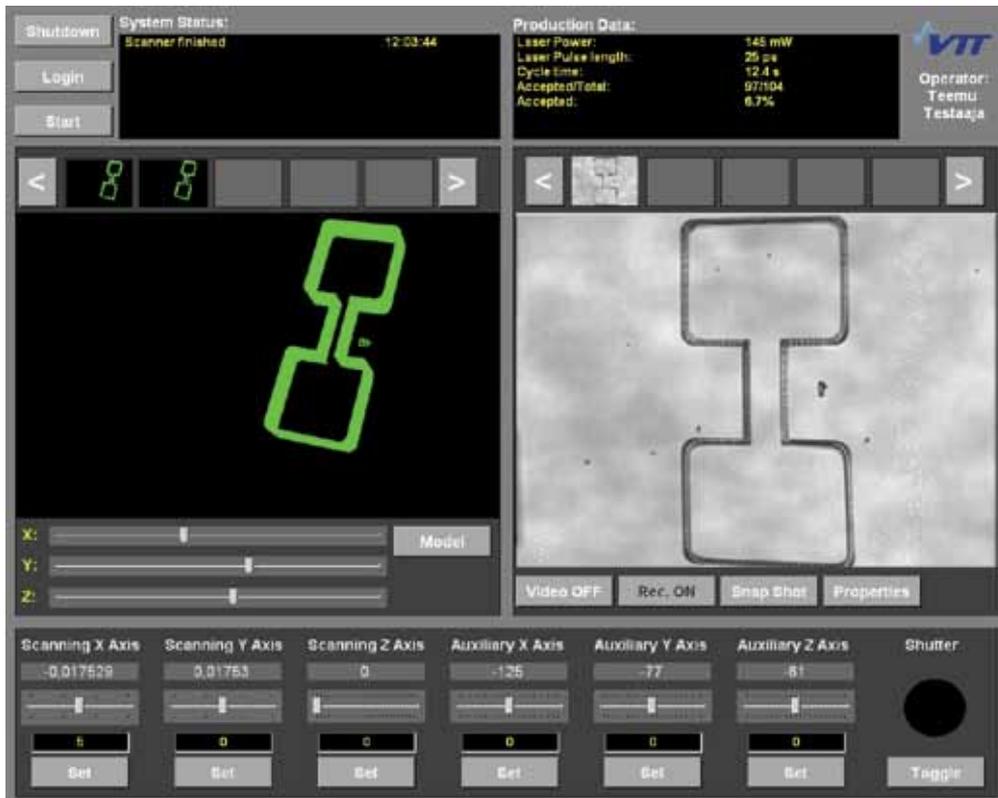
Figure 1. The graphical user interface of the 2-photon polymerization workstation. On the left side, the 3D CAD model, and on the right side, the polymerized structure.

used for joining silicon with glass. Real time measurement and control of the distance of the laser optics and the high-speed scanning stage were developed. An accuracy of 1 µm at the speed of 600 mm/s was achieved. A confocal sensor was interfaced to perform the profile imaging during scanning. At VTT, glass-to-glass welding was also developed. The work was reported in publications below.

Discussion

The ÄLLI project responded to the need of the industry to manage complex laser pro-cessing tasks by easily configurable, modular software. Interfaces to model CAD databases, intuitive user interfaces and real time control of
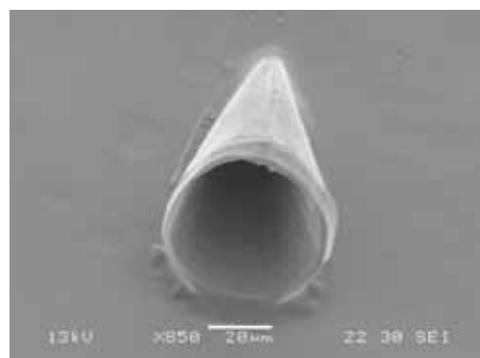
Figure 2. Polymerized 3D structure in a SEM picture (courtesy of Elli Käpylä in the joint project BioPulse that also used the software developed in ÄLLI).

the laser processes were developed for several different laser applications. In most cases, such facilities are crucial to the efficient use of modern high-speed pulse lasers.

Publications

Latokartano, J., Pajukoski, H. & Vuoristo, P. Axially symmetric Laser in surface treatment applications. 12th Nordic Conference on Laser Materials Processing, NOLAMP Conference 2009, Copenhagen, Denmark, 24–26 August, 2009. 10 p.

Pajukoski, H. Aksiaalisymmetrisen diodilaserin lisäaineen syöttö. Master's thesis. Tampere University of Technology, Finland, 2009. (In Finnish.)

Peltola, S., Kellomäki, M. & Viitanen, J. Two-photon polymerization of protein patterns with Nd: YAG pulsed laser, ICALEO 2008 Congress Proceedings, Nanomanufacturing Conference, pp. 93–98.

Vihinen, J., Latokartano, J., Pajukoski, H., Siekkinen, T. & Lassila, E. Direct Diode Laser with coaxial material feeding. Proceedings of the 5th International WLT-Conference on Lasers in Manufacturing 2009, Munich, Germany, June 2009. Pp. 257–261.

Figure 3. Transparent conductive ITO thin film patterned with a picosecond range laser without damaging the underlying glass surface.

Optimization of autonomous production cells – real time production intelligence (ATOR)

Juhani Heilala and Jari Montonen

VTT has developed customizable simulation software for use in production planning and capacity control for discrete part-manufacturing. Based on the production information, GeSIM simulates and visualizes resource use, work in process and delivery accuracy in the production system.

Introduction

Agile, fast and flexible production networks are a must for companies facing today's global competition. Delivering on the stated order date is the key element to customer satisfaction. In lean manufacturing, material stocks are kept as small as possible, while expensive resource use is kept as high as possible. One important decision in production planning is the scheduling and synchronization of activities, resources and material flow. The production personnel must seek a balance between customer orders and limited resources. The connections between manufacturing systems and processes are becoming more complex and the amount of data required for decision-making is growing.

Production planners need accurate and dynamic models of production, i.e. simulation models that use a production network and real shop floor data in near real time. The basic idea is to combine the strengths of automatic data analysis, calculations and simulation results with the visual perception and analysis capabilities of the human user who makes the final decisions. The use of simulation with an easy-to-use graphical user interface provides tools and methods for a manufacturing sce-

nario evaluation, scheduling optimization and production planning even for simulation non-experts (Figure 1).

Methods

Discrete-event simulation (DES) has mainly been used as a production system analysis tool to evaluate new production system concepts, layout and control logic. Recent developments have made DES models feasible for use in the day-to-day operational production and planning of manufacturing facilities [1]. Manufacturing system simulation with planned future operations, relevant resource and material data is a suitable management and evaluation tool to help production managers. These dedicated 'as built' simulation and calculation models provide manufacturers with the ability to evaluate the capacity of the system for new orders, unforeseen events such as equipment downtime, and changes in operations. The major challenges for such system (e.g. GeSIM) development are:

1. Data integration: Manufacturing operations planning is typically performed in a heterogeneous information system environment. Examples of such systems include: Enterprise Resource Planning (ERP), Manufacturing Execution System (MES), job shop supervisory and data acquisition systems, maintenance management systems, etc. GeSIM does not replace these existing systems; they remain in place as parallel systems, serving as sources of information for decision-making and means to implement the decisions. There is a need to transfer and share
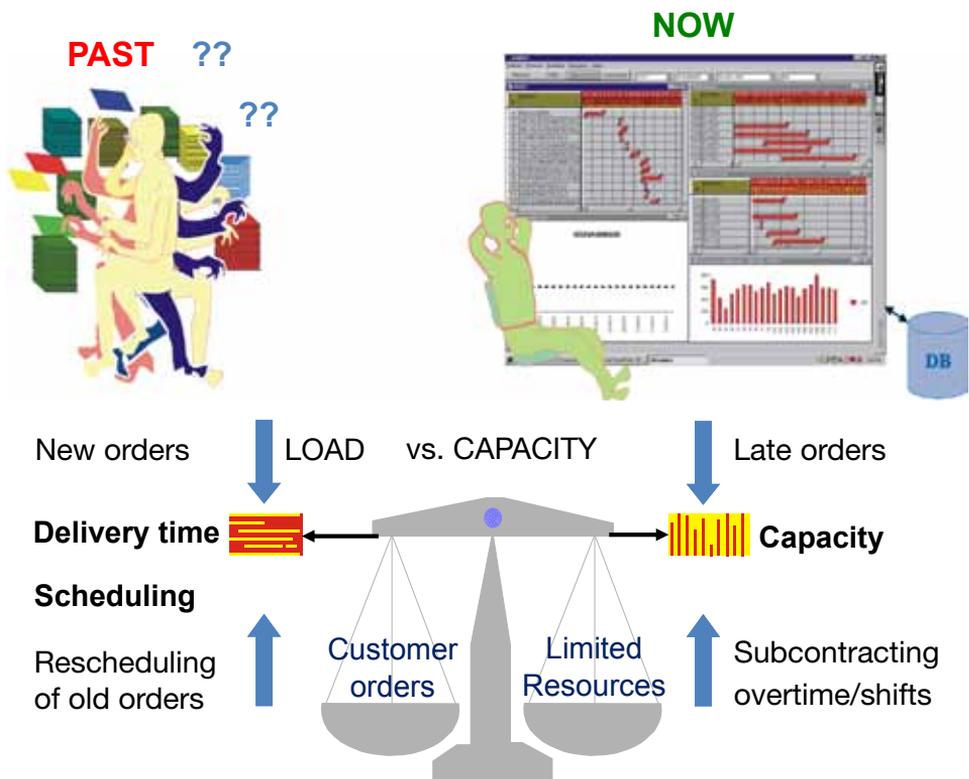
Figure 1. Simulation-based production planning.

data between GeSIM and other manufacturing software applications. Custombuilt proprietary interfaces do require customization, but GeSIM is quite flexible.

2. Automated simulation model creation and updates: There is a need for permanent, alwayson, synchronized factory models or models that can be created automatically on demand from ERP and other interoperable data sources and that are used for the manufacturing process and operations planning. GeSIM does support automated model building using selected data sources as input.

3. The visualization of results for interactive and effective decision-making: Simulation analysis produces a great deal of numerical information consisting of tables, listings and reports. It is difficult for a human decision-maker to locate the relevant pieces of information. Thus, the simulation results have to be presented in a visually effective way to speed up and improve the way the results will be understood. Different users require, or are allowed access to, different types of information, or the same information is presented differently. Time is an important factor in defining how much and what kind of data should be aggregated for the upper levels of the organization: a manager cannot afford to be 'swimming in data' when making a quick decision.

The efforts at VTT to overcome these challenges during the ATOR project are shown [1, 2, 3, 4].

Results

The aim of the ATOR project was to develop and demonstrate production simulation interfaces, autonomous product line/cell management with simulation methods to increase production efficiency and to build a Decision Support System (DSS) for production managers and supervisors in two industrial cases.

The developed tool GeSIM (see Figure 2) is useful in customer-driven manufacturing because it adds features for production planners and capacity managers that have not been provided by standard tools in the past. By integrating discrete-event simulation and traditional production planning methods, it is possible to forecast the required workloads with given input values. The simulation model and the developed graphical user interface make it possible to visualize the occurrence of potential bottlenecks or other production problems and to take corrective actions.

During the project, user-centric development process guidelines for such simulation application development were also evaluated
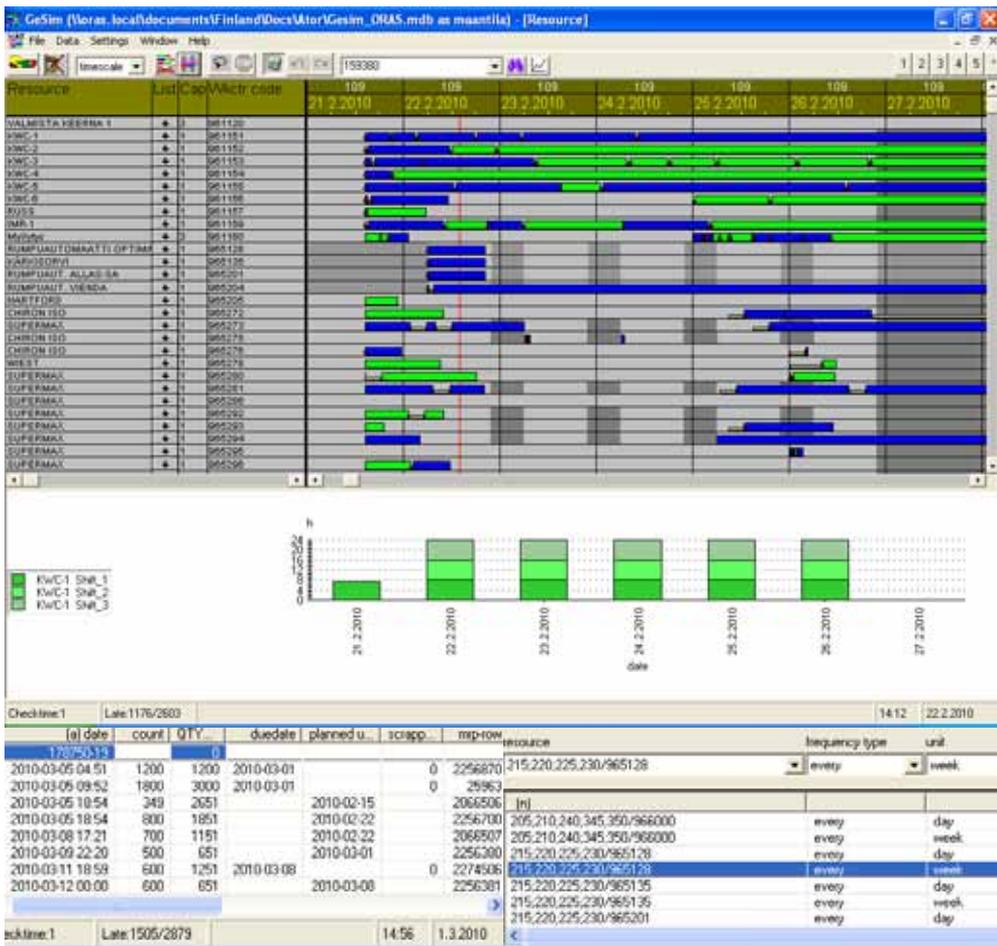

Figure 2. Simulation-based DSS; GeSIM user interface example.

with a real industrial case study [2, 4], and the standardization landscape was evaluated [3].

Discussion and exploitation potential

Some of the benefits of implementing an operational simulation scheduling system (e.g. GeSIM) include: less effort to plan day-to-day scheduling, customer order due date conformance, synchronization of flow through the plant, minimization of setups/changeovers, early warnings of potential problems, checks of critical resources and materials and, naturally, a 'what-if' scenario analysis for capacity planning. The presented methodology harmonizes the decision-support system for production and capacity management and uses near real time production status information. This type of operational decision-support system has many potential users, from operators on the production line to the plant manager and even upper management. The use of this kind of method can be applied to extended enterprises. External resources can also be shown, if the necessary information is available.

Acknowledgements

References

[1] Heilala, J., Montonen, J., Järvinen, P. & Kivikunnas, S. 2010. Decision Support Using Simulation for Customer-Driven Manufacturing System Design and Operations Planning. (Chapter 15). In: Devlin, G. (ed.). Decision Support Systems Advances in. Intech. Pp. 235–260. http://www.intechopen.com/books/decision-support-systems-advances-in/decision-support-using-simulation-for-customer-driven-manufacturing-system-design-and-operations-pla.

[2] Heilala, J., Montonen, J., Järvinen, P., Kivikunnas, S., Maantila, M., Sillanpää, J. & Jokinen, T. 2010. Developing Simulation-Based Decision Support Systems for Customer-Driven Manufacturing Operation Planning. Proceedings of the 2010 Winter Simulation Conference, WSC '10, Baltimore Marriot Waterfront, Baltimore, MD, USA, 5–8 December, 2010. Johansson, B., Jain, S., Montoya-Torres, J., Hugan J. & Yücesan, E. (eds.). IEEE. Pp. 3363–3375. http://www.informs-sim.org/wsc10papers/311.pdf.

[3] Kivikunnas, S. & Heilala, J. 2011. Tuotantosimuloinnin tietointegraatio. Standardikatsaus. VTT Working Papers 172. VTT, Espoo, Finland. 29 p. http://www.vtt.fi/inf/pdf/workingpapers/2011/W172.pdf. (In Finnish.)

[4] Heilala, J., Montonen, J., Usenius, T., Kuula, T., Maantila, M. & Sillanpää, J. User-centric development of simulation based manufacturing operation planning and scheduling system. Proceedings – 2011 IEEE International Symposium on Assembly and Manufacturing, ISAM 2011, Tampere, Finland, 25–27 May, 2011. IEEE Computer Society, p. 5942346. Doi: 10.1109/ISAM.2011.5942346.

Desktop assembly (DeskAssy)

Ilari Marstio

Introduction

Production philosophies have changed from traditional mass volume production to assemble-to-order-type thinking. This raises challenges for automated production lines. More flexibility is needed to handle short batches and ever-changing customized products. Many companies have fled to cheap labour countries and continued production manually.

New technologies and approaches clear the way fo r novel assembly con-cepts. The aim of this project was to create an assembly system concept for light and small products. This Desktop Light Assembly platform is

based on plug 'n' produce modules in which process and part-specific production equipment are independent of each other. The modules are floor space-saving, easily movable and changeable units. The degree of automation and capacity can be altered by adding modules or manual labour.

Results

A comprehensive technology survey was conducted on assembly technology. Based on the latest technology, a study from academia and fresh ideas, the Desktop Light Assembly Concept was invented. The concept is illustrated in Figure 1.

The ground-breaking Desktop Light Assembly Concept was created and demonstrated (Figure 3). Equipment can be freely modified and the assembly line can be customized according to the needs of the concept. The assembly line is constructed around the conveyor, which gives pneumatics, electrical connectors and the fieldbus to the modules that are attached to it. The conveyor system controls the flow of material. The assembled parts can be conveyed with palettes or by a belt conveyor. The modules can be attached to both sides of the conveyor. The modules consist of the intelligence needed to control the equipment on top of it, which means the PLC, IO signals and servo controllers. A process plate on which the actual process equipment sits can be attached on top of the module. The interface between the module and the process plate is only two pneumatic and electrical signals. In the fieldbus, there is a PC from which the system can be monitored, controlled
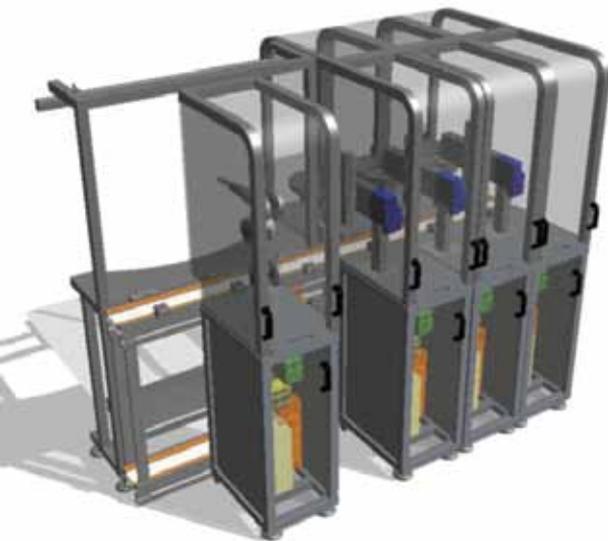
Figure 1. The Desktop Light Assembly Concept.

and programmed. There is a database on the PC in which all the created programs for different process plates exist. The modules are identical. Based on the process plate connected to a module, the right program is fetched from the database.

It is easy to make production changes with the concept. New process plates can be programmed offline and simulated. Changing the process plates requires minimal time. New modules can easily be added and the configuration of the assembly line is simple to change. The end-user will ultimately have a library of process plates and be able to build the required line configuration almost like with Lego blocks.

The space-savings and functionality are better than with a traditional robot cell. Previously, modifications had to be made to the whole cell and its software, but now only one part has to be changed. As modules are only one-quarter of the size of a traditional robot cell, much factory floor space can be saved.

The concept is a hybrid between centralized and distributed control systems. Control is distributed to the modules. This level of distribution was considered the most cost-effective. There is still one centralized control system from the PC that runs on top of the Visual Components' 3D Create to build the user interface (Figure 2). The models in the interface update according to the actual line changes. The simulation can also be run before realizing the actual line. With this virtual environment, the new programs are made for the new process plates and distributed to the modules.

Compared with traditional assembly systems (assembly lines, robot cells, manual workstations), the Desktop Light Assembly concept offers more flexibility to production. The line changes are easy and do not take up produc-
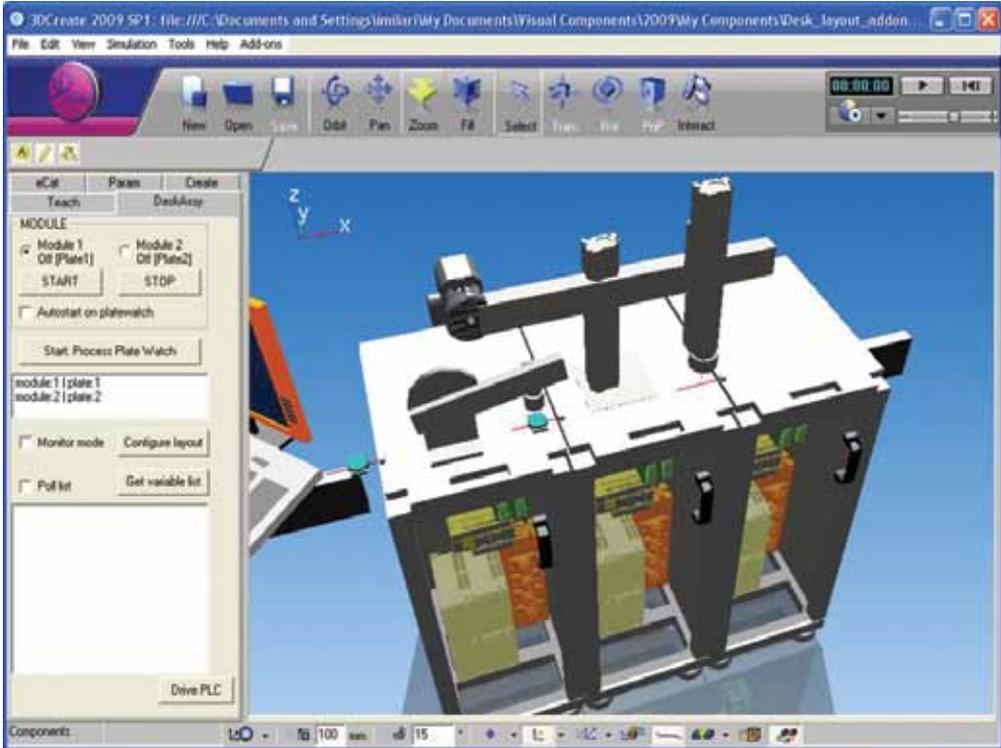
Figure 2. The Desktop Light Assembly user interface.

tion time. The concept also saves expensive production space. Changes are cost-effective to realize when only the equipment part needs to be replaced. Much research has recently been put into completely distributed systems in which intelligence has been distributed to individual components (grippers etc.) and, according to our study, this kind of approach did not seem to be realistic because of the complexity and sky-high costs.

Conclusions

The new production concept has been created. It is more expensive to realize than dedicated assembly lines, but in the long run the DeskAssy concept is more cost-effective. The ultimate vision would be to build an assembly line that is like plugging USB devices into the computer, with the connected devices being fully functional right after connection. It is a long way to that vision, many obstacles need to be crossed and big companies will need to agree to some new standards.

Publications

Malm, T., Viitaniemi, J., Marstio, I., Toivonen, S., Koskinen, J., Venho, O., Salmi, T., Laine, E. & Latokartano, J. Vuorovaikutteisen robotiikan turvallisuus. Suomen Robotiikkayhdistys Ry, Helsinki, Finland, 2008. 123 p. + app. 73 p. (In Finnish.)

Marstio, I., Haag, M. & Väätäinen, O. Self-configuring control system for modular assembly system. 2009 IEEE International Symposium on Assembly and Manufacturing, ISAM 2009, Seoul, Korea, 17–20 November, 2009, Pp. 379–382. Doi: 10.1109/ISAM.2009.5376972.

Salmi, T., Marstio, I., Malm, T. & Laine, E. Man-Robot Cooperation – New Technologies and New Solutions. Micro-Assembly Technologies and Applications. IFIP TC5 WG5.5 Fourth International Precision Assembly Seminar, IPAS'2008, Chamonix, France. Pp. 385–394. Springer, New York, 2008.

Figure 3. Desktop Light Assembly Platform demonstration.

Eco-efficient production

Marja Paju

Introduction

Eco-efficiency is based on 'more from less' thinking. It means reducing the use of material and energy, reducing the environmental impacts during a product's life cycle and maintaining the same time-efficient production. Eco-efficiency has a positive impact on a company's ecological competitiveness through the reduction in material needed by products, production and services, the reduction in the energy needed to produce products and services, and the reduction in the use of harmful materials and substances. Eco-efficiency can also mean improving the recyclability or durability of products. By examining production as a whole through a life cycle approach, it is possible to identify the different states of processes and logistics that are essential to developing eco-efficiency.

An eco-efficient production project was part of the Tekes SISU 2010 – Innovative Manufacture technology programme. The aim of the project was to test and develop existing eco-efficiency analysis methods for evaluating and improving eco-efficiency of production in the Finnish manufacturing industry. The project was coordinated by VTT and carried out between 08/2008 and 11/2010. The funding came from Tekes, VTT and four industrial partners: Iittala Group Oy Ab (Fiskars Oyj Abp), Oras Oy, Rautaruukki Oyj and Suunto Oy. The total budget was 667,000 €.

Methods

The framework of the Eco-efficient production project is presented in Figure 1. The project was carried out in five work packages (WP), which were:
- WP1: State of the art: Eco-efficiency in discrete manufacturing industry
- WP2: State of the art: Existing methods for evaluation of eco-efficiency
- WP3: Caste studies: Testing the chosen existing methods in industrial cases
- WP4: New methodology creation: Development of a new method to evaluate eco-efficiency
- WP5: New methodology testing: Evaluation and testing of the developed method.

The state of the art studies (WP1 and WP2) focused on methods and tools for discrete event simulation, sustainable value-stream mapping, life cycle assessment, material flow analysis and the carbon footprint. The case studies were conducted in WP3.

International collaboration was an important part of the project and one goal was to include a total of 12 months of researcher exchange in the project. The planned researcher exchange was carried out with NIST (National Institute of Standards and Technology), the USA, and AIST (National Institute of Advanced Industrial Science and Technology), Japan.

Results

The differences and similarities between the selected, existing eco-efficiency assessment methods were studied and identified. Life cycle assessment is the only ISO standardized method. Life cycle assessment and carbon footprint are useful methods to cover opera-
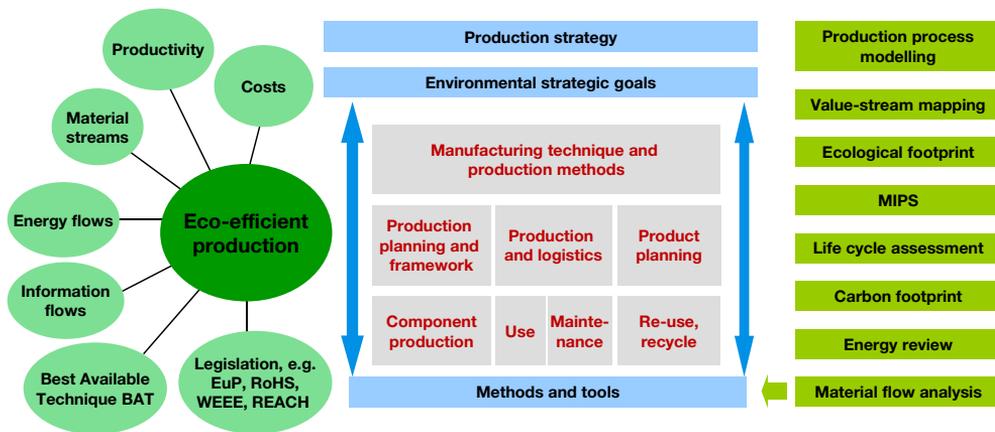
Figure 1. Framework of the eco-efficient production project.

tions systematically throughout a product's value chain. The environmental assessment methods focused solely on the environmental indicators and they were based on material and energy balances. Production-oriented assessment methods including discrete event simulation and value-stream mapping focus on time and volumes but can be employed in light environmental assessments, adding environmental indicators into the assessment. They commonly focus on the production floor operations. In spite of the method looked at, careful consideration of the objectives and the use of applications are determinants.

In the Ekoteho project, four industrial case studies were completed and a new methodology, ECOmap, created and tested. Four confidential industrial case studies were carried out, and the final research report, four conference papers and one master's thesis resulted from the project.

The ECOmap, shown in Figure 2, works on an existing commercial software platform, eVSM, and uses the process flow chart and worksheet. It is a simplified and connective process flow chart method. The platform uses pre-selected indicators. The method uses a limited number of visible parameters. The plat-

form has connections to web databases to import data.

Discussion and exploitation potential

It is becoming more important to control environmental impacts in the manufacturing industry, as the goal is shifting from conventional end-of-pipe technology to life cycle thinking. This shift can be accelerated with the right tools and methods.

Manufacturing systems, processes, products and related data are becoming more complex. Thus, product and manufacturing engineering and production management decisions require many interdependent factors and variables to be considered. To be able to consider the environmental impacts of a production process, it is important to assess the environmental parameters simultaneously in the same model along with the process parameters. Thus, the environmental considerations can be made in conjunction with production system planning. The development of a sustainable manufacturing system adds parameters that must be handled simultaneously. To incorporate environmental considerations while analysing manufacturing systems,

Spreadsheet MS Excel
input data + calculation + User interface to Visio

MS Excel link

Data link

Process map MS Visio
eVSM / MSVisio: results + input data
+ visualization

Selecting the indicators

Web database
Vehicle emissions (VTT Lipasto)

LAN -connection
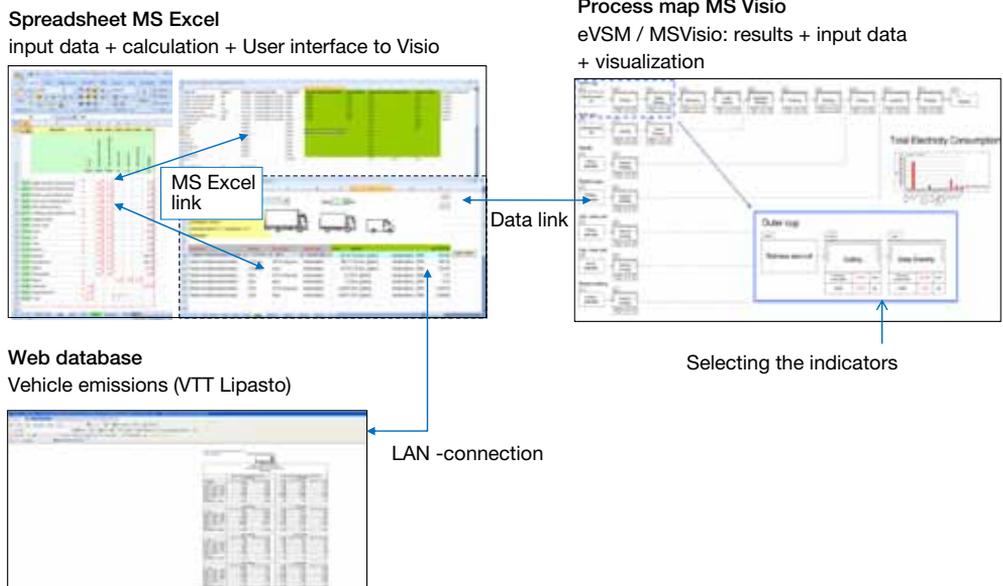
Figure 2. ECOmap on the eVMS platform.

it is essential to shift the focus away from economic growth to a mix of parameters.

The methods and tools for environmental assessment in the discrete part manufacturing industry can be divided into two categories: those that are used primarily for the assessment of environmental aspects, such as LCA, and those that use environmental assessment as an add-on element. Add-on tools require less effort to adapt to the existing manufacturing modelling tools, but they compromise on comprehensiveness on the environmental assessment part. There are a few tools that include operations beyond the facility. The environmental assessment-oriented tools are more comprehensive but require multidisciplinary expertise to use. Data collection could be a bottleneck to assessment methods that take a life cycle approach. The new method that was developed uses principles from existing

methods and takes a goal-oriented approach, a principle that is known in, e.g., LCA (ISO 14040, 2006). Choosing the right indicators according to the goal and setting the system boundaries are essential steps for the new methodology.

VTT's future work within eco-efficiency focuses on further testing the new methodology ECOmap with industrial case studies, creating case-specific ECOmap indicator repositories as well as linking the simulation and process flow chart. VTT also has a representative taking part in the standardization of ISO 14045 Environmental management – Eco-efficiency assessment of product systems – Principles, requirements and guidelines.

Acknowledgements

Publications

Heilala, J., Paju, M., Montonen, J., Hentula, M. & Heikkilä, A. Modelling and Simulation for Lean and Sustainable Manufacturing System Development, APMS 2010, International Conference, Competitive and Sustainable Manufacturing, Products and Services, Como, Italy.

Heilala, J., Paju, M. & Tonteri, H. Environmental Aspects Analysis of Products and Production Systems. EcoDesign 2009, 6th International Symposium on Environmentally Conscious Design and Inverse Manufacturing. Sapporo, Japan, 7–9 December, 2009. 6 p.

Paju, M. Tarkkuuselektroniikkatuotteen elinkaariarviointi tuotesuunnittelun tueksi (Life Cycle Assessment of Electronic Precision Instrument as a Support for Product Development).

Paju, M., Heilala, J., Hentula, M., Heikkilä, A., Johansson, B., Leong, S.K. & Lyons, K.W. Framework and Indicators for a Sustainable Manufacturing Mapping Methodology. 2010 Winter Simulation Conference, Baltimore, MD, USA. Includes description of the new methodology.

Paju, M. & Tonteri, H. Cradle-to-Customer Life Cycle Assessment for environmental conscious operations and product development: Case study of two precision instruments. In: Koukkari, H. & Nors, M. (eds.). Life cycle assessment of products and technologies. LCA Symposium. VTT Symposium 262. VTT, Espoo, Finland, 2009. 142 p.

Development of a manufacturing information portal for SMEs in traditional industries (Eskale)

Jukka Hemilä

Abstract

Today, markets offer a variety of enterprise information systems for manufacturing industries. In many cases, these systems are independent solutions without any communication links between them. In global business, in which SMEs in the manufacturing industry are today deeply involved, the requirements for information sharing are increasing. Information should be seamlessly available at all times for enterprises as a whole, as well as for the individual employees' needs. SMEs are facing the challenge of needing a common ICT solution to support their business functions; however, the applications available on the market are too complex for the purposes of an SME and any tailor-made solution tends to be too expensive for SMEs. This challenge has been the motivation for this research and development project, which aims to develop a supply-chain-oriented information platform for SMEs in the manufacturing industry.

Introduction

In this study we identified two ways for SMEs to take part in the global supply chain: 1) by supplying their own products to the global markets, and 2) by being a supplier to global customers. To ensure material or product availability in both cases, SMEs need information from the customer side, but they should also inform the customer about production and deliveries. The manufacturing SME's needs for information and its challenging role in global supply chains was the starting point for our ESKALE (Trans-European Sustainable Knowledge-Based Manufacturing for Small and Medium Sized Enterprises in Traditional Industries) project. The needs of the companies being studied are the basis of the requirements for the development of the Manufacturing Information Portal (MIP).

Methodology

This study was based on Yin's multiple case study definition [1]. We have developed a common framework for analysing end-user companies' needs. From the discovered needs, we developed a new method for handling information management in SMEs in the manufacturing industry. That method was tested with case study companies in order to see if and how it fits their needs. After the case test, the software developer created a working demo and, finally, a real solution for market needs.

Information systems for SMEs in the manufacturing industry

For the management of production-related information, SMEs could have Enterprise Resource Planning (ERP) systems. SMEs could have different operational tools for product design, CAD/CAM systems. The Product Data/Lifecycle Management (PDM/PLM) system is used for tracking the configuration of the part, billing the material, tracking the revisions and history of the design, and building the conditions. The product integration between the CAD and PDM systems improves the quality of design and the response time to market. Customer Relationship Management (CRM) is
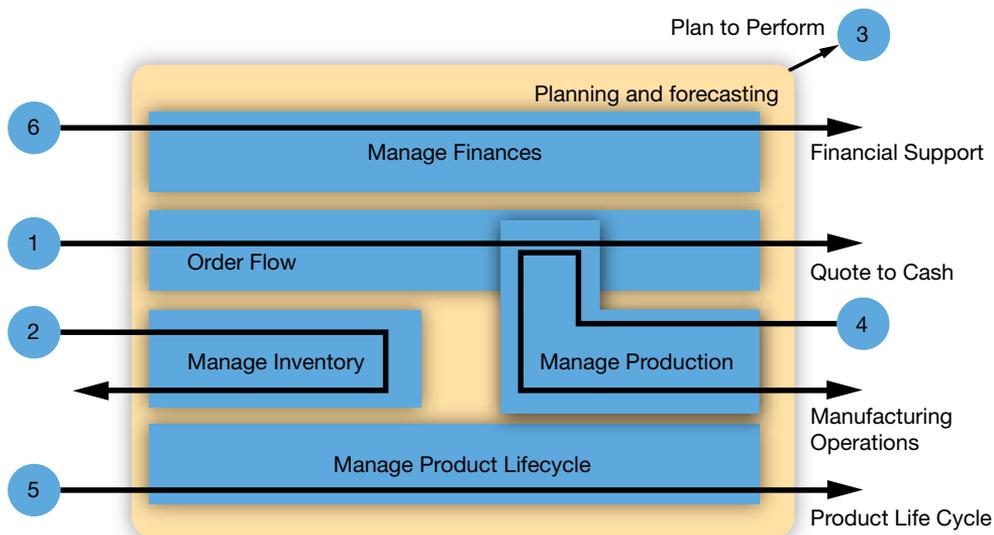
Figure 1. Key business flows (Modified from [3]).

a business strategy aimed at organizing and handling the business actions connected to customer relationships through the whole life cycle of the partnership with customers [2]. CRM systems are used to support marketing, sales and service processes. Supply Chain Management systems are used to handle and manage supply chains and, especially, the supply processes. Good SCM systems include acquisition (source), manufacturing (make) and logistics (deliver), but there could also be warehousing (store) and markets (sell). SCM systems are not widely used in small and medium-sized manufacturing companies. The SME usually only has production-related information tools, not supply chain-level management tools.

One method for analysing ICT in SMEs in the manufacturing industry is the process of flow analysis. Okrent and Vokurka [3] have defined the six core business processes in ERP systems: quote to cash, procure to pay, plan to perform, manufacturing operations, product life cycle and financial management (Figure 1). In our context of the traditional manufacturing industry there could be individual ICT tools to manage these processes and not only the ERP.

The lack of an existing common solution for supply chain-level in-formation, especially according to the needs of SMEs, was one of the main sources of motivation for the ESKALE project.

Development and requirements analysis of end-user companies

Four end-user companies were involved in our project. Two of them were from Finland and two from Germany. Three of the end-user companies were traditional manufacturers and one a logistics service provider. All manufacturers have their own products for the global and national markets, and all of the final products from the end-user companies could be sold directly to distributors; additionally, they all took the role of supplier in business with bigger global customers.

The analysis of end-user requirements and development challenges was carried out by an 'as-is' and 'to-be' process mapping analysis. The starting point of the analysis was the definition of the 'process reference model' (PRM). We created a common template for business processes in manufacturing companies. Then, with the end-user companies, their business

processes are described by selecting process phases from the PRM. In this way we created a common understanding of the business environments in end-user companies. The next phase was the analysis of existing information tools in end-user companies. That analysis was carried out by first defining the 'information reference model' (IRM), and then by fulfilling the IRM with end-user companies.

Discussion and conclusions

Globally operating companies should manage all supply chain processes (purchasing, making, delivering and planning), which requires a large amount of information. Lefebvre and Lefebvre [4] argue that SMEs can be more innovative than large organizations because they are less bound by bureaucracy and cumbersome organizational systems. SMEs will be able to be more competitive as they can introduce new technologies quickly, both manufacturing and supporting technologies. Investment in new technologies could be equally hard for SMEs however, due to their lack of resources. Companies have various sets of individual solutions without communication links to each other. The ESKALE project developed a solution called the Manufacturing Information Portal targeted at traditional SMEs in the manufacturing industry. The development of the MIP consisted of an existing business process analysis, ICT requirement analysis and literature survey of existing solutions targeted at manufacturing companies. All the ideas from the process analysis and the literature survey were included in the operational and technical requirements of the MIP. The ESKALE end-user companies implemented and evaluated the new MIP. The software provider was responsible for further development and commercialization of the MIP.

References

[1] Yin, R. Case study research: design and methods. 3rd edition, Applied social research methods series; v. 5. Sage Publications, Inc., 2003.

[2] Hemilä, J. Information technologies for value network integration. VTT Research Notes 2149. VTT, Espoo, Finland, 2002.

[3] Okrent, M., Vokurka, R. Process mapping in successful ERP implementations. Industrial Management & Data Systems, Vol. 104, No. 8, 2004, pp. 637–643.

[4] Lefebvre, E. & Lefebvre, L. Firm Innovativeness and CEO Characteristics in Small Manufacturing Firms. Journal Engineering and Technology Management 9(3–4), 1992, pp. 243–272.

Flexible and self-learning production systems in the sawmill industry (SisuPUU)

Arto Usenius, Antti Heikkilä and Timo Usenius

Present manufacturing systems in sawmills are highly automated and very cost-effective but inflexible. The products are mainly sensitive to economic fluctuations and competing standard products. Due to non-homogenous wood raw material, processing typically also produces secondary products that are not in demand. There is not necessarily a good match between available wood raw material and desired products. The missmatch causes economic losses and waste.

Considerable improvements in sawmill businesses can be achieved by moving forwards in the value chain – from standard products to wood products that provide added value to customers by developing:

1. New advanced and knowledge-intensive manufacturing system concepts based on systematic gathering and processing of data into information and knowledge for use in the effective processing of wood raw material into customer-specific, niche wood products – components and special sawn timber in order to achieve significant improvements in profitability and flexibility compared with the present manufacturing systems.

2. Scanning and measuring methods, integrated control systems, self-learning procedures for upgrading present manufacturing and strongly improving customer orientation and business economy.

3. Road maps for moving smoothly from the present production systems to future flexible and self-learning manufacturing systems.

Research results prove clearly that comprehensive exploitation of the properties and quality features of wood raw material and maximization of the value yield are not possible using the current sawing methods and systems.

Losses in value yield come from sawing batches of logs with fixed, pre-selected blade settings to try to maximize volume yield instead of value yield and from failures in the sawing processes. The focuses of this re-
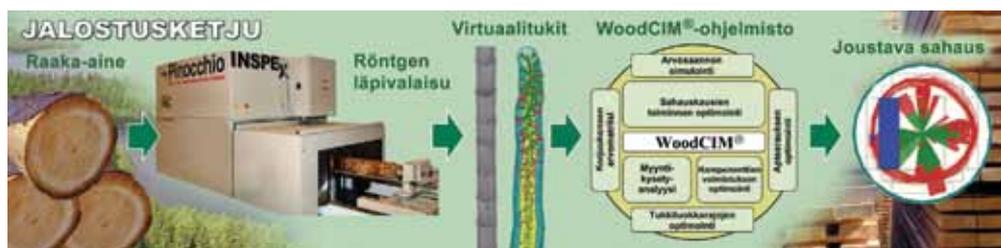
Figure 1. Advanced manufacturing technology and modelling of value chains play an essential role in the management and optimization of future value chains.

search project were on new manufacturing concepts (Figure 1). Through the implementation of advanced scanning and optimization technologies it is possible to execute individual sawing operations log by log and to optimize the quality and value of sawn timber and components. This also makes it possible to minimize the amount of low-grade and value timber pieces. According to the research results, by changing the processing concepts it is possible to increase the value of sawn timber production by at least 20 per cent. Halving the faults in manufacturing would provide potential for 10 per cent improvement in the sales value of production.

Sorting the logs into homogenous batches to be sawn by a more or less fixed blade setting is a very important part of the sawing process. Log sorting can be upgraded considerably by scanning the geometrical and internal properties of the logs instead of using conventional shape scanning. X-ray measuring technologies have shown to be an effective tool for detecting internal log properties like knots. The classification of logs should be done based on the sawing setup, sawn timber product properties or by picking logs based on their properties.

In theory, the best sawing method with regard to value yield is live sawing. Accurate scanning of the log provides information for the optimization of saw blade distances as well as positioning and feeding of the log into the sawing machine. The primary sawing operation produces flitches. After the sawing machine flitches are measured using a multisensory system, the resulting information shows how to split flitches into one or several wooden bars that will be cross cut into the desired lengths.

The sawmill company can improve the economic results considerably by moving forward in the value chain and manufacturing value-added wooden components itself or through networking. The sales value of low-quality sawn timber products can be improved by over 100 per cent if they are first converted into component-type products.

The key issue in new production and business concepts is the widespread use of information technology in the management, planning and control of conversion and delivery chains. VTT's WoodCIM® simulation and optimization models that support decision-making in the sawmill business applied to the Sisu-PUU research project are examples of models that can provide radically more information for optimization activities compared with manual planning operations. In the future, there will be many more operation alternatives to choose from than in the present situation.

Technologies for identification, i.e. through the marking of pieces, offer the possibility of linking together the products, wood raw material (logs) and processing parameters. It is possible to create feedback information by comparing realized processing results and estimated results. This strongly supports improvements in planning operations, processes and quality control. Based on the feedback information, it is possible to design and implement self-learning systems in which control parameter values are changed if there is a large enough cap between the realized and planned output result. There have to be decision rules for changing parameter values. A data mining approach can be used by developing the rules.

In the future, the sawmill will serve refiners and customers much better than today, i.e. by producing precise piece- and batch-based information on the properties of sawn timber and components and by transferring information forwards using making technologies.

The results produced in the SisuPUU project provide roadmaps towards the future. Part of the research results can be implemented without heavy investments, for example, by changing boarders of log classes. Part of the practical implementations requires further development, productization and commercialization.

Sawmills and technology providers have already shown great interest. Sawmills should execute analyses, as carried out in this research, in order to develop their own business proce-

dures: find out how potential, realistic changes influence the economic results, which depends on the customer structure, product specifications, properties of wood raw material, manufacturing technology, capacities, etc. Very good modelling methods and data bases have been created in SisuPUU in order to study new company-specific production systems.

Publications

Lyhykäinen, H., Mäkinen, H., Mäkelä, A. & Usenius, A. Predicting lumber grade and by-product yields for standing scots pine trees. In: Dykstra, D.P. & Monserud, R.A. (eds.). Forest Growth and Timber Quality: Crown Models and Simulation Methods for Sustainable Forest Management. USDA Forest Service – General Technical Report Report PNW-GTR. Vol. 791, 2009, 157–166.

Usenius, A. Adaptive and flexible production systems for woodworking industry. Proceedings Abstract. IUFRO All Division 5 Conference, Taipei, Taiwan, 29 October – 2 November, 2007.

Usenius, A. Flexible and Adaptive Production Systems for Manufacturing of Wooden Components. Proceedings Volume 1 of 18th International Wood Machining Seminar, Vancouver, Canada, 7–9 May, 2007, pp. 187–196.

Usenius, A. Puutuoteteollisuuden jalostusketjujen optimointi metsästä tuotteeksi (Optimization of conversion chains in wood products industry – from the forest to the end products). Finnish Operations research Society, INFORS 1/2007, pp. 20–29. (In Finnish.)

Usenius, A. & Heikkilä, A. WoodCIM® – model system for optimization activities throughout supply chain. COST E 44 Conference proceedings on Modelling the Wood Chain Forestry – Wood Industry – Wood Products Markets. Helsinki, Finland, 17–19 September, 2007. Pp. 173–183.

Usenius, A., Heikkilä, A., Song T., Fröblom J. & Usenius T. Joustavat ja itseoppivat tuotantojärjestelmät sahateollisuudessa (Flexible and Adaptive Manufacturing Systems for Sawmill Industry). VTT Research Notes 2544. VTT, Espoo, Finland, 2010. 217 p. http://www.vtt.fi/inf/pdf/tiedotteet/2010/T2544.pdf. (In Finnish.)

Usenius, A., Heikkilä, A., Song, T. & Usenius, T. Improvement potential of value yield in sawmilling through scanning of internal knot structure of round wood [keynotes speak]. Proceedings of the COST E 53 Conference and meeting in Lisbon, Portugal, 22–23 October, 2009. Santos, J.A. (ed.). Economic and Technical aspects of quality control for wood and wood products. COST, European Cooperation in the field of Science and Technical Research. 20 p.

Usenius, A., Heikkilä, A. & Usenius, T. Future Processing of Wood Raw Material. Key note paper. Proceedings of the 20th International Wood Machining Seminar. Skellefteå, Sweden, 7–10 June, 2011.

Usenius, A., Heikkilä, A., Usenius, T. & Holmila, P. Sawmilling and Sawing Process in the Future. Proceedings of the final conference of COST Action E53: Quality control for wood & wood products, Edinburgh, UK, 4–7 May, 2010. Incorporating the European Wood Drying Group workshop. Pp. 163–172.

Usenius, A., Song, T. & Heikkilä, A. Optimization of activities throughout the wood supply chain. Proceedings International Scientific Conference on Hardwood Processing. Quebec City, Canada, 24–26 September, 2007. Pp. 199–205.

Rapid economic production of Special products (SPECIAL)

Stephen Fox

Introduction

Products can be called Special when individual customers are given authority over their design and/or production. Smaller special products, such as jewellery and clothes, are made using bespoke processes. Larger special products, such as industrial engines and ships, are made using engineer-to-order processes.

Often, the production times and costs of special products are much higher than the production times and costs of mass-custom products. This is because mass customizers do NOT offer authority to individual customers. Rather, mass customizers offer choices from their pre-determined list of options. This means that mass customizers, such as Dell and Toyota, know the geometry of their products and configuration of components before any orders are received. As a result, they have been able to drive down their production times and costs by investing in near net shape manufacturing processes and assembly automation. In contrast, companies that make special products cannot predict the geometry of products and the configuration of components. Rather, they have to
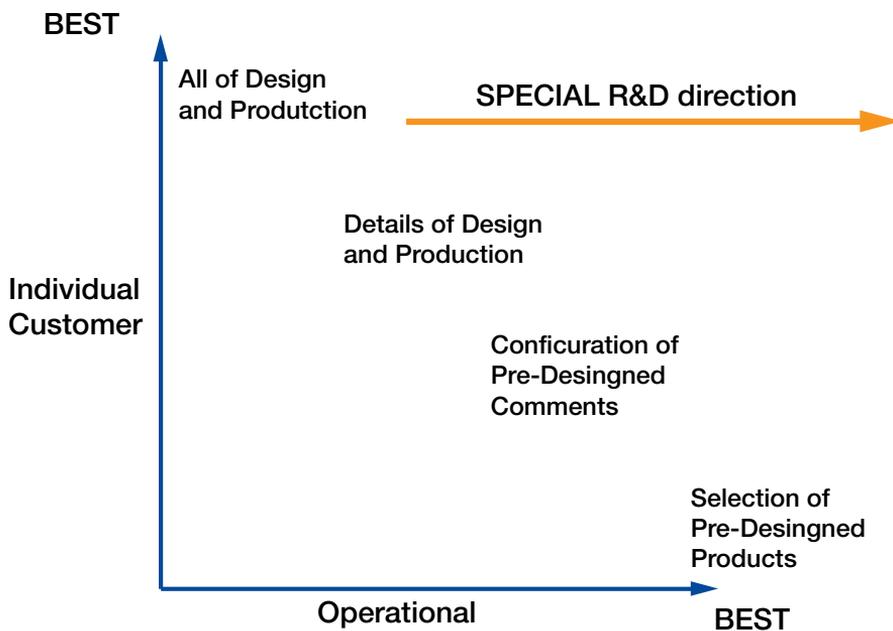
Figure 1. R&D direction of a special project.
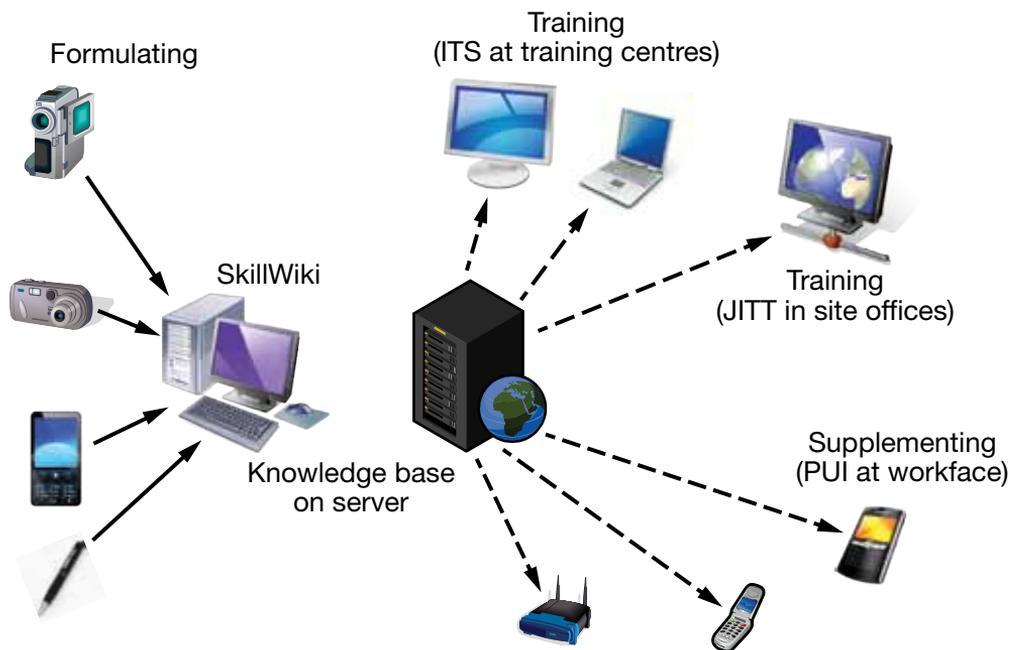
Figure 2. Enabling distributed capture and communication of manual skills [3].

wait to find out what each individual customer wants. This means that investments in near net shape manufacturing processes and assembly automation are often neither technically feasible nor economically viable.

Consequently, the companies that make special products continue to be reliant on subtractive manufacturing processes, such as cutting and drilling, and on the manual skills of human operatives. Moreover, the planning and costing of special production is extremely challenging because each product has to be engineered individually. This means that standard bills of materials and process routes cannot be developed once and used repeatedly. As illustrated in Figure 1, the R&D direction of the Special project was to improve the speed and economy of special production.

Results

Five Finnish companies that offer special products and face global competition partici-pated in the SISU project SPECIAL. Experts from VTT contributed to a range of process improvements within these companies. In particular, dynamic systems modelling and activity-based costing exercises were carried out to improve planning and costing [1].

Foreign collaboration focused on develop-ing innovative solutions to the companies' reli-ance on the manual skills of human operatives [2]. Research and development was carried out with the Fraunhofer Institute in Germany and Stanford University in USA. As illustrated in Figure 2 [3], due to the limited potential of assembly automation in special production, innovation has focused on enabling the real time communication of skill knowledge with-out human instructors.

Exploitation potential

Special Products are growing in importance as customers demand increasingly individual goods. The range of solutions developed during the Special Project can enable more companies to make more money from offering greater authority to individual customers.

References

 [1] Fox, S., Jokinen, T., Lindfors, N. & Ylen, J.-P. Formulation of robust strategies for project manufacturing business. International Journal for Managing Projects in Business, 2(2), 2009, pp. 217–237.

 [2] Fox, S. The importance of information and communication design for manual skills instruction with augmented reality. Journal of Manufacturing Technology Management, 21(2), 2010, pp. 188–205.

 [3] Fox, S., Ehlen, P. & Purver, M. Enabling distributed communication of manual skills. International Journal for Managing Projects in Business, 4(1), 2011, pp. 49–63.

Merging paradigms: engineering for a managed product life cycle (systems engineering)

Göran Granholm

Running a successful business in a world of constant change is a great challenge for all enterprises, not least within the manufacturing industry. Globally networked organizations do their best to adjust to new situations in order to launch new products fast and efficiently to a global market with rapidly changing customer preferences and fierce competition. The required speed of product development and production together with continuously evolving enterprise networks and business mergers generates an environment in which long-term strategic planning and well-managed product processes are difficult to establish and maintain. The risk is that processes remain suboptimal, leading to decreased productivity, quality problems and, in the end, higher cost of ownership for the customer. In order to deal with these challenges, a holistic approach must be applied that considers all aspects of the product life cycle from concept to disposal. This must be based on a management system for dealing with product and process data throughout the life cycle.

Introduction

A project called 'Systems Engineering – PLM integration' has been launched to deal with two seemingly different views of the product process. With a background in defence and aerospace sectors, Systems Engineering (SE) has a long tradition as a systematic approach to developing high complexity products. One of the cornerstones of SE is the focus on systematic verification and validation against a comprehensive set of requirements covering all phases of the product's life. PLM, or product life cycle management, on the other hand, has developed from the need to manage product- and process-related data throughout the product's life.

Essentially, SE focuses on the process whereas PLM focuses on the method and data. Consequently, Systems Engineering has remained more theoretical while the current understanding of PLM is still largely based on IT and PLM systems [1]. Recently, SE and PLM have both been developing towards a more holistic view of the product life cycle (Figure 1). Despite increasing overlaps of scope, SE and PLM have not frequently been studied together as synergistic approaches. This is now rapidly changing as an increasing number of PLM system providers have introduced support for SE-based processes in their products.

A prerequisite for increased automation and efficiency is a harmonization of processes, data representations and supporting tools. One of the most significant developments relating to the interoperability of tools and the integration of different engineering disciplines is the increasing use of models [2]. The models range from conceptual representations to functional simulation models and virtual reality. The development and standardization of models has been treated in some recent publications, mainly from a technical point of view [3, 4]. In addition to the technical issues, the adoption of these emerging tools and methodologies throughout the networked enterprise remains a challenge.
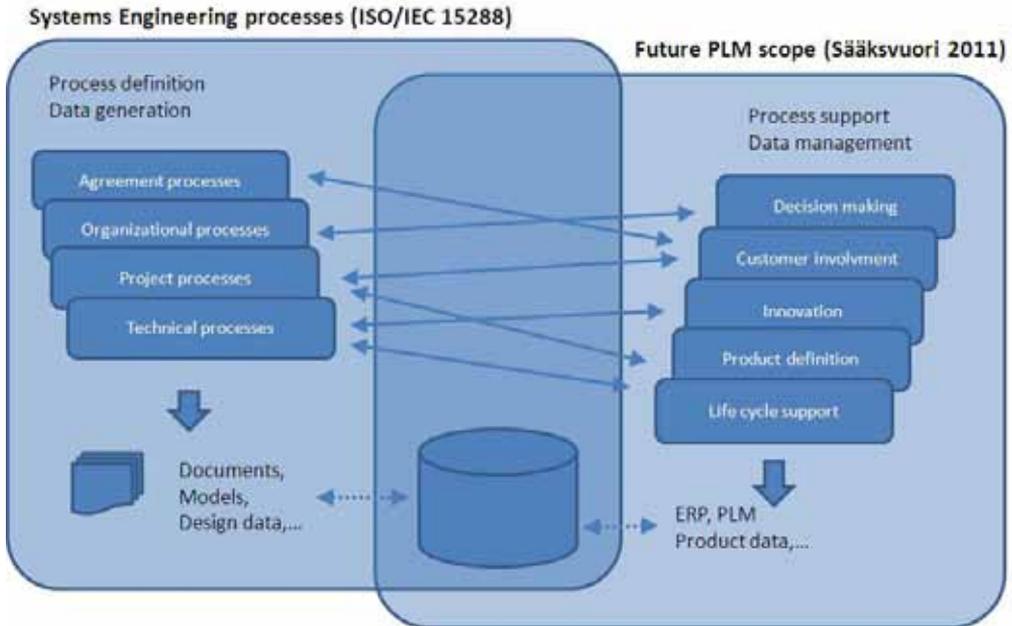
Figure 1. Systems Engineering – PLM integration.

Methods and goals

The aim of the project is to help companies in the manufacturing industry to find tools and methods suited to their specific needs to manage an integrated product design and life cycle management processes. Based on a comprehensive overview of current Systems Engineering practices and future trends, a model is developed that helps companies to focus their activities on important development targets.

One of the main challenges is to find ways to adopt the System Engineering processes to smaller enterprises operating in different roles in a networked business environment. Another important challenge is related to the implementation of new methodology, processes and data management in a network of independent companies. This and other identified research topics are treated in seminars and internal discussions in which best practices are sought through benchmarking with other companies. The project also aims to draw from the experience and knowledge gained from related research projects by establishing cross-project interest groups.

As a concrete goal, the project will produce practical guidance on the implementation of a managed product development and life cycle process targeting SMEs.

Partners

The project is funded by the Finnish Funding Agency for Technology and Innovation (TEKES) through the Digital Product Process research programme together with VTT and the participating companies Cargotec Oy, Insta DefSec, Oy, Patria Land Systems Oy, and Dassault Systèmes Finland Oy. The project has also invited a number of non-funding members representing Aalto University, Eurostep Oy and Finnish Defence Command with key knowledge in the area of research.

References

[1] Sääksvuori, A. PLM Vision 2016 and
     Beyond, Sirrus Publishing, April, 2011.

[2] International Council on Systems Engineer-
     ing. INCOSE Systems Engineering Vision
     2020, INCOSE-TP-2004-004-02, Septem-
     ber, 2007.

[3] Fasoli, T., Terzi, S., Jantunen, E., Korte-
     lainen, J., Sääski, J. & Salonen, T.
     Challenges in Data Management in Prod-
     uct Life Cycle Engineering. The 18th CIRP
     International Conference on Life Cycle
     Engineering, Technische Universität Braun-
     schweig, Braunschweig, Germany, May
     2–4, 2011.

[4] Alanen, J., Vidberg, I., Nikula, H., Papa-
     konstantinou, N., Pirttioja, T. & Sierla, S.
     Engineering Data Model for Machine
     Automation Systems. VTT Research Notes
     2583. VTT, Espoo, Finland, 2011. 129 p.
     http://www.vtt.fi/inf/pdf/tiedotteet/2011/
     T2583.pdf.

Automation isles for the future (TUAUSA)

Sauli Kivikunnas, Timo Salmi, Topi Pulkkinen and Mikko Sallinen

We present a concept for short-series production using industrial robots and advanced control systems and illustrate the operation in the pilot case. We call and define this system as 'isles of automation'. The concept is beyond the current robot work cells by the properties of flexibility, reconfigurability, context awareness and programmability. In the concept, modules are defined for programming, sensing, material handling and flow as well as communication. The overall architecture defines how these modules work together.

Introduction

Modern production is facing growing requirements for flexibility and productivity. Product life cycles are becoming shorter, the variety of products is increasing and the production costs should be reduced. At the same time, when the pressure to automate has risen, it is more difficult with well-established technologies. There is an obvious demand for new solutions that will open up new possibilities for flexibility. The requirements for short-series production are high-level flexibility for production changes and on-line adaptation for deviations in the workpieces. The production platform should be as reconfigurable as possible. This means that the requirements of flexibility concern solutions to hardware, software and communication. Features like reconfigurability, modularity, adaptivity and autonomy are desirable in all these solutions. The flexibility needs are mostly based on the parameters of batch size, the total volume of the product and the width of the differences in the part geometries. In modern manufacturing devices and systems, flexibility and versatility of automated production are largely defined by a priori order, task planning and programming. This is extended by their level of communication and autonomy to react in real time to initially unforeseen part tolerances and position deviations, not to mention, the escalating problem of scheduling in a highly dynamic environment. However, operations like this are too often far from the reality.

Methods

The concept of 'isles of automation' for short-series production has a modular structure, and it is realized as a highly flexible and controllable robotized system. It exploits the features of ubiquitous technology, including flexibility, adaptivity, context awareness and reactivity, which are beyond the current automation solutions. The production system easily adapts to new products or product variants and to deviation in workpieces. The data acquisition presents new possibilities when open interfaces are offered down to the sensor level. This means that sensors offer services and are visible to the whole control system. Sensors can be used for on-line purposes such as control but also off-line monitoring such as quality control and prognosis of the maintenance of the machines. This kind of features cannot be found in the current systems. The development of manufacturing systems has had two main approaches: Flexible Manufacturing Systems (FMS) and Reconfigurable Manufacturing Systems (RMS) [1]. The concept presented here has adapted features from both. The basic ele-
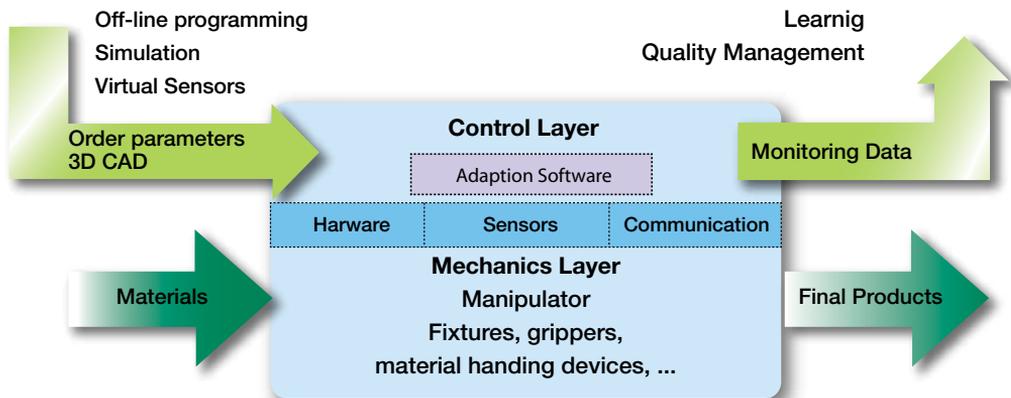
Figure 1. Automation island.

ment of the automation island is an industrial robot equipped with different kinds of external sensors and auxiliary devices combining mechanics, sensor technology and software together with intelligence in the form of a control and decision-making system. This gives high-level flexibility in terms of programmability, reusability and price. The operation of the automation island (see Figure 1) is managed by control software, the 'isle manager', which controls the execution of tasks. It also manages the sensing and reactions to unexpected situations in the robot cell. The work is carried out by communicating with distributed modules and providing the ways to carry out the tasks. The 'isle manager' is located in the application layer in the production cell and communicates within a production call and workflow manager in the engineering resources. [2, 3]

Results

The proposed concept was demonstrated in a pilot case [4] that considered the implementation of different parts of the concept, i.e., the production cell and engineering resources. The aim of the demonstration task was to deburr the bevels of a work object. As source information, there was a 2D drawing of the work object and information on the bevels. In the engineer-

ing resources, the programming of the robot motion paths was based on 2D CAD drawings. Sensing planning can also be carried out for the localization measurements of the work object. For the robot programming, a converter was developed to transform the 2D CAD data into 3D format. In the demonstration, the task-related tool tags were automatically generated for the surface of the CAD model, after which they were transformed into paths for the robot. This phase was supported by a robot motion path planner that calculated the paths for the robot motion such that all the points were reachable in a same joint configuration. Engineering resources would generate programs for the application layer in the production cell. This robot programming demonstration was carried out in the VTT laboratory. We used the ENVISION off-line programming tool by Delmia for visualizing the virtual robot cell and the transformation of the work object from 2D to 3D data. As a robot, we used the KUKA KR150-L110 industrial robot, and the deburring of the bevelling was done by a tool emulator. In the demonstration, we were content to show that the interfacing between the different parts of the system could easily be done. The generation of motion paths from 2D data was also successful.

Conclusions and exploitation potential

We presented a concept for a short series of manufacturing. The concept defines a system structure composed of engineering resources and production cells. We described the content of these in detail and illustrated a demonstration case in the laboratory in which selected parts of the concept were implemented in a robot cell. The demonstration gave very promising results on the usability of the concept. The overall idea behind it is to be able to respond to very challenging manufacturing problems to automatically process complicated objects and carry out reconfigurations between the products. In the future, the concept will also be implemented in several demonstration cases in different application areas. We can use additional tests to obtain feedback on the usability of the concept and iteratively improve it. In the future, the concept will also serve as a tool for design engineers to support the design of new flexible robot systems.

References

[1] Maraghy, H.A. Flexible and reconfigurable manufacturing systems paradigms. International Journal of Flexible Manufacturing Systems 17, Springer Science Business Media, 2006. Pp. 261–276.

[2] Salmi, T., Haataja, K., Sallinen, M., Göös, J. & Voho, P. Isles of automation – requirements and solutions for a high flexible concept of robotic systems. 2nd International Conference on Changeable, Agile, Reconfigurable and Virtual Production (CARV 2007). Toronto, Canada, 22–24 July, 2007. Pp. 894–903.

[3] Sallinen, M., Heikkilä, T., Salmi, T., Kivikunnas, S. & Pulkkinen, T. A concept for isles of automation: ubiquitous robot cell for flexible manufacturing. International Conference on Control, Automation and Systems, COEX, Seoul, Korea, 14–17 October, 2008. IEEE. Pp. 2246–2250.

[4] Pulkkinen, T., Heikkilä, T., Sallinen, M., Kivikunnas, S. & Salmi, T. 2D CAD based robot programming for processing metal profiles in short series manufacturing. International Conference on Control, Automation and Systems, COEX, Seoul, Korea, 14–17 October, 2008. IEEE. Pp. 156–162.

Ubiquitous manufacturing concept for SMEs (Umanu)

Mikael Haag

Introduction

The Umanu research studied the impact and applications of the ubiquitous manufacturing concept. In this sense, ubiquitous manufacturing means the usage and utility of ubiquitous computing concepts and technologies in a manufacturing environment. Simply put, this means embedding more intelligence into objects on the production line, making them communicate and using all the data this generates to further enhance the functionality and visibility of the production.

Methods

The basis of the ubiquitous manufacturing system is that all single key objects and processes also have a digital identity/identifier. The information relating to them can therefore easily be retrieved from the database, and all the relevant real world information should also be tracked and stored into these same data models. Some example queries that a system like this could handle are to find all of a certain type of tool in the plant or the exact location and stage of a single order.

The availability of all this information in digital form has been regarded by various sources with various terms, such as real-world visibility [1] or high resolution management [2]. This information supplied by the manufacturing processes is generated by discrete events and can include data such as a timestamp, location, resource identifier or object name and its state. These events can be combined to form a big picture that describes what is actually happening in the manufacturing line, and this big picture constitutes the data pool for high-resolution management. Here, the key factor is making all the real time information about the actual state of the manufacturing plant available, which works as a foundation for many potential enhancements for production.

This high resolution information should be generated automatically from the processes, thus there is no need to have external measurements on the functionality of the system. The methods for collecting the data from the production line can also include location-based systems and unique identifiers for actors, such as bar codes or RFID tags.

Results

In the analytical utility, the main advantages to which this abundance of information leads are enhanced decision-making and more controllable manufacturing. Besides allowing a more detailed view of manufacturing, the information generated by ubiquitous manufacturing can potentially allow previously hidden details to be found. The increased knowledge of the status of objects in the manufacturing plant naturally opens up possibilities in process automation and better visibility through transparency [3]. Moreover the transparency enables a large number of possibilities for recording data from the processes for analysis, for example, in order to find the bottlenecks and other critical points in the processes [3]. This recorded information can also be used in real time to further evaluate and evolve processes. These data can be used at plant level for making better calculations on the current capacity,
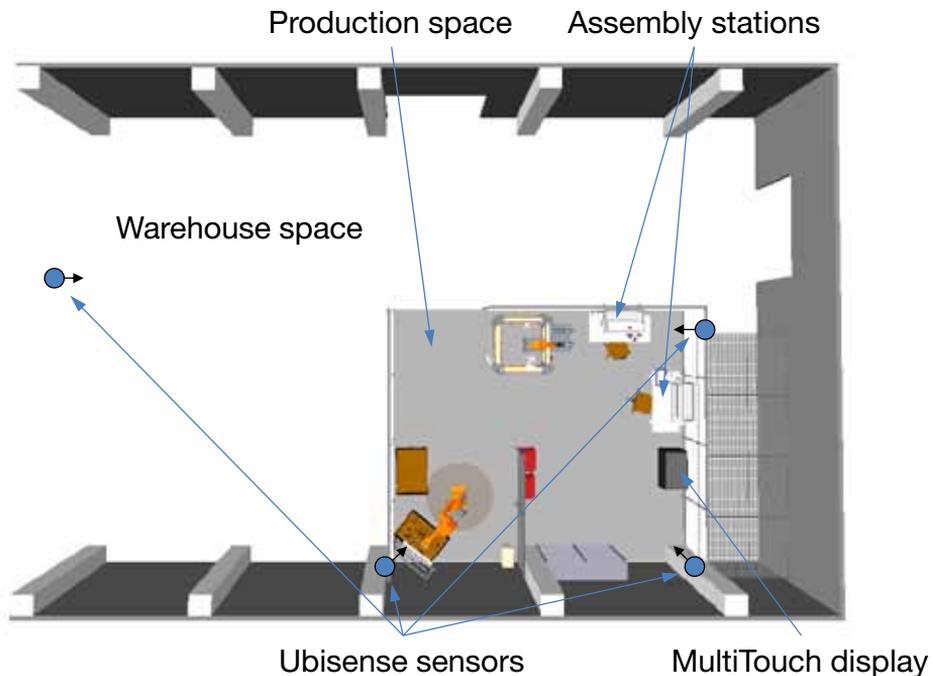
Figure 1. Ubiquitous assembly cell.

more accurate simulations and reality-based cost estimations and calculations. Real time real data knowledge can be used instead of estimates. The collectible data for these calculations could include, for example, process run times, material consumption, product manufacturing times phase to phase, the load and usage percentage of resources, idle times and time spent in queues, waste and loss of resources, number of defects and quality analysis of output. The generated meta-data also enhances traceability of the products.

Some operative possibilities enabled by transparency on the shop floor include real time information about the phase of production and the estimates of throughput time. This is naturally reflected in better tracking of orders and more timely deliveries, as the real time information is used to answer all the queries.

Plant-level operative applications can include, for example, automatic calculation of loading, materials management and man-

ufacturing control. Other operative planning actions can include automatic (crude) allocation of resources, work planning optimization, cost and time estimates based on real data instead of speculation and more timely resource usage.

The research also included a single demo of a demonstrated ubiquitous assembly cell to portray ubiquitous manufacturing. Visualization of the whole cell can be seen in Figure 1. The example focuses on robot-assisted manual work in which the worker is constantly located with machine vision and instructed according to the location and the phase of assembly. The system assists the worker by indicating which components to collect and from where and how to add them to the assembly. Component picking instructions are shown as component names, pictures and locations, and also indicate the correct picking location with lights. Assembly instructions are shown at the assembly station with an augmented reality application, indicat-

ing the correct way to insert the component. A visualization of a single workstation can be seen in Figure 2. Aiding the worker eases the load on the worker's memory, as it eliminates obsolete tasks such as choosing and remembering. The proposed assembly cell aims to shorten the ramp-up times of new products, add flexibility to the use of the work-force by enhancing worker training and improving quality.

Discussion and conclusions

Part of the findings from the study are that current technologies allow implementation of ubiquitous assembly environments but that there are two key requirements for the data modelling and management systems that still prevent the real applications on the factory floor. These requirements for enabling ubiquitous assembly cells in practice are:

•   interoperating data models (ontologies) for integrating product data and production data

•   singular lever item management, required for sensing and identifying discrete events from the assembly process.

These two requirements need to be tackled in order to create a fluent data flow from the process planning to the factory floor and to supply decision-making with higher resolution real time data instead of estimates. The research also studied preliminary solutions to fulfil these two requirements. These solutions include collection and usage of discrete events data from the assembly process, ranging from simple device outputs to the use of specific positioning and locating systems and RTLS. These collected data, which in themselves are rather meaningless, are combined with a digital representation of the factory resources, work plans and instructions enabling the identification of the exact real time state of all the items related to the assembly process, which, in turn, forms the basis for applications of ubiquitous assembly cells.
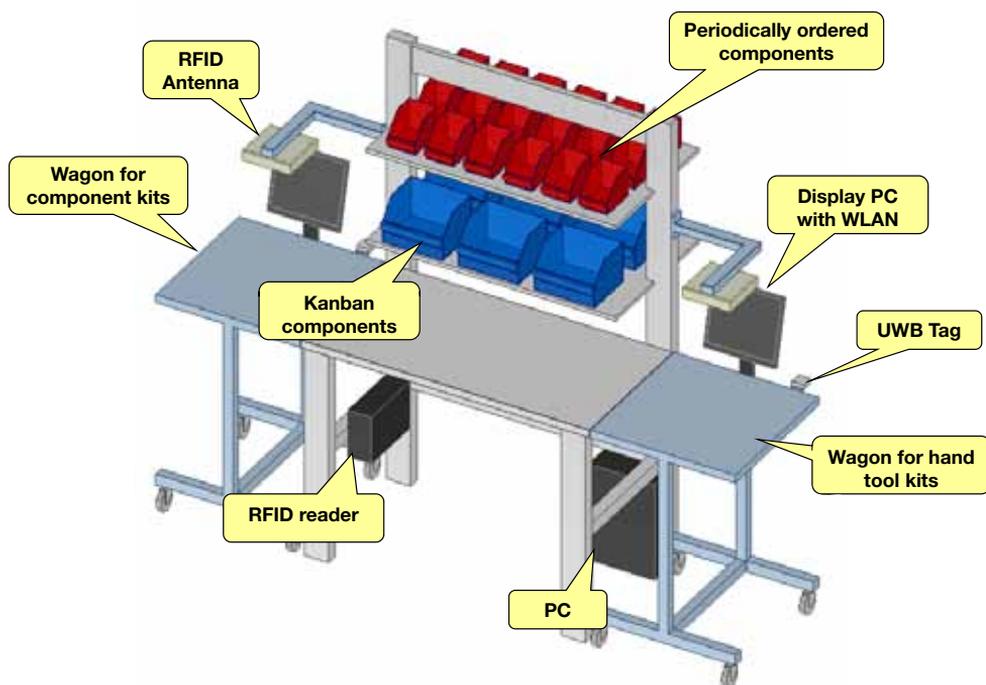
Figure 2. Single assembly station.

Exploitation potential

In a knowledge management sense, the ubiquitous manufacturing concept can yield high gains when correctly implemented. Although the implementation can be seen as very heavy and thorough, it should be possible to test it out by implementing it only partially in selected areas and using it only as an analytic application instead of an operative one. The operative planning applications can also be used with the addition of existing systems and human expertise to verify planning.

As ubiquitous manufacturing makes production more controllable and accurate in the sense of orders, it enhances the ability to fulfil orders, including specific ones by customers. Controllable production also makes it easier for the plant to adapt to changes in the event of reconfiguration and in the sense that it can ease the need for buffer stocks, reducing the amount of work in progress (WIP).

References

[1] Haller, S., Karnouskos, S. & Schroth, C. The Internet of Things in an Enterprise Context. Future Internet – FIS 2008, First Future Internet Symposium, revised selected papers. Springer-Verlag, 2008. 15 p.

[2] Subirana, B., Sarma, S., Fleisch, E. 2006. High-Resolution Management. IESE Alumni Magazine, July/September, 2006, pp. 8–13.

[3] Lucke, D. & Constantinescu, C. Smart Factory Data Model: Foundation of Context-Aware Applications for Manufacturing. 7th International Conference on Intelligent Computation in Manufacturing Engineering, CIRP ICME '10, 23–25 June, 2010. 4 p.

New joint production concepts for machine manufacturers and the foundry industry (VATU)

Jukka Väinölä and Mika Siren

Introduction

In the past few years, subcontracting in the metal industry has shifted significantly to foreign subcontractors, mainly due to the high labour costs in Finland. The metal subcontractors' distress has been deepened further by the global recession and the reduced demand for workshops. One of the sectors suffering the effects of globalization is the foundry industry. Production in low-cost countries (LCCs) and current trends in supply chain management and procurement are challenging traditional casting producers in countries with high labour costs, like Finland. Mass production and easy-to-cast components, in particular, are increasingly moving to foundries in LCCs.

The labour-intensive foundry sector has been forced to improve its performance and concentrate on more demanding materials, products and methods, small series, and prototype and single casting production. On the other hand, customer needs are increasing: shorter delivery times, higher quality and delivery reliability requirements are necessitating more efficient production and management, and a higher degree of processing requirements is calling for investment in new knowledge, equipment in production technology or production networks, and network management skills. The aging of skilled personnel is one of the threats of the near future to the labour-intensive sector. The commitment of the workers and the attractiveness of the industry sector will play a key role when looking for the next generation of foundry experts.

The three most important factors in current casting procurement are quality, delivery reliability and cost-effectiveness. Suppliers are expected to focus on customer needs, and deeper cooperation with suppliers should be of mutual interest. Manufacturing that remains near R&D is vital when seeking future success factors. To survive, the Finnish foundry industry has to find ways to improve its performance and develop new business concepts based on cooperation and serving customers.

The project 'New joint production concepts for machine manufacturers and foundry industry' was established in 2009 to improve cooperation between customers and foundries. Nineteen partners, seven foundries, four machine manufacturers, a trade union, the Federation of Finnish Technology Industries, TEKES, and the research partners Aalto University and VTT started the process to analyse and improve cooperation between Finnish industrial companies. As a result, advantages and disadvantages were found in the industry.

Methods

A survey among casting users and foundries was carried out to find the strengths and weaknesses of the Finnish foundries as suppliers. The participating companies were interviewed and a survey among the participants of the Annual Casting Users' Seminar 2010 was carried out to find answers and opinions to some specific questions. Workshops with partners focused on cooperation and its difficulties, best practices and experiences. Based on

surveys, interviews and workshops, the weak points and focus areas were identified and an overall picture built up of the state of the Finnish foundry industry together with the latest developments in cooperation.

Several hot-spots were selected to improve the competitiveness and attractiveness of Finnish casting suppliers. Tools and documentation to improve the trust level between parties were developed; the available tools, methods and practices outside Finland were evaluated; and workshops for different business groups were organized to add interaction. Trust and commitment were identified as essential factors to be developed in mutual cooperation. Separate studies were carried out on specific issues, including risk management, the environment and sustainability, robotics, networking, cost analysis, etc.

Results

The foundry industry in Finland is extremely diverse. The second largest foundry company in Europe is Finnish, but there are also several small and family-owned companies in the business. The variety of methods, materials and practices in foundries is wide and heterogeneous and there is a lack of common well-established practices and documentation in the business. One focus of the project was on developing better documentation covering the whole delivery process.

Improvements in employee commitment reflect directly on quality and delivery reliability. One focus point was commitment and the image question. Automation and robotics allow avoidance of heavy and risky stages and improve the efficiency of, for example, cleaning work. They also improve the image of the foundry.

The level of trust between cooperation parties in Finland often seems low. This weakens the supplier-customer relationship significantly. Improving trust is of mutual interest. A long-term partnership enables better understanding of the customer process and early supplier involvement in the design pro-

cess. This can lead to savings that cannot be achieved with remote suppliers.

This research showed that foundries and their customers use a wide range of different types of tools and processes to estimate manufacturing and purchasing costs for castings. The method may be a homemade Excel algorithm, a comparison with older similar castings or commercial calculation software based on activity costing. The method, which is used by companies, does not come from the size or type of the company or any other particular factor.

Surprisingly, the delivery times of Finnish foundries tend to be longer than the delivery times from LCCs, which, combined with a higher price and low delivery reliability, does not make Finnish suppliers more attractive than their competitors. Geographical vicinity combined with an understanding of customer needs must be exploited in the delivery times, together with cultural and lingual unity. If not, there is no factor that makes a local supplier more attractive than one abroad. Proximity, flexibility and professional, skilled workers are the biggest advantages of Finnish foundries. In the future, Finnish foundries should invest in customer service and in cutting the delivery times.

The ability of foundries to react quickly to volume changes is known to be generally poor. The importance of the agility aspects of the castings supply chain and foundry production is increasing. A foundry company that is restricted to using a single specialized non-agile foundry production unit may experience enormous difficulties satisfying its customers' needs and delivering a wide range (size, series size, material, complexity, etc.) of castings. Thus, it will exhibit low agility. However, a foundry company using multiple delivery channels with an agile supply system will excel in markets with frequent changes in terms of demand and production volume.

One way to survive is to adjust the casting production to prototype castings, zero series and single castings. The competitiveness and service capabilities of Finnish subcontractors can be improved to better meet the

Finnish workshop demands and expectations by directing the production processes and strengthening the cooperation already from the design phase. The lack of trust between cooperating parties is limiting Early Supplier Involvement (ESI). In the project, the best available practices for ESI were collected and a basic agreement structured based on the collected available materials and experiments.

As a result of the project, several development projects were proposed. A project concentrating on cooperation and quality improvements between Finnish steel foundries and customers was launched. The use of force control in robotized casting cleaning was one of the development targets. Environmental considerations and sustainability in casting supply chain management are a future research goal, and the use of LEAN methods in the Finnish foundry industry will allow it to concentrate on various technical and management improvements required in the supply chain and networks.

Publications

Angelva, O. Valutuotteen hankkiminen ja kustannuslaskenta. Master's thesis. University of Oulu, Finland, 2011.

Orkas, J., Piha, O. & Vainola, J. 2011. How to compete against global Competition. 51st International Foundry Conference Portoroz, 2011.

Piha, O., Niini, E. & Orkas, J. Agility in volume changes as a success factor in the future global foundry industry. World Foundry Congress, 2010.

Saarelainen, T., Piha, O., Orkas, J., Makkonen, P.E. Issues on procurement of castings. International Journal of Social Sciences 3:2, 2008, pp. 121–126.

Virta, J., Paro, J. & Vainola, J. Valutuoteteollisuuden tilanne Suomessa. Confidential project report. VTT, Espoo, Finland, 2011. (In Finnish.)

Manual work support throughout the system life cycle by exploiting Virtual and Augmented Reality (ManuVAR)

Boris Krassi

Introduction

ManuVAR is an EU research and development project [1, 2]. It focuses on the high value of high-knowledge manual work that cannot be offshored or automated because it constitutes the core of the business operation. It has to be made locally and manually with highly experienced and knowledgeable personnel. The success of the business relies on the knowledge and skills of the personnel rather than on minimizing labour costs.

The project aims to develop new technology and methods to improve manual work across five industry domains: terrestrial satellite assembly, design of assembly lines in small enterprises, maintenance in the railway sector, training in non-destructive techniques in power plant maintenance, and heavy machinery productization and maintenance.

Methods

ManuVAR combines several disciplines:
- Product life cycle management (PLM)
- Virtual and augmented reality technologies (VR/AR)
- Ergonomics methods and knowledge management.

The project workflow includes the following stages:
- identify the most common problem areas regarding manual work across industries
- design and implement a set of tools and methods to address these problem areas
- test the tools and methods in the laboratory and on the factory floor.

Results

ManuVAR has identified seven **key problem areas** regarding high knowledge, high-value manual work that is common to all five industry areas [2]:
1. problems with communication throughout the life cycle
2. poor interfaces to complex information systems
3. an inflexible design process in terms of adaptation to system customization and changes
4. inefficient knowledge management
5. low productivity
6. lack of technology acceptance of VR/AR technology
7. physical and cognitive stress.

To respond to these problem areas, the following three groups of results have been developed:
1. **Technological:** the platform of modular reconfigurable VR/AR tools; system architecture based on the 'virtual model'; and tested technical prototypes [5, 11].
2. **Methodological:** the key problem areas regarding manual work; the ManuVAR PLM model and its application methodology; the framework of ergonomics methods to support manual work throughout the system life cycle; training and implementation support methodology; and the knowledge management concept [4, 10].
3. **Policy:** recommendations and evidence for policymakers (industry, community, political) that high knowledge, high-value

Figure 1. The ManuVAR PLM model and the concept of bi-directional communication through the life cycle. Several actors (a worker, a designer and a human factors expert) located at different stages of the life cycle (outer layer) communicate off-line or on-line with each other via the virtual model (in the centre). Each actor has a customized view (user interface) of the shared virtual model. As soon as one actor affects the virtual model, all other actors are able to perceive the result. Compared with the process-driven communication in a chain, this communication is more flexible and allows easier change management and synchronization among multiple actors. Source: [5]

manual work can be an opportunity for European industries.

The main characteristics of the ManuVAR **system architecture** include (Figure 1):

- **Bi-directional** communication throughout the system life cycle (e.g. workers' feedback to the designers, the designers' recommendations to the workers) is accomplished by means of a 'virtual model'. The virtual model plays the role of a communication mediator – a single systemic access point to the variety of data, information, models on the system for all users in the life cycle – accessed as an integral system by 'virtual experiments' [5].

- **Adaptive VR/AR user interfaces** to the complex virtual model that fits all actors in the life cycle from workers to engineers and managers. The VR/AR interfaces are implemented through component reconfiguration with low-delay middleware (haptics, tracking, VR/AR visualization, application logic, connection to PLM systems) [3].

Figure 2. An example of the combined ManuVAR tool – participatory cross-disciplinary design review of a new product. Several experts – engineers, workers and managers – investigate a shared virtual environment view of the product (assembly sequence, ergonomics issues) before it is brought into production to find possible design faults. Source: [13]

- **Four groups of human factor methods** to cluster the principal ways to improve manual work from the system-cybernetics perspective [4]: workplace design, ergonomics evaluation, instruction delivery and training.
- **The knowledge management concept** based on Nonaka's organizational knowledge creation theory [12] with each modality of knowledge creation supported: externalization and internalization (adaptive and natural user interfaces with VR/AR), socialization (bi-directional communication and the virtual model) and combination (linking in the virtual model and connection to PLM systems).

The project has implemented four reconfigurable **application tools** that can be combined via the virtual model to solve a given industrial case (Figure 2):

- Contextual instruction delivery: AR, tracking; remote and local versions [7]
- Ergonomics evaluation: automatic physical and cognitive load analysis, full body motion capture [6]
- Task analysis and procedure validation: hierarchical task analysis tool, VR with haptics [8]
- Motor skill training: VR with haptics, precision-teaching theory [9].

Conclusions

Offshoring is a natural phenomenon. It will exist while there are big differences in labour costs, but European industries could turn their attention to business that cannot be offshored, e.g. unique or deeply customized products, main-

tenance of fixed installations, and operation and maintenance of machinery. This business is an opportunity for Europe because it relies on the knowledge and skills of people rather than on minimizing labour costs. ManuVAR has developed methods and tools for bi-directional communication and knowledge management for all actors in the life cycle, adaptive user interfaces with AR/VR, and application tools based on ergonomic methods improving high knowledge, high-value manual work.

Acknowledgements

References

[1] ManuVAR website: http://www.manuvar.eu.

[2] Krassi, B., D'Cruz, M. & Vink, P. ManuVAR: a framework for improving manual work through virtual and augmented reality. Proceedings of the 3rd International Conference on Applied Human Factors and Ergonomics, AHFE2010, Miami, FL, USA, 17–20 July, 2010. Published in: Vink, P., Kantola, J. (eds.). Advances in Occupational, Social, and Organizational Ergonomics. CRC Press, 2010.

[3] Krassi, B., Kiviranta, S., Liston, P., Leino, S.-P., Strauchmann, M., Reyes-Lecuona, A., Viitaniemi, J., Sääski, J., Aromaa, S. & Helin, K. ManuVAR PLM model, methodology, architecture, and tools for manual work support throughout system lifecycle.

[4] Aromaa, S., Viitaniemi, J., Leva, C. & Krassi, B. Integration of Human Factors methods to the ManuVAR Product Lifecycle Management model.

[5] Krassi, B., Strauchmann, M., Kiviranta, S., Leino, S.-P., Viitaniemi, J., Reyes-Lecuona, A. & Sääski, J. Virtual Model for Supporting Communication of Manual Work Information Throughout System Lifecycle. Fraunhofer Institute for Factory Operation and Automation (IFF) days 2010, Magdeburg, Germany, 15–17 June, 2010. Pp. 228–233. Full text: www.vtt.fi/inf/julkaisut/muut/2010/Krassi_et_al.pdf.

[6] van Rhijn, G., Bosch, T. & de Looze, M. Mixed Reality System and objective ergonomics evaluation for designing work stations in manufacturing industry. Joint VR Conference of euroVR and EGVE, Nottingham, UK, 2011. http://www.vtt.fi/inf/pdf/symposiums/2011/S269.pdf

[7] Azpiazu, J., Siltanen, S., Multanen, P., Mäkiranta, A., Barrena, N., Díez, A., Agirre, J., Smith, T. Remote support for maintenance tasks by the use of Augmented Reality: the ManuVAR project // ibid.

[8] Gaia, E., Basso, V., Vizzi, C., Virtual Reality for planning and validating spacecraft integrating procedures in Thales Alenia Space Italia // ibid.

[9] Poyade, M., Reyes-Lecuona, A., Frutos, E., Flores, S., Langley, A., D'Cruz, M., Valdina, A., Tosolin, F. Using virtual reality for the training of the Metallographic Replica technique used to inspect power plants by TECNATOM S.A. // ibid.

[10] Liston, P., Kay, A., Cromie, S., Leva, C., D'Cruz, M., Patel, H., Langley, A., Sharples, S., Aromaa, S. Evaluating the iterative development of VR/AR human factors tools for manual work. 18th World Congress of Ergonomics, 2012.

[11] Leino, S-P., Pulkkinen, A. Design for Human-Virtual Engineering is a Media for

Knowledge Transfer. International Design Conference, DESIGN2012, Dubrovnik, Croatia, 21–24 May, 2012.

[12] Nonaka, I., Takeuchi, H.A. Dynamic Theory of Organisational Knowledge Creation. Organisational Sciences, Vol. 5, Iss. 1, 1994, pp. 14–37.

[13] Heikkilä, J., Helin, K. & Leino, S.-P. Customer Requirements Validation with VR Technologie – Case Metso Minerals. In: Helin, K. & D'Cruz, M. (eds.). VR Conference of euroVR and EGVE. Current and Future Perspectives of Virtual Reality, Augmented Reality and Mixed Reality: Industrial and Poster Track, Nottingham, UK, 20–21 September, 2011. http://www.vtt.fi/inf/pdf/symposiums/2011/S269.pdf.

Enterprise networks

Strategic development of enterprise networks (Verka)

Katri Valkokari

Introduction

The rules of the game have changed dramatically in the past 15 years. The ability to build up effective and mutually beneficial partnerships and networks is the foundation of current business success. The key success factors of networks are the willingness and ability of companies to participate in them and the ability to use future business opportunities together with other companies entering the networks and business alliances. The company's own strategic decisions on networks (which networks to enter and why, in which role and with whom) should form the basis of network development.

The scope of the Verka project was the research of the network's growth and development dynamics. The aim was to configure new network development methods based on the theoretical background and the company's needs defined in eight Finnish technology industry case networks.

A need for new strategic network development methods was recognized, e.g. how to analyse a company's network relations in complex dynamic networks and how to find optimal partners and a common network strategy. There is a need to find ways to enhance the competitiveness of networks and organize long-term multilateral cooperation and development work in an effective way.

The Verka tools can be divided in two groups: 1) tools to describe the network environment and choose suitable partners to start the cooperation, and 2) tools to create the network strategy and agree on the ground rules of the cooperation.

Methods

The Verka toolbox for strategic network development is constructed based on previous network development cases in which researchers from the VTT Business and Technology Management Knowledge Centre have participated. The core companies in the previous case networks were HT Lasertekniikka Oy, Juha Lemponen Oy, Maaseudun Kone Oy and Nautor Oy, Reikälevy Oy ja Verkko A ry.

The structures of the networks, network life cycle phases, methods used and development themes of the case-networks were analysed. As a result, a new network life cycle model was developed and the needs for new network development methods were defined.

The tools were further developed and tested in three cases during the Verka project. Nekos (formerly Nekomat belos), Purso Tools and Arla-Ingman took part in the testing and development of the tools. The development work and the cases were presented in [1]. The Verka tools were also published in the working book and on the web pages (www.verka.fi).

Results

The toolbox for strategic network development is tailored for network developers. It offers tools to:
- identify the company's network portfolio and partnerships
- shape an optimal network structure and joint vision
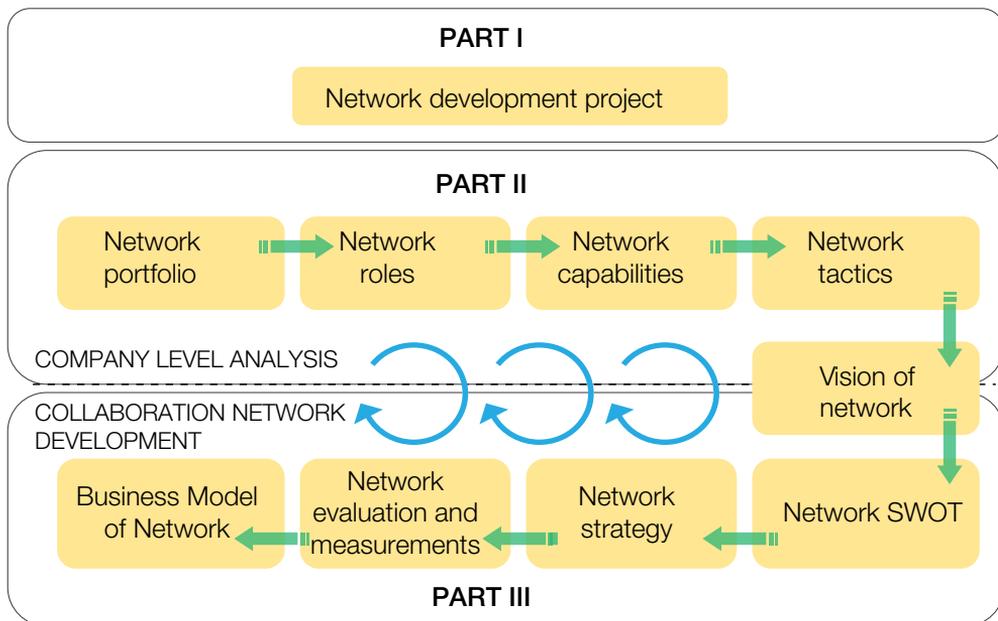
Figure 1. Structure of the Verka toolbox.

- identify network business opportunities and business concepts
- create a network strategy and competitive advantages
- organize a network operations model and systematic network development work
- manage and evaluate networks.

The toolbox includes three main modules (Figure 1): project planning for network development, company-level network analysis and collaborative network development. These three modules and each of the tools can be used separately.

The set of company-level tools includes the definition of a network portfolio, roles, capabilities and tactics. These tools can be used for the company's internal strategizing, positioning and decision-making. Network-level development work can be started from the vision of the network, and the network SWOT, strategy, evaluation and measurement methods, and business model of the network are thereby the

network-level tools. The first part of the toolbox summarized the researchers' experiences and knowledge of planning and implementing a network development project.

The Verka tools were published in 2007 and re-worked into an electronic format (mainly Word documents) with the SME Foundation and Onway Oy in 2009.

Discussions and conclusions

The Verka toolbox is based on the nine independent business network development projects. Several network companies also took part in the development and evaluation of the tools. Understanding the dynamics is vital for any strategic network development, including networks and communities focused on creating new knowledge.

The toolbox helps companies to negotiate roles, resources and operation models, and to demonstrate their value in different functions within the network. It supports a system approach to the business network.

Exploitation potential

The Verka toolbox is suited to strategic analyses and development of different kinds of business and development networks. It can broadly be used in innovation, R&D, production, sales and marketing networks in different branches and at different levels of networks.

The systematic development work supported by the toolbox enables the creation of the network's joint interests and shared intention. The tools support collaborative development work between the network partners.

Acknowledgements

Publications

Hyötyläinen, R., Anttila, J.-P., Hakanen, T., Kalliokoski, P., Poikkimäki, J., Valjakka, T. & Valkokari, K. PARTNET – Kehittyminen järjestelmätoimittajana. Tykes julkaisut, raportti 43. Helsinki, 2005. http://www.tekes.fi/ohjelmat/Tyke/Aineistot/Tykes+-ohjelman+raportit.

Valkokari, K., Kulmala H.I. & Ruohomäki I. Toimittajaverkoston johtamisen työkalut – Case Ruukin Kattoasennuspalvelun verkoston kehittäminen. Tykes julkaisut, raportti 44. Helsinki, 2006. http://www.tekes.fi/ohjelmat/Tyke/Aineistot/Tykes+-ohjelman+raportit.

Verkoston strategisen kehittämisen työkirja & Verka tool box (Menetelmiä verkostojen kehittämiseen). http://www.vtt.fi/proj/verka/index.jsp. (In Finnish.)

References

[1] Valkokari, K., Hakanen, T., Airola, M. Yritysverkoston strateginen kehittäminen. VTT Research Notes 2348. VTT, Espoo, Finland, 2006. http://www.vtt.fi/inf/pdf/tiedotteet/2006/T2348.pdf.

Management of dynamic networks and the performance of industrial systems (Dynamo)

Katri Valkokari

Introduction

"Strategic networks are long-term, purposeful arrangements among distinct but related for-profit organizations that allow those firms in them to gain or sustain competitive advantage vis-à-vis their competitors outside the network"

Jarillo, 1988

The main aim of the Dynamo research project was to create new concepts and methods for the management and control of business relationships and networks. A broader vision of the project is to identify the general trends of future success factors of the management of business relationships and networks.

The dynamo project aims to build practical tools especially for the management of performance and growth in a networked environment in order to find answers to a wide variety of questions in the context of industrial networks:

- How should a network that includes many kinds of partners be managed?
- What is the benefit to a company of belonging to a network?
- How can many different networks be joined at the same time?
- How can growth and economies of scale be gained through networking?
- How can new business ideas be developed through networking?
- Why invest in joint operations if it calls for resources?

- How can core competence be retained while cooperating with network partners?

The project was executed in cooperation with the Helsinki School of Economics, the University of Vaasa, the Helsinki University of Technology (BIT Research Centre) and the Research Institute of the Finnish Economy (ETLA).

Methods

The research strategy employed in our study was a qualitative multiple case study. An action research approach was used in order to research the phenomenon of network dynamics inside. Understanding the differences between the practical reasoning of managers and the academic interpretation also requires researchers to use second-order questions to determine local meanings.

Ten actors, with an interest in the management of networks, and their networks attended the Dynamo project. The actors were from various industries and very different in size and network position. The project was therefore able to have a broad view of the challenges and opportunities for network development. Compared with a single-case study, the advantage of a multiple-case study is that it gathers evidence from multiple cases and is thus regarded as more robust.

The summary of the case studies is presented in Table 1.

Table 1. Summary of case studies in the Dynamo project.

Actors	Challenges	Activities	Results
City of Mikkeli	Public and private partnerships and network	Development of a cooperation forum for the technical service unit	New operating model and network platform for PPP
Coor Service Management Oy	Public and private partnerships	Collaboration and formation of shared understanding within a development platform	New operating model and network platform for PPP
Fibox Oy Ab	Internal collaboration and development of solution business	Workshops to develop solution business and team working	Team-based collaboration model for the development of a solution business for selected key customers
Metso Minerals (Tampere) Oy	Management and development of a supplier network	Analyses and workshops' top defined network-level joint processes	Model for supplier network development Process development with key suppliers
Oy Kohiwood Ltd	Global material supplier's network strategy in furniture industry	Country-level review of strategic options' pricing tool for optimization of product mix	Customer co-operation model Global network strategy implementation start
TietoEnator Oyj Healthcare & Welfare	Customer co-operation in global markets, evaluation of new market areas	Internal expert interviews with-in the interviews of IT management in German hospitals	Development of operation model and offerings in a changing environment
Vaisala Oyj	Knowledge management within an internal network organization, cooperation of global teams	Analyses of teams' operation models for their reformation and development Knowledge management tool (an open-house portal) to support development of team work	Open House Portal and new operation model for internal global teams

Wärtsilä Finland Oy (Ship Power)	Re-organization of global sourcing and the challenges of a rapidly growing business in the context of the project business	Analysis of more than 20 co-relationships Portfolio for a supplier of network development tools	Model of Supplier's development discussions Cost structure opening with the pilot supplier
SOP Metal Oy	Management and development of customer partnerships	Systematic analysis of partnership and defining the development need in key customer relationships	Model for development discussions of partnerships
VM Group Oy	Strategic co-operation in the horizontal network	Developing the network strategy process Prioritization of partners and development of partnerships	Model for network's strategy process

Results

The project examined the networks as a dynamic framework linked to the business development of network actors. The rich empirical data deepened the understanding of network dynamics, and the development activities varied from the efficiency of supplier networks to the search for new business opportunities in customer networks. The network's development framework can contribute to actors learning as well as operational efficiency. On the other hand, it can also create innovation and new business opportunities.

The results point out the importance of contingency theory within both network research and practice. The starting point of the analysis was the positioning of the networks as a hybrid form of organizing between the markets and the hierarchies (Figure 1).

Discussion and conclusions

The Dynamo project provided theoretical and managerial contributions to the management and development of business networks. It created a vision for development paths and solutions to the future success of business relationships and networks.

As prior literature typically focused on the characteristics and development processes within one network type, this comparison between network types contributes to the existing literature of network management. Thereby, the study also proves that the different network types distinguished in several network typologies also exist in practice. Moreover, viewing business networks in terms of concurrently open and closed systems leads us to a new understanding of the role and limits of network management and different network forms.
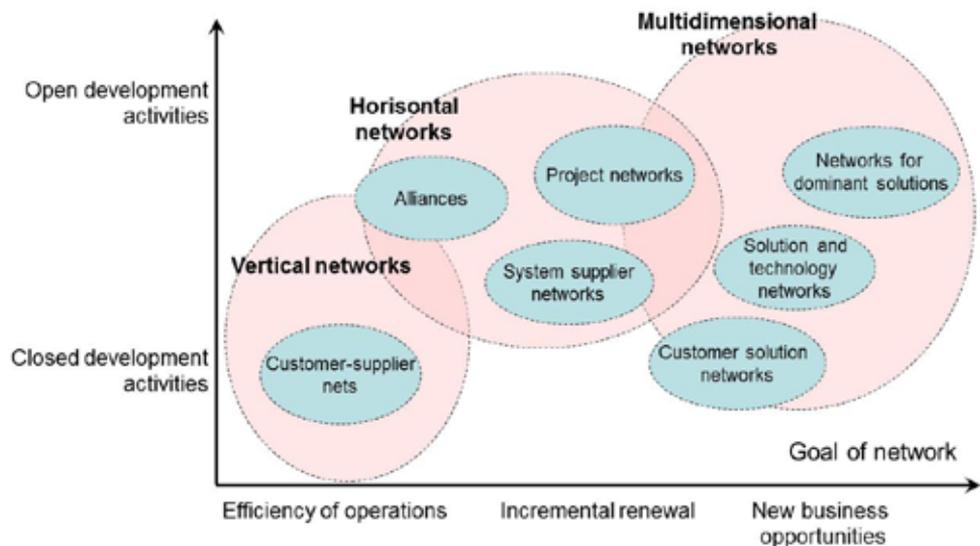
Figure 1. Network models.

Exploitation potential

Firms and their managers typically have more experience of certain business networks, and one important challenge is to understand that different network situations require different approaches. In order to use networks as a means of their business development, actors have to be able to analyse different network situations and their roles in different networks. First, the development of closed, vertical and rather hierarchical supplier networks focuses on the operation models of the network. Second, the development of more open horizontal networks between equal partners focuses on continuous development, joint problem solving and learning between network actors. Third, the development of multidimensional innovation networks focuses on emergent strategies and the interpretation of the future business opportunities of network actors.

Acknowledgements

Publications

Valkokari, K. Yhteisten tavoitteiden ja jaetun näkemyksen muodostuminen kolmessa eri-tyyppisessä verkostossa. VTT Publications 715. Dissertation. VTT, Espoo, Finland, 2009. 278 p. + app. 21 p. http://www.vtt.fi/inf/pdf/publications/2009/P715.pdf. (In Finnish.)

Valkokari, K., Anttila, J.-P., Hakala, T., Hyötyläinen, R., Korhonen, H., Kulmala, H.I., Lappeteläinen, I., Lappalainen, I. & Ruohomäki, I. Muutos on pysyvää – entä verkostot? Kolmen liiketoimintaverkoston kehityspolut. 2009. Raportteja 67. Tykes-ohjelma. http://www.tekes.fi/ohjelmat/Tyke/Aineistot/Tykes+-ohjelman+raportit. (in Finnish.)

Valkokari, K., Hyötyläinen, R., Kulmala, H.I., Malinen, P., Möller, K. & Vesalainen, J. (eds.). Verkostot liiketoiminnan kehittämisessä. WSOY Pro, Helsinki, 2009. 241 p. (In Finnish.)

Virtual organization management (ECOLEAD)

Martin Ollus and Iris Karvonen

Introduction

Today, the competitive environment in manufacturing and service industries is forcing these industries to change their operations. To be successful in a very competitive and rapidly changing environment, significantly improved competencies are needed. Small and medium-sized organizations, in particular, participate in networks to achieve a differentiated competitive advantage. By collaborating, they can rapidly respond to market demands by sharing competencies and resources. The new forms of operation affect business models, strategies, organizational and governance principles, processes and technological capabilities. Companies are increasingly restructuring their internal operating and information systems and re-engineering production processes to eliminate waste and lower costs. New organizational forms naturally emerge supported by collaborative tools based on the Internet, mobile computing and a better understanding of the mechanisms of collaborative networks [1].

There is growing awareness that the collaboration in networks has a multidisciplinary nature based on information and communication technologies, socio-economics, operations research, organizational business management, and legal, social security and ethical areas, among others. The European project ECOLEAD (European Leadership Initiative in Collaborative Network Organisations, 2004–2008) was launched to create the necessary strong foundations and mechanisms for establishing an advanced collaborative and network-based industry society, taking a holistic view on concepts, methods and tools for collaborative networked organizations.

As part of ECOLEAD, the Management of Virtual Organizations (VO) was studied. A Virtual Organization is defined as a set of col-laborating independent organizations, which, to the outside world, provide services and functionality as if they were one organization, supported by computer networks [2]. A VO is created within a collaboration network, called a Virtual Organization Breeding Environment (VBE). The VO is usually formed to create value for a customer [3]. It is a temporary consortium and is dissolved after the delivery of its product/service. Its duration may vary from very short-term tasks (hours or days) to extensive deliveries (years). New VOs can be formed for new emerging needs. The composition of the VO may vary even for similar tasks.

When a VO is closed, the possible continuation of similar tasks is not necessarily known and the dissolution phase ends the concrete collaboration. Actions to maintain the experience and collaboration potential are essential in this phase.

VO management

The main challenges for VO management (VOM) come from the temporary nature and distribution of operations in independent organizations with their own aims, behaviour and culture. VOM is defined to contain the organization, allocation and coordination of resources and their activities as well as their inter-organizational dependencies to achieve
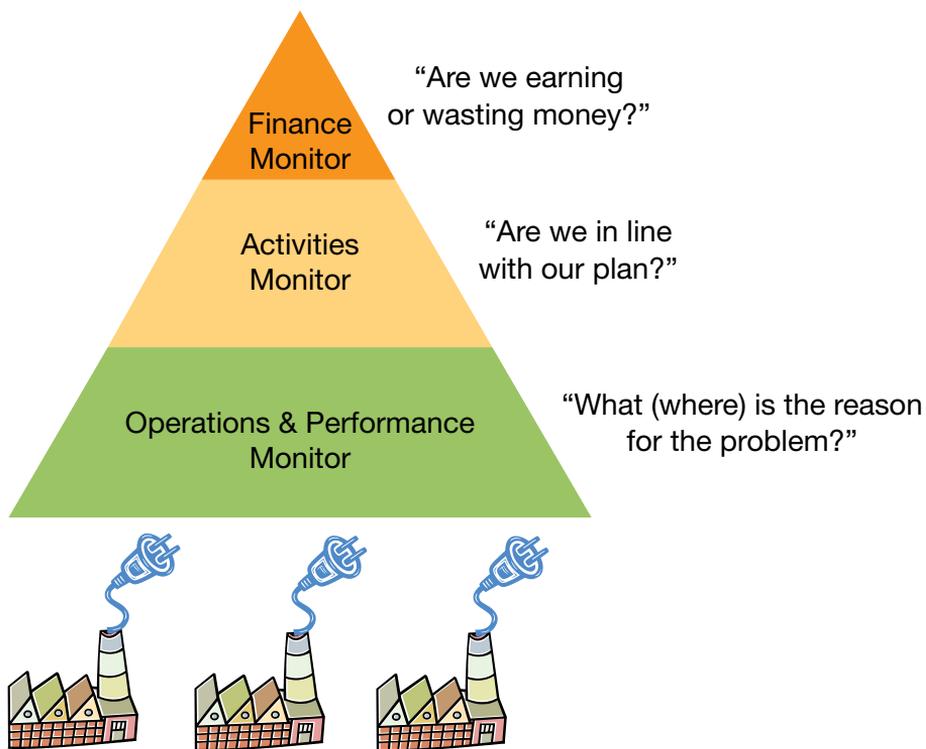
Figure 1. Management and monitoring activities.

the objectives of the VO within the required time, cost and quality frame [4]. It cannot necessarily be managed like a single organization.

In ECOLEAD, a concept of 'Real time VO management' was used for the development of e-services to support the VO manager's decision-making [5]. The management of collaboration requires continuous awareness of the state of the activities and tools for the implementation of the necessary actions. In most tasks, the managers are interested in the main status information, as in shown in Figure 1.

The necessary interventions have to be implemented taking into account the specific features of each VO, like the type of its objectives, its preparedness level, the risk involved in the objectives and the level of dependencies between the partners and tasks [4].

The developed management support contained a dashboard helping the VO manager(s) to define the necessary interventions. The dashboard is illustrated in Figure 2.

A distributed monitoring and management support system was developed and tested in a distributed environment with VO partners in several European countries.

VO inheritance

By definition, the VO is a temporary activity. Its disclosure may lead to a risk of losses of information, knowledge or other values. To reduce this risk, an activity called VO inheritance was developed. It is defined as 'the practice of storing and forwarding experiences and other non-proprietary assets created through collaboration in a VO' [6]. The aim is to strengthen the Network or VBE

by preserving common valuable outcomes ('VO heritage'). When the VO is dissolved, useful outcomes should be returned, 'inherited' by the VBE. In addition to the individual benefits for the VO members, the inherited assets can be used to improve the preparedness of the VBE. Furthermore, references and the reputation created by successful VOs can be used as promotional information for customers. Currently, most operating networks do not have systematic management of VO inheritance.

In ECOLEAD, components of VO inheritance were identified and inheritance processes, methods and mechanisms studied. In addition to intellectual inheritance, there are also other types of inheritance, such as financial and relational or social inheritance that need to be considered [7].

Conclusions

The preparedness of the network (VBE) impacts significantly on the success of VO management and VO inheritance. The VOs should be created fast. Consequently, VO management practices and principles should be prepared in advance within the VBE. The VO inheritance can be seen as an enabling activity for continuous improvement in the VBE using the experience gained in dissolved VOs.

In network collaboration, decisions are made in a decentralized manner. The intangible assets and collaboration ability have to be emphasized, although most coordination activities focus on the achievement of measurable aims and necessary management interventions, and actions focus on the enhancement of collaboration performance. This area seems to be an important issue for further development.
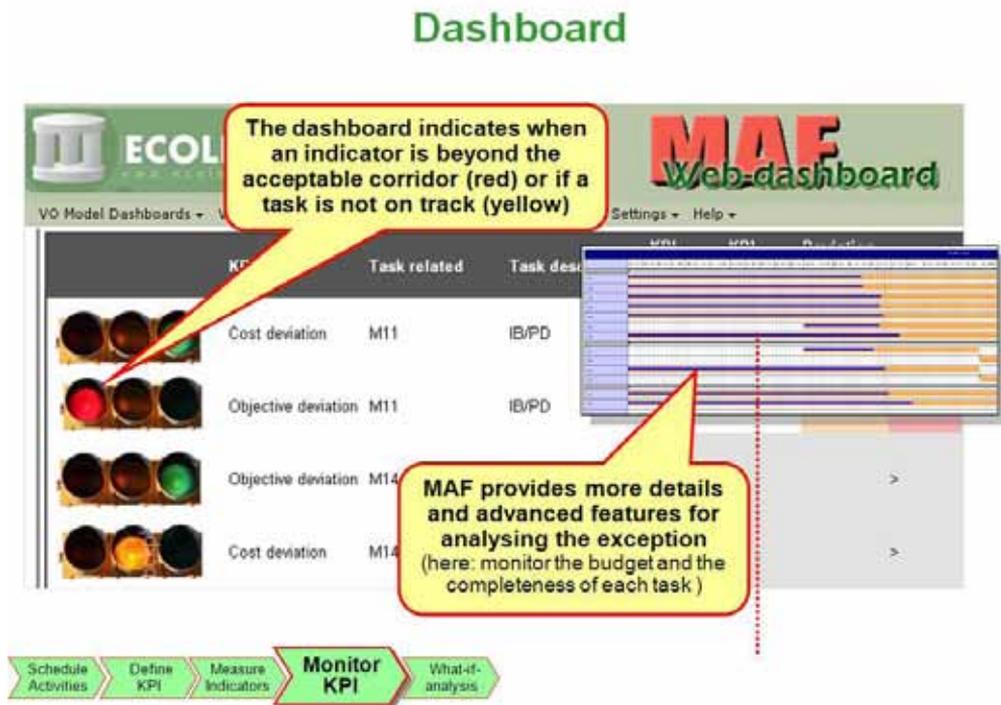

Figure 2. Management dashboard.

References

[1] Camarinha-Matos, L.M., Afsarmanesh, H. 2006. Collaborative networks: Value creation in a knowledge society. (Invited keynote paper). In: Proceedings of PROLA-MAT 2006, IFIP Int. Conf. On Knowledge Enterprise – New Challenges, Shanghai, China, Jun 2006, Springer.

[2] Camarinha-Matos, L.M., Afsarmanesh H., Ollus M. (eds.). 2008. Methods and tools for collaborative networked organizations. New York: Springer, ISBN: 978-0-387-79423-5.

[4] Karvonen, I., Salkari, I., Ollus, M. 2005. Characterizing virtual organization and their management. In: Camarinha-Matos, L., Afsarmanesh, H. & Ortiz, A. (ed.). Collaborative Networks and Their Breeding Environment. Springer. Pp. 193–204.

[5] Negretto, U., Hodik, J., Kral, L., Mulder, W., Ollus, M., Pondrelli, L., Westphal, I. 2008. VO Management Solutions. VO Management e-Services. In: Camarinha-Matos, L.M., Afsarmanesh H., Ollus, M. (Eds.) Methods and Tools for Collaborative Networked Organizations, New York: Springer. ISBN 978-0-387-79423-5.

[6] Karvonen, I., Salkari, I., Ollus, M. 2007. Identification of forms and components of VO inheritance. In: IFIP International Federation for Information Processing. Volume 243, Establishing the Foundation of Collaborative Networks. Camarinha-Matos, L., Afsarmanesh, H., Novais, P., Analide, C., (eds.). Boston, Springer. Pp 253–262.

[7] Karvonen, I., Salkari, I., Ollus, M. 2010. Increasing collaboration preparedness and performance through VO inheritance. International Journal of Services and Operations Management (IJSOM), Special Issue on Modelling and Management of Knowledge in Collaborative Networks. Vol. 6, No. 3, pp. 293–312.

[3] Kürümlüoglu, M., Nostdal, R., Karvonen, I. Base concepts. 2005. In: Virtual organizations. Systems and practices. Camarinha-Matos, L.M., Afsarmanesh, H., Ollus, M. (eds.). Springer. Pp. 11–28.

Collaborative Project Management (COIN)

Kim Jansson, Iris Karvonen, Mikko Uoti and Martin Ollus

Introduction

Today, many business activities are performed as collaborations in net-works. Dispersed partners come together to perform a specific task. Large-scale projects also consist of partners from a wide variety of organizations collaborating towards a common goal, despite different backgrounds, cultures and business behaviours. The success of the project depends heavily on the collaborative performance. Project management consists, to a large extent, of support and guidance for collaboration. In a distributed environment, the project management needs support from services for monitoring status and performance and for the implementation of its own actions.

The EU COIN Integrated Research Project has designed and developed prototypes and services for Enterprise Collaboration (EC) and Enterprise Interoperability (EI). Research in **EC** comes from a business perspective and identifies the process of enterprises – mainly SMEs – to set up and manage cross-enterprise win-win business relations in response to business opportunities. Research in **EI** originated in the IT world, and it identifies the capability of enterprise software and applications to be integrated at the level of data, applications, processes and models.

Services for Collaborative Project Management

The discipline of project management (PM) is well established, and it is an application area that is well supported by software solutions. However, the developments in Internet tech-nology, social media, participative co-creation and Web 2.0 applications also enable new working methods in the PM area. Based on industrial requirements and analyses of the current state of the art and research, the COIN project has recognized a real need for development in the area of Collaborative Project Management (c-PM).

c-PM is the discipline of planning, organizing and managing resources to obtain successful completion of specific project goals and objectives while adhering to the classic project constraints of scope, quality, time and budget. Collaborative Management of projects involves shared and delegated project management responsibility, often self-organized and trusted approaches, and non-hierarchical and participative management organization. VTT, as a partner in the COIN project, has developed services for c-PM. The developed innovative c-PM services are grouped into the **Project Alignment Booster (PAB) and Collaborative Project Meeting Process Management** (PMPM). The objective is to support 'social and collaborative Internet-based project management'.

Project alignment

Collaborative project management requires the participating organizations and people to share a common commitment and understanding of the project objectives, requirements and practices, and the partners to have sufficient competencies and skills for the project tasks. **Project alignment** is the process of ensuring that key stakeholders, in

geographically distributed projects, share a common understanding of project work processes, operational procedures, objectives and plans. The ideal situation is a completely unified project work process. Project alignment in a Collaborative Project is even more important. Alignment is not just a matter of agreement of certain project working habits, norms and styles: it often requires participation in a learning process. To build and increase the project alignment level, the working and experience level of project partners have to be analysed and measured.

PM software is a term commonly used to cover software targeted at aiding the project managers in managing their projects. This type of software usually covers functions of scheduling, budgeting, forecasting, resource allocation, progress monitoring, quality management, communication and documentation. The developed methodology and the Project Alignment Booster services include the following innovations and new development:

- The project alignment process.
- A collaborative and participative definition of unified and shared project work processes.
- A self-evaluation methodology to announce the partners' capabilities and engineering competencies.
- The possibility to analyse gaps between project-demanded skills and capabilities offered by the project partners. Based on the analysis, the collaborative project management can identify the need for additional capabilities and competencies. The monitoring of deviations assists in detecting project risks and possible timing problems.
- The Project Alignment Model (PAM) is a configurable framework that describes how alignment tasks and elements at different levels can be carried out.
- The inclusion of organizational culture elements into the PAM.

Collaborative Project Meeting Process Management

In project meetings involving participants from different time zones and latitudes, all the meeting participants cannot always be present at the same time, for many reasons. The participants may have different national and local habits with respect to patterns of religious holidays and vacations. The participants should be given the opportunity to contribute to project management decisions beforehand. Participants should contribute asynchronously to the meeting, independent of time and location.

The fundamental concept of developing services is to manage the whole of the long meeting process. The process extends from the planning of the meeting all the way to the finalization, e.g. from the agenda planning to the distribution of the meeting minutes. The individual steps in the meting process will invoke existing tools and services, preferably opening source-based services.

The development of the PMPM is based on the vision that globally distributed meetings should be conducted more efficiently than traditional local meetings through new processes and IT tools. The main concept of the developed services is to support the management of the whole of the long meeting process. The process extends from the planning of the meeting all the way to the finalization of the meeting, e.g. from the agenda planning to the distribution of the meeting minutes.

The development contains the following innovations:

- Support for the management of asynchronous and long meeting processes involving steps, e.g. participative definitions of agenda, call for participation, scheduling, standard agenda, contribution asynchronously in advance, reminders of meetings, on-line meeting, follow-up. The innovation is in the management of the whole meeting process.

- The establishment of application domain-specific process libraries for typical project meetings, for example, complex engineering projects.
- The best-suited tool for each step is based on the partners' 'on-line' status, role in the project, importance, etc. The tools used in the various steps can be defined beforehand or dynamically selected during the process execution.

Experience of using the c-PM services

The developed PAB and PMPM software has been evaluated in a global engineering company. The company is active in the pulp and paper, energy and infrastructure engineering domains. The business eco-system consists of 10–30 different organizations (owners, suppliers, engineering consultants, authorities, etc.), which are globally distributed to the most competent and cost-efficient project partners available. The company is building its future success on state-of-the-art engineering IT solutions deployed over an efficient network of partners. The project partners and participants must be able to communicate and announce their skills, knowledge and other intangible assets.

The company has had very positive experience of using the new tools. Project alignment services ensure that the project start-up is fast and smooth. The project members gain common knowledge and understanding of the project aims and tasks. Reservation and acquisition of the right resources for the project require less time and effort. Project alignment services offer an efficient way to find the best resources and how to use them in the most efficient way. No extra time is needed to acquire sufficient project work practice and engineering knowledge. Visualization of the project alignment status makes it easy for the project manager to monitor project resource availability. The PAM is a unified way to present knowledge and skill levels. The model can be used in work sharing between all the engineering offices worldwide. The PMPM make setting up and managing the meeting processes more efficient and reduces the need for travel.

Publications

IST FP7 IP Project 216256 COIN, Collaboration and Interoperability for Networked Enterprises. http://www.coin-ip.eu.

Jansson, K., Karvonen. I., Ollus. M. & Uoti, M. Collaborative project alignment, Proceedings of the 18th IFAC World Congress, Milano, Italy, 28 August – 2 September, 2011. Università Cattolica del Sacro Cuore. Vol. 18.

Jansson, K., Ollus, M.K., Karvonen, I., Uoti, M. & Riikonen, H. Social and Collaborative internet based project management. Proceedings of 15th International Conference on Concurrent Enterprising, ICE 2009, Leiden, Holland, 22–24 June, 2009.

Ollus, M., Jansson, K., Karvonen, I., Uoti, M. & Riikonen, H. H. Supporting Collaborative Project Management. Int. Journal on Production Planning & Control. Special issue 'Co-Innovation and Collaborative Networks', 2011. Guest Editors: David Romero, Arturo Molina, Luis Camarinha-Matos.

Sitek, P., Gusmeroli, P., Conte, M., Jansson, K. & Karvonen, I. (eds.). The COIN Book, Enterprise Collaboration and Interoperability, November 2011. Mainz Verlag, Germany.

Management of subcontracting cooperation in the metal industry (JOHTO)

Kai Häkkinen

Introduction

As subcontracting has increased and production has shifted to a networked and dispersed environment, the number of different problems has gradually increased, in particular with regard to the operation of the subcontractor network.

Dispersion often slows down operations and product development, which in turn weakens agility and competitiveness. This is because dispersed organizations work separately, with very limited hands-on cooperation.

The intensity and innovativeness of subcontracting cooperation can vary greatly. On the one hand, cooperation boosts operational efficiency, but, on the other, it requires various types of meetings, coordination and control, thus incurring so-called transaction costs.

The operational differences between the organizations are typically described in agreements, and, when necessary, the parties establish case-specific rules and guidelines. However, practical experience shows that such amendments and additions to agreements have not done much to improve the situation. It may be said that a joint management approach is required in addition to agreements in order to cover any contractual omissions and to take account of possible changes in conditions and the development point of view.

Methods

The problems of subcontracting cooperation have been researched, and there is research and practical data in this area. Practical literature is almost non-existent however. The aim of this research project was to develop practical applications for the subcontracting management concept and to test them with companies.

The research aim was to create practical guidelines for manufacturing companies while leveraging currently available theories and information. Discussions in brainstorming and planning sessions between the researchers and company representatives were the main research method.

Results

Several areas in subcontracting cooperation require control and management, which calls for joint management organization. However, this requires investment of time by numerous people. A principal typically has several subcontractors and cannot maintain continuous discussions with all of them. Only issues that are of strategic importance should be discussed together with the subcontractors, and the operational organizations should deal with any other issues.

The research participants decided to divide the jointly managed issues into two main categories: 1) management of routines and 2) management of development issues.

Management of routines

Once routines become well established and effective, there is usually no need to invest a
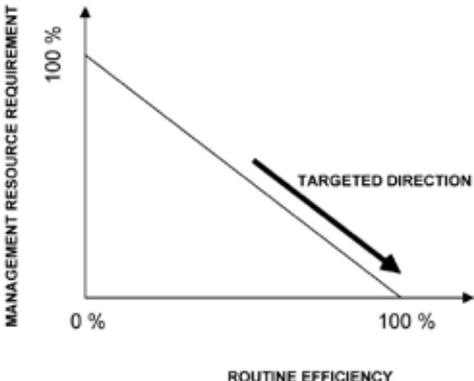
Figure 1. Management of routines.
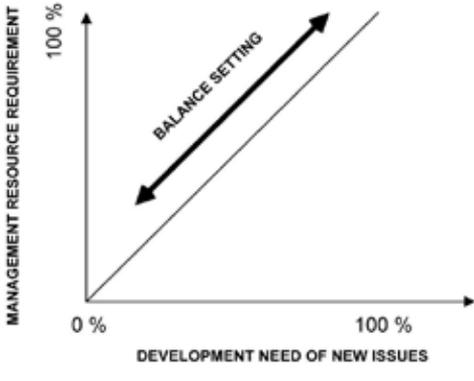
Figure 2. Management of development issues.
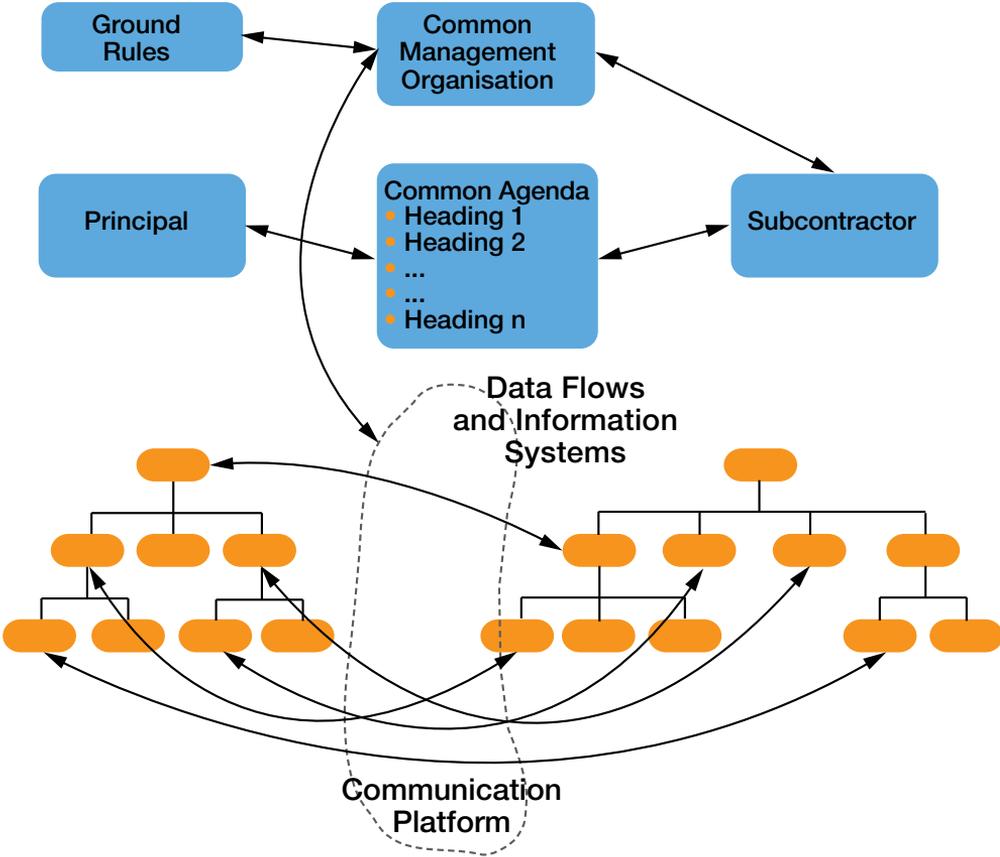
Figure 3. Joint management model.

Short Term Improvement of Capability

Q4

Costs
Agreements
Investments
Targets

Targets
Costs
Agreements
Investments
Capacity
Forecasts
Invoicing

Q1

Strategy
Delivery Accuracy
R&D
Changes

Strategy
Deliv. Accuracy
R&D
Changes
Quality
Logistics

Capacity
Forecasts
Invoicing
Roles

Roles
Efficiency
ICT-systems

Quality
Logistics
ICT-systems
Efficiency

Anniversary Clock for Inprovment

Q3

Q2

Figure 4. Normet Oy's Anniversary clock for improvement (http://www.nikolaisourcing. com/alihankinta2010/Normet.pdf).

large amount of resources in their management (Figure 1). The management of routines mostly consists of continuous monitoring to ensure that operations run as planned. Only deviations trigger action so that their causes can be identified and rectified.

Management of development issues

The development of products and operations is of vital importance. In this context, development issues are those that are the main focus of the joint management organization.

In the management of development issues (Figure 2), it is important to strike the right balance in each specific situation. During an economic upturn, for example, it often makes sense to tie fewer resources into development and to focus on delivering current orders. During a downturn and slower seasons, it makes sense to focus on development.

As a main rule, it is recommended that the joint management organization only discuss issues for which the promotion or development requires resources from both parties.

The research project developed a joint management model for subcontracting management (Figure 3). A common agenda is a central tool in the model, referring to the key issues in the parties' subcontracting cooperation. A joint management organization is also required, consisting of resources from both parties.

The joint management model requires efficient communication and data transfer between parties. Different information systems are required for different communication needs. At present, Internet-based solutions are of vital importance to the increasingly dispersed manufacturing operations.

Discussion

The management of subcontracting coopera-tion in the Finnish metal industry has improved continuously. A good example is the sub-contracting network management system developed by Normet Oy, which builds on the use of a so-called anniversary clock (Figure 4).

The management system is organized according to a schedule in which a network meeting bringing together all the main sub-contractors is organized four times a year. The issues on the agenda include new develop-ment ideas, currently ongoing development projects, any new problems, currently ongo-ing problem-solving projects and other issues. The anniversary clock specifies which topics are discussed at each network meeting.

The development roadmap for the sub-contracting network is based on Normet's strategy. Implementation is driven by the anniversary clock. By specifying the meet-ing agendas in the anniversary clock, Normet has created a dynamic management system in which the joint agenda comprises the four quarterly agendas. The anniversary clock introduces continuity and dynamics to the management system.

Publications

Häkkinen, K. Alihankintayhteistyön johtami-sesta metalliteollisuudessa. VTT Tiedotteita 2588. VTT, Espoo, Finland, 2011. http://www.vtt.fi/inf/pdf/tiedotteet/2011/T2588.pdf.

Häkkinen, K. Managerial approach to subcon-tract manufacture cooperation in the metal industry. Doctoral dissertation. VTT Publica-tions 676. VTT, Espoo, Finland, 2008. http://www.vtt.fi/inf/pdf/publications/2008/P676.pdf.

Partnership networks of the Finnish maritime cluster – Research focus on Chinese markets (SeaChi)

Kim Jansson

The Chinese economy is continuing to grow rapidly. The large size of China and its enormous population guarantee that the market volumes are always large in any business sector. Large multinational enterprises have grabbed this opportunity. The development must also be followed by Finnish SME companies operating as suppliers to the big players. The growth of the Chinese market also provides business expansion opportunities for SMEs.

China has declared that its objective is to be the leading shipbuilding nation by 2015. As a result, more and more ships and marine equipment manufacturing will transfer to China. The development also provides an opportunity for Finnish companies in the maritime sector. Many components are already delivered from Finland to China, but in the future there could be a need and pressure to manufacture the products closer to the market. Thus, Finnish suppliers need to watch the development of the Chinese market and create strategies to take advantage of it. SME companies have more limited resources than multinational enterprises. Cooperation with partners can lower the barrier to their establishment in China.

Objectives

The objective of the SeaChi project is to promote the competitive-ness of the Finnish marine industries on international markets, with special focus on partnership networks on the Chinese markets. Partial objectives are to:

- maintain up-to-date information about the development of the Chinese Maritime industry
- acquire information about the activities of the Finnish Marine Industries in relation to China
- support a successful entry to the Chinese markets by developing mutual networks and operating methods between Finnish companies
- develop a plan for the partnership network to establish in the Chinese markets
- improve the ability of Finnish companies to procure high-quality subcontracting cost-effectively from China.

It should be noted that actual establishment in China was not a project objective. Companies need to make separate decisions and make business plans to take that step.

Participants

VTT played two roles: it worked as a coordinator of the project and as a business networks expert. VTT's interest is in increasing the companies' expertise in entering the Chinese markets successfully and in extending its own knowledge of the establishment process. The project involved seven Finnish companies in the Maritime Cluster (ABB Marine, Wärtsila, Purso-Tools, Bodycote Lämpökäsittely, Paramet Konepaja, KMT Group Oy and Insinööritoimisto Comatec Oy). The main financing body of the project was the Finnish Funding Agency for Technology and Innovation (Tekes).

Method

VTT developed and used a method for managing group work processes that take place on the network and at corporate level in a multi-organizational team. It combines qualitative and quantitative tools to manage information. The method connects information processed at different levels and in different phases of the process and creates an 'audit trail' through the process. The project arranged industrial workshops, trading sessions, company interviews and fact-finding tours to China.

Results

The main result by the participating SME companies was raised awareness of possibilities and obstacles in Chinese operations. The SeaChi project also developed guidelines for the establishment of partnership networks in the Finnish Maritime Cluster.

Establishment in a new market area is always challenging. China is no exception. Based on the SeaChi project knowledge, the central questions for a manufacturing SME company that wants to establish Chinese operations are:

- secure a sufficient customer base and customer commitment
- total management of quality issues
- the location of the factory and logistics
- knowledge about labour markets
- training of own staff
- management of economic risks
- management of local support networks
- practical issue in the start-up process
- financing operation
- supporting the remote options from Finland.

Publications

Jansson, K., Mikkola, M., Ryynänen, T. Verkostoyhteistyöllä Kiinaan? SeaChi-projektin loppuraportti. VTT Tiedotteita – Research Notes 2398. VTT, Espoo, Finland, 2007. (In Finnish.)

Ryynänen, T., Jansson, K. A method to advance mutual understanding in a multi partnership project. The Business Review Cambridge, Vol. 8, No. 1, 2007, pp. 326–331.

Developing the strategic innovation capabilities of enterprises (InnoPro)

Tapio Koivisto

Introduction

Innovation and innovativeness are key to economic vitality. Given the new competitive conditions in the global economy, innovation is a crucial factor that affects the ability of firms to adapt to new constraints, take advantage of new business opportunities and create new business concepts. It also contributes significantly to company growth.

Innovation can take many forms. The argument for **strategic innovation** is voiced by a number of academics and consultants (see e.g. [1, 2, 3]). Strategic innovation can occur when a company identifies gaps in the industry positioning map and decides to fill them [4]. Gaps refer to: 1) new, emerging customer segments that other competitors have neglected; 2) new, emerging customer needs or existing customer needs not served well by other competitors; and 3) new ways of producing, delivering or distributing existing or new products or services to existing or new customer segments. Gaps appear for a number of reasons, such as changing consumer tastes and preferences, changing technologies, changing policies, etc. Gaps can be created by external changes or proactively by the company.

Purposes of the project

This paper is based on the project named 'Innovation Capability of Enterprises – InnoPro'. The project was implemented by the Strategic Innovations team of VTT Industrial System. The purpose of the InnoPro project was to develop a workable approach and method of intervention for developing the innovation capability of SMEs. A central issue was to develop an enterprise- and futures-oriented approach and method, considering the fact that firms are essentially heterogeneous [5]. Since firms are heterogeneous, there is no single correct model, method or 'best practice' for strategizing innovation. From the point of view of the enterprises, it is also essential to bear in mind that innovation involves a fundamental element of complexity and uncertainty (see e.g. [6]).

Most prescriptive text on strategic planning presumes that triggering change is simply a matter of environmental scanning and analysis and then paying heed to the often subtle signals of significant threats or opportunities. However, this view ignores the fact that members of social practices interact not with an objectively given environment but rather with perceptions of the 'environment'. They act the way they do because they think the way they do, and they think the way they do because they act the way they do.

The method of strategy sounding

The concrete strategy and method of intervention of our project is based on Jan-Peter Vos's [7, 8, 9] analysis of strategy making. The method of strategy sounding was developed to support identification, selection and retention of strategic opportunities.

The method of strategy sounding links together the six important strategic choices of an enterprise: the business choice, the vision choice, the tactics choice, the competence choice, the asset choice and the performance
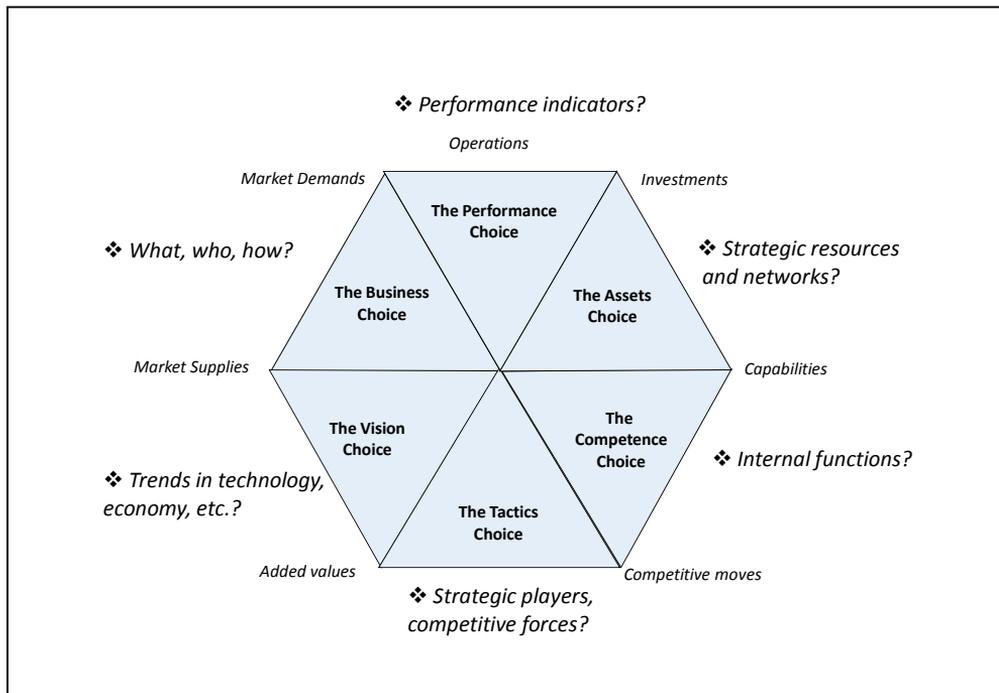
Figure 1. The method of strategy sounding.

choice. The method of strategy sounding represents a both/and approach to strategy making by combining the resource-/competence-based view and outside-in approach (e.g. Porter) to strategy. The method can be described by the cycle presented in Figure 1.

Results

According to our experiences, the theoretical and methodological outlines presented above are an appropriate point of departure in developing the strategic innovation capabilities of enterprises.

The strategy sounding method was implemented in the eight Finnish SMEs. The experiences from the cases contributed to the practising and elaboration of the method in relation to the strategic opportunity identification. With some of the companies, we started a more detailed collaborative development project based on opportunity selection and retention.

According to our experiences, a systemic approach to innovation seems to be an appropriate point of departure in developing the strategic innovation capabilities of enterprises. The strategy sounding method helped managers to reflect on the company's competences and to estimate the strengths and weaknesses from a real time perspective. Furthermore, it positively triggered the management of the case companies to reflect on their strategic opportunities. With regard to the problems of path dependency and self-reference, it is essential to examine the company's identity and internal and external environments from the perspective of the others and of collaboratively identifiable alternative opportunities. In this way, it is possible to develop, collaboratively, path-breaking and innovative abilities of enterprises.

Further research should be directed at enriching, expanding and deepening this approach and method. For example, the focuses required by large-scale enterprises, the fuzzy front end of R&D and the networked enterprises may differ in the detail.

References

[1] Hamel, G. & Prahalad, C.K. Competing for the Future. Harvard Business School Press, Boston, MA, USA, 1994.

[2] Drucker, P.F. The discipline of innovation. Harvard Business Review, 76(6), 1998, pp. 149–157.

[3] Styles, C. & Seymour, R. 2004. Creativity and Strategic Innovation. Proceedings of the ANZMAC 2004 Conference, Wellington, New Zealand, 29 November – 1 December, 2004.

[4] Markides, C. Strategic innovation. In: E.B. Roberts (ed.). Innovation. Driving Product, Process, and Market Change. Jossey-Bass, San Francisco, CA, USA, 2002. Pp. 9–40.

[5] Penrose, E. The Theory of the Growth of the Firm. Basil Blackwell, Oxford, UK, 1959.

[6] Dosi, G. The nature of innovative process. In: Dosi, G., Freeman, C., Nelson, R., Silverberg G. & Soete L. (eds.). Technical Change and Economic Theory. Pinter Publishers, London & New York, 1988. Pp. 221–238.

[7] Vos, J.-P. The making of strategic realities: An application of the social systems theory of Niklas Luhmann. Eindhoven University Press, Holland, 2002.

[8] Vos, J.-P. Developing strategic self-descriptions of SMEs. Technovation, 25, 2005, pp. 989–999.

[9] Vos, J.-P. Strategic Management from a Systems-Theoretical Perspective. In: Seidl, D. & Becker K.H. (eds.). Niklas Luhmann and Organization Studies. Kristianstad: Liber & Copenhagen Business School Press, Denmark, 2005. Pp. 365–385.

BestServ business models II (BeSeL)

Tapani Ryynänen

The transition by industrial companies from product-centric businesses to service-centric businesses has gained momentum over the last decades. The BestServ Business Models II project – BeSeL II – focused on understanding how this transition really affects companies, customer relations, management, processes, supplier networks, etc.

Introduction

Services – as an 'industry' – have become the engine of global business, especially in Western markets, in which services have become the key asset for gaining a competitive advantage. When the manufacturing industry has largely moved into low-cost and growing market countries, service-centric business models have enabled the creation and maintenance of successful businesses in developed countries.

However, as always in global business, these business models are also quickly emerging in developing markets.

The BeSeL II project has aimed to understand the complex challenges and business potential of service-centric business models. The project was initiated by the BestServ Forum (http://www.bestserv.fi). The first phase, BeSeL I, started in 2005, and the second phase started in 2007 and ended in December 2009. In BeSeL I, HANKEN and TKK-BIT Research Centre were also members of the research consortium. LTT-Research had a parallel research project that collaborated closely with BeSeL I.

Methods

Several research methods and theories have been put to use in both phases of the BeSeL
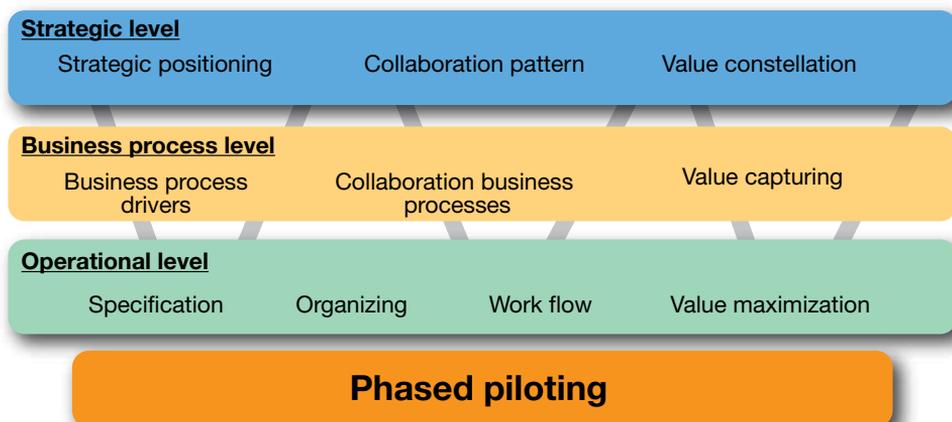
Figure 1. Relationship framework.

project, e.g. value creation and capture, economic modelling, process and system theories, innovation theories, service classification (e.g. SPA matrix), relationship marketing, service management and knowledge management.

Research material has been collected by means of interviews and collaborative group work. Qualitative analysis has then been applied.

Results

Several methods and tools have been developed. They have been published in research papers, seminar papers and publications. One example of a model from BeSeL I is a relationship framework that pinpoints the most important topics that should be focused on in customer relationships when developing new industrial services (Figure 1).

Conclusions

Over this four-year period, it has become quite clear that although many companies have decided to opt for service-centric business models, practical implementation and real operational changes take time. The service business requires systemic innovations and an iterative learning process, not only within a company but also across the business network.

The service business approach makes it possible for a company to pursue new revenue streams and customer segments by delivering total solutions. Value creation through service-based customerships provides a competitive edge that many system suppliers in particular need when a low-cost strategy leads companies to move their business into areas specializing in manufacturing or close to the end customer.

Exploitation

Dissemination allows industry to benefit from the BeSeL results. Several articles and seminar papers have been published. A book on the topic was published by Teknova: 'From Industrial Favours to Industrial Services – Profitable Growth as a Challenge' [1].

Key Researchers

Tapani Ryynänen, Iiro Salkari, Heidi Korhonen, Jari Kettunen, Raimo Hyötyläinen and Henri Hytönen from VTT, and Christian Grönroos, Pekka Helle and Robert Wendelin from Hanken

Publications

de Brentani, U. Innovative versus incremental new business services: Different keys for achieving success. The Journal of Product Innovation Management, 18, 2001, pp. 169–187.

Grönroos, C. & Helle, P. Adopting a service logic in manufacturing: conceptual foundation and metrics for mutual value creation. Journal of Service Management, Vol. 21, No. 5, 2010, pp. 564–590.

Helle, P. Re-conceptualizing value creation: from industrial business logic to service business logic, working paper, Hanken School of Economics Finland, 2010.

Helle, P. Towards understanding value creation from the point of view of service provision, conference report, EIASM Marketing Forum, Capri, 2009.

Hytönen, H., Jarimo, T. & Salkari, I. A model for value-based pricing of industrial services, 2nd POMS College of Service Operations Conference, Carmel, CA, USA, 2–3 June, 2006.

Korhonen, H., Piispa, T. & Salkari, Iiro. Organizational Challenges for a Supplier of Physical Goods Turning Service Provider. 6th International Conference on Knowledge, Culture and Change in Organizations, Prato, Italy, 2006.

Korhonen, T. Arvomallin soveltaminen palveluliiketoiminnan kehittämisessä. (Using Value Model in Industrial Service Development.) Master's thesis. BeSel project, Helsinki University of Technology, BIT Research Centre, Espoo, 2010. (In Finnish.)

Lehtiö, T. & Nopanen, E. Aineeton potentiaali palvelukokonaisuudessa, Mittausmenetelmiä ja tunnuslukuja. Helsinki University of Technology, BIT Research Centre, Report Series 2009/2, Espoo, Finland, 2009. (In Finnish.)

Ryynänen, T. Survival challenges of an in-house service innovation in traditional industrial context. Proceedings of the 2nd ISPIM Innovation Symposium, New York City, NY, USA, 6–9 December, 2009.

Ryynänen, T. & Malinen, P. Using Decision Point framework to analyse evolutionary steps in industrial service business. IFKAD Forum, 2008.

Ryynänen, T. & Salkari, I. A Systemic Methodology for Facilitating Service Innovations. ERIMA Conference, 2007.

Salkari, I. & Ryynänen, T. Getting a Grip of Customer Value Creation in Developing Industrial Services. ERIMA Conference, 2008.

References

[1] **Grönroos, C., Helle, P., Tinnilä, M., Hyö-tyläinen, R., Apilo, T., Korhonen, H., Malinen, P., Piispa, T., Ryynänen, T. & Salkari, I. Teollisuuden palveluksista palveluliiketoimintaan – haasteena kannattava kasvu. (From Industrial Favours to Industrial Services – Profitable Growth as a Challenge.) Teknologiainfo Teknova, Helsinki, Finland, 2007. (In Finnish.)**

Developing purchasing in industrial SMEs (SSOC2)

Markku Mikkola and Juha Pekka Anttila

Introduction

Agile and flexible manufacturing strategies are emphasized in Finnish manufacturing industries. This is due to the low volume characteristic of products, which also means that production batch sizes are relatively small. Companies have to adapt to this kind of environment by developing their operations accordingly. On the one hand, Finnish principal companies require broader supply entities (e.g. system deliveries) from their suppliers. On the other hand, they require further specialization (e.g. prototype manufacturing). Alongside toughening global competition, these demands also set a significant development challenge for the SME suppliers' purchasing development.

As companies grow and the proportion of purchases of the revenue increases, the importance of purchasing to making a profit also grows. Purchasing either creates or destroys the competitive advantage of the company. The question is not only about purchase prices but also about systematic purchasing methods and practices. The challenge for SME suppliers is how to apply efficient purchasing methods when the business environment demands flexibility and management of a large variety of purchase items. Developing appropriate purchasing methods and practices is important for a single SME as well as the whole industry.

Research problem and goals

The research aims to study and develop efficient purchasing applicable to companies that face the flexibility and agility challenge in their operations. The focus is on technology industry SMEs whose purchasing requires systematic development and which manage a relatively large supply base themselves. Purchasing is considered holistically, covering purchasing practices, organization and strategy (Figure 1).

The research questions are as follows:
- How can efficient purchasing practices be applied and implemented in technology industry SMEs while simultaneously maintaining flexibility and agility?
- How and with what steps can the role of purchasing be in-creased to the same level as other key functions in an organization and how can its seamless collaboration be ensured?
- How and with which kind of models can a SME use its own partners (customers, suppliers) in developing its purchasing function and participating in the development of the whole supply chain?

Results and benefits for companies

The research results contribute to the application and implementation of appropriate purchasing models in the context of flexible manufacturing strategy companies. During the project, the participating companies can use the expertise of the researchers in the analysis and development of their purchasing operations. An appropriate purchasing strategy and development plan are created for the company and selected development actions are also supported by the researchers.
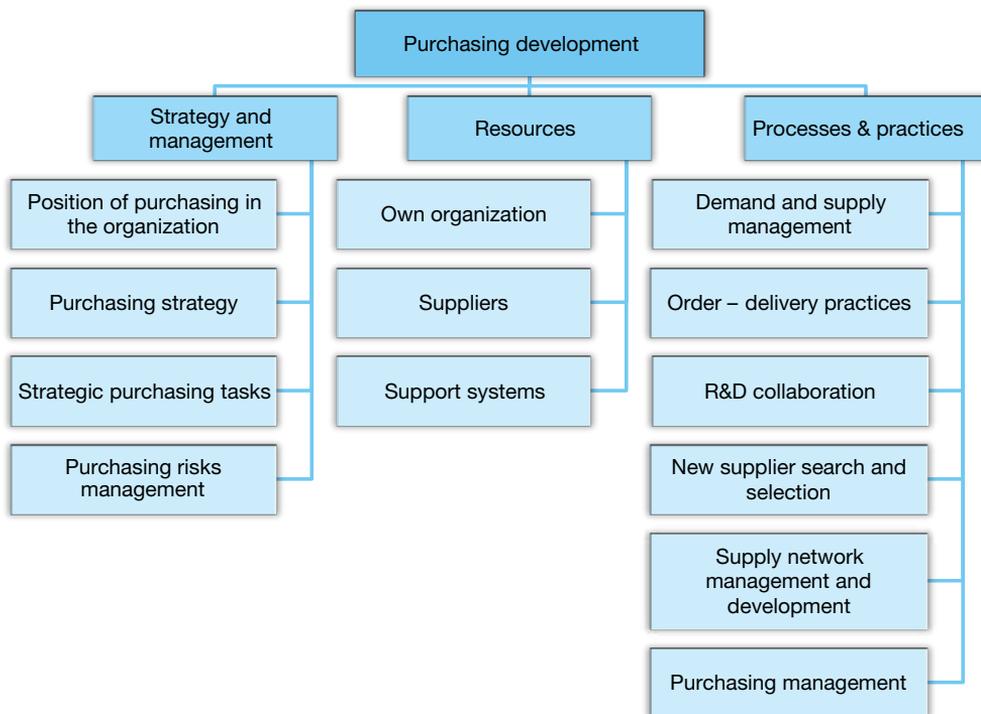
Figure 1. Framework for purchasing development (see the www.hankintatoimi.fi website, which was developed by VTT in collaboration with the Federation of Finnish Technology Industries Association in 2009).

Research execution

The research is carried out using a case study method. The data are gathered from company interviews, workshops and other relevant company material. The development plans are based on these company-specific data and are created in collaboration with the companies' key personnel. The general research results are based on qualitative analysis of the data. The research results are published in research institute publication series and conference papers. The VTT researchers in the project are Markku Mikkola, Juha-Pekka Anttila and Ari Jussila.

Tools for strategic planning and decision-making for future concepts of operation (UNIQUE)

Ismo Ruohomäki

Why produce? What should be produced? Where should it be produced? When should it be produced? How should it be produced? For whom should it be produced? These are the strategic questions that any company needs to ask itself before it begins to manufacture something to sell. Answering these questions in a global economy is necessary again and again throughout the company's lifetime when it wants to grow, maximize efficiency and, sometimes, to survive. Global firms have more choices for locating their activities than ever before. Answering these questions is tricky, and spontaneous solutions seldom hit the target. How can SMEs, in particular, be helped with their strategic production planning and decision-making? How can SME managers be helped to plan, profoundly, their production-related development issues and giant advances, especially when they are not familiar with these kinds of issues in their daily lives.

Introduction

The three main factors driving this study are globalization; everlasting need for competitiveness, especially in high-cost countries; the networked way of production; and new technological opportunities. The need for strategic agility is greater now than in the past. Being strategically agile demands constant reassessment of the production concepts of operation supporting the company's business. The concept of operations includes the company's expedient own or partnership-based manufacturing, sourcing and supply. The need to redesign the production concept, focus of the value chain, resources and technology assets has to flow out of the company's strategic objectives. Based on VTT's own experience, too often, a company's production activities live their own life with no coherence of competitive strategy. Secondly, many companies try to plan for only one 'likely future' with no alternative scenarios. Thirdly, companies tend to laggard in their decision-making. Finally, when the decision-makers have their back against the wall, they have no other course than to move forward, perhaps replacing out-of-date machinery, making urgent value chain decisions, cutting down overall costs that are too high or making hasty movements to grow globally. The reason for this may be imminent weaknesses in strategic planning. If the organization does not know where its production practices stand, it is unclear in determining where it wants to go and how it will get there.

Objectives

The research project 'UNIQUE – Tools for Strategic Planning and Decision Making for Future Concepts of Operation' aims to deepen knowledge about strategic production planning and decision-making. The project focuses on the OEMs – mainly SMEs – in the mechanical engineering industry, which is the largest sector in the technology industry, employing more than 125,000 people and contributing more than 20% of Finnish exports. The project develops and incorporates a profound understanding of strategic decision-making and, with special emphasis on the factors,
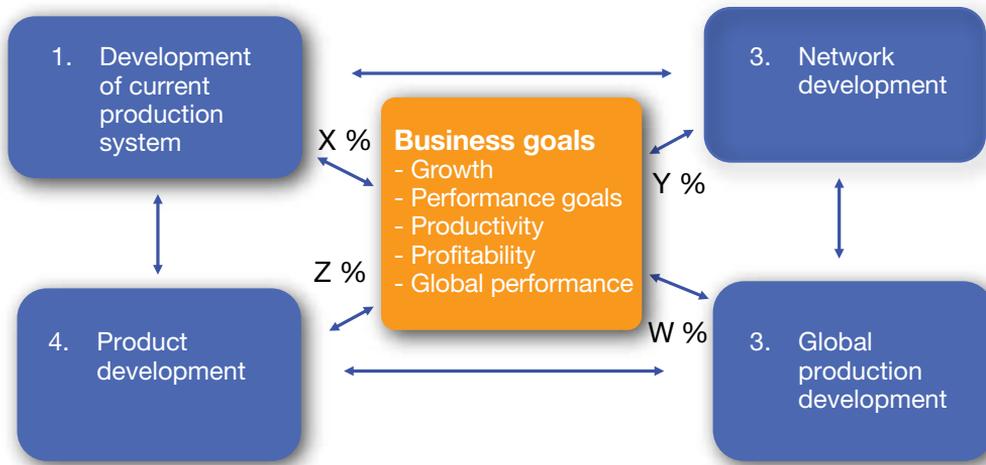
Figure 1. Four main strategic decision-making areas.

interactions and tools needed to pursue the most profitable production system. The 'bull's eye' target is perhaps not a relevant starting point for decision-making and resource use in this dynamic world. It is more realistic to find a company-specific way towards better decisions that may lead to manufacturing system perfection. Companies planning their first global production entries are also in focus.

Materials and methods

The research was done as a case study in four participating companies supported by comprehensive desk studies, researcher exchange, international cooperation, master thesis work and company reference studies. The following research methods were used in the desk study phase:

- literature review
- thematic SME management and expert interviews
- project steering group discussions and mini-seminars (partly external experts)
- project team roundtable discussions.

Results and discussion

The results of the project consist of the overall strategic decision-making model covering four key decision-making sub-areas and factors within them. On the way to better strategic choices, companies should seek development potential in the four categories that are illustrated in Figure 1.

Practical guidance is then given to each area in detail in order to provide profound understanding and guidance on seeking company-specific development potential. Making strategic production decisions without proper data to support them is the equivalent of spontaneous moves. Sometimes, however, the data required to make these decisions is not readily available or easily analysed. Practical hints are therefore given for mapping out all the available information. The decision-making process consists of six phases. Firstly, we recommended performing a rough analysis based on the initial phases to obtain an estimate of what the problems are and possible solutions for them. The analysis is then completed with an in-depth analysis creating 'a short list' of

alternative development scenarios and, finally, the one suitable for implementation.

Basic analysis methods and evaluation techniques were gathered and tested in practical company cases. The basic tool set consists of financial tools (activity-based costing, net present value), analytic tools (risk analysis, analytic hierarchy process) and strategic tools (value chain analysis, scenario analysis). The vision of the decision-making should be pursued in a manner that ensures optimum exploitation of company resources and maximizes efficiency. In a way, decision-making issues are closed to the essential principles of lean. The most relevant results and managerial guidance were collected in a business management book – Parempiin tuotantostrategisiin päätöksiin – published by Teknologiainfo Teknova Oy in September 2011. The book helps the management to plan and implement better choices, whatever these may be.

Key issues on the way to better decisions:
• Careful preplanning and reflection even if the time frame is limited
• Identifying all development options and scenarios
• Achieving the overall company goals and meeting the competitive strategy fit
• Obtaining sufficient and as accurate as possible internal and external information
• Integration of all necessary functions and stakeholders into the planning phase.

Finally, SMEs, in particular, all too often lack their own skilled personnel for sense-making preplanning for the decision-makers. The use of external resources could be one solution and VTT is of course one potential third-party consultant. As a matter of fact, this kind of strategically oriented partnerships could be one potential way for VTT to promote its impacts in industry.

Publications

Heikkilä, A. & Ruohomäki, I. The foreign direct investment decision in manufacturing firms: An empirical case study of a multi-attribute, decision-making and knowledge management method. International Journal of Operations & Production Management. To be published 2012.

Kansola, M. Tuotantostrateginen päätöksenteko yrityksissä. VTT Tiedotteita 2535. VTT, Espoo, Finland, 2010. http://www.vtt.fi/inf/pdf/tiedotteet/2010/T2535.pdf. (In Finnish.)

Ruohomäki, I., Anttila, J.-P., Heikkilä, A., Hentula, M., Kansola, M., Leino, K., Paro, J. & Salmi, T. Parempiin tuotantostrategisiin päätöksiin. Teknologiainfo Teknova Oy, Tampere, Finland, 2011. (In Finnish.)

Title	**Production matters** VTT in global trends
Author(s)	Kai Häkkinen (ed.)
Abstract	Finnish industry primarily manufactures various investment goods for companies and individual consumers. High-quality products have been successfully developed for what are often very narrow niche markets. In today's rapidly globalising world, however, companies are facing full-scale competition in all markets. To deal with these challenges, industry now needs new knowledge and know-how more than ever. This change has been brought about by the general digitalisation of both products and production processes. Digitalisation requires continuous competence development among company personnel. To acquire new knowledge to meet industry's current and future needs, VTT researchers must provide the utmost efficiency in the research and development of manufacturing methods, production processes and corporate networks. Major challenges facing manufacturing industry include the transition from resource-oriented production to knowledge-oriented production, and that from goods-oriented logic to service-oriented logic. VTT moves with the times and contributes to finding solutions to industry's problems. This report describes VTT's research results. These will help manufacturing industry to deal with the above challenges.
ISBN, ISSN	ISBN 978-951-38-7859-7 (softback ed.) ISBN 978-951-38-7860-3 (URL: http://www.vtt.fi/publications/index.jsp) ISSN 2242-1173 (softback ed.) ISSN 2242-1181 (URL: http://www.vtt.fi/publications/index.jsp)
Date	September 2012
Language	English
Pages	124 p.
Name of the project	Industrial biomaterials
Keywords	production, manufacturing, methods, factory, enterprise, networks, management, sme, assembly, organization
Publisher	VTT Technical Research Centre of Finland P.O. Box 1000 FI-02044 VTT, Finland Tel. +358 20 722 111

VTT Technical Research Centre of Finland is a globally networked multitechnological contract research organization. VTT provides high-end technology solutions, research and innovation services. We enhance our customers' competitiveness, thereby creating prerequisites for society's sustainable development, employment, and wellbeing.

Turnover: EUR 300 million
Personnel: 3,200

VTT publications

VTT employees publish their research results in Finnish and foreign scientific journals, trade periodicals and publication series, in books, in conference papers, in patents and in VTT's own publication series. The VTT publication series are VTT Visions, VTT Science, VTT Technology and VTT Research Highlights. About 100 high-quality scientific and professional publications are released in these series each year. All the publications are released in electronic format and most of them also in print.

VTT Visions
This series contains future visions and foresights on technological, societal and business topics that VTT considers important. It is aimed primarily at decision-makers and experts in companies and in public administration.

VTT Science
This series showcases VTT's scientific expertise and features doctoral dissertations and other peer-reviewed publications. It is aimed primarily at researchers and the scientific community.

VTT Technology
This series features the outcomes of public research projects, technology and market reviews, literature reviews, manuals and papers from conferences organised by VTT. It is aimed at professionals, developers and practical users.

VTT Research Highlights
This series presents summaries of recent research results, solutions and impacts in selected VTT research areas. Its target group consists of customers, decision-makers and collaborators.

Production matters
VTT in global trends

Finnish industry primarily manufactures various investment goods for companies and individual consumers. High-quality products have been successfully developed for what are often very narrow niche markets. In today's rapidly globalising world, however, companies are facing full-scale competition in all markets. To deal with these challenges, industry now needs new knowledge and know-how more than ever.

This change has been brought about by the general digitalisation of both products and production processes. Digitalisation requires continuous competence development among company personnel. To acquire new knowledge to meet industry's current and future needs, VTT researchers must provide the utmost efficiency in the research and development of manufacturing methods, production processes and corporate networks.

Major challenges facing manufacturing industry include the transition from resource-oriented production to knowledge-oriented production, and that from goods-oriented logic to service-oriented logic.

VTT moves with the times and contributes to finding solutions to industry's problems.

This report describes VTT's research results. These will help manufacturing industry to deal with the above challenges.