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MAXIMISING THE SAFE PORTION OF FOREST BIOMASS IN POWER PLANTS BY UTILISING PROTECTIVE PROPERTIES OF PEAT

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ABSTRACT: There is need to increase the portion of forest biomass in effective power plants. However, it must be done safely: examples of superheater damages exist. Maximum safe energy portion of wood biomass in its blends with different peats (and with one coal) was estimated with two indexes: molar S/Cl and molar (2S+Al)/ Cl ratios. These indexes are based on the capability of sulphur (as SO_3) and aluminium silicates to destroy corrosive alkali chlorides in power plant furnaces before their entering to superheaters. According to these calculations, safe co-firing of forest biomass up to 50-90 % energy portion with peats can be possible. These results must be implemented carefully because for example calcium can weaken the power of sulphur and more research work would be needed to know better the importance of Ca.

Keywords: Power plants, Forest biomass, Corrosion

1 INTRODUCTION

Many large CHP plants fired with solid fuels locating outside the Finnish coast and producing district heat to cities and electricity to the grid have traditionally burned peat as major portion (70-100% in energy content). Good examples are the 300 MWth bubbling bed and the 482 MWth circulating fluidised bed power plants in the city of Jyväskylä, Finland. However, due to CO_2 payments, such power plants are at present maximising the portion of biomass in their fuel. Waste-originated biomass is avoided due to different emission legislation including measurements of numerous elements and compounds from the flue gases and due to risks and/or problems in the furnace, fuel transporting, storing and feeding.

The largest sources of non-waste-based biomass to those plants in Finland are soft-wood originated forest biomass as a by-stream of wood production for paper manufacturing. Their chlorine content is low (0.02-0.03 wt%, originating mostly from needles and bark), but due to lack of elements protecting power plant superheaters against chlorine-corrosion even these Cl concentrations cause fouling and corrosion of superheaters in effective power plants (Tsteam >450 ^{o}C). These problems, which can lead to expensive damages, were not expected, and the high portion of peat protected earlier the superheaters. Recent experiences especially with 100% forest biomass have, however, revealed the risk.

The protective effect of peat against the chlorine induced superheater corrosion is mainly due to sulphur and partly due to aluminium silicates. Both of them can destroy alkali chlorides (Eq. 1) before their condensation on superheater tubes. Presence of alkali chlorides in superheater deposits can start corrosion (Fig. 1)

$$SO_3 + 2\ KCl + H_2O \rightarrow K_2SO_4 + 2\ HCl \ ; \ Al_2O_3 * 2\ SiO_2 + 2\ KCl + H_2O \rightarrow K_2O * Al_2O_3 * 2\ SiO_2 + 2\ HCl \qquad /1/ \ [1,2]$$

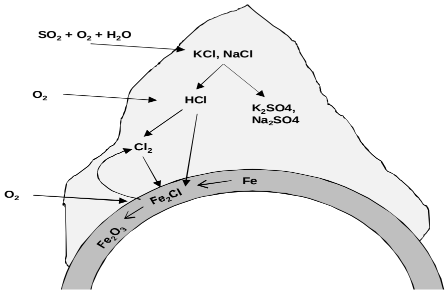

Figure 1. Illustration of chlorine originated superheater corrosion after Cl- condensation in the superheater deposits in form of alkali chlorides [3]

2 CALCULATIONS OF THE MAXIMUM SAFE PORTION OF FOREST BIOMASS IN THEIR BLENDS WITH PEAT IN VIEW OF SUPERHEATER FOULING AND CORROSION

All the results presented here are based on indexes calculated for blends with different forest biomass/peat ratios (molar S/Cl and molar (2S + Al/ Cl)). The needed fuel compositions are shown in table 1. All these fuel samples were analysed in VTT's earlier projects These indexes decrease with increasing portion of forest biomass in the blend. Results of the earlier experimental scale-up study (with VTT's 20 kW bubbling bed (BFB) reactor, with Metso Power's 2 MW industrial BFB pilot plant and with UPM Kaipola's 105 MW BFB power plant) [4] suggested the minimum safe molar ratio of S/Cl ≈ 3 and (2S + Al)/ Cl ≈ 14. These boundary values were applied to the blends shown in table 2. The high Cl concentration in pine bark may be partly originated from road de-icing salt. The selected peat samples differ strongly in their sulphur contents, but variations in aluminium concentrations are not strong. Instead, coal is much stronger enriched with Al-compounds, and therefore the importance of aluminium (see Eq. 1) should be clearly larger with the coal sample than with the peats to destroy alkali chlorides.

Table 1. Selected composition of the fuels under calculations.

Fuel	Sample	LHV	ash 815 ^oC	Cl	S	Al
		MJ/kg	wt% dry	wt% dry	wt% dry	wt% dry
Spruce bark	6	18.9	2.0	0.020	0.020	0.024
Forest residue	7	19.5	2.2	0.020	0.030	0.073
Whole tree (spruce)	4	18.7	2.2	0.020	0.020	0.050
Pine bark	2	20.0	2.0	0.050	0.040	0.065
Peat	1	21.0	4.2	0.030	0.160	0.350
Peat	4	22.4	5.1	0.022	0.310	0.636
Peat	5	20.2	9.5	0.03	0.66	0.500
Coal	1	27.8	16.1	0.03	0.59	2.620

The obtained highest safe portions of forest biomass for each calculated cases are shown in Table 2. The maximum safe portion of wood was 45% for blends of pine bark and the sulphur-lean peat. Instead, and according to these calculations, the energy portion of forest biomass can be safely increased to 90% with the most sulphur rich peat (sample 5) and with coal.

Results based on S/Cl ratios are similar to those based on (2S + Al)/Cl ratios with peat and wood blends due to the low Al content in peat. Therefore S/Cl may be sufficient among these two indexes. Instead, omitting the Al-containing index with coal would clearly underestimate the protective effect of coal (compare the values of indexes for coal-wood blends in table 2).

Table 2. Calculated maximum portion (on energy basis) of forest biomass in blends with protective fuels using the following limits to molar ratios in the blend compositions: S/Cl = 3 and (2S + Al) / Cl = 14.

Forest biomass	sample	Protective fuel	max % wood(1	max % wood(1
			S/Cl basis	(2S+Al)/Cl basis
Spruce bark	6	Peat 1	68	62
Spruce bark	6	Peat 4	85	84
Spruce bark	6	Peat 5	92	89
Spruce bark	6	Coal 1	89	93
Forest residue	7	Peat 1	73	71
Forest residue	7	Peat 4	89	91
Forest residue	7	Peat 5	93	92
Forest residue	7	Coal 1	92	95
Whole tree chips	4	Peat 1	69	68
Whole tree chips	4	Peat 4	88	88
Whole tree chips	4	Peat 5	93	92
Whole tree chips	4	Coal 1	89	94
Pine bark	2	Peat 1	45	42
Pine bark	2	Peat 4	73	68
Pine bark	2	Peat 5	83	75
Pine bark	2	Coal 1	75	86

1= from energy

3 CONCLUSIONS

This research gave qualitative information on maximum safe portion of forest biomass in blends with peat. With high wood portions sulphur content in peat does not be as problematic in view of SO_2 emissions as with low wood portions and can be effectively utilised as a protecting agent. However, accurate blending of wood with peat at the power plant area before feeding to the furnace would be very important if these information are utilised.

Mean sulphur concentration of the peat samples delivered and analysed by Vapo (19745 different) is 0.21 wt% dry [5]. The mean sulphur content in Finnish peat according to GTK's peatland survey project is 0.24 wt% dry [6]. These values fit between peats 1 and 4 (see table 1). Rough estimate of the maximum safe wood biomass portion in CHP combustion with an average Finnish peat would be 60-80% on energy basis, but averages of the other key elements than S should be known as well.

These results include some defects, and therefore more research would be needed. Calcium can bind sulphur and weaken markedly its power in reaction 1 (see the role of SO_3). However, correct estimate on the role of Ca would need much experimental and theoretical work. These calculations are based on rather restricted experimental data [4].

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