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Ash Deposit Formation and Removal in a Straw and Wood Suspension-Fired Boiler

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Utilization of biomass on large suspension-fired boilers is a potentially efficient method to reduce net CO₂ emissions and reduce the consumption of fossil fuels. However, ash deposit formation on heat transfer surfaces may cause operational problems and in severe cases lead to boiler stop and manual cleaning. Most studies on ash deposition and removal has been done on biomass grate boilers, while only limited data is available from biomass suspension-firing.

The aim of this study was to investigate deposit mass uptake, heat uptake reduction, deposit characteristics, and deposit removal by using an advanced online deposit probe in a full scale suspension-fired boiler using wood and straw pellets as fuel (Amageværket Unit 2, AMV2). The 250 MW_{th} boiler has maximum capacity of 60t/h biomass, owned by Vattenfall, and located in Copenhagen, Denmark. The maximum operation period of boiler was limited to two weeks when 100% straw was fired due to ash deposition in the superheater region that has tube spacing specified for coal-firing (113mm). A series of 3-5 days deposit probe experiments were conducted utilizing 35 to 100% straw with wood on mass basis. The applied deposit probe was water and air cooled, and it was possible to register deposit mass uptake, heat uptake, and flue gas temperature. The surface temperature of the probe was kept at 500 °C, and in some of the experiments, a CCD camera registered the deposit formation and removal process on the probe. The probe was placed in the superheater region (1st draught, flue gas temperature, 820-865 °C) and in the tube bank region (2nd draught, flue gas temperature, 580-605 °C). The percentage of ash in the applied straw and wood was 5.9 % and 3.3 %, while the K contents were 0.81% and 0.09% respectively.

During 35% straw share, the initial two hours deposit mass uptake rate was 52.8 (g/m²/h), while it was 353.8 (g/m²/h) during 100% straw-firing. All tests in the superheater region for all applied straw shares indicated that with increase in straw share, final deposit mass uptake increased. The comparison of current and previous full scale experimental studies conducted by CHEC indicated that there was not a big difference regarding final deposit mass uptake during straw suspension-firing and combustion on grate. The shedding (deposit removal) events were investigated when the nearby plant sootblower was shutdown. It was identified that the mass uptake signal increased linearly and then suddenly dropped when a complete layer of deposits was removed. The shedding events were confirmed through imaging data collected through a CCD camera and a complete layer of deposits removed can be clearly identified (shedding through debonding). The shedding investigation was also made when the nearby plant sootblower (4m below) was working. It was identified that the mass uptake signal remained stable and the deposits in small pieces were continuously removed during 35% and 65% straw-firing. Previous findings of Vattenfall indicated that a mixture of 50% straw with wood gave up to more than one month of continuous boiler operation, because plant sootblowers made the boiler operation stable. During 80% and 100% straw-firing, deposits were removed in small pieces but overall deposit weight uptake signal increased. The probe heat uptake reduction, in the superheater region, was reasonably similar for all applied straw shares. Even with a significant deposit build up on the windward probe direction, heat uptake remained approximately constant. This indicated that the heat transfer from the flue gas to the probe was dominated along the rear side, where little material was accumulated.

Elemental analysis of the fuel ash, fly ash and deposit samples was made using Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES) to determine elemental percentage of Al, Ca, Fe, K, Mg, Na, P, Si, S and Cl. Elemental composition of fly ash samples during straw suspension-firing indicated significant amounts of Si and Ca, compared to grate-firing fly ashes that has a higher content of K and Cl. Elemental analysis of the probe front side deposits indicated that the amount of K and Cl increased by increasing straw share, while Ca contents decreased. It was found that increased deposit surface temperature (> 550 °C) caused reduction of the Cl contents in the front layer of deposits. Based on the current findings, recommendations for the optimal operation strategy of straw and wood suspension-fired boilers with respect to minimization of deposit related problems could be provided.