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Shedding of ash deposits

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ABSTRACT

Ash deposits formed during fuel thermal conversion and located on furnace walls and on convective pass tubes, may seriously inhibit the transfer of heat to the working fluid and hence reduce the overall process efficiency. Combustion of biomass causes formation of large quantities of troublesome ash deposits which contain significant concentrations of alkali, and earth-alkali metals. The specific composition of biomass deposits give different characteristics as compared to coal ash deposits, i.e. different physical significance of the deposition mechanisms, lower melting temperatures, etc. Low melting temperatures make straw ashes especially troublesome, since their stickiness is higher at lower temperatures, compared to coal ashes. Increased stickiness will eventually lead to a higher collection efficiency of incoming ash particles, meaning that the deposit may grow even faster.

Deposit shedding can be defined as the process of deposit removal from the heat transfer surfaces. Mechanical and thermal shock devices for deposit removal can be implemented within into the boiler, which can be then referred to as artificial shedding. Sootblowing is one such process, where a pressurized fluid is used to cause a mechanical and/or thermal shock that would cause a failure or fissure in the deposit. On the other hand, shedding can be caused without any operational or mechanical influence by erosion, gravity shedding, or simply by a thermal shock. The mechanism that will be dominant depends on the ash characteristics and the boiler operation.

Different deposit characteristics will govern the ash deposit behaviour, and thus the mechanism of deposit shedding. The deposit strength will influence the erosion and gravity shedding mechanisms. The ash viscosity and the melting behaviour will govern the gravity shedding mechanism, while the thermal expansion coefficient will influence the thermal shock behaviour of the deposit.

Contents

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1. Introduction

The objective of this paper is three-fold: (1) to review the present knowledge on deposit removal, and shedding mechanisms, (2) to outline the different approaches to model these mechanisms, and (3) to provide a simple description of the mechanical and thermal properties of ash deposits. The review focuses attention on biomass combustion conditions, but also the experiences from the coal-firing systems and the kraft recovery boilers have been taken into account. The goal of this review is to provide appropriate background information for the direction of deposit removal. Also deposit formation mechanisms are being reviewed.

One of the major operational problems in solid fuel boilers is the formation of troublesome deposits, from ash species in the fuel. Ash formed during fuel thermal conversion and deposited on furnace walls and convective pass heat transfer surfaces, acts as a heat transfer resistance and may thereby inhibit heat transfer to the steam cycle. If not removed, deposits may reduce the boiler thermal performance and, in severe cases, completely block flue gas channels and therefore subsequently cause unscheduled boiler shutdowns. Ash deposits may also cause severe corrosion of heat transfer surfaces.

Power suppliers today use biomass fuels (mainly straw and wood chips), in addition to the more traditional fossil fuels (oil, coal, and natural gas). Due to the difference in composition between straw and coal, mainly in quantities of sulphur (higher in coal), and potassium and chlorine (higher in straw), the use of straw in combustion units is a serious technical challenge [1,2]. Danish experience shows that straw-firing causes the formation of large quantities of troublesome deposits, consisting mainly of potassium, chlorine and silicates, and to a lesser extent also of calcium and phosphorus [1,3,4]. The specific composition of biomass-derived deposits gives them different characteristics, compared to coal-derived deposits, i.e. different physical and chemical structures, etc. Melt formation at low temperatures makes straw ashes especially troublesome since it causes an increase in the stickiness of the deposit surface [3]. The appearance of a melt, and thus an increased stickiness, leads to a higher collection efficiency of the deposit toward incoming fly ash particles, resulting in a faster growth of the deposit.

Effective deposit removal is important in order to ensure a maximum boiler thermal efficiency. Deposit shedding is the process of deposit removal from a boiler surface which can be caused artificially as a part of the boiler operation, e.g. by sootblowing, or naturally, without any operational or mechanical influence. Mechanisms of natural shedding in combustion systems are: (1) erosion, (2) gravity shedding, and (3) thermal shock. Erosion is the process of removal of a sintered deposit by impacting hard fly ash particles, mainly silicates. Gravity shedding will occur when the gravity force on the deposit is strong enough to cause (1) a break inside the deposit, or (2) the flow of molten deposit. A break inside the deposit will occur when the gravity effect on the deposit becomes larger compared to: (1) the force holding the deposit together (deposit strength), or (2) the force holding the deposit and the tube together (adhesion). Melting can be considered as a type of gravity shedding, where the gravity force acts on a molten deposit forcing it to flow down the heat transfer surfaces. Thermal shock induced shedding is caused by sudden temperature changes, due to the difference in the thermal expansion coefficients of tubes and deposits. A sudden temperature gradient (due to fluctuations of the flue gas or steam temperature), may cause an uneven expansion of (1) deposit and tube, or (2) distinct, adjacent deposit layers, leading to deposit fractures.

The mechanism will be the dominant one depends on the ash characteristics and the conditions inside the thermal fuel conversion system. The chemical composition will directly influence the deposit strength, the melting temperature, and the thermal expansion, i.e. the deposit properties which will affect the above-mentioned mechanisms of shedding. The flue gas temperature will influence the deposit surface temperature, and thereby the temperature distribution inside the deposit. This will again influence the above-mentioned deposit properties as well as the physical state of the deposit, i.e. if it is molten or solid.

Ash deposits can be removed from the heat transfer surfaces by inducing mechanical or thermal stresses within the deposit. This can be done using the impact of the high pressure steam, air, or