Application of Fly Ash from Solid Fuel Combustion in Concrete

Abstract

Industrial utilization of fly ash from pulverized coal combustion plays an important role in environmentally clean and cost effective power generation. Today, the primary market for fly ash utilization is as pozzolanic additive in the production of concrete. However, the residual carbon in fly ash can adsorb the air entraining admixtures (AEAs) added to enhance air entrainment in concrete in order to increase its workability and resistance toward freezing and thawing conditions. The problem has increased with implementation of low-NOx combustion technologies. The present thesis concerns three areas of importance within this field: 1) testing of fly ash adsorption behavior; 2) the influence of fuel type and combustion conditions on the ash adsorption behaviour including full-scale experiments at the power plant Nordjyllandsværket, unit 3; 3) post treatment of fly ash to lower its AEA adsorptivity. The foam index test is the method usually employed to determine the degree of fly ash interference with AEAs in concrete. The test involves the use of commercial AEAs and visual observation of foam stability. These facts reduce the reproducibility of the test, because commercially available AEAs vary in strength, and the criteria for foam stability are operator dependent. The objectives were to develop a new method based on dynamic surface tension measurements, using the bubble pressure method, on filtrate from a fly ash and cement suspension. A pure surfactant was added to the suspension as a substitute for a commercial AEA. The new method and the foam index test have been compared on fly ashes acquired from power plants in Denmark and the U.S. The results revealed a good relationship between the two methods. However, the new method has a low sensitivity toward small variations in AEA adsorption between different fly ashes and it requires further work before a finished procedure is accomplished. Finally, it was shown that changes in temperature affect both test methods. Pulverized fuel has been combusted in an entrained flow reactor to test the impact of changes in operating conditions and fuel type on the AEA adsorption of ash and NOx formation. Increased oxidizing conditions, obtained by improved fuel-air mixing or higher excess air, decreased the AEA requirements of the produced ash by up to a factor of 25. This was due to a lower carbon content in the ash and a lower specific AEA adsorptivity of the carbon. The latter was suggested to be caused by changes in the adsorption properties of the unburned char and a decreased formation of soot, which was found to have a large AEA adsorption capacity based on measurements on a carbon black. The reactor was modeled with CFD and a relationship between oxygen concentration in the early stage of combustion and the AEA adsorption properties of the ash was observed. The NOx formation increased by up to three times with more oxidizing conditions and thus, there was a trade-off between the AEA requirements of the ash and NOx formation. The type of fuel had high impact on the AEA adsorption behavior of the ash. Ashes produced from a Columbian and a Polish coal showed similar AEA requirements, but the specific AEA adsorptivity of the carbon in the Columbian coal ash was up to six times higher. The AEA requirements of a South African coal ash was unaffected by the applied operating conditions and showed up to 12 times higher AEA adsorption compared to the two other coal ashes. This may be caused by larger particles formed by agglomeration of the primary coal particles in the feeding phase or during the combustion process, which gave rise to increased formation of soot. A low-NOx tangential fired 875 MWth power plant burning bituminous coal have been operated under extreme conditions in order to test the impact of the operating conditions on fly ash adsorption behavior and NOx formation. It was found that the AEA adsorption of the fly ash was reduced up to five times compared to reference operation, when the plant was operated with minimum furnace air staging, three levels of burners instead of four and without recycled flue gas. The lower AEA requirements of the fly ash at these conditions were primarily caused by a reduction in total carbon content, while the AEA adsorptivity of the residual carbon was lowered to about 60 % of reference value. The tested operation mode, however, increased the NOx level in the flue gas before the DeNOx plant by 60 % compared to reference operation. The AEA requirements of a fly ash can be suppressed by exposing it to oxidizing species, which oxidizes the carbon surface and thus prevents the AEA to be adsorbed. In the present work, two fly ashes have been ozonated in a fixed bed reactor and the results showed that ozonation is a potential post treatment method that can lower the AEA requirements of a fly ash up to six times. The kinetics of the carbon oxidation by ozone was found to be fast. A kinetic model has been formulated describing the passivation of carbon and it includes the stoichiometry of the ozone consumption (0.8 mol O3/kg C) and an ineffective ozone loss caused by catalytic decomposition. The simulated results correlated well with the experimental data.

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