Applied Thermal Engineering 42 (2012) 90–100

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

CFD based prediction of erosion rate in large scale wall-fired boiler

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ARTICLE INFO

Article history:
Received 22 November 2011
Accepted 8 March 2012
Available online 16 March 2012

Keywords:
Wall-fired furnace
FLUENT
Multiphase flow
Particle trajectories
Erosion rate

ABSTRACT

In pulverised coal fired boilers, entrained fly ash particles in the flue gas may cause erosive wear on metal surfaces along the flow field. This can have a significant effect on the operational life of various sections of the boiler (in particular convective heat exchanger tubes). In this work, Computational Fluid Dynamics (CFD) based code FLUENT was used in conjunction with a developed erosion model for a large-scale furnace to understand the flow field and identify the areas likely to be subjected to erosion under various operating conditions. An Eulerian–Lagrangian approach was used to analyse the continuum phase and particle tracking for individual coal particles. The flow field has been thoroughly examined in terms of velocity, particle and temperature profiles along the gas flow path. The data obtained on particle velocities and trajectories have been utilised to predict the extent of erosion in selected areas of the boiler. Predictions have been found to be in good agreement with the published data as well as plant observations for velocities ranging from 15 to 32 m/s showing a deviation of 0.60%. The results obtained from the present work for understanding erosion pattern in boilers are not only of practical significance but also provide a platform for the development of an erosion tool which could assist power utilities in avoiding unnecessary shutdowns and penalties associated with replacement of boiler components.

1. Introduction

In today's competitive power generation industry efficient operation of the furnace is of significant interest. All design parameters of the furnace are focussed on achieving the maximum life of the boiler and boiler tubes, maximum thermal efficiency, low NO_x emissions and maximum power generation. The furnace efficiency mainly depends on the raw coal characteristics and coal combustion can be affected by several factors such as pulverised coal particle size distribution, gas and particle temperature, ratio of coal and air supplied, rate of devolatilization of coal particles and char oxidation. Another constraint is ash generation during the combustion process. Ash related problems are always difficult to predict due to complexity involved in ash transformation process during combustion [1–4]. It has been observed that around 20% of ash produced during combustion has an erosive effect on the wall surface of the burner and boiler tubes [5]. It is known that coal is a mixture of combustible solid hydrocarbon and incombustible mineral matter. The mineral grains undergo many complex and differing interactions, including oxidation, decomposition, coalescence, fragmentation and vaporization, generating ash particles of different shape and size with different composition [6]. These ash particles are entrained in the flue gas along the furnace domain and impact on the wall surfaces during their passage through the boiler. Some of the fly ash particles during their travel towards chimney will have impact at a certain angle with relatively high velocity, damaging the target surface. The tendency of ash particle on impacting or sticking to the boiler surface is a function of ash particle size, shape and its composition. Large ash particles tend to impact onto boiler heat transfer surfaces by inertia, whereas fine ash particles tend to reach wall surfaces by thermophoresis or Brownian motion [1,7]. For example, a 60 μm ash particle was estimated to reach the deposit surface almost three times faster compared to 30 μm particle primarily due to inertial effect. The two most abundant constituents of ash are silica and alumina, but alumina is in softer form in most pulverised coal. In contrast, silica in the form of quartz is known to be potentially abrasive in nature due to its angular morphology and plays an important role in the erosion process [8]. Studies show that the impaction of solid ash particles on a metal surface causes two type of wear. Repeated

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1359-4311/$ – see front matter
doi:10.1016/j.applthermaleng.2012.03.015