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A Literature Review of Erosion and Corrosion of Bed Coil of Coal Combustion Process

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ABSTRACT

Atmospheric fluidized bed combustor (AFBC) boilers for steam or electricity generation is gaining popularity because of its ability to burn wide variety of fuels with low atmospheric emissions. The erosion is caused by the direct impingement of in-bed particles on the tube surfaces. Super heater coils of an AFBC boiler are found to be affected extensively by solid particle erosion. The purpose of this paper is to present a literature review of current explanations on parameters which affect on the erosion-corrosion of bed coil like coal properties, air flow velocity, tube material, nozzle diameter, thickness and pitch of bed coil or tube, elevation of the boiler tubes to a higher position in the unit and etc. Furthermore, several different hypotheses based on experimental, analytical, and numerical studies have been put forward to describe the Optimization of bed coil of coal combustion process.

***Index Terms* -** Erosion, Corrosion, CFD Analysis.

1. INTRODUCTION

In combustion applications, the use of fluidized bed technology is based on the use of fluidized solid material acting as heat storage. This hot solid material rapidly dries the incoming fuel, and simultaneously stabilizes the combustion reactions. However, the presence of large quantity of erosive material sets additional requirements for the materials used in the boiler parts, as well as generates need for boiler designs minimizing the risk of material loss caused by particle erosion. In a fluidized bed boiler, several areas exist in which the wear is solely related to the presence of fluidized bed material.

Erosion is defined as a process by which material is removed from the layers of a surface impacted by a stream of abrasive particles. Erosion can be broadly classified as solid particle erosion, slurry erosion and cavitation erosion. When the particles strike the substrate, part of their kinetic energy is spent on creating new particles, part on indentation of substrate, and a part on rebounding.

Fluidized bed technology has been utilized by the process industry since the 1920s. The first applications can be found from metallurgy and refinery processes. Foster Wheeler has been utilizing the fluidized bed technology for combustion

since the end of the 1960’s. The first fluidized bed boilers were of bubbling bed type (BFB), in which the fuel is fed on

top of a sand bed, which is kept in fluidized state by primary air. This technology is still competitive in combustion of biofuels and different sludges due to the relatively low investment cost. The first commercial fluidized bed boilers utilizing a solids separator for solids recirculation was constructed in the 1970's by Lurgi (Reh et al. 1979). The idea of a circulating fluidized bed (CFB) boiler is to use a relatively high fluidization velocity (up to 6 m/s) and then to return most of the escaping bed material back to the furnace with a cyclone.

Finnie [1] proposed the first analytical erosion-model. This model included a variety of parameters that influence the amount of material eroded from a target surface and the mechanism of erosion. It was observed that the wear of a surface due to solid particle erosion depends on the motion of the particles in the fluid, as well as the behavior of the surface when struck by the particles. These two parts of the problem are related in that a surface, roughened by erosion, may increase the fluid turbulence, and hence, accelerate the rate of material removal.

Foley and Levy [2] investigated the erosion of heat-treated steels. The testing was conducted at room temperature using aluminium oxide particles with an average size of 140 lm in an air stream. An attempt was made to characterize the erosion behavior as it relates to the mechanical properties obtainable in these alloys by conventional heat treatments. It was found that the ductility of the steels had a significant effect on their erosion resistance which increased with increasing ductility, and that hardness, strength, fracture toughness and impact strength had little effect on erosion behavior.

Xie and Walsh [3] measured the erosion of carbon steel by fly-ash and unburned char particles in the convection section of an industrial boiler firing micronized coal. Ash and char particles suspended in the flue gas entrained by the jet were accelerated towards the surface of the specimen under varying temperatures (450–650^{0}C). Changes in the surface

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were measured using a surface profiler. They observed that erosion was slowest at the lowest metal temperature, regardless of the jet gas composition; and, under the nitrogen jet, erosion increased with increasing temperature. They have presented a model for simultaneous erosion and oxidation which is consistent with the temperature and oxygenation dependencies of the erosion rate.

2. ROLE OF PROCESS CONDITIONS

According to Meuronen (1997), erosion of heat transfer surfaces is dependent on process conditions, particle flow density, mass flow and velocity, angle of collision, and material properties of both the colliding particle and the heat transfer surface. Combustion reactions may generate components which initiate corrosion reactions of the heat transfer surfaces. When erosion is combined with corrosion, resulting erosion-corrosion may unexpectedly result in a very complex and rapid metal degradation (Reponen et al. 1999).
This type of wear is very difficult to detect reliably, because there are very few detectable corrosion products left on the sample. Several tests for erosion-corrosion have been reported (Wright, Nagarajan and Mertz 1984, Rautala et al. 1988), but generally, the results of these tests apply only on the process conditions used during the tests. General rules to estimate the rate or to reduce erosion-corrosion are not available. Different tube coatings for protection have been tested with varying results, see for instance Dutheillet and Prunier (1998). Currently, the best means of protecting heat transfer surfaces from erosion-corrosion is a proper boiler design.

3. ENHANCEMENT OF BED COIL TUBE

To enhance the bed coil tube is analyzed and experimental results are compared with the ANSYS CFX analysis results to optimize the design specification and parameter. Therefore this paper concentrates on the review of modeled and analyzed Erosion and Corrosion of bed coil tube component.
Some research papers are here:

S. Bahadur b [4], A number of parameters for characterizing the angularity of particles had been proposed in the literature. These parameters serve as good indicators of irregularity as opposed to roundness, but fail to provide a good measure of angularity. The relevant parameter in erosion was angularity and not irregularity. In that work, a new parameter for characterizing the angularity of particles was proposed. It took into account the sharpness of particle comets and the probability of these comers contacting the target surface. The particles of SiO2, garnet, Al2O3 and SIC are characterized for angularity in terms of this parameter and compared with other measures, P^2/A and W/L, where P, A, W and L denote the perimeter, area, width and length of the particle, respectively. It was found that the new parameter provides the characterization for even where the other measures fail. In addition to the above, the effect of particle angularity and size on the erosion of 1020 HR steel in a fluidized bed atmosphere at 500oC and 5 m/s impingement velocity was studied. It was found that the erosion rate increases with increases in both particle angularity and size.

Fig. 1- Bed Coil Tube

John Stringer [5] Heat-exchanger tubes in fluidized bed combustors (FBCs) often suffer material loss due to combined corrosion and erosion. Most severe damage is believed to be caused by the impact of dense packets of bed material on the lower parts of the tubes. In order to understand this phenomenon, a unique laboratory test rig at Berkeley was designed to simulate the particle hammering interactions between in-bed particles and tubes in bubbling fluidized bed combustors. This paper described the characteristics of this test rig, reviews results at elevated temperatures and compares them to field experience. At higher temperatures, deposits of the bed material on tube surfaces could act as a protective layer. The deposition depended strongly on the type of bed material, the degree of tube surface oxidation and the tube and bed temperatures. With HCl present in the bed, wastage was increased due to enhanced oxidation and reduced oxide scale adherence.

Xuan Shia, Yaowu Shi [6] Tube coils made of 25Cr-20Ni austenitic stainless steel were horizontally installed in the fluidized bed of an actifier column of a catalytic cracker installation in an oil refinery unit. Catalyst particles and flue gases were moved in the fluidized bed. When the catalyst lost activity, carbon in the catalyst was burned out in the fluidized bed to recover the activity of the catalyst. Meanwhile, a steam–water mixture was formed with a pressure of 4 MPa and saturation temperature of 250^0C in the tube coils by the heating of the flue gases. Thus, the heat in the fluidized bed was utilized to generate steam. However, after the installation had been in service for about 40 days, leakage occurred in the tube coils. In general the positions of leaks were in the upper part of the tubes within about 6 m of the

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inlet. Microscopic analyses indicated that cracks initiated at local corrosion pits where chloride ions present in the feed water enriched and accumulated. The crack propagated in an inter granular or trans granular manner. Obvious striations were found on the crack surfaces at some positions. Based on the failure analysis and heat transfer calculation, failure of the tube coils was mainly caused by the effects of corrosion fatigue. The lifetime of the tube coils could be prolonged by changing the steam–water flow conditions.

William Yang [7] A CFD model of a 375 MW tangentially-fired furnace located in Australia's Latrobe Valley has been developed. Coal feed rates, air flow rates, coal particle size distribution and coal properties, obtained from plant data, are taken as input conditions in the CFD simulation. A level of confidence in the current CFD model has been established by carrying out a mesh independence test and comparing simulated results against power plant measurements. Performance of two turbulence models, standard k-ε model and SST model, are compared. The effect of particle dispersion on predicted results is found to be insignificant. The validated CFD model is then used to simulate several brown coal combustion cases at full load with different out-of-service firing groups.

4. WEAR OF BOILER COMPONENTS

Different boiler components show different wear behavior depending on the location and operating temperature. The main components of a fluidized bed boiler may be listed as follows:

- Furnace and other evaporating surfaces
- Solids separator and return (only in CFB boilers)
- Super heaters and other flue gas cooling elements
- Fuel feeding
- Ash discharge systems
- Flue gas cleaning
- Air and flue gas blowers
- Steam ducts
- Steam turbine with accessories

The scope of this paper is limited to problems characteristic to fluidized bed combustion, i.e. the parts which are in contact with the fluidized solid material and ashes.

5. INTRODUCTION TO CFD MODELING

CFD is concerned with numerical solution of differential equations governing transport of mass, momentum and energy in moving fluid. Using CFD, one can build a computational model on which physics can be applied for getting the results. The CFD software gives one the power to model things, mesh them, give proper boundary conditions and simulate them with real world condition to obtain results. Using CFD a model can be developed which can breed to give results such that the model could be developed into an object which could be of some use in our life. [1]

Modeling is the mathematical physics problem formulation in terms of a continuous initial boundary value problem (IBVP)
IBVP is in the form of Partial Differential Equations (PDEs) with appropriate boundary conditions and initial conditions.
Modeling includes:
1. Geometry and domain
2. Coordinates
3. Governing equations
4. Flow conditions
5. Initial and boundary conditions
6. Selection of models for different applications

Solve the Navier-Stokes equations (3D in Cartesian coordinate).
Computational fluid dynamics techniques have revolutionized engineering design in several important areas, notably in analysis of fluid flow technology. CFD provides numerical approximation to the equations that govern fluid motion. Application of the CFD to analyze a fluid problem requires the following steps. First, the mathematical equations describing the fluid flow are written. These are usually a set of partial differential equations. These equations are then discretized to produce a numerical analogue of the equations. The domain is then divided into small grids or elements. Finally, the initial conditions and the boundary conditions of the specific problem are used to solve these equations. The solution method can be direct or iterative. In addition, certain control parameters are used to control the convergence, stability, and accuracy of the method.
A typical CFD simulation consists of several stages:
(1) A pre-processor, which is used to input the problem geometry, generate the grid, and define the flow parameter and the boundary conditions to the code.
(2) A flow solver, which is used to solve the governing equations of the flow subject to the conditions provided. There are four different methods used as a flow solver:
✓ Finite Difference Method
✓ Finite Element Method
✓ Finite Volume Method
✓ Spectral Method
(3) A post-processor, which is used to massage the data and show the results in graphical and easy to read format.
Computational fluid dynamics readily complements the previous dimensions of pure experiment & theory. Computational fluid dynamics in principle, allows the practical solution of the Exact Governing equitation of applied Engineering problems.

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6. CONCLUSION

The issue concerned in all explanations of Erosion and Corrosion of Bed Coil of Coal Combustion Process. It is concluded that the CFD analysis results fairly matches with the Experimental Results. This shows that CFD Analysis is a powerful tool to replace costly experiment and lengthy calculation.

From the above all the literature review and study I am much more interested to work on Experimental and CFD Optimization of Bed coil of coal combustion process.

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