Technical Progress Report No.8

Analysis/Control of In-Bed Tube Erosion
Phenomena in the Fluidized Bed
Combustion (FBC) System

to

U.S. Department of Energy
Pittsburgh Energy Technology Center
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for

Project No: DE-FG22-92MT92021

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October 1994

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SUMMARY

This technical report summarizes the research work performed and progress achieved during the period of July 1, 1994 to September 30, 1994.

The metal wastage of AISI 1018 low carbon steel at different particle velocity was discussed to understand the erosion phenomena of in-bed tube in FBC system. At both low velocity (2.5 m/s) and high (30 m/s), the maximum metal wastage was occurred at 45° of impact angle. The erosion rates at low particle velocity were two (2) to three (3) orders of magnitude lower than those at high particle velocity.

The characteristics of anti-erosion and design considerations were discussed and suggested for some basic design guidelines, which might be important to the designer of bubbling fluidized combustors. The working principle and mechanism of anti-erosion devices will be discussed. Based upon the understanding of the working principle and mechanism of anti-erosion devices, different types of anti-erosion tube will be designed for the cold model bench-scale FBC system.

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SECTION 1

Discussion on Metal Wastage

1. Effect of Particle Impact Velocity

A series of the metal wastage test [1] was carried out on AISI 1018 low carbon steel at an elevated temperature condition (300°C) with different particle impact velocities. At both low velocity (2.5 m/s) and high velocity (30 m/s), the metal wastage rate of AISI steel specimens demonstrated higher wastage at shallow angle than at a steep angle with a maximum erosion rate occurring at 45° impinging angle as shown in Figure 1. For low velocity, the thickness loss was increased from 8 µm to 14 µm when the thickness loss at 90° compared with that 45°. For high velocity, it was increased from 49 µm to 86 µm, respectively. It can be seen that the erosion wastage rates at low particle velocity were two to three orders of magnitude lower than those at high particle velocity.

These results are correlated with the material wastage observations of in-bed steel tubes in FBCs [2]. In operating of actual AFBC boilers, the maximum wastage of in-bed steel tubes occurred at the underside of the tube with maximum wastage occurring at approximately 30° to 45° to either side of the center line [3] in other words at the bottom 135° and 225° [4]. Typically, ductile materials exhibit maximum wastage at shallow impact angle whereas the brittle materials exhibit maximum erosion at steep impact angles. In these test, the higher angle of maximum erosi-

V =2.5 m/s, t = 96 hrs. loading 9000 g

V=30 m/s, t=4 hrs. loading 375 g

Figure 1 Erosion Wastage for 1018 Low Carbon Steel Specimen Eroded at Different Test Conditions.

on for 1018 steel (a ductile material) was attributed to the formation of thin oxide scale on the surface of 1018 steel which would influence the erosion mechanism.

It is known that the mass removal process of in-bed tube of FBC is affected by the particle impact velocity. The test results [1] indicated that the bottom surface had higher wastage rate due to the frequent particle impacts, while the top tube surface had lower wastage rate due to less particle collisions.
lower wastage rate

SECTION 2

Discussion on Anti-Erosion Method

1. Characteristics of Anti-Erosion and Design Considerations

The material wastage of in-bed tube surfaces is a problem which has become increasingly important to the designer of bubbling fluidized bed combustors. As the operational experience has increased, the problem of material wastage has become more widely reported. In-bed tube erosion is a problem of the fluidized bed combustion systems for which no simple remedy is available. Some basic design guidelines are being identified, but the prediction of life expectancy of in-bed tubes remains an art which currently relies more upon experience than rules [5].

The remedies for in-bed tube erosion can include as follows:

- o fitting protection systems
- o changing system variables
- o consideration of alternative materials for tubing
- o surface treatments and coating of the tubing

Several factors influence that the erosion of in-bed tube of cold model: tube position within the bed, distance of the tube from the distributor, bed materials and particle size, location along the tube circumference, and use of flow disruptive devices.

(i) Design an Approach

It is suggested that if a successful plant is to be designed

with minimum risk of tube wastage problems, a number of points should be addressed before detailed design is commenced.

Main considerations for the designer are:

- o acknowledge that tube material wastage exists
- o consider a cost effective solution addressing both capital and maintenance costs
- o design for ease of access and maintenance
- o consider previous experience and learn from catastrophic failures
- o consider plant operating load pattern
- o review the possible effects of system variables

(ii) Provide a Cost Effective Design

An FBC system could be designed based on low fluidizing velocities and the best available materials. As an example, the Foster Wheeler power products recently investigated the capital and maintenance cost implications of a variety of alternative solutions to the erosion problem [6]. The cost variations were considered with several options as follows:

- o plain tube
- o finned tube
- o finned and pinned tubes
- o ball-studded tube

(iii) Consider the Effect of System Variables

The factors considered to influence rate of in-bed tube erosion are as follows:

- o fluidizing velocity
- o bed material
- o bed particle size
- o bundle geometry
- o tube-to-distributor clearance
- o tube material and coating of tube surface
- o tube protection system

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