Technical Progress Report No.11

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
P.O. Box 10940, MS 921-118
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for

Project No: DE-FG22-92MT92021

by

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July 1995

SUMMARY

This technical report summarizes the research work performed and progress achieved during the period of April 1, 1995 to June 30, 1995.

In this study, the preliminary analysis of test data and understanding of the erosion behavior of resistant coatings for the in-bed tube materials were discussed for one the remedies of preventing in-bed tube erosion.

The material wastage of the specimen was determined by weight and thickness loss measurements. The morphologies of the specimens were examined by scanning electron microscopy (SEM). For the material wastage of the coating specimens, High Velocity Oxygen Fuel (HVOF) coatings (DS200) and the arc-sprayed coating at elevated temperature condition exhibited 2 to 3 times lower erosion wastage than that of AISI 1018 steel.

For the angular dependence of erosion rate, two coatings exhibited the ductile behavior as demonstrated by higher wastage rates at shallow impact angle than that at steep impact angle.

Tests will be continued and compared with erosion test results from higher velocity test conditions.

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SECTION 1

Erosion Resistant Coatings of In-Bed Tube Materials

Reducing the material wastage by erosion of in-bed tubes in FBCs is one of the most vital steps in their development and maintenance for large-scale commercial use. In this study, different resistant coatings applied to protect the surface of in-bed tube materials as erosion remedies.

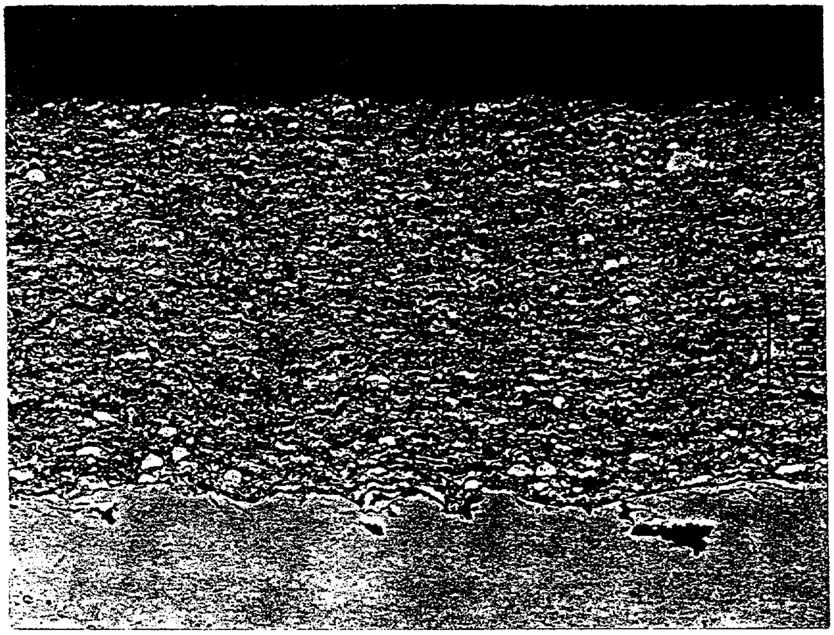
1.1 Test Conditions

a. Test Specimens and Materials

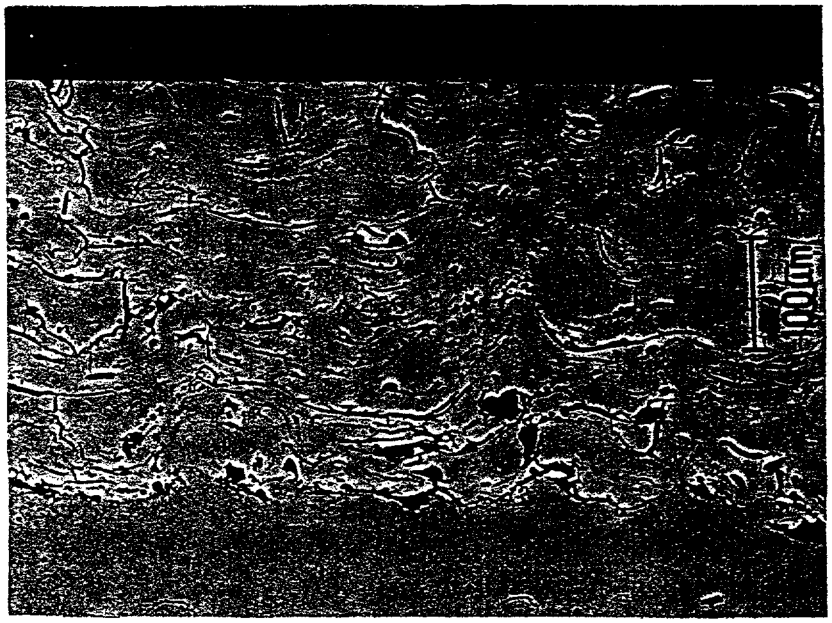
AISI 1018 low carbon steel and two thermal spray coatings on mild steel were used as target materials. High Velocity Oxygen Fuel (HVOF) thermal spraying was employed as the coating process for one specimen. Wire arc spraying was employed for the other specimen. The characteristics of the materials are listed in Table 1. The test surfaces of the target materials were polished using a succession of SiC paper down to 600 grit prior to testing. Figure 1 shows cross sections of the target coating specimens.

Table 1 Characteristics of the Test Specimens

Target Material	Application Process	Normal Composition	Thickness (µm)	Porosity (%)
1018 Steel	--------	Fe 0.2C	_____	0
DS-200	HVOF	$75Cr_3C_2$-25NiCr	566	<2
Armacor M	Wire Arc Spray	Fe25Cr3B2Si	302	2-4



a) HVOF Cr_3C_2-NiCr coating



b) Arc-sprayed FeCrSiB coating

Figure 1 Cross Sections of Target Coating Specimens

b. Test Particles

Quartz silica particles were used as the erodent particles. The mean particle size was 742 μm with a mean particle density of 2556 kg/m^3.

c. Test Procedures

In order to simulate material wastage of in-bed tubes in FBC, the tests were carried out in the elevated temperature blast nozzle type tester [1]. Air, which created generally oxidized atmosphere at elevated temperature, was the carrier gas for the particles. Particle impact velocity was established by setting a pressure drop across the nozzle using a metering system connected to an air compressor. The tests were carried out at test temperature of 300 ^{o}C and impact angles of 30^{o}, 45^{o}, and 90^{o}. A test time of 96 hours was used at a particle loading of 9000 g. The low particle impact velocity (2.5 m/s) was applied to simulate the erosion condition [2].

The material wastage of the specimen was determined by weight measurements, which was weighed after test period on a balance with a resolution of 0.1 mg. The metal wastage of the specimen was also determined by microscopic dimensional measurements of cross-sections through the area greatest metal loss to determine the thickness of the remaining sound metal. The morphologies of the specimens were examined and analyzed using scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS).

SECTION 2

Results and Discussion

At low impact velocity, 2.5 m/s, the metal wastage rate of AISI 1018 steel specimens showed higher wastage at a shallow angle of impingement than at a steep angle, with a maximum erosion rate occurring at a 45° impingement angle [1]. These results correlate to erosion test results reported and to wastage observations of in-bed steel tubes in FBC [3,4]. In this test, the higher angle of maximum wastage for 1018 steel (ductile material) was attributed to the formation of a thin oxide scale on the surface of the steel, which influenced the erosion mechanism.

For the material wastage of the coating specimens, HVOF Cr_3C_2-NiCr cermet coatings (DS200) and the arc-sprayed FeCrSiB coating (Armacor M) at elevated temperature condition exhibited 2 to 3 times lower erosion wastage than that of AISI 1018 steel as shown in Table 2.

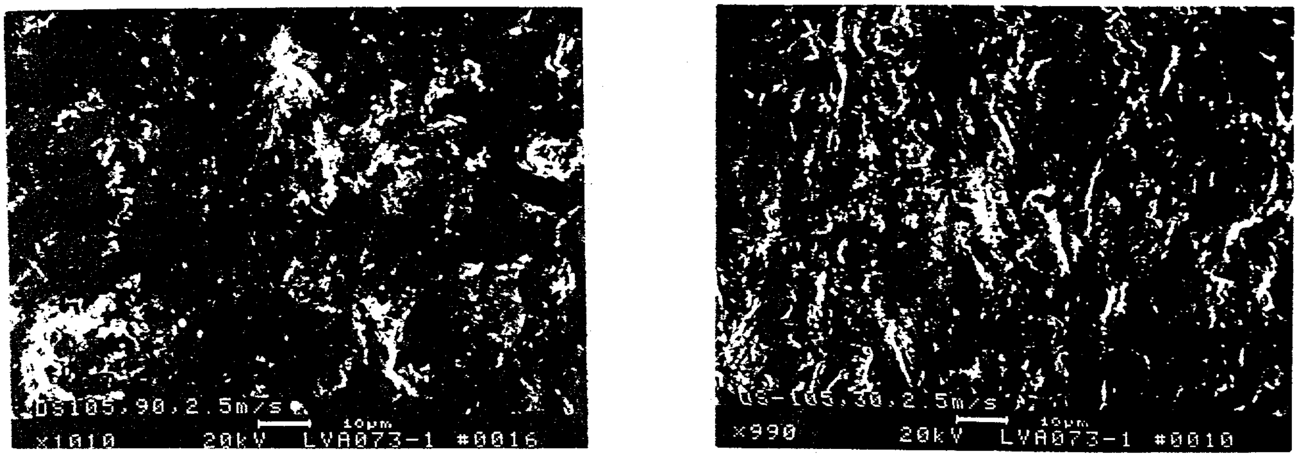
Table 2 The Material Weight Loss at Test Condition

Target Material	Weight Loss (mg) Impact Angles; 30°	45°	90°	Thickness Loss (um) 30°	45°	90°
1018 steel	(2.0)	1.6	(2.2)	12	14	8
DS-200	(0.7)	(1.1)	(2.2)	6	4	~0
Armacor M	0.9	0.8	(1.0)	10	5	3

( ) denotes weight gain

For the angular dependence of erosion rate, two coatings exhibited the ductile behavior as demonstrated by higher wastage rates at shallow impact angle than that at steep impact angle. Most metals including mild steel eroded by hard angular particles exhibit ductile erosion behavior in angular dependence of erosion rate, and material removed from surface by ductile cutting and deformation cutting.

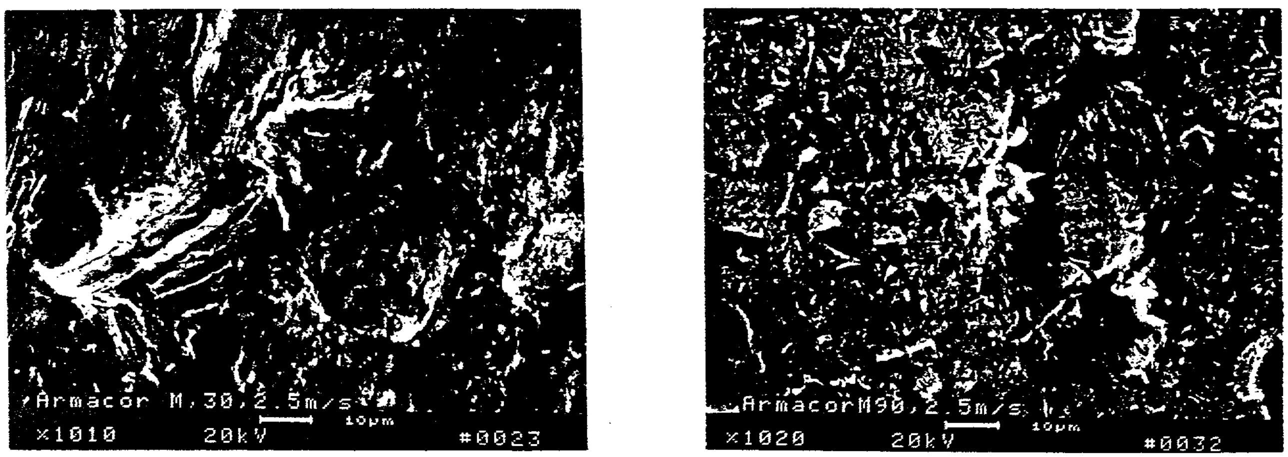
As shown in Figures 2,3, and 4, there were some evidences of deformation indicated by narrow gouges, striations, small craters and indentations on the eroded surfaces of the coating specimens. Some erodent particles were also embedded in the surface of specimen eroded at 90^{o} of impact angle as proven by Energy Dispersive Spectroscopy (EDS) analysis. As shown in Figure 1-b, the low erosion resistance of Armacor M coating was attributed to larger "splat" size, higher porosity and presence of radial and tangential microcracks or inclusions within the coating. When these weak boundaries were impacted by hard angular particles at normal angle, this kind of coating cracked readily along the weak boundaries and impact damage was dominated by brittle fracture mechanism, even though impacted at very low velocity.



a) Surface (α=90°, V=2.5 m/s),

b) Surface (α=30°, V=2.5 m/s)

Figurre 2. The surface of HVOF Cr_3C_2 coating eroded at V=2.5 m/s.



a) Surface (α=30°, V=2.5 m/s),

b) Surface (α=90°, V=2.5 m/s)

Figure 3. The surface of arc-sprayed FeCrSiB coating eroded at V=2.5 m/s.

Figure 4 The cross section of arc-sprayed FeCrSiB coating eroded at V=2.5 m/s, α=90°.

REFERENCES

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