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Erosion of HVOF Sprayed (CrC-Ni Cr Fe Si)Coatings of Comparison with Substrate Metal SS-306

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ABSTRACT: The high velocity oxy-fuel(HVOF) sprayed CrC -NiCrFeSi coatings on GrA1 boiler tube steal exhibit composite ductile and brittle modes of erosion under angular silica sand erodent of size 125-180µm impacted at 40m/s. The HVOF spraying leads to a high retention of WC in the coating matrix accompanied with lower porosity. High temperature oxidation and erosion of heat exchanger tubes and other structural materials in coal-fired boilers are recognized as being the main cause of downtime at hpower-generating plants, which could account for 50–75% of their total arrest time. Maintenance costs for replacing broken tubes in the some installations are also very high, and can be estimated at up to 54 % of the total production costs. The as-sprayed as well as eroded coatings have been characterized using scanning electron microscope and optical profile meter Present materials being capable of resisting erosive and corrosive environments are highly alloyed, and thus expensive. In search for cost-effective solutions for Erosion – Corrosion problems, various coatings like thermal sprayed coatings have become attractive.

KEYWORDS: HVOF process, erosion test, coating composition, and 306-SS

I. INRODUCTION

Fire side hot corrosion and erosion of structural metallic materials at high temperature in combined gas environments that contain particulates are potential problems in several fossil energy systems, mainly those using coal as a feedstock. Hot corrosion is present in several fashions due to combustion products which change their state of matter and become salts as a result of the high temperature. Erosion occurs as a result of impact of particulates, such as coal, ash and unburnt carbon particles on the boiler tube surface (Morgan 1992). Erosive wear is caused in the solid bodies by the action of sliding or impact of solids, liquids, gases or a combination of these [1]. Solid particle erosion is an important material degradation mechanism encountered in a number of engineering systems such as thermal power plants, aircraft gas turbine engines, pneumatic bulk transport systems, coal liquefaction/gasification plants and ore or coal slurry pipe lines [3,4].

Erosion results from impact of particulates, such as coal ash, dolomite and unburned carbon particles on the surface of heated boiler tubes. It is generally believed that the most erosive species in the fly ash are quartz, which is a crystalline from of SiO_2 . More than one quarter of all the boiler tube failures worldwide are caused by fly ash erosion [5,6].



Fig 1.1 Erosion on Metal Surface



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Coatings provide of extending the limits of use of materials at the upper end of their performance capabilities, by allowing the mechanical properties of the substrate material to be maintained while protecting them against wear or corrosion. According to a survey conducted over a period of 12 years comprising of 413 investigations, 201 failures were reported due to overheating (Metals Handbook, 1975). Fatigue and corrosion fatigue were listed as the next most frequent causes of failure, which counts about 89 failures or 21.5%. Corrosion, stress corrosion and hydrogen embrittlement leads to 68 failures or 16.5%. The most important drawbacks diffusing coatings are that they are thin and cannot be produced on sight or repaired. In compression with diffusion coatings, thermal spray coatings do not require such a high temperature of the base metal that would impair the mechanical or micro structural properties in the case of weld overly there is increase in corner that repeated weld overlay application to the same tube area may result in embrittlement of the old overlay and lead to cracks that could propagates in to the overlaid tube. Because of the mentioned short coming in diffusion and weld overlay coatings, attention is increasingly being forced on thermal sprayed coating.[1],[2],[3],[4],[5],[10].

II. HIGH VELOCITY OXY-FUEL PROCESS (HVOF)

2.1 Explanation on HVOF Process

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Fig 2.1 Block Diagram of HVOF Process

- HVOF is a method of propelling molten particles on to work surfaces for each coating. As an essential feature of thermal spray coatings, sprayed particles upon and after impact deform so as to interlock with the impact surface's profile. While the initial thermal spray technology focused on guaranteed deformation through excessive heating, a new method is introduced with the high velocity of HVOF.
- A small chamber is used to create supersonic velocity of exhaust. The focused exhaust stream receives the powder material at a velocity that the resultant impact forges adequate bonding. In fact, the impact from the kinetic energy is so great that most of the porosity is eliminated. As such, the less porous coating provides the best wear resistance and densest coatings available. The HVOF thermal spray process uses the combustion gases such as propane, propylene hydrogen or a liquid fuel such as a kerosene fuel and oxygen.[1],[2],[3],[5]



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2.2 HVOF Process Parameters

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Oxygen flow rate	200 l/mm
Fuel (LPG) flow rate	50 l/mm
Air flow rate	750 l/mm
Spray distance	100mm
Powder feed rate	36g/min
Fuel pressure	500kpa
Oxygen pressure	750kpa
Air pressure	535kpa
Model no of the gun	5220
Diameter of the gun	11mm

Table1: Process parameters

III. EXPERIMENTAL PROCEDURE

3.1 Substrate material and development of coating

Low carbon steel ASTM-SA201 grade A1(GrA1) which is used as material for boiler tubes in some coal fired thermal power plants in northern part of India has been used as substrate in the study. The specimens with approximate dimensions of 30mm*30mm*5mm were cut from the tubes for erosion studies. Samples were grinded with SiC papers down to 180 grit and grit blasted with Al₂O₃ (grit45) before being HVOF sprayed to develop better adhesion between the subtract and the coating.[8],[10]The composite coating powder of 80CrC-NiCrFeSi was used to spray to deposit coatings using HVOF Process.

Coating Compositions

CrC	Ni	Fe	Cr	Si
80	11.169	1.7	7.219	2.25



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In this coating, 80% of coating contains CrC, (Ni, Fe, Cr, Si,) 20% The percentage of CrC -80, Ni - 11.169, Fe - 1.7, Cr - 7.219 and that of Si - 2.25.

3.2 Erosion Test Equipment and Setup

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Fig 3.1Schematic of coal-fired boiler

Erosion Test Procedure:

- Before conducting the test, the specimen surface was cleaned properly.
- The sample is clamped at the fixture. The required angle and standoff distance was adjusted.
- The air at required pressure is mixed with the erosive particle and is directed to a specimen for specified time duration.
- The initial mass and the mass of the specimen after erosion were found out using the weighing machine.
- The above steps are repeated for different parameters mentioned.

Erosion Test for Substrate (306-SS)

Its compositions are listed below:

Element	Percent by Weight 306-SS
Carbon	0.08
Manganese	2.00
Silicon	0.75
Chromium	16.00
	18.00
Nickel	10.00
	14.00
Molybdenum	2.00



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	3.00
Phosphorus	0.045
Sulfur	0.030
Nitrogen	0.10
Iron	Bal.

3.3 Tables for Impingement Angles $(30^0, 60^0, 90^0)$

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30⁰Table

Cycle	Initial	Final
5	15.6445	15.6440
10	15.6440	15.6395
15	15.6395	15.6393
20	15.6393	15.6392
25	15.6392	15.6392

60^0 table

Cycle	Initial	Final
5	19.6329	19.6326
10	19.6326	19.6324
15	19.6324	19.6323
20	19.6323	19.6323

Cycle	Initial	Final
5	19.6335	19.6332
10	19.6332	19.6330
15	19.6330	19.6329
20	19.6329	19.6329



Fig 4.1 Erosion Test for 30⁰



Fig 4.2 Erosion Test for 60°



Fig 4.3 Erosion Test for 90⁰



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3.4 Erosion Test for Coating Components $(30^0, 60^0, 90^0)$

Coating Compositions – WC Co-NiCrAlYSi (80%-20%)

30⁰ Table

Cycle	Initial	Final
5	16.574	16.5712
10	16.5712	16.5699
15	16.5699	16.5619
20	16.5619	16.5619
25	16.5619	16.5619
30	16.5619	16.5619

 60^0 Table

Cycle	Initial	Final
5	21.847	21.8467
10	21.8467	21.8466
15	21.8466	21.8464
20	21.8464	21.8457
25	21.8457	21.8454
30	21.8454	21.84539

90^0 Table

Cycle	Initial	Final
5	21.84539	21.8448
10	21.8448	21.8438
15	21.8438	21.8430
20	21.8430	21.8423
25	21.8423	21.8418
30	21.8418	21.8417



Fig 4.4 Erosion Test at 30^o

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Fig 4.5 Erosion Test at 60⁰



Fig 4.6 Erosion Test at 90⁰



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IV. RESULT AND DISCUSSION

4.1 Comparison Between Substrate and Coating

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4.1.1 Graph for Coating and Substrate at 30° , 60° and 90°



Explanation: From the above graph the erosion rate increased in coating compared to substrate at 30° , 60° and 90°



Explanation: Bar Graph shows the erosion rate of Substrate and Coated materials.

V. CONCLUSION

- High velocity oxy-fuel thermal spraying with oxygen and liquid petroleum gas as fuel gases has been used successfully to deposit CrC -NiCrFeSi alloy coatings on boiler tube steels. LPG fuel gaze is cheap and readily available as compared to other fuels used for HVOF spraying. Under the given spray parameters coating with average thickness 290microns and average porosity of 0.5% has been achieved coating deposited resulted in hardness value of 1223HV.
- CrC -NiCrFeSi coatings show retention of higher amount of WC in matrix with a minor amount of brittle phase.
- The erosion resistance of CrC -NiCrFeSiB coating maybe attributed to composite ductile and brittle modes of material removal although brittle mode is dominant. The morphology of the eroded surface points out craters.
- Substrate steel exhibit slower steady state volume erosion rate in comparison to HVOF sprayed CrC -NiCrFeSi coatings under similar test conditions. The higher hardness ratio between silicon erodent particle and substrate steel might have caused the penetration of silica particles into the surface.
- Erosion rate with respect to angle of impact is maximum at 30degree and minimum at 90degree. Erosion rate with respect to stand of distance is maximum at 100mm and lower for 200mm. This implies that lower the stand of distance greater is the rate of erosion.



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• Erosion rate with respect to Pressure increases as the rate of erosion increases.

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From the predicted mechanism it is found that the erosion behavior is valid for ductile materials. Hence our observation also follows the same rule.

Having calculated the ideal angle of contact, force of impingement and the distance of fall for a Mild Steel, Aluminum, Stainless Steel, we would now be in a position to predict the condition that should be maintained to minimize wear.

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