

Comparative Study of Erosion for the HVOF Spray Coating (WC-NiCrFeCo) with Substrate Metal SS-306

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ABSTRACT: The material(316-SS) used for high temperature applications in high temperature environment. the solid particle erosion experiments will be carried out at the surface Engineering Laboratory, using air-jet erosion test rig as per ASTM-G76 standard. The materials used is 316-SS. Conducting the experiment at different impact angles It is a well-known fact that materials that consist of both brittle and ductile constituents can show erosion behavior in either a ductile or a brittle manner. The high velocity oxy-fuel (HVOF) sprayed WC-NiCrFeCo coatings on GrA1 boiler tube steel exhibit composite ductile and brittle modes of erosion under angular silica sand erodent of size 125-180 μ m impacted at 40m/s. The HVOF spraying leads to a high retention of WC in the coating matrix accompanied with lower porosity. The as-sprayed as well as eroded coatings have been characterized using scanning electron microscope and optical profilometer.

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

I. INTRODUCTION

Manifestations of solid particle erosion in service usually include thinning of components, a macroscopic scooping appearance following the gas particle flow field, surface roughening, and lack of the directional grooving characteristic of abrasion and in some but not all cases, the formation of ripple patterns on metals [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 [2,3].

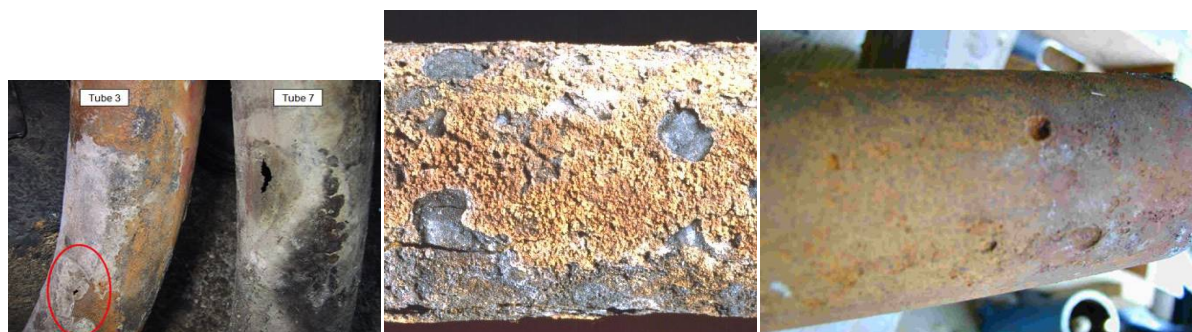


Fig 1.1 Erosion on Metal Surface

Power plants are one of the major industries suffering from severe corrosion and erosion problems resulting in the substantial losses. 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 form of SiO₂ and mullite. More than one quarter of all the boiler tube failures worldwide are caused by fly ash erosion [4,5].

There are many coating deposition techniques intended, level of adhesion required (size, shape, and metallurgy of the substrate), and availability and cost of the equipment. In general, widely used techniques to obtain coatings on boiler tubes or weld overly, diffusion coating, thermal spraying and laser cladding. The most important drawbacks diffusing coatings are that they are thin and cannot be produced on sight or repaired.. 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

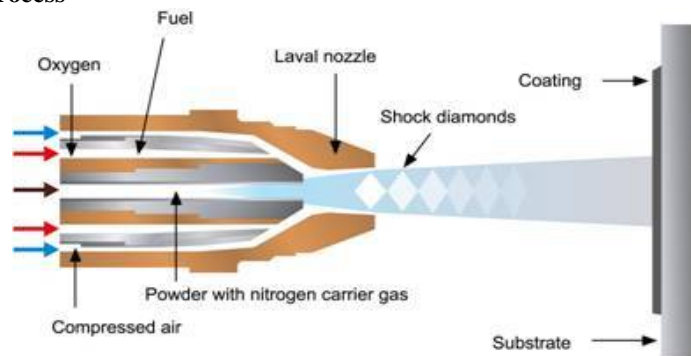


Fig 2.1 Block Diagram of HVOF Process

As with all thermal spray coating processes, HVOF coating material is heated and accelerated by a gas stream to a component's surface, to attain better properties. With the HVOF coating the gas stream is produced by mixing and igniting oxygen and fuel (gas or liquid) in a combustion chamber and allowing the high pressure gas to accelerate through a nozzle. Powder is introduced into this stream where it is heated and accelerated towards a component's surface. The resulting thermal spray coating consists of thin overlapping platelets process[2],[3]

- 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.
- 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]

2.2 HVOF Process Parameters

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

2.3 Coating Compositions

WC	Ni	Cr	Fe	Co
35.5	36	18.5	5	6

In this coating, 35% of coating contains WC and 65% of NiCrFeCo.
The percentage of WC -35.5, Ni – 36 , Cr -18.5 , Fe - 5, and that of Co-6

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 substrate and the coating. [8],[10]

The composite coating powder of 80%Wc-NiCrFeCo was used to spray to deposit coatings using HVOF Process.

3.2 Powder and Coating Characterization Techniques

The surface and cross section of coated samples with were wheel cloth polished for metallurgical examination. Zeiss Axiovert 200 MAT inverted optical microscope, fitted with analyzing software zeiss Axiovision release 4.1 used for optical microscopy. porosity and average coating thickness was measured with image analyzing software. surface roughness of the coating was recorded with WYKO NT1100 optical profilometer using veco version 32 software Vickers micro hardness measurements (leitz's hardness tester) using 2.94N were performed in order to access the hardness across the coating and to ascertain substrate plastic strain hardening promoted by the high velocity projection

3.3 Erosion Test Equipment and Setup

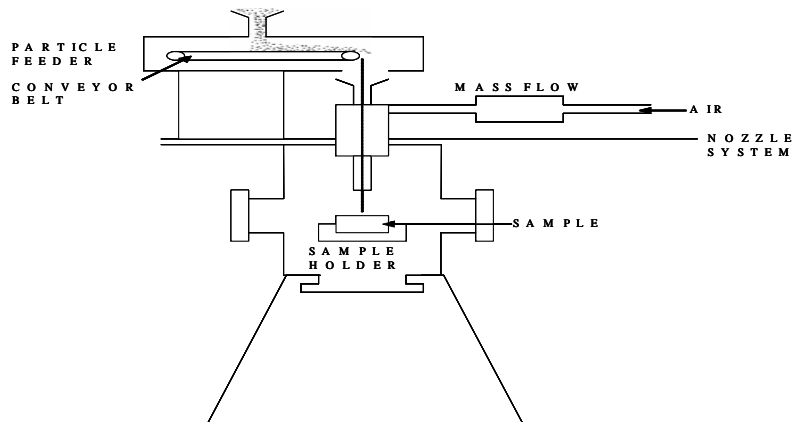


Fig 3.1 Block Diagram of Erosion Test Equipment

EXPERIMENTAL PARAMETERS

1. Angle :

The angle can be varied by using the fixture arrangement. Different angles which can be used are 30°, 60°, 90°.

2. Pressure :

Different values of pressure which can be used are 4Kgf/mm², 5 Kgf/mm² and 6 Kgf/mm².

3. Stand off distance:

It is the distance between the nozzle tip and the specimen of the surface. The stand off distance can be varied by adjusting nozzle height using the screw arrangement. The different values of stand off distance used were 100mm and 200mm.

3.4 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 3.00
Phosphorus	0.045
Sulfur	0.030
Nitrogen	0.10
Iron	Bal.

3.5 Tables for Impingement Angles (30°, 60°, 90°)

30° Table

Cycle	Initial	Final
5	15.6445	19.6440
10	15.6440	15.6395
15	15.6395	15.6393
20	15.6393	15.6392
25	15.6392	15.6392

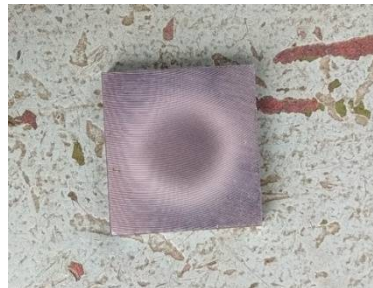


Fig 3.2 Erosion test for 30°

60° Table

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



Fig 3.3 Erosion Test for 60°

90° Table

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

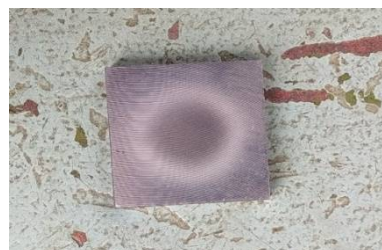


Fig 3.4 Erosion Test for 90°

3.6 Erosion Test for Coating Components (30°, 60°, 90°)

Coating Compositions – Wc-NiCrFeCo(80%-20%)

30° Table

Cycle	Initial	Final
5	15.73	15.7286
10	15.7286	15.7273
15	15.7273	15.727
20	15.727	15.7266
25	15.7266	15.7266
30	15.7266	15.7265



Fig 3.5 Erosion Test at 30°

60° Table

Cycle	Initial	Final
5	21.2661	21.2652
10	21.2652	21.2633
15	21.2633	21.2617
20	21.2617	21.261
25	21.261	21.260
30	21.260	21.260



Fig 3.6 Erosion Test at 60°

90° Table

Cycle	Initial	Final
5	21.2723	21.2707
10	21.2707	21.2696
15	21.2696	21.2689
20	21.2689	21.2668
25	21.2668	21.2661
30	21.2661	21.2661

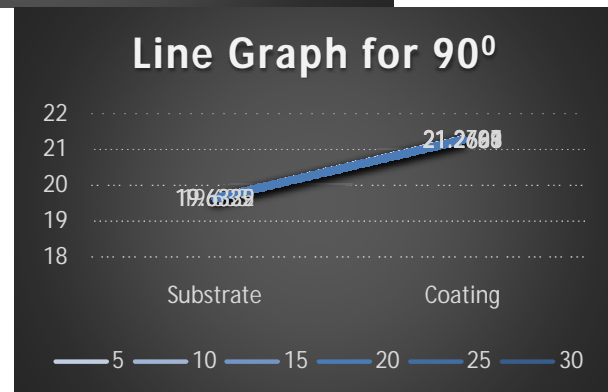
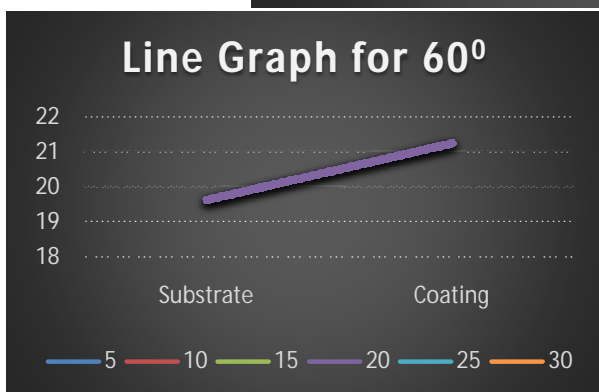
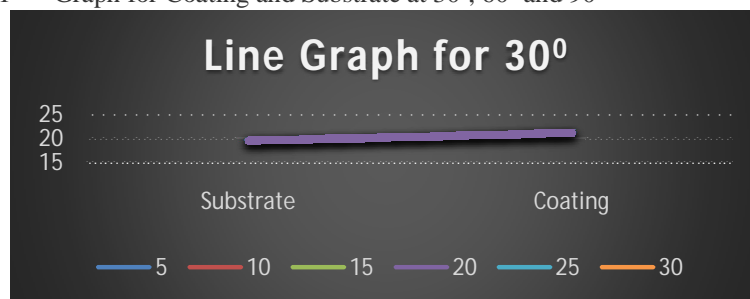


Fig 3.7 Erosion Test at 90°

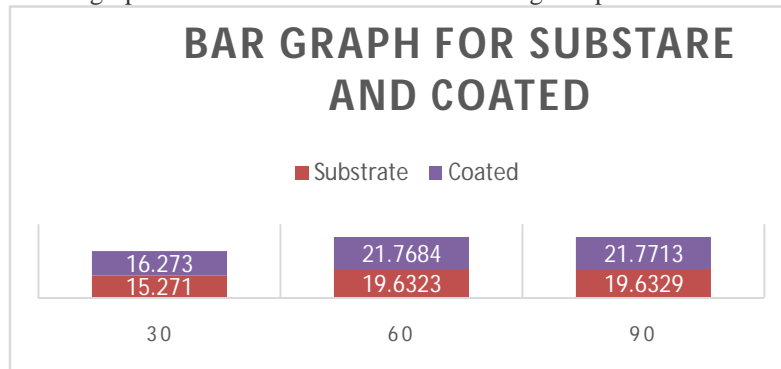
IV. RESULT AND DISCUSSION

4.1 Comparison Between Substrate and Coating

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 WC-NiCrFeCo alloy coatings on boiler tube steels. LPG fuel gas 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.
- WC – NiCrFeCo coatings show retention of higher amount of WC in matrix with a minor amount of brittle phase.
- The erosion resistance of WC- NiCrFeCr 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 WC-NiCrFeCr 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.
- Erosion rate with respect to Pressure increases as the rate of erosion increases.

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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