

HVOF Sprayed Coating's (WC-Co Ni Cr Si) to Conduct the Erosion Test

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ABSTRACT: 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-CoNiCrSi 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. INRODUCTION

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

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 [5,6].



Fig 1.1 Erosion on Metal Surface

Generally speaking, coatings can be regarded as materials with greater resistance to the significant surface degradation process. 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. An advantage of coating is that are relatively cheap and they can be applied insitu. 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. 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

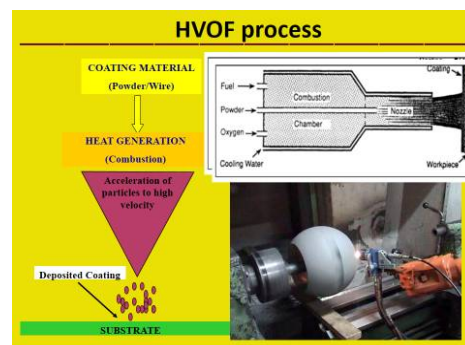


Fig 2.1 Block Diagram of HVOF Process.

- 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]

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

2.2. Coating Compositions

WC	Co	Ni	Cr	Si
66.4	13.6	8.67	7.82	1.557

In this coating, 80% of coating contains WC Co and 20% of Ni Cr Fe Si.
The percentage of WC - 66.4, Co - 13.6, Ni - 8.67, Cr- 9.82, and that of Si - 1.557.

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 Al_2O_3 (grit45) before being HVOF sprayed to develop better adhesion between the substrate and the coating. [8],[9],[10]

The composite coating powder of 80%WC CO-NiCrFeSi was used to spray to deposit coatings using HVOF Process.

3.2 Erosion Test Equipment and Setup

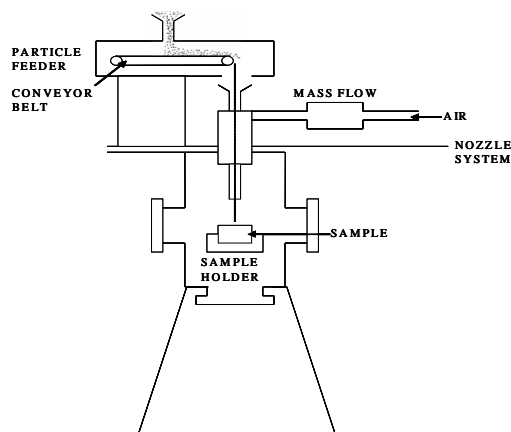


Fig 3.1 Block Diagram of Erosion Test Equipment



Fig 3.2 Air Jet Erosion Test Machine

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.

3.3 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.

1.6 Tables for Impingement Angles (30°, 60°, 90°) 30°Table

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

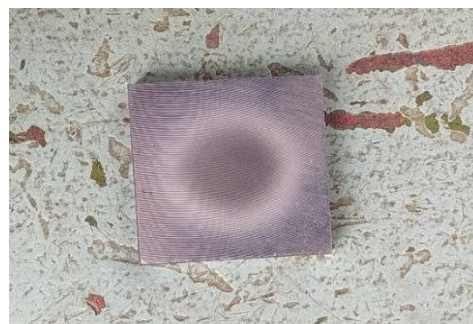


Fig 4.1 Erosion Test for 30°

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 4.2 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

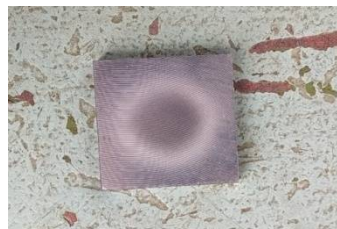


Fig 4.3 Erosion Test for 90°

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

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

30° Table

Cycle	Initial	Final
5	16.2802	16.2773
10	16.2773	16.2760
15	16.2760	16.2743
20	16.2743	16.2736
25	16.2736	16.2730
30	16.2730	16.2730



Fig 4.4 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 4.5 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

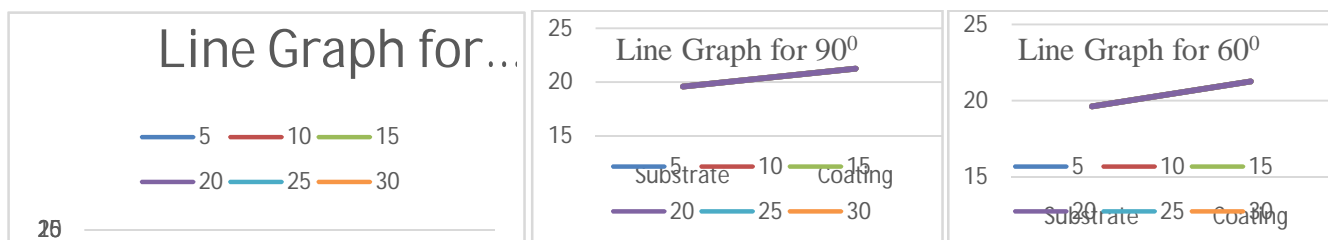


Fig 4.6 Erosion Test at 90°

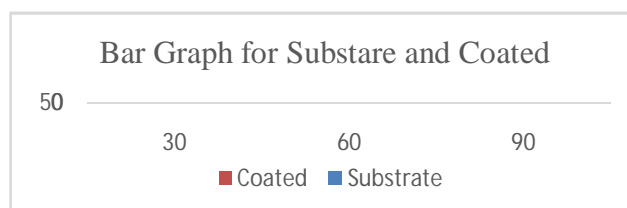
IV. RESULT AND DISCUSSION

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 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 Co-NiCrSi 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 Co- NiCrAlYSi coatings show retention of higher amount of WC in matrix with a minor amount of W₂C brittle phase.
- The erosion resistance of WC Co- NiCrSi 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 Co-NiCrSi 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.

REFERENCES

1. P.H.Shipway, The potential of WC-Co hardness and HVOF sprayed coatings to combat water droplet erosion, www.elsevier.com, Wear 271(2011) 1418-1425.
2. L.Thakur, A comparative study on slurry and dry erosion behaviour of HVOF sprayed WC-CoCr coatings, www.elsevier.com, Wear 303(2013) 405-411.
3. Guoliang Hou, Cavitation erosion of several oxy-fuel sprayed coatings tested in deionized water and artificial seawater, www.elsevier.com, Wear 311(2014) 81-92.
4. J.R.Laguna-Camacho, solid particle erosion behaviour of TiN coating on AiSi 4140 steel, journal of surface engineered materials and advanced technology, (2014), 4, 1-8.
5. M.S.Mahdipoor, HVOF sprayed coatings of nano-agglomerated tungsten-carbide powders for water droplet erosion application, www.elsevier.com, Wear 330-331(2015) 338-347.
6. Yan Wang, Cavitation erosion of plasma-sprayed CoMoCrSi coatings, www.elsevier.com, Tribology international 102(2016)429-435.
7. Gabriel Taillon, Cavitation erosion mechanisms in stainless steel and in composite metal-ceramic HVOF coatings, www.elsevier.com, Wear 364-365(2016) 201-210.
8. A.K.Krella, Cavitation erosion of CrN/CrCN multiplayer coating, www.elsevier.com, Wear 386-387(2017) 80-89.
9. Chuhong Wang, Indentation and erosion behaviour of electroless Ni-P coating on pipeline steel, www.elsevier.com, Wear 376-377(2017) 1630-1639.
10. G.V. Kachalin, Experimental research results of solid particle erosion resistance of blade steel with protective coating, Journal of physics:conf.series 891 (2017) 12259.
11. Hongwei Zhang, solid particle erosion-wear behaviour of Cr₃C₂-NiCr coating on Ni-based super alloy, Advances in mechanical engineering, (2017) vol. 9(3) 1-9.
12. Kumar R.K, A pragmatic approach and quantitative assessment of slit erosion characteristics of HVOF and HVOF processed WC-CoCr coatings, www.elsevier.com, Material and Design 132(2017) 79-95.
13. L.Venkatesh, Microstructural response of various chromium carbide based coatings to erosion and nano impact testing, www.elsevier.com, Wear 386-387 (2017) 72-79.
14. M.A.Gonzalez, Study of the erosion wear behaviour of cryogenically and tempered WC-CoCr coating deposited by HVOF, www.elsevier.com, Wear 376-377 (2017) 595-607.
15. Miguel angle Reyes Mojena, Neural network analysis for erosive wear of hard coatings deposited by thermal spray: Influence of microstructure and mechanical properties, www.elsevier.com, Wear 376-377 (2017) 557-565.
16. Sebaestein Lavinge, Cavitation erosion behaviour of HVOF CaviTec coatings, Elsevier, Wear 386-387 (2017) 90-98.