Retraction

Retraction: Erosion Studies of WC-Co-Cr Mixed TiC Powder Sprayed by HVOF Process on 16/5 Martensitic Stainless Steel (IOP Conf. Ser.: Mater. Sci. Eng. 1145 012117)

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This article (and all articles in the proceedings volume relating to the same conference) has been retracted by IOP Publishing following an extensive investigation in line with the COPE guidelines. This investigation has uncovered evidence of systematic manipulation of the publication process and considerable citation manipulation.

IOP Publishing respectfully requests that readers consider all work within this volume potentially unreliable, as the volume has not been through a credible peer review process.

IOP Publishing regrets that our usual quality checks did not identify these issues before publication, and have since put additional measures in place to try to prevent these issues from reoccurring. IOP Publishing wishes to credit anonymous whistleblowers and the Problematic Paper Screener [1] for bringing some of the above issues to our attention, prompting us to investigate further.

[1] Cabanac G, Labbé C and Magazinov A 2021 arXiv:2107.06751v1

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Erosion Studies of WC-Co-Cr Mixed TiC Powder Sprayed by HVOF Process on 16/5 Martensitic Stainless Steel

Guru Prakash 1, 2, S Manjunath Yadav 2 and Sumeer K Nath 2
1Department of Materials and Metallurgical Engineering, MANIT Bhopal, Bhopal, Madhya Pradesh, India, 462003
2Metallurgical and Materials Engineering Department, IIT Roorkee, Roorkee 247667, India
manjunathyadav5@gmail.com 2

Abstract. WC-Co-Cr powder was mixed with 5% micron sized TiC powder to form blended powder. The blended powder was deposited on 16/5 martensitic stainless steel (16/5 MSS) by high velocity oxy fuel process. The microhardness of the blended coating, WC-Co-Cr and 16/5 MSS was found to be 1271, 1081 and 337 VHN respectively. The coated specimen and 16/5 specimen were examined for slurry erosion test for 48h. The weight loss of the coated and coated specimen was measured after every 6h. WC-Co-Cr coating has the maximum erosion resistance behavior followed by blended coating and 16/5 MSS. The volume loss of modified coating due to erosion was found to be 65% less in comparison to 16/5MSS. The enhanced erosion resistance of the blended coating is attributed to higher hardness of the coating w.r.t 16/5 MSS.

Keywords: Slurry erosion, 16/5 Martensitic stainless steels, High velocity oxy fuel (HVOF) process, Microhardness, EDS

1. Introduction
16/5 martensitic stainless steel is a low C steel which has high toughness, strength and toughness [1]-[3]. This steel finds application in the fabrication of hydroturbines. The hardness of 16/5 MSS ranges from 350-400 VHN. Silt particles are present in the river water. The silt mainly comprises of quartz. The hardness of the quartz particle as reported by researcher is 850-1100 VHN [4][5]. Since there is difference in the hardness of 16/5MSS and quartz particle so the 16/5MSS stainless is easily eroded by the silt particles. Frequent shutdown to repair the eroded turbines by repair welding reduces the efficiency of the hydroturbines [6].

Slurry erosion tests are carried out in slurry pot tester [7-9]. Slurry erosion test is also conducted using jet type test rigs.

The properties of 16/5MSS can be improved by heat treatment and surface modification technique. Surface modification technique enhances the slurry erosion resistance of steels. One such process is surface modification by applying hard powder by high velocity oxy fuel (HVOF) process. HVOF coatings have high hardness, good adhesion to the substrate [10-12]. In HVOF process oxygen and fuel are mixed and subsequently ignited to generate gas with high pressure. The powder is injected at the path of the high-pressure gas which is heated and are ejected at high velocity from the HVOF gun. Hard powder has been deposited on 16/5 MSS by HVOF process.
In view of the above-mentioned facts, we find that less work has been reported on silt erosion of 16/5MSS. So, an attempt is made to enhance the resistance to silt erosion of 16/5MSS by deposition of TiC blended WC-Co-Cr coating. The resistance to slurry erosion of blended coating is compared with WC-Co-Cr coating and 16/5MSS and is presented in this paper after detailed characterization and mechanical property measurement.

2. Experimental procedure

2.1. Fabrication of the coating

16/5 Martensitic stainless steel having 0.07 C, 16.16 Cr, 5 Ni, 1 Si (in wt. %) was used as substrate. The dimension of 16/5MSS used to deposit cermet powder was 20 x 20 x 5 mm. Micron sized TiC powder was blended with commercially available WC-Co-Cr powder for 3 h in a ball mill. Prior to deposition of coating the shot peening by Al₂O₃ particles of 16/5MSS samples was done to accomplish a surface roughness Rₐ of 6-8 µm. The powders were deposited by high velocity oxy fuel (HVOF) process. The process was carried out by Suzler JP5000 gun. The fuel used was kerosene. The flow rate of fuel was 375 ml/min. The oxygen flow rate for the HVOF process was 880 ml/min. The standoff distance for the test was 300 mm. The powder flow rate was 72g/min.

The specimen was cross-sectioned hot mounting was done at 150° C. FESEM was used to examine the cross sectioned coated specimen. Elemental analysis was done by EDS technique. Omnitech hardness tester measured the microhardness of the coatings.

2.2 Slurry erosion experiment

The slurry erosion test was done in slurry pot testing machine shown schematically in Figure 1. The samples were polished with 100, 320, 1000 and 1500 emery papers followed by cloth polishing using diamond paste. The size of the sand particles ranges from 210-310 µm. The hardness of the particle was found to be 850 VHN. The concentration of sand in the slurry was 10 wt. %. The loss in weight of specimens on account of erosion was recorded after every 6 h. The total period of slurry erosion test was 48 h. The rotation per minute of specimens was 500 rpm. The speed of slurry particle w.r.t the test specimen was 4.50 m/s. The slurry eroded surface of all the 3 specimens were observed using SEM to establish the erosion mechanism. Two sets of experiments were conducted to study the slurry erosion behaviour.

3. Results and discussion

3.1 Coating characterization

SEM image of TiC powder is shown in Figure 2. It can be observed that the average particle size is 1 µm. The SEM image of cross-sectioned coated specimen is illustrated in Figure 3. The thickness of
the WCCoCr and the blended coating specimen is 380 and 390 µm respectively. The porosity of both the coatings is found by image analysis technique 2.3 and 3.05 % respectively.

![Figure 2. SEM micrograph of TiC powder](image)

![Figure 3. SEM micrograph of a)WC-Co-Cr b) blended coating](image)

The characteristics of the coatings are illustrated in Table 1.

| Properties | 16/5 MSS | WC-Co-Cr coating | Blended coating |
|------------|----------|------------------|-----------------|
| Av. Hardness (VHN) | 356 | 1081 | 1271 |
| Av. coating thickness (µm) | - | 380 | 390 |
| Porosity (%) | - | 2.3 | 3.05 |

The EDS analysis of the blended coating is shown in Figure 4. It is observed the element Ti is observed in the blended coating and is uniformly dispersed.
3.2 Slurry erosion test

The variation of cumulative loss with time is shown in Figure 5. It was found that there is an increase in volume loss with time for all the three specimens. The volume loss of blended coating is 65% less than that of 16/5 MSS. However, it was found that the volume loss of WC-Co-Cr coating is 71% less than that of 16/5 MSS.

![Figure 5. Plot of volume loss w.r.t. time for 16/5MSS, WC-Co-Cr coating and blended coating](image)

Figures 6a, 6b show the SEM micrograph of 16/5 MSS before and after slurry erosion test respectively. It is observed that 16/5 MSS has undergone significant erosion after 48 hr of test. Craters and grooves are observed. Figures 6c, 6d illustrate the SEM micrograph of WC-Co-Cr coating before and after slurry erosion test respectively. It is visible that craters are formed due to carbide pull-out from the coatings due to striking erodent particles. Figures 6e, 6f show the SEM micrograph of WC-Co-Cr coating before and after erosion test respectively. It can be seen that there is material removal due to the striking erodent particle.
Figure 6. SEM image of a) 16/5 MSS before erosion b) 16/5 MSS after erosion c) WC-Co-Cr coating before erosion d) WC-Co-Cr coating after erosion e) blended coating before erosion and f) blended coating after erosion

The enhanced erosion resistance of the blended coating w.r.t 16/5 MSS is due to high hardness vis a vis 16/5 MSS. The hardness of the blended is 4.5 times that of the 16/5 MSS. However, the experimental data shows there is reduction in the erosion resistance of the blended coating w.r.t WC-Co-Cr which is attributed to higher porosity of the blended coating.

4. Conclusions
   ➢ TiC modified WC-Co-Cr was successfully deposited by HVOF process.
   ➢ There is an enhanced hardness of the blended coating in comparison to 16/5MSS.
   ➢ The increase in the erosion resistance of the blended coating is attributed to higher hardness of the blended coating w.r.t 16/5MSS.
   ➢ Although, the blended coating has higher resistance w.r.t to 16/5 MSS but it has slightly lower resistance than WC-Co-Cr coating. The main reason for this reduction in erosion resistance is due to higher porosity of the blended coating.

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