



Research Paper

STUDY OF WEAR BEHAVIOUR OF HVOF AND COLD SPRAYED COATINGS ON BOILER STEELS

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In this study two commonly used steels in boiler plants, i.e. (SAE-213) T-22 and SA516 (Grade-70) were coated with different thermal spray processes namely HVOF and cold spray. The coating powder used was made up of NiCrTiCRe powder. The performance of the coated as well as uncoated material was investigated using a pin-on-disc machine [Model: Wear and Friction Monitor Tester TR-20], supplied by M/S DUCOM, Bangalore (INDIA) wear using different loads.

Keywords: T-22 and SA516 steels, Cold spray process and HVOF spray process, NiCrTiCRe coatings

INTRODUCTION

High-temperature corrosion, erosion and wear of heat transfer pipes in coal-fired boilers, such as tubes for superheaters and water walls, are recognized as severe problems, resulting in tube thinning and premature failure (Stringer, 1998; and Sidhu *et al.*, 2006). Super alloys have been developed for high temperature applications; however, these alloys are usually not able to meet the requirements in both the high-temperature strength and corrosion or erosion resistance simultaneously. One possible way to solve these problems is applying a thin layer of anti-wear and anti-

corrosion coating with good conductivity, such as thermal sprayed nickel or iron-based alloy coatings (Branagan *et al.*, 2005; and Sidhu *et al.*, 2006). The High Velocity Oxy/air-Fuel (HVOF-HVAF) process is one of the most popular thermal spraying technology and has been widely adopted in many industries due to its flexibility, cost effectiveness and superior quality of the coatings obtained (Sidhu *et al.*, 2005). It is often seen that the cold-sprayed particles adhere only on “nascent” surfaces produced by the impacts of high-velocity sprayed particles which pryovoke the fracture of the pre-existing oxide layers of the substrate

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(Ichikawa *et al.*, 2006). Cold spraying is based on the utilization of significantly low process temperatures with high particle velocities. A coating is formed when powder particles impact at high velocities (above the material-dependent critical velocity) with high kinetic energy on the sprayed surface, deform and adhere to the substrate or to other particles (Schmidt *et al.*, 2006; and Papyrin *et al.*, 2007). In the cold spray process, a gas is accelerated to supersonic velocity by a converging-diverging type nozzle (Stoltenhoff *et al.*, 2001). Suitable powders for cold spraying have specific particle size with narrow particle size distribution, depending on powder materials (Champagne, 2007). The gas temperature affects the gas and particle velocity, meaning higher velocity at higher temperature. Reportedly, increased particle temperature also improves the coating quality in the cold spray process (Richter and Ho, 2006; and Kreye *et al.*, 2006). Cold spray coatings also show low residual stresses, rather high adhesion, and hardness normally higher than that of the corresponding bulk materials. High hardness is caused by significant work hardening of the sprayed particles (Van Steenkiste *et al.*, 2002). With the HVOF spraying technique low porosity of metallic and ceramic-metallic (cermet) coatings can be achieved, having good oxidation resistance and adhesion properties as well as faster deposition rates compared with other spray and coating processes (Sovolev *et al.*, 2004). If the substrate is more noble than the coating (i.e., stainless steel) the coating acts as a sacrificial anode accelerating its corrosion (Berget *et al.*, 1997). With the HVOF spraying technique low porosity

of metallic and ceramic-metallic (cermet) coatings can be achieved, having good oxidation resistance and adhesion properties as well as faster deposition rates compared with other spray methods.

MATERIALS AND METHODS

The material used in the current investigation is of (SAE-213) T-22 and SA516 (Grade-70) boiler steel coated with NiCrTiCRe powder. Two types of coatings technologies were used in present work, HVOF and cold sprayed methods. The cold spray coating was sprayed at ASB Industries Inc Barberton, Ohio, USA. The process parameters were kept constant throughout the coating process. The HVOF coating was sprayed at M/S Metallizing Equipment Co. Pvt. Ltd., Jodhpur (India) by using commercial High Velocity Oxy-Fuel (HVOF) thermal spray system. A Hipojet-2100 HVOF system was used for the powder spraying. Standard spray parameters, as mentioned in the manual of the Hipojet-2100 were used for depositing the coatings. Liquefied Petroleum Gas (LPG) was used as a fuel. The process parameters were kept constant throughout the coating process. The specimens were cooled with the compressed air jets during and after spraying. The rectangular specimens having dimensions 5 mm × 5 mm × 20 mm were prepared from the boiler steels.

The microhardness of the coatings on the surface was measured with a load of 2.942 N using the Digital Micro Vickers Hardness tester (SHV-1000, Chennai Metco, Pvt., Ltd, Chennai, India). The tribological properties of the materials were evaluated using pin-on-disc apparatus. Dry sliding wear tests for

the uncoated, coated (HVOF as well as cold sprayed) T-22 and SA516 steel were conducted using a pin-on-disc machine [Model: Wear and Friction Monitor Tester TR-20], supplied by M/S DUCOM, Bangalore (INDIA).

All the wear tests were conducted at sliding speeds of 1m/s under normal loads of 10 and 20N for a total sliding distance of 1080 m. The test was conducted for 9 cycles. Sliding distance for each cycle was taken constant. Weight loss after each test cycle was measured to a precision of 0.01 mg and wear rate was determined as a function of sliding distance. Before and after each test, both the disc and specimens were cleaned with acetone and were dried in the air in order to avoid contamination.

RESULTS AND DISCUSSION

Microhardness

The microhardness values were measured on the surfaces of the uncoated steels as well as the on the surface of the coatings. The measured average values for both T22 and SA516 steels are given in Table 1. The analysis of the values show that the microhardness value of SA516 steel is more in comparison to T22 steels for both coated and uncoated steels.

Table 1: Microhardness Values for Uncoated and Coated Steels		
Name	T22	SA516
Uncoated	190 Hv	230 Hv
Cold Spray (NiCrTiCRe)	222 Hv	290 Hv
HVOF (NiCrTiCRe)	365 Hv	396 Hv

Wear Study

In this work wear testing was performed on pin-on-disc machine using procedure

discussed before. The graphs were plotted using the total wear rate w.r.t no of cycles. Figure 1 shows the wear rate of both T22 and SA516 uncoated steels at velocity of 1m/s and load of 20 N. As clear from the graph the wear rate of T22 steel is more in comparison to SA516 steel. As discussed before the microhardness value of SA516 steel was found to be more in comparison to T22 steel which might have led to better wear resistance in case of SA 516 steel.

Figure 1: Graph Representing the Wear Rate of Uncoated T22 and SA516 Steels at V = 1 m/s and L = 20 N

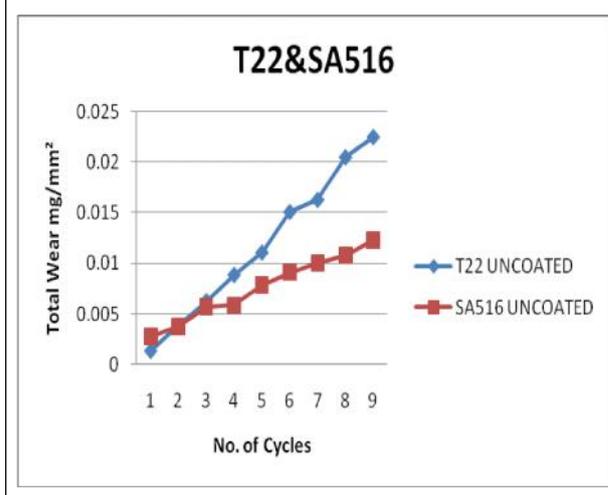


Figure 2 shows the wear rate of uncoated T22, cold and HVOF sprayed NiCrTiCRe coatings. As clear from the graph the wear rate of uncoated T22 steel is more than both of the coating. This shows that both the coatings were successful in reducing the wear rate. Amongst the two coatings HVOF sprayed coating showed lesser wear rate than cold spray NiCrTiCRe coating. Microhardness of HVOF sprayed coating on T22 steel was found to be higher than cold sprayed counterpart which might have led to better wear resistance of the same.

Figure 2: Graph Representing the Wear Rate of Uncoated and Coated T22 Steel at V = 1 m/s and L = 20 N

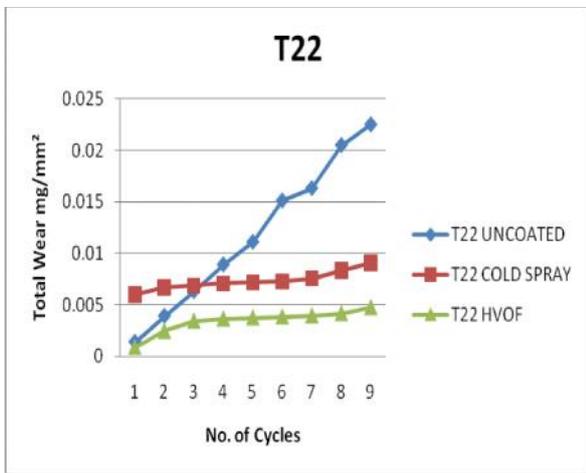
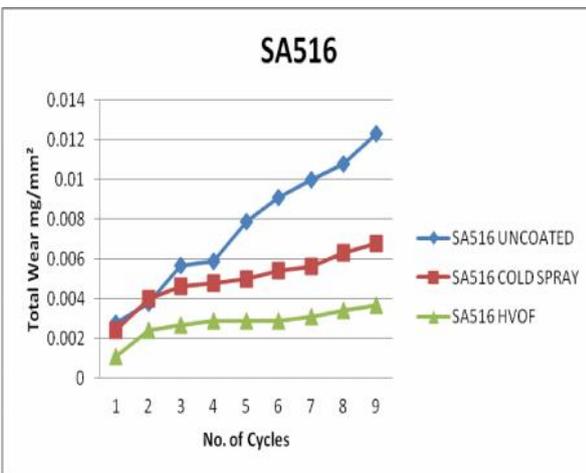


Figure 3 shows the wear rate of uncoated SA516, cold spray and HVOF spray NiCrTiCRe coatings. As clear from the graph the wear rate of uncoated SA516 steel is more than both the coatings. This shows that the coatings were successful in reducing the wear rate of the steel. Amongst the two coating HVOF spray coating was better than cold spray NiCrTiCRe coating on SA516 steel. The

Figure 3: Graph Representing the Wear Rate Uncoated and Coated Steels at V = 1 m/s and L = 20 N



microhardness values given in Table 1 shows that in case of SA516 steel the HVOF spray coating possess higher microhardness value than cold spray coating which might have led to better wear resistance of the HVOF spray coating.

CONCLUSION

Boiler steels (SAE-213) T-22 and SA516 (Grade-70) steels were successfully sprayed with NiCrTiCRe coatings using High Velocity Oxy Fuel (HVOF) and cold spray processes. It was observed from the wear rate graphs that the cumulative wear rate of both T-22 and SA516 uncoated steels was higher than the cold spray and HVOF spray coated steels. Hence it may be concluded that both the coatings were successful in reducing the wear rate of the steel.

Amongst the two coatings, HVOF sprayed coatings were found to be more wear resistant as compared to cold sprayed coatings for both T-22 and SA516 steels. The higher microhardness of the HVOF spray coatings in comparison to cold sprayed coatings might have led to its better wear resistance.

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