DEVELOPMENT OF HVOF COATING TO PROTECT MATERIAL FROM WEAR IN TURBINES

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Abstract : High-Velocity Oxy-Fuel (HVOF) process is one of the widely used and recent trends in thermal spraying techniques due to its viability to produce dense deposits, with relatively low porosity. After a thorough review, WC-NiMoCrFeCo coating powders were selected to be coated on the SS316 substrate material in order to assess the adhesive wear of coated and uncoated specimens. The wear resistance of the coatings is higher than that of uncoated samples and the coatings exhibit high hardness with a high volume fraction of carbides being preserved during the spraying, and have different wear behavior when compared to uncoated material.

IndexTerms **- Wear,HVOF,coatings,Adhesive,Turbines.**

1. INTRODUCTION

Degradation of materials due to wear at room temperature or at elevated temperature is encountered in large variety of engineering industries. Because of the increased interest in the wear and friction properties of alloys, the development of wear protection systems in industrial applications is an important topic from both engineering and an economic perspective. [1-4] an approach where in mechanical strength is accomplished by alloy development and wear resistance by surface coating is now generally acceptable practice in fossil fuel energy processes. The High-velocity oxy-fuel (HVOF) processes belong to the family of thermal spraying techniques, and are widely used in many industries to protect the components against wear, erosion and corrosion. [5-9]

Wear can be divided into sliding wear, which occurs in the absence of hard particles and abrasive wear, which occurs in their presence. The sliding wear resistance of un-coated and coated special steel were determined by Pin-on-disk tribometer, using EN-32 steel plate and SiC grinding papers of mesh size 400, respectively. The Earlier studies have shown that HVOF sprayed WC based Coatings have excellent wear resistance compared with CrC based coatings. Although the carbides are wear resistant in most environments, the wear resistance of the carbide based coating largely depends on the binder phase like (Co, Ni, Co, Cr, and Mo). [10-12] therefore composite carbides and alloy binders are expected to achieve both excellent wear and corrosion resistant performance at room temperature. In this paper the Wc-NiMoCrFeCo powder was coated by using HVOF process and wear resistance of this coating were evaluated at different loads and speeds. [13-14]

2. EXPERIMENTAL CONDITIONS AND PROCEDURES

2.1 Machine setup

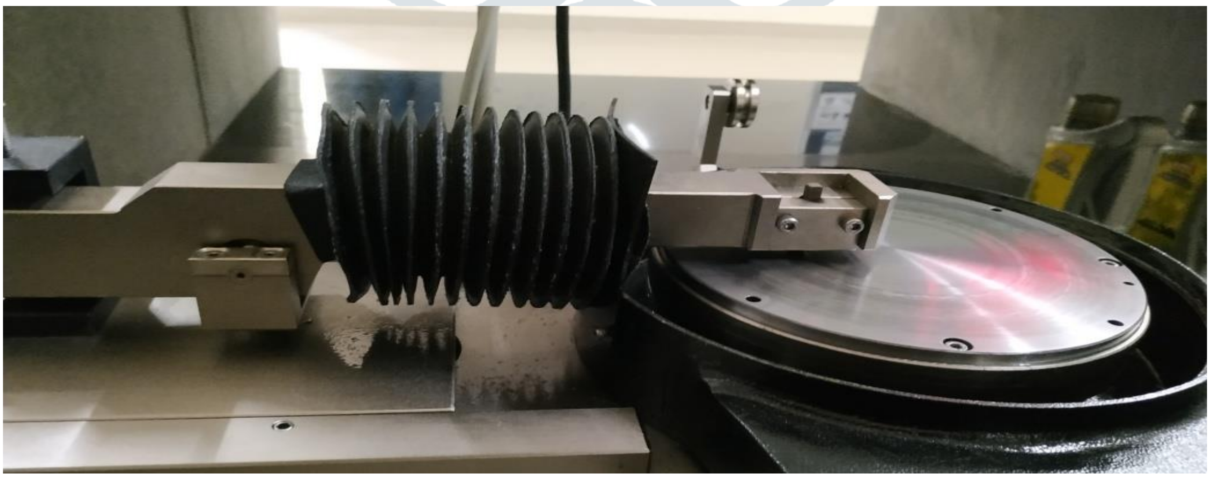

Fig 1 Adhesive wear setup

Pin-on-disk apparatus (Fig 1) is used to evaluate the dry sliding wear resistance at room temperature. Samples to be tested are placed in specimen holder designed by us specially to carry out project. A desired load is applied externally on the holder holding the specimen rigidly placed inside it. The specimen is in contact with the disc having a dimension of 25x5x5mm cut by EDM (Electro Discharge Machining).The edges of the samples are made flat to avoid damage on the disc material. The wear tests have been conducted under the varying load of 3kg (29.43N), 4kg (39.24N), and 5 kg (49.05N) and keeping 600rpm speed as constant and with a varying speed of 500rpm, 600rpm & 700 rpm keeping 5kg load as constant. The wear test has been carried out for a total sliding distance of 0.07 meters in the time interval of 5 minute.

2.2 Test Specimen

The material used for experimentation is Stainless steel (SS-316) of 5*5mm in dimension with a thickness of 25mm. Chemical composition of the material is as shown in Table 1. The hardness of work piece material is approximately 334 BHN. Cutting has been carried out on 25 mm length and 5*5 dimensions.

Table 1 Chemical composition of SS-316 as a base metal

Name	Fe	Cr	Ni	Mn	Si	C
Percentage	Bal	16-18%	10-14%	2%	0.75%	0.08%

2.3 Coating

A coating is a covering that is applied to the surface of an object, usually referred to as the substrate. The purpose of applying the coating may be for wear resistance. The coating itself may be an all-over coating, completely covering the substrate, or it may only cover parts of the substrate. Coatings can be measured and tested for proper opacity and film thickness by using a drawdown card. A major consideration for most coating processes is that the coating is to be applied at a controlled thickness, and a number of different processes are in use to achieve this control.

Thermal spraying techniques are coating processes in which melted (or heated) materials are sprayed onto a surface. Thermal spraying can provide thick coatings (approx. thickness range is 300 micrometres to several mm, depending on the process and feedstock), over a large area at high deposition rate as compared to other coating processes such as electroplating, physical and chemical vapour deposition. Coating materials available for thermal spraying include metals, alloys, ceramics, plastics and composites. They are fed in powder or wire form, heated to a molten or semi-molten state and accelerated towards substrates. Combustion or electrical arc discharge is usually used as the source of energy for thermal spraying. Resulting coatings are made by the accumulation of numerous sprayed particles. The surface may not heat up significantly, allowing the coating of flammable substances to be deposited. Coating quality is usually assessed by measuring its porosity, oxide content, macro and micro-hardness, bond strength and surface roughness. Generally, the coating quality increases with increasing particle velocities. The macrographs of the coated samples is shown in Fig 2.

Fig 2 Coating samples of Wc-NiCrMoFeCo

2.4 HVOF Coating technique

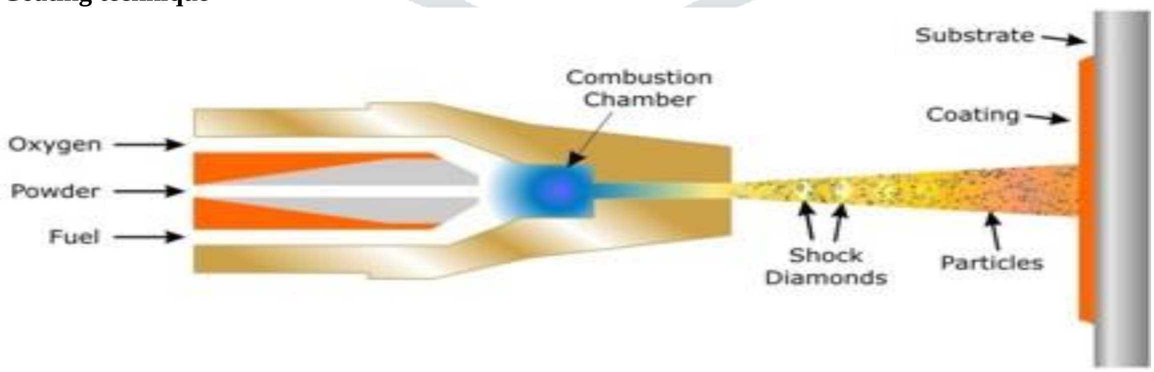

Fig 3 HVOF Technique

During the 1980s, a class of thermal spray processes called high velocity oxy-fuel spraying was developed (Fig 3).A mixture of fuel and oxygen is fed into a combustion chamber, where they are ignited and combusted continuously. The resultant hot gas at a pressure close to 1 MPa emanates through a converging–diverging nozzle and travels through a straight section. The fuels can be gases (hydrogen, methane, propane, propylene, acetylene, natural gas, etc.) or liquids (kerosene, etc.). The jet velocity at the exit of the barrel (>1000 m/s) exceeds the speed of sound. The process has been most successful for depositing cermet materials (WC–Co, etc.) and other corrosion-resistant alloys (stainless steels, nickel-based alloys, etc.).

2.5 Coating powder

Coating compositions has to be formulated so as to impart wear resistance. The major criteria for the development of an optimized coating are that the coating should form thermodynamically stable protective phases on its surface by the reaction with the process environment. A commercially available WC-NiMoCrFeCo powder was used in this study of experimentation.

3. RESULTS AND DISCUSSION

3.1 coefficient of friction for substrate and coating material

3.1.1 Varying load

The Fig 4 shows the variation of coefficient of friction with increasing load for adhesive wear test. The coefficient of friction for the SS 316 material is more as compared to the coated materials. With increase in load, the coefficient of friction is more for coated WC-NiMoCrFeCo (80-20%) as compared to WC-NiMoCrFeCo (35-65%).The coefficient of friction increases steadily upto a load of 4 kg and then is stabilised as shown. The coefficient of friction does not remain constant but instead increases with increasing load. This may be due to the fact that, the real constant area between the pin and the disc decreases at high load which leads to higher flash temperature, thereby resulted in softening of the specimen under consideration.

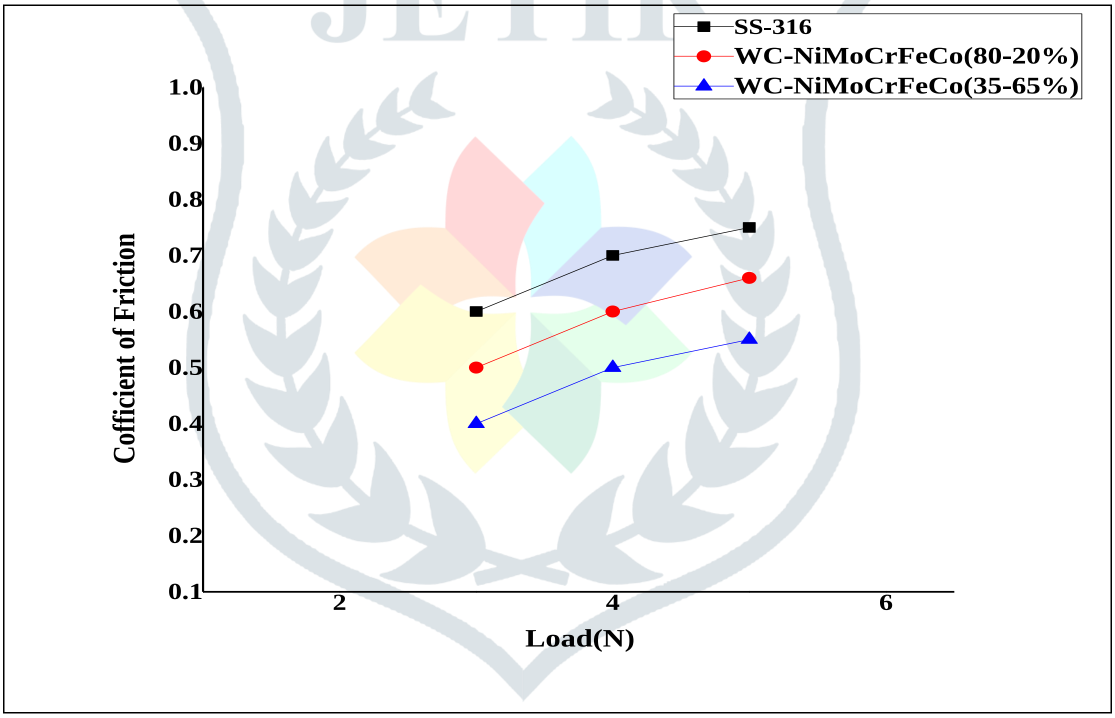

Fig 4. Coefficient of Fiction VS sliding distance for load vary in SS-316 and WC-NiMoCrFeCo (35-65%) And WC-NiMoCrFeCo (80-20%)

3.1.2 Varying speed

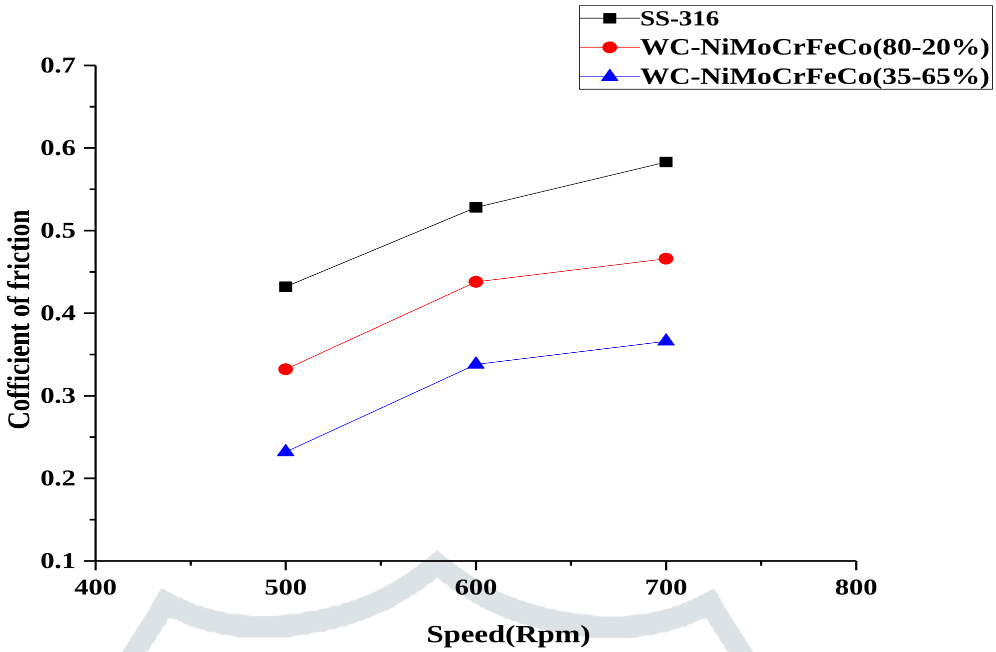

Fig 5. Coefficient of Fiction VS sliding distance for speed vary in SS-316 and WC-NiMoCrFeCo (35-65%) And WC-NiMoCrFeCo (80-20%)

The Figure 5 shows the variation of coefficient of friction against speed in rpm during adhesive wear test. After a short running period, the friction force stabilized to relatively constant value. Occasional spikes in the force when observed, possibly indicative of layer abrasive particles becoming trapped in the interface and also may be due to variation in contact between the sample and the counter face. The graphs indicate that the uncoated samples have higher co-efficient of friction than coated samples.

3.2 Wear rate for substrate and Coating material

3.2.1 Varying load

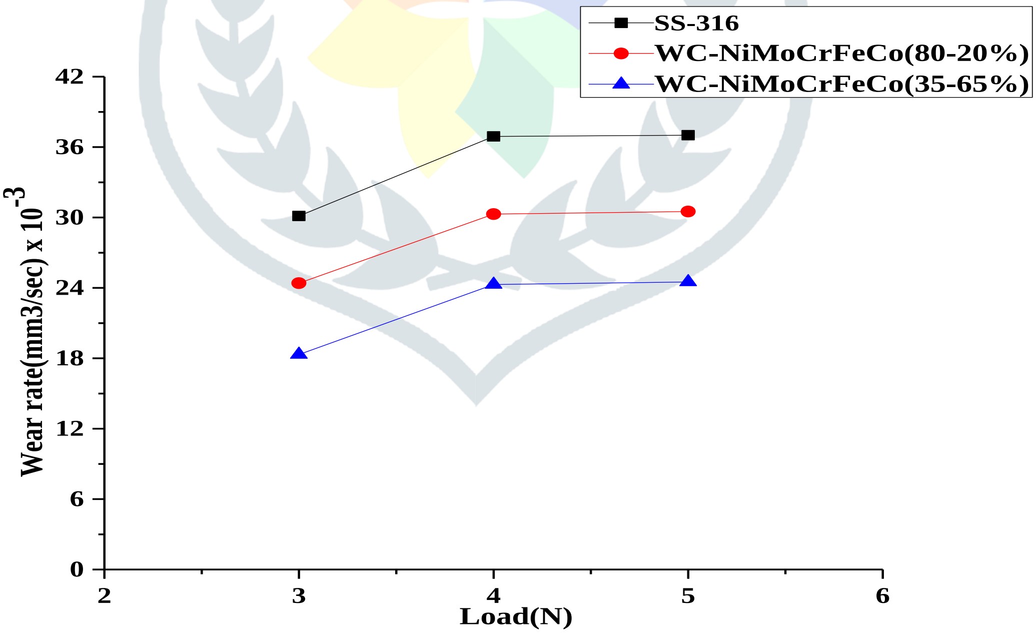

Fig 6 Wear rate VS sliding distance for load vary in SS-316 and WC-NiMoCrFeCo (35-65%) And WC-NiMoCrFeCo (80-20%)

Fig 6 shows that variation of wear rate with respect to load. The wear rate increases for both the substrate and the coated materials with increase in load. The wear rate for the substrate material is higher as compared with the coated materials. Amongst the coated materials, coated WC-NiMoCrFeCo (80-20%) material has a relatively higher rate as compared to WC-NiMoCrFeCo (35-65%).

3.2.2 Varying speed

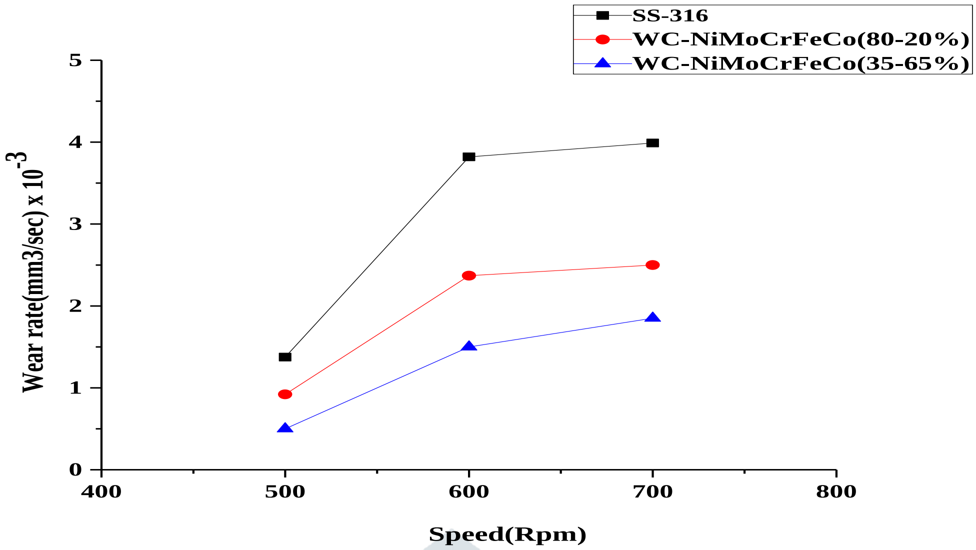

Fig 7 Wear rate VS sliding distance for Speed vary in SS-316 and WC-NiMoCrFeCo (35-65%) And WC-NiMoCrFeCo (80-20%)

The Fig 7 shows the variation of wear rate with increase in speed. The wear rate is more for the substrate SS 316 material as compared to both the coated materials. The coated material WC-NiMoCrFeCo (80-20%) has a higher wear rate as compared with WC-NiMoCrFeCo (35-65%) coated material. The coefficient of friction increases more upto a speed of 600 rpm and is then stabilised at a speed of 700rpm.

4. COMPARATIVE STUDY OF COATED AND UNCOATED MATERIAL:

4.1 Coefficient of friction

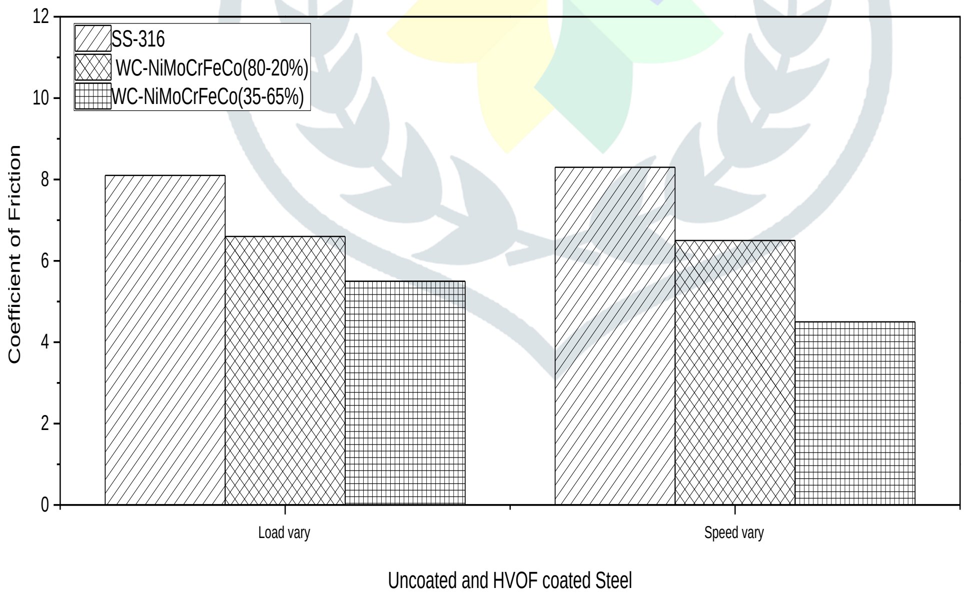

Fig 8 coefficient of friction v/s loads and speeds for coated and uncoated materials

The Fig 8 shows variation of coefficient of friction with varying loads and speeds. With increase in load, the substrate material is found to have a highest value of COF when compared to coating WC-NiMoCrFeCo (80-20%) And WC-NiMoCrFeCo (35-65%). With increase in speed, the coefficient of friction of substrate material is higher than the coated WC-NiMoCrFeCo (80-20%) and WC-NiMoCrFeCo (35-65%) materials.The coating WC-NiMoCrFeCo (35-65%) is having less value of the coefficient of friction when compared with WC-NiMoCrFeCo (80-20%).

4.2 Wear rate

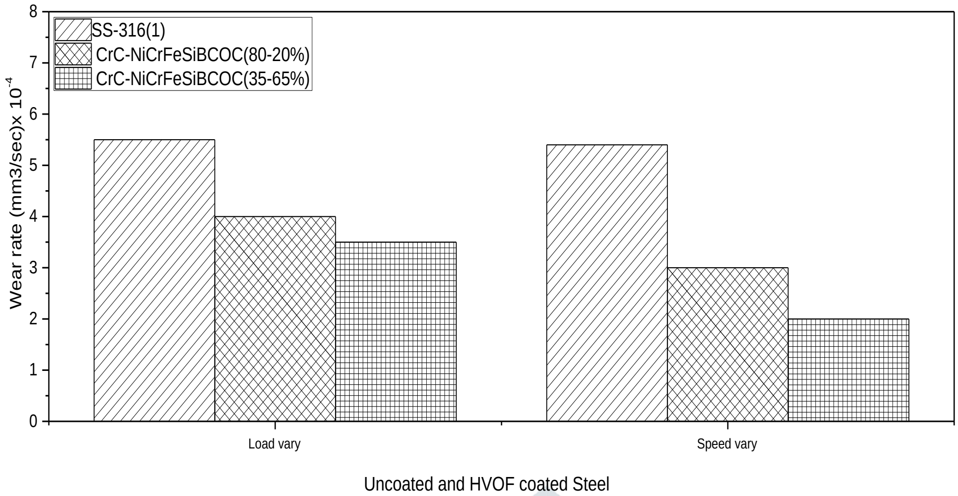

Fig 9 wear rate v/s loads and speeds for coated and uncoated materials

The Fig 9 shows variation of wear rate with varying loads and speeds. With increase in load, the substrate substance is found to have a highest value of wear rate when compared materials WC-NiMoCrFeCo (80-20%) and WC-NiMoCrFeCo (35-65%).With increase in speed, the wear rate of substrate material is higher than the WC-NiMoCrFeCo (80-20%) and WC-NiMoCrFeCo (35-65%). The coating WC-NiMoCrFeCo (35-65%) is having less value of wear rate when compared with WC-NiMoCrFeCo (80-20%).

5. CONCLUSION:

- High velocity oxy-fuel thermal spray process using oxygen and liquid petroleum gas as the fuel gas have been used successfully to deposit NiCr and WC-Co alloy on special steel SS-316.
- Under the given spray parameters seemingly layer structured coating with average thickness of 300μm is obtained.
- The frictional coefficients for uncoated and coatings are in the range of 0.3 - 0.7.The frictional coefficient appears to be somewhat dependent on porosity, micro structural homogeneity and composition of the oxide. It is found to be independent of the hardness.
- The wear resistance of the coatings is higher than that of uncoated samples. The unique micro structure containing flat un-melted particle is expected to improve the wear resistance in the coating

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