Studies on Wear Behavior of Uncoated And Hvof Sprayed Coating

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Abstract- *Thermal spraying process is used to deposit oxidation and corrosion resistance coatings for many high-temperature industrial applications such as in Heat exchanger, Power plants etc., 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, 35WC-65NiCr and 35*Cr_3C_2*-65NiCr coating powders were selected to be coated on the (SS-304) substrate material in order to assess the adhesive and abrasive wear of coated and uncoated specimens.The wear resistance of the coatings is higher than that of uncoated samples.*

Keywords- SS-304, HVOF, WEAR ,COATING

I. INTRODUCTION

Currently special steel and super alloys are being used to increase the service life of the boilers, especially in the superheater zones of the boilers and new generation ultra and supercritical boilers.Although the special steel and super alloys have adequate mechanical strength at elevated temperatures, they often lack resistance to combined wear, erosion-corrosion environments. Wear resistance of components can be greatly increased by protective coatings and this is a growing industry of considerable economic importance. Among the various coating methods, High Velocity Oxy Fuel (HVOF) spray process has grown in to a well-accepted industrial technology for obtaining wear and corrosion resistant layer for both development of materials and modern coating technology because of advances in powder and wire productions.

II.LITERATURE REVIEW

E. Fernandez and M.Cadenas (11) has worked on dry sliding wear of NiCrBsi coatings deposited on the plates of grey cast iron (DIN GG30) using laser cladding technique, the parameters of which were such as to provide almost crack-free coatings with minimum dilution and very low porosity.

The wear behaviour was determined by using block-on –ring dry sliding liner contact at several loads (30-100N) and sliding speeds (0.65-2.6m/s).The density of the coating, friction coefficient and wear rate coefficient k(mm3/N m) were estimated using a method founded upon PV factor theory. When load or speed increases, the coefficient of friction diminishes.For a 30N load, a superficial oxidation mechanism with loosening of the generated oxide layer predominated as the principal wear mechanism. Adhesion and oxidation wereobserved for higher loads.

C.Leyens et .al(2) has conducted adhesive & abrasive wear test on substrate materials such as Ti alloys (Ti-6Al-4V) by using pin on disk machine. The parameter which they have selected wear area-200mm2, load-980N,Speed-5m/s , conductedupto 5hrsand electroplating. The application of these material are in aerospace , automobile , marine, & chemical industry.The coating powder used is Ti-15V-13Al-3Cr-3Sn.

III. OBJECTIVES

1. Development of wear resistance coating by using HVOF thermal spray process.
2. Characterisation of AS-Sprayed coating to know it’s suitability for use in boiler steel.
3. Conduct wear test of coated and uncoated specimen under various condition of testing

IV. METHODOLOGY

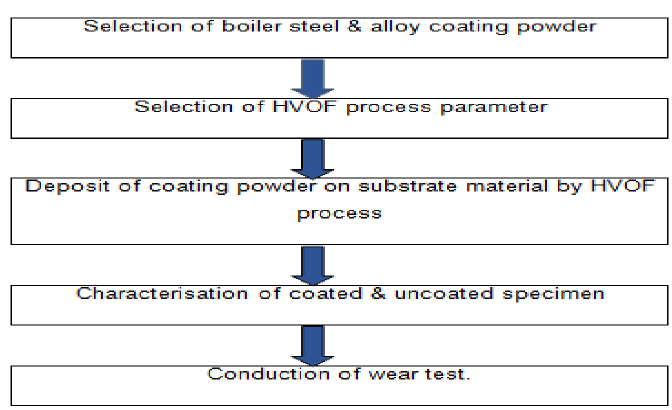

Fig.1. Flow chart of Methodology

The Fig 1 shows the flow chart of methodology. The first step is to select steel and alloy coating powder for boiler application HVOF spraying has been carried out using HIPOJET 2700 equipment (Spraymet limited Bangaluru), to deposit coating powder on substrate material. After deposition of powder, the coated and uncoated specimens were characterized and Adheive wear and Abrasive wear test were conducted for different loading condition.

HVOF Technique

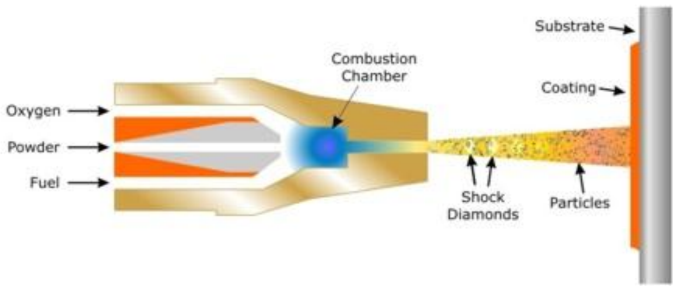

Fig.2.High velocity oxy-fuel (HVOF) torch

V. EXPERIMENTATION

A simplified schematic of a high velocity oxy-fuel (HVOF) torch is shown in Fig 2. It consists of a combustion chamber and a nozzle with connecting orifices and a tube that allows injection of the powder into the nozzle. Carefully metered oxygen and fuel gas are introduced into the combustion chamber. The fuel gas is usually propane, propylene, liquid fuels or hydrogen, although other hydrocarbons can be used. Continuous combustion of the oxygen and fuel occurs in the combustion chamber and the resulting hot, high pressure gas is allowed to expand and accelerate through orifices into the nozzle. A carefully measured flow of powder is introduced axially into the nozzle, allowing sufficient heating and acceleration of the powder particles. Thepowder is heated and accelerated by the products of the combustion, usually to temperatures above its melting point and to velocities approaching or exceeding 1800 ft/sec (550m/sec). The most frequently used coating compositions are typically carbidebased, but most cermets and metals, as well as some oxides with sufficiently low melting points, can be deposited by HVOF

WEAR EXPERIMENTAL SETUP

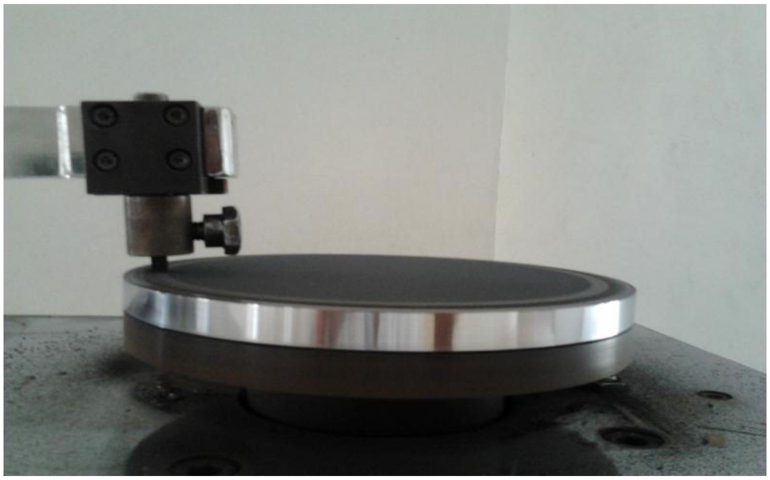

Fig.3. Abrasive wear setup showing the specimen mounted inside the holder

Sliding Wear Setup

- Pin-on-disk apparatus (Friction and Wear Monitor CONTECH Micro Systems) is used to evaluate the dry sliding wear resistance at room temperature(Fig 3).
- Samples to be tested are placed in specimen holder to carry out the work..
- A desired load is applied externally on the holder holding the specimen rigidly placed inside it. The specimen is in contact with the disc.
- The counter disc was made of EN-32 which is plane Carbon steel case hardened to attain a hardness of 62-65 HRC.
- Samples used for wear test are NiCrWc and $35Cr_3C_2$-*65NiCr* coated and uncoated ss304 special steel.
- Specimen’s specification: - 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 normal load of 1kg (9.8 N), 3kg (29.43N), and 5 kg (49.05N) speed: 200rpm at track radius 7cm.
- The wear test has been carried out for a total sliding distance of 8790 meters in the time interval of 100 minutes.
- The thickness loss measurements were obtained for every ten minutes duration.

Abrasive Wear Setup

Two body abrasion tests determine the wear resistance of a material when the relative motion is caused between the abrasive surface and a contacting pin of the test material. Considerably pin-abrasive wear testing has been reported to be done with pin-on-disc equipment. The work of this type of machine, reviewed by Moore [15], helped to establish the effect of many parameters such as abrasive material and size, specimen load, and speed, on two body abrasion.

- Two body abrasive wear test were carried out using same pin-on-disc apparatus.
- SiC (micro-hardness 2500Hv) grinding papers, #600 (grit size 30µm) was used as counter abrasive.
- Load and other parameters remain same as in sliding wear.
- Each material was tested during 20000 revolutions as the disc was rotated with 200rpm for 100min, renewing the paper every 10 min.

DEVELOPMENT OF COATING

SUBSTRATE MATERIALSS-304 has been selected as substrate material. The nominal composition of the special steel is given in the below Table 1.

Table 1. Nominal composition of substrate

Sl. No.	Alloy Grade	Chemical Composition (wt. %)					
		Fe	Cr	Ni	Mn	Si	C
1	SS 304	Bal	19	9.25	2	1	0.08

in which Cr, Ni, Mn, Si, and C is as given in above table and the balance is Fe.

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. The "classical protective phases will be Cr_3C_2 and Wc as well as some of the spinals.In the present study the coating powders of *35WC-65NiCr and 35*Cr_3C_2*-65NiCr were selected.The chemical composition,particle size and shape of all the powders have been reported in Table 2.*

Table 2. Chemical composition, particle size and shape of the coating powder

Coating powder	Chemical composition	Shape	Particle size
NiCrWc	NiCr65% Wc 35%	Square	300µm
NiCrCr3C2	NiCr65% Cr3C2 35%	Square	300µm

DEPOSITION OF COATING

HVOF spray process will be used for deposition of these coatings on super alloy substrate and the parameters listed in Table 3. The As-spayed coatings are subjected to furnace heat treatment so as to develop the required protective surface oxide layer.

Table 3. Spray parameter for HVOF spray process

Oxygen pressure	160 to 170 PSI
oxygon flow rate	32-34 SCFH
Hydrogen Pressure	120-140 PSI
hydrogen-flow rate	55-65 SCFH
Spray distance	8-10 INCH
Powder feed rate	80-100 g/min
Velocity	1200min/sec

LPM: liters per minute.

VI. STUDIES AND FINDING

POROSITY, SURFACE ROUGHNESS AND THICKNESS OF THE COATING

Summary of coating properties are reported in Table 4.The Maximum value of porosity measured along the cross-sectional area using image analyzer software, found to be 0.95%. Similar observations are made by Sidhu et. al., (13) and Aalamialeagha et. al., (12) for HVOF sprayed Ni-Cr coatings. Thickness of the coating lies in the desired range of 210-270 µm. For HVOF nickel chrome based coatings, typical coating thickness is in the range of100-300µm, suggested by Nicholls,(15).Higher surface roughness value Ra of the order 14µm is mainly due to greater size of feed stock powder used in the study

Micro-hardness along the coating region found to be vary with the distance from the coating substrate interface and found to be in the range of 284-389Hv(Fig 4).This variation in micro- hardness value might be due to presence of porosity, oxide, un-melted and semi melted particles, and inclusions in the microstructure of coating. Similar variation in micro-hardness value of HVOF sprayed NiCr coatings are reported by Ak et al., (16).

Table 4.Summary of Porosity, Thickness, Micro-hardness and Roughness.

Descriptions	
Porosity (%, Max.)	0.95
Thickness (μm)	210-270
Surface Roughness (μm)	14
Micro-hardness (Hv)	284-389

MICRO HARDNESS OF THE COATING

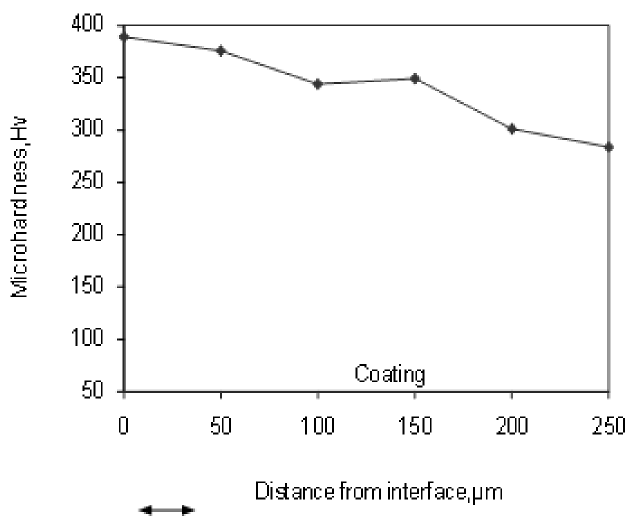

Fig. 4.Micro-hardness profile measures across the coating.

Friction behaviour

The fig.5 shows the variation of coefficient of friction against sliding distance during adhesive wear test for 1kg. As shown in fig.5 coefficient of friction is more for substrate material and less for NiCrWc coating. Coefficient of friction for NiCr-Cr_3C_2 is in intermediate. Same pattern is followed for adhesive wear test for 3kg and 5kg which are shown in fig.6 and fig7 respectively.

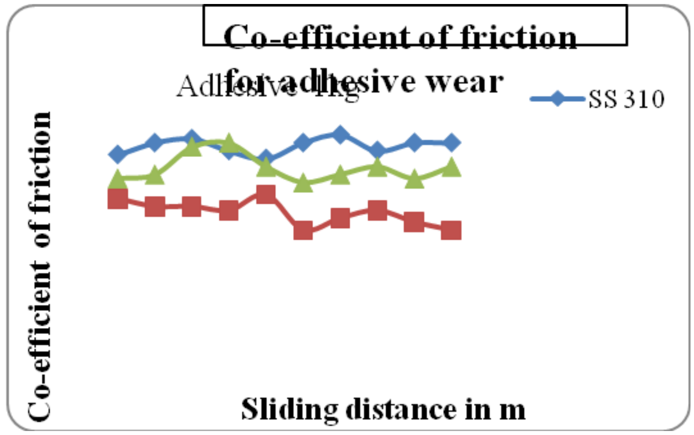

Fig.5. Coefficient of friction v/s sliding distance for adhesive wear test (1kg)

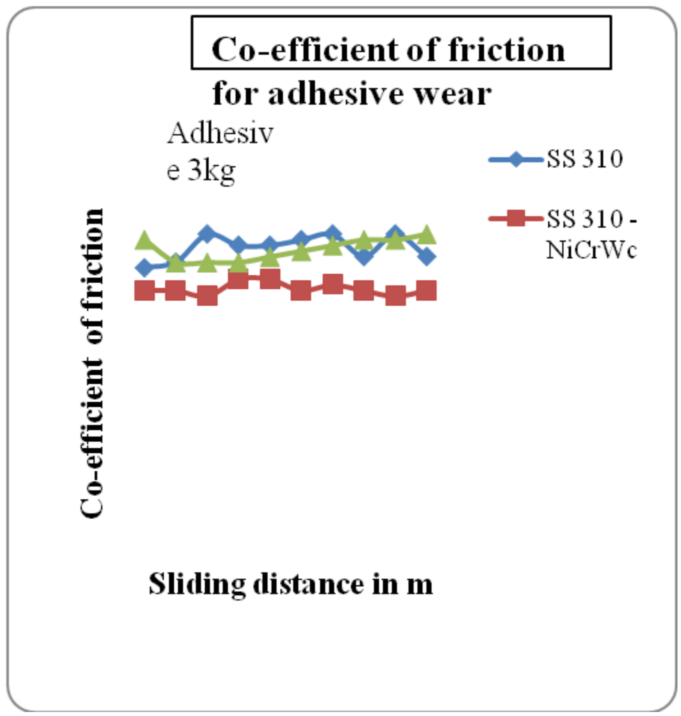

Fig.6 Coefficient of friction v/s sliding distance for adhesive wear test (3kg)

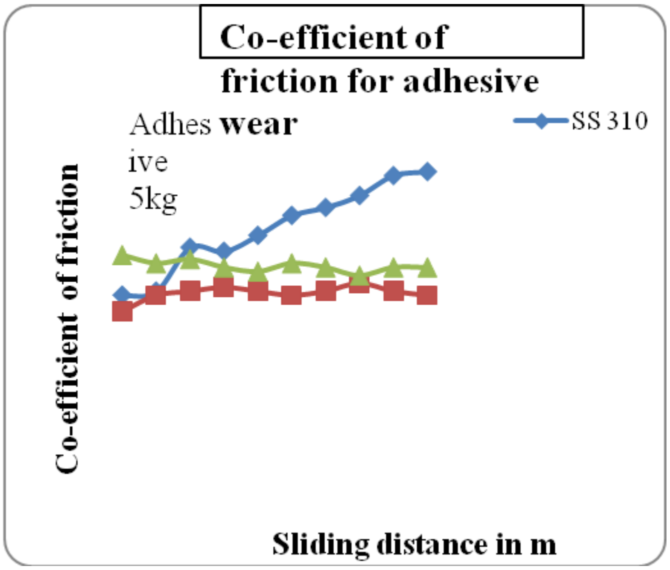

Fig.7.Coefficient of friction v/s sliding distance for adhesive wear test (5kg)

The fig.8 shows the variation of coefficient of friction against sliding distance during abrasive wear test for 1kg. As shown in fig.8 coefficient of friction is more for substrate material and less for NiCrWc coating. Coefficient of friction for NiCr-Cr_3C_2 is in intermediate. Same pattern is followed for abrasive wear test for 3kg and 5kg which are shown in fig.9 and fig.10 respectively.

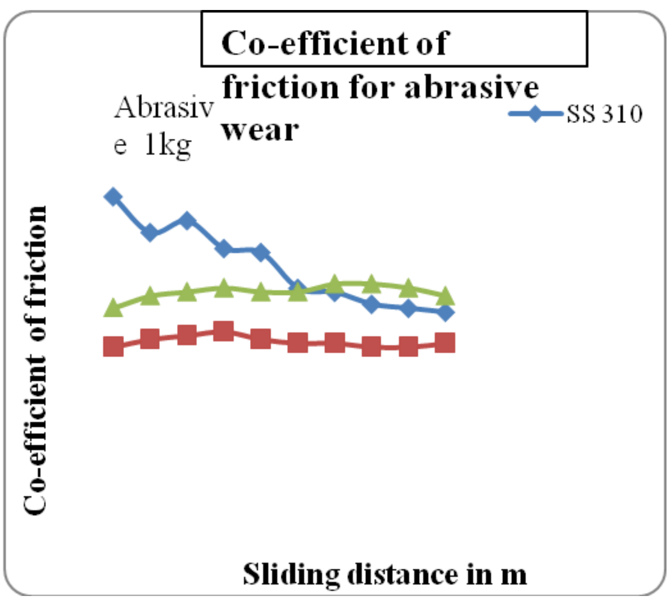

Fig.8.Coefficient of friction v/s sliding distance for adhesive wear test (1kg)

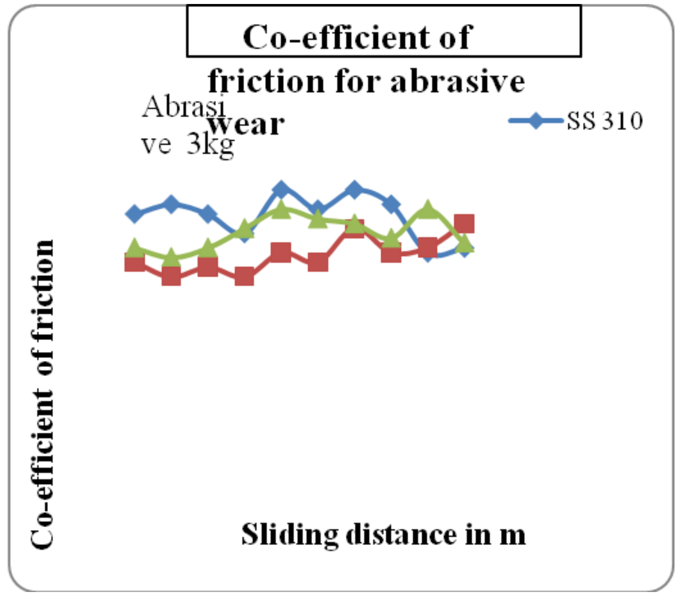

Fig.9.Coefficient of friction v/s sliding distance for abrasive wear test (3kg)

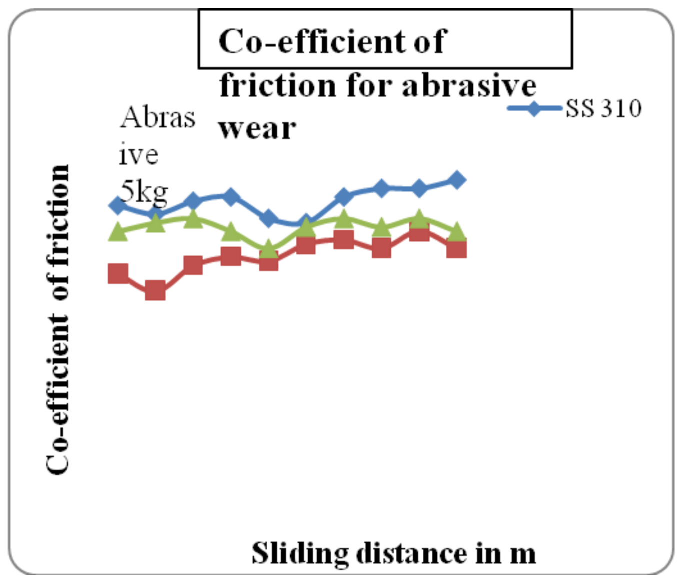

Fig.10.Coefficient of friction v/s sliding distance for abrasive wear test (5kg)

Comparision of Wear resistance

Adhesive wear:

Below figure shows the comparision of wear resistance for adhesive wear. As shown in Fig.11 the wear resistance for SS-304 (Uncoated) is less and wear resistance for SS-304 NiCr-Cr_3C_2 (coated) is slightly more than SS-304 (Uncoated). The wear resistance for SS-304 NiCrWc (Coated) is more compare to SS-304 (Uncoated) and SS-304 NiCr-Cr_3C_2 (coated). Hence the SS-304 NiCrWc is preferred as its wear resistance is high.

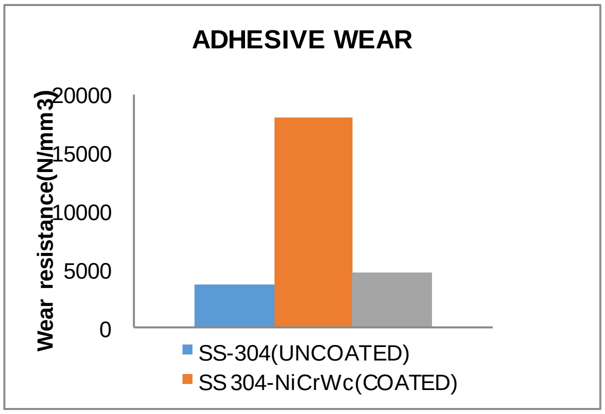

Fig.11.Comparision of wear resistance (Adhesive)

Abrasive wear:

Below figure shows the comparision of wear resistance for abrasive wear. As shown in Fig.12 the wear resistance for SS-304 (Uncoated) is less and wear resistance for SS-304 NiCr-Cr_3C_2 (coated) is slightly more than SS-304 (Uncoated). The wear resistance for SS-304 NiCrWc (Coated) is more compare to SS-304 (Uncoated) and SS-304 NiCr-Cr_3C_2 (coated). Hence the SS-304 NiCrWc is preferred as its wear resistance is high.

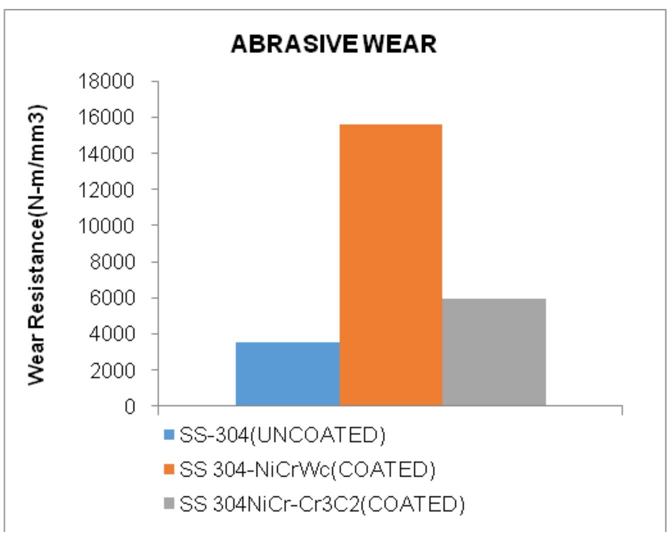

Fig.12.Comparision of wear resistance (Abrasive)

VII. CONCLUSION

1. High velocity oxy-fuel thermal spray process using oxygen and liquid petroleum gas as the fuel gas have been used successfully to deposit NiCrWc and NiCr-Cr3C2 alloy on SS-304. Under the given spray parameters seemingly layer structured coating with desired thickness range of 210-270 μm and lower porosity content, less than 0.95% has been achieved.
2. Micro hardness of the coating found to be vary with the distance from the coating substrate interface and is in the range of 284-389Hv.This variation in micro hardness value might be due to presence of porosity, oxide, melted and semi melted particles in the microstructure of coating.
3. The frictional coefficients for uncoated and coatings are in the range of 0.3 - 0.7.The frictional coefficient appears to be some what dependent on porosity, micro structural homogeneity and composition of the oxide. It is found to be independent of the hardness.
4. Un-coated super alloy shows the higher average specific wear rate when compared to coatings.
5. 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.
6. The specific wear rate and volume loss of dry sliding wear test is found to be very less in comparison to abrasive wear with SiC paper for both uncoted and coated samples.

VIII. SCOPE FOR FUTURE WORK

Some of the recommendation for future work are as follows:

- In the present study of coated surface (NiCr) shows very good results of wear resistance under room temperature.It can be tested on high temperature environment also.
- The fatigue wear resistance and fracture toughness of the coating can be evaluated
- Modeling and analysis of thermal stresses and temperature distribution in the coating can also be carried out.

IX. ACKNOWLEDGEMENT

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