SLIDING WEAR BEHAVIOUR OF HVOF SPRAYED WC-12CO BASED COATINGS ON AISI 4140 STEEL ALLOY

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ABSTRACT- *AISI 4140 steel alloy is a very weak and low alloy steels which depend on substances or elements other than carbon and iron to increase their mechanical properties like hardness, toughness, tensile strength. WC-Co coatings made by Thermal spray process are well known for their corrosion, wear and oxidation resistance. The co efficient of friction significantly decreases when a tribolayer is formed by the coatings under high temperatures in dry sliding contacts. In our current study we used compositions like Al2O3 and CeO2 that are mixed with WC-12Co powders and this composition significantly increased the wear resistance, performance at elevated temperatures. Here we used HVOF technique to produce coatings. The study we made shows that low co efficient of friction is produced by these coatings when compared to base metal AISI 4140 steel alloy. The coatings formed made tribolayer which was smooth and oxide based on the wear surfaces and the debris of wear included micro and nano metric crystalline oxide particles.*

KEYWORDS: ***AISI 4140 steel alloy, thermal spraying, HVOF, WC-12Co, Al2O3, CeO2, hardness and wear test.***

1. INTRODUCTION

Material wear is a common problem in many industries which cause material loss, that can result in refurbishment or replacement of component. This wear problem can be controlled by proper material selection. But change of base material leads to increase in material cost and leads to new challenges. The performance of the component can be improved by altering the surface by surface engineering techniques. One of the process in surface engineering is the thermal spraying that is the coating process that is used to impose thick wear resistant coatings on large surfaces. Spraying process is done by spraying the powder or wire form feedstock material in heated form. These heated particles are projected with great velocity on the surface of component and solidify and interlock with underlying surface. These thermally sprayed materials have application in many fields. In thermal spraying, hard metal materials are manufactured by sintering and agglomeration process. The current technique to manufacture hard metal coatings is HVOF (high velocity oxy-fuel) flame spray process. In this process particles are accelerated with high velocities (500-800m/s) and dense coatings are produced. The fuels used in HVOF technique are propylene, kerosene and hydrogen. The service life of materials or machine parts are reduced due to many problems. This service life can be improved by thermally sprayed coatings. Thermal spray coating has many other applications like for coated shafts, ball valves, piston sleeves operating at high temperature. The base metal used AISI 4140 steel has wide range of applications in connecting rods, hollow shafts, axles on forming disc, crankshafts and many more. The property of AISI 4140 steel alloy is low sliding wear resistance and unstable friction characteristics. The present investigation has been done to study the wear behavior of AISI 4140 steel in two different conditions.

2. MATERIALS

2.1 AISI 4140 STEEL

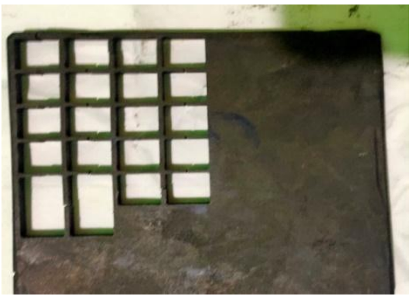

Fig 1 AISI 4140 STEEL Base Metal

AISI 4140 is produced in an electric or oxygen furnace by placing carbon, iron and other alloying elements in it. The alloying elements included in AISI 4140 are manganese, chromium and molybdenum. The properties of AISI 4140 are good hardness penetration and high strength, superior toughness, good wear resistance and good ductility.

MECHANICAL PROPERTIES	METRIC	IMPERIAL
Hardness, Brinell	194	194
Hardness, Knoop (converted from Brinell hardness)	216	216
Hardness, Rockwell b (converted from Brinell hardness)	90	90
Hardness, Rockwell c (converted from Brinell hardness)	15	15
Hardness, Vickers (converted from Brinell hardness)	208	208
Tensile Strength, ultimate	657Mpa	96000psi
Tensile Strength, Yield	416Mpa	60300psi
Elongation at Break (in150mm)	24.7%	24.7%
Reduction of Area	55.9%	55.9%
Modulus of Elasticity (Typical for steel)	206Gpa	29800ksi
Poisson Ratio (Calculated)	0.295	0.295
Machinability (Based on AISI1212 as 100% machinability)	64%	64%
Shear Modulus	80.5Gpa	11650ksi

2.2TUNGSTEN CARBIDE – COBALT (WC-12Co)

WC-Co has good wear resistance. The coating is produced using HVOF technique. The properties of WC-12Co are high hardness and fracture toughness. At less than 45N load and at 0.25 and 0.5ms^{-1} velocity WC-12Co exhibits lower wear rates. The tribo film formed will break at higher loads by compressive shear stresses which results in more abrasive wear rates and increasing COF with increasing load.

2.3ALUMINIUM OXIDE (Al_2O_3)

Aluminium is the most widely used effective material in the field of engineering. The raw materials used to manufacture alumina are readily available at reasonable price.

PROPERTY	VALUE
Melting point	2062^0C
Boiling point	2877^0C
hardness	14-20 GPa
Electrical resistivity	11^{12}-11^{13} Ω.m
Mechanical strength	350-650 MPa
Compressive strength	2500-4500 MPa
Thermal conductivity	25-35 W/mK

2.4 CERIUM OXIDE (CeO_2)

CeO_2 is an oxide of the earth metal cerium. It appears in pale yellow-white and will be in powder form. For purification of element from the ore, CeO_2 is the main component. Cerium is extracted from the mixture of bastnaesite and monazite. After this Ce is extracted from the by adding an oxidant and then by adjusting pH.

3. METHODOLOGY

The coating composition are

- WC-88%, Co-12%
- WC-12Co(95%) + CeO_2(5%)
- WC-12Co(75%) + Al_2O_3(25%)

This process is done on the following stages:

First surface preparation is done which is necessary step before coating. To do this molten zinc is applied on the surface which reacts and remove the dust, greece, oil etc. By doing this the surface is cleaned and is ready for coating. After this the coating process is done by using HVOF technique. In this process, the gases like propene, propylene, hydrogen, kerosene etc. are burnt in the combustion chamber and through orifice it is expanded out at very high velocity. At this temperature, the injector sprays the powder on the surface with hot gases in axial direction with higher velocity and acceleration to produce a coating. After coating, the material is cut into pieces by using electron discharge machining for the test to be conducted. After the material cutting process, the two tests conducted are Wear test and Micro Vickers Hardness test.

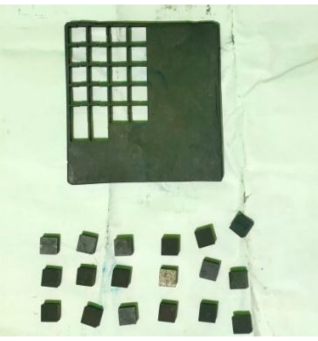

Fig 2 Coating material cut into pieces

4. MECHANICAL TESTS

4.1 WEAR TEST

The sliding wear test were done using a pin or disc type wear test machine. The parameters studied or considered are normal pressure, sliding distance. This test were carried out under normal pressure, constant sliding speed and distance at different temperatures and measured with a LVDT. The test was conducted at room temperature, 100^0c and 200^0c to study friction and wear properties. The test was conducted at 5N, 10N, and 15N load at 420rpm disc rotation speed for 6min, keeping sliding distance 700m and track diameter of 90mm.

4.2 MICRO VICKERS HARDNESS

Micro hardness testing is made by application of load P on the specimen by a diamond indenter. The result is measured with the help of optical microscope and the hardness is examined as the wear stress applied underneath the indentor. We used HWMMT-X7 Micro Vickers hardness tester to conduct the test.

5. RESULT AND DISCUSSION

5.1Wear test results on Pin on Disc machine

The material sample is cut into dimension of 10*10*5mm as per ASTM-G99 standard for pin on disc apparatus.

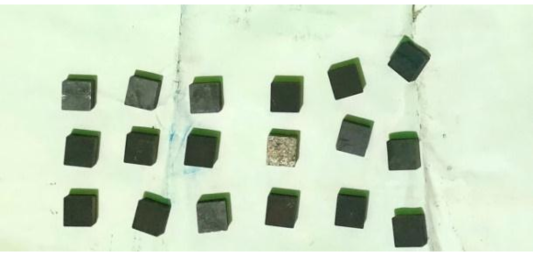

Fig 3 samples of coated material for wear test

Process parameters of wear test:

Sl. No	Type of metal surface	Load in N	Temperature in ^{0} c	Speed in rpm	Sliding distance in m
1	Base metal	5,10,15	30,100,200	424	712.5
2	Coated metal	5,10,15	30,100,200	424	712.5

Wear rates of samples used in pin on disc operation:

T (^{o}C)	Load (N)	Base metal wear rate (g/m)	Average	Coated metal wear rate (g/m)	Average	Average
30	5	$9.82*10^{-6}$	$9.83*10^{-6}$	$5.61*10^{-6}$	$5.62*10^{-6}$	$4.92*10^{-6}$
	10	$9.83*10^{-6}$		$5.62*10^{-6}$		
	15	$9.84*10^{-6}$		$5.64*10^{-6}$		
100	5	$6.33*10^{-6}$	$6.32*10^{-6}$	$2.80*10^{-6}$	$2.81*10^{-6}$	$1.83*10^{-6}$
	10	$6.32*10^{-6}$		$2.81*10^{-6}$		
	15	$6.31*10^{-6}$		$2.82*10^{-6}$		
200	5	$3.52*10^{-6}$	$3.52*10^{-6}$	$1.21*10^{-6}$	$1.23*10^{-6}$	$7.018*10^{-7}$
	10	$3.51*10^{-6}$		$1.23*10^{-6}$		
	15	$3.54*10^{-6}$		$1.25*10^{-6}$		

Micro Vickers Hardness test results

Sample details: Dimension cut 10*10*5mm

Fig 4 samples cut for hardness test

BASE METAL:

For 1 kg: **For 2 kg**

Hardness HV1 Hardness HV1

1. 198 1. 190

2. 202 2. 194

3. 198 3. 196

Average = 199.3 HV1 Average = 193.3 HV1

COATED METAL: WC-12Co + Al_2O_3

For 1 kg: **For 2 kg**

Hardness HV5 Hardness HV5

1. 205 1. 198

2. 198 2. 198

3. 205 3. 205

Average =202.66 HV5 Average = 200.33 HV5

COATED METAL: WC-12Co +CeO_2

For 1 kg: **For 2 kg**

Hardness HV5 Hardness HV5

1. 205 1. 198
2. 196 2. 198
3. 196 3. 204

Average = 199 HV5 Average = 201 HV5

CONCLUSION

To conclude from the experimental tests conducted it is clear that the hardness of AISI 4140 steel alloy is increased by coating the WC-12Co mixture on it. From micro Vickers hardness test it is concluded that hardness of AISI 4140 steel alloy is increased further with heat treated at 600^0c for 6 hours. The wear resistance is also increased after coating. The wear resistance property of heat treated coated AISI 4140 steel alloy is higher when compared to coated metal. Thus the wear resistance property of the coated material is greater or higher than that of base metal.

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