Sliding Wear Behavior of ASSAB 88 Tool Steel

Virendra Singh Rana[1], Arun Negi[2], Dr.B.Gangil[3], Mr.B.S.Bhandari[4]
[1, 2, 3, 4] *(Department of Mechanical Engineering H.N.B Garhwal University)*

Abstract

In the present work, tungsten carbide (WC-Co) and chromium carbide based coating (Cr_3C_2-NiCr) were deposited on commercially available ASSAB 88 tool steel the substrate material by Detonation Gun-spray process and analyzed with regard to their performance under sliding wear conditions. Sliding wear testing machine was used for wear test for coated as well as uncoated specimens at constant load i.e. at 1500 gram and at different time i.e. 60 minute, 90 minute and 120 minute; which results that Tungsten carbide coating (WC-Co) shows better wear resistance properties in comparison to uncoated ASSAB 88 tool steel and chromium carbide based coating (Cr_3C_2-NiCr).

Keywords –*ASSAB 88 tool steel, detonation gun*

I. INTRODUCTION

In the industrial applications there are several materials that are being used and there mechanical and physical property plays a major role in their successful implementation as tool. One such material is ASSAB 88 also known as cold work tool steel widely used in punch and die. There are several situation of wear and tear due to friction in a simple component and these can lead to failure of the material, along with the failure of tool due to relative motion if not properly designed. To improve the productivity and increase the life of tools including metals, ceramics, polymers, and composites can be coated by similar or dissimilar materials. Primary purpose of coating is usually to combat sliding, abrasion wear which is very often in relative motion applications.

There are various methods for applied coating .One of the best method is thermal spray coating. Thermal spraying, a group of coating processes in which finely divided metallic or non-metallic materials are deposited in a molten or semi molten condition to form a coating [1]. The coating material may be in the form of powder, ceramic-rod, wire, or molten materials [2]. A major advantage of thermal spray processes is the extremely wide variety of materials that can be used to produce coatings [3, 4]. Virtually any material that melts without decomposing can be used. A second major advantage is the ability of most thermal spray processes to apply coatings to substrates without significant heat input. Thus, materials with very high melting points, such as tungsten, can be applied to finely machined, fully heat-treated parts without changing the properties of the part and without excessive thermal distortion of the part. A third advantage is the ability, in most cases, to strip off and recoat worn or damaged coatings without changing part properties or dimensions [5].

Thermal spray processes that have been considered to deposit the coatings are enlisted below [6]:

[1] Flame spraying with a powder or wire.
[2] Electric arc wire spraying.
[3] Plasma spraying.
[4] Cold spray.
[5] High Velocity Oxy-fuel (HVOF) spraying.
[6] Detonation Gun.

Here we are using detonation gun process for applied coating due to their advantage over other thermal spraying process:

[1] Increase in wear resistance by several times superior to other coating techniques currently available in Indian market.
[2] Dense microstructure (0.1-1% porosity).
[3] Smooth surface finish (1-4 micrometer Ra).much smoother finishes could be obtained by post-coating grinding.
[4] Extremely high coating bond strength (>10,000 psi).
[5] Very Low substrate temperatures.
[6] Ability to rebuild and repair of the coated parts.

II. EXPERIMENT DETAIL

Commercially available ASSAB 88 tool steel was used as the substrate material and commercially available metalizing powders namely WC-Co and Cr_3C_2-NiCr were used for the purpose of coating whose chemical composition is given in table 1.

Table 1: Chemical Composition (wt. %) of the Substrate used

S. No.	Element	Substrate
1	C	0.9
2	Si	0.9
3	Mn	0.5
4	Cr	7.8
5	Mo	2.5
6	V	0.5
7	Fe	Balance

A. Development of Coating

1) *Substrate Preparation*

Prior to the coating, the ASSAB 88 tool steel of dimensions 30mm x 6mm for cylindrical for abrasion cleaned with acetone and grit blasted at a pressure of 5 kg/cm2 using aluminium oxide(Al_2O_3) of grits size 30 grade and again cleaned and dried. The standoff distance in shot blasting was kept between 120 mm-170 mm.

2) *Deposition of Coating*

The grit blasted substrate was held suitably in a fixture and the coating deposition was carried out within the samples in the stationary condition with gun traversing to and fro to obtain the desired coating thickness. The coating of samples were carried out at SVX Powder M Surface Engineering (Pvt.) Limited, Greater Noida. The spraying conditions adopted for the coatings are given in table 2.

Table 2: Spraying Condition Adopted for Detonation Spray Process

S.No.	Parameters	WC-Co	Cr_3C_2-NiCr
1	O_2 flow rate (SLPH)	2640	2800
2	C_2H_2 flow rate (SLPH)	2240	2240
3	Carrier gas(Nitrogen) flow rate (m^3/h)	960	1040
4	Spray distance(mm)	165	165
5	Frequency of shots (shots/sec.)	3	3

B. *Detonation Gun*

A Detonation gun consists of a water cooled barrel several feet long and about one inch in diameter with some associated valuing for gases and powder, as shown schematically in Figure 1. A carefully measured mixture of gases, usually oxygen and acetylene, is fed to the barrel along with a charge of powder (usually with a particle size less than 100 microns). A spark is used to ignite the gas and the resulting detonation wave heats and accelerates the powder as it moves down the barrel [7]. The gas is traveling at a supersonic velocity and the powder is entrained for a sufficient distance for it to be accelerated to a supersonic velocity as well, typically about 760 m/sec (2400 ft/sec) [8]. A pulse of nitrogen gas is used to purge the barrel after each detonation. This process is repeated many times a second. Each individual detonation results in the deposition of a circle (disk) of coating a few microns thick and about one inch in diameter [9]. The coating is made of many overlapping disks. Careful fully automated disk placement results in a very uniform coating thickness and a relatively smooth, planar surface. Detonation gun coatings thus consist of multiple layers of densely packed, thin particles tightly bonded to the surface [**10**].

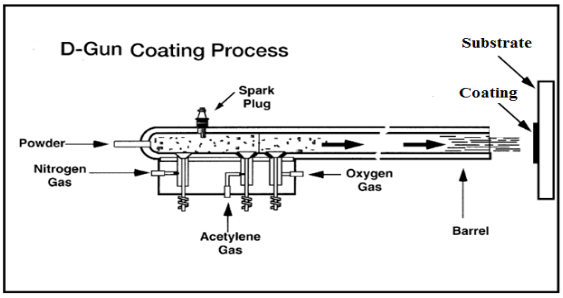

Fig. 1: Schematic of Detonation Gun Process [10].

III. TEST APPARATUS

WEAR STUDY USING PIN-ON-DISC WEAR TEST RIG:

A. *Experimental Set Up*

Dry sliding wear tests for the uncoated and detonation sprayed ASSAB 88 tool steel, were conducted using a pin-on-disc machine [Model: ED-201]. Some photographs of the set up of the machine are shown in Figure 3. The tests were conducted in air having relative humidity in range from 40 to 75 %. Wear tests were performed on the pin specimens that had flat surfaces in the contact regions and the rounded corner.

B. *Sliding Wear Studies*

The pins were polished with emery paper and both disc and the pin were cleaned and dried before carrying out the test. The pin was loaded against the disc through a dead weight loading system. The wear test for coated as well as uncoated specimens was conducted at constant load i.e. at 1500 gram and at different time i.e. 60 minute, 90 minute and 120 minute. The track radii for the sliding disc were kept at 37mm. The speed of the rotation (480 rpm) of the disc for all cases was so adjusted to keep the linear sliding velocity at a constant value of 1.9 m/s. Wear tests have been carried out for a total sliding distance of 13390 m, so that only top coated surface was exposed for each detonation sprayed sample. Weight losses of each sample were measured after 60, 90,120 minutes to determine the wear loss. The pin was removed from the holder after each run, cooled to room temperature, brushed lightly to remove lose wear debris, weighed and fixed again in exactly the same position in the holder so that the orientation of the sliding surface remains unchanged. The weight has been measured by a micro balance to an accuracy of 0.001 g.

(a) (b)

Fig. 2: (a) Pin-on-disc Wear Test Machine and (b) Weighing Apparatus.

The pin was held stationery against the counter face of a rotating disc made of ASSAB 88 tool steel at 74 mm track diameter. ASSAB 88 tool steel is a plain carbon steel; case hardened 62 to 65 HRC as provided with the pin-on-disc machine. The technical data and specification of the machine is given in the table 3:

Table 3.Technical Data and Specification of the Machine.

Parameter		Min	Max
Pin	Diameter	6 mm	
	Length	30 mm	
Disc	Diameter	100 mm	
	thick	6 & 8 mm	
Wear track data		50 mm	80 mm
Disc		480 rpm	
Normal load		5 N	30 N

C. *Dry Sliding Wear Behaviour*

On the basis of different parameter like sliding distance, weight loss and time we have studied the sliding behaviour of different sample of without coated, WC-Co coated on ASSAB 88 tool steel and Cr_3C_2-Ni-Cr coated on ASSAB 88 tool steel. There result and discussion are given below:

Table 4. Uncoated ASSAB 88 tool steel.

S. No.	Initial Wt. of job (gm)	Final Wt. of job (gm)	Loss of Wt. (gm)	Disk Speed (rpm)	Sliding Distance (m)	Total Time (min)	Load Applied (gm)
1.	9.6691	9.6630	0.0061	480	6690	60	1500
2.	9.6691	9.6610	0.0081	480	10040	90	1500
3.	9.6691	9.6494	0.0197	480	13390	120	1500

Table 4 shows the values of weight loss of uncoated ASSAB 88 tool steel at varying sliding distance and time. Weight loss increases as the time increases.

Table 5. Cr_3C_2-NiCr Coated ASSAB 88 Tool Steel.

S. No.	Initial Wt. of job (gm)	Final Wt. of job (gm)	Loss of Wt. (gm)	Disk Speed (rpm)	Sliding Distance (m)	Total Time (min)	Load Applied (gm)
1.	10.1188	10.1180	0.0008	480	6690	60	1500
2.	10.1188	10.1172	0.0016	480	10040	90	1500
3.	10.1188	10.1140	0.0048	480	10040	120	1500

Table 5 shows the values of weight loss of Cr_3C_2-Ni-Cr coated ASSAB 88 tool steel at varying sliding distance and time. In this case weight loss is minimum as compared to uncoated ASSAB 88 tool steel.

Table 6. WC-Co coated ASSAB 88 Tool Steel.

S.No	Initial Wt. of job (gm)	Final Wt. of job (gm)	Loss of Wt. (gm)	Disk Speed (rpm)	Sliding Distance. (m)	Total Time (min)	Load Applied (gm)
1.	8.4038	8.4035	0.0003	480	6690	60	1500
2.	8.4038	8.4028	0.001	480	10040	90	1500
3.	8.4038	8.4010	0.0028	480	13390	120	1500

Table 6 shows weight loss of WC-Co coated Assab88 tool steel at varying sliding distance and time. In this case weight loss is minimum as compared to uncoated ASSAB 88 tool steel.

D. *Calculations of Wear Rate*

The wear rate data for the coated as well as uncoated specimens were plotted with respect to sliding distance to establish the wear rate. Wear rate was estimated by measuring the mass in the specimen after each test and mass loss, Δm in the specimen was obtained. Care has been taken after each test to avoid entrapment of wear debris in the specimen. Wear rate which relates to the mass loss to sliding distance (L) was calculated using the expression:

$$w_r = \frac{\Delta m}{L}$$

The volumetric wear rate W_v of the specimen is related to density (ρ) and the abrading time (t). It was calculated using the expression:

$$w_v = \frac{\Delta m}{\rho . t}$$

For characterization of the abrasive wear behavior of the specimen, the specific wear rate is employed. This is defined as the volume loss of the specimen per unit sliding distance and per unit applied normal load. Often the universe of specific wear is expressed in terms of the volumetric wear rate as

$$w_s = \frac{w_v}{w_v \cdot F_n}$$

Where, V_s is the sliding velocity.

Dry sliding wear rate table are below:

Table 7. Uncoated ASSAB 88 Tool Steel.

S. No	Initial weight of job (gm)	Final weight of job (gm)	Loss of weight (gm)	Disk speed (rpm)	Total distance (m)	Wear rate (gm/m) 10^{-8}	Load applied (gm)
1	9.6691	9.6630	0.0061	480	6690	91.180	1500
2	9.6691	9.6610	0.0081	480	10040	80.677	1500
3	9.6691	9.6494	0.0197	480	13390	147	1500

Table 7 shows the values of wear rate of uncoated ASSAB 88 tool steel at varying sliding distance and time. Wear rate increases as the time increases.

Table 8. Cr_3C_2-NiCr Coated ASSAB 88 Tool Steel.

S. No	Initial weight of job (gm)	Final weight of job (gm)	Loss of weight (gm)	Disk speed (rpm)	Total distance (m)	Wear rate (gm/m) 10^{-8}	Load applied (gm)
1	10.1188	10.1180	0.0008	480	6690	11.95	1500
2	10.1188	10.1172	0.016	480	10040	15.936	1500
3	10.1188	10.1140	0.048	480	13390	35.847	1500

Table 8 shows the values of wear rate of nickel chromium coated ASSAB 88 tool steel at varying sliding distance and time. Wear rate increases as the time increases.

Table 9. WC-Co coated ASSAB 88 Tool Steel.							
S. No.	Initial weight of job (gm)	Final weight of job (gm)	Loss of weight (gm)	Disk speed (rpm)	Total distance (m)	Wear rate (gm/m) 10-8	Load applied (gm)
1	8.4038	8.4035	0.0003	480	6690	4.48	1500
2	8.4038	8.4028	0.001	480	10040	9.96015	1500
3	8.4038	8.4010	0.0028	480	13390	20.91	1500

Table 9 shows the values of wear rate of tungsten carbide coated ASSAB 88 tool steel at varying sliding distance and time. Wear rate increases as the time increases.

Dry sliding specific wear rate in terms of volumetric wear rate tables are below:

Table 10. Uncoated ASSAB 88 Tool Steel.							
S. No.	Initial weight of job (gm)	Final weight of job (gm)	Loss of weight (gm)	Sliding velocity (m/s)	Volumetric wear rate (m3/s) 10^{-11}	Specific wear rate (m3/N-m) 10^{-15}	Load applied (gm)
1	9.6691	9.6630	0.0061	1.9	22.0630	77.414	1500
2	9.6691	9.6610	0.0081	1.9	19.53125	68.530	1500
3	9.6691	9.6494	0.0197	1.9	35.626	125	1500

Table 10 shows the values of specific wear rate of uncoated ASSAB 88 tool steel at varying sliding distance and time. Specific wear rate increases as the time increases.

Table 11. Cr_3C_2-NiCr coated ASSAB 88 Tool Steel.							
S. No.	Initial weight of job (gm)	Final weight of job (gm)	Loss of weight (gm)	Sliding velocity (m/s)	Volumetric wear rate (m3/s) 10^{-11}	Specific wear rate (m3/N-m) 10^{-15}	Load applied (gm)
1	10.1188	10.1180	0.0008	1.9	2.8935	10.152	1500
2	10.1188	10.1172	0.016	1.9	3.858	13.536	1500
3	10.1188	10.1140	0.048	1.9	8.680	30.456	1500

Table 11 shows the values of specific wear rate of nickel chromium coated ASSAB 88 tool steel at varying sliding distance and time. Wear rate increases as the time increases.

Table 12. WC-Co coated ASSAB 88 Tool Steel.							
S. No.	Initial weight of job (gm)	Final weight of job (gm)	Loss of weight (gm)	Sliding velocity (m/s)	Volumetric wear rate (m3/s) 10-11	Specific wear rate (m3/N-m) 10-15	Load applied (gm)
1	8.4038	8.4035	0.0003	1.9	1.0850	3.8070	1500
2	8.4038	8.4028	0.001	1.9	2.4112	8.4603	1500
3	8.4038	8.4010	0.0028	1.9	5.0636	17.767	1500

Table 12 shows the values of specific wear rate of tungsten carbide coated ASSAB 88 tool steel at varying sliding distance and time. Specific wear rate increases as the time increases.

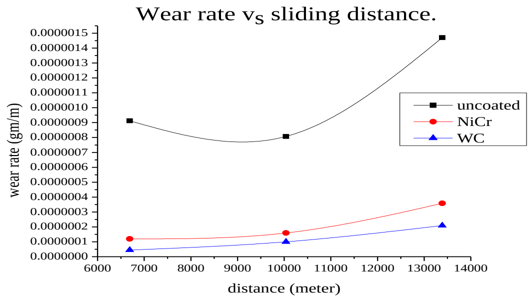

Fig. 3: Wear Rate V$_s$ Sliding Distance.

Figure 3 shows the graph between the wear rate and sliding distance for uncoated and coated sample. It can be referred that wear rate is maximum for uncoated work piece and then for Cr_3C_2-NiCr coated sample. The value of wear rate is minimum for tungsten carbide sample.

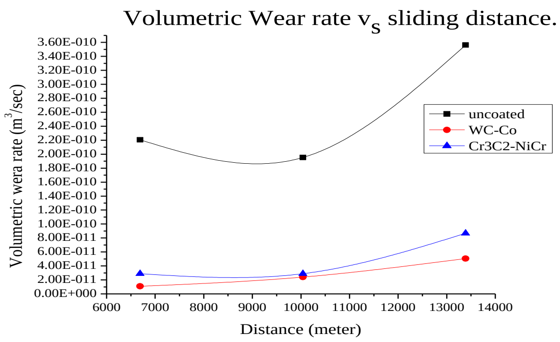

Fig. 4: Volumetric Wear Rate V$_s$ Sliding Distance.

Figure 4 shows a curve plotted between the volumetric wear rates and sliding distance. The curve shows that maximum value of wear rate for uncoated sample and then for Cr_3C_2-NiCr coated sample. WC-Co coated on ASSAB 88 tool steel shows the lesser wear rate as compared to both uncoated and Cr_3C_2-NiCr coated sample.

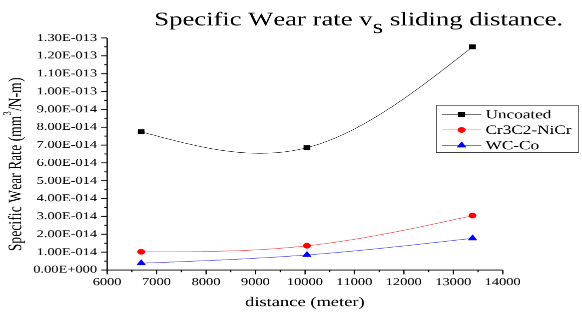

Fig. 5: Specific Wear Rate V$_s$ Sliding Distance.

Figure.5 shows the graph between the specific wear rate and sliding distance. Initially the value specific wear rate for uncoated sample decrease with respect to sliding distance but then value of specific wear rate increase as sliding distance increase. The value of specific wear rate is maximum for uncoated sample and then for Cr_3C_2-NiCr coated sample. The value of specific wear rate is minimum for tungsten carbide sample coated sample.

IV. CONCUSION

This study basically evaluates the sliding wear property of Assab88 tool steel and the above two coatings applied on it. Hence in accordance with our material we draw the following conclusions:

1. Wear resistance of the coated Assab88 tool steel is superior to uncoated Assab88 tool steel.
2. Tungsten carbide coating shows better wear resistance properties in case of sliding wear test.

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