ISSN: 0971-1260
Vol-22-Issue-16-August-2019

A Study on Applications of Hardfacing Techniques To Improve Wear Resistance Using Chromium Based Hardfacing Alloy.

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Abstract

Hardfacing is a methodology used to improve surface characteristics for a material, by depositing an alloy layer on base metal to improve the wear resistance. Wear resistance depends upon type of deposition method and alloy. In the present work, a study on hardfacing had been done to understand different techniques used to carry out hardfacing such as thermal spraying welding and allied methods. Among all methods, welding methods play key role due to low cost and easilyavailability. Different wear mechanisms were also studied such as abrasion, erosion, fretting to name a few.A test was carried out to see the effect of hardfacing on the wear resistance of mild steel specimen using chromium based hardfacing alloy. Specimen were hardfaced using single and multiple hardfacing layers with Shielded metal arc welding (SMAW). It was observed that specimen with multilayers of hardfacingexhibits better resistance to wear as compared to single layered hardfacing specimen.

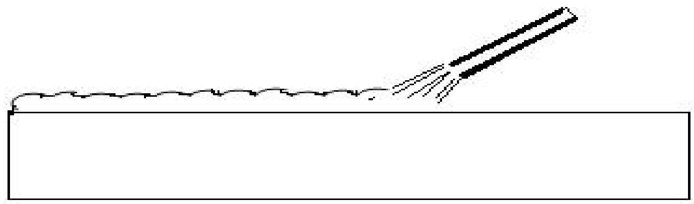
Keywords: hardfacing, wear, Shielded metal arc welding (SMAW), hardfacing alloys

1.Introduction

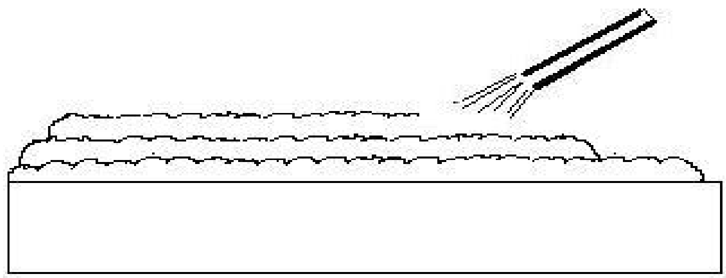
Hardfacing is the deposition of an alloy on the metal substrate to improve the desired properties such as wear resistance, hardness, stability at high temperature incorporating different methods such as thermal spraying, welding etc.[1]. Figure 1 demonstrates hardfacing as a process to improve surface properties. Hardfacing is more economical as compared to some conventional methodologies to improve the properties of surface rather than treating the entire component for the same, as it involves deposition of a hardfacing layer on the surface of low cost base metal.[2]
Since the hardfacing enhances the life span of material, hardfacing alloys must possess below mentioned desired properties [3]:

1.1 Hardness
a) Macro-hardness.
b) Micro-hardness (individual material hardness such as that of deposition material).
c) hardness at high temperature.
d) strength for creep (for elevated temperature devices).

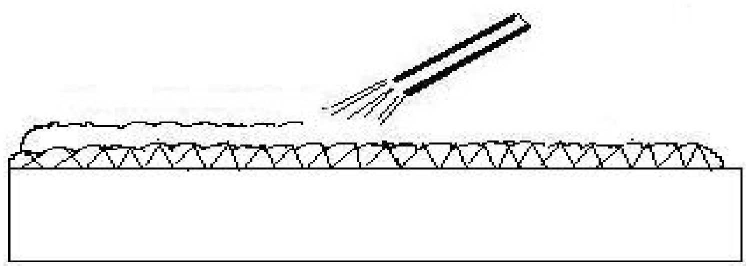
1.2 Resistance to Abrasive particles
a) low load abrasive resistance.



(a)



(b)



(c)

Figure1: Layout of hardfacing. Hardfacing materials can be added to base metal as a) a single layer, b) certain layers. And sometimes, c) a buffer layer is pasted onto the base metal before the application of hardfacing alloy to provide better bonding between different layers.

b) high load abrasive resistance.
c) resistance under wet conditions
1.3Resistance to heat
a) Resistance to oxidation.
b) high temperature fatigue.
1.4 Corrosive-resistance
1.5 surface properties
a) Frictional constant.
b) Surface layers.
c) Lubrication.

2.Literature review

Buchely M.F et al. (2005) made a study for the comparison of material properties and wear resistance for different hardfacing materialsincorporating chromium carbides, complex and

ISSN: 0971-1260
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tungsten carbides. They used ASTM A36 as base metal to be welded with shielded metal arc welding process and found that 3 layered complex carbides shows best abrasion wear resistance, whereas in single layer, higher dilution increases wear losses. W-rich hardfacing alloy shows good abrasion wear resistance in single layer due to large MC carbide size. Wear mechanisms observed as microcutting, brittle-fracture, ploughing of carbides [1].

Chang C.M et al. (2010) studied the microstructure and abrasionproperties of carbon Fe-Cr-C alloys. ASTM A36 steel plate is hardfaced with GTAW process. They observed that with increase in carbon content, hardness Improves and chromium carbide refines. Wear resistance increases with carbon content but eutectic matrix damages due to abrasive particles. High carbon Fe-Cr-C alloy possessed excellent wear resistance[4].

Correa E.O et al. (2007) investigated the relation among abrasion wear-resistance and micro-structure of alloy for hardfacing based on Fe-Cr-C-Nb-V system. Alloy-750 demonstrates microstructure for improved wear resistance and resilience as compared to conventional alloys. which is due to distribution of very fine Nb rich carbides in an austenitic matrix. Related to above research, alloy 750 is suggested to be used than conventional H.C.O materials for applications subjected to abrasion resistance and impact strength for prolonged lifespan of components[5].

Coronado John J. et al. (2009) studied the effect of welding procedures on abrasion wear. In this work, four kind of hardfacing alloys deposited with two different welding processes viz FCAW and SMAW in the pattern of single and triple layer. Results showed FCA weldingresultsgood wear properties in single and triple layers. Abrasion wear mechanisms were micro-cutting, micro-ploughing and wedge formation. matrix micro-structure andCarbide has more importance than hardness in abrasivewear of alloys[6].

Choteborsky R. et al. (2008) studied the hardfacing alloy reinforced with primary Chromium carbides and complex carbides for their wear resistance. GMAW process is used for deposition of hardfacing alloy upon low carbon steel plate. They found two-layer complex carbide shows best wear resistance whereas MC carbide has decisive influence on abrasion wear resistance and they act a barrier against the advancement of abrasive particles[7].

Chatterjee S. et al. (2006)investigated the influence of welding procedures upon performance of Cr based hardfacing alloy upon cast iron such as with and without preheating, single and double hardfacing layer and with or without buffer layer. They found max bound strength between the substrate and deposit is obtained with buffer layer. possibilityof surface cracks of alloystermed as cracks length/ area is affected on pre-heat, no of layers and Cr/C ratios of hardfacing alloy.[10]

Gualco A. et al. (2010) made a study to measure the effect of shield gas, heat energy and after weld heat treatment on micro-structural evaluation and wear properties of improved AISI H1E3 martensitic steel depositionthrough semiautomatic gas shield arc welding methodwith tubular metalcored wire and found that shielding gas shows little effects on weldsdeposition chemistry. extra heat supply results in large carbide precipitations, hence lower hardness. Whereas low heat input results in higher hardness. PWHT results in reduction of 30% wear resistance as compared to as welded specimens.[11]

Klimpel A. et al. (2009) compared the quality of deposits in submerged arc welding (SAW) surfacing of low alloy steel with super-ferritic filler material. They found that microstructure of

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3rd layer have super ferritic phase but that of 1st and 2nd shows the influence of base metal. Hardness is maximum at 3rd layer (360 HV1) whereas 1st and 2nd layers shows lower hardness due to higher dilution. Stress levels increases from 300 MPa in 1st layer to 500 MPa in 3rd layer.[12]

Klimpel A. et al. (2007) studied the effects of GMA metal core wire hardfacing parameters on erosive and abrasive wear properties of single and third layered cermetal deposits with nickel based core wire. They concluded hardness isproportional to value of heat input. WC carbide population densities, sizesalong with distributions in Ni-matrix is a function of GMA heat input. Low heat input deposit providesten times mmoreabrasive wear propeties and four times more erosion wear resistance over hardox 400 steel.[13]

3.Harfacing materials applications

The wide range of applications, starting from the most critical,as in crushing of rock, to the applications for minimizationofdirect metal wear as in valve mechanisms operating under tight clearances[7]. The application of hardfacing alloys for critical components are briefed in figure2 (a and b).

The showel teeth made of lowalloy cast iron, and sometimes of steel. The working range of new tooth and treated toothcan be enhanced by hard-facing. The hardfacing material provide excellentabrasive resistance for areas, in which the frontal edge isexposed to intensive wear [5]. Nickel and cobalt based hardfacing materials are suitable for high temperature and corrosive stability of the applications. Shearblade figure in 2 (c) and valve seats figure in2 (d) are hard-faced by satellite category of cobaltbased and hastelloy basedNi,Cr alloy to obtain high strength at elevated temperature[9].

(a) **(b)**

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(c) **(d)**

Figure 2: a) shovel teeth; b) trencher chain, c) hot shear blade; d) valve seats [3]

4.selection of hardfacing materials

Wear and cost plays dominate role in selecting hardfacing materials. Along with that base metal composition, method of hardfacing, type of wear resistance, operating conditions plays major role in hardfacing materials selection. Following key parameters should be considered while making a selection [14,15].

I. Operating conditions.
II. Hardfacing material selection.
III. Comparison of hardfacing metal composition with base metal.
IV. Hardfacing method.
V. Cost and percentage dilution.

5. Hardfacing methods

The various processes used for hardfacing are listed in figure 3. hardfacing can be done with welding or spraying. In welding, oxyacetylene or arc welding processes are extensively used depending upon the requirements and availability of equipments. Oxyacetylene welding is used for small parts and for precise build-up. Arc welding processes are most commonly used, because they yield high deposition rates and simplify extensive build-up on heavy components. Some of them can be used in semi-automatic or fully automatic form for hardfacing standard components on a production scale. Metalspraying with oxyacetylene flame or plasma-arc, a process closely allied to welding, is also widely popular in the maintenance field [3,7,14,15].

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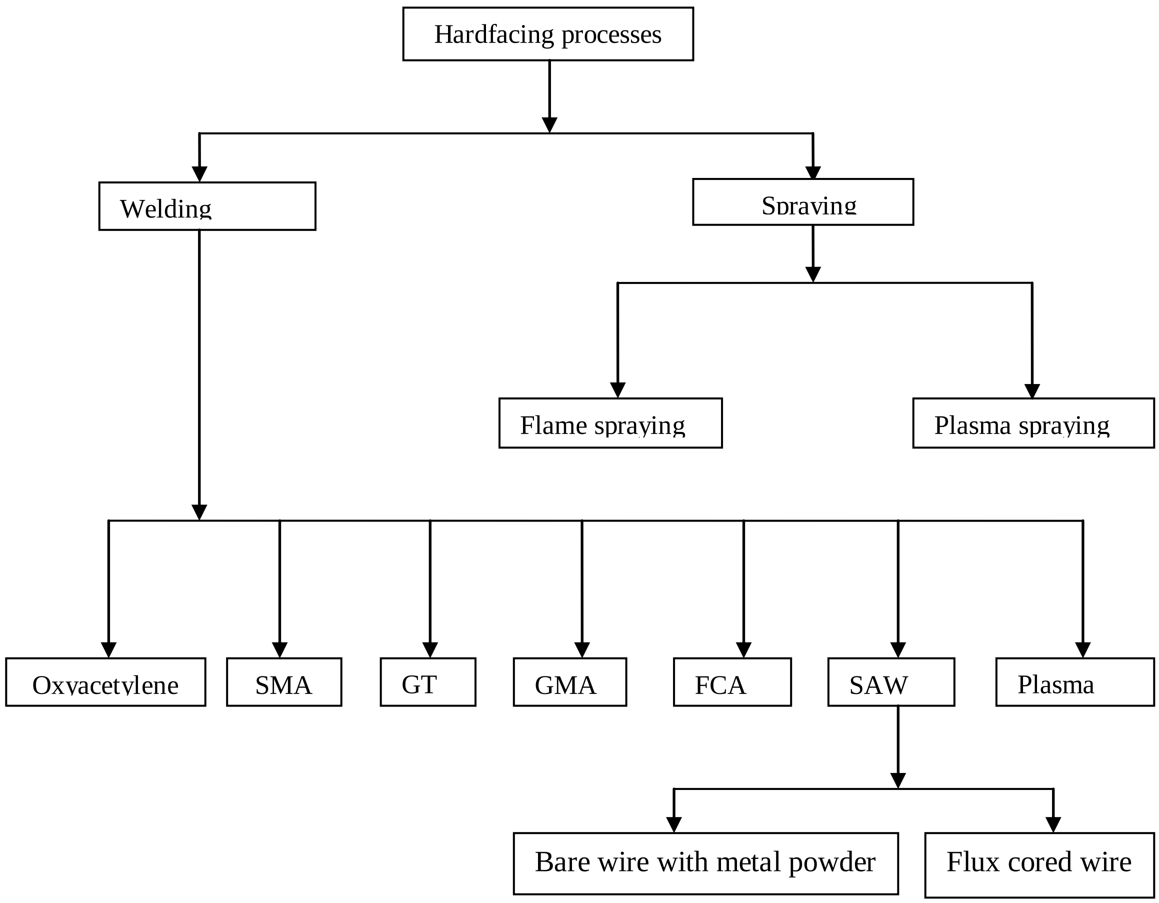

Figure 3: Schematic representation of various processes used for hardfacing.

5.1Hardfacing by welding (Shielded metal arc welding (SMAW) based hardfacing)

Shielded metal arc welding (SMAW) is widely used for the hardfacing, because of its low cost, great versatility, and the availability of a wide range of sizes and type of hardfacing electrodes. The schematic representation of SMAW welding is shown in figure 4.

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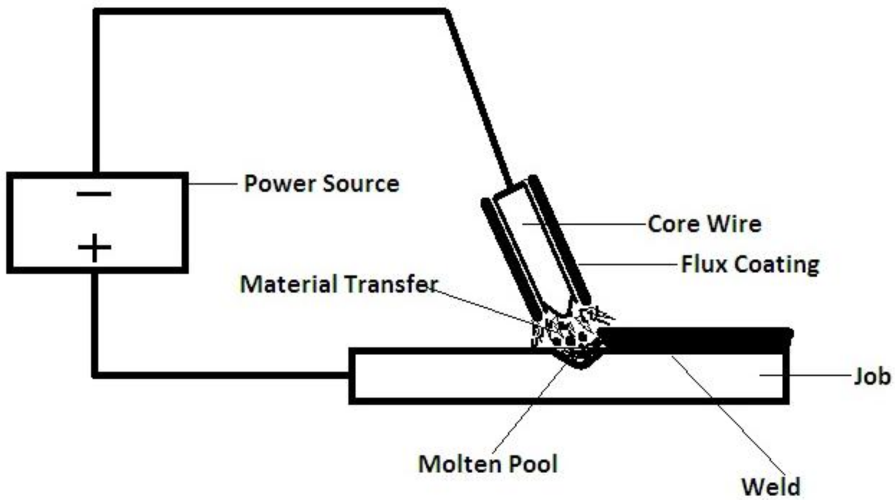


Figure 4: Representation of SMAW set-up.

Welding can be done on any size and shape of job, in any position and at any location [7]. The welder can control heat input rate, dilution by base metal and can easily cover irregular areas. He can use stringer bead technique to minimize heat input or weave technique to maximize heat input. He can direct the arc on the molten puddle and control the size of the puddle to reduce dilution of the base metal (for example, in welding for austenitic manganese steel) [6].

6.concept of Wear

Wear is one of the three major reason for the failure of industrial components and assemblies. The other being fatigue and corrosion degradation. Wear is time consuming, although results in lesser efficiencies by increasing power and oil consumption, component replacement frequency. Broadly the wear can be classified into following categories [7].

6.1 Wear by adhesion

I. Oxidation wear.
II. Metal wear.
III. Galling wear.

6.2 Wear by abrasion

I. Low loadabrasion wear.
II. High load abrasive wear.
III. Abrasive wear by gouging.

6.3 wear by Erosion

I. Particles impingements.
II. Cavitations.

6.4 Fretting

6.1 Wear by adhesion

Wear by adhesion results from rubbing between two metallic surfaces in the absence of any abrasive particles. Under low load applications, an oxide layer builds up between rubbing surfaces due to frictional heating due to sliding motion.This oxide layer prevents any type of metallic interactions between two surfaces, thereby results in low volume loss as a result of rubbing. This wear comes under low or oxidation wear. Under high load application, the rubbing of metallic surfaces can result in metallic bonding thereby influences high metal losses. This type of wear comes under metallic/severe wears. othertype of wear named as galling, is a special form of severe adhesive wear. It occurswhen wear debrisesarebigger than clearancesand seizures of the slidingparts arise. often, small amount of sliding motion creates galling and furtherloss of thepart. In some situations where it is not possible to do lubrication, hardfacing can help improve the surface properties against adhesive wear such as exhaust valve of an IC engine. Mosly moving parts in machinery can be treated to have better resistance to wear [9].

6.2 Abrasive wear

Low load wear by abrasion results by cutting actionsof sliding abrasive particles stressed under limiting compressive strength. In Low load wear by abrasion, wear out surfaces contains scratching marks level of under surface damage is minimum.Highload wear by abrasion takes place under high stress conditions results in crushing of abrasive particles. In this type of the wear, high stresses results in massive plastic deformation of ductile material constituents.Abrasive wear by gougingdescribes a condition under larger grooves of the worn out surfaces. [16].

6.3 Erosion

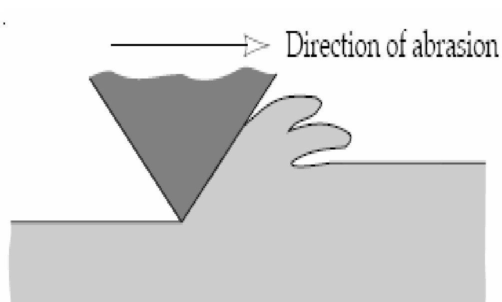
Particles impingementserosive wear takes place action of particles moving in the fluids. The particles moving in the air or water creates contact stress as soon as they encounter a surface due to the kinetic energy they possess. Impingementswear varies direction of impingement with respect to the surface. Cavitation includes collapse of air bubble by turbulences.When air bubbles strike a surface, wear arise as a result of shock energy released by bubble. This is termed as erosion by cavitations.

6.4 Fretting

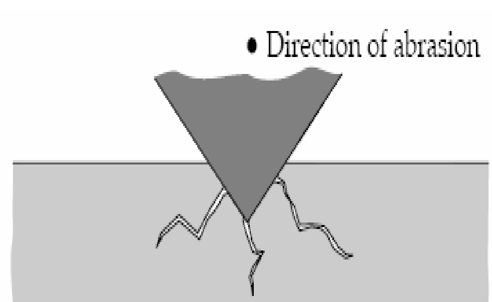
Combined oxidation and abrasion wear results in fretting.

6.5 Mechanism of the wear by abrasion

wear by abrasion supposed to be resembled with cutting by series of machine tools or saw.but microstructureobservations shows cutting of tool can only be compared with sharper grit particle, although many other phenomenon takes place underneath. [13]. The sharper grit or metal particles can do wear by microcutting, microfracture, pullout of grain or accelerated fatiguesthrough cyclic defections as shown in figures5.



1. Cutting



2. Fracture

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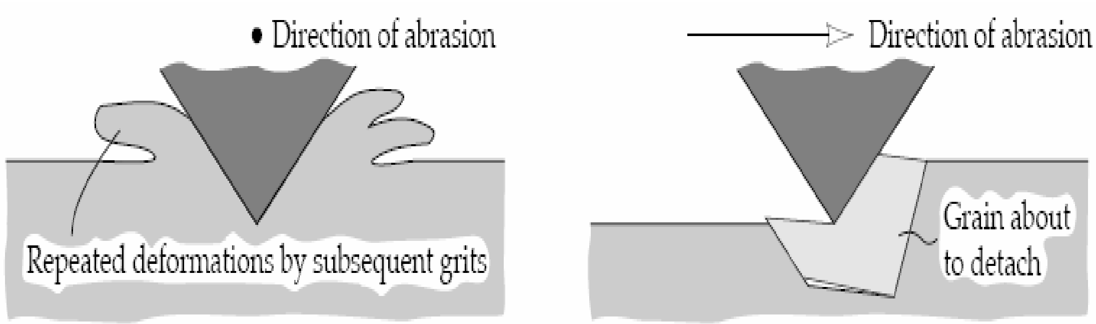

3. Fatigue by repeated ploughing 4. Grain pull-out

Figure 5:wear by abrasion mechanism.

7.Experimentation for wear

A test study was carried out to evaluate the wear resistance of hardfaced mild steel specimen with following specifications of hardfacing alloy and base metal using SMAW. A buffer layer was deposited on all specimen before hardfacing.

7.2 Hardfacing electrode

The electrode used for hardfacing has the chemical composition as table 1:

Table 1: Chemical composition of hardfacing electrode

C	Si	Mn	Cr	Mo	V	Fe
.65	1.1	.7	7.8	1.1	.8	Rest

7.3 Buffer layer electrode

Buffer layer electrode is used before hardfacing with properties given in table 2:

Table 2: Chemical composition for buffer electrode

C	Si	Mn	P	S	Fe
.10	.65	1.5	.030	.030	Rest

7.4 Base plate used

Table 3 shows chemical proportions of Mild steel. The plate with dimensions of 100×50×10 mm is used for experimentation.

Table 3: Chemical composition of base plate

C	Si	Mn	P	S	Fe
.26	.17	.401	.095	.033	Rest

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Sample number	Parameters	
	Current (ampere)	Hardfacing layer
01	170	3
02	170	1
03	150	3
04	150	1

Table 4: Process parameters selected for testing

The process parameters used for hardfacing are given in table 4.

4.2.3 Wear resistance testing

Wear resistance testing has been done on pin on disc machine. Prior to wear resistance testing, the pins with dimensions of 6mm dia. ×25 mm length have been prepared (figure 6) with CNC wire cut EDM, model Robofil 290 charmiles, Switzerland. Wear test parameters are given in table 5.

Table 5: Parameters for wear resistance test

Disc rotating speed	250 cpm
Disc diameter	8 cm
weight	3Kg
Distance to wear	1500 Metres
Stages	4
duration	24 Minutes

The pins used for wear resistance test are shown in figure 6.

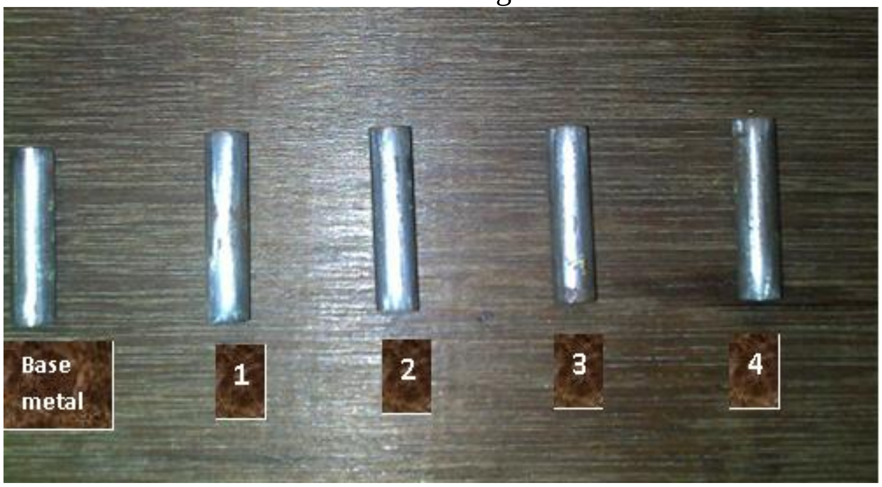

Figure 6: Pins for wear resistance testing

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8. Wear resistance

Wear resistance test results are shown in figure 7.

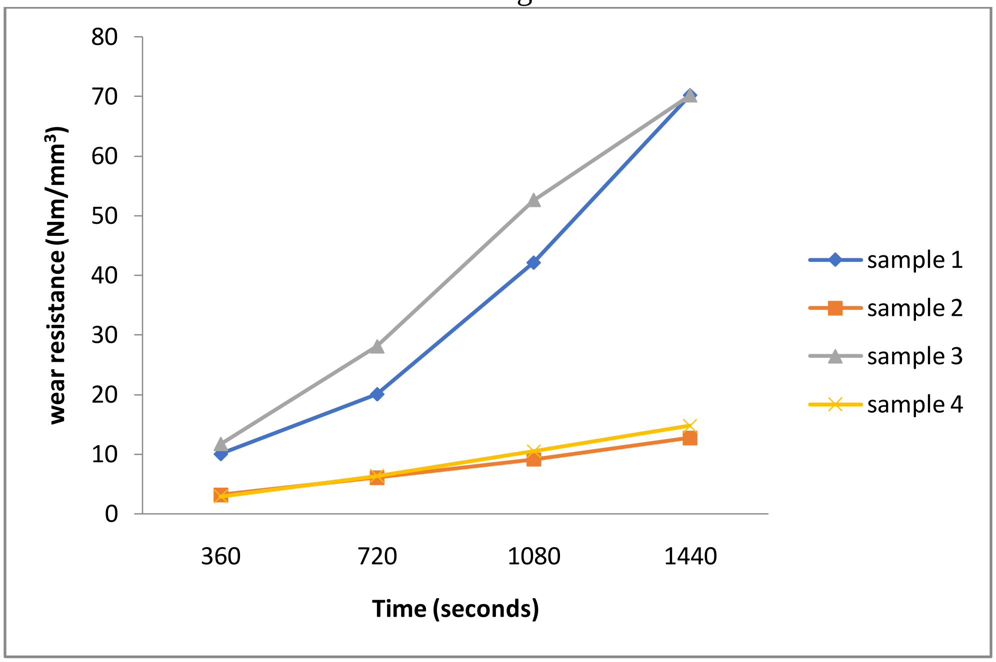

Figure 7: Wear resistance vs time

Low wear rate gives high wear resistance. It is observed from figure 5.20 that the wear resistance is maximum for third sample,thereby minimu wear rate of all tested specimen.Accordingly sample number 2 exihibits low wear resistance with maximum wear rate among tested specimen.Icrease in wear resistance can be attributed to increased amount of wear resisstant carbides and alloying elements in the base metal. Accordingly first and third specimen shows better wear resistance duue to increase amonut of Cr, V and Mo supplied by hardfacing alloy due to 3 layers of deposits as compared to sample 2 and 4 with only single hardfacing layer. Among sample 1 and 3,sample 3 performs marginally better due to low heat input result in lower dilution levels.

9.Conclusions

Hardfacing is a methodology used to improve surface characteristics for a material by depositing an alloy layer on base metal to improve the wear resistance. Wear resistance depends upon type of deposition method and alloy.hardfacing can be carried out by thermal spraying, welding and allied methodologies. Different hardfacing alloys are available to enhance the surface properties of materials for desired operating conditions such as abrasive resistance can be improved by chromium based alloys. Nickel and cobalt based hardfacing alloys can increase wear resistance and corrosion resistance at higher temperature working conditions. following conclusions were observed from test study for wear resistance

1. wear resistance increases with increases in hardfacing layers and decrease with increases in heat input.
2. wear resistance increasesby 78.45%,when hardfacing layers are increased from 1 to 3.
3. wear resistance decreases by 9.48%, with 13.33% increase in current.

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10.Future scope

1. The work can be carried out with other design techniques like fractional factorial design, Taguchi orthogonal array, Response surface methodology etc.
2. The effect of dilution on wear resistance can be studied with other hardfacing deposits based on titanium, nickel, cobalt, tungsten etc. alloys.

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