COMPARISON OF MICROSTRUCTURE AND WEAR RESISTANCE OF CR-TI-MO AND CR-V BASED HARDFACING ALLOYS FOR HIGH TEMPERATURE TOOL INDUSTRY

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Abstract— The adhesive and abrasive wear of cutting tools, drilling tools, mining equipments, piston rods, valves seats etc. can be decreased by the Shielded Metal Arc Welding (SMAW) of hardfacing alloys on their surface. A study has been undertaken to compare the wear resistance of Cr-Ti and Cr-Vanadium based hardfacing alloys as a function of Hardness, composition, Carbides formation and microstructure. According to the Optical and Scanning Electron Microscopy and ASTM G-77 & ASTM G-99 Standard wear tests, the results show that the formation of majorly $(Cr,Ti)_7C_3$ carbides in addition with (Fe,Mo,Ti)C in the Cr-Ti-Mo based alloy, has the greater wear resistance than the $(Cr, V)C_2$, $(Cr,V)_7C_3$ formation in Cr-V based hardfacing alloy. The formation of (Fe, Ti)C changes the microstructure of the coating alloy from hypereutectic to hypoeutectic which has greater wear resistance in comparison to hypereutectic and Eutectic microstructure. In addition to this, Cr-Ti based alloy shows the micro hardness up to 750 HV, where as Cr-V based alloy shows the micro hardness up to 650 HV. In addition to the wear resistance, Ti-Mo based alloy showed more resistance to erosion and galling by reducing the stacking fault energy of the matrix or being a hcp stabilizer. Initial observations showed the it has the potential to replace the expensive Tungsten and Cobalt alloys for high temperature wear conditions.

Index Terms— Hardfacing alloys, microstructure, Carbon Carbides, wear mechanism,

I. INTRODUCTION

Hardfacing alloys composition is affected by the different types of wear in different applications because of the elements' varying bonding strength and erosion rates.

There are many types of wears to be considered in the different applications naming a few like, adhesive wear (two metals surface in relative motion and in contact with each other under load), abrasive wear (hard surface move along the other under load), erosive wear (particulate impacts a surface causing material to be removed from the surface), fatigue wear (due to repeated motion and stressing by bearing load) and corrosion wear. Thus ASTM has developed many kind of standards Test Methods for the different types of abrasions, ASTM G76 (Erosion wear), ASTM G99 (Fatigue wear), ASTM G99-05 (Abrasive wear), ASTM G77-05 (Adhesive wear). For our appropriate results we have done ASTM G77-05 and G99-05 for metal-metal wear and metal-earth wear conditions.

There are many microstructures which influence the wear resistance properties of the specimen like, bainite, maternsite, ferrite, austenite, but carbides shows the best wear resistant properties, with in which the primary M_7C_3 or MC shows the maximum resistant to wear than completely eutectic structures. The further addition of elements like Molybendum, Titanium and Vanadium in high Chromium based alloys, increases the wear resistance and hot hardness properties. Vanadium exist in the form of $(VCr_2)C_2$ whose size changes from refinement to course. Whereas Titanium exist in the form of TiC in austenite which hinders the dendrite development. Molybendum plays a good role in early carbide formation.

For the microstructure characterization, the metallographic specimen is needed to be prepared by following five different steps: sampling, mounting, grinding, polishing and etching. Sampling is the proper selection of the specimen for the microstructure analysis. After the implication of hardfacing alloy coating by SMAW on the cast iron or S.S. plate, the specimen should be cut to desired size for mounting using a laboratory abrasive saw. And the hot mounting of the sample is carried out properly for the grinding and polishing. Grinding and polishing is carried out in an automated machine, for the proper speed (RPM) of wheel at 150-400RPM, and grinding is done with a 220 or 240 and 500 grit size SiC paper, which is followed by diamond polishing of 9 micrometer paste on a napless cloth, followed by 6 micrometer, 3 micrometer, 1micrometer and finally 0.25micrometer for the proper polishing. After every grinding step, specimen is cleaned by tap water. The final step etching is the most important step to be carried out to see the microstructure details. There are many etchants used, which depends on the composition of the specimen. There are different types of etchants for different composition and results, naming a few like Nital, Picral, Glycerigia, Beraha cdS, Murakami reagent, aqua regia, Beraha Martensite, Klemm 1, Molybdate reagent, Selenic acid reagent etc.

Fig. 1: Mounted and Polished Hardfacing alloy 1(Cr-Ti-Mo)

II. EXPERIMENTAL PROCEDURE

A. Welding Conditions and Material Composition

Two Hardfacing electrodes was developed, their respective composition has been given in Table 1. After extrusion of the electrodes, they were baked for 3-4 hours at 300°C. Then, Hardfacing is done on ASTM A36 Steel plate by Shielded metal arc welding (SMAW). The composition of ASTM A36 Steel plate is described in Table 2 and SMAW parameters in Table 3. Only One coating of each composition is applied on the different steel plates. SMAW was carried out normally, with no complication with adequate dilution rate and deposition rate.

Table 1: Chemical Composition of Electrodes

Approximate Chemical Composition (wt %)	Cr	Si	Ni	Mn	Mo	Ti	V	Fe
Hardfacing facing alloy 1 (Cr-Ti-Mo)	11%	0.75%	0.60%	1.60%	0.80%	3.80%	-	Balance
Hardfacing facing alloy 2(Cr-V)	8%	0.75%	0.60%	1.60%	-	-	5%	Balance

Table 2: Composition of ASTM A36 Steel Plate (wt%)

C	Si	S	Cu	P	Fe
0.25	0.4	0.05	0.2	0.04	Balance

Table 3: SMAW Process Parameters

Electrode	Current (A)	Voltage (V)	Speed(mm/min)	No. of Layers
Hardfacing alloy 1	120 A	20V	180-190	1
Hardfacing alloy 2	120 A	20V	180-190	1

Fig. 2: Mounted and Polished Hardfacing alloy 2(Cr-V)

B. Micro Hardness Measurement

Vicker's Hardness Test method was used to measure the micro hardness of the various microstructure phases of both the specimens, in accordance with the ASTM E384 Standard. Result of the test is showed in the Table 4 for

Cr-Ti-Mo based alloy and Table 5 for Cr-V based alloy. Specimen 1 shows the Micro Hardness up to 750 HV and Specimen 2 shows micro hardness up to 650 HV.

C. Metallography and Microstructure Characterization

Microstructure analysis has been done using the Optical and Scanning Electron Microscope (SEM). Both the specimens were properly mounted, and then they were were grinded and polished using 9 micrometer diamond paste on napless cloth, which was followed by 6 micrometer, 3 micrometer, 1 micrometer and 0.25 micrometer.

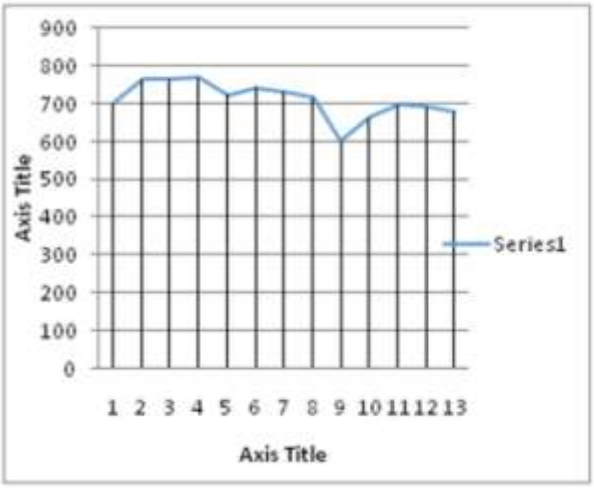


Table 4: Result of Vicker’s Hardness Test for Specimen 1, micro hardness is in HV.

Mounted and Polished Specimen 1 and Specimen 2 are shown in Fig. 1 & Fig. 2 respectively.

Specimen 1(Cr-Ti-Mo Based alloy) was etched with 2ml HCL , 0.5 ml selenic acid and 100ml Ethyl Alcohol for 5 minutes.

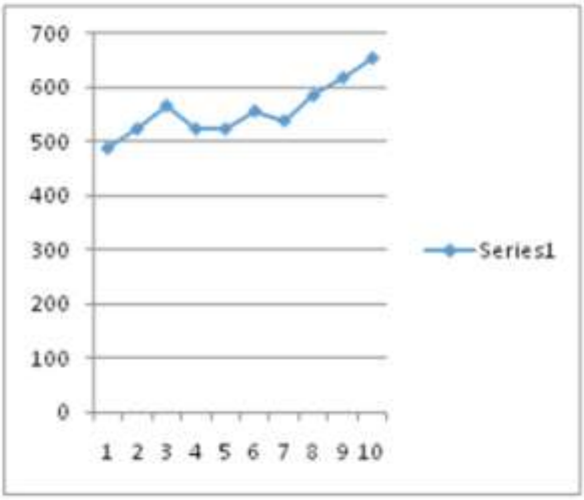
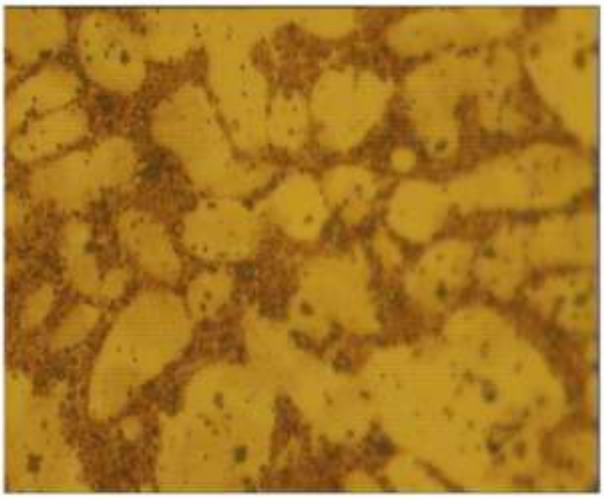


Table 5: Result of Vicker’s Hardness Test for Specimen 2, micro hardness is in HV

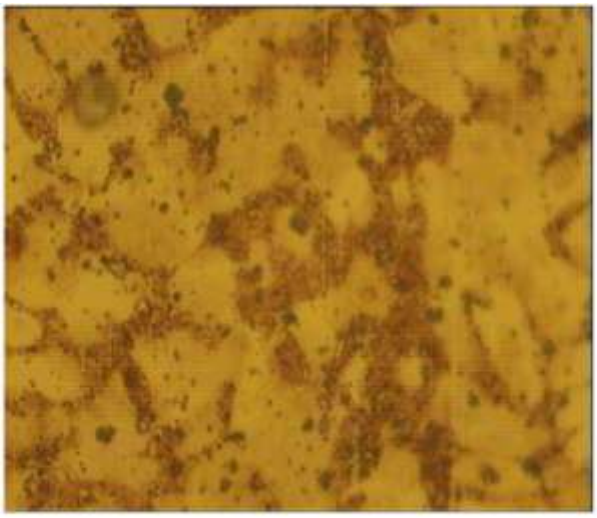
Specimen 2 (Cr-V Based alloy) was etched with 50ml of Sodium Thiosulphate and 1 gram of Potassium metabisulfite for 70 seconds.Different carbides formation could be easily recognized from the Microstructure and further types of structures have been described in the following figures.

Fig. 3: (a)



(b)

(c)

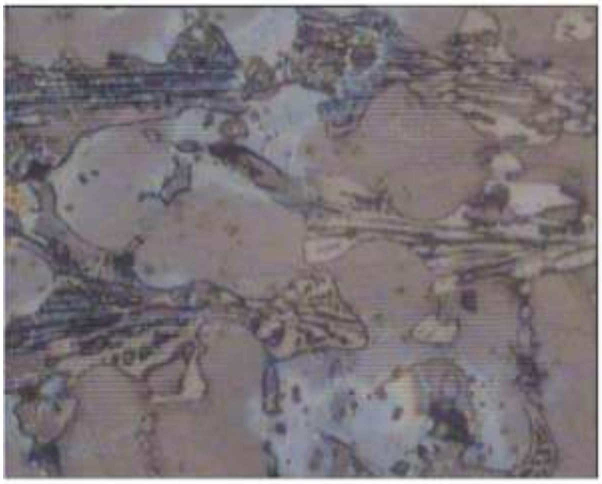


(d)

(e)

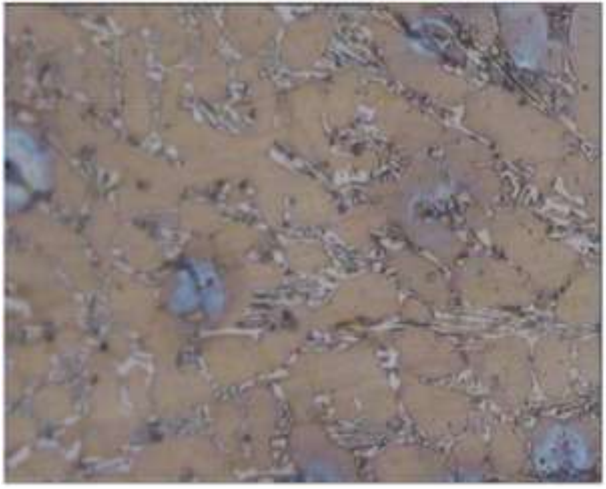
Fig. 3: Hardfacing microstructures of Specimen 1(Cr-Ti-Mo) a: 50x view shows the (Cr,Ti)C carbide formation in large yellow spots, b: 50x view shows the MoC carbide formation in small green spots, c: 20x view shows the dendritic microstructure formation. d & e: 10x view shows the dendritic growth at the base metal and welding boundary.

Fig. 4 (a)

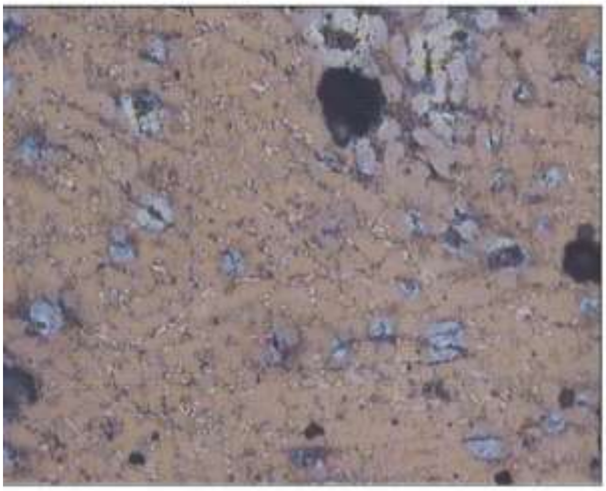


(b)

(c)



(d)



(e)

Fig. 4: Hardfacing microstructure of specimen 2(Cr-V)

a: 100x view shows the $(Cr,M)_7C_3$ carbides formation in large white spots with black linings, b: 100x view shows the $(V,Cr_3\ M)C_2$ carbides in small patches. c: 50x view shows the $(Cr,\ V)_7C_3$ carbides and $(Cr,\ V)C_2$ carbides. d & e: 20x view shows the presence of other alloying elements like: Si, Mn and Ni

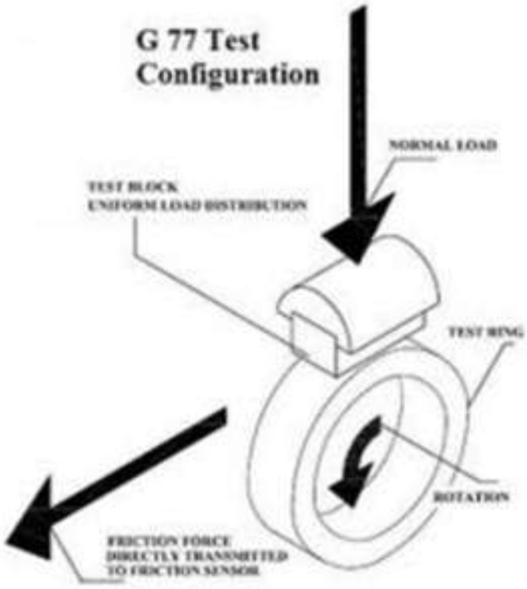


Fig. 5: Schematic of the Block on Ring Test Method, ASTM G-77 Standard method.

Wear Test

ASTM G-77-05, Block on the Ring Method, standard test method was carried to do the wear testing both the samples.

Standard testing parameters (Speed of Ring and Normal load applied) along with the dimensions of Block (Specimen) and the ring has been specified in the Table 6. Fig. 5 shows the schematic of the Block on Ring Test Method.

Before starting the test, specimen was cleaned in an ultrasonic bath and then rinsed in the methanol solution.

Another ASTM G99-05, Pin on Disc Method, standard test method was carried to do the wear testing both the samples.

Standard testing parameters (RPM of Pin & Disc and Normal load applied) along with the dimensions of Pin and Disc has been specified in the Table 7Fig. 6 shows the schematic of Pin on Disc method.

The results were determined by the weight loss with 0.1 mg resolution of both the samples in the above mentioned two standard tests. And it was found out that Cr-V based alloy sample has approximately 15% more weight loss than the Cr-Ti-Mo based alloy sample. Thus clearly showing the

	Ring Speed	Normal Load	Ring O.D.	Block Length	Breadth	Width
Hardfacing alloy 1	1m/s	25N	35 mm	15.75 mm	1mm	6.35 mm
Hardfacing alloy 2	1m/s	25N	35 mm	15.75 mm	1mm	6.35 mm

Table 6: ASTM G-77 testing parameters and Standard ring & block dimensions

	Disc RPM	Normal Load	Pin Dia	Disc Thickness	Disc Dia
Hardfacing alloy 1	80 RPM	20N	5mm	5mm	50mm
Hardfacing alloy 2	80 RPM	20N	5mm	5mm	50mm

Table 7: ASTM G-99 testing parameters and Standard dimensions of Pin and Disc

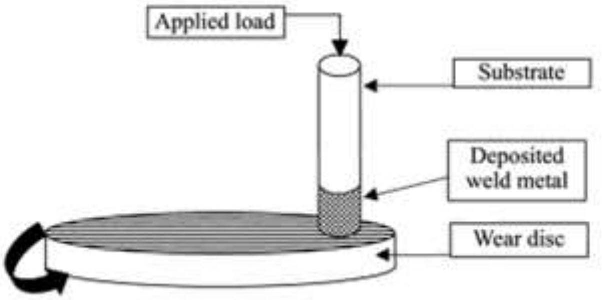


Fig. 6: Schematic of the Pin on Disc Test Method, ASTM G-99 Standard method.

Better ear resistance of specimen 1.

III. RESULTS AND CONCLUSION

Microstructure:

Microstructure of Specimen 1(Cr-Ti-Mo based alloy), etched with 2ml HCL, 5ml Selenic Acid and 100ml Ethyl Alochol for 5min., the images clearly shows the formation of (Cr,Ti)C formation in 50x view, while the minor spots shows the

presence of other alloying elements like Si, Ni, Mn, S. Initial images shows the high Chromium rich spots, which has the eutectic microstructure. Small green spots shows the formation of MoC in the second image. 20x view of third and fourth image, shows the dendritic microstructure growth due to the Chromium carbide formation, and it can be observed that there is a transformation of eutectic microstructure to hypoeutectic microstructure due to the formation of Titanium carbides. This dendritic growth at the boundary of weldment and base metal increases the bond strength which further helps in wear resistance.

Micro Structure of Specimen 2(Cr-V based alloy), was etched with 50ml of Sodium thiosulphate and 1gm of potassium metabisulfite for 60 seconds. Images clearly shows the formation of Cr_7C_3 and $Cr_{23}C_6$ carbides in the initial images of 100x and further images shows the $(Cr,V)C_2$ carbides formation in the small patches. These microstructure has the proeutectic structure, where hardness value is in between 450-550 HV. And further images of 50x and 20x view shows the presence of other alloying elements in very finite colored spots.

Wear Resistance:

Both the Block on Ring and Pin on Disc ASTM standard wear test method have shown that hardfacing alloy based on Chromium-Titanium and Molybendum has greater wear resistance than hardfacing alloy based on Chromium-Vanadium.

Presence of rich M_7C_3 coarse structures carbides in the specimen 1 reduce the chances of cutting and grooving in addition to it, presence of MC prevents the removal of M_7C_3 which enhances the wear properties and reduces the metal removal rate.

Thus it can be concluded that wear resistance of any hardfacing alloy depends majorly on the types and distribution of carbides and their microstructure matrix. And it further influences the Hardness and other mechanical properties.

IV. REFERENCES

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