Effect of 7016 Electrode on Hardfacing Welding

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Abstract— In this paper it is shown that some problems related to Welding arises because of ineffective way of doing Hardfacing welding, due to which cracks, porosity and also life of weld is reduced. Here environmental condition also plays vital role in Welding Process. The correct hardfacing welding work is progressed by using the Hardfacing electrode such as E7016 and E7018 electrode with the help of using effective Hardfacing welding and environmental condition. Different Samples of MS2062 Plates with 1 layer, 2 layer, 3 layer of E7018 electrode and also the sample with base layer of E7016 weld electrode and above that three layers of E7018 welding electrode were prepared for testing the properties of materials. The following tests were done such as Hardness test, Bend test, Chemical analysis, micro structural and wear test. The results were found as, The hardness is maximum in sample B followed by sample A3, sample A2, sample A1 and Base metal. Mass loss is minimum in sample B followed by sample A3, sample A2, sample A1 and Base metal. The wear vs time graph has been shown in Fig. It presented the wear of all samples for duration of 10 minutes. The wear was minimum in sample B followed by sample A3, sample A2, sample A1 and Base metal.

Keywords: 7016 Electrode, Hard Facing Welding

I. Introduction

Hard surfacing is the deposition of a special alloy material on a metallic part, by various welding processes, to obtain more desirable wear properties and/or dimensions. The properties usually sought are greater resistance to wear from abrasion, impact, adhesion (metal-to-metal), heat, corrosion or any combination of these factors. A wide range of surfacing alloys is available to fit the need of practically any metal part. Some alloys are very hard, others are softer with hard abrasion resistant particles dispersed throughout. Certain alloys are designed to build a part up to a required dimension, while others are designed to be a final overlay that protects the work surface [1].

Hardfacing is a commonly employed method to improve surface properties of agricultural tools, components for mining operation, soil preparation equipments and others. An alloy is homogeneously deposited onto the surface of a soft material (usually low or medium carbon steels) by welding, with the purpose of increasing hardness and wear resistance without significant loss in ductility and toughness of the substrate. A wide variety of hardfacing alloys is commercially available for protection against wear. Deposits with a microstructure composed by disperse carbides in austenite matrix are extensively used for adhesive applications and are typically classified according to the expected hardness. Chromium rich electrodes are widely used due to low cost and availability; however, more expensive tungsten or vanadium rich alloys offer better performance due to good combination of hardness and toughness. For metal to metal sliding or rolling, where wear is mainly due to sub-surface fatigue, oxidation and adhesion, materials with carbon content between 0.1and 0.7 wt.% and up to 20% alloy (Cr, Mn, Mo, W and/or V) are usually employed. Several welding techniques such as oxyacetylene gas welding (OAW), gas metal arc welding (GMAW), shielded metal arc welding (SMAW) and submerged arc welding (SAW) can be used for hardfacing. The most important differences among these techniques lie in the welding efficiency, the weld plate dilution and the manufacturing cost of welding consumables. SMAW, for example, is commonly used due to low cost of electrodes and easier applications [2]

Among the different wear mechanisms, mild oxidative is characterized by the formation of oxide layers on the sliding surfaces between two pieces, which strongly influences wear behaviour. In the initial stage of sliding process a severe wear occurs and opposed surfaces achieve conformity. An area of actual contact, considering of several large plateaus, is established. Given sufficient frictional heating the contacting plateau oxidize preferentially. Oxide islands are developed on this surface carrying the external load. Therefore, the plateau grows in height. In the course of many passes this increase in height is spread over the whole contacting area. Beyond a critical oxide film thickness, the plateau becomes unstable and breaks up to form wear debris. The above description cycle starts again and the oxidative wear mechanism advances. This wear mechanism could be operative in a range of service conditions, where low loads and slow velocities are characteristics.

The present investigation aims to study the effect of multilayer hardfacing in terms of their chemical composition, microstructure, microhardness and metal-metal wear resistance of ASTM A36 low carbon steel weld deposits produced with iron based hardfacing electrodes. In this paper we have shown that how the presense of 7016 Electrode matters. This electrode 7016 is a low hydrogen, all position electrode used for welding heavy duty steel structures and plates. This electrode provides excellent arc stability and produces X-ray quality weld deposits with higher crack resistance, elongation and ductility than other mild steel electrodes. 7016 yields a beautiful bead appearance with easy slag removability. Typical applications would include strength members of ship hulls, rolling stocks, machinery, bridges, free-cutting steels, hi-sulfur steels and medium carbon steels [3].

II. Literature review

A.

The hardfacing using submerged arc welding with additional metal powder has been a new way to extend the service life of the machine parts related to several wear mechanisms. Therefore, this research aims to compare the welding parameters of submerged arc welding which welded with martensitic steel wire without additional powder and low carbon steel wire with and without additional powders added to the weld metal. Then the macro and microstructure, chemical composition, welding dilution and the hardness of the weld metal were studied. The results presented that the weld metal of martensitic steel wire without additional powder showed martensitic and austenitic microstructure. Using low carbon steel wire without additional powder showed ferrite and pearlite microstructure. While the welding with additional powders, the microstructure depends on the type of metal powder used. These microstructures consist of ferrite with dense pearlite and ferrite mixed with martensite. In addition, it was found that the addition of metal powder to the weld metal reduced the dilution and increased weld metal hardness. However, both the microstructure and the hardness of the weld metal with powder addition are different from those of the weld metal welded with martensitic steel wire without powder addition.

This study investigated the bead on the plate onto low carbon steel plate (SS400 steel) for base metal (BM) which is 50.8 mm wide, 203.2 mm long and 9.5 mm thick. The welding using AC/DC inverter power source Esab Aristo 1000 AC/DC SAW with the universal welding automat Esab A2 Multitrac A2TF twin-wire submerged arc welding machine. The welding using two types of wire electrode consists of martensitic steel wire and low carbon steel wire with a diameter of 2.4 mm. During welding, high basics flux was used to cover the arc. The welding condition using martensitic steel type wire without additional powder was named MA. The welding using low carbon steel wire without powder was named FE, while the welding of low carbon steel added ferrocarbon powder was named FE-C. The welding filled ferrochromium additional powder was named FE-CR and the welding was filled both the ferrocarbon and ferrochromium additional powder was named FE-C-CR. Tables II and III show the chemical compositions of the welding wires, additional powders, and flux.

The results show that the additional powder added to the weld metal influences the metallurgical properties and mechanical properties of the welding metal. This can be summarized as follows:

1) The sample welded with martensitic steel wire without powder addition has martensitic and retained austenitic structure with high hardness and the high percentage of welding dilution as well.
2) The sample of low carbon steel wire without powder addition has ferritic and pearlitic structure and shows the highest welding dilution.
3) Ferrocarbon and ferrochrome powder can be used as alternative materials to improve the properties of the weld metal obtaining high hardness. [4]

B.

In this paper, a good welding performance of submerged-arc hardfacing flux-cored wire has been developed to repair surface of the roll, and the microstructure, degree of hardness and wear-resisting property of its deposited metal samples are also investigated. It is found that the hardness of the hardfacing metal is homogeneously distributed and the microstructure is martensite, residual austenite and carbonitride precipitates. As a result, the hardfacing metal with homogeneous distribution of very fine carbonitride particles has a best wear-resisting property, which can significantly extend the service life of the roll. For each sample, the tests were carried out three times and their averages were taken for evaluation.

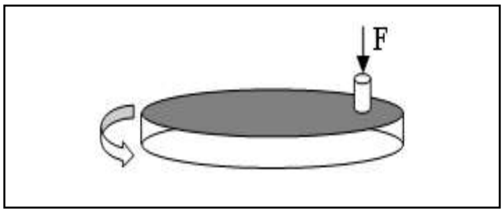


Fig. 1: Schematic illustration of the pin-on-disc wear tester

Conclusion: The microstructure of the hardfacing metal of it is lath-shaped martensite, the residual austenite and carbonitrides distributing on the grain boundary and the martensite bulk. The hardfacing metal with homogeneous distribution of very fine carbonitride particles has better wear-resisting property than the same type of material AISI410.[5]

III. EXPERIMENTAL PROCEDURE

A. Materials and Welding Process

We took two base metal sample plate of MS2062 and formed two samples. Sample A without 7016 base weld layer and in sample A we have 3 sub samples A1, A2, A3 which are one, two, three layer of 7018 weld electrode respectively. Sample B which has base layer of 7016 weld layer and above that three layers of 7018 welding electrode.

Fig. 2: sample A (A1, A2, A3)

Fig. 3: sample B

Material	MS2062
Length	200mm
Width	120mm
Thickness	10mm
Thickness of weld	15mm
Length of weld	120mm
Width of weld	50mm

The welding process was carried out by SMAW hardfacing welding method for improving the hardness of the material and improving the wear resistant property of the material. Here we have used MS 2062 as base material.

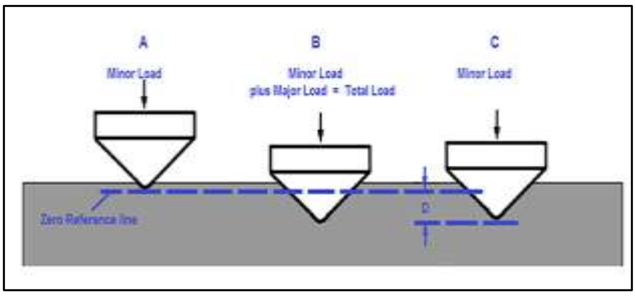
Machine used for the welding process.

Input Supply	415 +/- 15% V AC
Phase	THREE
Frequency	50 HERTZ
Maximum Installed Power	18.4 KVA / 23 HP
Duty Cycle	60%
Input KVA @ 60%	18.4 KVA
Input KVA @ 100%	13 KVA
Current @ 60%	400 AMPS DC
No Load Voltage	70 VOLTS DC
Current Range	20-410 AMPS D
CArc Force Range	20-200 AMPS DC
Power Factor	0.93
Insulation Class	H
Protection Class	IP-23
Efficiency	85%
Type of Cooling	FORCED AIR
Weight	31 Kg
Dimension	540*275*510mm
Recommended Electrode	4 mm

Fig. 4: Welding machine

B. Hardness Test

Test Method Illustration
A = Depth reached by indenter after application of preload (minor load)
B = Position of indenter during Total load, Minor plus Major loads
C = Final position reached by indenter after elastic recovery of sample material
D = Distance measurement taken representing difference between preload and major load position. This distance is used to calculate the Rockwell Hardness Number.



Rockwell Hardness Testing LoadsSheet metal can be too thin and too soft for testing on a particular Rockwell scale without exceeding minimum thickness requirements and potentially indenting the test anvil. In this case a diamond anvil can be used to provide a consistent influence of the result. [6]

C. Chemical Composition

Compound piece is the game plan, type, and proportion of particles in atoms of concoction substances. Concoction organization differs when synthetic compounds are included or deducted from a substance, when the proportion of substances changes, or when other synthetic changes happen in synthetics.

The concoction structure of a substance decides the intramolecular powers and properties of the substance. This implies the manner in which molecules are assembled in something decides the shading, thickness, quality, surface and different properties of the thing. Scientists can utilize tests to become familiar with the concoction structure of a substance, including a pH test, combustibility test, substantial metal test and so on.

Compound sythesis can be characterized as the course of action, proportion, and kind of particles in atoms of synthetic substances. It is the compound sythesis of a substance that decides the properties of the substance. [7]

1) Principle of Optical Emission Spectrometry

Optical outflow spectrometry includes applying electrical vitality as sparkle produced between a terminal and a metal example, whereby the disintegrated particles are brought to a high vitality state inside an alleged "release plasma".

These energized particles and particles in the release plasma make a remarkable emanation range explicit to every component, as appeared at right. Hence, a solitary component creates various trademark emanation ghostly lines.

Consequently, the light produced by the release can be supposed to be an assortment of the

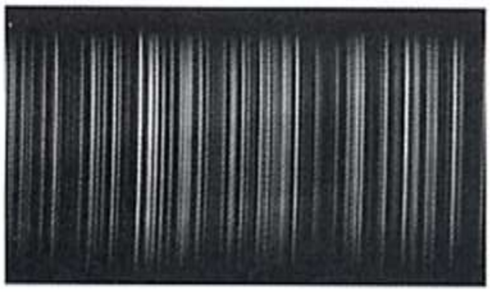


Fig. 5: sprectrum lines

Spectral lines ghostly lines created by the components in the example. This light is part by a diffraction grinding to remove the emanation range for the objective components. The force of every outflow range relies upon the centralization of the component in the example. Indicators (photomultiplier tubes) measure the nearness or nonappearance or nearness of the range extricated for every component and the force of the range to perform subjective and quantitative examination of the components. [8]

D. Bending Test:

The bend test is a straightforward and reasonable subjective test that can be utilized to assess both the pliability and adequacy of a material. It is frequently utilized as a quality control test for butt-welded joints, having the benefit of effortlessness of both test piece and gear. No costly test gear is required, test examples are handily arranged and the test can, whenever required, be done on the shop floor as a quality control test to guarantee consistency underway. The curve test utilizes a coupon that is twisted in three point bowing to a predetermined edge. The outside of the bend is widely plastically disfigured so any deformities in, or embrittlement of, the material will beuncovered by the untimely disappointment of the coupon. The bend test might be free framed or guided.

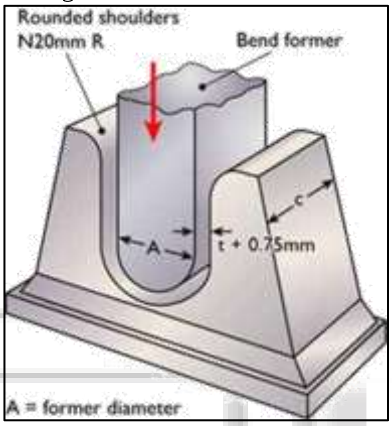


Fig. 6: a guided bend test jig that uses a male and a female former, the commonest form of equipment

Procedure:

1) Take a test specimen of the steel rod.
2) Measure the diameter of the steel rod. Take at least 3 readings and calculate the mean.
3) Now place the test specimen in the bending table specimen should be kept in the bending table in such a way that the plane
4) Intersecting the longitudinal ribs is parallel to the axis of the pin.
5) Select suitable rang of scale.
6) Start the machine and start applying load continuously and uniformly throughout the bending.
7) As the load is applied on the rod it will start bending.
8) Discontinue the application of load when the angle of bent specified in the material specimen has been achieved before rebound.
9) Take out the specimen and examine the tension surface of the specimen for cracking.

E. Wear Test

The wear test for all examples was done on pin on disc mechanical assembly. For ascertaining the wear rate, the examples were weighed when the wearing of a pin on the turning plate and the contrast between the underlying and last weight were determined. The weighing was done on a machine with a least check of 0.0001gm. The example was mounted oppositely on a fixed bad habit with the end goal that its one of the face is compelled to press against the spinning disc. The spinning plate must be harder than the pin tests which results to wear the outside of tests.

A standard example of barrel shaped shape having measurement (Length-30mm, Width 8mm) was removed from hardfaced plates and base metal additionally for metal-metal wear test (pin on disc) as appeared in The test was performed on wear and grinding screen TR-201 machine at welding metallurgy lab.

Fig. 7: Specimen Extracted From Hardfaced Plate

Applied load	30N
Speed	500 rpm
Disk diameter	100mm
Track diameter	60mm
Test time	10 minutes
Sliding velocity	1.57 m/s
Sliding distance	942 meters

F. Parameters for Wear Test

Hence wear loss, wear rate, and wear resistance have been calculated as

– Weight loss =Initial weight – final weight (gm)
– Wear rate = weight loss/test time (gm/hr)
– Wear resistance = 1/wear rate.

Wear rate was calculated by measuring initial and final weights of samples. Loss in weight was calculated for the running wear period of 10 minutes. Then the wear rate was calculatedperhour i.e. for 60 minutes from the loss of weight for 10 minutes.

IV. RESULT

A. Hardness Test

The course of the hardness of multilayer hardfacing by Iron based hardfacing electrode showed a strong effect of mixing the weld and base metal. The hardness of the cladding in its first layer in the area of melting rises sharply to an average value of 40HRC. The second layer reaches an average value of 45HRC, while in three layer hardfacing the hardness reaches around 53HRC. For all samples the course of hardness curves are formed by observations taken along and across the weld cross section.

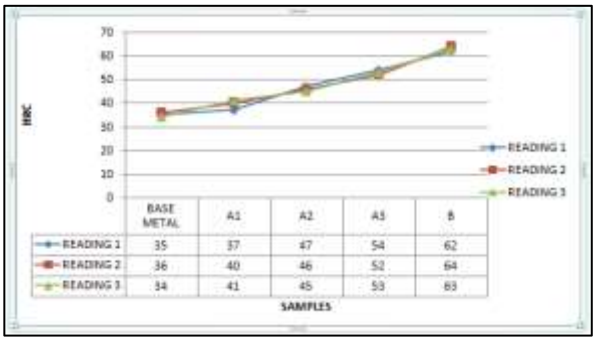
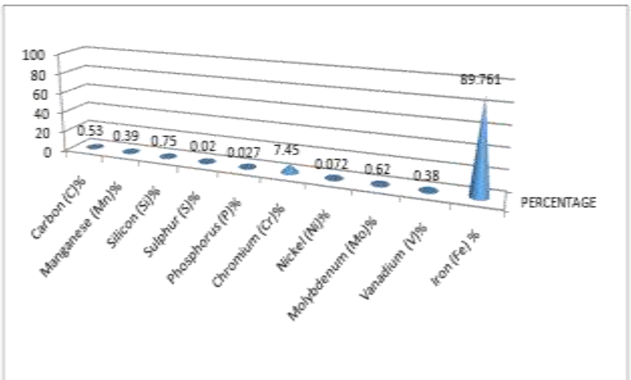


Fig 7: Hardness values graphical representation

B. Chemical Composition

The deposited material was a modified version with higher content of C and Cr and the addition of Si, Mo and V. these changes in chemical composition were designed to improve the wear behaviour of these deposits. As the number of layer increased, there were changes in chemical composition i.e. percentage of formation of carbides results in increase in hardness and improved wear. Sample C has been observed the highest weight percentage of C, Cr, and other alloying elements.



	Carbon (C)%	Manganese (Mn)%	Silicon (Si)%	Sulphur (S)%	Phosphorus (P)%	Chromium (Cr)%	Nickel (Ni)%	Molybdenum (Mo)%	Vanadium (V)%	Iron (Fe) %
PERCENTAGE	0.53	0.39	0.75	0.02	0.027	7.45	0.072	0.62	0.38	89.761

Fig. 8: Chemical Composition graphical representation

C. Bending Test

	Side Bend-1
Base Metal+ Weld Overlay(mm)	10.00+12.00
TotalWidth(mm)	22.00
Thickness(mm)	10.00
Former Dia.	4Xt
Position	180°
Remark	Unsatisfactory

Table 1: Side Bend Test Result

D. Wear Test

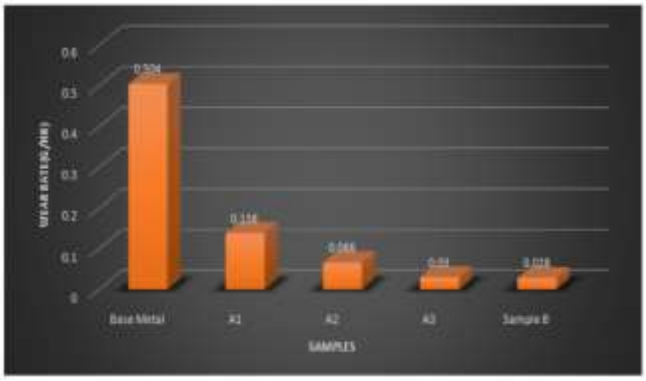


Fig. 9: Wear rate graphical representation

Wear rate was plotted on the graph against time in Fig 8 which shows amount of wear of a calculated interval of time of hardfaced deposits. Sample C has least wear compared to other.

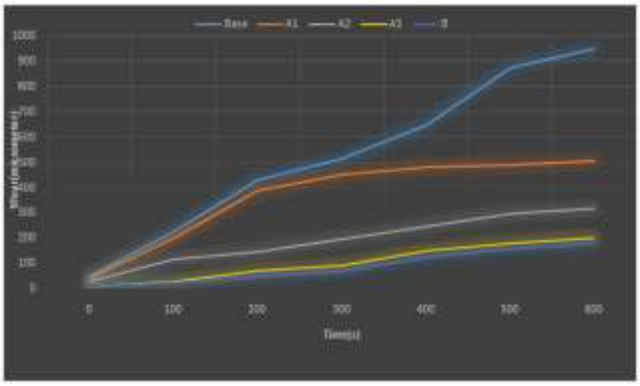


Fig. 10: Wear rate variations

This shows the presence of higher amount of Cr results in increased carbide formation which acts as barrier to the removal of material in wear, hence lower wear rate. Except Cr, other key elements Mo and V, this tends to increase in hardness. As the hardness increases, there is decrease in wear rate. Wear rate decreases with time and tends to stable.

Calculation of Wear Rate of Sample A:

- In 10 minutes sample losses weight = 0.0468
- For 1 minute sample will lose weight = 0.00468
- For 60 minutes sample will lose weight = 0.2808 (g/hr).

Samples	Initial wt. (g)	Final wt. (g)	Weight loss (g)	Wear rate (g/hr)
A	10.046	10.023	0.023	0.138
B	11.969	11.958	0.011	0.066
C	13.389	13.384	0.005	0.03
BM	9.107	9.023	0.084	0.504

Table 2: Wear Table

V. CONCLUSION

1) Mass loss is minimum in sample C followed by sample B, sample A and Base metal. The wear vs time graph has been shown in Fig. It presented the wear of all samples for duration of 10 minutes. The wear was minimum in sample C followed by sample B, sample A and Base metal.
2) We have found out that if base layer of electrode 7016 (low hydrogen) is used then the hardness value should increase and if the 7016 electrode base layer is not used then the hardness value is less compared to the previous.
3) Also if number of hardfacing welding layer is increased then there is increase in hardness value on the expense of increasing thickness.
4) Maximum hardness of 54 HRC is achieved in three layer hardfacing while 47 HRC in two layer hardfacing and 41 HRC in single layer hardfacing. Single layer hardfacing deposit shows epitaxial growth in the deposits. Two and three layer hardfacing samples shows a microstructure composed of martensite and retained austenite, with a pattern of dendrites segregation which became more refined. These changes result to increase in hardness.
5) The sample welded with martensitic steel wire without powder addition has martensitic and retained austenitic

structure with high hardness and the high percentage of welding dilution as well.

6) The hardness and wear values confirm the correctness of the principal that the maximal properties are not achieved by hardfaced materials until the third layer. For practical application it is necessary to execute the welding process with minimal melting of the base material and low heat input. All samples with low heat input exhibited high alloy content and high proportions of martensite and retained austenite results high hardness
7) In set condition of wear, the hardfacing made up to three layers seem more favourable. The tough martensite and retained austenite dispersely reinforced by a carbidic phase provides good resistance to adhesive wear. In terms of chemical composition and manufacturing technology, these hardfacing appear economical despite of replacing worn out parts by new one.
8) Minimum wear rate of 0.03 gm/hr is observed in three layers hardfacing followed by wear rate of 0.066, 0.138 and 0.504 gm/hr in two layer hardfacing, one layer hardfacing and base metal respectively. From these obtained result it is concluded that increase in number of layers results to decrease in wear rate due to increase in hardness.
9) The sample of low carbon steel wire without powder addition has ferritic and pearlitic structure and shows the highest welding dilution.
10) A nitrogen-alloying submerged-arc hardfacing flux-cored wire has been prepared through nitrogen replacing parts of carbon. By deposited it onto the substrate above two layers, the hardfacing metal with homogeneously distributed hardness can be got. And the microstructure of the hardfacing metal of it is lath-shaped martensite, the residual austenite and carbonitrides distributing on the grain boundary and the martensite bulk.
11) Based on the obtained results, it can be concluded that maximum results are achieved in three layers hardfacing in terms of high hardness and increased wear rate although there was not too much increase in hardness w.r.t. two layers hardfacing. Therefore only to achieve the desired maximum hardness, three layer hardfacing is allowed otherwise two layer hardfacing is better as per economical point.

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