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Experimental Analysis on The Effect of Manual Metal Arc Gouging Over 316 Stainless Steel

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Abstract :
As austenitic stainless steels have an adequate combination of mechanical properties, conformability and resistance to corrosion they are used in a wide variety of industries, Such as the shipping, food, transport, nuclear and petrochemical industries. Among these austenitic steels, 316 stainless steels have attracted prominent attention due to their excellent mechanical properties. Sea fastening welded structures, body making, maintenance and repairing, heavy vessels, dry docks using the technique of gouging for variety of purposes. Mainly most of the workers in this industry using gouging as a metal removal process, but it is using mainly for weld removal. Conventional cutting is a common method of metal removal and cutting. Evaluate the effectiveness of welded specimen after gouging and Conventional cutting by considering the mechanical properties, the surface topography and carbon deposition content. To verify which method is fruitful over chosen marine grade steel. , so we are taking AISI 316 stainless steel using in marine applications and gouging technique to find the best effective method over 316 stainless steel.

Keywords: Gouging,316 stainless steel, mechanical properties, CHN analysis , MMA Gouging.

Introduction

Gouging is a method used to melt or fuse metals in a narrow groove. There are four common gouging methods. They are mechanical, oxy-fuel, plasma arc and air carbon arc. Mechanical gouging is done through grinding and hand-milling and is widely used in metalworking shops. Oxyfuel gouging is performed using oxygen and fuel gas, while plasma arc gouging is an adaptation of plasma cutting. Indian shipping industry is heavily using this technique of gouging for various aspects. The main aim of gouging technique is the removal of welds. The gouging techniques mainly adopting in the shipping field are manual metal arc gouging and air carbon gouging. The removals of metals are commonly accomplished with the help of this technique.

The common cutting technique employed in our workshop and mechanical industry is conventional cutting. [1]

Types of Gouging

There are mainly four types of gouging

- Manual metal arc gouging(MMA)
- Air carbon gouging(ACA)
- Oxy fuel gouging
- Plasma arc gouging(PAC)

2.1 Manual Metal Arc Gouging (MMA)

As in conventional MMA welding, the arc is formed between the tip of the electrode and the work piece. MMA gouging differs because it requires special purpose electrodes with thick flux coatings to generate a strong arc force and gas stream. Unlike MMA welding where a stable weld pool must be maintained, this process forces the molten metal away from the arc zone to leave a clean cut surface.

The gouging process is characterized by the large amount of gas which is generated to eject the molten metal. However, because the arc/gas stream is not as powerful as a gas or a separate air jet, the surface of the gouge is not really as smooth as an oxyfuel gouge or air carbon arc gouge. [2]

Materials and Methods

3.1 Material Selection

316 stainless steel of the required dimensions and size prepared.The chemical composition of 316 stainless steel by (wt %) is given as Follows C-0.8, P-0.045, S-0.030, Si-0.75, Mn-2.00, Ni- 10-14, Cr-16-18 and N-0.10.

3.2 Preparation of Test Specimen

The test specimen for analysis of different mechanical and wear properties like toughness, hardness CHN analysis, micro structure evaluation, weld ability determination were prepared as per ASTM standard.

Mechanical properties results

4.1 Toughness Test

The test is conducted for the three welded samples of stainless steel previously cut using gouging and conventional cutting. The test consist of measuring the energy absorbed in breaking a 10mm×10mm×55mm ASTM standard notched specimen by giving a single blow by swinging hammer. The specification of charpy machine used for the toughness test of present work is as follows.

Weight of hammer = 21 kg
Angle of hammer striking e = 300 degree
Radius of curvature of striking edge = 2 mm

TABLE 1.
Toughness at Room Temp (N/m)

Metal	s/n	MMA KJ/cm^2	Conventional cutting KJ/cm^2
AISI 316	1	68.5×10^4	52×10^4
	2	67×10^4	52.7×10^4
	3	68.4×10^4	53.4×10^4

4.2 Brinell's Hardness Test

Hardness may be defined as resistance of metal to plastic deformation usually by indentation. However the term may also refer to stiffness or resistance to scratching, abrasion or cutting. Indentation hardness may be measured by various hardness tests like Brinell's, Rockwell's etc. The test is conducted for the three welded samples of stainless steel previously cut using gouging and conventional cutting.

Applied force (P) N = 187.5
Diameter of indenter (D) (mm) = 2.5

TABLE 2.
Brinell's Hardness Value

Metal	Method	Indentation Diameter (d)	Hardness Value
AISI 316	MMA	1.0mm	228.76
	Conven-tional cutting	1.1mm	187.23

Abrasive Wear Test

The material considered for this experiment is AISI 316 under room temperature with dimensions 4.0cm x2.5 cm x 0.5 cm. The materials are previously cut using the MMA

gouging and conventionally cutting techniques and welded with a 316EL electrode by arc welding. The test was conducted on a machine called Pin on disc machine. The sample was mounted perpendicularly on a stationary vice such that its one of the face is forced to press against the abrasive that is fixed on the revolving disc. Hence it is the abrasive paper that tends to wear the surface of the samples. When the disc rotates for a particular period of time, the sample can loaded at the top to press against the disc with the help of a lever mechanism. In this experiment the test can be conducted with the following parameters [3]

(1) Load
(2) Speed
(3) Time
RPM - 300
Time - 5 Minutes
Type of Abrasive - Emery, 80 grit size.
Hence wear volume, wear rate and wear resistance can be calculated as follows.

1. Wear volume:-
Wear volume = weight loss / density
Density of specimen AISI 316 = 7.99 g /cm3

2. Wear rate:-
It is defined as wear volume per unit distance travelled
Wear rate =wear volume / sliding distance(s)
Sliding distance (s) can be calculated as
Sliding distance (s) = V x time = (2 π R N / 60) x time
Where, R = radius of abrasive wheel (7.25cm)
N = R.P.M (300)
Π = 3.14 (constant)
Time = 5 minute = 300 S

3. Wear resistance:-
Wear resistance is a reciprocal of wear rate
Wear resistance = 1 / wear rate.

TABLE 3.
Wear Resistance of Conventional cut metal

Metal	Conventional cut at 14.7 N		
	s/n	Weight loss (g)	Wear Resistance, $cm^2 \times 10^{-7}$
AISI 316	1	0.22	0.248
	2	0.21	0.261
	3	0.21	0.261

TABLE 4.
Wear Resistance of Manual metal arc gouge

Metal	MMA Gouged at 14.7 N		
	s/n	Weight Loss (g)	Wear Resistance $cm^2 \times 10^{-7}$
AISI 316	1	0.18	0.303
	2	0.17	0.322
	3	0.19	0.288

6.0 CHN Analysis

CHN Analysis is a form of Elemental Analysis concerned with determination of only Carbon (C), Hydrogen (H) and Nitrogen (N) in a sample. The most popular technology behind the CHN analysis is combustion analysis where the sample is first fully combusted and then the products of its combustion are analyzed. Here 3.2 g of metal powder after three processes being analyzed to find out its carbon percentage, so that we can easily predict the weld ability nature of these metal after cutting using Dearden and o'neil table as follows.

TABLE 5.
carbon percentage and weld ability table

0.35	0.35-0.40	0.40-0.45	0.45-0.50	above 0.50

excellent	Very good	good	Fair	poor

TABLE 6
Carbon & Nitrogen percentage in metal powder

s/r	Powder(3.2 g)	Carbon %			Nitrogen %		
1	Conventionally Cut welded region	0.48	0.52	0.50	0.19	0.21	0.22
2	MMA gouged region	0.34	0.37	0.36	0.09	0.12	0.10
3	MMA gouged welded region	0.41	0.42	0.44	0.14	0.15	0.14

7.0 Surface Topography Study

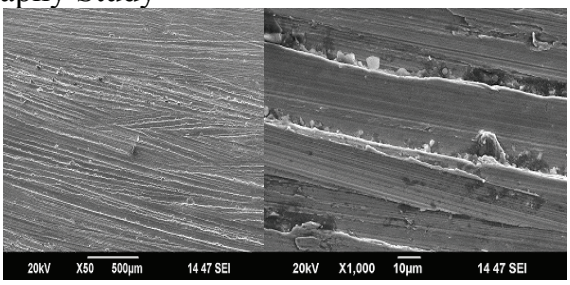

Fig1. Conventionally Cut region

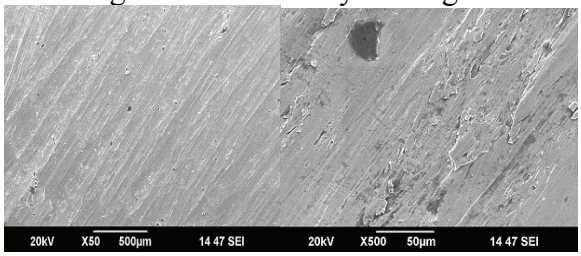

Fig 2. MMA Gouged region

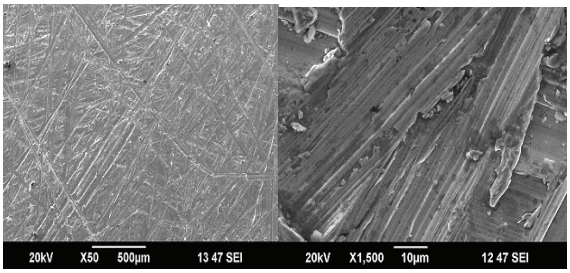

Fig 3. Conventionally cut welded region

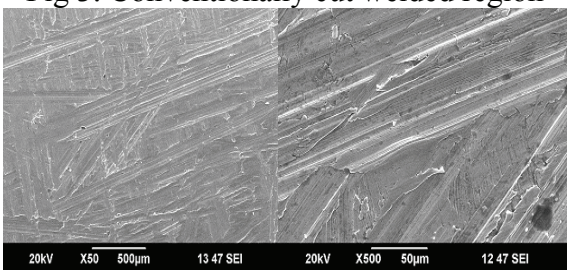

Fig 4. MMA Gouged welded region

Results and Discussions

8.1 Results of Toughness

1. At room temperature, the AISI 316 has more toughness at manufactures condition than that of the gouged and conventionally cut pieces.
2. MMA gouged welded pieces, has more toughness than that of the conventionally cut welded pieces.
3. AISI 316, the increase in room temperature may decrease the toughness value.
4. As from the Charpy results, the heat flow over the AISI 316 through various processes like metal cutting, welding, notch producing can decrease the toughness as compared to the manufactures condition.[4]

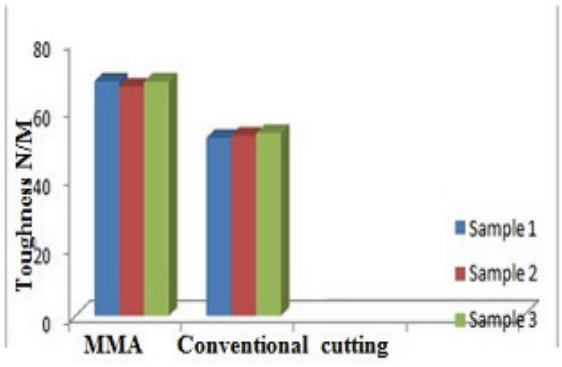

Fig 5. Toughness comparison of AISI 316

8.2 RESULTS OF HARDNESS

1. Hardness of the 316 stainless steel when welded after MMA gouging and conventionally, so from this it is concluded that the MMA gouging process has high hardness value
2. MMA gouged and conventionally cut welded metal shows a little higher hardness values than that of base metal.
3. MMA gouged welded metal having good resistance over deformation from indentation, scratching, cutting or bending

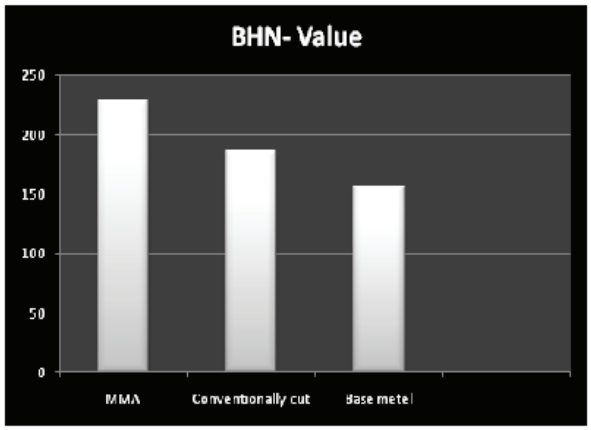

Fig 6. Hardness comparison of AISI 316

8.3 RESULTS OF CHN ANALYSIS

1. Determination of carbon in 3.2 gm of MMA gouged metal piece ranges from 30-40% & conventionally cut welded piece ranges from 45-55% for AISI 316 as from Dearden and O'Neal formula; the carbon ranges have a better control over the weld ability of materials.
2. For manual metal arc gouging, the carbon percentage ranges from 30-40% the metal piece can produce good weld, may be an excellent weld.
3. MMA gouged welded piece of AISI 316 is in a range of getting good weld
4. Low levels of nitrogen can produce porosity in weld metals. Conventionally cut welded region have more nitrogen% than that of the MMA gouged and MMA Gouged welded pieces.
4. If the carbon percentage is over 50%, the weld cannot be considered as a permanent nature. In conventionally cut welded pieces, the weld defect can occur in the form of incomplete penetration and blow holes usually due to the heavy percentage of carbon content, which may be up to 70% in most of the cases of various classes of steel.
5. For conventionally cut welded pieces, the carbon percentage ranges from 45-55%, the metal piece can produce fair weld, may be a poor weld.

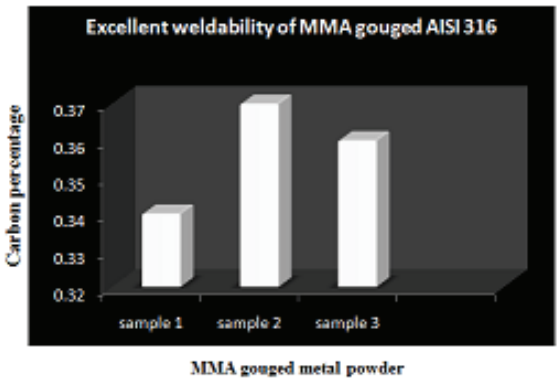

Figure 7. Excellent weldability of MMA gouged 316

8.4 RESULTS OF ABRASIVE WEAR TEST

1. Weight loss is maximum in abrasive test is for conventionally cut welded 316 and is lowest for Manual metal arc gouged
2. Temperature has also a great influence over the abrasive wear rate [5].
3. The wear rate is heavily depending upon the load applied, as the load applied increases, the wear rate increases linearly. Here to find out the optimized cutting the load is taken as 14.7. [6]
4. Manual metal arc gouged AISI 316 has higher wear resistance over emery, 80 grit size abrasive paper on the pin on disc apparatus.
5. From all the details, AISI 316 give the best results of wear resistance and Manual metal arc gouging gives the best wear resistance nature.

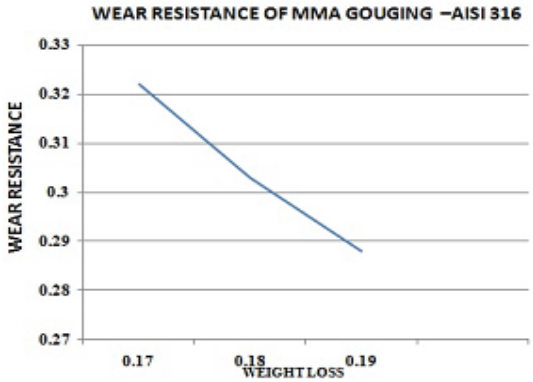

Figure 8. Wear resistance of MMA gouged AISI 316

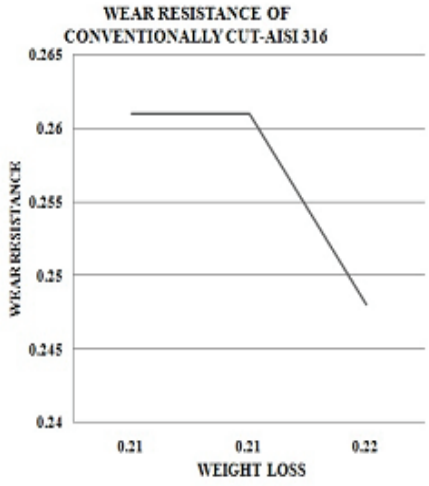

Figure 9. Wear resistance of conventionally cut AISI 316

8.5 RESULTS OF SEM IMAGES

1. The low magnified SEM images of conventionally cutting, shows porous gaps, cracks at the heat affected zone. The magnification at high levels showing the incompleteness in the metal cutting at the root level like non uniform metal edges segregates at the root level.

2. The conventionally cut welded metal piece at its heavy magnification showing the elasticity behavior prolongs in all magnification ranges.
3. MMA gouging of AISI 316 seems to be more precise, as from SEM images the surface roughness from visible eye is better. A few segregated patches of metal particles are seen on lower magnification. Despite of these facts, MMA gouged welding is best suited for AISI 316, stainless steel.

CONCLUSIONS

1. Stainless steel cutting can preferable with gouging technique, especially MMA gouging is the better cutting method as compared to conventionally cut.
2. Conventionally cut metals did not possess better weld as compared to the MMA gouging, because the carbon deposition percentage over the weld material is comparatively very high as compared to gouged metal pieces. So a better welding can be capable by gouged metal pieces.
3. As from the Charpy results, the toughness of MMA gouged cut metals has high value as compared to conventionally cutting methods
4. A material wear resistance rate is its main property for its prolonged use in various applications. Here even at a room temperature and for a common load, the wear resistance is more for MMA gouged and the material loss on the abrasive paper is less.
5. As from the Brinell hardness test results, the hardness of MMA gouged weld metals has high value as compared to the conventionally cut weld metal pieces.
6. The roughness and surface predictions of cut metals can be detected form the SEM

images. A clear and more finished cut is obtained from MMA gouged process. SEM images of conventionally cutting, shows porous gaps, cracks at the heat affected zone. The MMA gouging shows a better surface finish than the conventionally cutting process.

6. As a generalized conclusion, MMA gouging process is a better metal cutting process than conventionally cutting and from the experimental analysis and investigation. It can be more preferable to stainless steel grades; AISI 316 shows the clear indication of this.

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