Microhardness Characteristics of Preheat-Treated Welded Locally Produced Ductile Iron.

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ABSTRACT

In an attempt to study and evaluate the hardness characteristics of a welded preheated ductile iron, the specimen was heat-treated at various temperatures ranging between 100°C – 400°C over a consistence soaking period of 30 minutes per treatment; submerged arc welding (SAW) method was adopted for the joining and microhardness tester used to measure the hardness at a regular interval of 3mm from the fusion zone. From the results, it was observed that, ductile iron, when preheated before welding, have a significant improvement on the hardness property and thus broaden the scope of application.

(Keywords: SAW, submerged arc welding, microhardness, HAZ, PMZ, FZ, weld crack)

INTRODUCTION

Manufacturing processes entail the alteration of the form, shape and/or physical properties of a given material(s). It can be classified as formation or deformation of materials via joining mechanism thus altering the properties of the material. Welding has become a dominant process in manufacturing that involve two or more materials permanently joined together by coalescence, which is induced by a combination of temperature, pressure and other metallurgical conditions. An atomic bonding configuration is formed having a natural electron configuration between the two materials by bringing their surfaces together [4].

The objective of improving weldability may be achieved by either pre or post heat treatment, or both. To achiev**e** these objectives, researchers have attempted to vary some factors [1] to improve the mechanical properties like suitable welding speed and welding current which must be predetermined before welding. The main cause of welding quality problems is the high amount of carbon in the cast iron and the high cooling rates of weld operation which cause the formation of very hard and brittle structures. This makes the material susceptible to cracking upon cooling. To obtain a joint with minimal defects and controlled microstructure, and suitable mechanical properties would require suitable preheating and post weld heat treatment. This study, therefore, is based on the micro-examination of hardness across the welded sections of a pretreated ductile iron by fusion welding [3].

MATERIAL, EQUIPMENTS AND METHOD

Material used is ductile iron of chemical composition 93.52%Fe, 3.6%C, 2.5%Si, 0.007%P, 0.3%Mn, 0.01%S, 0.014%Mo, 0.05%Mg, shielded metal electrodes. A muffle furnace and a power saw were among the equipment used for preparing the materials for welding. The length, breath and height of the cast iron bar used was sectioned to rectangular cross section and measured to be 40mm, 10mm and 23mm respectively using a power saw with constant lubrication and a digital Vernier caliper.

Sample Preparation

The material was preheated at varying temperatures of 100°C, 150°C, 200°C, 250°C, 300°C, 350°C, and 400°C. At each preheating temperature, the samples were soaked for 30 minutes in order for the material to attain a homogenous temperature. This is necessary to avoid *weld crack* that could ensue should the material be weld from room temperature which will thus has adverse effects on the structure, mechanical properties and the performance of the specimen in any engineering applications.

Welding

The pretreated specimen was cut with the aid of a self-lubricating power saw to standard V-shape configuration. The two half was thereafter joined together by SAW method using ECI z308 electrode of a standard length [2] with composition as shown in Table 1. The welding was carefully done using ESAB-180 welding machine model to maintain the weld pass, speed and good quality as the weld quality of any material depend, among others, on the skill of the operator.

Table 1: Chemical Composition of the Electrode Used.

Material	Composition (wt %)
C	1.50
Mn	2.00
S	0.80
Ni	0.015
Si	94
Fe	2.0

Table 2: Welding Characteristics Adopted.

Weld speed	100mm/min
Current	170A
Electrode used	ECI z308
No. of pass	1

Microhardness Testing

A Leco LM-700$_{AT}$ microhardness tester was used to carry out the hardness evaluation. Prior to the operation, the specimen Surface was ground in a *Buehler Isomet* grinder/polisher using abrasive paper of grit 60, 240, 320, 400, 600, and 1200/2400µm sequentially in order to obtain a flat and smooth surface; polished with rayon fine polishing cloth to a mirror-like shiny surface. A flat smooth shiny surface was necessary to enhance a clear view of the structure and indentation. The polished specimen was placed on the anvil of the micro hardness tester, adjusted until a clear view of the surface structures were seen; start the machine for the indenter to form a diamond-like impression on the surface of the specimen. An indenting *load* of 490.3MN (~50.3 kgf) was applied over a *dwell period* of 10 seconds to create the indentation of the surface. The impression, which is later viewed with the aid of an inbuilt microscope, is then captured (both horizontally and vertically) with the aid of an attached camera and the hardness value of that point of indentation is digitally displayed. Several points on the surface of the sample were indented and captured (at every 3mm interval beginning from the center of the weld fusion zone), the average of all the measurements were then automatically calculated which gives the hardness value of the sample in consideration.

RESULTS AND DISCUSSION

Figure 1 shows the plots of microhardness analysis of the untreated and pretreated ductile iron before welding. The measurement was taken at an interval of 3mm starting from the center of the weld fusion zone in a digital displayed microhardness tester. For thorough comparison and comprehension, each of the plots was superimposed over the other and serves as a datum for the assessment of the other plots. The plot shows that the hardness of the weld fusion zone (i.e., center) increases as the pretreatment temperature increases. The reason for these expected increments is as a result of the absence of crack formation which could have ensued had it not be preheated. Detail of the hardness results is further shown in Table 3 and 4 (Appendix).

The results show that for all temperatures taken into consideration, the fusion zone possesses high hardness values with 200 and 250^{o}C possessing the highest values of 553HV each. As the tests proceed to the base/edge of the specimen, the values experience a sharp decrease in the hardness values; this is as a result of formation of cementite in the internal structure of the specimen. A sinusoidal gradual increment was observed in the PMZ as a result of the phase transformation that takes place in that region and the peak value was reached at the HAZ (sample treated at 100^{o}C).

In the overall (Figure 2), samples treated 150 – 250^{o}C before welding exhibited a significantly high microhardness values ranging between 474 – 543HV in comparison to the untreated sample that has a lesser hardness value of about 424HV. Like in medium carbon steel, the low hardness values recorded for the others (i.e., 100, 300, 350, and 400^{o}C) could result from the spheroidization and primary recrystallizaton which are dominant during welding [5] as a result of high carbon content.

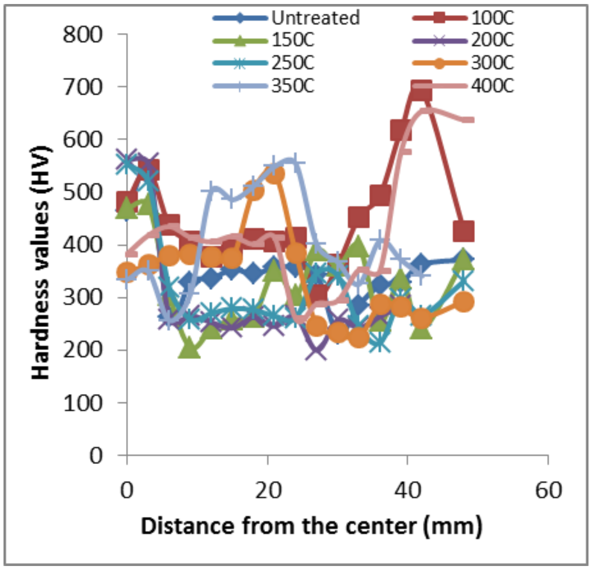

Figure 1: Variation of Hardness Values with Distance from the Center of the Welded Specimen at Various Temperatures.

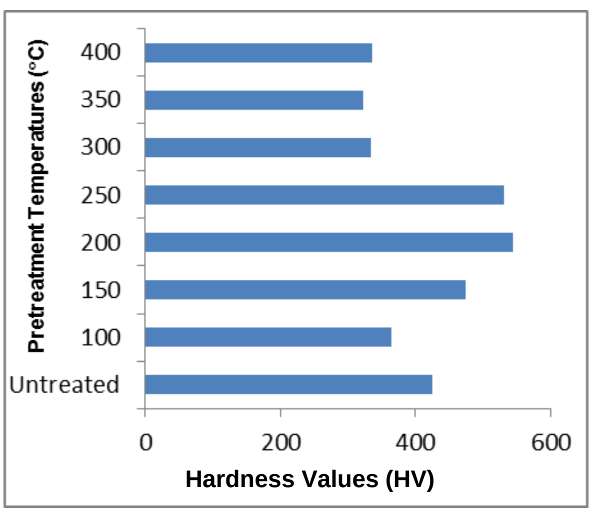

Figure 2: Summary of Hardness Values of Pretreated Ductile Iron at Various Temperatures.

CONCLUSION

In an attempt to study and evaluate the hardness characteristics of a preheated ductile iron, a muffle furnace was used to prepare the sample to an elevated temperature at various temperatures ranging between 100 – 400^{o}C; welded at that temperature and a microhardness tester was used to evaluate the hardness properties by measuring it at an interval of 3mm from the center of the fusion zone. From the results, it was observed that:

- Preheating at 400^{0}C before welding resulted in the formation of fewer hard structures in the FZ, UMZ, and PFZ, but having a high area fraction of the hard structures (martensite and carbides) at the HAZ.
- Preheating temperatures of 300^{0}C and 350^{0}C before welding produced a higher area fraction of hard structures in the PMZ and fewer hard structures in the FZ and HAZ.
- Preheating temperatures of 100^{0}C, 150^{0}C, 200^{0}C, and 250^{0}C, did not reduce FZ hardness relative to other zones.

The adoption of submerged arc welding on preheat-treated ductile iron using ECI z308 electrodes significantly enhances the hardness property of the material when compared to the untreated specimen.

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APPENDIX

Table 3: Variation of Microhardness Value (HV) with Distance from Center of Weld and Preheating Temperature.

Distance from center (mm)	PREHEATING TEMPERATURE							
	0°C	100°C	150°C	200°C	250°C	300°C	350°C	400°C
0	465.5	482.7	469.0	560.6	553.0	348.3	334.0	383.0
3	533.4	541.9	476.1	554.2	519.9	362.0	349.0	417.9
6	263.7	436.8	304.8	258.5	318.8	380.0	256.1	434.7
9	329.5	405.8	205.3	266.0	258.6	382.0	306.2	414.3
12	335.7	375.9	240.1	252.6	270.0	376.0	502.0	405.6
15	353.3	391.2	258.2	242.1	278.7	375.0	485.5	415.7
18	344.9	410.4	263	262.3	276.3	503.0	511.1	400.8
21	356.4	406.4	350.7	245.3	264.8	536.0	548.6	413.5
24	358.1	412.8	303.5	264.0	261.1	384.9	554.2	259.3
27	344.1	302.8	389.7	199.5	345.6	246.2	400.8	288.1
30	230.4	361.7	359.3	257.1	341.2	233.8	367.1	294.0
33	285.2	452.5	397.6	242.6	246.2	223.6	325.2	352.6
36	322.5	494	254.3	263.8	213.8	285.9	407.5	350.7
39	328.7	616.9	336.7	284.4	296.1	282.0	371.4	576.7
42	362.9	692.1	241		266.3	261.4	340.6	654.2
48	371.9	425.0	372.4		331.3	292.6		637.0

Table 4: Average Microhardness Values of Welded Preheat-Treated Ductile Iron.

Pretreatment temperatures (°C)	Average Hardness values
No preheat	424.10
100	364.60
150	474.70
200	543.55
250	531.62
300	334.00
350	322.67
400	335.77

SUGGESTED CITATION

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