Analysis of Welding Defects and Weldment Hardness of Wrought Iron in Manual Metal Arc Welding

Vijay Prakash Sharma[1] Lalit Kumar Sharma[2]
[1,2]Department of Mechanical Engineering
[1,2]BML Munjal University, Gurugram

Abstract— The manual metal arc welding defects on wrought iron having dimension 112mm x 75mm x 8mm with electrode E 6013 are determined by experimental survey and testing. So that we can obtain the better practices while welding the wrought iron. The hardness of the weldment is measured by Vickers hardness test. The welding defects are determined keeping in consideration reinforcement, penetration depth, porosity and bead width as crucial parameters. To measure the change in the hardness of the wrought iron weldment we took three work pieces and welded them at same voltage and varying the cooling temperature of weldment.

Key words: Manual Metal Arc Welding, Porosity, Hardness, Weldment, Weld Penetration, Bead Width, Reinforcement

I. Introduction

All around the world nowadays two metals can be easily joined with each other with the help of welding as compared to earlier days. Welding means joining of two metals with the help of heat or pressure. It finds a wide range of applications in all branches of the industries and construction. Welding is used to construct the structure in civil industries for example bridges, building etc. It is also used for the repair of the broken parts. Welding makes a permanent joint. This joint is very strong. Welding process is widely used in the manufacturing of automobile, aircraft, railways, etc. It is also used in the cutting process due to which it reduces the cost of expensive cutting. Metal arc welding is the most flexible fusion welding and one of the most widely used welding process. The weldments prepared by arc welding process generally offers good strength and hardness properties. The mechanical vibrations into the weld specimen during welding process improves weld joint properties significantly. In manual metal arc welding process an arc is generated between a coated consumable electrode and the work piece. The metallic core wire is melted by the arc and is diffused to weld pool. Slag is formed on the surface of the weld pool and slag is removed after welding. Butt welding is used to connect parts which are nearly parallel. It can be used to run a processing machine continuously as opposed to have restarted such machine with a new supply of metals. Butt welding is an economical and consistent way of joining process using supplementary components. Metal arc welding was performed on wrought iron. Steady state vibrations were produced and welding carried out in horizontal position. The indicators of quality welding technology are the absence or limited occurrences of such imperfections as melt-through, incomplete fusion, incomplete root penetration for a single-side butt joint weld, excess penetration, undercut, cold and hot cracking, excess weld metal etc. Most of these imperfections are caused by incorrect process parameters or an improper relationship between the parameters.

Such proof testing, however, is at high stress levels that is enough to produce plastic strain at regions in the vessel where mechanical stress concentrations exist, either because they are introduced by normal fabrication procedure or because vessel design incorporated such stress concentrations. In some cases this procedure is being designed specifically to produce such strains which is called pre stressing or over-stressing. In order to ensure against brittle fracture during the overstressing cycle, this is often done above ambient temperature and thus is known as "warm pre stressing." In evaluating warm pre stressing and proof testing procedures which concludes that beneficial effects for warm pre stressing have been demonstrated in a number of laboratory tests and, in principle, should have considerable value in enhancing the fracture capability of pressure vessels. On the other hand, proof testing is basically an inspection technique that provides only marginally small increments of information. It should also be noted that proof testing, if done at higher temperatures, constitutes a warm pre stress points out that the effectiveness of both procedures applies only to the extent that the sense and pattern of stressing reproduces those occurring in operational service, i.e. it is very difficult by pressure alone to attain stresses that match in magnitude and sense all of the operational stresses.

Use of warm prestressing has many advantages. It will accomplish not only a proof test but will also serve as a means of brittle fracture control. Indeed, in cases where thermal stress relieving of a completed vessel is not economical or practical, it has been suggested that mechanical overstressing should be used in place of thermal stress relief. Even in cases where overstressing does not replace thermal stress relief, traditional proof testing at levels high enough to produce plastic yielding will result in the same effect in terms of subsequent aging behavior. When a pressure vessel is placed in service where reliability is particularly critical, and flaw growth is known to be likely during operation, periodic proof testing of the vessel has sometimes been part of the operating plan. Thus repeated cycles of plastic straining and service are anticipated for such vessels.

At present, there are several methods of determining the parameters of the regime, but some of them do not allow you to quickly calculate the optimal welding parameters; others are too complicated for everyday use by welders. Considerable progress has been made in numerical simulation of the welding process. Today, many manuscripts describing numerical models of various kinds of welding have been published. However, just as the experimental method, numerical simulation requires considerable time to find welding parameters. Both methods determine an “allowable” range of welding parameters after experiments using the “trial and error” method, but there is no guarantee that the final range of welding parameters is optimal in terms of quality and productivity.

In addition, there are commercially available software systems that are designed to manage work pieces. The program helps the technologist only to fill tables with data manually. The "electrical information" includes welding parameters because welded joint quality is multifaceted. There are many criteria for determining it. Each such criterion estimates only certain areas of weld quality. For example, there are criteria that establish the geometric quality or strength of a joint. Other criterion describe the absence of defects such as undercuts, cold cracking and so on. Determination of optimal welding parameters in the case of multiple criteria is very difficult for mathematical solution. Joint quality has been critically assessed by exhaustively testing butt joints in elevated temperature for tensile stress rupture and high cycle fatigue. These tests have demonstrated that butt joint efficiencies of 70-90% can be developed in both cast and wrought nickel base super alloys that are extremely difficult to fusion weld. This represents an eight fold increase in strength over the strongest joints produced by conventional brazing with nickel base brazing filler metals. In the majority of brittle fracture causalities in welded structures it has been reported that the fracture initiated at a pre-existing or elongated weld defect or crack along the bond or in the weld metal rather than in the base metal. Sometimes the brittle fracture is influenced by the superposition of welding residual stress. In addition, the effect of super-imposition of residual stress on the increase in brittle fracture initiation temperature for various high strength steels was investigated theoretically by means of fracture mechanics concept. The objective of this investigation on wrought iron is to determine what changes occur in the heat-affected zone during welding. The heat affected zone was studied with reference to hardness, reinforcement, depth of penetration, bead width and porosity.

II. METHODOLOGY

A. Manual Metal Arc Welding

Manual metal arc welding was first invented in Russia in year 1888 which involves bare electrodes. As the coated electrodes were not developed at that time. In the early 90s the coated electrodes were being developed. But it was adopted slowly. Manual metal arc welding is a type of the metal arc welding which came under the fusion classification of welding. It works on the principle of the arc produced. The manual metal arc welding machine which is used in this work study is shown in the figure 1 as follow:-

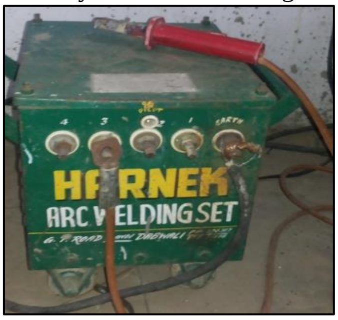

Fig. 1: Manual metal arc welding machine

In manual metal arc welding machine which is used in this study have five terminals out of which the right terminal is an earth terminal as shown in the figure 1. The remaining four terminals are used to supply the different current ranges according to our requirement. This machine uses an alternating current (AC) as a power source. The earth terminal is fixed and connected with a black wire as shown in figure 1. Red wire is also used, whose one end is connected with any one of the four terminals which can be changed as required and the other end is connected with the electrode holder. Manual metal arc welding is performed manually with the help of a welder. The technical specification of the manual metal arc welding machine which is used in this work study is shown in the table 1 as follow:

Welding Machine Model	Welding Current Range (amp)	Striking Voltage (V)	Duty Range	Welding Voltage	Primary Voltage (V)	Primary Current (amp)
2013	60-450	200-220 Single phase	55-58%	220 AC Voltage	200-220	60-90

Table 1: Technical specification of manual metal arc welding machine

When we performed the manual metal arc welding with the help of machine, then the polarity is not a concern because we have used alternating current as a power source. In which same amount of heat is produced on both work piece and electrode. Since the metal arc welding is performed manually by the welder, therefore it is known as manual metal arc welding process. In this welding there is no use of the pressure to complete the welding. No separate filler metal is used in this experimentation because the electrode itself acts as a filler metal. An electrode has the same composition as the metal have.

B. Working principle

The manual metal arc welding work on the principle of arc being produced. To produce an arc and to make a stronger joint, first clean the work piece because dust, rust, paint and other impurities are present on the material which has to be welded. Make proper connection with the electrode and the work piece with the machine and set it at required current range. The diagram of the arc welding process is shown in the figure 2 as follow:-

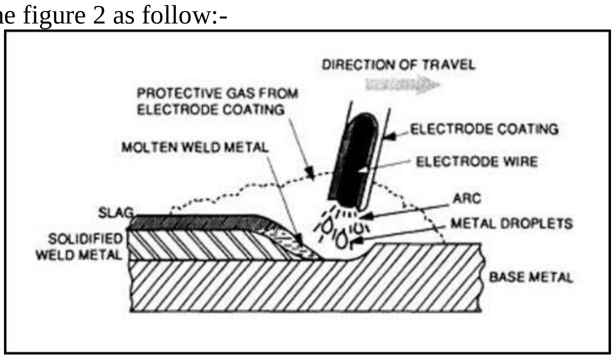

Fig. 2: Arc welding process

When all the connections are properly done and welding circuit gets completed then electrode was being brought near to the work piece at starting point. Now the arc is generated between the electrode and the work piece. When work pieces were brought together and separated by a distance 2 to 4 mm because the current start flowing continuously through a path of ionized particles and arc is produced. When the electrode strikes with the work piece, heat is generated and material starts melting. After completion of the welding process material gets solidified.

C. E 6013 Electrode

In this work we have used a consumable coated electrode. It is manufactured by the Mangalam Company and its coding is "E 6013". Where according to BIS coding 'E' represent its method of manufacturing i.e. solid extrusion method. The first digit represent the type of covering i.e. calcium carbonate and fluoride. The second digit represent the welding position i.e. horizontal, vertical or overhead. The third digit indicates the welding current condition which is given by the manufacture of electrode. So the welding condition of this electrode is D+, A 90. It means in direct current power source this electrode is connected with positive terminal and in case of alternating current power source the open circuit voltage is not be less than 90 V. The fourth digit indicates its mechanical properties such as tensile strength, approximate yield strength etc. So this electrode is held by the electrode holder. This electrode also acts as the filler metal because it is coated with the flux. It provides a protective slag over the hot metal. The slag is being removed when the welding process is completed. Due to the presence of the protective layer of slag, it slows down the cooling rate of weld and protects the work piece from hardening and cracking. The electrode is present in form of stick having length 300mm and diameter 3.15mm. When the welding is performed with this electrode then gases are produced, they make their own environment and protect the work piece from the oxidation reaction. This electrode is also used because it produced fewer spatters as compare to the bare electrode. It should be noted that both the peak temperature and the integrated time experienced by any point in the heat-affected zone, increases continuously as the distance from the fusion line is diminished. Therefore, if normal grain-growth behavior were experienced, the grain diameter should increase continuously as the distance from the fusion line diminishes.

Fig. 3: E 6013 electrode.

The coding system indicates some characteristics of the electrodes. The coding is printed on each electrode. Each coding consist of a prefix letter, a code number and in some cases one or more suffix letters. The coding system covers both classification (type of electrode) and specification (requirement of weld metal). The electrode used in this work is shown in figure 3 as follow:-

III. WELDING DEFECTS

Melting rate (resulting from selected welding parameters) and welding speed define the heat input. As it can be changed within certain limits, melting rate and welding speed do not limit each other, but a working range is created. If the heat input is too low i.e. too high welding speed, a definite melting of flanks cannot be ensured. Poor power results in lack of fusion. With too high heat input i.e. too low welding speed, weld pool starts to flow away in the area in front of the arc. This effect prevents melting of the base metal. The arc is not directed into the base metal but onto the weld pool and flanks are not entirely molten. Thus lack of fusion may occur in such areas. Compared with a neutral position, seam gets wider with a positive inclination together with a slight reduction of penetration depth. A negative inclination leads to narrower beads. The second part of the figure shows the torch orientation transverse to welding direction with multi pass welding. To avoid weak fusion between layers, the torch orientation is of great importance, as it provides a reliable melting and a proper fusion of the layers.

With a false torch orientation, perpendicular flank is insufficiently melted which results in lack of fusion. While welding I groove in two layers, it must be ensured that the plate is completely fused. The concentration of the melt exceeds the maximum equilibrium concentration which forms at the end of solidification and leads to a very much enriched crystalline solid whose melting point is considerably lower when compared with the firstly developed crystalline solid. Such concentration differences between first and last solidified crystals are called segregations.

IV. LITERATURE REVIEW

The various researches which are done in the related area are as:-

Kuang-Hung Tseng *et al.* [1], worked on 316 L stainless steel and studied the effects of arc welding on penetration depth and bead width. Appropriate solvent mixture was methanol and water with 60 and 40 percent respectively. Results shows that flux mixture not only improves joint penetration but also leads the uniformity of profile. Ronny M. Gouveia *et al.* [2] studied the effects of heat treatment on weldment of high strength ductile cast iron. Weldability of the material used was assessed in terms of weldment mechanical properties and changes in the structure before and after welding due to thermal cycle imposed. In the heat affected zone joints were successfully achieved and promising results were obtained. Wallin, J. G. *et al.* [3], investigated the effects of coated welding electrode on weld deposit in the welding of cast iron. Results shows that ductility, resistance to cracking and fracture toughness improved due to weld deposit composition. Weld deposit composition comprises Ni (54-

60%), Mn (3.5-5.5%), Carbon (0.9-1.4%) and Magnesium (0.3-4%) along with oxides and rare earth metals. Boob N Ajay *et al.* [4], performed their work on "study the effect of manual metal arc welding process parameters on the width of heat effected zone (HAZ) on MS 1005 steel". They investigated the width of HAZ with various process parameters like heat input and welding speed. In their work they selected a wrought iron specimen which have dimensions 125mm x 75mm x 5mm and performed manual metal arc welding and investigated effects on single V butt joint. After their investigation they found that because of coarsening of original austenite grain and formation of brittle microstructure are the main causes due to which the toughness in coarsened grain zone is decreased. Kumar Harish *et al.* [5], worked on "to study the corrosion characteristics of wrought iron under different atmospheric conditions by vapors phase corrosion inhibitors". Four different vapor phase corrosion inhibitors (VPCIs) i.e. N-N-Dimethyl aniline (DMA), Morpholine, Cyclohexyl amine and Hexamethylene amine were tested for wrought iron under different corrosive atmospheric conditions at 40°C by Weight Loss, Eschke test, Salt Spray and SEM techniques. All the four VPCIs show very high corrosion inhibition efficiency i.e. 96-98% toward wrought iron in different corrosive environment like high relative humidity, 3.0% sodium chloride and high temperature i.e. 40°C. Out of four investigated VPCIs, Cyclohexyl amine (CHA) shows best corrosion inhibition efficiency in different corrosive environment. Akpan. A. *et al.* [6], performed their work on the "inhibition of Wrought iron corrosion in hydrochloric acid solution by ciprofloxacin drug" which is eco-friendly and commercially available inhibitor. They studied their work at room temperature by weight loss technique. They found that the drug have a medium inhibitory action on the corrosion of wrought iron. The inhibition efficiency can be increased with an increase in the concentration of the inhibitor. Chen S. J. *et al.* [7], performed their study on "Gas Tungsten Arc Welding Using an Arcing Wire" in this study they completely melted the wire at high speeds without heat transferred from the weld pool. In the study it was found that a side arc is added into the gas tungsten arc between the wire and the same tungsten. In doing so the anode provide a gas metal arc welding melting mechanism to melt the wire at high speed. As a result, the deposition rate is increased and the ability to provide a desirable deposition rate and base metal melting freely. The analysis of this research suggests that the deposition speed can be achieved and the wire melting mechanism for arcing wire gas tungsten arc welding is similar as in case of the gas metal arc welding but the arcing wire in gas tungsten arc welding offers the arc controllability. Experimental data and comparative analysis suggest that the arcing process improves the weld controllability i.e. the ratio of the wire melting heat over the total heat input, from (0.25%) in hot-wire GTAW to (0.71%). Nik Wan B.W. *et al.* [8], performed their work "study the corrosion behavior of wrought iron in sea water which is taken from different sites by using the weight loss and potentio dynamic polarization test". They observed that there was a slight difference in the corrosion behavior. The first sample have higher corrosion rate and corrosion current densities (Icorr) because its corrosion potential (Ecorr) is negative. If there is small difference in sea water parameter then the corrosion behavior of wrought iron is same. Shukla. K. Ratnesh *et al.* [9], performed their experiments on "Comparative study of friction stir welding and tungsten inert gas welding process". Investigation has been carried out on microstructure, micro hardness distribution, tensile properties and fracture surface morphology of weld butt joints of 6061 T6 aluminum alloy. Two different welding processes were used in this study, conventional tungsten inert gas (TIG) process and an innovative solid state welding process known as friction stir welding (FSW) process. Micro hardness distribution results shows general decay of mechanical properties of TIG joints mainly due to high temperature experienced by the material. In FSW joint, lower temperatures are involved in the process due to severe plastic deformation induced by the tool motion and lowers decay of mechanical properties. In the nugget zone a slight recovery of hardness is observed due to recrystallization of very fine grain structure. Hence from industrial point of view FSW process is very useful as it saves energy, have higher tensile strength and prevents the joints from fusion related defects. Yarmuch R. A. M. *et al.* [10], performed their study on "Variable AC Polarity GTAW Fusion Behavior in 5083 Aluminum". To weld the aluminum alloy an AC power source is rarely used because it has maximum penetration when more than 50% of the AC cycle is spent on electrode negative polarity. Increased weld bead fusion, penetration and volume occur in gas tungsten arc welding of 5083 aluminum alloy as the electrode has positive polarity portion of the cycle. Frequency variations of the AC cycle between 20 and 240 Hz do not affect the fusion geometry dimensions. Lienert J.T. *et al.* [11], demonstrated the "feasibility of the friction stir welding (FSW) for joining of wrought iron". Peak surface temperature of the work piece measured is close to 1000°C. Thermocouple and infrared camera system tools were used during the welding. When they compared the change in dimension of the tool, then they observed that the greatest change in the dimension of the tool is in the initial stage. Microstructure of the welds is examined under the optical and electron microscopy. Measurement of temperature and microstructure tells that the peak temperature of the stir zone is exceeded to 1100°C and surpassed 1200°C.

V. EXPERIMENTAL SETUP

To perform the manual metal arc welding on wrought iron three work pieces were taken. The dimensions of work pieces are 112mm × 75mm × 8mm. The work pieces of the above dimensions being cut by using hand hacksaw. The diagram of work piece is shown in the figure 4 and the chemical composition of the wrought iron which is being used in this study is shown in table 2 respectively as follow:-

Fig. 4: Work piece of wrought iron

S.No.	Elements	Observations (%)
1	Carbon	0.240
2	Silicon	0.143
3	Manganese	0.453
4	Phosphorus	0.096
5	Sulphur	0.068
6	Chromium	0.011
7	Molybdenum	0.001
8	Nickel	0.001
9	Aluminium	0.001
10	Arsenic	0.003
11	Boron	0.0008
12	Cobalt	0.00
13	Copper	0.01
14	Niobium	0.004
15	Lead	0.004
16	Tin	0.00
17	Titanium	0.003
18	Tungsten	0.00
19	Vanadium	0.00
20	Iron	98.96

Table 2: Chemical composition of work piece

Now bring the manual metal arc welding machine near the work piece and connect it with the alternating current which is our power supply source. The two work pieces were brought near to each other. The work pieces were connected with earth terminal of the manual metal arc welding machine. The electrode E 6013 was held by an electrode holder. The three pieces were weld at same voltage and current. After this welding process was performed which is shown in the figure 5 as follow:

Fig. 5: Performing Welding

When the distance between the electrode and the work piece is between 2 to 4 mm an arc is produced. Once the arc is produced then move the electrode from top to bottom slowly to complete the weld. The diagram of the arc produced is shown in figure 6 as below:-

Fig. 6: Arc produced

Various parameters used during the welding process is shown in the table 3 as follow:-

Work piece	Temperature of Cooling Media		Current Range (amp.)	Work piece Dimension (mm)	Electrode Used	Voltage (V)
	Initial (ºC)	Final (ºC)				
8603	31	31	60 – 70	112 x 75 x 8	E 6013	220
8604	16	40	60 – 70	112 x 75 x 8	E 6013	220
8605	40	65	60 – 70	112 x 75 x 8	E 6013	220

Table 3: Parameters and current ranges

When the welding process on the three work piece (8603, 8604, 8605) gets completed, then the work pieces are being transported to other place because the work pieces have very high temperature just after the welding process. Work piece 8603 is being welded at room temperature and therefore its final temperature is same. So in order to cool work pieces no. 8604, 8605 we have to submerged it fully at the different containers having water at temperatures initially 16ºC and 40ºC respectively. The cooling process is an important factor which can affect the strength, hardness and other properties of the work piece or weldment. If the weldment is cooled at very low temperature just after the welding process, then due to suddenly decrease in the temperature of the hot weldment, cracking and other effects are produced in the weldment. When the work piece cooled, we remove the slag from the weldment which is occurring during welding process. The temperature rises in the containers are also obtain by digital thermocouple. The diagrams of weldments are shown in the figure 7 as follow:-

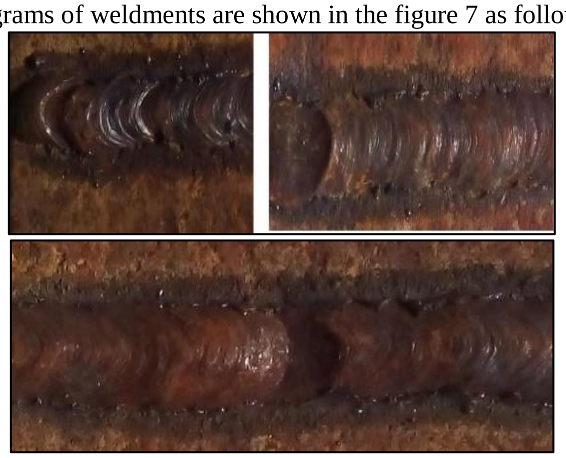

Fig. 7: Weldment of three work pieces

Now the manual metal arc welding process on three work pieces gets completed. We saw that various welding defects were produced. In developing a test program to study, it soon became apparent that uniform straining of a small flaw free specimen could not duplicate the mechanical effects that exist in the region at the tip of a sharp crack in a thick walled pressure vessel. The stress state conditions represented by this situation may indeed never be duplicated satisfactorily in any laboratory test. However, a simulation of this condition could be attempted by studying the behavior of a specimen which contained a sharp natural flaw. Now we can perform the Vickers hardness test on the wrought iron weldment to find that which weldments have highest hardness and how the temperature difference effects the hardness of the weldment.

VI. Result and Discussion

The defects on the various work pieces are listed below

Parameters	Observation of point 1 (mm)	Observation of point 2(mm)
Bead Width	8.1	9.8
Reinforcement	1.69	1.51
Penetration depth	2	1.80
Porosity	Nil	Nil

Table 4: For work piece 8603

Parameters	Observation of point 1 (mm)	Observation of point 2(mm)
Bead Width	10.11	9.57
Reinforcement	1.98	0.56
Penetration depth	1.05	2.20
Porosity	Nil	Nil

Table 5: For work piece 8604

Parameters	Observation of point 1 (mm)	Observation of point 2(mm)
Bead Width	10.79	9.94
Reinforcement	1.12	0.69
Penetration depth	0.77	2.03
Porosity	Nil	Nil

Table 6: For work piece 8605

These observations shows that the maximum bead width was obtain in sample 8605, the reinforcement and maximum penetration depth obtain at work piece 8604. No porosity was observed in any work pieces. After knowing the defects we performed Vickers hardness test on the weldment of entire work pieces to know the hardness. It is an indentation test which uses a calibrated machine to force a square based diamond pyramid indenter. The indenter have 136° angle between opposite faces. The technical specification of the Vickers hardness test machine is shown in table 7 as follow:-

Name of Instrument	Make	Load range	Model number	Instrument ID number	Calibration Agency
Micro Vicker hardness tester	LECO	10gm. – 1 Kg	LM-300AT	HL/MET/001	CANAN

Table 7: Technical specification of Vickers hardness testing machine

In above table we have shown you the various technical specification of Vickers hardness testing machine which we used to find the hardness of the entire weldment. The diagram of the Vickers hardness testing machine is shown in figure 8 as follow:

Fig. 8: Vickers hardness testing machine

The machine shown in the above figure is used to know the hardness of the entire work pieces weldments. All the readings were obtained when we applied 1Kg load on the entire work pieces weldments. To find the hardness of the weldment of entire work piece, first off all we select a sample (whose hardness is determined), then from the weldment area of the sample we cut a small piece. Now the cutting weldment piece is placed in the mould of the machine and load of 1Kg is applied on the weldment piece and we get the reading of the weldment hardness. In similar way the process is applied on the other weldment pieces to get their hardness. The various readings obtained after performing the Vickers hardness test are shown in table 8 as follow:-

Sample	Work piece dimension (mm)	Temperature of Cooling Media		Material used	Vickers hardness
		Initial (°C)	Final (°C)		
8603	112 x 75 x 8	31	31	Wrought iron	164.7HV 5
8604	112 x 75 x 8	16	40	Wrought iron	173 HV 5
8605	112 x 75 x 8	40	65	Wrought iron	170 HV 5

Table 8: Vickers hardness test readings

The various reading of the Vickers hardness test which we are obtained on all the work pieces weldments shown in the above table. The reading on the first work piece (Sample 8603) weldment indicates that the hardness obtain by vicker hardness test is 164.7HV5 is minimum hardness obtain in comparison to the various temperatures as in case of sample 8604 at temperature 16ºC and sample 8605 at initial temperature 40ºC. Hence the best vicker hardness number is obtain at sample 8604 having the value173HV5 and a moderate value of the vicker hardness number is obtain at temperature sample 8605 initially at 40ºC as170HV5 173. The readings on the entire work pieces shown in table 8 are obtained for 1 N force. This is the result of hardness which we are obtaining for the entire weldment of wrought iron.

VII. CONCLUSIONS

After completing the manual metal arc welding process and Vickers hardness testing process on wrought iron work pieces, we came to the conclusion that welding of a wrought iron work piece having dimension 112mm×75mm×8mm with manual metal arc welding having electrode E 6013 the current range of 60-70 amp, having initial temperature at 16ºC and final temperature at 40ºC give the best hardness of weldment. If we increases the cooling temperature of the weldment the hardness number varies moderately and more ductile form of weld is obtain at higher cooling temperatures.

As a scope of future work, this study can be extended by considering other parameters like different electrodes, welding machine, method of cooling, current range etc. and measure the effect on the hardness of the wrought iron weldment. The other mechanical properties like tensile strength, compressive strength, toughness etc. can be measured. The microstructure of the weldment, grain size etc. can also be studied.

REFERENCES

[1] Kuang-Hung Tseng et al., "Research on bead width and penetration depth of multicomponent flux-aided arc welding of grade 316 L stainless steel", Powder Technology, Volume 311, 15 April 2017, Pages 514-521
[2] Ronny M. Gouveia et al., "Study of the Heat-Treatments Effect on High Strength Ductile Cast Iron Welded Joints", Metals 2017, 7(9), 382
[3] Wallin, J. G. et al., U.S. Patent No. 9,409,259. Washington, DC: U.S. Patent and Trademark Office, 2016
[4] Boob. N Ajay et al., "Study on effect of manual metal arc welding process parameters on width of heat affected zone (HAZ) for MS 1005 steel", International journal of modern engineering research' Volume 3, May–June 2013, Page no. 1493–1500.
[5] Kumar Harish et al., "Corrosion characteristics of wrought iron under different atmospheric conditions by vapors phase corrosion inhibitors", American Journal of Materials Science and Engineering, Volume 3, March–May 2013, page no. 34-39.
[6] Akpan A. et al., "Inhibition of wrought iron corrosion in hydrochloric acid solution by ciprofloxacin drug inemesit", International journal of corrosion, March–May 2013, page no. 1–5.
[7] Chen S.J. et al., "Gas Tungsten Arc Welding Using an Arcing Wire", Supplement to welding journal, American welding society, October 2010, Page no. 261–269.
[8] Nikwan B.W. et al., "Corrosion behavior of wrought iron in seawater from two different sites of Kuala terengganu coastal area", International journal of basic and applied science, Volume 11, December 2011, Page no. 75–80.
[9] Shukla K Ratnesh et al., "Comparative study of friction stir welding and tungsten inert gas welding process", International journal of science and technology, Vol. 3 No. 6, June 2010, Page no. 667–671.
[10] Yarmuch R.A.M. et al., "Variable AC Polarity GTAW Fusion Behavior in 5083 Aluminum", Welding research, July 2007, Vol. 86, Page no. 196–200.
[11] Lienert J.T. et al., "Friction stir welding studies on wrought iron", Supplement to welding journal, American welding society, January 2003, Page no. 1–9.
[12] Bajaj Sandeep et al., "Strength of materials", Edition 2011, North publication, Page no. 345.
[13] Bajaj Sandeep et al., "Workshop technology-I", Edition 2011-2012, volume 1, Ishan's publications, page no. 1,38,40,41.
[14] Bhalla Pankaj et al., "Machine design and drawing", Edition 2012, North publication, page no. 130.
[15] Boniszewski T. et al., "Fine oxide particles in wrought iron CO_2 weld metal", Supplement to welding journal, American welding society, January 1972, page no. 19–22.
[16] Ellis G.R.S et al., "Continues drive friction welding of wrought iron", Supplement to welding journal, American welding society, April 1972, page no. 183–197.
[17] Key F.J. et al., "Anode/Cathode Geometry and Shielding Gas Interrelationships in GTAW", Supplement to welding journal, American welding society, December 1980, Page no. 364–370.
[18] Ouden Den G. et al., "Influence of chemical composition on wrought iron weld metal notch toughness", Supplement to welding journal, American welding society, March 1975, Page no. 87–94.