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EVALUATION OF RESIDUAL STRESSES FOR STEEL COMPONENTS SUBJECTED TO VARIED WELDING AND HEAT TREATMENT PARAMETERS

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ABSTRACT

Residual stresses form a major part of causing catastrophic failure among majority of the manufactured components. Residual stresses are the stresses that remain in a solid material after the original cause of the stresses has been removed. The current work involves the process of welding using varied parameters like current as well as varied quenching methods. Residual stresses were measured for each of the variable and are computed. It is observed from residual stress measurements that furnace cooling medium of quenching has shown lower values of residual stress when compared to the counterparts.

Key words: *Residual stress, X- ray diffraction, welding parameters, heat treatment, quenching*

1. Introduction

Welding is widely used to join metallic parts in ship, aircraft, automotive and bridge building industries. As a result of thermally induced plastic deformations during the welding process, the internal stresses, namely, the welding residual stresses remain in the welded components and structures. Residual stresses are generated, upon equilibrium of material, after plastic deformation that is caused by applied mechanical loads, thermal loads or phase changes. Mechanical and thermal processes applied to a component during service may also alter its residual stress state. The first classical solutions for the heat sources were developed by Rosenthal back in 1941 and later by Rykalin and others in the 1950s to obtain transient temperature of welded plates. In the welding process, the Fusion Zone (FZ) and the Heat Affected Zone (HAZ) regions experience high temperatures, which cause phase transformations and alterations in the mechanical properties of the welded metal. The estimates of temperature distribution in multiple pass welding is more complex than in the single pass processes due to superimposed thermal effects of one pass over the previous passes. The effect of thermal cycles obtained from the distributed (Gaussian) heat source model are found to be more reliable than those obtained from the concentrated (point) heat source model (1). The Finite ElementMethod (FEM) is the overall dominant tool used for analyzing various types of welded joints (2).

It was discussed in detail (3) the various issues involved in the development of material models used for residual stress analysis. Computed distortions and residual stresses through the 3D finite element simulations of multi-pass welding of a 316L stainless steel (4) There are many factors that affect the residual stress distribution in weldment components. According to [5], this is the factor that affects the distribution of residual stress in weldment components: i. The existence of residual stress before welding (manufacture and fabrication) ii. Material properties (weld and parent metal) iii. The geometry of the joined components iv. Restrain applied v. Welding procedure vi. Operation after welding. In [6] prove that steel type influence residual stress. It founds that for low carbon steel (S15C) has an insignificant effect on the welding (tungsten inert gas (TIG) arc welding) residual stress, but there is a significant effect on the welding residual stress of medium carbon steel (S45C). In the study, compressive stress exists in the fusion zone. While, high tensile stress existed in the weld zone. Residual stress gives both positive and negative effects to welding component, usually the compressive residual stress lead to positive or beneficial effect to the components. Researchers found that residual can prevent origination and propagation of fatigue cracks, increase corrosion resistance [7, 8], increase life time of weld components [9] and prevent stress corrosion cracking failures [10].

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2. Experimental Procedure

Mild steel is chosen as the material with thickness of 6mm to undergo welding (Manual Metal Arc Welding) upon varied parameters subsequently followed by residual stress analysis. Three different welding current values are chosen viz 100, 120 and 140 amperes. A mild steel electrode with specification of E - 6013 (AWS) of diameter 3.15 was used. These welded pieces were also subjected to heat treatment process of heating up to 9500C and then quenched in five different media namely air, water, oil, ice and furnace cooling. Once these samples were quenched, residual stress measurements were carried out to determine the stress levels. The X-ray residual stress measurement test rig works on the basic of X – Ray diffraction technique and was measured using an X – Ray residual stress analyzer as per ASTM standards.

3. Results and Discussions

After the heat treatment and quenching process the materials undergone residual stress calculation. The residual stress was calculated by X ray diffraction machine. The results obtained are shown in the table. The results for 3 different batches are represented in different tabular column. Results obtained are as shown below in table 2,3,4. Each batch is off different ampere rating. Batch 1 is for 100 amperes, batch 2 is for 120 amperes, batch 3 is for 140 amperes.

3.1.Batch 1 (100 amperes)

Batch 1 is the welding done with the current supply of 100 amperes .The table 1 shows the residual stress for the 5 mediums (ice, water, air, oil, and furnace) which will be compared with the normal welded material. Normal describes the material which had not gone through any heat treatment or cooling condition. Furnace cooling gives the best result as it has residual stress of -41Mpa, which means that it will reduce the breaking tendency of the material and provide good strength.

Table 1. Residual stress table for batch 1

SL NO.	HEAT TREATMENT CYCLE	CURRENT INPUT (amp)	SAMPLE DESIGNATION	RESIDUAL STRESS (MPa)
1	Normal	100	100 – Normal	-120
2	Ice		100 – Ice	-116
3	Water		100 – Water	-100
4	Air		100 – Air	-86
5	Oil		100 – Oil	-70
6	Furnace		100 – Furnace	-41

3.2 Batch 2 (120 amperes)

Batch 2 is the welding done with the current supply of 120 amperes. The table 2 shows the residual stress for the 5 mediums (ice, water, air, oil, and furnace). Furnace cooling gives the best result as it has residual stress of -39 Mpa.

Table 2. Residual stress table for batch 2

SL NO.	HEAT TREATMENT CYCLE	CURRENT INPUT (amp)	SAMPLE DESIGNATION	RESIDUAL STRESS (MPa)
1	Normal	120	120 – Normal	-126
2	Ice		120 – Ice	-110
3	Water		120 – Water	-96
4	Air		120 – Air	-81
5	Oil		120 – Oil	-64
6	Furnace		120 – Furnace	-39

3.3 Batch 3 (140 amperes)

Batch 3 is the welding done with the current supply of 140 amperes. Table 3 shows the residual stress for the 5 mediums (ice, water, air, oil, and furnace) which will be compared with the normal welded material. Furnace cooling gives the optimum result as it has residual stress of -36 Mpa.

Table 3. Residual stress table for batch 3

SL NO.	HEAT TREATMENT CYCLE	CURRENT INPUT (amp)	SAMPLE DESIGNATION	RESIDUAL STRESS (MPa)
1	Normal	140	140 – Normal	-132
2	Ice		140 – Ice	-102
3	Water		140 – Water	-91
4	Air		140 – Air	-74
5	Oil		140 – Oil	-62
6	Furnace		140 – Furnace	-36

3.4 Graphical representation of residual stress

Graph 1 –Residual stress graph for normal material which had not gone through any heat treatment or cooling condition.

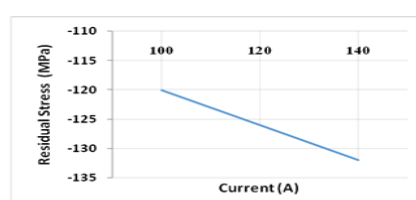

Fig 1. Residual stress graph for normal material

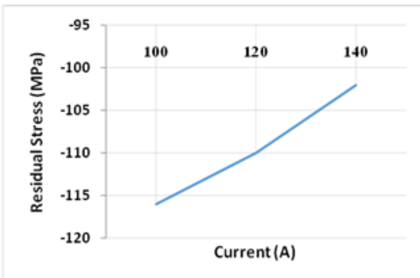

Fig 2. Residual stress graph for ice quenched material

Fig 2 shows the residual stress graph for ice quenched material which had gone through heat treatment and ice cooling condition. It shows the comparison of residual stresses for ice quenched material with the 3 different ampere ratings.

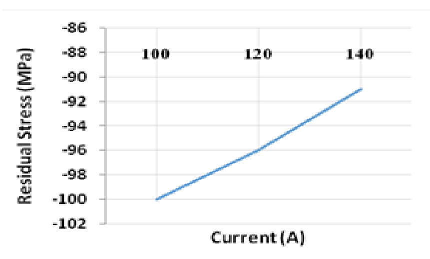

Fig3. Residual stress graph for water quenched material

Graph 3 – Residual stress graph for water quenched material which had gone through heat treatment and water cooling condition.

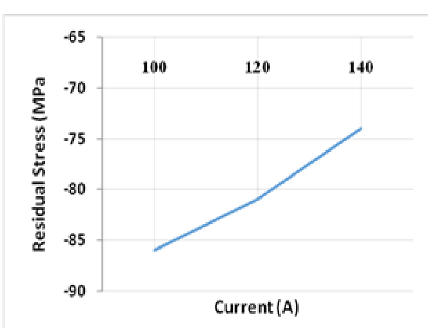

Fig4. Residual stress graph for air quenched material

Graph 4 – Residual stress graph for air quenched material which had gone through heat treatment and air cooling condition. It shows the residual stress for air quenched material with the 3 different ampere ratings.

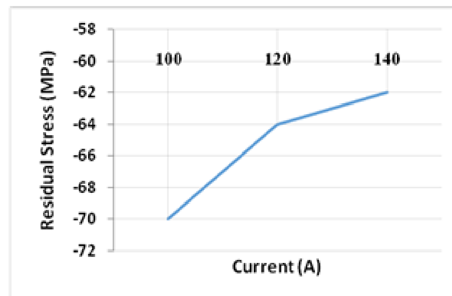

Fig5. Residual stress graph for oil quenched material

Graph 5 – Residual stress graph for oil quenched material which had gone through heat treatment and oil cooling condition. It shows the residual stress for oil quenched material with the 3 different ampere ratings.

Graph 6 – Residual stress graph for furnace quenched material which had gone through heat treatment and furnace cooling.

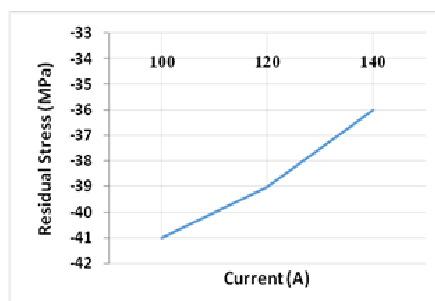

Fig6. Residual stress graph for furnace quenched material

4. Conclusion

Mild steel samples were successfully welded and underwent heat treatment and quenching process to obtain good strength and reduce breaking tendency. The results obtained clearly shows that the residual stress of furnace cooling gives the best result in terms of lower residual stress when compared to the counterparts. This indicates that when compared to all other quenching mediums (air, water, oil, ice) furnace cooling gives the best way to reduce the residual stress and provide less breaking tendency.

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