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RESEARCH ARTICLE

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ANALYSIS OF CHANGE IN MECHANICAL BEHAVIOUR OF WELDED STEEL ALLOY BY POST WELD HEAT TREATMENT.

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ABSTRACT

In this paper we have analysed the effect of post weld heat treatment on mechanical properties of welded steel alloy specimen. Two specimens one of austenitic Stainless Steel and second one is Low Alloy Steel (similar to AISI 8740) were welded using gas tungsten arc welding (GTAW). Specimen was then subjected to heat treatment process in electrical Full-Muffle furnace. Welding parameters and heat treatment temperature, soaking time were selected as per phase diagram of specimen material. Welded specimen was then tested for mechanical properties before and after heat treatment. Analysis shows that post weld heat treatment have makeable` effect on mechanical properties, especially on tensile strength of welded specimen. Improvement in strength after heat treatment confirms that stress relieving objective is achieved. Microstructure examination confirms formation of martensite along with other phases.

Keywords: PWHT, steel alloys, stress relieve, strength, phase diagram

INTRODUCTION

Heat treatment operation is a process involving heating at a specific rate and soaking at specific temperature for predetermine period of time. Objective of this mechanism is to obtain desired micro structure and hence some predetermined mechanical, thermal, electrical properties [1-5]. Heat treatment is widely used method to achieve desired properties in various metals and alloys. Steel is widely undergone heat treatment process to obtain or to change mechanical properties as per application requirement. Different microstructures and properties can be observed in steel during heat treatment process. Phase transformation takes place during heating and cooling, which results in change of microstructure in a solid state.

In heat treatment, overall thermal energy participates and modifies only structure. There are other heat treatment processes such as Thermo mechanical treatments, which modify component shape and structure, and thermo chemical treatments which modify surface chemistry and structure [6, 7].

Welding is process directly linked to various applications of steel alloy. Whenever two metal or alloy specimens are welded Stress introduced in the welded part due to rapid melting and cooling of metal or alloy. This internal stress affects the mechanical properties of the metal or alloy. Most of time there is loss of strength of specimen. Welded specimen is more prone to fracture at value smaller than as expected from properties of material [8-12]. All this is due to stress introduced in the welded specimen. Post weld heat treatment is a process that can solve this problem. Post weld heat treatment results in improved mechanical properties as reported by many researchers. Here in post weld heat treatment process suitable welding process is utilised to weld two metals or alloys. Welded part is then subjected to heat treatment at some predetermined temperature and soaking for a specified period. All parameters are fixed as per material phase diagram [13-20].

In this paper two different steel alloys were selected to study effect of heat treatment on welded joint or we can say on properties of welded sample. Gas arc welding was used. Main objective is to achieve stress relive, which is confirmed by observing change in mechanical properties after PWHT [21-25].

MATERIALS & METHODS

(i). Materials:

Austenitic stainless steel & Low alloy steel (similar to AISI 8740) plates of 12 mm was used in present study (From En Kay suppliers). The chemical compositions and mechanical properties of two alloys are given in Table 1 & Table 2.

(ii). Methods:

Sample preparation (for welding) & process parameters: Single V-groove butt joints were prepared by welding two alloy specimens by using gas tungsten arc welding (GTAW) process. Length and width of each weld pad was 500 and 250 mm respectively.

Post weld heat treatment:- To study effect of Post-weld heat treatment samples (Total five samples were prepared) prepared with desired dimensions as mentioned above were subjected to heat treatment with Electrical Full-Muffle furnace at the predetermined temperature range as per sample material phase diagram. These samples were then soaked and air cooled at room temperature.

Parameters Involved:

Furnace Temperature	550^0C to 580^0C
Furnace Wall material	Stainless steel
Insulation material	Glass wool
Heating Elements-	Nycrome 8020
Walls Filler Material-	Ceramic Fiber
Cycle Time	1 hrs
Soaking Time	45 Minutes

Sample preparation for Microstructure examination: All sample after heat treatment were cut (at weld joints) and polished with diamond polishing machine using alumina abrasive and different grades of emery papers. After this they are subjected to etching with Nital reagent to expose the microstructure of specimen. Microstructure analysis was then performed with optical microscope to study effect of post weld heat treatment on the welding interface and overall weld sample.

Residual Stress measurement:-

There are many methods such as Weld Strength measurement, X-Ray diffraction per ASTM E915-83, High Speed Hole Drilling with strain gauges per ASTM E837-85, Barkhousen Noise Analysis method for making any kind of determination that stresses have been reduced[3,4,5,10]. In the present work tests to confirm the stress relieve in specimen is to measure the strength of the weld joint using Universal Testing Machine after stress relieve heat treatment and hardness after heat treatment .

RESULTS & DISCUSSIONS

(1) Strength Measurement:

As per theory of welding, various stresses introduced in the sample after welding. This is a mechanical stress which introduced in the sample, because of rapid melting of material and solidification of weld joint. Stress in the weld joint, decreases the strength of bonding between two alloys (Austenitic Stainless Steel and Low Alloy Steel) and also a surface under residual stress cannot sustain additional stress during service life. After Heat Treatment, stress relieves results in the enhanced strength of weld joint [1-5]. In present work five samples were prepared and average of all results were considered for analysis.

Stress Type	= Tensile Stress
Initial Gauge Length	= 40mm
Peak Load	= 187.12 KN
Maximum Cross Head Travel	= 20.7mm

Tensile Strength **(Before HT)** = 570.66 N/mm^2
Load at Break = 180.60 KN
Required Break Load After stress relieve = 90 KN (mini.)

(2) Hardness Measurement: -

Five samples were prepared for hardness testing. Hardness test was performed before and after heat treatment. Rockwell hardness Tester in HRC mode is used for hardness measurement with a load of 150 Kg.

Indenter Used = Diamond Cone
Load Applied = 150 Kg
Hardness before heat treatment = 50 HRC

Results shows increase in hardness with PWHT that is related to the phase change in the alloy with formation of martensite (it contributes to hardness of material). Percentage of carbon in the iron alloy is another factor that decides, how much of improvement will be there in hardness after heat treatment [3, 18]. The plot below shows formation of phase with percentage of carbon & variation in Hardness of material.

(3) Microstructure Analysis:-

The investigated material is a weld specimen of Austenitic Stainless Steel and Low Alloy Steel. Specimen for microstructure examination was prepared by cutting a weld sample (before and after HT) in the smallest cross-section to examine the material microstructure. Sample shows a normalized microstructure (Before HT, figure 2). MnS elliptic inclusions surrounded by a short alumina layer are present. Examination of the microstructure (After HT) along the cross-section of a specimen shows a martensitic microstructure. Specimen shows a mixture of martensite and ferrite until 2.5mm in depth. In core the initial microstructure made of ferrite and pearlite is not affected by the heat treatment. Phase transformation in steel during Heat Treatment is related to the diffusion of interstitial carbon. Also the amount of martensite that forms is a function of the temperature to which the austenite is cooled and not a function of time [1-6, 18].

Table 1: Chemical compositions of alloys used.

Elements	*Austenitic Stainless Steel (in Wt %)*	*Low Alloy Steel (in Wt %)*
C	0.032	0.38/0.43
Si	0.486	0.10/0.35
S	0.009	0.040(max.)
P	0.026	0.025(max.)
Mn	1.055	0.70/1.00
Ni	10.594	o.40/0.70
Cr	16.213	0.40/0.60
Mo	2.081	0.20/0.30
V	0.092	-------
Cu	0.552	-------
W	0.09	-------
As	0.086	-------

Sn	0.017	-------
Co	0.205	-------
Al	0.017	0.032(max.)
Pb	0.019	-------
Ca	0.0002	-------
Zn	0.0002	-------
Fe	Balance*	Balance*

(*Reference to the 'balance' of a composition does not guarantee this is exclusively of the element mentioned but that it predominates and others are present only in minimal quantities.)

Table 2: Mechanical properties of alloys used.

Mechanical Property	*Tensile Strength (MPa)*	*Yield Stress 0.2 % (MPa)*	*Elongation (%)*	*Hardness (HRC)*
Low Alloy Steel	850/1000	680(mini.)	12	B30
Austenitic Stainless Steel	621	290	55(% in 2'')	B80

Table 3: Welding Parameters involved.

S.No.	*Process Name*	*Frequency/Value/Type*
1	Welding position	Flat
2	Welding speed (mm/min)	180 mm
3	Welding Amperes (Amps)	80-100
4	Arc voltage (volts)	20
5	Preheat temperature (K)	410
6	Filler Rod Size	1.6mm
7	Electrode diameter (mm)	1 mm, 0.04 inches
8	Gas used	Argon

Table 4:- Tensile Strength test data (PWHT samples).

Specimen	**Maximum Load (KN)**	**Load at break (KN)**	**Percentage Elongation (%) & Reduction in Area (mm)**	**Tensile Strength (N/mm^2)**
S1	165.32	164.32	Negligible	651.03
S2	163.72	147.73	-	649.73
S3	144.08	144.08	-	567.39
S4	154.47	154.47	-	650.15
S5	155.67	155.47	-	649.89

Table 5 Hardness data (PWHT samples).

COMPONENT	LOAD APPLIED (Kg)	TOUCH POINT HARDNESS (HRC)	HARDNESS (HRC)
H1	150	256	53
H2	150	255	52
H3	150	256	53
H4	150	256	53
H5	150	255	52

Touch point hardness- it refers to hardness when indenter just touches the surface of specimen, before actually pressing it[3].

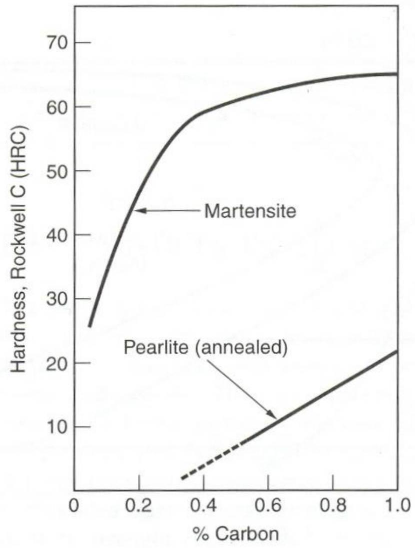

Figure 1: Phase diagram of steel show variation of hardness with % carbon & phase formed.

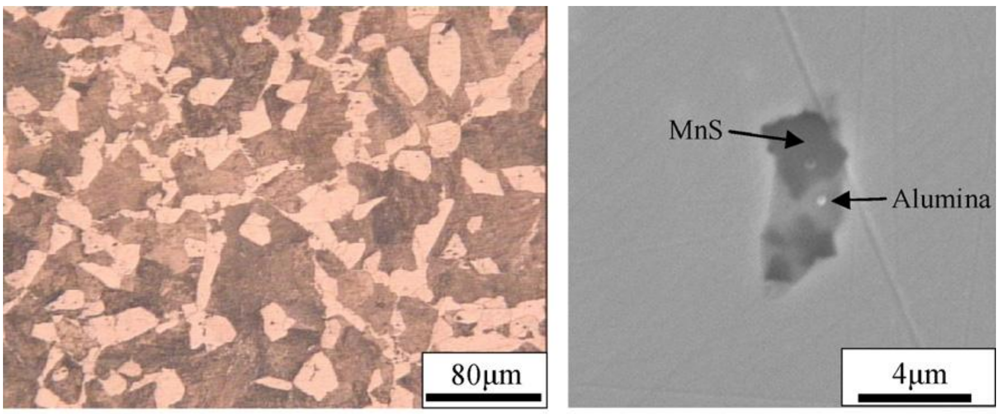

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Figure 2: Microstructure of welded sample before heat treatment.

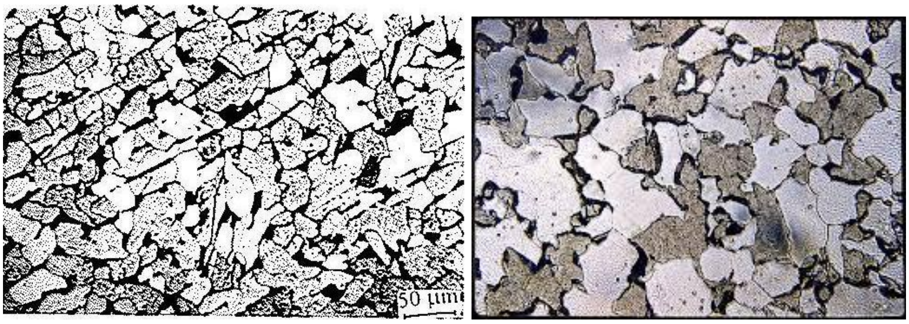

Figure 3: Microstructure of welded sample after heat treatment.

Conclusion: PWHT treatment results in increase in strength of welded joint, thus stress relieving objective is achieved. Increase in hardness confirms formation of hard phase i.e. martensite, that is also confirmed by microstructure examination. PWHT at about 550^0c for 45 minutes is sufficient to retain the mechanical properties. Improvement in hardness is not much as expected from PWHT, but tensile strength have excellent jump after PWHT. This is because in case of dissimilar alloys having different coefficients of thermal expansion, phase change & hence improvement in hardness is small. Overall PWHT treatment is a excellent tool for improvement in properties of welded materials, but the properties of welded materials plays a important role in achieving objectives of Post Weld Heat Treatment.

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