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Analysis of change in mechanical properties and microstructure of steel specimen under PWHT

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ABSTRACT

In this work, we have analyzed the effect of heat treatment on the properties of steel specimens before and after welding under various heat treatment processes. Specimens were subjected to heat treatment in an electric muffle furnace. Heat treatment temperature, soaking time and cooling rate were selected as per phase diagram of specimen material. Specimens (before and after welding) were tested for mechanical properties before and after heat treatment. Different heat treatment processes compared with respect to their effect on the properties of single and welded specimens.

Keywords— *Heat treatment, Soaking, Steel, Welding, Post heat treatment*

1. INTRODUCTION

There are two mechanisms which can change properties of metals or alloys by heat treatment: the formation of martensite which causes the crystallite to deform intrinsically, and the diffusion mechanism which causes changes in the homogeneity.[1-15] Heat Treatment is heating and cooling of metals to change their properties as per phase diagram, without changing the shape of the sample product. Aim to select suitable metal or alloy is a key requirement in the manufacturing industry. [16-24] Welding is most common in all manufacturing works. Further Post Weld Heat Treatment (PWHT): a method which leads is variation in properties and hence performance of metal or alloy parts in applications. [25-30] Keeping all in view the present dissertation work planned with the following objectives:

- To study properties of steel specimen before and after welding.
- To analyze the effect of heat treatment on mechanical properties of steel specimen under PWHT process.
- To characterize specimen for analysis of microstructural behavior under PWHT process.
- To compare mechanical behavior under different heat treatment parameters before and after welding.

2. MATERIALS AND METHODS

2.1 Materials

Mild steel specimen square shape specimen (4.9 cm x 4.9 cm) and thickness 0.7 cm were used in present work. The same sample used for hardness and then used for impact strength measurement.

2.2 Methods

2.2.1 Welding process parameters: Single Butt V-weld butt joints welding specimen was prepared by using shield arc welding process. Length and width of each weld pad was 4.6 cm and 1.2 cm respectively and thickness 0.3 cm.

Fig. 1: Samples before HT

2.2.2 Heat treatment: To study the effect of heat treatment, the sample prepared with desired dimensions as mentioned above were subjected to heat treatment with Electrical Muffle furnace at the predetermined temperature range as per sample material phase diagram. These samples were then soaked and air-cooled at room temperature. Heat treatment performed for Sample before welding and sample after welding. Two HT processes namely annealing and normalizing were performed.

Fig. 2: Welded specimen before HT

Fig. 3: Welded specimen after HT

3. RESULTS AND DISCUSSIONS

3.1 Hardness measurement

Samples were prepared for hardness testing. Hardness test was performed before and after heat treatment for single and welded specimens. 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

Table 1: Rockwell Hardness testing data before and after Welding/HT

Specimen	Load Applied (Kg)	Touch Point Hardness (HRC)	Hardness (HRC)		
			Before HT	After HT (Annealing)	After HT (Normalizing)
Single (before welding)	150	255	49	47	56
Welded sample	150	255	47	46	50

In the case of annealing, both samples show some decrease in hardness after HT, as expected. Further, there is a decrease in hardness observed after welding which indicates stress introduced after welding, additionally loss in hardness after welding is recovered in normalizing process, may be due to stress relieve and normalization phase transformation factor.. Similar effect of the normalizing process observed in the single specimen (Without welding). Phase change in the alloy with the formation of martensite (it contributes to the hardness of material), results in an improvement in hardness after HT. Percentage of carbon in the iron alloy is another factor that decides, how much improvement will be there in hardness after heat treatment. The plot below shows the formation of phase with the percentage of carbon and variation in Hardness of material.

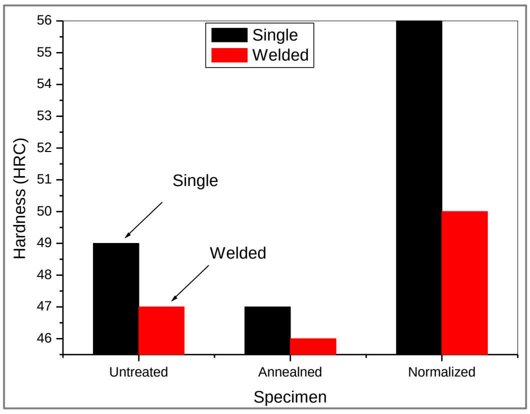

Fig. 4: Plot showing variation in hardness before and after heat treatment

3.2 Toughness/ Impact Strength

Toughness requires a reasonable value of ductility in the material so that material delays fracture or we can say material deforms first before facing fracture. As material lost hardness, it retains some amount of toughness. In case of annealing operation, there is a decrease in hardness, which on the one hand give an indication that amount of energy absorbed before fracture will increase, on another hand it requires strength so that to withstand applied load or to resist fracture. Similar theory is applicable for normalizing operation. Charpy test technique used in present work. [31, 32]

Table 2: Toughness test data before and after HT/Welding

Specimen/ HT operation	Toughness (Joules)		
	Before HT	After HT (Annealing)	After HT (Normalizing)
Single (before welding)	38	40	33
Welded sample	40	38	36

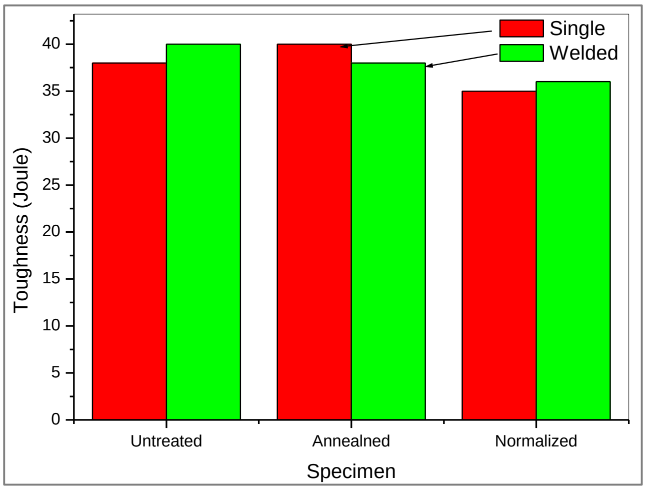

Fig. 5: Plot showing variation in toughness with HT/welding process

4. CONCLUSIONS

From all the characterizations and study of various parameters involved in heat treatment, we conclude that annealing and normalizing have a significant and different effect on the properties of alloys. Additionally, welding also contributes to variation in mechanical behavior. Following conclusions have been drawn:

- Heat treatment mild steel specimen results in variation in mechanical properties to a significant amount.
- Annealing reduces hardness with the destruction of cementite/pearlite networks during phase transformation by heat treatment. Normalizing results in the formation of martensite, cementitious and hence improves hardness.
- Welding results in a decrease in hardness indicates stress introduced by welding. Increase in hardness after HT in weld sample observed in normalizing, which shows that the sample retains hardness lost in welding through stress relieve by HT.
- Annealing increases toughness, whereas normalizing result in a decrease in toughness.
- All above heating rate, phase transformation, specimen condition, and soaking rate are the key factor which decides properties of the specimen before and after heat treatment.

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