

A REVIEW ON EFFECT OF PREHEATING AND/OR POST WELD HEAT TREATMENT (PWHT) ON HARDENED STEEL

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Abstract— Most of the welding of steel is fabrication and repair welding. Following a welding operation, the cooling and contracting of the weld metal cause stresses to be set up in the weld and in adjacent parts of the weldment which results to cracking and embrittlement in steel welds. The best way to minimize above difficulties is to reduce the heating and cooling rate of the parent metal and HAZ. Pre heating and/or Post heating have been widely employed in welding operation for preventing cold cracking. This paper presents the effect of preheating and/or PWHT on maximum HAZ hardness, cold cracking susceptibility and residual stresses of various hardened steel types.

Keywords— Carbon Equivalent (CE); Heat-affected zone (HAZ); Weld metal (WM); Microstructure; Post Weld Heat Treatment (PWHT); Hardened Steel;

I. INTRODUCTION

Steels containing excessive carbon exhibit increased strength and hardenability and decreased weldability [1]. Q. Xue et al stated When High carbon steel is welded, it is heated; the micro structure of heated portion is different from that of the base metal and is described as the Heat Affected Zone (HAZ) [2]. Rapid heating and cooling take place throughout welding, which generate severe thermal cycle near weld line region. Non uniform heating and cooling in the material, due to thermal cycle cause thus generating harder heat affected zone, residual stress and cold cracking inclination in the weld metal and parent metal as shown in figure 1 [3].

Residual stresses usually result from differential heating and cooling are very Harmful for weld [4]. Contraction of weld metal along the length of the weld is to a degree prevented by the large adjacent body of cold metal. Therefore residual tensile stresses are set up along the weld. The properties of welds often cause more problem than the parent metal properties, and in many cases they govern the overall performance of the structure [5].

To get rid of these problems some heat treatment before welding (Preheating) and after welding, Post Weld Heat

Treatments (PWHT) are employed. Effective preheat and post heat are the primary means by which acceptable heat affected zone properties and minimum potential for hydrogen induced cracking are produced.

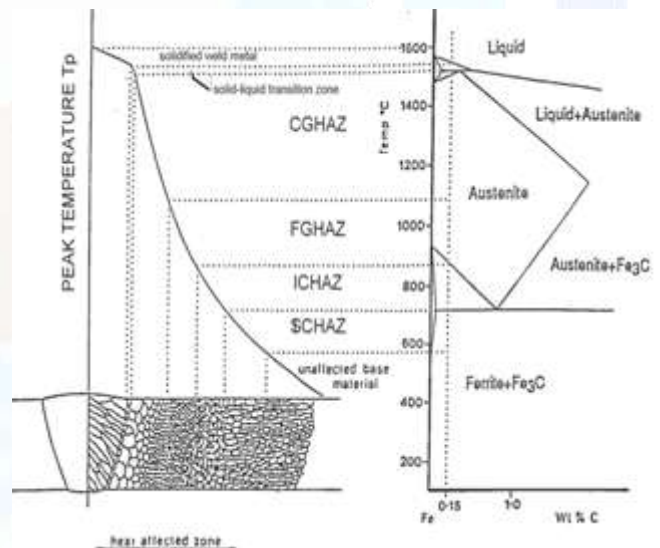


Fig. 1 Schematic illustrations of the various single-pass HAZ regions with reference to the Iron-carbon equilibrium diagram [6].

II. FUNDAMENTALS OF PRE HEATING

The heating of metal to some predetermined temperature before actual welding is preheating. The purpose of the preheating is to influence the cooling behavior after welding so that shrinkage stresses will be lower and cooling rate will be milder [5]. Pre-heating makes the metal more receptive to welding. The minimum preheating temperature to be assured to avoid cracking depends on the following factors:

- Carbon equivalent expressing carbon
- Condition of base metal prior to welding,
- Thickness of base material,

- Constraint level,
- Hydrogen available risk.

Usually, a hard microstructure is produced in heat affected zone (HAZ) due to rapid heating and cooling, characteristics of welding. The hard micro structure of the HAZ is one factor responsible for the property deterioration of welds. The heat-affected zone (HAZ), which is cooled at different rates and includes different regions of microstructure, is often considered the source of failure in a welded joint as shown in figure [6]. A simple method is available to determine if preheat is required in welding a steel.

The hardenability of steel is approximately related to its carbon content plus the content of certain other alloying elements. An indication of the hardenability, called a “carbon equivalent” also known as CEV, can be calculated as follows [7]:

$$CEV = \% C + \% \frac{Mn}{6} + \% \frac{Ni}{15} + \% \frac{Cr}{6} + \% \frac{Mo}{4} + \% \frac{V}{5} \quad (1)$$

This formula is valid when the percentages are within this range of carbon is less than 0.50 % , manganese is less than 1.60 % , nickel should be less than 3.50 % , molybdenum should be less than 0.60 % , chromium should be less than 1.00 % and copper less than 1.00. The table below gives the suggested preheat treatment for different values of carbon equivalent.

TABLE 1
RANGE OF CARBON EQUIVALENT AND TREATMENT
RECOMMENDED

Carbon Equivalent (%)	Recommended Treatment
Up to 0.30	Preheat optional
0.30 to 0.45	Preheat at 93 to 204° C
Above 0.45	Preheat at 204 to 371° C

Some steels, particularly those having carbon equivalent greater than 0.45%, may require post heat as well as preheat. This is particularly true in welding heavy sections. However, for most plain carbon and alloy steels, only preheat is needed if any treatment is required at all. For particular steel, preheating requirements and critical preheating temperature may be selected according to the % of carbon present in that steel as shown in Fig. 2.

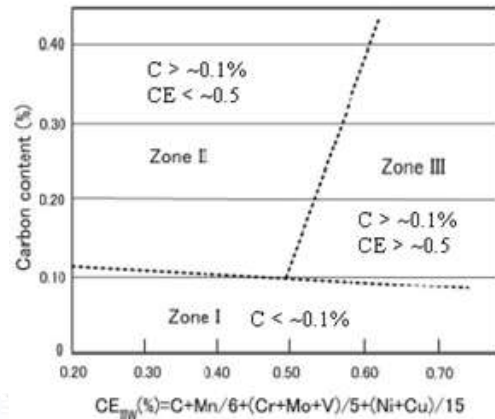


Fig. 2 Graville Diagram

III. FUNDAMENTALS OF POST WELDING HEAT TREATMENT

By adopting proper provisions after welding one can retard the cooling rate after Welding [6]. The functions of a PWHT are to temper the martensite in the weld metal and HAZ, in order to reduce the hardness and increase the toughness, and to decrease residual stresses associated with welding [7, 8]. By reviewing the current literature [9], available on the subject of Post Weld Heat Treatment (PWHT), one can see that recommendations are usually dependent upon specific alloys and filler metals involved, but also on thickness and restraint of welded joints. Post heating is used to minimize the potential for hydrogen induced cracking (HIC) [5]. For HIC to occur three variables must be present: a sensitive microstructure, a sufficient level of hydrogen, or a high level of stress. The necessity for PWHT depends on material and service requirements. Other factors that influence the need for PWHT are dimensions, joint design, welding parameters and the likely mechanism of failure.

TABLE 2
SUGGESTED POSTHEAT TIME AND TEMPERATURE FOR TYPICAL
HARDENED STEEL

SAE steel	Post heat Temperature °C	Post heat Time min	Maximum Quench Hardness, Rc
4615	371 to 482	10	45
4640	315 to 482	25	48
5140	315 to 538	15 to 25	62
6145	315 to 538	25 to 33	61
8630	315 to 482	15 to 25	53

IV. THERMAL STRESS RELIEF

Stress relief heat treatment is used to reduce the stresses that remain locked in a structure as a consequence of manufacturing processes. The residual stresses due to welding are of a magnitude roughly equal to the yield strength of the

parent material [10]. Uniform heating of a structure to a sufficiently high temperature, but below the lower transformation temperature range, and then uniformly cooling it, can relax these residual stresses [5, 11].

By stress relieving there is greater dimensional stability during machining, the potential for stress corrosion cracking is reduced and finally the chances for hydrogen induced cracking are also reduced. The temperature reached during the stress relief treatment has a far greater effect in relieving stresses than the length of time the specimen is held at that temp [12]. The closer the temperature is to the recrystallization temperature, the more effective it is in the removal of residual stresses. As well as heat input is inversely proportional to cooling rate as shown in figure 3 [8].

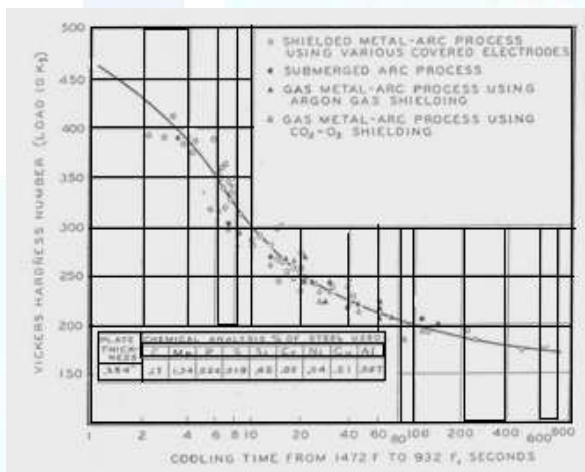


Fig. 3 HAZ Hardness Vs. Heat Input

V. DISCUSSION

The study of the previous work reviews that effective preheat and/or post heat are the primary means by which acceptable heat affected zone properties, minimum potential for hydrogen induced cracking and minimum residual stresses are created.

Some researchers concluded that microstructure of the HAZ is responsible for the property deterioration of weld and cold cracking susceptibility some of the researchers observed that the increase of preheating and/or PWHT coarsened the microstructures of weld and HAZ and significantly influenced the properties of the weld joints.

While studying the effects of pre-and post weld Heat Treatment on mechanical properties, some researchers observed that toughness decreases after stress relieve operation on other hand toughness increases if only PWHT is applied. Welding stresses can be reduced by 21- 32% by using new welding technique i.e. parallel heat welding process (PHW).

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