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Postweld Heat Treatment

What is PWHT?

Postweld heat treatment (PWHT), defined as any heat treatment after welding, is often used to improve the properties of a weldment. In concept, PWHT can encompass many different potential treatments; however, in steel fabrication, the two most common procedures used are **post heating** and **stress relieving**.

When is it Required?

The need for PWHT is driven by code and application requirements, as well as the service environment. In general, when PWHT is required, the goal is to increase the resistance to brittle fracture and relaxing residual stresses. Other desired results from PWHT may include hardness reduction, and material strength enhancements.

Post Heating

Post heating is used to minimize the potential for hydrogen induced cracking (HIC). For HIC to occur, the following variables must be present (see Figure 1): a sensitive microstructure, a sufficient level of hydrogen, or a high level of stress (e.g., as a result of highly constrained connections). In ferritic steels, hydrogen embrittlement only occurs at temperatures close to the ambient temperature. Therefore, it is possible to avoid cracking in a susceptible microstructure by diffusing hydrogen from the welded area before it cools. After welding has been completed, the steel must not be allowed to cool to room temperature; instead, it should be immediately heated from the interpass temperature to the post heat temperature and held at this temperature for some minimum amount of time. Although various code and service requirements can dictate a variety of temperatures and hold times, 450°F (230°C) is a common post heating temperature to be maintained for 1 hour per inch (25 mm) of thickness.

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Post heating is not necessary for most applications. The need for post heating assumes a potential hydrogen cracking problem exists due to a sensitive base metal microstructure, high levels of hydrogen, and/or high stresses. Post heating, however, may be a code requirement. For example, ASME Section III and the National Board Inspection Code (NBIC) both have such provisions. The Section III requirement for P-No. 1 materials is 450 to 550°F (230 to 290°C) for a minimum of 2 hours, while the NBIC requirement is 500 to 550°F (260 to 290°C) for a minimum of 2 hours. Furthermore, post heating is often required for critical repairs, such as those defined under the Fracture Control Plan (FCP) for Nonredundant Members of the AASHTO/AWS D1.5 Bridge Welding Code. The FCP provision is 450 to 600°F (230 to 315°C) for "not less than one hour for each inch (25 mm) of weld thickness, or two hours, whichever is less." When it is essential that nothing go wrong, post heating can be used as insurance against hydrogen cracking. However, when the causes of hydrogen cracking are not present, post heating is not necessary, and unjustifiable costs may result if it is done.

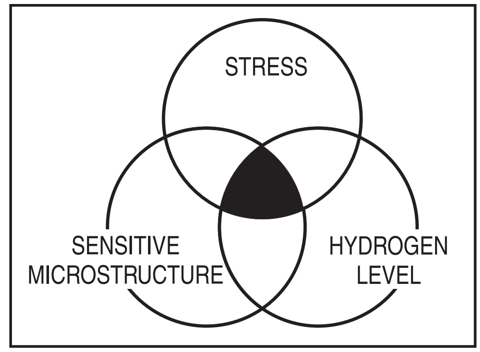

Figure 1. Criteria for hydrogen induced cracking (HIC).

Stress Relieving

Stress relief heat treatment is used to reduce the stresses that remain locked in a structure as a consequence of manufacturing processes. There are many sources of residual stresses, and those due to welding are of a magnitude roughly equal to the yield strength of the base material. Uniformly heating a structure to a sufficiently high temperature, but below the lower transformation temperature range, and then uniformly cooling it, can relax these residual stresses. Carbon steels are typically held at 1,100 to 1,250°F (600 to 675°C) for 1 hour per inch (25 mm) of thickness.

Stress relieving offers several benefits. For example, when a component with high residual stresses is machined, the material tends to move during the metal removal operation as the stresses are redistributed. After stress relieving, however, greater dimensional stability is maintained during machining, providing for increased dimensional reliability.

In addition, the potential for stress corrosion cracking is reduced, and the metallurgical structure can be improved through stress relieving. The steel becomes softer and more ductile through the precipitation of iron carbide at temperatures associated with stress relieving.

Finally, the chances for hydrogen induced cracking (HIC) are reduced, although this benefit should not be the only reason for stress relieving. At the elevated temperatures associated with stress relieving, hydrogen often will migrate from the weld metal and the heat affected zone. However, as discussed previously, HIC can be minimized by heating at temperatures lower than stress relieving temperatures, resulting in lower PWHT costs.

Other Considerations

When determining whether or not to postweld heat treat, the alloying system and previous heat treatment of the base metal must be considered. The properties of quenched and tempered alloy steels, for instance, can be adversely affected by PWHT if the temperature exceeds the tempering temperature of the base metal. Stress relief cracking, where the component fractures during the heating process, can also occur. In contrast, there are some materials that almost always require PWHT. For example, chrome-molybdenum steels usually need stress relieving in the 1,250 to 1,300°F (675 to 700°C) temperature range. Thus, the specific application and steel must be considered when determining the need, the temperature and time of treatment if applied, and other details regarding PWHT.

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The filler metal composition is also important. After heat treatment, the properties of the deposited weld can be considerably different than the “as welded” properties. For example, an E7018 deposit may have a tensile strength of 75 ksi (500 MPa) in the “as welded” condition. However, after stress relieving, it may have a tensile strength of only 65 ksi (450 MPa). Therefore, the stress relieved properties of the weld metal, as well as the base metal, should be evaluated. Electrodes containing chromium and molybdenum, such as E8018-B2 and E9018-B3, are classified according to the AWS A5.5 filler metal specification in the stress relieved condition. The E8018-B2 classification, for example, has a required tensile strength of 80 ksi (550 MPa) minimum after stress relieving at 1,275°F (690°C) for 1 hour. In the “as welded” condition, however, the tensile strength may be as high as 120 ksi (825 MPa).

The objective of this article is to introduce the fundamentals of postweld heat treatment; it is not meant to be used as a design or fabrication guide. For specific recommendations, consult the filler metal manufacturer and/or the steel producer.

For Further Reading

ASM Handbook, Volume 6 – Welding, Brazing, and Soldering. American Society for Metals, 1993.

Bailey, N. *Weldability of Ferritic Steels.* ASM International/Abington Publishing, 1994.

Evans, G.M. and Bailey, N. *Metallurgy of Basic Weld Metal.* Abington Publishing, 1997.

Metals Handbook, Volume 4 – Heat Treating. 9th Edition. American Society for Metals, 1981.

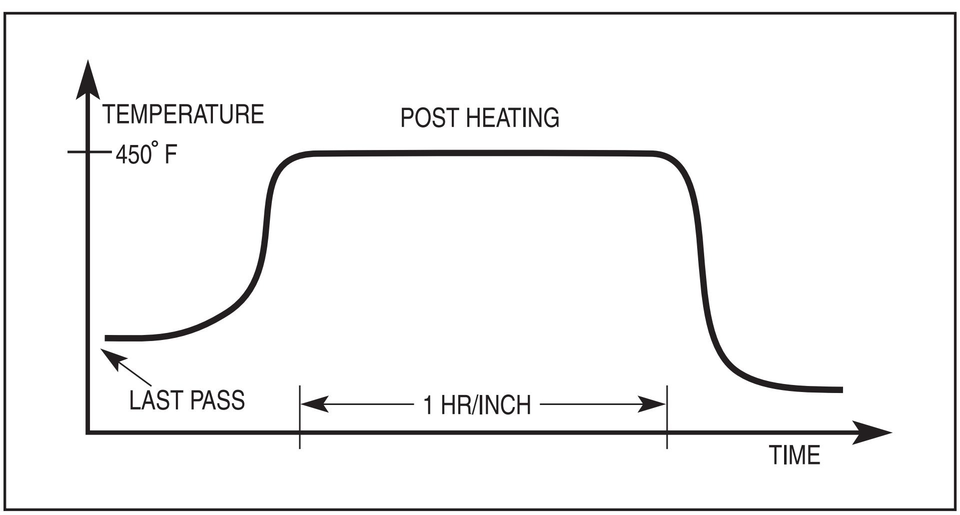

Figure 2. Post heat applied immediately after last pass.