Key Concepts in Welding Engineering

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The Importance of Interpass Temperature

"Interpass temperature" refers to the temperature of the material in the weld area immediately before the second and each subsequent pass of a multiple pass weld. In practice, the minimum specified interpass temperature is often equal to the minimum specified preheat temperature, but this is not required according to the definition.

Why Is Interpass Temperature Important?

Interpass temperature is just as important as, if not more important than, preheat temperature, with regard to the mechanical and microstructural properties of weldments. For instance, the yield and ultimate tensile strengths of the weld metal are both a function of the interpass temperature. High values of interpass temperature tend to reduce the weld metal strength. Additionally, higher interpass temperatures will generally provide a finer grain structure and improved Charpy V notch toughness transition temperatures. However, when interpass temperatures exceed approximately 500°F (260°C), this trend is reversed. For example, the American Welding Society (AWS) Position Statement on the Northridge Earthquake recommends that the interpass temperature should not exceed 550°F (290°C) when notch toughness is a requirement.

Why a Maximum?

It may be important to impose control over the maximum interpass temperature when certain mechanical weld metal properties are required. The AWS Position Statement is one example with regard to notch toughness, and there could be many others. For example, if a designer expects a minimum strength level for a particular component that could experience extremely high interpass temperatures (i.e., due to its size or welding procedures), a maximum interpass temperature should be specified. Otherwise, the weld metal strength could be unacceptably low.

A maximum interpass temperature is also necessary for quenched and tempered (Q&T) steels, such as ASTM A514. Due to the heat treating characteristics of the base metal, it is critical that the interpass temperature be controlled within limits which will help provide adequate mechanical properties in the weld metal and the heat affected zone.

It may be important to control the maximum interpass temperature when certain mechanical properties are required

Keep in mind, however, that maximum interpass temperature control is not *always* required. In fact, the *AWS D1.1-98 Structural Welding Code – Steel* does not impose such control.

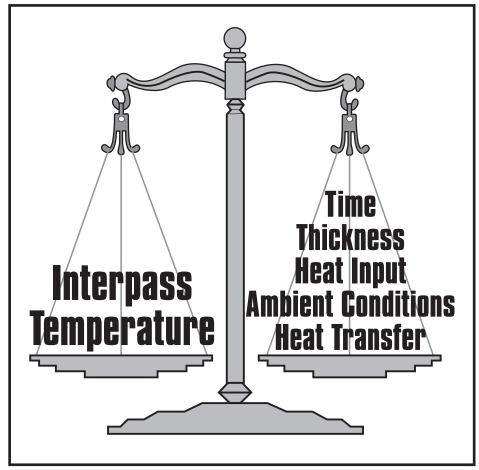

Figure 1. Balancing the variables of interpass temperature.

A Delicate Balance

Particularly on sensitive base metals, the minimum interpass temperature must be sufficient to prevent cracking, while the maximum interpass temperature must be controlled to provide adequate mechanical properties. To maintain this balance, the following variables must also be considered: time between passes, base metal thickness, preheat temperature, ambient conditions, heat transfer characteristics, and heat input from welding.

For example, weldments with smaller cross-sectional areas naturally tend to "accumulate" interpass temperature: as the welding operation continues, the temperature of the part increases. As a general rule, if the cross-sectional area is less than 20 in^2 (130 cm^2), then the interpass temperature will tend to increase with each sequential weld pass if normal production rates are maintained. However, if the cross-sectional area is greater than 40 in^2 (260 cm^2), then the interpass temperature generally decreases throughout the welding sequence unless an external heat source is applied.

How Is Interpass Temperature Measured and Controlled?

One accepted method of controlling the interpass temperature is to use two temperature indicating crayons. A surface applied temperature indicating crayon (often referred to by the trade name Tempilstik) melts when the material to which it is applied reaches the crayon's melting temperature. The crayons are available in a variety of melting temperatures, and each individual crayon is labeled with its approximate melting point.

Figure 2. Tempilstiks™ help control interpass temperature.

One temperature indicating crayon is typically used to measure both the minimum specified preheat temperature and the minimum specified interpass temperature, while the second is a higher temperature crayon used to measure the maximum specified interpass temperature (if required).

The welder first heats the joint to be welded and checks the base metal temperature at the code-designated location by marking the base metal with the first temperature indicating crayon. When the minimum specified preheat temperature is reached (when the first crayon mark melts), the first welding pass can commence. Immediately before the second and subsequent passes, the minimum and maximum (if specified) interpass temperature should be checked in the proper location. The lower temperature crayon should melt, indicating that the temperature of the base metal is greater than the melting temperature of the crayon, while the higher temperature crayon should not melt, indicating that the base metal temperature is not above the maximum interpass temperature.

If the lower temperature crayon does not melt, additional heat should be applied to the joint until the crayon mark on the base metal melts. And if the upper temperature crayon melts, the joint should be allowed to slowly cool in the ambient air until the upper temperature crayon no longer melts, while the lower temperature crayon does melt. Then the next welding pass can begin.

Where Should Interpass Temperature Be Measured?

There are both codes and industry standards that specify where the interpass temperature is to be checked. Both the *AWS D1.1-98 Structural Welding Code – Steel* and the *AWS D1.5 Bridge Welding Code* require that the interpass temperature be maintained "for a distance at least equal to the thickness of the thickest welded part (but not less than 3 in [75 mm]) in all directions from the point of welding." This makes sense, and is conservative when controlling the minimum interpass temperature. However, if maximum interpass temperature is also to be controlled, then the actual interpass temperature in the adjacent base metal may significantly exceed the maximum specified interpass temperature. If this is the situation, it is more appropriate to measure the temperature 1 in (25 mm) away from the weld toe.

In other cases, specific industries have adopted self-imposed regulations. For example, in one shipyard the interpass temperature must be maintained 1 in (25 mm) away from the weld toe and within the first foot (300 mm) of its start. In this particular case, the preheat is applied from the back side of the joint so as to completely "soak" the base metal.

Although there is some debate as to where the interpass temperature should be measured, most experts agree that it must be maintained for some reasonable distance away from the welded joint. Since this decision may greatly influence the fabrication cost, a reasonable and practical location must be determined. One foot away from the joint is probably excessive, while a tenth of an inch, or on the weld itself, is not right either. However, one inch from the weld toe seems appropriate.

Weldments with smaller cross-sectional areas tend to "accumulate" interpass temperature

Summary

- The effects of the welding process, procedures, and sequence of welding must always be taken into account to maintain interpass temperatures within the proper range.
- The effects of both minimum and maximum interpass temperature should be considered with regard to the mechanical and microstructural properties of the weld metal and the HAZ.
- The interpass temperature should be maintained throughout the full thickness of the base metal and some reasonable distance away from the weld, approximately equal to one inch, unless codes specify otherwise.

For Further Reading...

AWS Structural Welding Committee Position Statement on Northridge Earthquake Welding Issues. The American Welding Society, 1995.

ANSI/AWS D1.1-98 Structural Welding Code – Steel. The American Welding Society, 1998.

ANSI/AASHTO/AWS D1.5-96 Bridge Welding Code. The American Welding Society, 1996.

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