Heat in put and techniques

Objective: At the end of this lesson you shall be able to
- **describe the effects of heat on the properties of metals.**

Weldments, preheating, heat affected zone, interpass temperature.

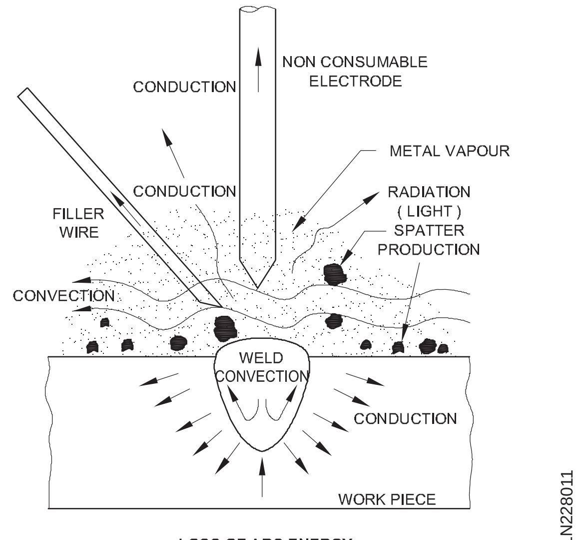
Introduction: During welding, the parent metal is heated to melting point and after that it is allowed to cool rapidly. The adjacent portion to the welded zone is also heated by to a lower temperature. This causes certain phase transformations and on rapid cooling, due to heat transfer through the colder portion of parent metal and atmosphere, the materials hardness and hence mechanical properties are also affected.

The width of parent metal that is affected due to the above cycle is called 'Heat Affected Zone'. It is quite clear that the hardness depends on rate of cooling. Higher the cooling higher will be the hardness. In order to control the cooling rate pre-heating and interpass temperature controls are adopted.

In order to relieve the welding induced stresses and to achieve better metallurgical structure to meet service conditions, post - weld heat treatment is followed.

Heat input: The energy supplied by the welding arc in a fusion welding process is called arc energy and is calculated from current voltage and welding speed. However all the arc energy is not utilized for welding; some of it is invariably lost as shown in Fig.1

Fig 1



LOSS OF ARC ENERGY

The extent of energy loss varies with the welding process, welding parameters, type of material, preheat temperature etc. To account for the energy loss and estimate the actual energy given to the workpiece, a term known as heat input is employed.

The heat input of a single pass weld is calculated by multiplying the efficiency of the welding process and arc energy. Therefore heat input at best can serve as a rough guide to the amount of heat supplied to the workpiece.

Temperature changes in welding: Heat moves from one area to another whenever there is a difference in temperature. Just as water flows downhill, so that flows down the temperature hill, warning cold objects at the expense of warmer ones.

When the source is moved away, the heat in the weld is conducted outward into the plate. The temperature of the weld has fallen, while the plate temperature near the weld is rising.

The weld has cooled still further and the plate temperature is still rising. The metal reaches a maximum temperature less than the melting point of the weld metal, and cooling sets in.

Heat Affected Zone (HAZ): The energy applied to create a weld joint is dissipated by conduction to the base metal, welding fixtures and the environment. That part of the base metal experiencing various thermal cycles is called the heat affected zone (HAZ)

During welding, the HAZ does not undergo welding but experiences complex thermal and stress alterations. The imposition of welding thermal cycles on the base material causes in the properties of the HAZ.

A welding thermal cycle is characterized by heating rate, peak temperature and cooling rate. Thermal cycles are also affected by heat input, preheating temperature, plate thickness and joint geometry.

Weld joint: A weld joint consists of several zones.

1 Weld metal or mixed zone which is essentially a solified structure.

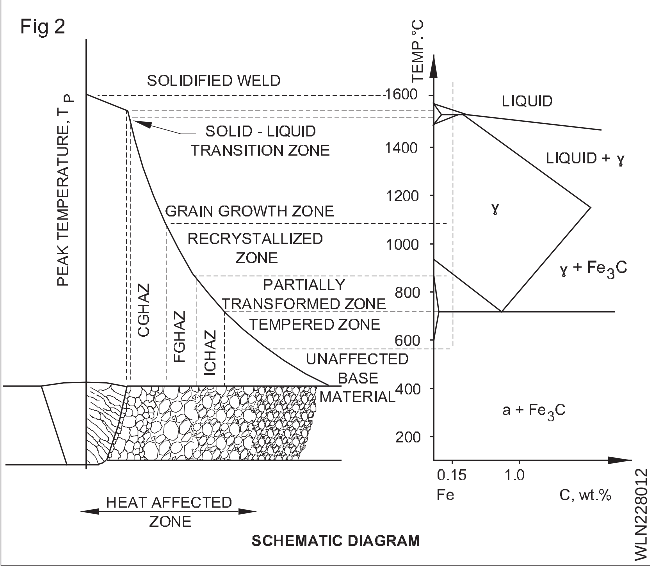
2 Unmixed zone in the base metal adjacent to the fusion line where the base metal has melted but is not mixed with the filler material.

3 Partially melted zone which has been thermal cycles with peak temperatures and,

4 Heat affected zone which has not melted but is exposed to thermal cycles with temperature less than the solids temperature.

Each zone because of its characteristic micro structural features has different properties.

Heat affected zone microstructure: The relevant portion of the iron-carbon phase diagram along with a schematic sketch of a weld and HAZ is shown in Fig.2



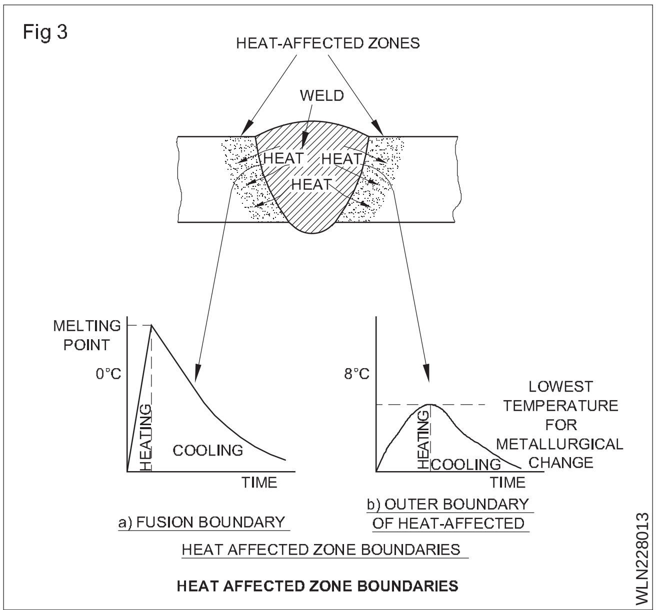
The region of the HAZ where extensive grain growth of the weld metal takes place is referred to as coarse grained HAZ (CGHAZ) 1300°C.

The region of the HAZ next to it,where peak temperature is in the range of 900-1200°C and austenite grain size remains small, is called fine grained HAZ (FGHAZ).

CGHAZ is having maximum hardness and poor toughness properties compared to the rest of the HAZ. So the preheat temperature used to reduce the cooling rate.

Heat affected zone and how to avoid risk of cracking

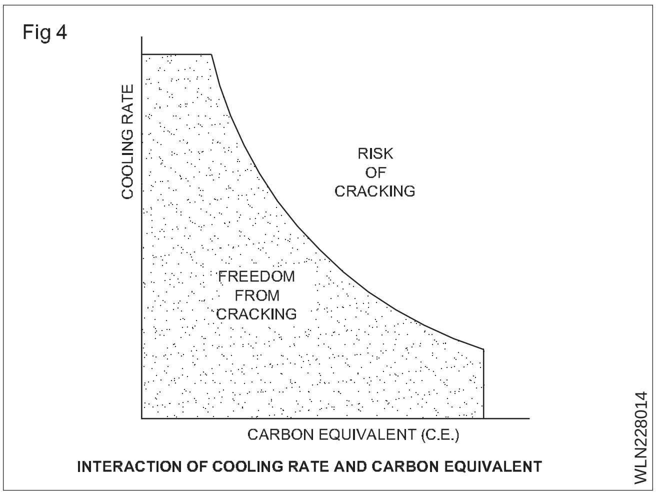
The region of the parent metal, which undergoes a metallurgical change as a result of the thermal cycle is called heat affected zone. A typical HAZ is shown if Fig 3.



If the carbon equivalent (CE) exceeds 0.4,the welding situation changes due to the possibility of cracking in the heat affected zone and due to increase in volume of martensite, cracks will usually develop the phenomenon called underbead cracking.

The normal structural steel has a hardness of 190-200 BHN. In HAZ,depending upon thickness,carbon content,hardness of 350-450 BHN may be reached. The level of hardness depends upon cooling rate. The risk of cracking is higher when hardness exceeds a certain level corresponding to higher rate of cooling.

The interaction of cooling rate and carbon equivalent is illustrated in Fig 4. At low levels of carbon equivalent fast rates can be tolerated before there is risk of cracking; except in thick section, HAZ cracking is rarely experienced with CE values below 0.39%. At high levels of CE,say around 0.48%,there is high risk of cracking even at slower cooling rates.



However, Appropriate preheating of the parent metal and or low levels of hydrogen in the weld metal can eliminate this problem.

Higher level of hydrogen is harmful. Hydrogen is absorbed in the molten weld pool from a variety of sources, moisture in the flux covering of an electrode or in the shielding gas, grease on the joint faces and so on. Hydrogen can flow (diffuse) readily through hot steel and pass from the weld pool in to the HAZ causing a major risk of cracking.

Gas shielded processes such as MAG and TIG are inherently low in hydrogen with levels 5-10 ml/100 gram and are thus effective in avoiding cracking.

Heat input and the thickness of the metal in the joint affect the cooling rate in the unit.

In thick sections cooling rate is faster than in thin. Preheating temperature slows down the cooling rate through the temperature range within which a hardened structure is formed i.e., 300-200°C. Preheat also helps to reduce the risk of cracking by allowing any hydrogen in the heat affected zone to flow into the parent metal where hardening has not taken place.

The interdependence of principal factors i.e., CE, cooling rate (heat input, joint type and thickness), hydrogen conent and preheat (temperature of parent metal during welding) governing the risk of HAZ cracking is complex.

The problem of underbead cracking can eaily be overcome by preheating the weld joint just prior to welding or by choosing a proper low hydrogen electrode.

Purpose of preheat: There are four reasons why preheat is useful in weld fabrication. They are

a The use of preheat lowers the cooling rates in the weld metal and in the heat affected zone. This results in a more ductile metallurgical structure, one that will resist weld cracking.

The slower the cooling rate permits hydrogen to diffuse out harmlessly, without causing cracking.

Preheat reduces shrinkage.

It also brings same steels above the temperature where brittle fracture might occur during welding.

No steel is immune to hydrogen-induced cracking. Additionally, preheat can be used to help ensure specific mechanical properties, such as notch toughness.

Heat distribution and effects of faster cooling

Objective: At the end of this lesson you shall be able to
- **explain the necessists of heat distribution in welding.**

Heat input is increased with increasing wire feeding speed but increasing welding speed decreases the welding heat input. When heat input increases, the cooling rate decreases for weld metal and increases the volume fraction of tempered martansite and coarsening of the microstructure of weld zone.

The outcome of microstructural examination and mechanical tests should that fast cooling, immediately after submerged welding can reduce the width of heat affected and coarse grained zones, as well as improving the low temperature impact toughness.

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