Lecture 5: Fusion Welding

Introduction

The purpose of the next three lectures is to illustrate how one aspect of a process of great importance in industry, might be modelled. The first lecture introduces the process in the context of steels, the second lecture introduces steel microstructure and the third a model for the fusion zone of the weld microstructure.

Fusion welding is of greatest importance in the fabrication of engineering structures. There are many ways in which the process is carried out, but all of them involve the deposition of a small amount of molten steel within a gap between the components to be joined. When the steel solidifies, it welds the components together. Fig. 1 illustrates the process. The heat source can be varied, but common sources include the electric arc, resistance to electrical current, lasers, electron beams and friction. The source of metal can be a manually fed wire, wire fed automatically from a spool, metallic powder or metallic foil. In autogenous welds there is no external source of metal. The process achieves very high temperatures so the region subjected to heat must be protected from the environment. Typical methods of protection include shielding with inert gas, shielding with flux powder which melts to form a protective slag, and welding in a vacuum.

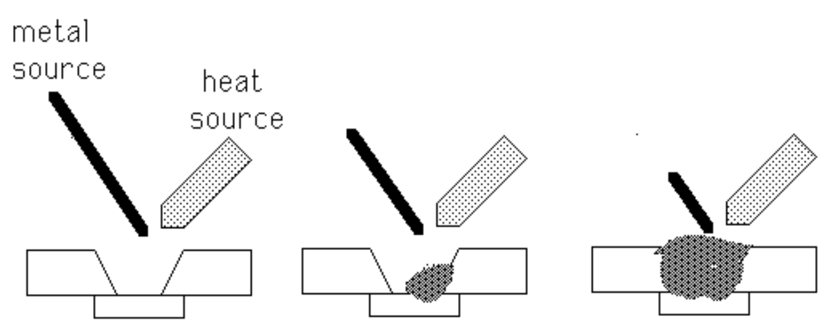

Fig. 1: Schematic illustration of the welding process.

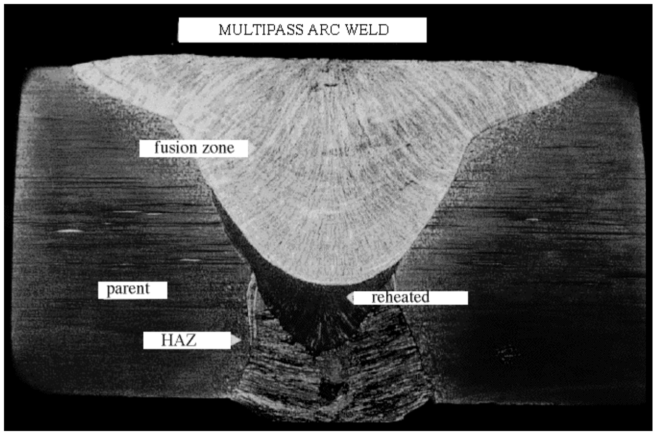

Fig. 2: A multipass arc weld illustrating the heterogeneous microstructure. The plate is about 20 mm thick. Photograph courtesy of L.–E. Svensson.

The metallurgy of the welded joint can be categorised into two major regions, the fusion zone and the heat–affected zone (Fig. 2).

The fusion zone represents both the deposited metal and the parts of the steel component melted during the process, and is a solidification microstructure. The heat–affected zone, on the other hand, represents those regions in the close proximity of the weld, where the heat input during welding changes the microstructure without melting the steel. Virtually every aspect of phase transformations in steels is relevant to the subject of welding. There is an opportunity for a whole series of transformations to occur successively as the weld cools from the liquid state. Because of time limitations, we shall focus only on the as–deposited microstructure of the fusion zone.

Iron

The two main crystal structures of iron are illustrated in Fig. 3. Austenite with the face–centred cubic structure is stable at temperatures in the range 911.5– 1394.0 °C, whereas ferrite (body–centred cubic structure) is stable at temperatures less than 911.5 °C or greater than 1394 °C to the melting temperature. Thus, ferrite is the first solid–phase to form on cooling liquid iron; it then undergoes solid–state transformation into austenite, which on further cooling reverts to ferrite. This sequence is essentially correct for the vast majority of steels, which are alloys of iron.