

Welding

As mentioned in the previous section, high-melting ceramics are usually joined by sintering. The same is true for high melting-point metals such as tungsten. However, a long list can be compiled of techniques to join lower melting-point metals, and even lower softening-point plastics, by melting a bit of each piece to be joined. We will sample just a few of these welding methods.

Metals – Gas Welding

Flame as a heat source has long been used. Among the many gases used, very common is acetylene. The process is referred to sometimes as *oxyacetylene welding*, from the use of two gas-filled cylinders, one containing acetylene and the other pure oxygen. This mixture produces a very hot flame of ~3500 °C. For comparison, the propane/air flame used with the soldering of copper plumbing burns at ~2000 °C.

An advantage of gas welding is portability, as no source of electricity is required. Another advantage is that the intense heat of the oxyacetylene torch can be used to cut metals as well as join them. A disadvantage is that this technique is not amenable to automation, nor is it as precise as some of the electric arc methods.

Metals – Shielded Metal Arc Welding

This is one of several formal names given to what is informally known as stick welding, the process that probably first comes to mind when anyone thinks of welding. An operator, wearing a mask as protection against intense heat and light, manually holds a welding rod that is attached to a source of electricity. An electric arc between the rod and the metal work piece supplies the heat necessary for melting the metals to be joined.

The core of the welding rod is a consumable metal that melts and provides filler to the solidifying weld. The rod is coated with a flux that comes off during welding to form a protective gas shield over the molten metals. During solidification, a slag generally forms that floats on the molten metal, and which must be later removed. Shielded metal arc welding is used primarily for steels. Its principal disadvantage is that, like gas welding, quality welds depend on the skill of the welder.

Metals – Metal-Inert-Gas (MIG) Welding

Metal-Inert-Gas welding was originally developed to join aluminum and other nonferrous metals but is now used extensively to join most metals, including steels. The process can be automated to be used with robotic welding. This makes MIG the most widely used industrial welding process.

In this process, a consumable metal wire is fed through a nozzle and serves as both electrode and filler. Simultaneously, an inert gas is fed through the nozzle to shield the molten metals from oxidation.

Metals – Tungsten-Inert-Gas (TIG) Welding

Somewhat similar to MIG is *Tungsten-Inert-Gas welding*. Here, a non-consumable tungsten electrode is used, along with a shielding inert gas. A filler metal is required, but because the filler does not pass through the electric arc, many different fillers are available, making TIG a very versatile process. TIG is, however, significantly slower than other arc welding processes and is generally considered to be more complex and require greater operator skill than MIG. TIG is often the choice for joining thin sections, especially stainless steels.

Metals – Heat Affected Zone

The designation of *heat affected zone* is used to refer to metal that was not melted during welding, but that lies close enough adjacent to the weld that it underwent changes during heating and cooling. One example will illustrate that the metallurgical details of welding can be complex.

Stainless steels rely on a chrome oxide skin to be chemically passive. During welding, chrome oxide in the heat affected zone can disassociate, and the chromium atoms can recombine into more stable chrome carbides. Now the metal in the heat affected zone is depleted of chromium to reform chrome oxide, and corrosion can occur along the weld.

One prevention is to start with a stainless steel with especially low carbon content. Another possibility is to tie up the carbon atoms by adding to the alloy a *stabilizer* such as titanium; titanium carbides are more stable than chrome carbide and will form preferentially.

Plastics

With lower softening temperatures than the melting temperatures of metals, plastics can be joined with some techniques not available with metals. Radio frequency electromagnetic waves have been used, as well as ultrasonic mechanical vibrations. Friction welding by rapidly rubbing plastics against each other has been successful. Unique to plastics is *solvent welding*. At room temperature, a solvent dissolves the faces of the plastics to be joined. The polymer molecules mingle in a common liquid pool. Upon evaporation of the solvent, the polymer molecules are entangled into a tight, rigid bond. The gluing of PVC pipes and fittings is an example of solvent welding.