Welding (Metals Joining)

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Welding is part of a larger category called metals joining. Within that category, there are three types of operations that can be performed:

1. Soldering
2. Brazing
3. Welding

There is actually a fourth method of joining metals which is mechanical bonding. Examples of mechanical bonds include bolting two parts together, riveting, etc.. This operation is not dependant on the type of material being joined.

Soldering, brazing and welding are operations that involve heat and the processes used in each of these depend on the metals being joined. All of them can be performed on cast iron however there are some considerations that need to be mentioned.

Soldering

By nature, soldering is a low strength bond. Chances are there are no cast iron applications that will require soldering and it is not necessary to further explain. Soldering is used to join copper plumbing pipe and is used with electrical components. Dura-Bar is not commonly used in either industry. Brazing will be the most common method of joining dissimilar metals using low (below melting point) temperatures.

Brazing

Brazing, by definition, is the joining of metals through the fusion of non-ferrous alloys. The brazing rod, usually a bronze alloy, melts and becomes an interface between the two metals being joined. Brazing alloys have melting points above 800F but lower than the metals being joined.

For cast iron, brazing temperatures need to be below 2050F; the melting point. However,

phase transformations in the microstructure of cast iron and steel will occur above 1200F so brazing temperatures should be in the 800 – 1000F range to avoid any softening of the substrate metals.

Brazing is a higher temperature and higher strength bond in comparison to soldering. The strength of the bond depends on:

1. Strength of the filler metal
2. Strength of the bond between filler metal and cast iron part

Three major advantages of brazing ferrous alloys are:

1)   There is no reduction in hardness or strength of the metals being joined because the process takes place below the critical temperature.
2)   Dissimilar metals can be joined together; for example an alloyed gray iron part can be welded to a steel mounting plate on a road grater. The alloyed gray iron is very hard and wear resistant but would probably crack under the stresses during operation. The steel plate is not nearly as wear resistant as the alloyed iron. Ideally, the wear plate assembly needs to have the impact strength and flexibility of plate steel for mounting but the wear resistance of iron for grating. Brazing the steel plate onto the iron wear pad offers a perfect solution.
3)   The surface area of bonding contact can be quite large. The 4" steel plate in the above example has a 4 in^2 contact area of bond. If the strength of the brazing rod used to bond the metals together was as low as 30,000 psi, it would take nearly 480,000 pounds of force to separate the steel plate from the alloyed iron pad!

The bonding strength between cast iron and the bronze rod can be weakened because of the graphite flakes or nodules on the surface. The surfaces should be degraphitized before brazing which is a very simple procedure. The most common method is with an oxygen flame causing the graphite to leave in the form of a gas. A salt bath is also effective for cleaning the surfaces.

Next, there should be a surface cleaning operation – all types of fluxes are used and the procedure for surface cleaning is very standard and will be similar to the cleaning for steel brazing.

Welding

Welding is a higher strength bond compared to brazing and soldering and it involves heating the parts to be joined above their melting point.

The main difference between iron and steel is that when they are rapidly solidified, carbides form in cast iron. Steel can be rapidly solidified without forming carbides. It is important not to water-quench a freshly welded cast iron part otherwise the fusion zone will

be extremely hard and brittle. The reason cast iron forms carbides is related to amount of carbon present in the austenite during the actual welding operation. As the parts to be welded are heated to their melting point, carbon diffuses into the molten iron "bath". The amount of carbon that is soluble in molten iron increases with increasing temperature. This is the same thing that takes place during casting of gray or ductile iron.

At 2500F, there can be as much as 5% carbon completely dissolved in the molten iron, but at 2050, the molten iron can only hold up to 2%. Dura-Bar gray and ductile iron grades will have as much as 3.6% total carbon in the form of either graphite nodules or flakes, or dissolved in the matrix. Some of the carbon in the form of graphite will dissolve into solution during welding, saturating the molten iron with carbon.

As the weld solidifies and cools, the carbon will precipitate back out of the fusion zone to form graphite, but since it is impossible to control the precipitation as is done during continuous casting, the graphite will not necessarily form in a desirable shape.   In fact, the entire fusion zone, both the graphite and the matrix structure would resemble a very low quality, low strength, very brittle, casting.

This is not a concern with low-carbon steel bar stock. Since low carbon steel has much only about 0.20% carbon the molten metal in the fusion zone will never become saturated with carbon and graphite will not form as it cools. High carbon steels are difficult to weld for similar reasons as cast iron.

Anatomy of a Weld
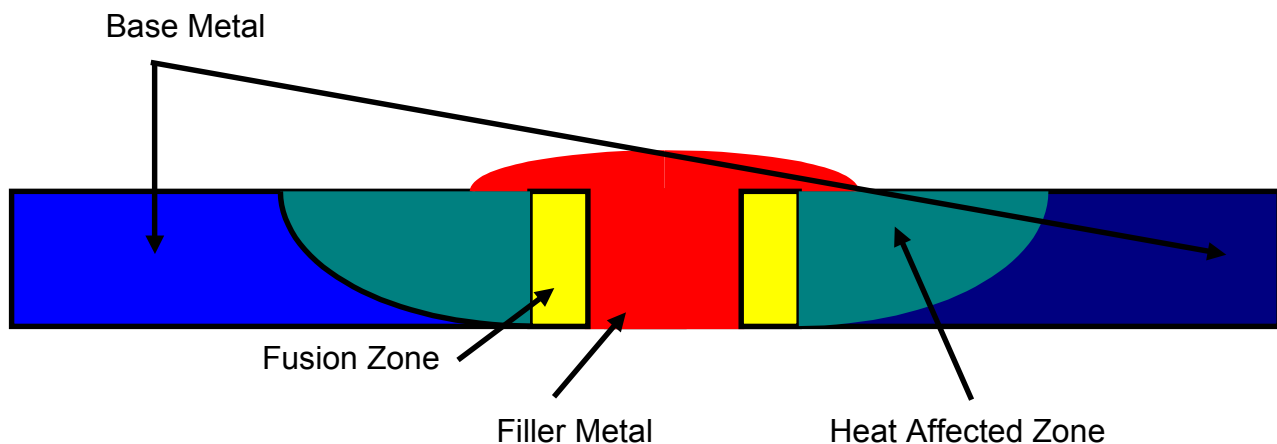
The reason heat-treating cast iron (as well as carburized and high carbon steels) is possible is because of the carbon present in the matrix. In cast iron, carbon is present in the matrix (and graphite) and is plentiful.   Remember that low carbon steels are very easy to weld, high carbon steels are difficult to weld.

Welding involves heating the parts to be joined to a temperature above their melting point, adding molten metal called filler metal between the joints and then cooling to room temperature. The portion of the weld that has been melted and joined with the filler metal is essentially a small casting. The heat-affected zone is actually a heat-treated region. The same considerations that take place in casting and heat-treating iron (or steel) have to be taken into account when welding.

The key to successfully welding Dura-Bar gray and ductile irons is to prevent carbon from diffusing out of the fusion zone into the weld puddle. If a typical low carbon steel welding rod is used, carbon will diffuse out of the cast iron into the molten steel turning it into cast iron, or at least high carbon steel. The filler metal becomes high in carbon turning it into a very low quality form of cast iron and the fused base metal no longer has its original properties. The weld is very brittle and will probably crack immediately when the part cools to room temperature.

The best way welding methods for Dura-Bar involves the use of a filler metal that will not allow carbon to diffuse into it. There are several commercially produced welding rods that are made specifically for cast iron. They contain high levels of nickel, that prevents carbon diffusion. Other alloys are also added to the rod to improve the strength of the filler metal. Since carbon does not diffuse out of the fusion zone, the substrate, and the welding zone does not lose its integrity.

Welding tests on Dura-Bar 65-45-12 using a high nickel welding rod have been performed by INCO in their Newton, NC plant. In those tests, welded Dura-Bar plates had no decrease in tensile strength or fatigue properties across a weld joint compared to test specimens that have not been welded at all.