Welding Cast Iron and Other Irons

Abstract:

The term **cast iron** is a rather broad description of many types of irons which are castings but which may have different properties and serve different purposes.

In most welding processes the heating and cooling cycle creates expansion and contraction, which sets up tensile stresses during the contraction period. For this reason, grey cast iron is difficult to weld without special precautions. On the other hand, the ductile cast irons such as malleable iron, ductile iron, and nodular iron can be successfully welded. For best results, these types of cast irons should be welded in the annealed condition.

The term **cast iron** is a rather broad description of many types of irons which are castings but which may have different properties and serve different purposes. In general, a cast iron is an alloy of iron, carbon, and silicon in which more carbon is present than can be retained in solid solution in austenite at the Eutectic temperature.

The amount of carbon is usually more than 1.7% and less than 4.5%. There are many types of cast iron; in fact, pig iron, which is the product of the blast furnace, can be considered cast iron since it is iron cast into pigs or ingots for later re-melting and casting into the final form. The most widely used type of cast iron is known as grey iron. Its tonnage production exceeds that of any other cast metal.

Grey iron has a variety of compositions but it is usually such that the matrix structure is primarily pearlite with many graphite flakes dispersed throughout. Grey cast iron is used in the automotive industry for: engine blocks and heads, automatic transmission housings, differential housing, water pump housing, brake drums, and engine pistons. There are exceptions to this but the exceptions are usually aluminium, which is readily identifiable from cast iron.

There are also alloy cast irons which contain small amounts of chromium, nickel, molybdenum, copper, or other elements added to provide specific properties. These usually provide higher strength cast irons. One of the major uses for the higher strength irons is casting automotive crankshafts. These are sometimes called semi steel or proprietary names.

Another alloy iron is the austenitic cast iron which is modified by additions of nickel and other elements to reduce the transformation temperature so that the structure is austenitic at room or normal temperatures. Austenitic cast irons have a high degree of corrosion resistance.

White cast iron is another type of iron, in which almost all the carbon is in the combined form. This provides a cast iron with higher hardness which is used for abrasion resistance.

Another class of cast iron is called malleable iron. This is made by giving white cast iron a special annealing heat treatment to change the structure of the carbon in the iron. By so doing, the structure is changed to pearlitic or ferritic which increases its ductility.

There are two other classes of cast iron which are more ductile than grey cast iron. These are known as nodular iron and ductile cast iron. These are made by the addition of magnesium or aluminium which will either tie up the carbon in a combined state or will give the free carbon a spherical or nodular shape rather than the normal flake shape in grey cast iron. This structure provides a greater degree of ductility or malleability of the casting.

The grey cast iron has a very low ability to bend and low ductility. Possibly a maximum of 2% ductility will be obtained in the extreme low carbon range. The low ductility is due to the presence of the graphite flakes which act as discontinuities.

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Preparation for Welding

In preparing the casting for welding it is necessary to remove all surface materials to completely clean the casting in the area of the weld. This means removing paint, grease, oil, and other foreign material from the weld zone. It is desirable to heat the weld area for a short time to remove entrapped gas from the weld zone of the base metal.
Where grooves are involved a V groove from a 60-90° included angle should be used. Complete penetration welds should always be used since a crack or defect not completely removed may quickly reappear under service conditions.

Preheating is desirable for welding with any of the welding processes. It can be reduced when using extremely ductile filler metal. Preheating will reduce the thermal gradient between the weld and the remainder of the case iron. Preheat temperatures should be related to the welding process, the filler metal type, the mass and the complexity of the casting.

Arc Welding

The shielded metal arc welding process can be utilized for welding cast iron. There are four types of filler metals that may be used: cast iron covered electrodes, covered copper base alloy electrodes, covered nickel base alloy electrodes and mild steel covered electrodes. There are reasons for using each of the different specific types of electrodes as follows: the machinability of the deposit, the colour match of the deposit, the strength of the deposit, and the ductility of the final weld.
When arc welding with the cast iron electrodes, preheat to between 120° and 425°C is necessary, depending on the size and complexity of the casting and the need to machine the deposit and adjacent areas. In general, it is best to use small-size electrodes and a relatively low current setting. A medium arc length should be used and if at all possible welding should be done in the flat position.

Arc welding contd.

There are two types of copper-base electrodes, the copper tin alloy (ECuSn-A and C) and the copper aluminium (ECuAl-A2) types. The copper zinc alloys cannot be used for arc welding electrodes because of the low boiling temperature of zinc. Zinc will volatilize in the arc and will cause weld metal porosity. The copper tin electrodes will produce a braze weld having good ductility. The ECuSn-A has less amount of tin. It is more of a general purpose electrode. The ECuSn-C provides a stronger deposit with higher hardness.

The copper aluminium alloy electrode (ECuAl-A2) provides much stronger welds and is used on the higher strength alloy cast irons.

When the copper base electrodes are used, a preheat of 120-200°C is recommended and small electrodes and low current should be used. The welding technique should be to direct the arc against the deposited metal or puddle to avoid penetration and mixing the base metal with the weld metal. Slow cooling is recommended after welding. The copper-base electrodes do not provide a good colour match.

There are three types of nickel electrodes used for welding cast iron. The ENiFe-CI contains approximately 50% nickel with iron, the ENiCI contains about 85% nickel and the ENiCu type contains nickel and copper. The ENiFeCI electrode is less expensive and provides results approximately equal to the high-nickel electrode. These electrodes can be used without preheat; however, heating to 40°C is recommended. The nickel and nickel iron deposits are extremely ductile and will not become brittle with the carbon pickup. The hardness of the heat-affected zone can be minimized by reducing penetration into the cast iron base metal. The copper nickel type comes in two grades; the ENiCu-A with 55% nickel and 40% copper and the ENiCu-B with 65% nickel and 30% copper. Either of these electrodes can be used in the same manner as the nickel or nickel iron electrode with about the same technique and results. The deposits of these electrodes do not provide a colour match.

Mild steel electrodes (E St) are not recommended for welding cast iron if the deposit is to be machined. The mild steel deposit will pick up sufficient carbon to make a high-carbon deposit which is impossible to machine. Additionally, the mild steel deposit will have a reduced level of ductility as a result of increased carbon content. This type of electrode should be used only for small repairs and should not be used when machining is required.

Minimum preheat is possible for small repair jobs. Here again, small electrodes at low current are recommended to minimize dilution, and to avoid the concentration of shrinkage stresses. Short welds using a wandering sequence should be used and the weld should be peened as quickly as possible after welding. The mild steel electrode deposit provides a fair colour match.

Oxy-Fuel Gas Welding

The oxy-fuel gas process is often used for welding cast iron. Most of the fuel gases can be used. The flame should be neutral to slightly reducing. Flux should be used. Two types of filler metals are available: The cast iron rods (RCI and A and B) and the copper zinc rods (RCuZn-B and C).
Welds made with the proper cast iron electrode will be as strong as the base metal. The RCI classification is used for ordinary grey cast iron. The RCI-A has small amounts of alloy and is used for the high strength alloy cast irons and the RCI-B is used for welding malleable and nodular cast iron. Good colour match is provided by all of these welding rods. The optimum welding procedure should be used with regard to joint preparation, preheat, and post heat.

The copper zinc rods produce braze welds. There are two classifications: RCuZn-B, which is manganese bronze and RCuZn-C, which is a low-fuming bronze. The deposited bronze has relatively high ductility but will not provide a colour match.

Gas Metal Arc Welding

The gas metal arc welding process can be used for making welds between malleable iron and carbon steels. Several types of electrode wires can be used, including:

- Mild Steel (E70S-3) using 75% Argon + 25% CO_2 for shielding.
- Nickel Copper (ENiCu-B) using 100% Argon for shielding.
- Silicon Bronze (ECuZn-C) using 50% Argon +50% Helium for shielding.

In all cases small diameter electrode wire should be used at low current. With the mild steel electrode wire the Argon-CO_2 shielding gas mixture is used to minimize penetration. In the case of the nickel base filler metal and the copper base filler metal the deposited filler metal is extremely ductile. The mild steel provides a fair colour match. A higher preheat is usually required to reduce residual stresses and cracking tendencies.

Flux-Cored Arc Welding

This process has recently been used for welding cast irons. The more successful application has been using a nickel base flux-cored wire which produces a weld metal deposit very similar to the 50% nickel deposit provided by the ENiFe-CI covered electrode. This electrode wire is normally operated with CO_2 shielding gas but when lower mechanical properties are not objectionable it can be operated without external shielding gas. The minimum preheat temperatures can be used. The technique should minimize penetration into the cast iron base metal. Post heating is normally not required. A colour match is not obtained.
Flux-cored self-shielding electrode wires (E60T-7), operating with electrode negative (straight polarity), have also been used for certain cast iron to mild steel applications. In this case, a minimum penetration type weld is obtained and by the proper technique penetration should be kept to a minimum. It is not recommended for deposits that must be machined.

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