WELDING OF DUCTILE IRON
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Ductile Iron is the easiest of all the cast irons to weld. The ferritic grades (lower strength) are more weldable than the high strength grades. To accomplish proper welding the following information and suggestions should be carefully complied with.

Welding Metallurgy
Since most welding operations are where one or more materials are repaired or joined together with a filler material at a high temperature, the metallurgy of all these materials and the temperature changes that they undergo are very important. We can create areas in the parent material(s), called the heat affected zone (HAZ) and the fusion zone (FZ) due to melting and then refreezing at rapid cooling rates. The amount of carbon in the matrix is then very important as to whether carbides, pearlite, and/or martensite can be formed in these zones. Higher matrix carbon contents will usually give more problems. Careful control of the welding process will produce the best possible final microstructure.

We usually divide welding into two categories - repair and fabrication. However, for both of these processes the new area/material in the welded zone should have at least the same mechanical properties as the Ductile Iron parent material so that the toughness and/or fatigue properties, as well as the machinability of the part/assembly are maintained.

Welding Processes
There are two basic types of welding processes and a number of specialized types under these categories.

1) Oxyfuel Welding (OFW) can be done with oxygen & acetylene gas fired torch, a Ductile Iron filler rod and some flux to reduce the oxidation/slag products formed during welding. The process involves melting the area on the casting and the filler material with the torch, forming a molten pool and then allowing the mass to solidify and slowly cool.

2) Arc Welding consists of melting the parent material and an electrode with the heat generated by an electrical arc produced between them. Very high temperatures (up to 9000°F (5000°C)) produce rapid melting, but these temperatures can have significant effects on the final microstructure. There are a number of different methods to do this using special types of electrodes including wire and even shielding gases to minimize oxidation.

Equipment and Filler Materials
The variety of equipment and materials for welding is so numerous that they cannot adequately be covered in this sheet. Please consult one of the references at the end for more specific information.

Joint Design and Preparation
The preparation of the joint is dependent upon the design, type of material, thickness, welding process and service requirements. The decisions about these factors must be made before the welding process begins. Figure 1 shows some possible ways to prepare joints for the welding of two distinct components. All casting joint surfaces should be freshly ground or machined so that they do not have rust, dirt or oils on them.

Thermal Cycling
The thermal cycle of the welding process can have an effect on the structure produced and the stresses (possible cracking of the weld) that are generated. All materials to be welded that contain a high carbon content will also give some problems. A range of matrix structures can be produced depending upon the solidification rate, cooling rate and chemistry of the parent and filler metals during welding. However, cracking of a weld is a function more of composition and temperature rather than of microstructure. Figure 2 shows the relationship between carbon equivalent (CE) and preheating temperatures to avoid cracks in the welded zone.

Preheating and slow cooling of the parts can make the welding operation easier. In addition to reducing thermal cracking, the hardness and residual stresses can also be reduced giving very similar mechanical properties in the HAZ and FZ. Care must be taken to avoid rapid and non-uniform heating. Slow cooling may be obtained by using thermal blankets to retain heat.
Weld Deposit Microstructure

The weld deposit may be graphite free or contain some nodules or flake graphite. Spheroidal (nodular) graphite structures can be obtained with most methods, but this will be determined by the filler material and the welding technique. If there is any unwanted cementite or martensite in the weld, a heat treatment may have to be done to change the microstructure. Preheating of the parts can help to prevent them from forming.

After welding the welded area should be free of defects including gas holes and slag inclusions.

Today you can find many examples where a Ductile Iron casting has been welded to form a fabrication with another Ductile Iron part or with a piece of steel. This is especially true in the car manufacturing industry. Using welding processes in this way can expand the market for Ductile Iron castings into areas previously reserved only for steel.

For more detailed information on specific welding processes and techniques as well as examples of fabrication and repair, the reader is referred to the following publications:


Note: QIT Technical Service Representatives are there to answer questions about welding as well as any others about Ductile Iron.

**Figure 1.** Joint Design Improvements.

**Figure 2.** Relationship between Carbon Equivalent and No-Crack Temperature for Cast Irons.