Welding-ductile-iron requires knowledge and skill.

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How to weld Cast Ductile Iron

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welding of Cast Iron in general.

Ductile Iron, although less ductile than wrought steel, is however much more ductile than other types of Cast Iron.

This quality, very important for certain applications, is achieved by careful additions of manganese and tiny amounts of magnesium or cerium in the melt.

The result, upon solidification and cooling of the castings, is that it produces graphite agglomerations of spherical shape, called nodules, instead of the common graphite flakes present in gray iron.

Each nodule is surrounded by a zone of ferrite (carbon-free iron) with the balance of the metal matrix usually in the form of ferrite or pearlite.

Graphite, an essential constituent, is the stable form of pure carbon in cast iron.

Graphite flakes interrupt the continuity of gray cast iron matrix and as such contribute to the damping properties of that material and to its brittleness.

Graphite spheroids, on the contrary, act as crack arresters, giving to the ductile irons remarkably improved mechanical properties.
Nodular or ductile irons are available with pearlite, ferrite or pearlite-ferrite matrices which offer a **good combination** of strength and toughness, greater ductility, excellent wear resistance and fatigue strength properties.

The mechanical properties of ductile iron as determined by tensile test, beam test, ring bending test, and bursting test, including modulus of elasticity, tensile elongation and impact strength are **many times** those of gray cast iron.

Welding is commonly used on cast items to **salvage castings** by removing defects, to repair worn or damaged parts, or to **fabricate** parts from two or more separate components.

Successful application of Welding-ductile-iron requires **understanding** of the base metal metallurgy of ductile iron, of the welding influence of fusion processes on microstructure and on the effects of heat treatment.

Furthermore the **absence** of welding defects must be assured, the deployment of sufficient mechanical properties must be achieved and the machinability of the welded portions must not be impaired.

Fusion welding of cast irons starts with intricate base metal phase morphology, involves melting or transformation of the **phases present** and the re-solidification of this melt.

Three distinct regions are formed by Welding-ductile-iron, namely the fusion zone, the **partially melted zone**, and the heat affected zone (HAZ). Unless cared for properly, the welds are prone to cracking in all the three regions.

Within the fusion zone, the molten casting and the deposited filler metal can mix freely affecting the **dilution** extent.

Some of the carbon will enter into the weld pool to the effect that mechanical properties may **suffer** when dilution by the casting is excessive.

As with any base material, the success of Welding-ductile-iron depends on suitable equipment, **correct procedures**, skilled and qualified welders, and effective quality control procedures.

When Welding-ductile-iron one should remember that the fusion zone **will not resolidify as ductile iron** because the graphite will precipitate as vermicular or quasi-nodular.

That is why ductility and impact resistance will be **drastically reduced**, and some carbides are likely to form, particularly in the pearlitic grade.

Furthermore the Heat Affected Zone will produce **martensite**, hard and brittle, especially in the pearlitic grade, that must be heat treated as explained down this page to restore some ductility.

Ductile iron is **more susceptible** to welding stresses, and more likely to crack while welding or during cooling.

Therefore, **highly stressed** ductile iron castings or portions thereof should never be welded.

It is recommended not to perform welds if their section is **more than 20%** of the metal thickness.

**Standard Welding-ductile-iron Procedure**

**Preheating** should be done preferably in a temperature-controlled furnace at 290 °C (550 °F) by raising gradually the heat from
room temperature to avoid temperature gradients and internal stresses.

Holding at temperature should last for at least one hour per inch (25 mm) of thickness but not more than six (6) hours.

The effect of preheating is to reduce the cooling rate after Welding-ductile-iron.

This will effectively avoid or reduce the formation of martensite, the hard phase prone to cracking under stress.

The interpass temperature should be preferably 320 °C (600 °F) but in any case not more than 370 °C (700 °F).

The shielded metal arc welding process (SMAW) is commonly used for Welding-ductile-iron.

American Welding Society, 01-Jan-1990, 10 pages

Detailed information can be obtained also from publications of Electrode Manufacturers like those of the following links (no endorsement intended).


http://www.hobartbrothers.com/downloads/McKay_Catalog_LR.pdf

http://www.esabna.com/EUWeb/AWTC/Lesson5_36.htm

Direct Current with positive electrode, (reverse polarity DCRP) is required for the electrodes recommended.

The voltage and amperage settings should be based on recommendations of the electrode manufacturer.

Nickel containing electrodes are preferred because nickel does not form carbides and has low carbon solubility.

Therefore carbon is rejected as graphite from the melt upon cooling. Shrinkage stresses and cracking are reduced.

AWS ENiFe-CI and ENiFe-CI-A have about the same content (50%) of nickel and iron.

Their strength, higher than that of high nickel electrodes, is suitable for Welding-ductile-iron even for thick sections.

Upon dilution with the base metal, the composition of the weld metal approaches 30% Ni and 70% Fe which has the lowest thermal expansion of all nickel-iron alloys, contributing to the reduction of shrinkage stresses.

For Welding-ductile-iron of the high strength grades the nickel-iron-manganese electrodes, designated ENiFeMn-CI, can be used.

These are suitable also for wear resistance applications and for surfacing or buildup of worn out parts.
To avoid absorption of humidity, the electrodes must be stored in a **warm, dry oven** after the cans are opened. The weld bead should be of stringer type.

If previous weld deposit is present, the arc should be struck on **existing beads**.

Careful attention should be applied to **remove slag** from the weld deposit between each pass by chipping, peening and wire brushing.

**Post Weld Heat Treatment (PWHT).**

To restore the ductility of welded joints in ductile irons, to levels near those of the original casting, heating to 480 °C (900 °F) and slow air cooling are sufficient for **moderate stress relief** and softening.

Treatments designed to **dissolve any carbides** that have formed in the welded region provide greater properties improvements.

A treatment which **transforms to ferrite** the structure of the heat affected zone matrix would be suitable for a ductile iron with a ferritic matrix.

For obtaining ferrite and pearlite on cooling from austenite, as required for a **stronger ductile iron** with a matrix containing pearlite, the following treatment could be used.

It is intended to transform any martensite, produced after cooling from Welding-ductile-iron, back to **austenite**.

**Heat** to 900 °C (1650 °F) at less than 55 °C (100 °F) per hour and hold for 25 minutes per centimeter (or one hour per inch) of thickness.

Furnace cool to 260 °C (500 °F), again at the **same hourly rate**, then cool to room temperature in still air.

If a **softer ferrite matrix** is needed, it can be achieved as follows:

Heat to 840-900 °C (1550-1650 °F), at less than 55 °C (100 °F) per hour and **hold** at this temperature for 25 minutes per centimeter (or one hour per inch) of thickness.

**Furnace cool** to 675 °C (1240 °F) (at less than 55 °C (100 °F) per hour) and hold for 5-6 hours, then furnace cool to 260°C (500 °F) (at less than 55 °C (100 °F) per hour) before **cooling to room temperature** in still air.

Alternatively, to perform **tempering** of the normalized structure obtained above, one can proceed as follows:

When the temperature of the casting is **below** 320 °C (600 °F), it may be placed into a tempering furnace, held at 320 °C (600 °F) for 25 minutes per centimeter (or one hour per inch) of thickness for six hours maximum.

Then it may be **heated slowly** to 650 °C (1200 °F). Hold at that temperature for 25 minutes per centimeter (or one hour per inch) of thickness for six (6) hours maximum and **cool in still air**.

The reasons why the heating and cooling rates are **restricted** is to minimize the development of thermal stresses in the castings.

The necessary skills for Welding-ductile-iron must be developed by dedicating **sufficient training and exercise** toward building the necessary expertise and by performing inspection and tests on welded castings.

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