CIGWELD

WELDING OF CAST IRON

Introduction

This guide is not an exhaustive reference. Nonetheless, it provides the reader with a thorough technical guide to the welding of a number of different types of cast iron.

Types of Cast Iron

Cast irons can generally be divided into the following groups:

1. **Grey Cast Irons**

   Nominally contain 2.5-4.0% carbon and high silicon. Used for many applications, including those under conditions of static compressive load, lightly stressed process equipment and where severe thermal and mechanical shock would not normally be expected.

   Due to the presence of graphite in its structure, grey cast iron is easily machined, helps in the lubrication of sliding surfaces and is therefore good for bearings and for damping mechanical vibration. Grey cast iron is however quite brittle and has low tensile strength. It has uses in the machinery and automotive industries, including brake drums, clutch plates and cam shafts. Furnace parts, ingot and glass moulds and melting pots that operate at elevated temperatures are made of grey cast iron, as are various types of pipes, valves, flanges and fittings for both pressure and non-pressure applications.

2. **SG-Spheroidal Graphite Cast Irons (Nodular Cast Iron, Ductile Cast Iron)**

   SG cast irons have mechanical properties similar to those of mild steel and far greater than grey cast iron, in many cases replacing steel castings and forgings as well as grey cast iron in many applications. SG cast irons contain graphite making them machinable.

   Applications include culverts, sewers, pressure pipes as well as fittings, valves and pumps. The advantages of these products are their relatively good toughness and weldability when compared to grey cast iron

3. **Austenitic Cast Irons**

   Austenitic cast irons are nickel alloys of grey, SG and white cast irons.

   Due to the nickel addition, austenitic cast irons exhibit corrosion resistance, erosion resistance, cavitation resistance and exhibit resistance to high temperature service. Austenitic cast irons are stronger and tougher than grey cast iron, producing good wear and galling resistance as well as good machinability.

   Austenitic (SG) cast iron is approximately twice as strong as austenitic (grey) cast iron.

   Austenitic white cast irons containing nickel, chromium and molybdenum make up the range of Ni-Hard, Ni-Resist and Nicrosilal grades. Ni-Hard is used for abrasion resistance, Ni-Resist for corrosion resistance and Nicrosilal for heat resistance.

4. **White Cast Irons ("Chilled" Iron)**

   Unlike the grey and SG cast irons, white cast irons are virtually free of graphite. They are quite unmachinable and very brittle with high hardness and low tensile strength. They are often used in the manufacture of crushing rolls.

   "Meehanite"* is a high tensile white cast iron made by adding calcium silicide to white cast iron. The silicide addition gives uniform hardness as well as physical properties superior to that of grey cast iron.

   *(registered trademark of International Meehanite Metal Co. Ltd.)

5. **Malleable Cast Irons**

   Malleable cast irons, which include the white heart and black heart irons, are formed by heating white iron for a set period of time. Malleable cast irons have a higher tensile strength and better ductility than grey cast iron and will bend or deform before breaking as well as standing shock better than grey cast iron.

   Applications include flanges, pipe fittings and valve parts. Automotive parts include steering components, compressor crank shafts and hubs, transmission and differential parts, connecting rods and universal joints.

Identifying the type of cast iron:

There are a number of ways of identifying the type of cast iron that is to be welded.

1. **Visual observation**

   Grey and SG cast iron have a dirty, dark grey appearance due to the presence of graphite in the structure. White cast irons will have a whitish colour in a fracture in the casting. Malleable and austenitic cast irons have a cleaner appearance than grey or nodular.

2. **Source of supply**

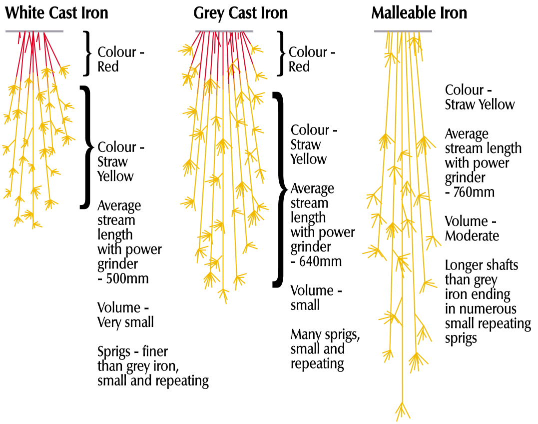
   If possible, check with the supplier of the cast iron. Quite often the item will be an old item in need of repair, so its origins may be difficult to discern.

3. **Mechanical tests**

   These are the best tests for identification.

   a) Spark test

   An easy and useful method is the spark test. The metal is touched against a high speed emery wheel and the sparks are observed against a black background. The sparks should then be compared against the chart below. SG cast irons can be identified in the same manner as malleable cast irons. Meehanite cast irons can be identified in the same manner as grey cast irons.



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b) Chisel test
Can be used for the separation of grey cast iron and malleable iron. Grey cast iron chips break easily, whereas chips from malleable cast iron will curl from the corner of the piece.

c) Spectrographic analysis
This test is the most accurate of all. However it needs to be undertaken by a qualified laboratory to ensure accurate results.

Welding Cast Irons

In general cast irons can be welded using the MMAW, FCAW, Gas and Braze Welding, Brazing, Powder Spraying and Soldering processes. The table below is a process selection guide listing the relevant CIGWELD consumable.

Process / Cast Iron	MMAW	FCAW	Gas Welding	Braze Welding	Brazing	Soldering
Grey	1	2	3,5	4, 5	4, 5	7
SG (Nodular/ Ductile)	1	2		4, 5	4, 5	
Austenitic	1					
White	Considered unweldable					
Ni-Hard	Considered unweldable					
Ni-Resist	1					
Nicrosilal	Considered unweldable					
Malleable	1	2		4, 5	4, 5	
Meehanite	1					

1=Castcraft 55, Castcraft 100
2=Nicore 55
3=Comweld General Purpose Cast Iron
4=Comweld Comcoat C, Comweld Manganese Bronze
5=Comcoat N, Comcoat Nickel Bronze
6=Comweld 965 Silver Solder

Preparation prior to welding

General

Cast iron is considered weldable, although to a far lesser degree than carbon steel. There have been many successful cast iron repair welds performed in maintenance and casting reclamation applications. The degree of brittleness and likelihood of cracking of the welded material will depend on the type of casting the heat treatment and the welding procedure. For example SG cast iron is more likely to absorb welding stresses than grey cast iron.

Preparation

The most important aspect of welding cast iron is to have the surface clean and free of defects prior to welding.

Grinding & machining

All sand, slag and scale must be removed from the area of the casting to be welded by mechanical means such as grinding, machining, chipping or rotary burrs. Physical defects such as blowholes, sand inclusions, sponginess and shrinkage cracks need to be removed. Cracks should be excavated to their full length and depth. Excavate spongy areas and pinholes. Quite often a pinhole will open up to expose a large cavity hidden underneath. During preparation grinding wheels can become impregnated with carbon which can be smeared on the finished surface making joining difficult because of the high carbon content of the surface. Because of this the final 1-2mm should be prepared by chipping, rotary burrs or a coarse file to clean the surface.

Oxy-acetylene

An oxidising oxy-acetylene flame can be used to burn off any surface graphite. This also provides a light preheat which is advantageous.

Arc-air gouging

Arc-air gouging is not usually recommended. However, it can be used to remove the bulk of metal providing the last 1-2mm is removed by grinding.

Oil soaked castings

Often castings are soaked in oil due to their environment eg. gear boxes. They may appear clean after mechanical cleaning, however oil will still be present in the pores of the casting. The elimination of the residual can be achieved by heating the casting to 200-300°C for 2-3 hours followed by wire brushing. This will help overcome porosity and poor welds. "Gassy" castings can be treated by heating the weld area to a dull red for a short time before welding. For small components, treatment in a furnace at 650°C for 15 minutes will give fairly complete degasification. On heavier castings the relevant face is welded and the resultant porous metal is removed and the surface rewelded until a clean surface is obtained.
Castings high in phosphorous are difficult to weld and can be identified by a glassy and shiny appearance. Often brazing is the best way to repair these castings.

To repair cracked castings, drill a hole at each end of the crack to prevent it spreading further and grind out to the bottom. Begin welding at the drilled end of the crack, where restraint is greatest and move towards the free end.

Castings which have to transmit fairly heavy working loads often have the weld joint assisted by mechanical means, such as bolted straps, or hoops which are shrunk on. Broken teeth of large cast iron gears are sometimes repaired by studding. Holes are drilled and tapped in the face of the fracture and mild steel studs screwed in. These are then covered with weld metal and built up to the required dimensions. They are machined afterwards or ground to shape.

Precautions when welding cast irons

Factors to consider are the same whatever the type of cast iron.

1. Low ductility with a danger of cracking due to stresses set up by welding. (This is not so important when welding SG iron due to its good ductility)
2. Formation of a hard brittle zone in the weld area. This is caused by rapid cooling of molten metal to form a white cast iron structure in the weld area and makes the weld unsuitable for service where fairly high stresses are met.
3. Formation of a hard, brittle weld bead due to pick-up of carbon from the base metal. This does not occur with weld metals which do not form hard carbides such as Monel and high nickel alloys. These are used where machinable welds are desired.

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Preheating

Although a large amount of satisfactory welding is done without preheating, cracking due to the rigidity or lack of ductility of castings, especially complicated shapes, may be minimised by suitable preheating.

In general all cast irons need to be preheated when oxy-acetylene welding to reduce the heat input requirements. High preheat is needed when using a cast iron consumable because the weld metal has low ductility near room temperature. A consumable that deposits relatively low strength, such as Castcraft 100, can be used with the base metal at or slightly above room temperature. The weld can readily yield during cooling and relieve welding stresses that might otherwise cause cracking in the weld.

1. Local preheating occurs where parts not held in restraint may be preheated to about 500°C in the area of the weld, with slow cooling after welding is completed. Cracking from unequal expansion can take place during the preheating of complex castings or when the preheating is confined to a small area of a large casting which is why local preheating should always be gradual.

2. Indirect preheating involves a preheat of 200°C for other critical parts of the job in addition to local preheating. This is done so that they will contract with the weld and minimise contraction stresses. Such a technique is suitable for open frames, spokes etc.

3. Complete preheating is used for intricate castings, especially those varying in section thicknesses such as cylinder blocks. It involves complete preheating to 500°C followed by slow cooling after welding. The preheating temperature should be maintained during welding. A simple preheating furnace may be made of bricks into which gas jets project. Another may be filled with charcoal which burns slowly and preheats the job evenly.

Postweld Heating

After any welding on cast iron, especially welds intended for use in severe service or subject to close machining tolerances, the slowest cooling rate possible should be allowed, the part either remaining in the preheating furnace or cooling under a blanket of insulating powder or sand. It is sometimes the practice to post-heat welded joints to relieve stresses and soften hard areas. In this case it is normal to heat the casting to a temperature of 595-620°C. The casting should be held at this temperature for one hour per 25mm of thickness. The cooling rate should not exceed 10°C per hour until the casting has cooled to about 370°C. (For maximum softening and stress relief, heat at 900°C followed by slow cooling to 540°C or lower.) To obtain optimum ductility, the above heat treatment should be carried out immediately following welding.

For the best results with SG cast iron, the casting should be placed in a furnace (595-650°C) and the temperature raised to 900°C. The casting should be held at temperature for 2-4 hours. It is then cooled to 705°C, held there for 5 hours, then cooled to 590°C in the furnace and finally to room temperature. Malleable cast iron may be reheat-treated after welding.

Peening

Satisfactory welds may be made on cast iron without preheating by using electrodes depositing soft metal and peening the weld with a blunt tool (such as a ball hammer) immediately after welding. This spreads the weld metal and counteracts the effect of contraction.

Good practice is to deposit short weld runs (50mm at a time) and then peen before too much cooling takes place. (Castcraft 100 is soft and allows peening).

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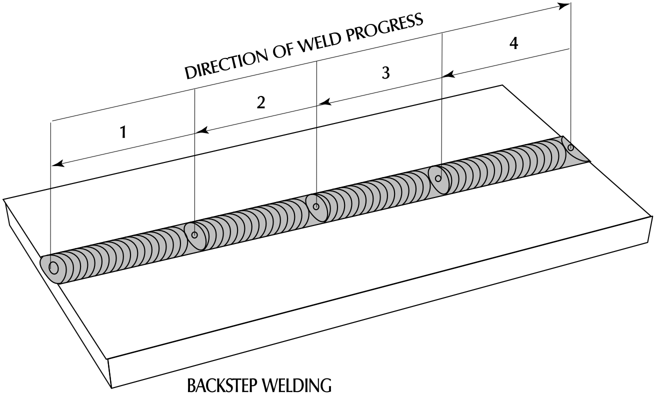
Joint Design

In general, joint design used for carbon steels are applicable for cast irons. Below are some suggested single-vee and double-vee preparations.

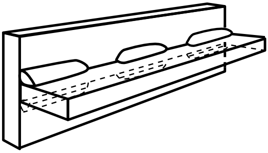
Welds should be as narrow as is practical for access - particularly for grey iron, as wide welds build up more stress than narrow ones. A double vee uses only half the weld metal of a single vee. For thick materials that are not accessible from both sides, a U-preparation is a good compromise.

See diagrams below for various joints designs:

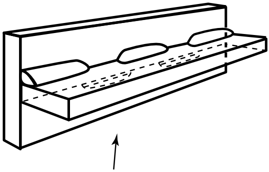
Longer joints can be welded using the backstep, block, cascade, chain intermittent and staggered intermittent methods



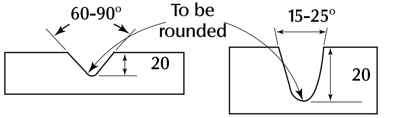
BACKSTEP WELDING



INTERMITTENT CHAIN WELDING



INTERMITTENT STAGGERED WELDING



V-groove for narrow defects, U-grooves for deep defects

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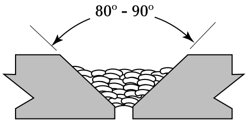
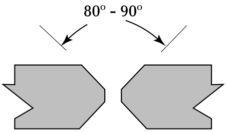
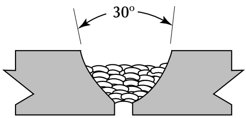


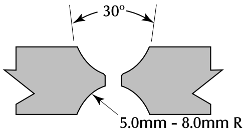
Root face 1.6mm or less
Root gap 1.6mm
Up to 20mm thick



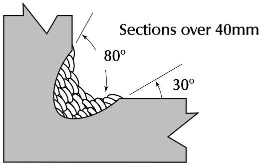
Root face 1.6mm or less
Root gap 3.2mm
20 - 40mm thick



Root radius 1.6mm - 3.2mm
Root gap 3.2mm



Root face 3.2mm
Root gap 3.2mm



Corner defect repair weld

MMAW welding of cast irons

The most suitable electrodes for MMAW of cast irons are pure nickel (AWS A5.15 ENi-CI, Castcraft 100) and 55% nickel / 45% iron (AWS A5.15 ENiFe-CI, Castcraft 55).

Grey Cast Iron

Castcraft 100 is more suitable for single layers and for filling small defects as the deposit remains highly machinable. Single-layered welds of Castcraft 55 are not as machinable as Castcraft 100, however they do have increased strength and ductility. Castcraft 55 welds are more tolerant towards contaminants such as sulphur and phosphorous and are superior to Castcraft 100 electrodes when welding castings high in phosphorous.

Peening is a must for grey cast irons.

Joining of cast iron to steel can be performed with either Castcraft 55 or 100, but Castcraft 55 is preferred. Ferrous based electrodes, including hydrogen controlled types are generally not recommended for welding cast iron. Brackets, lugs and even wear plates can be attached to castings using the correct parameters and Castcraft 55.

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SG Cast Iron

Grey iron can be repaired with either Castcraft 55 or 100 whereas SG cast iron can only really be repaired using Castcraft 55 due to its higher tensile strength and better ductility. When welding SG cast irons, penetration should be low and wide joints or cavities should be built up from the sides towards the centre. Stringer beads or narrow weaves should be used. Deposit short beads and allow to cool to preheat temperature. Peening is advisable but not as critical as when welding grey cast iron.

Austenitic cast irons

These are usually welded with Castcraft 55. Although Austenitic castings can be welded with Castcraft 55 the weld may be unsuitable for applications where corrosion/heat resistance qualities do not match the parent metal.

GMAW welding of cast irons

Cast irons are generally considered unweldable using the GMAW process.

FCAW welding of cast irons

Flux cored welding of cast irons is carried out using higher current than that for MMAW. This is offset by faster travel speeds as for normal FCAW welding. Both grey, SG and malleable cast irons can be welded using the FCAW process. Preparation and heat treatment are much the same as for MMAW.

The most suitable consumable that can be used is an AWS ENiFe-CI equivalent like Nicore 55.

Oxy-acetylene welding of cast irons

For successful oxy fusion welding, it is essential that the part be preheated to a dull, red heat (approximately 650°C). A neutral or slightly reducing flame should be used with welding tips of medium or high flame velocity. The temperature should be maintained during welding. As with MMAW preparation it is necessary to use a furnace to ensure even heating of large castings. It is important that the casting be protected from draughts during welding and provision should be made to ensure that the required preheat is maintained. It is important to avoid sudden chilling of the casting otherwise white cast iron may be produced which is very hard and brittle. This may cause cracking or make subsequent machining impossible.

Oxy welding is suitable for grey cast irons with an AWS A5.15 RCI (Comweld General Purpose Cast Iron - Super Silicon), RCI-A type electrode and should be used with a suitable flux such as Comweld Cast Iron Flux.

An AWS RBCuZn-D (Comweld Nickel Bronze & Comweld Comcoat N) type can also be used with Comweld Bronze Flux.

SG cast irons can only be oxy welded with an AWS RCI-B type consumable.

Braze Welding of cast irons

Braze welding should only be used to repair old castings because of the poor colour match achieved with newer castings. Braze welding is suitable for grey, SG and malleable cast irons, however joint strength equivalent to fusion welds are only possible with grey cast iron. A neutral or slightly oxidising flame should be used.

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Braze welding has advantages over oxy welding in that the consumable melts at a lower temperature than the cast iron. This allows lower preheat (320-400°C). As with other forms of welding the surface must be properly cleaned so that carbon doesn't contaminate the weld deposit.

The applicable consumables to use are AWS RBCuZn-C (Comweld Manganese Bronze & Comweld Comcoat C) types and AWS RBCuZn-D (Comweld Nickel Bronze & Comweld Comcoat N) types.

Brazing of cast irons

Any brazing processes suitable for steel are applicable to cast irons. Pre- and post- braze operations should be similar to that of standard brazing processes.

Consumables suitable for brazing carbon steel can be used for cast irons.

Powder Spraying of cast irons

Powder spraying is particularly suited to edges, corners, shallow cavities and thin sections as there are usually no undercut marks. Porous metals can be surfaced before arc welding.

As with other welding processes, the base metal must be extremely clean and free from contaminants. Cavities and porous areas must be ground out to a saucer or cup shape with no overhanging edges. Sharp corners, edges and protruding points must be removed or radiused as they may go into solution in the molten metal causing hardspots.

Spraying and fusing should be as per the normal powder spraying process.

Poor quality or difficult irons can be joined by coating both parts separately with 1-2 mm of spray-fused alloy and then joining the coatings together with a suitable nickel MMAW electrode.

Consumables are based on a nickel-silicon-boron mixture.

Soldering of cast irons

Soldering of cast irons is usually limited to the repair of small surface defects, often sealing areas from leakage of liquids or gases. The casting must be thoroughly cleaned.

A suitable consumable is Comweld 965 Solder.