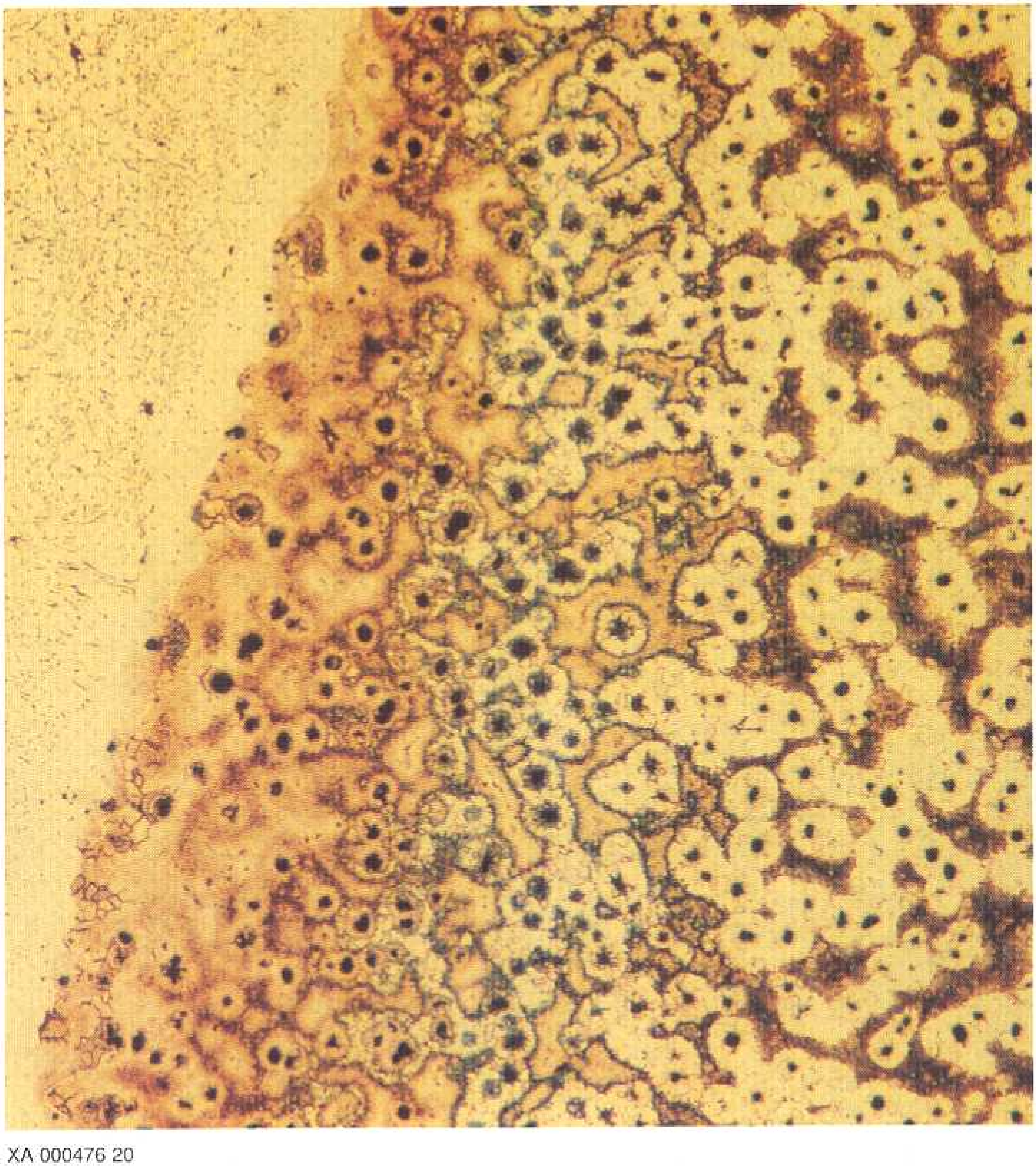
MMA Welding of cast iron



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Content

1 What is cast iron?

1.1 GENERAL

By alloying pure iron with carbon the melting point can be lowered from 1534 C (pure iron) to 1147 C (4.3 % C). This reduction is used industrially to produce cast iron. Cast iron therefore, has a high carbon content (between 2 and 5 %) which considerably affects its weldability. In addition to this phosphorus and sulphur content are usually higher than for ordinary steel, which further affects the weldability.

Pure iron, alloyed primarily with 2–5 % carbon shows low ductility, low hardness and low strength, and is on the whole a very brittle material. To improve these properties (and to render the iron additional properties like heat-, corrosion- and wear resistance), cast irons are often alloyed and/or heat treated. The numerous amount of alloys so created may for convenience be divided into the following groups.

- Grey cast iron
- White cast iron
- Malleable cast iron
- Ductile cast iron
- Compacted graphite cast iron
- Alloyed cast iron

1.2 GREY GAST IRON

Grey cast iron is the most common type of cast iron (around 70 % of all cast irons are grey). The microstructure consists of graphite flakes distributed in a matrix of ferrite, pearlite or both. The graphite possesses zero strength, and therefore rupture will always appear in this phase, and since graphite is grey, the fracture surface will look grey. Thereby the name. Grey iron usually contains up to 4.5 % C and up to 3 % Si. It is made by slow cooling of the casting. Some old types may contain considerable amounts of sulphur and phosphorus,which can make welding difficult. However, on modern castings this is seldom the case, and welding is most often employed without complications.

1.3 WHITE CAST IRON

White cast iron is evaluated on hardness/wear resistance and mostly used for such purposes. It is of similar composition to grey iron, but with a lower silicon content. Sometimes it is also alloyed with carbide stabilizers such as Cr, Mo and V. The microstructure consists of carbides distributed in a martensitic or pearlitic matrix. The carbides are hard and brittle, and render the fracture surface a whitish colour. Thereby the name. It is made by rapid cooling with "chills". It is to be considered as non weldable, although successful weld surfacings have been achieved on crusher rolls using OK Autrod 12.51. The hardness was rendered the mild steel weld metal through carbon pick-up from the white iron. To join white iron, however, welding is not recommended.

1.4 DUCTILE CAST IRON

Ductile cast iron have similar composition to grey iron, but usually higher purity. The addition of small amounts of magnesium brings the graphite into forming spheroids, uniformly dispersed throughout the structure, instead of flakes like in grey iron. This will, in the annealed state, render ductile iron mechanical properties similar to mild steel. Welding is therefore seldom difficult with these irons. However, the violent heat treatment involved in welding, together with the dilution from the cast iron, still calls for the use of special electrodes and careful planning of the procedure.

1.5 COMPACTED GRAPHITE CAST IRON (CG-IRON)

Compacted graphite cast iron (CG-iron) may be considered as an intermediate between ductile and grey iron. It is produced by adding controlled amounts of magnesium, titanium and cerium to a composition similar to grey iron. Welding should be performed as for grey iron.

1.6 MALLEABLE CAST IRON

Malleable cast irons are produced by heat treatment of white cast irons to render them more ductile than grey irons. They have lower carbon and silicon content than grey irons, to secure white iron solidification. The microstructure consists of aggregated, somewhat irregular nodules of graphite distributed in a matrix of ferrite, pearlite or tempered martensite. Mechanical properties are similar to ductile iron. Welding of malleable iron may produce a thin white iron zone in the weld and the portion of the HAZ adjacent to the weld metal. This is not serious in many applications. However, parts produced to be welded are often rendered excellent weldability by a decarburizing heat treatment.

1.7 ALLOYED CAST IRON

Alloying elements are added to improve properties like heat-, corrosion- and wear resistance and to increase strength. Examples are "Ni-resist" (corrosion resistance), "nicrosilal" (heat resistance), and "meehanite" (high tensile). These irons show a weldability similar to ductile irons.

However, one special type of alloyed iron is "Ni-hard", which is more like a white iron and therefore to be considered as non weldable.

2 Factors affecting weldability

2.1 GENERAL

White iron and "Ni-hard"-types, because of their exteme brittleness, generally crack when attempts are made to weld them. Trouble may also by experienced when welding white-heart malleable cast iron, due to porosity caused by gas held in this type of iron. Other grades of cast iron are being successfully welded every day, provided the correct procedure is employed. Successful welding of cast iron is mainly depending on minimizing the influence of the following:

- Cooling stresses
- Irregular shape of the casting
- Hardening of the HAZ
- Carbon pick-up from the base metal
- Oil impregnation of cast iron

2.2 COOLING STRESSES

The weld metal will contract upon cooling. This contraction is generally larger than the corresponding contraction of the cast iron. Due to the brittleness of cast iron, the resulting contractional stresses must be accomodated in the weld metal if cracking is to be avoided.

2.3 IRREGULAR SHAPE

Iron castings are usually designed for rigity. They are seldom of uniform thickness, and generally they are of intricate shape with rapid changes of section. Thus, they will not readily adjust themselves to local contraction, and due to their low ductility, new fractures are liable to occur. (SG iron, due to its good ductility, is not so sensitive in this respect).

2.4 HAZ AND FUSION LINE

The heat affected zone of the cast iron adjacent to the weld, will be hardened during welding due to the high carbon content. The hardness of the non melted part of the HAZ is mainly depending on cooling rate, and the width mainly on applied heat input.

The portion of the HAZ closest to the fusion line will contain partially melted material. The microstructure of this zone is very complex and consists of a mixture of martensite, austenite, primary carbide, and lederburite which surrounds partially dissolved nodules or flakes of graphite. This portion is the hardest zone in the weld.
The extent and hardness of this zone is mainly depending on applied peak temperature, heat input and cooling rate during welding. Since the peak temperature is fairly equal in MMA welding, regardless of consumable choice, the properties will also here mainly depend on heat input and cooling rate.

2.5 CARBON PICK-UP FROM BASE METAL

The dilution with base material will cause carbon pick-up in the weld metal. It will also cause increased weld metal content of sulphur and phosphorus if such are present in the cast iron.

2.6 OIL IMPREGNATION OF THE CAST IRON

Oil may be absorbed in graphite and micropores, thereby penetrating deep into the cast iron. During welding, this oil will evaporate and cause porosity in the weld metal.

3 How to control these factors

3.1 COOLING STRESSES

Cooling stresses may be lowered by:

Using correct welding parameters.

Weld with short stringer beads, low amperage and plan the bead sequence.
The smaller the volume to cool, the smaller the cooling stresses. Consequently, short beads are preferred to long ones.
Weaving will result in larger parts of the weld to cool, thereby increasing cooling stresses. Stringer beads are therefore preferred.
In multilayer welding, subsequent layers will heat previous layers, thereby releasing some of the stresses built up during welding of previous layer.
To further lower the heat input, in particular when welding thin sections, it has been proved useful to weld in the vertical down position. This is possible using the OK 92.60.

Using consumables that provides a ductile weld metal

Residual stress levels in weld metal are usually in the region of its yield stress. Consequently, to lower the residual stress levels or cooling stresses, weld metal with low yield stress are preferred to such with high yield stress.

Performing preheating

The yield stress of any material generally decreases with increasing temperature. Consequently, if the contractional stresses originating from welding could be fully accomodated in the weld metal at a higher temperature than room temperature, the residual stress level would be lower. Consequently, preheating may lower the influence of cooling stresses.

Peening

Peening will introduce compressive stresses in the weld metal instead of the tensile stresses introduced during the welding operation. This is the most useful method to avoid cracking in cast iron welds.

3.2 IRREGULAR SHAPES

To avoid cracking in associated parts of the casting due to contractional stresses caused by welding, it is often useful to expand this part by preheating in order to balance these stresses. This type of preheating is commonly named indirect preheating. Fig 1 shows the application of this preheating, as a general rule.

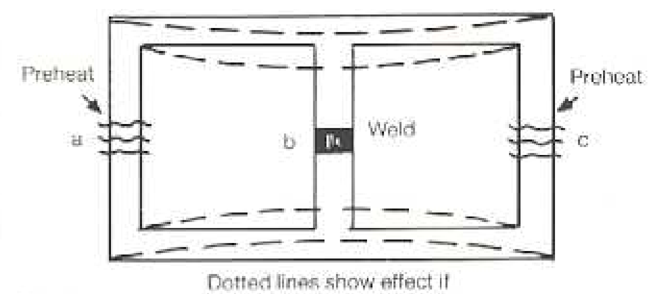


Fig 1

when using this procedure it is better to heat a large area to a low temperature than to heat a small area to a high temperature. However, a high local preheat in the joint will still be necessary, if a soft machineable weld is required.
When welding an intricate casting containing rapid changes of section, the general preheating should be maintained at a temperature just under red heat. Where this is not possible, many repairs can be made satisfactorily with a general preheat to black heat with a local preheat on the joint. All preheating should be carried out slowly to allow a uniform distribution of heat to build up in the casting. General preheating up to a temperature of around 600°C may be carried out in a suitable improvised furnace using gas heating or charcoal.
Finally, the more intricate the shape, the greater the need for evenly applied preheating.

3.3 HAZ AND FUSION LINE

The hardness of the HAZ maybe lowered by preheating. However, to reach a substantial hardness reduction, the casting would need to be preheated to around 500°C.
The hardness of the partly remelted zone close to the fusion line may be lowered by reducing the time at the peak temperature during welding (e.g. using low amperage).

3.4 CARBON PICK-UP FROM BASE METAL

Carbon pick-up from base metal will always occur in cast iron welding. In principal, there is two ways of minimizing the effects of this.

1 Using high preheating in combination with slow cooling, to avoid the detrimental effects of the carbon pick-up. This is essential when using Fe-based consumables.
2 Using consumables where the carbon pick-up is not detrimental. This is by far the most used method, and the consumables are mostly of Ni-based type.

3.5 OIL IMPREGNATION OF CAST IRON

When oil has penetrated deep into the cast iron, it is impossible to remove by any degreasing agent, since this will affect only the surface oil.
Instead the oil has to be burnt off by comparably long heat treatments at temperatures around 500°C. Normal heating time may be 4–8 hours.
On many applications this is not possible, and for such, gauging with OK 21.03 may provide a suitable enough solution.
Should porosity still occur, the best way to produce sound welds is to repeatedly remove the weld metal by grinding and reweld it until no porosity occurs.

4 Welding procedures

4.1 CLEANING

All surfaces must be cleaned prior to welding. Cast iron itself, is of such low strength that it is unnecessary to further weaken the welded joint by omitting this important precaution.

- **Oil, grease, etc.**
  Surfaces shall be thoroughly degreased chemically, otherwise porosity will result.
  If the cast iron has long been in contact with oil, (like gears immersed in oil or gear boxes holding oil), the oil may be absorbed by the graphite or micropores. This way oil can penetrate deep into the casting. To remove such oil, which otherwise will evaporate during welding, chemical degreasing is not enough. Instead the casting must be heated to burn out the oil. This is done at temperatures around 400–500°C for several hours.
  It is obvious that this is not always possible, and for such applications, gauging with OK 21.03 often provides a suitable enough solution, by local burnout of the oil. In addition to this, gauging will provide the most suitable joint configuration.
- **Dirt, cast skin, paint, etc.**
  It belongs to normal welding procedure to remove contaminations like these prior to welding. However, the nickel based consumables normally used for the welding of cast iron are more sensitive to contamination from this than mild steel consumables.
  So, be sure to make a thorough cleaning. Generally it is enough to clean the area within 20 mm from the weld.

4.2 JOINT PREPARATION

- Joint angles should be wider than for mild steel, around 80–90 degrees.
- All sharp edges must be rounded off, to minimize heat concentrations.
- Generally u-grooves are preferred to v-joints. This is the prime reason why gauging is so beneficial in comparison with other methods for prepairing cast iron joints.
- Cracks must be fully opened to allow accessability. However, leave 2–3 mm on the root side to allow easy fitting. Use OK 21.03 for joint preparation on all cracks.
- Cavities like blow holes, etc. must be opened and cleaned.

Joint preparation in Cast Iron

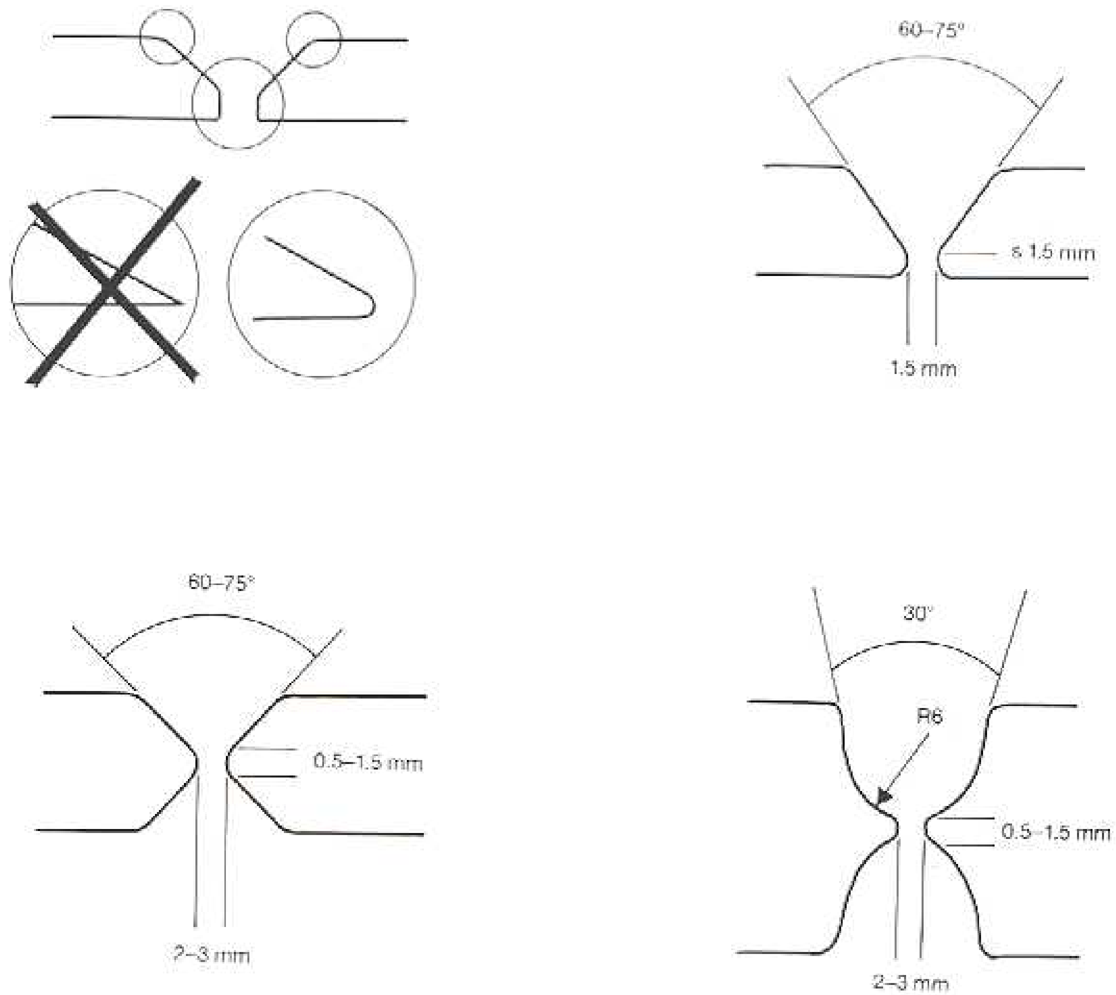


Fig 2

4.3 PREHEATING

4.3.1 Preheating methods

Although a satisfactory joint can be achieved without preheating, the risk of cracking due to the rigidity or lack of ductility especially in complicated shapes is considerably reduced by preheating.

There are three methods of applying preheat to the castings:
Local preheating, to retard the rate of cooling of the weld joint.
General preheating, to release internal locked-up stresses and to retard cooling of the weld. If the temperature is raised to above 450°C, a slight improvement in ductility occurs, which increases with further increase in the temperature. This allows for some stress adjustment and greatly reduces the distortional tendencies and the risk of cracking in the joint being welded, as well as reducing the hardness of the weld deposit and heat affected zones.
Indirect preheating, which is often valuable, if used with caution, for expanding an associated part of the casting in order to balance contractional stresses caused by welding.

4.3.2 Preheating levels

All levels of preheating is usually beneficial. However, there may be a point in establishing some "key-levels".

- **Ambient temperature**
  Securing that the casting is of at least ambient temperature will secure that no air moisture will condensate on its surface.
- **80–100°C**
  Preheating to around 80–100°C will secure that all wet surfaces will dry, thereby no hydrogen contribution from air humidity.
- **200–250°C**
  Preheating to around 200–250°C is used on ductile iron to prevent martensite formation in the HAZ. It is not necessary to preheat these irons to higher temperatures. Sometimes it may even be dangerous, since preheating in the region of 300–500°C may promote precipitation of proeutectoid cementite, which considerably lowers their ductility.
- **Up to 500°C**
  Indirect preheating is used at all temperature levels up to 500°C. The higher, the better, provided both heating and cooling is slow.
- **500–600°C**
  500–600°C is used on grey and CG iron to achieve lowest possible hardness in the HAZ.

4.4 WELDING

4.4.1 General

As mentioned above welding can be performed with different levels of preheating. As a general rule, the higher the preheating level, the less rigid the welding procedure. To facilitate the recommendations, we will here work with three different temperature levels:

- Room temperature **(cold welding)**
- 250°C **(semi-hot welding)**
- 500°C **(hot welding)**

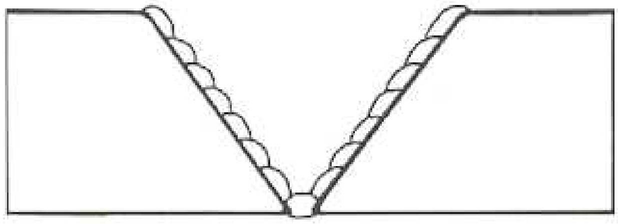
Further we need to differ between three kinds of welds:
Buttering layers
Single layer welds
Multilayer welds

4.4.2 Buttering layers

On some welds it is often beneficial to use a "buttering" technique. In short this means that one (or both) of the surfaces to be welded, are surfaced prior to the joining operation. The reasons for using this technique may be either metalurgical or mechanical. Fig 3 A.

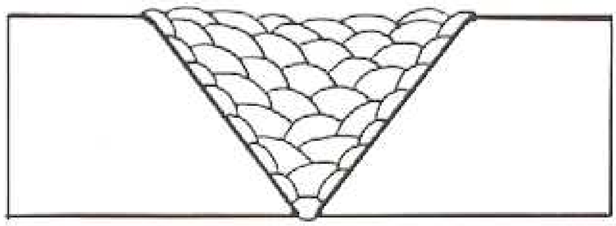
Metalurgical
To avoid formation of brittle phases in dissimilar welds.

Mechanical
To allow for coolings stresses to more affect the ductile buttering layer than the brittle HAZ of the base material. (Of course the HAZ of the base metal will be affected by cooling stresses from each weld bead, but they will be spread out over a larger area and the hard phases of the HAZ will be annealed).
Buttering is employed primarily on:
Multilayer welds, to allow for less rigid welding procedures on the fill runs. This is mainly due to the following:



Buttering technique

Fig 3 A



Multilayer with buttering technique

Fig 3 B

- The contractional stresses from the cooling weld metal in subsequent beads will be accomodated in the buttering layer, thereby lowering the stress level and the risk of cracking.
- The heat from subsequent beads will anneal the HAZ in the cast iron, and lower the stress level in previous beads.
- No dilution from the cast iron will occur, due to the insulating buttering layer.

Welds between cast iron and other metals like steel, copper alloys or nickel alloys, to secure good weld bond.
Rebuilding larger surface defects, resulting from overmachining, casting operations or mechanical forces, etc.
The idea here is to frame the defect, using short stringer beads followed by immediate peening. The rest of the rebuildning can then be commenced using a less rigid welding procedure.
Welds performed under heavily restrained conditions, e.g. replacing a hollowed damage with a mild steel plate.

4.4.3 Single layer welds

On single layer welds, all weld metal is in contact with the cast iron. Further, no heat treatment of the HAZ by the welding of subsequent beads will occur. This calls for particularly rigid welding procedures and/or preheating.

Cold welding

The hardness of the HAZ will depend on the cooling rate. The only way to lower this without preheating is to use a higher heat input. This will, however, imply a larger weld pool and thereby higher cooling stresses, which is even more detrimental than the HAZ hardness.

Therefore, do not use high heat input!

Instead the HAZ zone shall be as thin as possible to limit the dangerous area, and cooling stresses must be neutralized. It is therefore extremely important to follow below procedure recommendations.

- Weld with short stringer beads (2–3 cm).
- Use thin gauge electrodes and weld with low amperage.
- Welding on DC negative will result in lower dilution from base material, and may be beneficial, in particular when welding on grey cast iron with pure nickel electrodes.
- The intermediate temperature shall be kept below 100°C.
- Use the back-step technique shown in fig 4.
- Hammer the weld surface with a rounded tool (peening), directly after welding. The more the weld metal is allowed to cool, the greater the risk of cracking due to cooling stresses. Therefore peening should be performed while the weld metal is still red-hot. It is important not to hammer perpendicular to the weld bead, but rather from the end of the weld towards the starting point. This is to avoid causing cracks by the peening operation itself.

Back-step welding

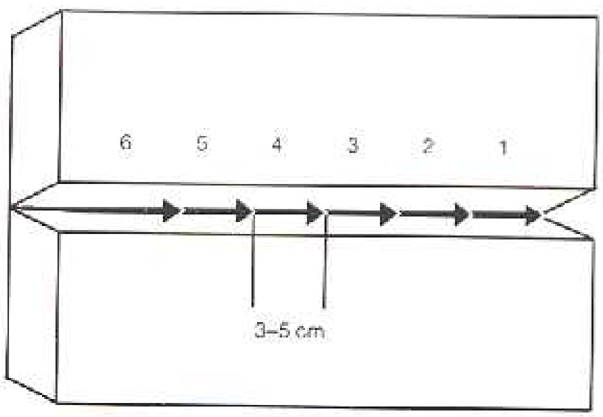


Fig 4

Semi-hot welding

This preheating level is mostly used for the welding of ductile iron and therefore the below recommendations are given for this material.

Preheating as mentioned above will lower the cooling rate, and thereby the hardness of the HAZ. However, the reduction in hardness will be marginal with a preheat level of only 250°C, and therefore the procedure recommendations given in section 3.1 are valid also here, though somewhat less rigid.

- Interpass temperature shall be kept at 250°C.
- Short stringer beads shall be used (no weaving!). Maximum 50 mm.
- The back-step technique shown in fig 4 is preferred.
- The amperage may be increased in relation to cold welding, but still thin gauge electrodes and moderate amperages must be used.
- Peening shall be performed (see section 3.1).
- Slow cooling is imperative!

Hot welding

This preheating level is mostly used for smaller castings, because of the difficulty involved in heating large parts. Hot welding is most beneficial on grey and CG iron. On SG-iron, however, preheating should not exceed 350°C.

- The welding may be carried out as for normal steel welding, with the exception that peening should be performed.
- OK 92.60 should be preferred to OK 92.18, since this high preheating will substantially increase the dilution from base material, and OK 92.60 is the most tolerant of the three in this respect.
- Slow cooling is imperative!

4.4.4 Multilayer welds

- All beads in physical contact with the cast iron shall be welded according to the procedure given for single layer welds.
- The last bead must not be welded directly to the cast iron, but on top of a previous welded bead.
- The best results in multilayer welding on cast iron are always achieved using the buttering technique (see fig 3).

4.5 POST WELD HEAT TREATMENT

The most common heat treatment after welding is stress-relief annealing. It has been questioned whether it will improve the properties of the weld or not, but its use is widely spread, and the overall experience seems to be good.

Tempering to lower the hardness of the weld may also occur. This is particularly useful when welding with Fe-based consumables.

4.6 COOLING

Because of the low thermal expansion of cast irons, (in comparison with most weld metals used), and because of the often intricate shape of the castings, slow cooling is essential in all cast iron welding.

Slow cooling may take place in a cover of saw dust, vermiculite, hot dry sand or in the oven used for the preheating operation.

5 Some common applications

5.1 FOUNDRY DEFECTS

These defects are mainly cavities and blowholes.

- They must first be opened up and cleaned of dirt like trapped sand etc.
- Use OK 92.18 or OK 92.60 to fill the cavity.

5.2 REPAIRS

5.2.1 General

Cast iron repairs can generally be classed into two groups, lightly stressed applications and heavily stressed applications.
Where the defective part is under stress, the repair normally consists of cutting and welding the defective material without providing additional strengthening material.
Where the defective part must be capable of transmitting high loads, the repair is often achieved with the aid of mechanical means, because the tensile strength of a cast iron weld is usually insufficient.

5.2.2 Cracks (light stress)

It is essential to determine the exact length of a crack. A safe general rule is to cut out more material along its length than is really necessary to ensure that the whole of the crack has been entirely removed.
The practice of drilling a small hole (~3 mm in diameter) accurately located at either end of the crack, to prevent it from spreading during the repair is often employed with good results. Where cutting out and welding do not involve much work, it is often advisable to free one end of the crack by cutting out to the edge of the casting. Where the crack has already spread to an edge, welding should start from the fixed end and travel outwards. The point at which welding should commence in cases other than the above must be decided on the merits of each repair. A typical method of repair of a crack in the centre of a casting is shown in fig. 5.

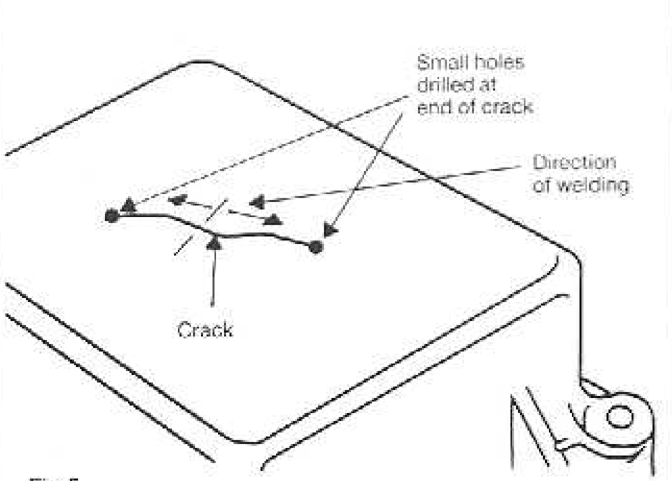


Fig 5

Alignment of workpiece

All surfaces that shall be mechanically attached to another surface, must be fixed accurately in that position during welding. If not, any misfit between the surfaces will result in cracking when mounting the repaired part.
One very common example of this, is cracked braces on electrical engine housings (see fig 6). Welding a broken brace without proper fixing often results in the brace not being in plane. When tightening the bolts upon mounting the engine, a new crack will occur due to the low ductility of the cast iron.

5.2.3 Fractures (high stress)

Failure by fracture is usually due to a sudden increase in the working load, and the repair must be capable of transmitting the load carried by the parts in question. This is often achieved by mechanical means which consists of reinforcing the joint with some form of cover straps fixed by bolts, or preferably by shrinking on a hoop or band to carry the tensile load.
Fractures which may cover areas in thin sections, such as water jackets, are often best rapaired by removing the defective area and welding in a mild steel patch.
Another form of repair which is occasionally successfully used, but not always recommended, consists of studding. Mild steel studs are inserted into the faces of the fracture and welded to the cast iron before the main job of welding up the joint is commenced. It is essential to thread the studs and screw them firmly into the parent metal. The use of studs in butt welds is somewhat ineffective where tensile stresses are involved, since welding often serves to loosen the studs. For reinforcing broken gear teeth, however, where shear stresses are involved, studding is a useful strengthening device.

5.2.4 Hollowed damages

A hollowed damage in iron castings may be repaired in the following way:

- Remove all damaged material from the cast iron (preferably by grinding).
- Round off all sharp edges.
- Grind the edges of the cast iron to around 45 degrees.
- Butter the edges of the cast iron with OK 92.60 or OK 92.18.

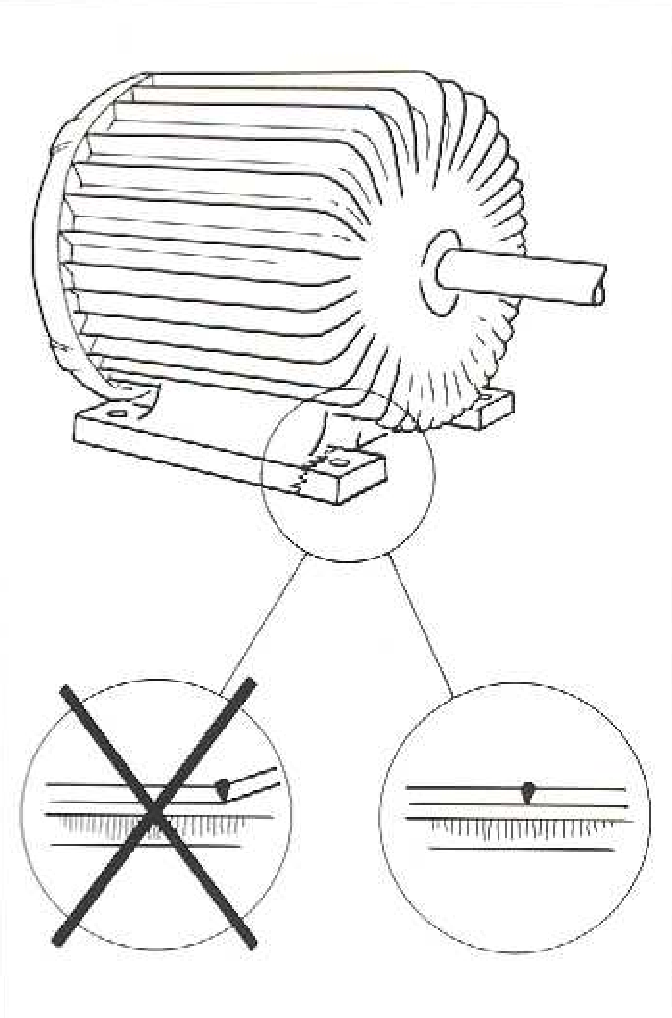


Fig 6

- Cut a mild steel plate to fit into the buttered hollowed section. Because of the great difference in heat expansion between steel and cast iron, it is better to use a steel plate with about half the thickness of the cast iron. This will also lower the amount of weld metal needed, thereby making it easier to limit the heat input.
- Grind the edges of the mild steel to around 45 degrees. (Leave 2 mm root face to facilitate fixing of the two surfaces).
- Tack weld the steel plate in to the cast iron.
- Weld with short stringer beads using the back-step technique. Place the beads one after the other as in fig 8.
- When peening, hammer towards the weld bead rather than perpendicular to the weld surface, to avoid cracking the weld.

If all pieces of broken cast iron are possible to use in the repair operation, there is no need for a mild steel replacer. It is then also possible to weld without the buttering layer, even though this still will provide a better weld.

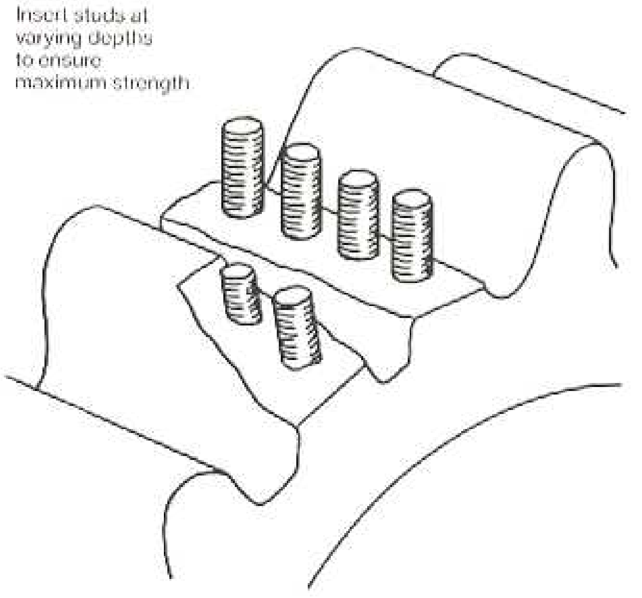


Fig 7

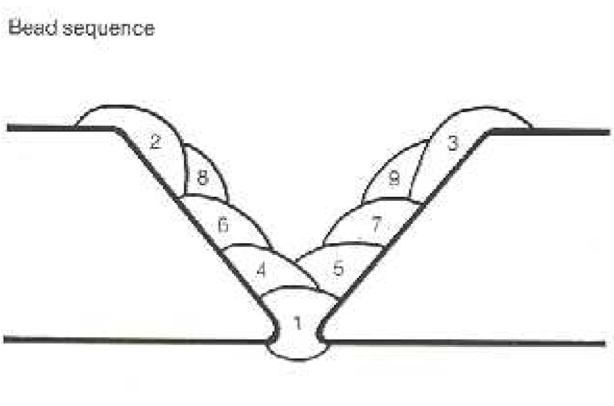


Fig 8

5.2.5 Burnt castings

The term "Burnt cast iron" generally describes a cast iron, which is oxidized both on the surface as well as within the material. This oxidation occurs when the casting has been exposed to high service temperatures. Depending on the alloying content it may start already at 400°C.

Burnt cast iron is characterised by:

1. A visible oxide-skin forming on the surface.
   This oxide consists of Fe_2O_3, Fe_3O_4 and FeO. Fe_2O_3 holds most oxygen and will therefore take the outer place of the three. Oxides of alloying components may of course also be found in this oxide complex.
2. Internal oxidation
   Oxygen penetrates quickly into the material along the graphite flakes. For thermodynamical reasons, the result is not only burning of graphite to CO and CO_2, but also the formation of iron oxides. This iron oxide will form in a zone surrounding the graphite flakes. If excess oxygen is still available and the temperature is right, the graphite will be burnt off. The graphite is then replaced either with iron oxide or not at all, leaving an empty space within the structure. This process is continuous and will continue until the material is destroyed.
   The iron oxide is more voluminous than iron which causes a "swelling" of the casting. The presence of iron oxides will also result in an increased hardness.

This, together with the rough and dirty surface, makes burnt castings very difficult to weld, unless the worn parts of the surface are removed. Therefore, on such applications it is always best to grind or gauge down to sound metal before welding.

As an emergency solution on smaller castings with burnt or corroded surfaces, the following procedure may help to create a suitable enough bond.

- Clean the surface from all dust and loose attached damaged material. This may be done with a steel brush or grinding.
- Use OK 91.58 to strike repeatedly over the surface in the same way as striking a match. This will cause some steel metal from the electrode to stick on the worn surface, providing a better bond during the actual welding.
- Use OK 92.60 for the actual welding.

Experience has shown that OK Selectrode 94.25 may provide successful welds where Ni-based electrodes have failed. So have for instance exhaust manifolds been successfully welded on many occasions.

5.2.6 Thin sections

Thin sections are found in many castings, such as engine blocks, cylinder heads, valves, etc. The main problem is to avoid applying too much weld metal in order to minimize the cooling stresses. There will also be difficulties in peening, since the hammering in itself may crack the weld.

The best way to apply just enough weld metal is to weld in the vertical down position. This is possible, using the OK 92.60, which has a special coating that permits welding in this position.

To avoid breaking the casting during peening, it is better to hammer in a 45 degree angle towards the welded bead, rather than perpendicular to the weld surface.

6 Consumables

6.1 GENERAL

Electrodes for cast iron welding:

- OK 91.58 – Mild steel composition
- OK 92.18 – Pure nickel electrode
- OK 92.60 – Nickel-iron composition
- OK 94.25 – Copper-tin composition

6.2 IRON BASED ELECTRODES

OK 91.00 is developed for the repair of hugh iron castings, such as steel ingot moulds, bottom plates and slag pots. It deposits a weld metal of cast iron composition, giving similar colour and rusting properties. The weld metal will be fairly hard when welding without preheating.

OK 92.60 is used for refilling of cavities or surface defects. The weld metal will be hard and brittle, and therefore it is not recommended for joining. Colour and rusting properties will be similar to cast iron. It is also used to secure good bonding on burnt cast iron, such as exhaust manifolds, doors for martin and coke-ovens, etc.

6.3 NICKEL BASED ELECTRODES

OK 92.18 is used for welding of all cast irons. The weld metal is ductile and very easily machineable. It is recommended for refilling of cavities, general repair and where machineable welds are required on cast iron with hardnesses around 150 HB. It must not be welded in more than two layers, so for multilayer welds, use OK 92.60 for the fill runs and OK 92.18 for the cap runs. It is not recommended on high sulphur or high phosphorus irons.

OK 92.60 is used for cold welding of all cast irons. It is particularly useful for ductile iron because of its higher strength. It is recommended when machineable welds are required on cast irons with hardnesses around 250 HB. It is more tolerant to dilution with sulphur and phosphorus than OK 92.18

6.4 COPPER BASED ELECTRODES

OK 94.25 is primarily used for the welding of copper alloys. However, experience has shown that good results may be achieved using this electrode on high sulphur cast irons. On some occasions it has also proved helpful on burnt cast iron, when Ni-based electrodes have failed. The machinability is not as good as for OK 92.18.

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