Some aspects of Cast Iron Welding

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Introduction

Welding of cast iron has been mainly limited to repairing and salvaging work. Some complicated separately-cast parts have also been joined to the main castings by welding but large scale production of gray iron structures by joining two or more parts has not been feasible.

Gray and nodular castings are not always sound and so minor design and machining problems are always there. Satisfactory welding procedures may reduce the overall costs by minimising rejection.

The Welding Processes

The following methods have been found successful for gray cast iron repairing (i) Oxy-acetylene fusion welding, (ii) Carbon-arc welding, (iii) Braze welding, (iv) Metallic arc welding.

In the oxy-acetylene fusion welding process, a torch with neutral or slightly carburizing flame is used. Cast iron fillers containing 3-3.5% Silicon are used with a cast iron welding flux. V-grooves having enough width are used to permit easy manipulation of torch. No studding is necessary. Hardening of heat affected zone is eliminated as heat required for proper fusion will also act as pre-heating agent. Pre-heating in this process only speeds up welding. Flux is sprinkled into and around the groove and properly heated to melt it, filler wire dipped in flux is melted continuously and a molten pool of metal is allowed to form. The tip of the rod is dipped in this pool to enable the floating of slag. Base metal must be melted before the pool is formed. Stress relieving at 600°C has been found beneficial. The structure of a carefully prepared weld by this process will have the same structure as parent metal with smaller grain size.

Carbon-Arc Process

Here the filler and the flux are the same as in the oxy-acetylene process and heat is supplied by the arc between carbon or graphite electrodes and the work. Pre-heating is necessary to prevent hardening of HAZ. In this process, manipulation of welding pool is difficult.

Braze Welding

Slightly oxidizing flame as a source of heat and a 60—40 brass filler are used in this process. Two commercially available fluxes—tinning flux for coating the surface of Cast Iron and a welding flux for the brazing operation—should be used. V-grooves are

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made by chipping and graphite is removed completely as it hampers brazing operation. Cleaning should be made by wire brush or graphite be burned with oxy-acetylene flame. Pre-heating may be done only to speed up the welding. On the cold cast iron surface, brass does not spread well and there is possibility of oxide film formation between the two surfaces. When this spreading is proper, brass penetrates into the grains of iron. Braze welding provides very good strength: only difference is the colour mis-match. In fact, braze welding of cast iron has a greater advantage as it provides greater plasticity to the resulting joint because in other welding processes the cast iron is liable to melt and forms a brittle chilled layer on the seam, upon solidification. In case of braze welding, both the seam and the base (cast iron) have similar values.

Metal Arc Welding

In this process, low carbon steel, cast iron, pure nickel and monel electrodes have been used. The most successful electrode is however '55 Ni-45 Fe'.

Cast iron electrodes have not given successful results. While using steel electrodes without pre-heating, good bonds are not obtained. Some improvement has been achieved by a technique known as studding. The material is veed, drilled, tapped and studs are screwed in the bevelled faces in a staggered pattern. Diameter and number of studs depend on the thickness of the C. I. piece. First, beads are welded around the stud ends projected outside, next, steel is deposited between the beads so that it covers the C.I. surface. The first layers absorb carbon form C. I. and if cooling is quick, the weld will be hard and brittle. To minimise this, multipass deposit is favourable because subsequent layers will anneal the previous ones and provision should be there, for a multi pass deposit.

Good results have been obtained with non-ferrous electrodes and in most cases they are used. The use of non-ferrous electrodes has solved one of the metallurgical problems in welding cast iron due to the fact that they do not harden and the deposits are machinable. Adjacent to the line of fusion, there will be some hardening which can be prevented by pre-heating above 500°F. The hardened zone can also be eliminated by cooling the deposit to 200°F before applying another layer, thus automatic tempering is effected. Pure nickel electrode and Monel (70 Ni & 30 Cu) electrode, have long been used in cast iron welding. In multipass welding, the HAZ is softened by the heat of subsequent deposit but cracking may occur before the subsequent deposit is made.

"Cold welding" technique has been successfully used with all these electrodes as well as with cast iron filler. This technique is carried with a short arc ; the deposit should be small at a time. After allowing the heat to be dissipated, next deposit should be made. The finished weld should be covered with asbestos sheet to retard cooling. In this process, "make & break" technique is most suitable. One "55 Ni-45 Fe" electrode has given weld of strength comparable to that of base metal with a preheating temperature of 320°C and with intermediate heat treatment. Minimum porosity has resulted with the stringer bead technique and short arc length. The use of "55 Ni-45 Fe" electrode has been favoured because stress is well accommodated both in base and weld metal and also due to the fact that cast iron & 55 Ni-45 Fe alloy has the same co-efficient of expansion. Due to the higher content of iron, hot shortness due to base metal contamination is eliminated. The dilution of base metal is limited as the welding pool is very fluid. A preheating temperature of 600°F has been recommended while using this electrode. If after buttering with this electrode the weld is stress relieved at 1200°F, the remainder of welding can be carried out at room temperature. If sulphur content is ensured at a lower level, this electrode is less sensitive to cracks. This intermediate heat treatment has been successful so far as the strength is concerned.

Effect of Welding on different Cast Irons

Gray cast iron contains carbon in the pearlite structure and as graphite flakes. The greatest limitation in the welding of gray cast iron is difficulty in producing a sound weld. Due to its specific micro-structure, this material is much sensitive to the effect of heat. Cast iron is cooled from 1100°C at a rate exceeding 320°C/minute. The material will be susceptible to cracking by subsequent loading. As, in almost all the fusion welding processes, the material is heated above the critical temperature, the best way to retard the cooling rate is pre-heating the metal. Though the optimum pre-heating temperature is a function of several factors, a pre-heating temperature of 450°C has been recommended. At this temperature, welder may find it difficult to work, so a compromise should be made.

In nodular cast iron, graphite takes the form of nodules by the addition of nodularising agent like magnesium. This material having more ductility is less sensitive to the variation of weld metal and cracking than G. C. I. But high carbon content and discontinuous matrix present the same problem in both the cases. The nodular shape of graphite gives stronger, tougher and more ductile material. Heat affected zone is confronted with brittle zone of untempered martensite and cementite. Diffusion of carbon from base metal to weld metal results in a hard, un-machinable carbide structure.

Malleable cast iron contains iron and "Temper carbon" produced by special annealing heat treatment of white cast iron. In this free form of carbon, metal is not hardened and poses less serious problems in welding.

The weldability of nodular cast iron is to some extent better than of G. C. I. because sulphur & phosphorus contents are less and so the chance of hot cracking of weld metal is less.

The basic metallurgical changes taking place during welding of gray & nodular cast irons is same. Around 800°C, graphite starts to go into solution and at the same time, cementite is precipitated either at the grain boundaries or within the austenite grains at higher temperature. Upon cooling, cementite net-work is retained but the austenite transforms either to martensite or to pearlite depending on the carbon content. As a result, the heat affected zone of fusion welds has a complex hard & brittle structure consisting of remelted regions, undissolved graphite, martensite, pearlite (coarse or fine) & some ferrite. Of the precautions to be taken to minimise these—low hydrogen electrodes, proper pre-heating and proper technique have been recommended.

Nodular castings are being increasingly used because of their improved strength and ductility over gray cast iron. We have already discussed that the use of arc welding forms extremely brittle carbide mass in the fusion line due to rapid solidification of small pool formed during welding. Good ductility can only be obtained if a graphitizing anneal is followed to decompose this carbide. But in welded applications, there is hardly any convenience for this type of annealing; naturally a process without post weld annealing is better.

This has been achieved by the use of "buttering" technique. This technique consists of depositing a first layer of softer material and then final deposit is made on it. This eliminates the deposition of material all at a time affecting the HAZ and the subsequent deposits only affect the 'buttered' mass. Sometimes same electrode (Pure Ni) can be used for both the purposes. In case of repairing of new castings, this can be performed prior to annealing thus eliminating the formation of carbide during buttering. The subsequent welding of such parts affect only the buttered mass and do not create carbide deposits. The vital point in this case is the selection of "buttering" electrode & subsequent welding electrode. The buttering by ERNiFe electrodes and subsequent final welding using ERN 69 (Ni 67%, Cr 15%, Fe 8%, Mn 7%, Cb 2%, Ti 1%) have given satisfactory result. No transformation product such as carbide, martensite or bainite has been found between NiFe & N69 deposits. The ductility of welded joints made with this process has been found to be far superior to the ductility of as welded joints without buttering and is equivalent to annealed weldment. No post weld heat treatment is necessary but buttering should be carried out prior to Graphitizing anneal or a similar heat treatment be given prior to final welding.

Experimental Work

In our actual work, we have repaired damaged cylinder heads of diesel locomotive engines. The damage was caused on the top (Fig. 1) and also in the adjacent water passage (Fig. 2) by cracking. The material of the cylinder head is alloy cast iron which analyses as:—C-3.19%, Si-1.75%, Mn-0.61%, S-0.06%, P-0.15%, Cr-0.43%, Mo-0.65%.

Selection of Process and Material

Different processes were chosen viz Metal arc welding, Oxy-acetylene welding and Braze welding. For proper pre-heating, a heating chamber of refractory bricks was made. The temperature of the furnace was maintained between 300-400°C.

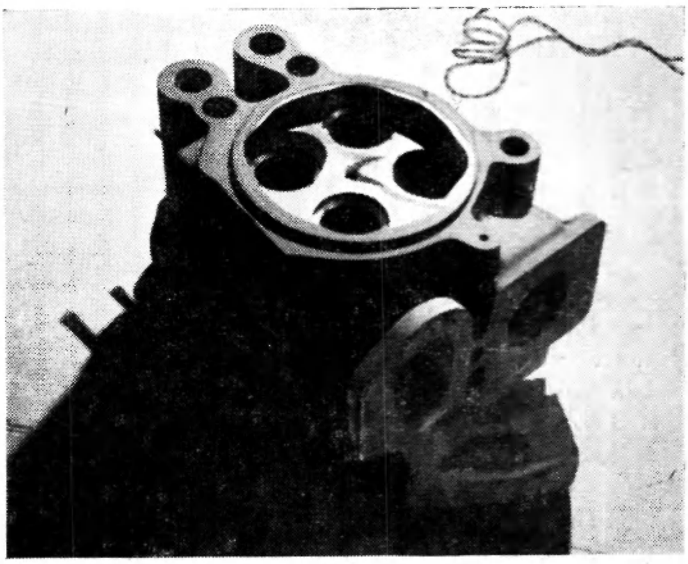

Fig. 1

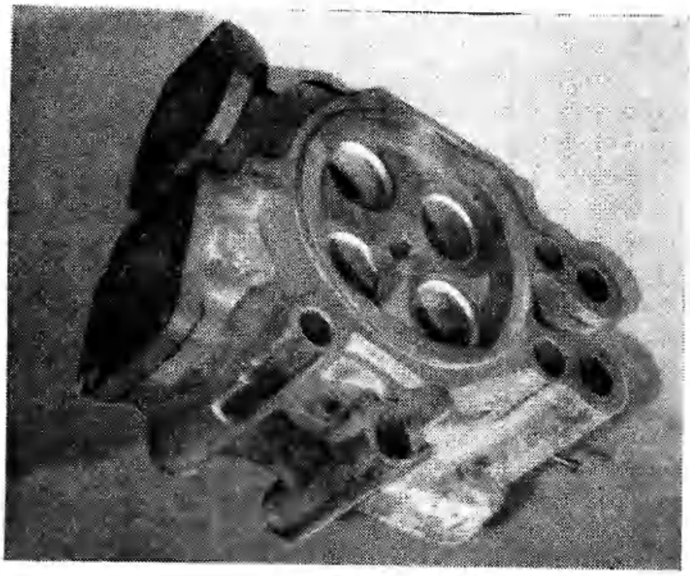

Fig. 2

For metal-arc welding, the selected electrode was pure Nickel (99% Ni). The deposition was made by cold welding followed by peening. Peening helps proper distribution of stress thus minimising the chance of cracking due to stress accumulation during cooling. Grain refinement is effected when peening is carried out in a red hot state and so it should be carried out immediately after deposition because, if done after the mass has cooled, the deposit will be cold worked and ductility will be lost.

Figure 1 shows the Veed portion from top in which deposit was made. The deposit was found to be free from any defect and machinable. The hardness when measured with impact hardness tester was found to vary between 106-109 BHN. The micro-structure of the interface has been shown in Fig. 3. It shows that the parent metal structure has not been affected and nickel deposit is found to have picked up a little Carbon (Graphite) which is negligible.

In the Oxy-acetylene process, the filler material was chosen to be of the same composition as that of the base metal and the flame used was slightly carburising. The micro-structure (Fig. 4) shows the distinct variation is a must as the time for solidification of weld is small and time necessary for the growth of Graphite is not sufficient. This does not affect the properties.

The material for braze welding was Tobin Bronze (57% Cu, 40% Zn, 1% Sn, 1% Fe, 1.0% Mn). The flame was slightly oxidizing. The microstructure (Fig. 5) shows a distinct bond between the brazing

Fig. 3

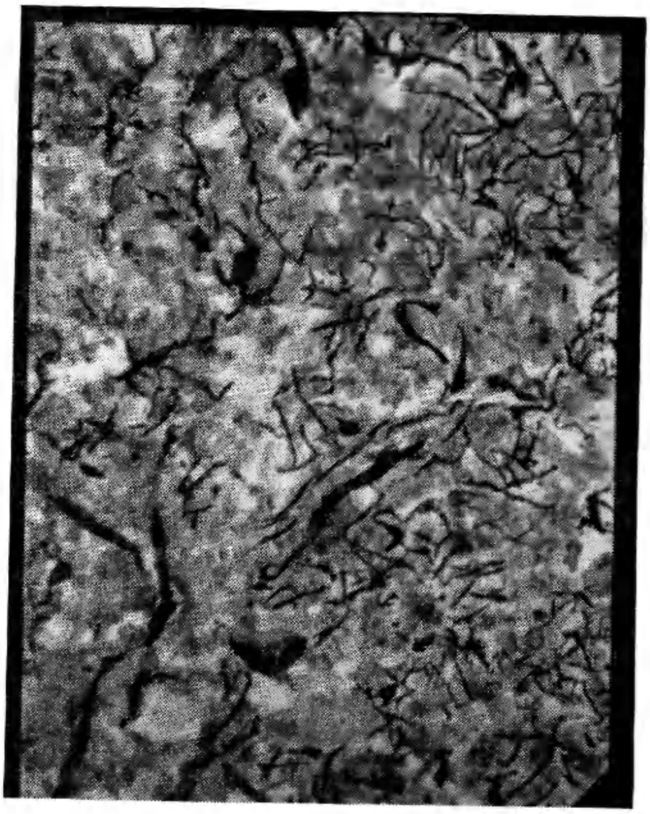

Fig. 4

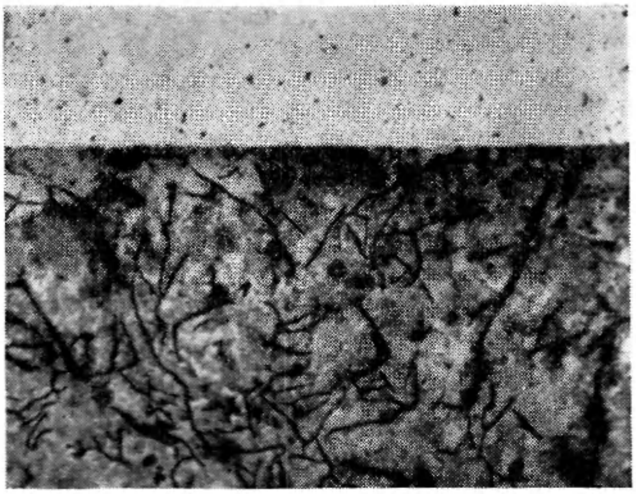

Fig. 5. *Mag. 75x*
Interface between Cast iron and bearing material.

and the parent metal. As the brazing material has a lower melting point and oxy-acetylene flame supplied sufficient heat, the HAZ is not hardened. Pre-heating in this case only speeds up the welding.

The liquid penetrant test and the magnetic crack detector revealed no crack. The heat effected zone was found to be unaffected.

Conclusion

Through our investigations, we have found that proper choice of process and material in cast iron welding can minimise the rejection of castings not only in the foundry but also of the old ones made unserviceable by damages like cracks, corrosion etc. India is still importing complicated castings made of cast iron whose rejection means a loss of foreign exchange. The repair of such damages is inevitable.

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