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Maintenance and repair welding of castings

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Well over 85% of all weld repairs in the field of service repair and maintenance welding are carried out on castings. In many respects the repair and maintenance technological side has to be highly alert, because modern engineering developments constantly create gaps in the acquired knowledge, gaps that have to be closed with the aid of welding engineering and metallurgical work. New concepts of weld metal chemistries also have to be developed to meet these contingencies and to maintain the repair and maintenance field as a specialised operation, even though largely operating outside that line of welding controlled or guided by national or international standards. Full metallurgical backing is just as essential as welding engineering, and both these functions are usually controlled by one man, the Welding and Metallurgical Engineer. His job is to examine a damaged component, assess all the facts, carry out the required tests, then draw up a welding technique and choice of welding material and often do the practical repair himself. Quality control of all welding products brought into the company may be his responsibility also, together with the development of custom-made weld metal chemistries and fluxes. Unfortunately a repair technique used on one casting is not a panacea: each repair must be considered individually. The case histories discussed in this Paper merely brush the myriad of problem repairs in the repair and maintenance field.

CASE HISTORY NO. 1

Metal-arc repair to cast iron bridge

In 1968 serious cracks were observed in the structural members of the Osney Bridge, Fig.1, which carried the A.420 over the River Thames in the western approach to the City of Oxford. The structural beams are cast iron similar to BS 1452, Grade 14. The cracks had propagated to the fillet area from focal stress points and in some instances had encroached into the cruciform section of the upright. Seventeen cracks were found, all similar in magnitude, every one on the side nearer the crown of the bridge section.

The exact cause of the damage was not known, but it is assumed to be associated with cyclic loading caused by the passage of heavy vehicles during the war periods, and the

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presence of large surface sand scabs in an area adjacent to the focal stress points.

In view of the extent of cracking a repair was necessary, and, because of the condition of the parent metal, it was necessary to effect the repair by metal-arc welding. A high safety factor was achieved by incorporating into the weld repair plain carbon steel bars, which extended across the front face of the web, thus giving an additional bond to more sound areas.

A section of the parent metal was removed for analysis which showed the phosphorus content to be 0.9%. A special welding procedure and technique had to be devised to minimise weld metal repulsion and to eliminate lack of fusion and cracking dangers.

The bridge, which was completed in 1888, consisted of eight arch ribs, two sections of which were more recent additions to widen it; these were sound. The remaining seven inner arch ribs contained 112 'junctions', seventeen of which had suffered extensive cracking.

A two-stroke, 200A, 450 cycle, AC welding machine was positioned on the bank, and the earth lead was fixed to the outside section of the bridge. The welding lead, which measured 100m was laid across the river bed and brought up into a barge to a receiving plate from which two electrode holders were taken.

In view of the amount of inter-deposit work of peening, deslagging and cooling, it was possible to have uninterrupted welding from both leads, though not simultaneously.

All the members of the bridge were ground and dye penetrant tested, Fig.2a. A 6mm diameter hole was then drilled at the termination of each crack which was afterwards cut through with a hacksaw, Fig.2b. The cracks were ground out U fashion, one-third from each side, and a nickel strip inserted. The insertion of the nickel strip was a new technique devised by the author, Fig.2c.

The electrode used for the entire repair was a 60%Ni-40%Fe type, of 3.2mm diameter, as this allowed better practical control during welding which was carried out in the flat, horizontal/vertical, and vertical up positions.

It was necessary, when welding began at 0800hr, to use a propane torch to warm the parent metal to $>30^{o}C$ to avoid condensation and any danger of hydrogen-induced heat-affected zone (HAZ) cracking.

The technique of inserting the nickel-iron strip into the hacksaw cut through the crack may be summed up as:

1. The hacksaw cut removes any rust and impurities which may cause outgassing during welding, with subsequent disruption of the welding arc.

2. The metallurgical notch effect at the root is possibly minimised.

3. Practical tests and metallurgical examination of typical sections showed clearly that the weld metal on the initial weld beads on the outside of the joint was allowed to contract by the closing of the joint faces into the annealed nickel strip.

4. Although no significant additional strength would be achieved in the joint by welding each side into the nickel strip, the neatness of the joint and other attendant advantages can be appreciated.

The bar-reinforcing operation was prefaced by a weld cladding operation. A 12mm diameter 0.4% carbon steel bar, bent to fit the configuration, was then positioned and fillet welded to the clad layer, Fig.3. The yield strength of the bar and weld metal was calculated at $>460N/mm^2$ which added a high safety factor to the repair.

It is suggested that in view of the excessive sand scabs, which had to be ground away at the joints, this repair was possible only by metal-arc welding. The success of this repair, after more than three years, may be of real significance, as this is, to the author's knowledge, the first of its kind.

CASE HISTORY NO. 2

Repair of a furnace roll

Attempts at weld reclamation on 25/12 Cr-Ni furnace rolls (C=0.5%) from a Priest normalising furnace, which had been in service for some years, were unsuccessful because of the severely embrittled state of the parent metal; this had resulted in extensive cracking in both weld metal and parent material. The preweld solution heat treatment was not possible with the equipment available. The author was asked to investigate the problem.

The roll, which measured 5.5m in length, 419mm in diameter, with a wall thickness of 38mm, was constructed from a barrel, centrifugally cast in one piece, with a bell-end casting (static cast) welded into each end after shrink-fitting.

During service, the maximum live load of 1783kg is distributed over a 3.2m length, and the maximum temperature was estimated at $960^{o}C$, although this ceiling temperature

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depended on the specific heat treatment being carried out. Each roll is driven from one end at 1rev/min.

Service failure of the rolls was caused by extensive cracking in the weld/parent area of the original fabrication, a situation which often results in complete separation of the bell-end casting from the barrel during service. This particular roll had been in service for seven years, and the problem seemed relevant to all the other rolls in the furnace as regular replacement was becoming necessary.

Preparation of weld area

Complete removal of the cracked and eroded weld metal and adjacent parent metal to provide a joint design free from defect, produced a channel 127mm wide; this promoted a condition which underlined the stress problem because of the extensive weld deposit then required.

A section of sound parent metal was removed from the joint area for metallographic examination. The structure, Fig.4, is basically austenitic with prolific intergranular $M_{23}C_6$ carbide, which has coarsened, presumably because of the relatively long periods at high temperatures. The presence of sigma is indicated by the random needle-like phase.

Further sections were taken of weld deposits, tests being carried out on joint faces in the repair area using conventional welding metal. The 'bead-on-plate' test was also conducted on various parts of the joint, and gross fissuring occurred around the entire periphery of the deposit.

The tests proved that a conventional weld repair was totally impractical, especially in view of the extensive joint preparation necessary to provide a sound parent area.

The embrittlement of high chromium and austenitic chrome/nickel steels by the formation of sigma and $M_{23}C_6$ carbide can occur when service temperatures in the range 680°-850°C are encountered. Although the degree of embrittlement may be extensive in many situations, experience indicates that the component can still continue to give satisfactory service, although any attempts at weld repairs are largely unsuccessful because of parent metal cracking caused by nonuniform expansion and contraction, and the stresses created by weld metal contraction.

Although the maximum operating temperature of the furnace, 960°C, is above the upper critical temperature range for the formation of sigma, it must be realised that such a furnace may frequently operate or be held for long periods within the 600°-850°C range, and once the sigma phase has been formed the maximum operating temperature of 960° is too low for rapid dissolution.

Problems to be overcome

It was established from weld deposit tests that a number of problems had to be surmounted for a successful repair to be obtained.

Firstly, parent metal embrittlement, presumably caused by the prolific formation of $M_{26}C_6$ carbide and some sigma, reduced the parent metal ductility, and the stresses created by localised expansion and contraction, because of heat from the welding operation, could not be absorbed without cracking occurring.

Secondly, the extensive joint preparation required demanded a prodigious amount of weld metal which would produce very large strains on the joint walls.

This particular problem of embrittled cast austenitic steels is synonymous, from a practical point of view, with the low ductility found in certain grades of grey cast iron, although to a lesser degree. Newly developed techniques have now largely overcome this problem in welding cast iron.[1] The technique used involves depositing short stringer beads of weld metal which are rapidly quenched with an air line with extensive peening of the weld beam immediately the arc is extinguished. The technique achieves:

(a) The peening operation which should reduce the height of the weld bead by one-third, using a three-pound ball-pane hammer, minimises the weld metal contraction stress which may be serious in large fills.

(b) Quenching the weld bead maintains the casting at room temperature, thus alleviating the serious problem of localised expansion and contraction.

Extensive bead-on-plate tests were then carried out, observing the air quench and peening techniques, and fully crack-free deposits were obtained. It was, therefore, decided to proceed with the repair.

Repair technique

To minimise the reaction stress the entire joint area was clad, using a 'soft arc' coating 25/20 Cr-Ni type metal-arc deposit. A 3.2mm diameter electrode was employed to limit the region of contraction strain, before peening of the deposit reversed this stress to a compressive one to the base metal.

After the joint faces were completely clad a close inspection revealed no evidence, at this stage, of cracking in the weld or base metal. It was then anticipated that a limited degree of ductility would be afforded by the clad layer against contractional stresses which might exist when the joint itself was filled progressively.

The root deposit was completed next, using the back-step technique with air quenching and comprehensive peening. It was decided to incorporate 19mm round bar sections in the repair in a 'Jacob's Ladder' formation to reduce the amount of weld metal required by 6kg and thus the overall strain, Fig. 5a.

AISI Type 304 bars were the only bar material available and although it is inferior to the furnace roll material, it was adopted because it would be well below the surface layers. The bars were raised and tacked at each end to allow complete root penetration from both sides, still using a 3.2mm diameter electrode. The bars were then dressed down with a hammer, having previously been bent to the required shape to produce a consistent root gap. The repair proceeded using the same technique of depositing short runs, immediately peening with a simultaneous quench, using an air line with a jet forced as high as could be tolerated.

The joint was filled in the next stage using a block sequence with 5mm diameter electrodes, and was finished in the inter-block areas after the entire circumference had been covered to reduce the degree of stress in the joint. A final capping layer was deposited without peening, Fig. 5b.

It is appreciated that, in some quarters, peening is considered to be detrimental to the corrosion resistance of an austenitic stainless steel, and also that the susceptibility to the formation of the sigma phase may be enhanced by this operation. However, peening was a technique which was found to be essential in this repair. The capping weld deposits induced a certain amount of stress relaxation in the underlying beads (which had been work-hardened by peening), and thus some benefit would be obtained, even though the transformed area would extend through only that portion of the remelted bead and HAZ produced in that same bead.

This particular repair was in service for about three years when it was removed for another cause. Numerous rolls have been repaired using the same technique.

CASE HISTORY NO. 3

Repair of wet liner seal in ship's engine

When a ferromagnetic cast iron is welded without preheat, hard constituents are formed in the HAZ; these include carbides, martensite, and bainite. Where stresses are induced as a result of contractional strains, unless minimised by special welding techniques, this embrittled area can create cracking problems. However, cold welding is widely exercised, and is a viable method of repair and reclamation.[1] It is also a proven method of welding white cast irons.[2] However, it is incorrect to assume that a preheat should not be used whenever possible. In fact it is highly desirable to preheat pearlitic SG cast irons to around 250°C to avoid cracking, and even grey flake irons benefit enormously from some degree of preheat.

The repair to a ship's wet liner seal was a typical example of a repair where preheating could not be used. However, owing to the importance of the operation it had to be shown quite clearly that a sound technique was to be used. The area to be welded, Fig. 6, was tested to ascertain the extent of the damage. The broken-out section, Fig. 7, was also damaged and this was prepared and preheated to 400°C, then heavily clad on the joint edges and outside faces, where two high tensile bars were to be positioned. A postweld heat treatment of 900°C was carried out to dissolve the carbides in the HAZ.

The object of welding the broken section in this way was to achieve a mechanical joint in addition to the joint proper; Fig. 8 shows the general idea. The joint faces of the main casting were then clad, using short runs and peening, and maintaining a localised interpass temperature of 100°C with large soft flame burners.

The patch was fitted into position and welded in the same manner, i.e. short runs and peening.

The two bars (12.7mm diameter) were of En 110. These were initially clad with the TIG process and a nickel wire containing titanium (employing a 250°-300°C preheat) to allow the relatively cold welding of the bars to the casting at a later time, and so avoid HAZ cracking in the bars. Figure 9a shows the completed repair with one bar visible.

The final stage of the repair was the tinning of the inside face of the broken section, using a tin-based solder having a high melting point. This was then scraped in to within 0.025mm using an accurately ground template, Fig. 9b.

It will be appreciated that, apart from a sound weld repair, a mechanical joint of some strength was achieved, and in addition there were two high tensile bars overlapping the joints. Reference to Fig.8 will show that the heat-treated broken section will really comprise the full wedge shape, as illustrated, thus giving a mechanical joint of some strength.

Bronze castings

Aluminium bronzes occupy a pre-eminent position in many industries because of their mechanical strength and resistance to attack to a wide variety of corrosive media. The duplex aluminium bronzes in the cast form find a wide outlet for pump castings, shafts, valves, and gear wheels, etc.

The welding of aluminium bronze is heavily documented in technical literature. However, there are a few slants on the welding of castings in the repair and maintenance field that are worthy of mention.

The attack caused to component parts working in liquid media can be a complex combination of corrosion, cavitation, pitting, deposit attack and impingement attack, or any single one of these. Figure 10a shows damage caused mainly by cavitation to an aluminium bronze impeller in the paper industry. Figure 10b shows the completed repair. This is interesting from the point of view that Superston-40 weld metal was used to repair this duplex bronze, using the TIG process. An increase in the working life was obtained with an increase in efficiency. No postweld heat treatment was employed.

Stainless steel rings have also been used in this particular area on pump impellers in the mines, but loosening of the rings caused problems. Experimental work was carried out and a successful result obtained by depositing an 18/8/3 Cr-Ni-Mo weld metal to the face. To achieve a weld deposit which would exhibit adequate ductility a thin layer of copper was deposited on the aluminium bronze, using TIG AC, and then a layer of nickel, TIG DC-. The final two layers of austenitic stainless steel were then deposited. When these particular impellers were due for repair, only a deposit of austenitic stainless steel was required. To ensure this the area was initially cut back to allow an adequate deposit of the final layer.

Aluminium castings

Like aluminium bronze, aluminium castings are also widely used and well documented with regard to welding. However, the gear pump casting, Fig.11, was repaired in an interesting way. The worn internal bores were degreased, rotary wire brushed, and the casting preheated to 200^{o}C. Using an oxyacetylene torch and a special flux a tin-based alloy was deposited without fusion. Metallographic examinations have shown that a bond is achieved by the weld metal dissolving the surface of the aluminium, or interalloying. The weld metal used is a derivative of a bearing metal, i.e. tin-based and containing antimony to form SbSn cubes, and copper to form $Cu_6 Sn_5$ needles. A super wear surface is obtained after boring, and field tests have proven this method.

CONCLUSIONS

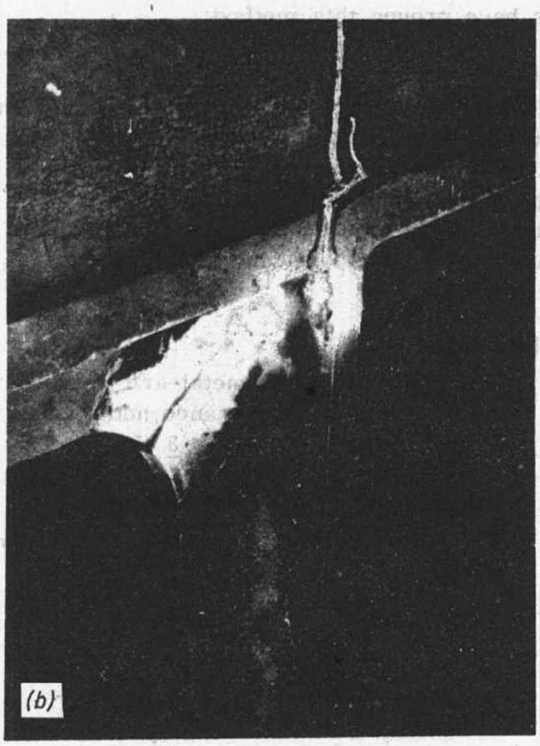
Various selected repairs of castings have been discussed in some detail, even though these repairs do not portray in any depth the full range of problems met in service R and M welding. It is hoped that a general idea has been portrayed to those unfamiliar with this line of repair.

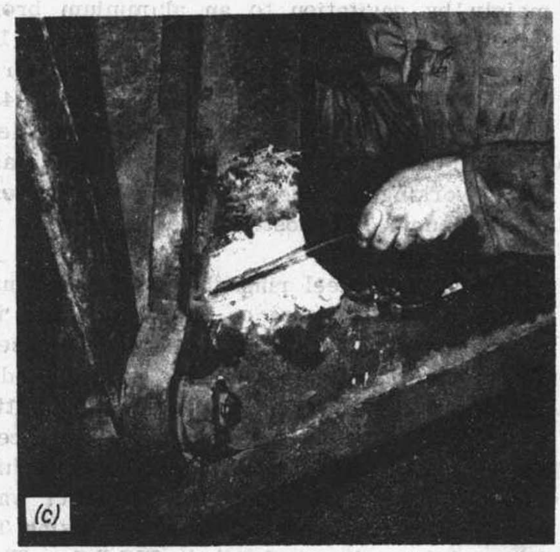
REFERENCES

1 COOKSON, C. 'The metal-arc welding of cast iron for maintenance and repair welding'. Metal Constr., 3 (5), 1971, 179-84.

2 COOKSON, C. 'Metal-arc welding of white cast iron'. Metal Constr., 5 (10), 1973, 370-73.

1 Osney Bridge

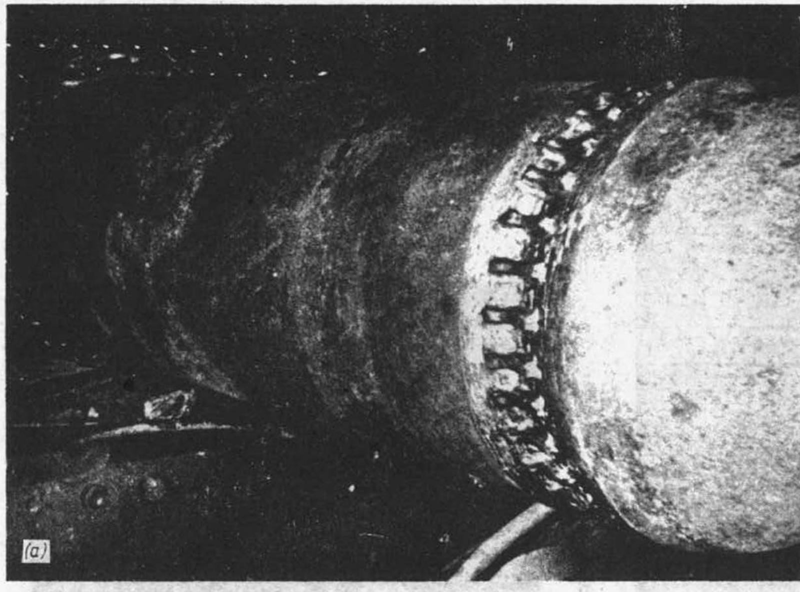


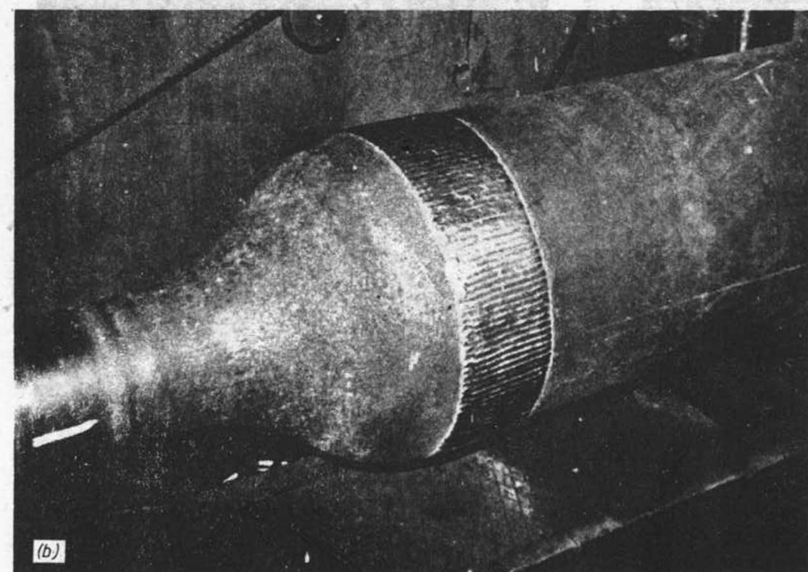


2 Osney Bridge showing: (a) cracks, dye penetrant tested, (b) cutting with hacksaw, and (c) nickel strip in place

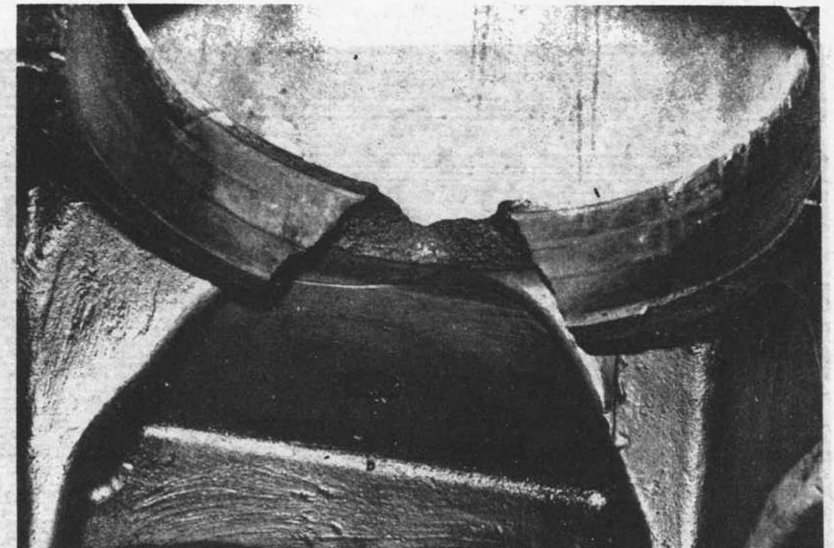
3 Repaired section showing bar in position

4 Structure of fur..ace roll x500

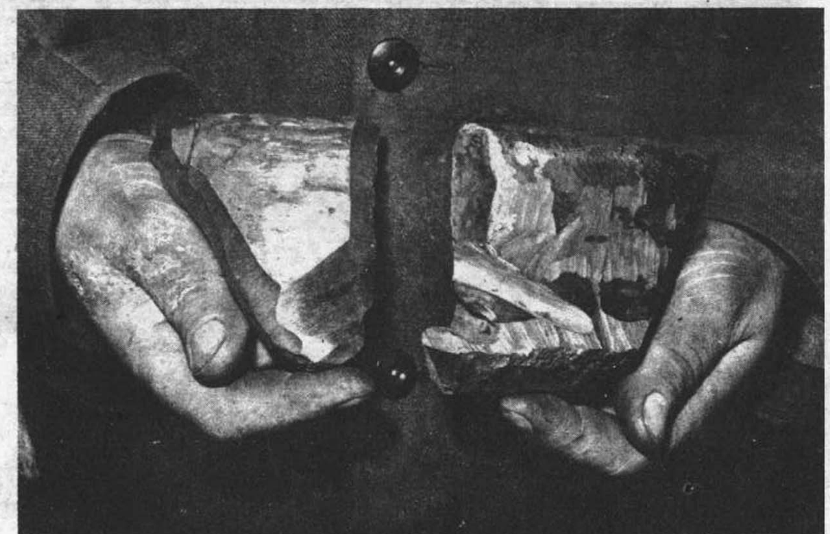




5 Furnace roll showing: (a) clad faces and bars in position, (b) completed roll



6 Area of wet liner to be welded



7 Damage to broken-out section

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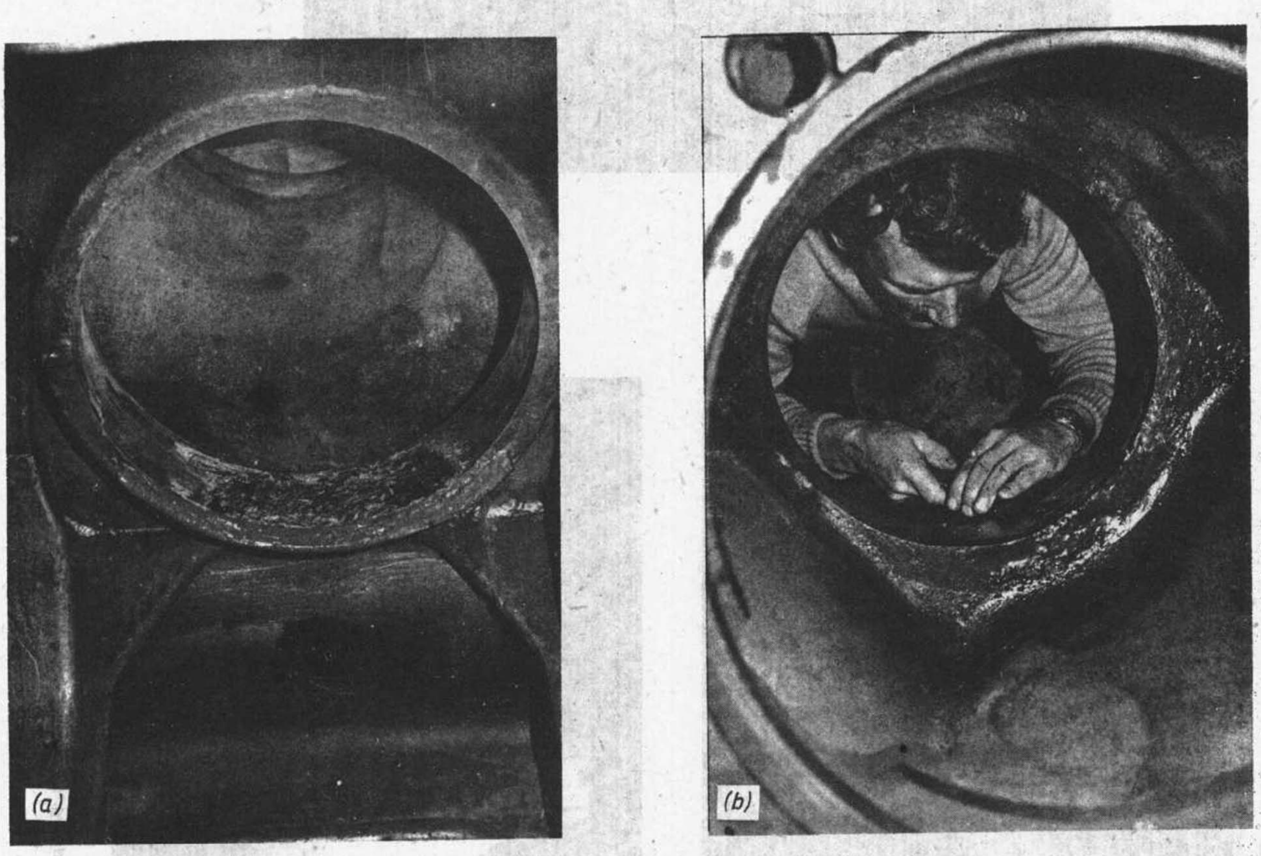
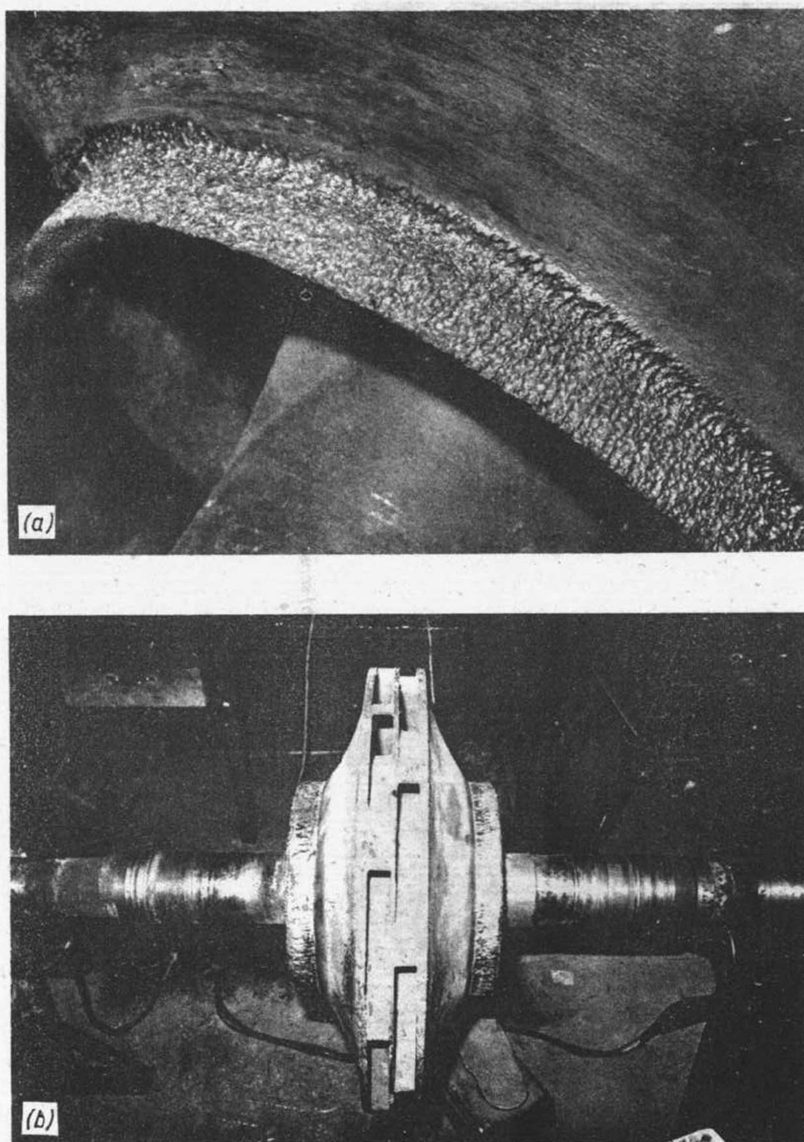
8 Drawing of technique, ...HAZ



9 (a) completed repair, (b) scraping in operation



10 Aluminium bronze impeller showing: (a) close up of cavitation damage, (b) repaired impeller

11 Aluminium gear pump casting

Castings in high alloy corrosion- and heat-resisting fabrications

By R.F. Atkinson, BSc (Met), D.W.O. Dawson, BSc, AIM, and B.M. Patchett, BASc, MSc, PhD, PEng, FWeldI

Engineers and designers now recognise that welding castings to castings and castings to forgings can frequently be the most economical way of producing complex components. With the development of modern foundry technology the properties of a forging can in most instances be matched by a casting, and with modern welding technology high efficiency joints can be produced between the two. There are duties where the directional properties of forging can be used to advantage, but conversely there are some instances where cast materials are superior to wrought materials, for example in resistance to creep. In the latter field the coarser grain size of castings and the fact that compositional variations can be made without consideration of the effect on hot working processes means that castings can be made significantly stronger. This Paper, however, is not for the purpose of comparing forgings and castings, and the fact that the producers are currently trying to emulate each other by such methods as continuous casting and centri-spinning is sufficient evidence that no significant boundaries now exist between the two.

The development of the technology of welding cast to cast components and cast to wrought components to produce complex components is always more easily accomplished on sites where both foundry and fabrication facilities exist. This is so in the authors' Company and over the past twenty years the development and use of cast wrought products has been rapid. Great impetus was given to this development by the introduction of the centrifugal casting process which made readily available tubes in sizes up to 762mm diameter and 4.5m in length and in virtually any alloy.

Many of the examples given in this Paper make use of centrifugally cast tube. By giving examples of the successful use of welded castings in a wide range of industries it is hoped that any remaining doubts regarding the performance of welded castings in service will be removed and their use extended.

The industries considered are the food, chemical, petrochemical and nuclear industries.

WELD FABRICATION OF CAST COMPONENTS IN THE NUCLEAR INDUSTRY

The nuclear industry has provided the designer with excellent opportunities for utilising castings in welded fabrications. Being a new industry there were no traditional designs or materials for reactor components, particularly the British reactors, and designers were free to choose from the whole range of materials and material forms to produce the most economical and safe designs.

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Reactor types

The majority of reactors in the USA and the European Continent were developed on entirely different lines from those in the UK. The reactors in the USA, the pressurised water reactor (PWR) and the boiling water reactor (BWR) use high purity water to remove heat from the reactor core, the British Magnox and AGR reactors use carbon dioxide gas. The operating pressures and temperatures of the PWR and BWR systems are about 15.8N/mm^2 and 300^o-320^{o}C, and 6.9N/mm^2 and 210^o-240^{o}C respectively. In contrast the first Magnox operated at 0.67-1.0N/mm^2 and a temperature of 345^o-400^{o}C and the AGR reactors at a pressure of 3.4-4.1N/mm^2 and a temperature of 650^{o}C.

The material and design problems and hence the welded castings used in the American reactors are, therefore, very different from those in the UK reactors.

Welded castings in reactors in the USA

To circulate the large quantities of water to cool the reactor high pressure pumps are needed and large numbers of valves and smaller pumps. Single pumps are required which are capable of circulating 300 000-440 000 litre/min and, because it is necessary to maintain the purity of the water, these are constructed in stainless steels of the CF8 (18%Cr-8%Ni) and CF8M (18%Cr-10%Ni-3%Mo) types. The volute pump casing of such a pump weighs up to 45 tons and because of the high working pressure contains sections up to 280mm thick.

Being a nuclear application the castings have to be manufactured to ASME III Nuclear Power Plant Components - Class I involving radiography to ASTM E71 Class II and liquid penetrant testing. To enable the foundry to guarantee this standard of soundness some of these large castings are made in several pieces and welded together using submerged-arc and electro-slag welding. [1]

In addition to the large casings, smaller pump casings in both carbon and stainless steel are also required to meet the radiographic requirements of ASME III. Many of these components are already available in the pump and valve industry but only to a commercial standard and these are upgraded by welding to meet the nuclear standard. This practice may be regarded by some as questionable but up to 5% of the casting can be deposited weld when the upgrading of the casting is complete. Unlimited welding of castings is still permitted and indeed is still an essential feature of those produced for the PWR and BWR reactors provided it is done to a procedure which satisfies the ASME III code. No problems are encountered in service as a result of this feature.

Welded castings in UK reactors

The size of castings used in the UK Magnox and AGR gas-cooled reactors are much smaller ranging from 5-230kg in weight. The majority of these castings are to be found in the fuel stringer assemblies, a schematic diagram of which is shown in Fig. 1. In the two reactors of a typical AGR station there are 616 of these assemblies and in a Magnox station approximately 800. The castings are all located in the gag unit of the assembly, the purpose of which is to control the flow of gas through the reactor. The gag unit is approximately 6m long and the whole fuel stringer assembly 22mm long.

Figure 2 shows in more detail the gag unit and the location of the cast components. As can be seen this section of the assembly is composed of static and centrifugally cast components welded or mechanically joined to welded or wrought tube. All the cast components are manufactured from stainless steels of the 18%Cr-8%Ni and 18%Cr-10%Ni-3%Mo types with cobalt control (0.10 or 0.25% max.) and ferrite control (5-15%) to ensure good weldability. One of the largest castings used in this section is the neutron shielded scatter plug; the assembly of this into a tube consisting of centrifugally cast tube and spirally welded tube is shown in Fig. 3.

The purpose of the neutron scatter plug is to prevent the neutrons escaping from the reactor while not unduly obstructing the passage of the carbon dioxide gas. The neutron scatter plug shown in Fig. 3 weighs over 230kg and is only one of several designs used in reactors. In one of the earlier reactors this was cast in one piece but in this reactor it is cast in five sections. It was demonstrated on prototypes that this particular configuration could not be cast in one piece, to the required soundness, without padding which was difficult and costly to remove without destroying the contour of the casting.

They were eventually produced in five sections by the shell moulding process with the following advantages:

(a) soundness to ASTM E71 - Level I
(b) excellent surface finish and contour to assist gas flow
(c) cheaper overall production cost

The five castings are bolted together through a centrally drilled hole. The assembly is then inserted into a tube consisting of a length of spirally welded tube with centri-spun tube sections welded on each end. The neutron scatter plug is then fixed in place by ten plug welds through holes already drilled in the spirally welded tube. This welding can be seen being carried out in Fig. 3, the process being manual TIG with matching composition filler.

In the gag assembly there are several welds between centri-spun and spirally welded tube and typical of these is the tube assembly housing the neutron shield plug. The centri-spun tube is machined down to the 4.5mm thickness of the spirally welded tube and the two are joined by automatic pulsed TIG with no filler addition. The use of pulsing enables full penetration to be consistently maintained without the need for weld preparation. The weld configuration and a typical microstructure are shown in Fig. 4.

As can be seen from Fig. 2 there are several welds in the assembly between static cast components and wrought or spirally welded tube. The venturi tube is the second largest casting in the assembly weighing 135kg before profiling. This is reduced to the section of 4.5mm and welded to spirally welded tube in a similar manner to the one previously described.

WELD FABRICATION OF CAST COMPONENTS FOR THE FOOD AND CHEMICAL INDUSTRIES

The examples selected from the food and chemical industry are relatively small in size but extremely large in number. In this industry large numbers of valves, cocks, and pipe fittings are used made in two stainless steel alloys, PARALLOY 0S, which is a free machining cast 304 grade and PARALLOY 3S which is a free machining 316 Mo-bearing grade. The Mo-bearing material is always used when the fitting is in contact with the process stream, particularly in food processing where chloride solutions are common. The Mo-free 0S material is used only for connections not in direct contact with the process stream. Both grades are free machining because of the addition of sulphur which considerably improves machining production rates on automatic machines. Although there is a small drop in the resistance to chloride pitting when free machining material is used, it does not significantly affect the life of the component nor its suitability for food processing equipment in comparison with stainless steel containing no sulphur.

Threaded fittings can be made as one-piece castings, but the majority of fittings involve welds between two castings or a casting and a wrought component. A typical example is the collection of pipe fittings shown in Fig. 5 which have cast and threaded connectors welded to wrought pipe sections. The sections are also welded at the junction between the leg of the T and the drawn lip on the body.

A further example is the three-way cock body shown in Fig. 6. This is a good example of castings being joined by welding to produce more complex components. The main part of the body is a casting and to it are welded three connectors, also castings. This component can be produced with a variety of connectors.

The great majority of the small cast fittings used are welded using the manual TIG process with 316 S96 filler wire additions. The larger castings can be metal-arc welded, but this is comparatively rare.

A very large number of these components are produced per annum involving tens of thousands of weld passes. Even the low incidence of cracking in welds can amount to a significant total number of defects, and steps taken to avoid these problems are therefore fully justified to minimise production delays.

Cracking when it occurs is nearly always in the weld metal between wrought and cast products, and there are several contributory factors. Wrought material has a high nickel content to improve its workability; this produces a finished product which is fully austenitic. There are two important aspects to consider in the castings, i.e. the sulphur content and the ferrite level. Free machining stainless steels contain about 0.3% sulphur, which tends to produce sulphide eutectics at grain boundaries in solidifying weld metal. Ferrite level is, however, particularly important since fully austenitic alloys are very prone to solidification cracking, even in the absence of sulphur.

Castings usually contain some ferrite, especially when Mo is present. However, it is possible within the compositional ranges of most stainless steel specifications to produce castings containing little or no ferrite unless the castings are ordered to a controlled ferrite content, e.g. 5-15%. Controlled ferrite castings are more costly to produce, however, and the increased cost is not justified in view of the very small percentage which cause welding problems. Efforts have therefore been made to modify the welding procedure to accommodate those castings containing no ferrite.

Welding cast low ferrite free machining stainless steels

Welding experiments have shown that the risk of cracking can be eliminated by adjusting the composition of the filler wire to ensure an adequate level of ferrite to cope with the compositional variations. Low carbon 316 S92 filler wire promotes ferrite via the molybdenum addition and the low carbon level; however, even this wire has not proved to be entirely effective under particularly adverse compositional conditions. The low carbon high silicon 316 S93 wire contains even higher levels of ferrite formers, and is now used for all welded fittings. It has the added virtue of producing a very smooth, flat bead surface as a result of the effect of silicon on molten metal fluidity, which minimises the polishing work necessary for fittings used in the food industry.

The basic difficulty in using S96 wire, or to a lesser extent S92 low carbon wire, is that the specification covers compositions producing nil ferrite levels, as shown in the Schaeffler diagram, Fig. 7. Therefore cracking difficulties occur when these wires and zero ferrite castings are welded together.

The S93 grade wire is the only one where the specification guarantees some ferrite in the weld, and as a result sound welds are always possible, even with zero ferrite tubing and a zero ferrite casting containing sulphur, Fig. 8. These components and wire had the following compositions (%):

	C	Si	Mn	Ni	Cr
Tube	0.03	0.58	1.55	12.00	17.3
Cast fitting	0.08	1.15	0.73	8.8	17.2
Filler wire	0.03	0.77	1.63	13.06	18.83

	Mo	S	N	Ferrite
Tube	2.72	0.02	0.022	Nil
Cast fitting	2.05	0.25	0.094	Nil
Filler wire	2.73	0.007		5

This wire composition can also be used to make multipass TIG welds in thick cast free machining 316 stainless. The only reservation on the use of this filler would be for high temperature service conditions, since the high silicon and molybdenum levels could possibly encourage sigma phase formation.

WELD FABRICATION OF CAST COMPONENTS FOR HIGH TEMPERATURE APPLICATIONS

This section of the Paper is concerned with the weld fabrication of cast components for the manufacture of plant designed to operate at high temperatures.

The examples selected here to demonstrate the use of welded castings include the furnace (reaction) section and collector manifold of steam-reformer and steam-cracking (pyrolysis) plant which operate in the temperature range 600° to 1150°C.

Steam-reforming plant

Diagrammatic sketches of the furnace and collector manifold sections of a typical steam-reforming plant indicating the position of welds are shown in Fig. 9.

Briefly, steam reforming involves the reaction between hydrocarbons, such as naptha or methane, and steam in the presence of a nickel catalyst which is packed in the furnace tubes to form carbon monoxide and hydrogen. As the reaction is endothermic the furnace tubes are heated externally by combustion of natural gas or refinery gas/oil resulting in furnace tube wall temperatures of 850°-1000°C. The operating pressure in the furnace tubes is of the order of 30 atmospheres.

The collector manifold section is of course outside the furnace box and the temperature in this region is only of the order of 600°-800°C.

The dimensions of the furnace tube sections and collector manifold components shown in Fig. 9 are as follows. The furnace tubes are approximately 12 metres long, with an outside diameter of 100-220mm and wall thickness of 13-25mm. These tubes are usually fabricated by butt welding three machine-bored centrifugally cast HK40 (25/20Cr-Ni-0.4%C) tube lengths together using the MMA or the APV automatic TIG-welding technique. [2]

As will be seen from Fig. 9 not only are cast HK40 components welded together using matching composition fillers, but also HK40 is joined to carbon or low alloy steel flanges using fillers of HK40 composition or of Inconel type, e.g. INCO weld 'A' or Inconel 182 and Inconel 82. Additionally, Inconel-type fillers are used to join HK40 castings to wrought Incoloy 800 (20/32Cr-Ni-Ti-Al-0.1%C) pigtails.

The collector manifold section is approximately 4-15 metres long with an outside diameter of 250mm and wall thickness of 25mm. The major diameter of the reducer is of the order of 500mm. The sockolets have a diameter of approximately 30mm. Since the collector manifold system operates at a relatively low temperature range of 600°-800°C and is subject to a fair amount of thermal shock and strain, relatively low carbon high alloy 20/32Cr-Ni steels such as Cast PARALLOY CR32W (20/32Cr-Ni-Nb-0.1%C) and the equivalent wrought Incoloy 800 (20/32Cr-Ni-Ti-Al-0.1%C) are used.

It will be seen in Fig. 9 that the various components which make up the collector manifold are normally butt welded together using either fillers of matching composition when welding cast PARALLOY CR32W (20/32Cr-Ni-Nb-0.1%C) or INCO weld 'A' when welding wrought Incoloy 800 (20/32Cr-Ni-Ti-Al-0.1%C).

It should be noted that for reasons of practical accessibility the automatic TIG process is not employed for the fillet welds joining the sockolets to the manifold, nor the butt welds joining the reducer to the manifold composite section.

Also it will be noted that the Incoloy 800 pigtails joining the furnace reaction tubes to the collector manifold are welded into position on site.

Steam-cracking (pyrolysis) plant

Briefly, steam cracking involves the cracking or

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