TIG Welding of Defective Leaded Bronze Castings

By N. K. SARKAR*

Introduction

Indian Railways are one of the major consumers of leaded bronze castings in the country. The necessity of a procedure for salvaging defective leaded bronze castings was felt when, in the foundries, due to minor defects viz. porosities, blow holes, small cracks etc. at or adjacent to the surface, castings had to be remelted resulting in the loss of metals, man hours, etc. Though the appropriate method for bringing down rejection is elimination of such defects by proper method study, a number still contain such defects, which can be reclaimed by welding.

Literature survey indicated that Tin bronzes containing about 5% lead do not seem to have any problem during welding whereas lead greatly in excess of 5% causes porosity and weakness in the weld.

Preliminary experiments conducted with conventional arc and gas welding processes gave unsatisfactory welds on leaded bronze castings though reasonably satisfactory welding could be obtained on phosphor bronze and gun metal castings.

This paper deals with the work done for satisfactory welding of leaded bronze castings conforming to IS: 1458-65 by the tungsten inert gas welding method.

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Weldability of Bronzes

Bronzes are principally alloys of copper and tin although other elements like lead, zinc, phosphorus etc. are often added for suitable modification of its properties and to suit various applications. Due to the wide separation of the liquidus and solidus lines in the phase diagram, coring occurs leading to precipitation of the 'S' constituent, which is retained substantially in the cast structure as diffusion is slow. The axes of primary dendrites which solidify earlier contain less tin than in the space between them. The wide freezing ranges make the bronzes prone to cracks while cooling from elevated temperatures due to hot shortness. The weld deposits also tend to contain porosities due to oxide formation and gas absorption.

Tin in bronze acts as its own deoxidant, but its reaction is somewhat violent and may lead to the formation of blow holes and much oxide of tin in the weld deposit. Lead does not alloy with copper and it consequently exists as randomly distributed particles in the matrix. In addition, because of its high specific gravity, lead tends to sink to the bottom of the weld puddle.

Experimental Work

With a view to reclaim the defective tin bronze castings, preliminary work was carried out with both the metal arc welding and gas welding methods using the indigenously available electrodes/filler rods.

Copper-tin alloy type flux coated electrodes were used with metal arc welding while silicon bronze, phosphor bronze and manganese bronze filler rods with suitable fluxes were used for oxyacetylene gas welding. The evaluation of the butt welded test joints was carried out by transverse tensile, hardness, macro and micro tests. Extensive studies were also made by building up grooves of different dimensions on test plates. It was concluded that reasonably satisfactory welding was possible on bronze castings conforming to IS: 1458/65 class I & II (Phosphor bronze & gun metal) but class III & IV leaded bronzes were prone to produce porosity and cracks in weld.

Tungsten inert gas welding technique at that stage was chosen because of non-availability of suitable filler rods/suitable electrodes indigenously. Besides, this process could be used without the use of fluxes and the chances of atmospheric oxygen coming into play in this process was eliminated due to the coverage given by the inert gas 'Argon'.

Test plates of 250mm $\times$ 125 $\times$ 10mm, conforming to Bronze class III of IS: 1458/65 and cast in sand moulds were used for welding. One of the most disconcerting problems in welding was the variation in the mechanical properties of the parent metal. Not only did these values vary with different plates poured from different heats but there was considerable variation in properties of the test plates cast from the same heat.

Appendix 'A' gives the chemical composition and physical properties of the test plates used for the experiment. The test plates found satisfactory on ultrasonic testing were taken up for welding.

A series of butt welds were made with these cast plates. The plates were preset so that it became straight after welding. A 3.0 mm thick copper backing strip was used to ensure proper penetration. A root gap of about 3 mm at one end and 6 mm at the other was used to avoid closing up of the gap due to expansion of the plates during welding. The test plates were preheated to about 250°C to 300°C before welding. Inter pass temperature was maintained at 250°C.

The conductivity of tin bronzes is relatively low so that high heat input is not necessary, but pre-heating was effected in order to reduce the risk of crack due to shrinkage. Care was also taken to prevent stressing the joint while it is hot and puddling or overheating was also avoided to minimise segregation and absorption of gases.

The test specimens were welded with direct current and straight polarity i.e. the job being connected with the positive pole to gain maximum of two third of the heat input on the work plate. With the reverse polarity i.e. the electrode being connected with the positive pole, the arc was neither stable nor steady. 2.4 mm dia. tungsten electrode was used. Currents used varied between 152 amp. and 185 amp. with the flow of argon gas between 8 & 10 litres per hour. The test plates after welding were kept under dry asbestos powder to retard the cooling rate.

Conventional phosphor bronze, manganese bronze, silicon bronze and phosphor copper filler rods were used during the experiments. From these experiments it was observed that no fruitful purpose would be served as they were prone to produce porous and hard weld deposits often containing cracks.

Fig. 1 shows the presence of porosities and blow holes in the weld made with phosphor bronze filler rods while *Fig.* 2 shows the presence of longitudinal cracks in the weld made with silicon bronze filler rods. The weld joints made with manganese bronze filler rods were also found to contain cracks. *Fig.* 3 shows the photomicrograph of one of the weld deposits made with silicon bronze filler rods. The micro structures consisted of α-brass only and no lead globules were present. The hardness of weld deposits were found to be 20 to 50 BHN higher than those obtained on parent plates. The results are tabulated in Appendix. 'A'.

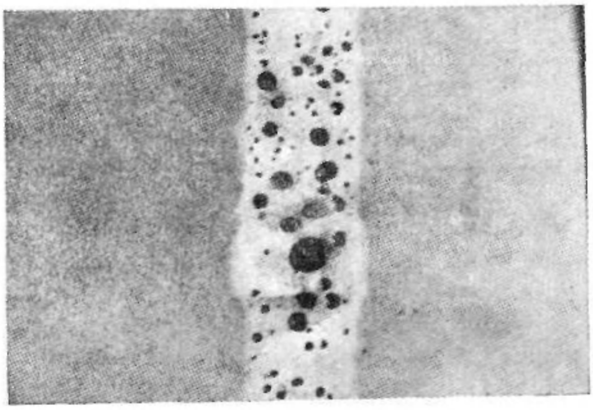


Fig. 1. Photograph showing the porosities and blow holes in the weld.

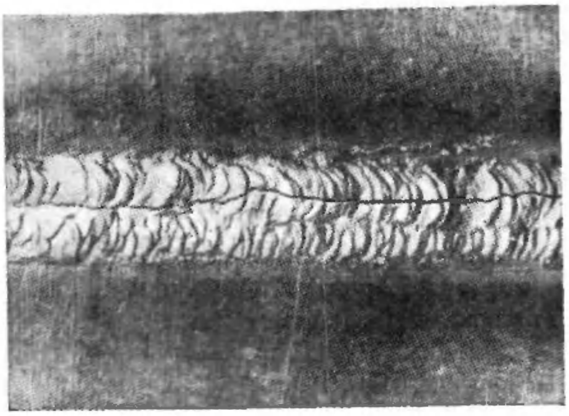


Fig. 2. Photograph showing longitudinal crack in the weld.

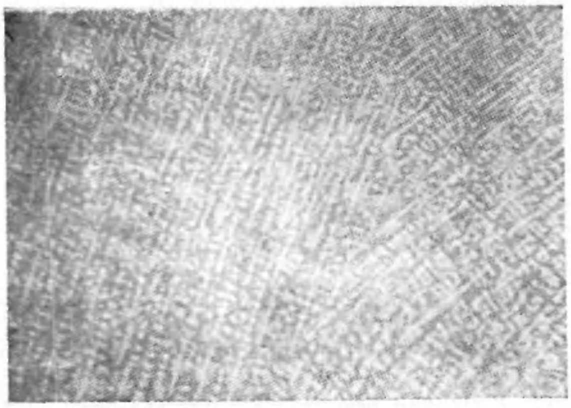
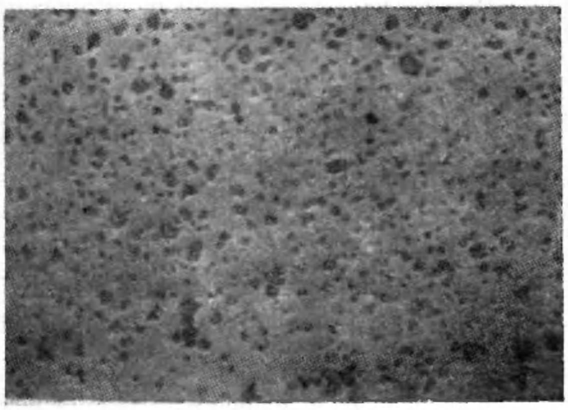


Fig. 3. Photo micrograph showing the presence of α-brass in the weld made with silicon bronze filler rods.

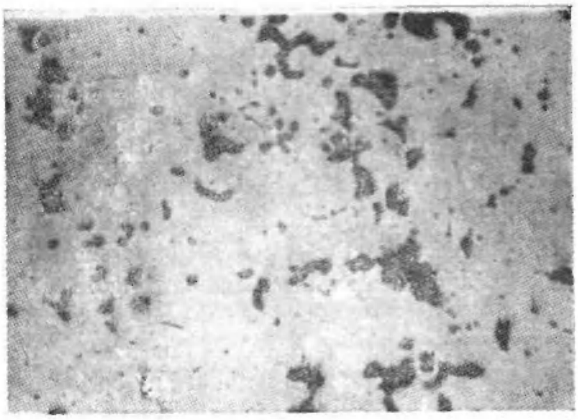
(etched—mag. × 100)

Development of Filler Rods

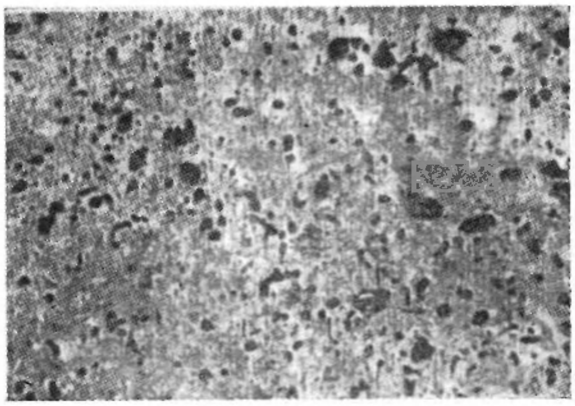
A second thought was given to reassess the problem in a different manner in view of the results obtained from the above experiments. As a result, the foremost was the development of the filler rods to give a defect free weld deposit having fine and uniform distribution of lead and physical properties as close as possible to the castings. A thought on the compensation of the loss of lead as oxides during welding had to be given during the development of filler rods keeping in view the prevention of lead segregation in the weld metal. The presence of a strong deoxidiser was also found to be inevitable in the filler rods to prevent oxidation during welding. The flowability of the filler rods during welding was also another important consideration.



4 (a). Weld metal.



4 (b). Parent metal.



4 (c). Heat affected zone.

Fig. 4. Photomicrographs showing the lead distribution of parent metal, weld metal and Heat affected zone of a weld.

(unetched—100)

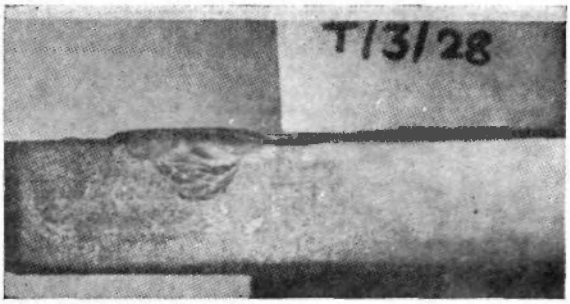


Fig. 5. Photograph showing defect free weld deposit.

After a series of experiments, the desired compositions had been achieved and the filler rods were covered by Indian Patent Nl. 11-7640. These filler rods were used for preparing further a series of test weld specimens using the same procedure as described earlier. The test welds were subjected to various metallurgical tests. The transverse tensile test results obtained on test pieces were 90% minimum of the strength of the parent plates used. The difference in hardness values of the weld deposit and the parent plates was between 7 and 10 BHN. Macro examination carried out on the off-cut end pieces of the test weld joints showed full penetration and fusion without any welding defect.

Micro examination revealed fine and uniform distribution of lead globules without any coring in the weld matrix while the parent metal consisted of cored structure of α—solid solution and $(\alpha+\delta)$ eutectoid. Micro structures further revealed freedom from defects e.g. porosities, cracks, lack of fusion etc. *Fig. 4* shows the micro structures of the weld metal, parent metal and heat affected zone.

After proper evaluation of welding of leaded bronze cast plates by TIG welding, reclamation work was carried out on defects made artificially for further ensuring the suitability of welding process, Grooves of different nature and dimensions were prepared on bronze cast test plates. The welding procedure as mentioned earlier was followed including preheating and post weld treatment. The reclaimed areas were sectioned both longitudinally and transversely and etched with 50% ammonia solution. The weld deposits were free from harmful defects as can be seen in *Fig. 5* Hardness survey revealed 7 to 10 BHN higher than those of the parent plates used. Micro examination revealed fine and uniform distribution of lead particles in the matrix without coring.

Conclusion

The conventional manual metal arc welding, TIG and gas welding procedures using the indigenously available electrodes/filler rods as revealed in the preliminary experiments established that reasonably satisfactory welding could be carried out on bronze castings conforming to IS: 1458/65 Class I & II but yielded unsatisfactory mechanical properties in class III & IV bronzes often associated with welding defects e.g. cracks, porosities, slag inclusion etc. Besides, the chemistry of the weld deposits did not match with that of the parent metals used.

The specially developed filler rods when used with TIG welding gave defect-free welding on leaded bronze castings conforming to class III of IS: 1458/65. The chemistry of the weld deposits too matched with that of the parent metals. The micro structures of the weld deposits also revealed uniform distribution of lead globules in the matrix without lead segregation and other welding defects.

References

1. Modern Castings, May, 1964.

2. M & C Report No. K-73 published by Research Designs & Standards Organisation, Lucknow.

APPENDIX 'A'

Chemical Composition & Physical properties of Parent Plates used and Weld Deposits obtained with TIG Welding

Sl. No.	Parent Plates Sn%	Parent Plates Pb%	Parent Plates Cu%	Filler rods used	Weld Deposits Sn%	Weld Deposits Pb%	Weld Deposits Cu%	UTS (Kgf/sq. mm) Parent plates	UTS (Kgf/sq. mm) Weld deposits	Average BHN Parent Plates	Average BHN Weld deposits	Remarks
1	2	3	4	5	6	7	8	9	10	11	12	13
1.	7.43	14.4	R	Phosphor bronze	—	—	—	13.0	Not carried out due to excessive porosities.			
2.	—do—	—do—		,,	—	—	—	,,			—do—	
3.	—do—	—do—		Silicon bronze	—	—	—	,,	Not carried out due to cracks.			
4.	7.88	14.10	R	,,	1.38	1.50	R	14.5	14.65	80	136	**Hardness too high.**
5.	—do—	—do—		Manganese bronze	—	—	—	,,	Not carried out due to cracks.			
6.	7.56	14.0	R	,,	—	—	—	12.0	12.5	60	103	**Hardness too high.**
7.	—do—	—do—		Phosphor Copper	0.60	0.32	R	,,	—	60	180	—do—
8.	7.42	14.54	R	,,	0.61	0.30	R	15.0	—	62	180	—do—
9.	7.03	14.10	R	80 X	—	—	—	14.0	16.0	74	113	—do—
10.	—do—	—do—		63 X	6.98	13.4	R	,,	13.8	71	95	Hardness difference by 24 points.
11.	7.42	14.54	R	42 X	7.2	14.7	R	15.0	13.4	60	76	Hardness difference by 16 points.
12.	—do—	—do—		29 X	6.7	18.49	R	,,	15.5	71	80	Hardness difference by 9 points.
13.	6.7	14.50	R	,,	6.3	16.15	R	13.0	13.5	64	80	Hardness difference by 16 points.
14.	—do—	—do—		,,	6.2	16.3	R	,,	13.8	69	86	Hardness difference by 17 points.
15.	7.52	14.2	R	16 X	6.93	17.82	R	11.0	10 5*	52	62	Hardness difference by 10 points.
16.	—do—	—do—		,,	7.0	17.0	R	,,	10.3*	52	64	Hardness difference by 12 points.
17.	—do—	—do—		,,	6.96	17.5	R	,,	10.2*	54	64	Hardness difference by 10 points.
18	6.70	14.68	R	15 X	6.70	16.01	R	10.8	10.2	59	69	Hardness difference by 10 points.

1	2	3	4	5	6	7	8	9	10	11	12	13
19	—do—	—do—		,,	6.80	17.0	R	,,	9.9*	62	74	Hardness difference by 12 points.
20.	6.08	14.17	R	14 X	5.98	17.5	R	14.5	14.7*	62	72	Hardness difference by 10 points
21.	—do—	—do—		,,	5.93	18.2	R	,,	14.3*	60	68	Hardness difference by 8 points.
22.	7.88	14.0	R	,,	6.30	18.0	R	,,	15.5*	62	70	—do—
23.	—do—	—do—		,,	6.46	17.9	R	,,	14.2*	60	67	Hardness difference by 7 points
24.	—do-**	—do—**		,,	—	—	—	—	—	62	69	—do—
25.	—do-**	—do—**		,,	—	—	—	—	—	58	65	—do—

Note:

1. *Marked test pieces were prepared as shouldered test pieces. These broke through parent metal—away from the heat affected zone. The rest of the test pieces were prepared as notched tensile test pieces.
2. **Marked plates were used for reclamation work.
3. Serial Nos. 9 to 25 were welded with experimental filler rods.