



APPLICATION OF GTAW METHOD FOR SURFACE REMELTING OF COPPER DUCTILE CAST IRON

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Abstract

The GTAW method was employed for surface remelting of copper ductile cast iron of 0.48 or 0.95 % copper content by mass and pearlitic/ferritic or pearlitic structure. The cold remelting or multiple remelting technique was adopted to harden the cast iron. The remelted layers underwent tests of hardness, tests of micro-hardness of individual structural components and microscopic tests (LEM). The tests focused on the presence of macro- and micro-cracks within the hardened layer.

Keywords: *copper ductile cast iron, surface hardening, GTAW method*

1. Introduction

The presence of copper in cast iron favours the creation of a pearlitic matrix during the eutectoid reaction and slightly increases hardenability of cast iron. The copper content in cast iron usually does not exceed 2% [10].

Copper ductile cast iron of pearlitic structure is characterized with high tensile strength (grades with strength exceeding 600 MPa), increased hardness and relatively low plasticity [11]. Many applications require cast iron of improved abrasive wear resistance. In such cases, it is necessary to surface harden surfaces subjected to abrasive wear and contact load. The required high abrasive and contact wear resistance of castings may be ensured by surface hardening. The most frequently used methods for cast iron hardening include: casting method, induction or flame surface hardening [1,5]. As an alternative to those methods, hardening techniques using concentrated energy sources may be used, e.g. GTA welding [2-4, 6-8, 12-14].

Study [9] showed that depending on the cast iron grade and remelting parameters, macro- and micro-cracks of various intensity occur in the remelted layer. Their presence, especially in case of contact stresses may cause accelerated wear of the hardened layer through flaking and pitting.

The direct purpose of the research described herein was to obtain, with the surface remelting method, a layer with hardness and macro- and micro-structure ensuring optimum tribological properties of copper cast iron.

2. Material, programme and research object

Two grades of copper ductile cast iron with chemical composition given in table 1 were used for the tests.

Table 1. Chemical composition of cast iron, % mass

Cast iron identification	C	Si	Mn	P	S	Cr	Cu	Ti	Mg
A	3.76	3.07	0.35	0.07	0.02	0.04	0.48	0.024	0.06
B	3.66	2.63	0.29	0.09	0.015	0.03	0.95	0.016	0.07

The cast iron identified with letter A has a pearlitic/ferritic structure (approx. 15% of ferrite) and is classified as EN-GJS-600-3. The cast iron identified with letter B, as-cast, has a pearlitic structure and is classified as EN-GJS-700-2 (fig.1).

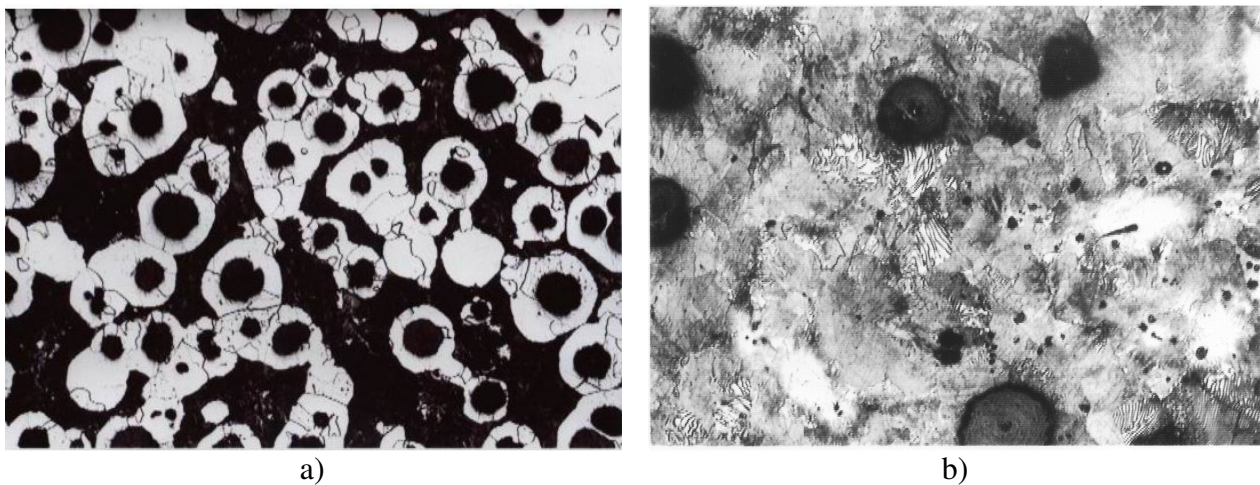


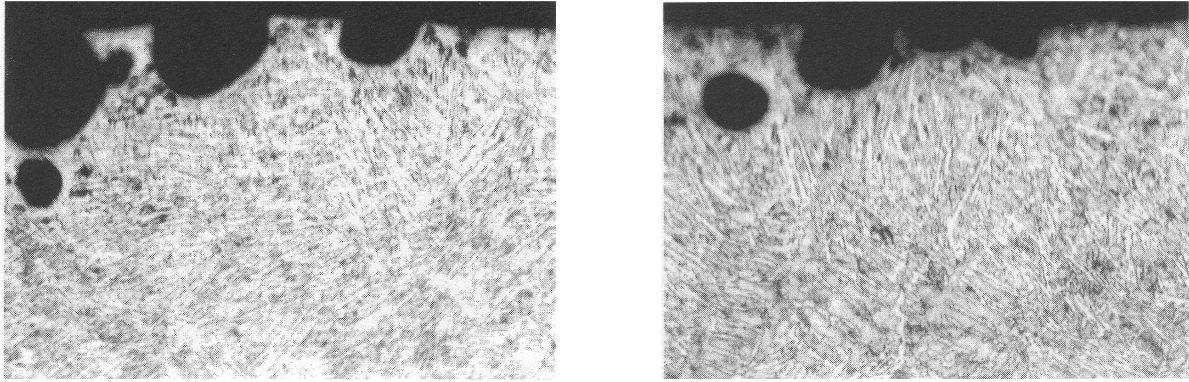
Fig.1. Cast iron micro-structure, a) pearlitic/ferritic cast iron – A, b) pearlitic cast iron – B, microscope magnification 170x, etching with 2% HNO_3

For the purpose of surface remelting of A and B cast iron, the GTAW method was applied with a 2.4 mm diameter tungsten electrode. Argon 4.0 was used as shielding gas. Travel speed of a nonconsumable electrode was 200 mm/min. Cast iron A was remelted once with 80; 120; 160 or 200A current and repeatedly with 160A current. Cast iron B was remelted once and repeatedly only with 160A current.

The phase composition of the remelted layer was determined by X-ray diffraction. Micro-hardness measurements were made for individual structural and phase components using Hanneman tester. Measurements of hardness on the remelted surface were performed using the Rockwell method, C scale. The structure of remelted layers was evaluated on lateral metallographic microsections etched with nital.

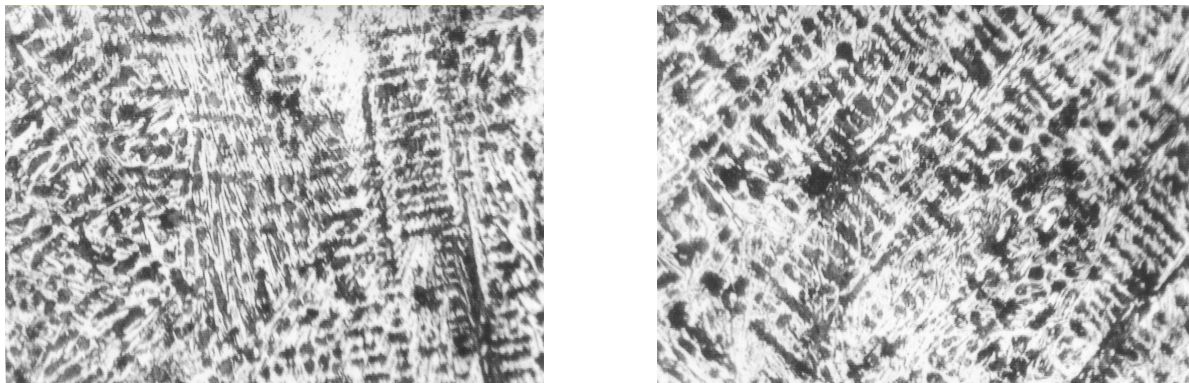
3. Research results and analysis of the results

The structure of cast iron A and B remelted once includes, in the surface zone, cementite and martensite (fig.2), whereas in case of repeated remelting – transformed ledeburite (fig.3).



*Fig. 2. Structure of the surface-adjacent layer of cast iron remelted once
a) cast iron A b) cast iron B, magnification 400x, etching with 2% HNO₃*

Regardless of the cast iron grade and current parameters of the melting process, the phase composition of the remelted layer remained the same.



*Fig. 3. Micro-structure of the surface-adjacent layer of cast iron remelted four times
a) cast iron A, b) cast iron B, magnification 400x, etching with 2% HNO₃*

Regardless of the copper content in cast iron and the number of times remelting is repeated, the intermediate layer (heat affected zone) is characterized with the same type and distribution of structural components. In the micro-area directly adjacent to transformed ledeburite (melted area), there are globular graphite precipitates surrounded by ledeburite and martensite. In that area, partial remelting occurred in the process (fig.4).

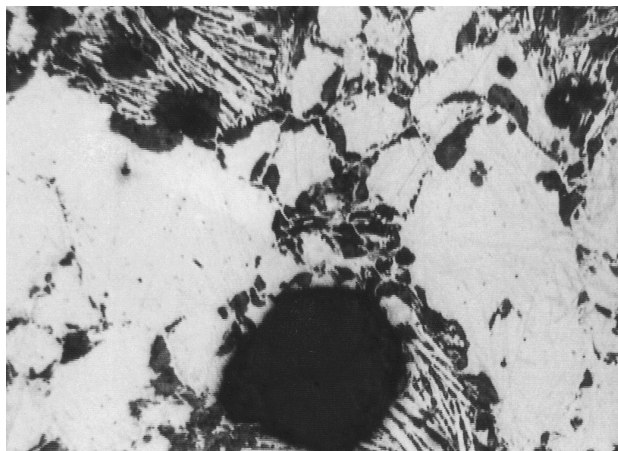


Fig. 4. Micro-structure of the partial remelting zone of cast iron B, remelted 6 times, magnification 400x, etching with 2% HNO₃

Further away from the partial remelting surface, there is a solid layer of martensite. In that layer, there are cracks perpendicular to the remelted surface that are orientated parallel to the remelting direction (fig.5).

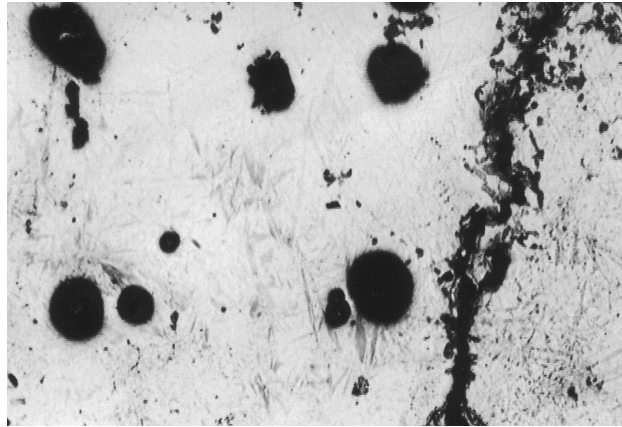


Fig. 5. Micro-structure of the martensitic zone of cast iron B, remelted 6 times, magnification 70x, etching with 2% HNO₃

It must be emphasized that cracks occur only in the martensitic structure zone. They do not continue into the adjacent areas. Further deep, there is a mix of martensite grains against the pearlitic background (fig.6).

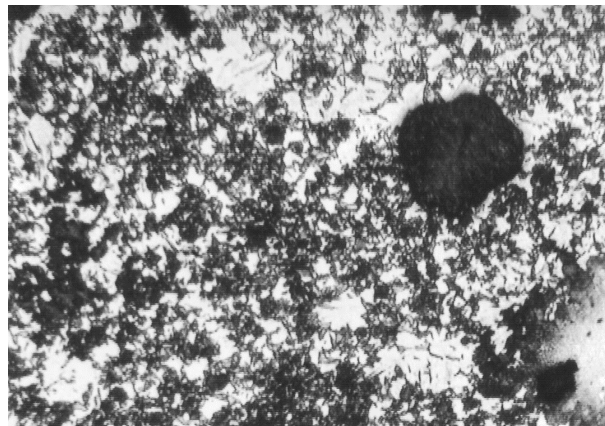


Fig. 6. Micro-structure of the partial martensitic transformation zone of cast iron B, remelted 6 times, magnification 170x, etching with 2% HNO₃

Further away from the surface, there is a fine-grained mix of light martensite grains against the pearlitic background (fig.7). The base material is coarse pearlite (fig.8).

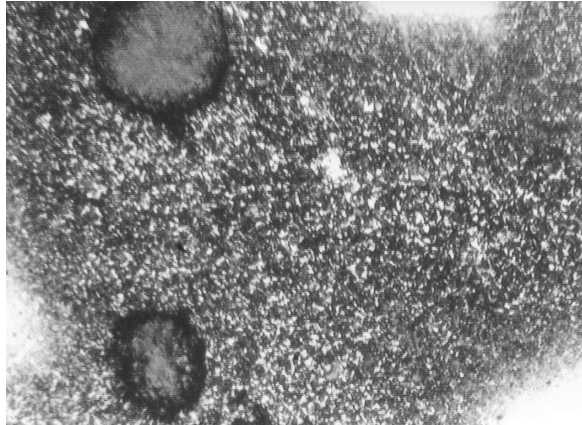


Fig. 7. Micro-structure of the fine-grained martensitic/pearlitic mix of cast iron B, remelted 6 times, magnification 170x, etching with 2% HNO_3

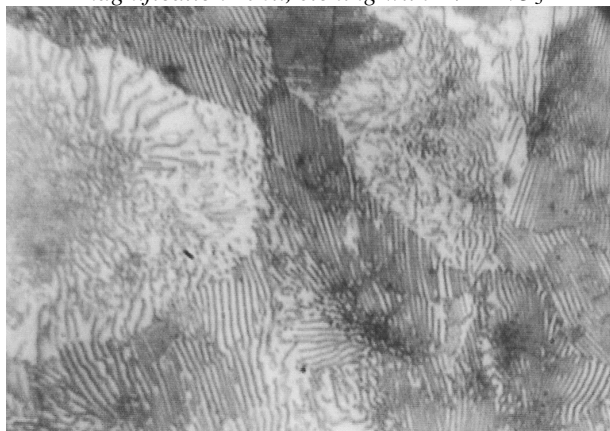


Fig. 8. Micro-structure of the base material, magnification 170x, etching with 2% HNO_3

The width of the remelted layer of cast iron B depends to a small extent on the number of remelting operations so that for the material remelted 6 times it is 13mm and for the material remelted 4 times – 11mm. The thickness of the remelted layer of the ledeburitic structure is greater in case of remelting repeated 6 times – 1.9mm and 1.3mm for remelting repeated 4 times. The width of the martensitic layer under the ledeburite layer is significantly greater for remelting repeated 6 times – 1.3mm, while for remelting repeated 4 times it is 0.8mm.

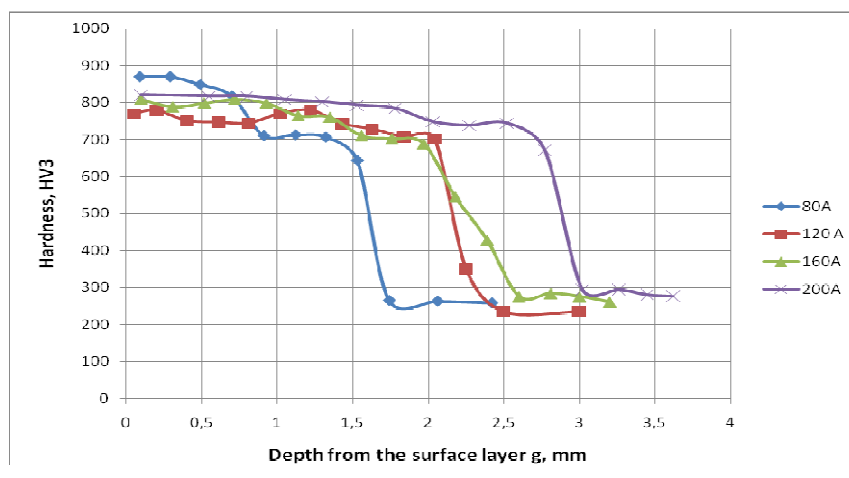


Fig. 9. Distribution of hardness in the hardened layer of cast iron A

The analysis of distribution of hardness HV3 of cast iron A measured along the remelting axis from the surface into the material enables estimation of thickness of specific zones of the remelted layers (fig.9). As the current increases from 80 to 200 A, the thickness of the remelting zone changes from approx. 1.5 to 2.5 mm, while the thickness of the heat affected zone – from 0.4 to 0.6 mm.

Micro-hardness $\mu\text{HV}0.1$ of individual structural or phase components in the layer remelted four or six times of cast iron B is as follows: for remelting repeated 4 times, micro-hardness of ledeburite is 841 μHV and micro-hardness of martensite – 859 μHV , while for remelting repeated 6 times, micro-hardness is respectively 737 and 903 μHV . Micro-hardness of martensite grains in the partial martensitic transformation zone is 702 μHV . Micro-hardness of the fine-grained mix of pearlite and martensite is 373 μHV .

Hardness of cast iron B remelted 4 times measured on the surface is 59HRC, while hardness of cast iron remelted 6 times – 57HRC.

4. Conclusion

When copper cast iron, with both lower (0.48% Cu) and higher copper content (0.95% Cu) is remelted only once, hardness measured on the surface of the material within 66÷68 HRC, which results from the martensitic/cementitic structure of its surface-adjacent layer. Repeated remelting results in the ledeburitic structure of the outer zone. Hardness of the transformed ledeburite is by about 10 HRC lower than hardness of the cementitic/martensitic mix. Hardness and micro-hardness of ledeburite is affected by the number of remelting operations. Fewer remelting operations result in greater hardness and micro-hardness of ledeburite, due to a smaller spacing of cementite in ledeburite. The number of remelting operations has no significant influence on geometric parameters of the remelted material (depth, width of zones). The parameters used for the research did not eliminate micro-cracks within the remelted layer. Whenever the cast iron was remelted repeatedly, micro-cracks in the intermediate layer (martensitic structure) occurred between the remelted material and the base material. Cast iron B with higher copper content has a thicker martensitic layer due to its greater hardenability. In general, the GTAW-based premelting process is an effective method for surface hardening by creating structures of fine tribological properties. Cracks should be eliminated by optimizing remelting conditions for specific chemical composition of cast iron.

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