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Interface Carbon Content and its Influence on Carburization of Steel in Bimetallic Castings

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Abstract

Modern materials engineering is increasingly moving away from monolithic structures in favor of bimetal components. Layered castings combining steel and cast iron provide an excellent response to the conflicting operational requirements that machine parts must meet. Combining the high ductility and strength of steel with the exceptional abrasion resistance and vibration damping properties of cast iron allows for the creation of components that are both durable and crack-resistant. The key to success in this technology is achieving a permanent diffusion bond at the interface between the two phases, which requires precise control of the thermal and physicochemical parameters of the casting process. This paper presents the impact of the difference in carbon content between the joined layers on diffusion efficiency and, consequently, joint quality.

Keywords: Bimetallic casting, Stainless steel, Grey cast iron, Microstructure, Carburized layer

1. Introduction

Industrial development is inextricably linked to the search for increasingly better materials with diverse properties. A challenge in finding such materials is undoubtedly the cost of producing the material, which increases with more precise, more laborious processing or the cost of the material itself [1-3]. To address this problem, materials with different properties have been combined to create bimetals [4, 5].

One of the basic materials used in the production of bimetals is the combination of structural steel with various materials with different required properties. One of the first methods of joining materials used in bimetals was copper brazing, later replaced by joining the materials in a casting mold. The fundamental problem when making bimetallic castings between steel and cast iron is the difficulty of obtaining a high-quality joint at the interface between these materials [6, 7]. The formation of a bond between layers in bimetallic castings occurs primarily through the diffusion of carbon, but in the presence of a large concentration difference at the contact interface, diffusion of other elements, such as chromium, is also possible. The extent of diffusion, and thus the quality of the bond, is influenced by the heating temperature of the sheet, i.e., its uniformity of heating, slow heat dissipation, and the difference in the concentration of elements, primarily carbon, at the interface between the steel sheet and the cast iron layer [8–10]. The presented research attempts to link the difference in carbon content between the steel sheet and the cast iron layer with the depth of carbon diffusion into the sheets.

2. Research Methodology

The effect of carbon content on the bond in a bimetallic casting was determined by conducting a series of melts in which the carbon content was gradually increased within a planned range from 0.5 to 4.0% by weight [11]. Due to the melting process being conducted in a small-volume furnace, the achieved carbon content was lower than planned. The achieved and planned carbon contents are presented in Table 1.

Table 1.
Carbon content in individual castings

Casting number	1	2	3	4	5	6	7	8
Intended C content in the alloy [%]	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
Obtained C content in the alloy [%]	0.48	0.83	1.38	1.87	2.20	2.57	3.19	3.72

The selected test casting was a bimetal based on a 125x5x105 mm sheet with a working layer height of 40 mm. The sheet carbon content was 0.18% C. Figure 1 shows the dimensions of the model set against the background of the molding box.

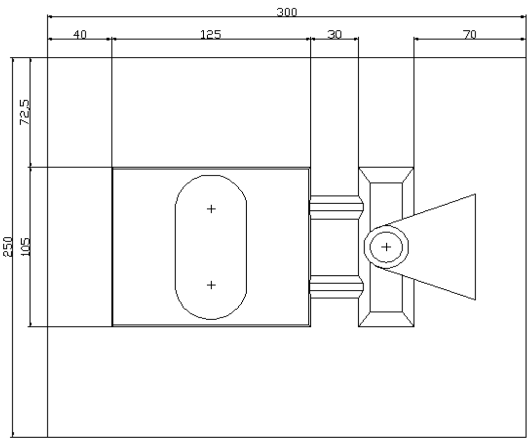

Fig. 1. Diagram of a bimetallic casting

Ultrasonic testing was performed on the resulting bimetallic castings to determine the degree of bonding between the sheet and the working layer. An ultrasound examination was performed to assess the percentage of the joint surface area, which was preceded by metallographic examination. The examination was performed using the echo method with the transducer positioned on the sheet metal side. The ultrasonic testing results are shown in Table 2.

Table 2.
The obtained joint surface in a bimetallic casting

Casting number	1	2	3	4	5	6	7	8
Connection area [%]	0	0	73	93	100	100	100	100

Samples were cut from the resulting castings for metallurgical testing. The sampling scheme is shown in Figure 2.

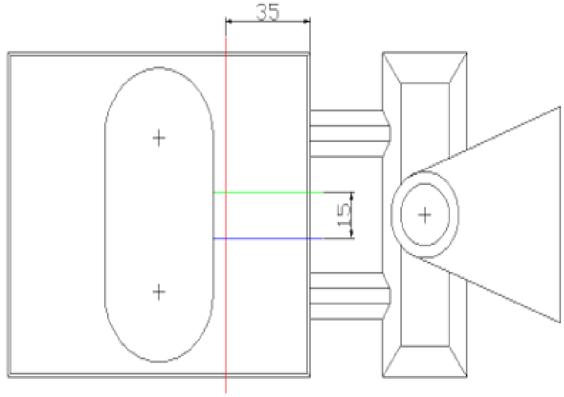

Fig. 2. Method of sampling bimetallic castings

Using cut samples, metallographic examination of the joint between the steel sheet and the cast iron surface layer was performed.

3. Evaluation of the casting structure in the joint zone

Although ultrasonic testing revealed no connection between the sheet and the cast layer, localized areas of connection were found. Where there is no connection, the sheet acts as a cooling bed, influencing the direction of the structure formation and the proportions of ferrite and pearlite. Figure 3 shows the gap between the sheet and the cast iron, and Figure 4 shows the location of the connection.

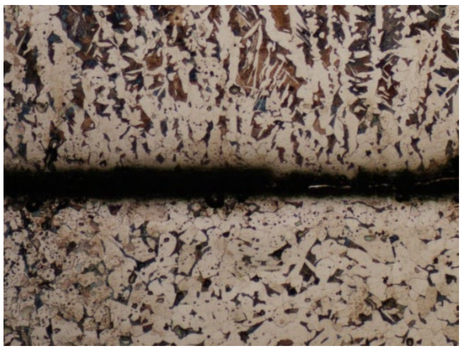
Fig. 3. Casting 1, boundary between the sheet metal and the cast part without connection

In the case of casting 1, however, only a few point connections were made; the photos show one of several such connections. The lack of a clear boundary between the working part material and the supporting part material results from the similar ferrite-pearlite structure of both alloys (0.3% difference in carbon content between the alloys). However, the pearlite-to-ferrite ratio, varying transversely to the connection line, is visible.

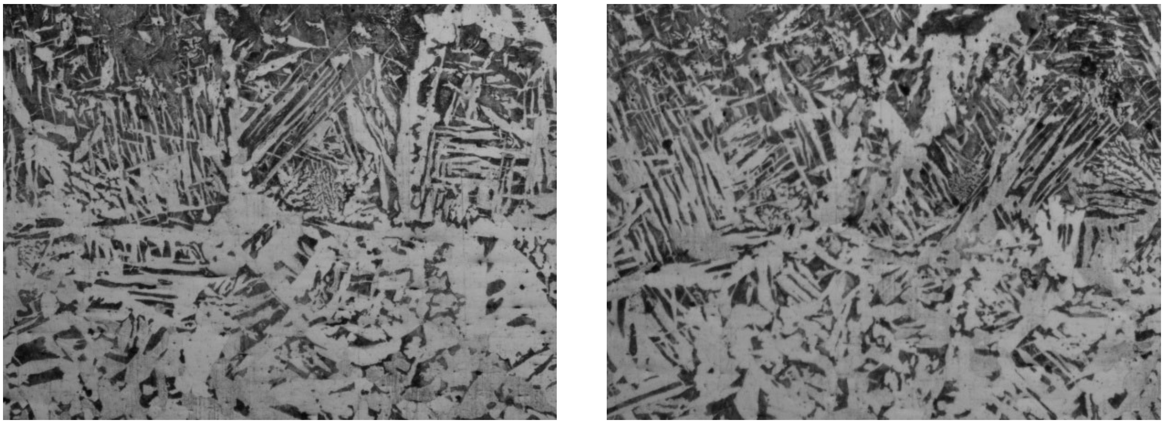

Fig. 4. Casting 1 connection zone, magnification x50

In casting 2 (0.83%C), similar to casting 1, only a few joints occurred. However, in this case, a clear boundary is visible between the working material with a pearlitic structure and the supporting material with a ferritic-pearlitic structure. A transition layer appeared, where the steel sheet layer was carburized, resulting in an increased pearlite content in the alloy (Fig. 5). Decarburization lines are also visible in the working material.

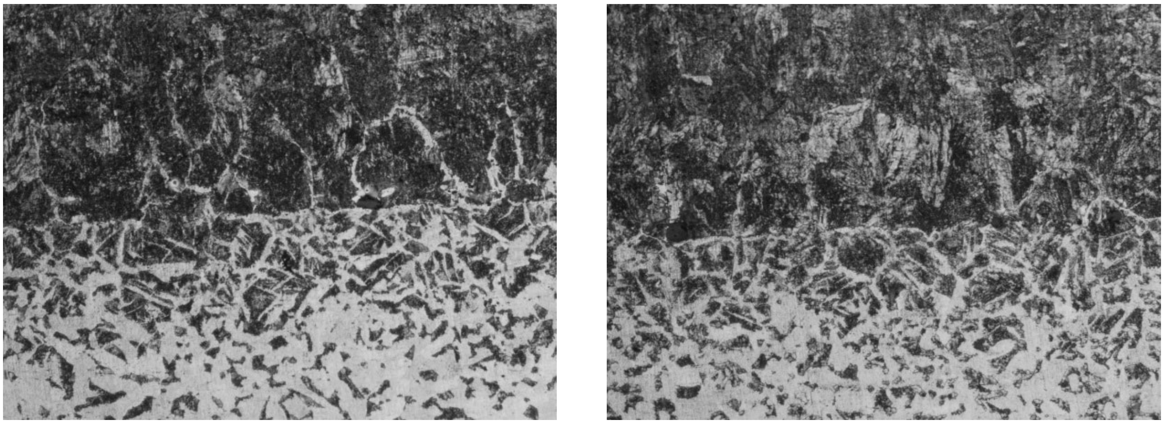

Fig. 5. Casting 2 connection zone, magnification x50

In the case of casting no. 3 (1.38%C), as expected, we observe a pearlitic structure with cementite precipitates in the working layer. As we approach the sheet, the cementite disappears and the structure transforms into a pearlitic one. Similarly, in the sheet, ferrite is replaced by pearlite due to diffusion. As we move deeper into the sheet, ferrite precipitates reappear.

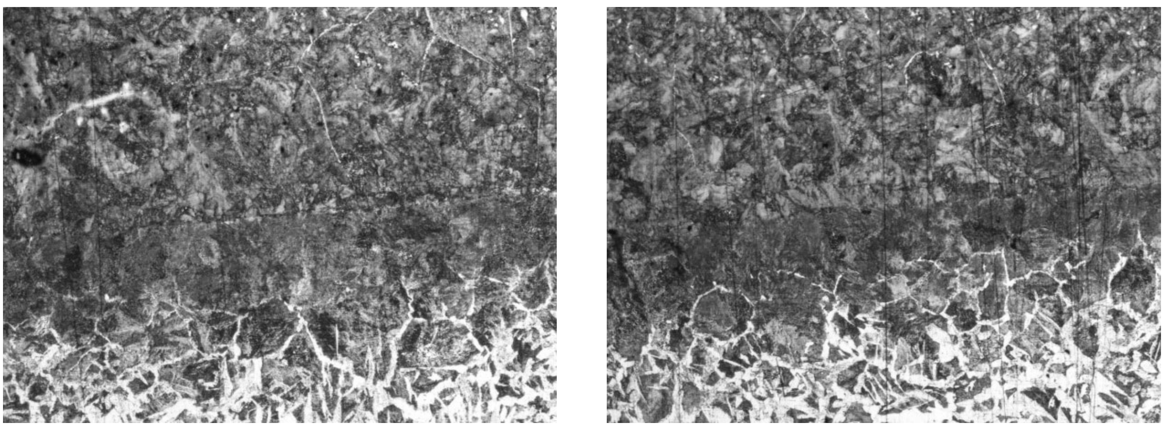

Fig. 6. Casting 3 connection zone, magnification x50

In the photos of the structure of casting 4 (1.87%C) one can observe (Fig. 7) an increase in the cementite content in the alloy compared to sample 3 and an increasing zone of pearlitic structure in the steel insert and the appearance of a clear strip with a super-eutectoid structure.

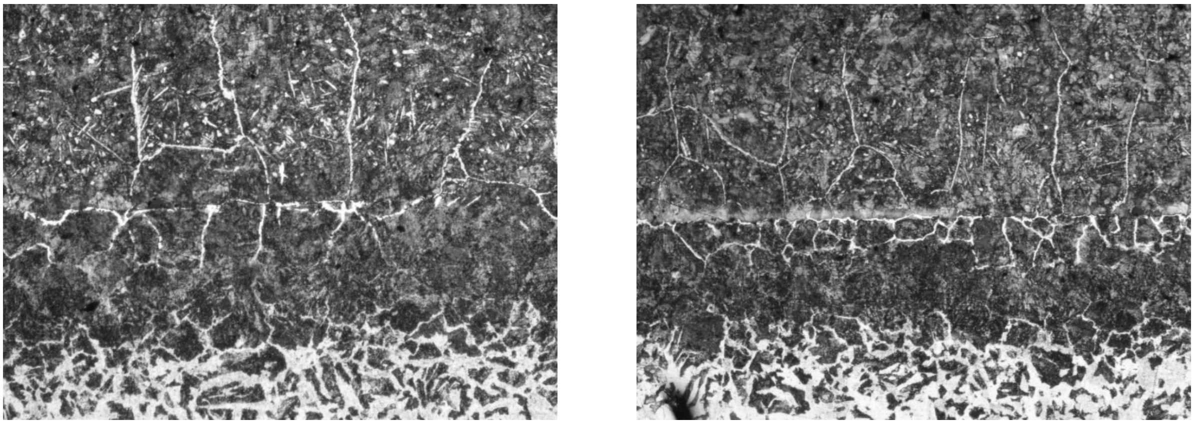

Fig. 7. Casting 4 connection zone, magnification x50

In the case of casting 5 with a 2.20% C content (Fig. 8), the photos show a pearlitic structure with secondary cementite and transformed ledeburite. The bimetallic casting joint line is clearly visible. We also observe an increase in carbon content in the steel sheet, as evidenced by the precipitates of cementite at the pearlite grain boundaries.

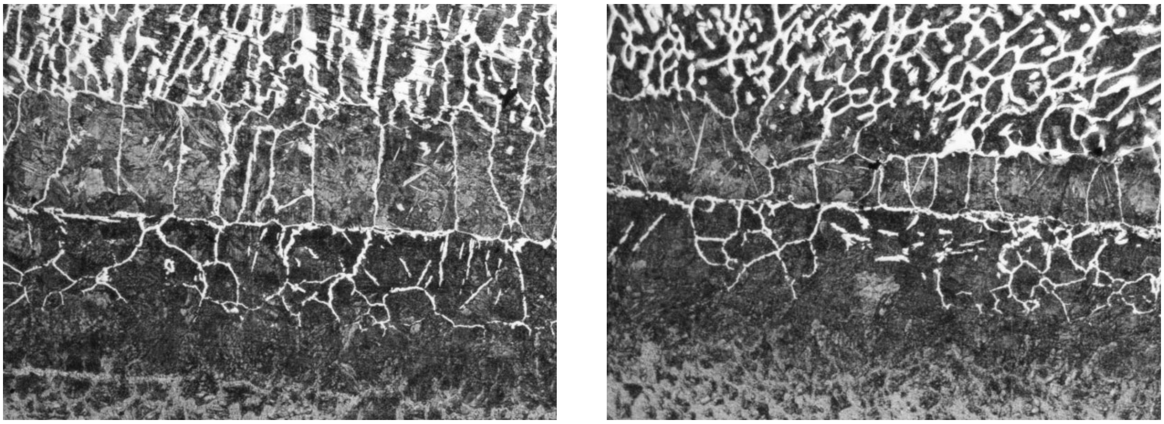

Fig. 8. Casting 5 connection zone, magnification x50

In casting no. 6 (2.57% C), we observe a structure very similar to casting no. 5. More cementite is observed in the cast layer, resulting from the increased carbon content. The carburized zones of the sheet and the decarburized zones of the cast iron appear almost identical.

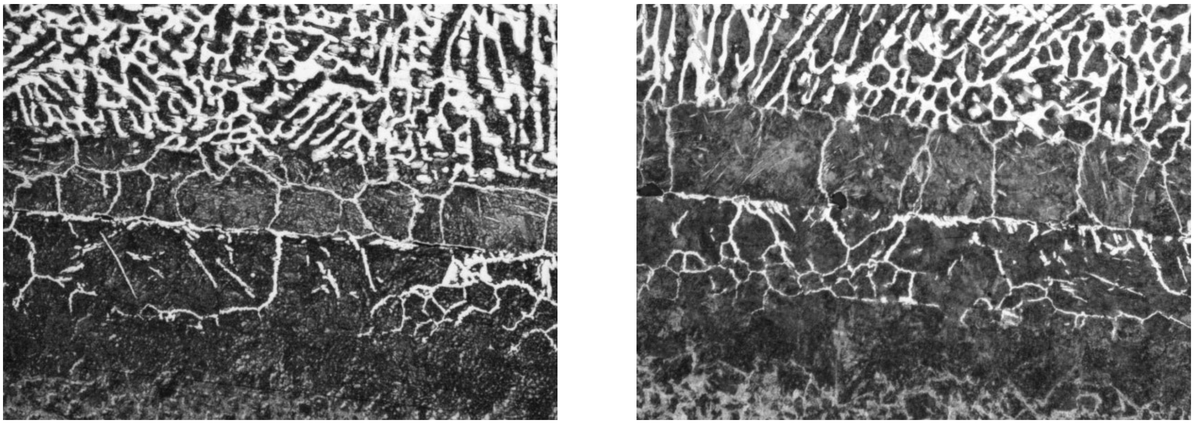

Fig. 9. Casting 6 connection zone, magnification x50

In casting no. 7 (3.19% C), we observe a clear division into zones with different structures. The cast iron has a characteristic hypoeutectic white cast iron structure. At the interface between the cast iron and the sheet, a distinct decarburized layer is visible, followed by a layer of carburized sheet metal at the interface between pearlite and cementite, and deeper within, a layer of pearlite.

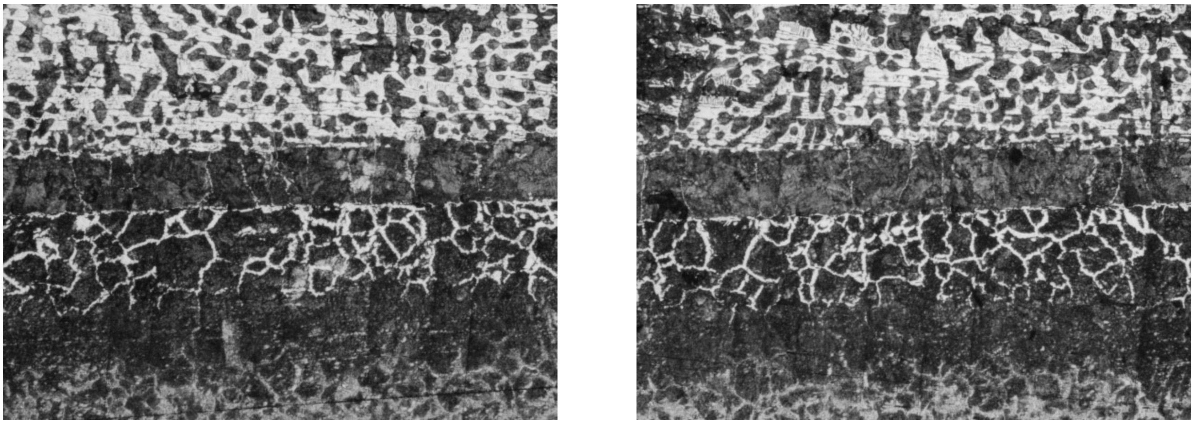

Fig. 10. Casting 7 connection zone, magnification x50

Increasing the carbon content to 3.72% C caused a change in the cast iron structure. The cast layer crystallized as gray cast iron (Fig. 11). The remaining structure is similar to that of casting no. 7. We observe distinct zones of cast iron decarburization and steel carburization.

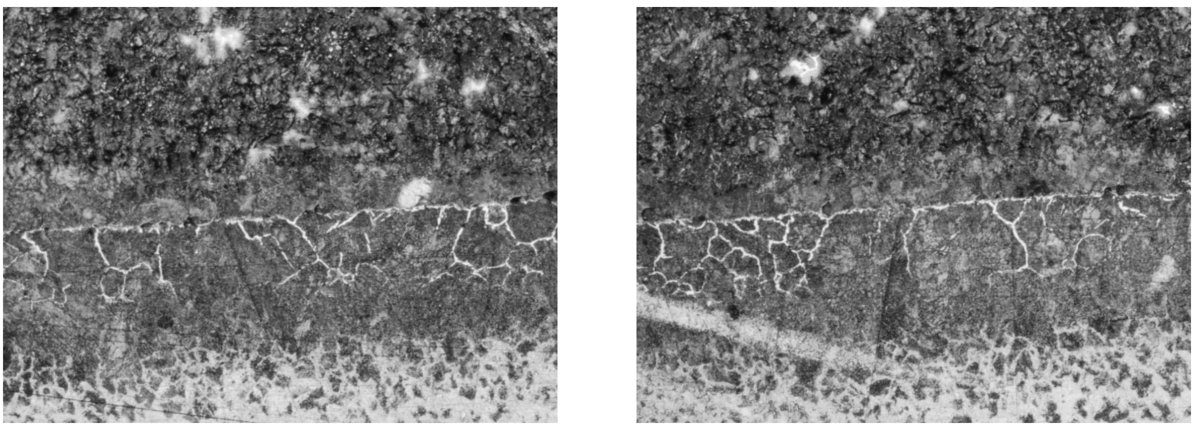

Fig. 11. Casting 8 connection zone, magnification x50

The study of the connection between the sheet metal and the cast layer also included quantitative tests measuring the thicknesses of the decarburized and carburized layers, as well as the amount of pearlite in the carburized layer of the sheet metal. The results are summarized in Table 3.

Table 3.
Results of analysis of metallographic samples

Casting No.	Actual C content [%]	Length of decarburization in the working material [µm]	Carburization depth of the steel insert [µm]
1	0.48	0	17.8
2	0.83	146.6	347.4
3	1.38	498.7	572.5
4	1.87	548.2	512.5
5	2.20	295.9	434.5
6	2.57	231.4	422.7
7	3.19	174.9	501.2
8	3.72	168.4	415.7

It is clearly visible that as the amount of carbon in the cast layer increases, the carburization depth increases, reaching approximately 0.5 mm. The data from the table are presented in Figure 12.

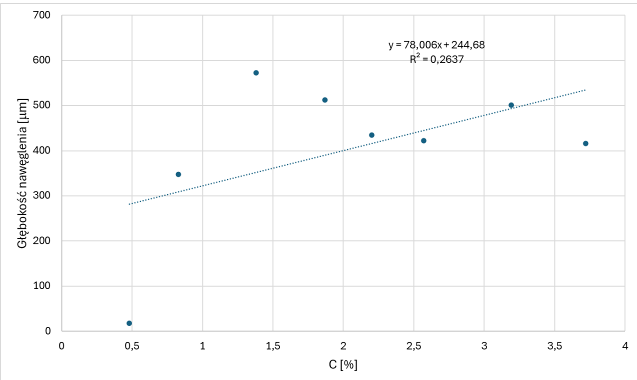

Fig. 12. Carburization depth as a function of carbon content

The depth of decarburization decreases with increasing carbon content in the cast layer. The amount of pearlite in the cast layer, after exceeding 1.3%, fluctuates around 70%.

As the carbon content increases, the diffusion depth shows a slight downward trend, while the decarburization length decreases significantly. This decrease may be due to slower diffusion due to saturation of the layer in the sheet and a decrease in the casting temperature during the formation of the joint with the addition of increasing amounts of carbon. As a result, the amount of carbon supplied is disproportionately high compared to the amount of carbon diffusing into the layer in the sheet, resulting in a correspondingly smaller amount of working material to meet the diffusion needs. This results in a decrease in the decarburization length while maintaining a similar diffusion depth.

4. Conclusions

1. Carbon content significantly affects the joint formed in a bimetallic casting and the depth of carbon diffusion into the steel insert.
2. Achieving a joint in a bimetallic casting is only possible when an appropriate difference in carbon content is achieved between the working and supporting parts. Based on the test results, this difference should be greater than 1.2% C.
3. The best joint quality was achieved with a carbon content of 2.2-2.57%; in this case, the resulting transition zone has an almost purely pearlitic structure.
4. Based on the ultrasound examination of the casting and considering the joint arrangement in the casting relative to the gating system, it can be concluded that to achieve better joint quality, the castings should be poured with a more overheated metal, or a longer cooling time should be provided.

References

[1] Górny, Z. (1987). Reinforced and multilayer castings. *Solidification of Metals and Alloys*. (in Polish).

[2] Szajnar, J., Wróbel, P. & Wróbel, T. (2010). Multi-layers castings. *Archives of Foundry Engineering.* 10(1), 181-186.

[3] Gawroński, J., Szajnar, J. & Wróbel, P. (2004). Study on theoretical bases of receiving composite alloy layers on surface of cast steel castings. *Journal of Materials Processing Technology*. 157-158, 679-682. DOI: 10.1016/j.jmatprotec.2004.07.153.

[4] Jura, S. & Suchoń, J. (1995). Layered castings sort steel cast iron. *Solidification of Metals and Alloys*. 24, 67-70. (in Polish).

[5] Bartocha, D., Suchoń, J. & Jura, S. (1998). *Layered castings. Solidification of Metals and Alloys*. 38, 151-156. (in Polish).
[6] Wróbel, T. (2016). *Layered castings made by method of mould cavity preparation with monolithic insert*. Katowice-Gliwice: Archives of Foundry Engineering – Monograph. (in Polish).
[7] Wróbel, T. (2011). Ni and Cr base layers in bimetallic castings. In 20th Anniversary International Conference on Metallurgy and Materials, 18-20 May 2011 (pp. 758-764). Brno, Czech Republic.
[8] Szajnar, J., Dulska, A., Wróbel, T. & Suchoń, J. (2014). Diffusion of C and Cr during creation of surface layer on cast steel casting. *Archives of Metallurgy and Materials.* 59, 1085-1087. DOI: 10.2478/amm-2014-0186.
[9] Wróbel, T. (2014). Characterization of bimetallic castings with an austenitic working surface layer and an unalloyed cast steel base. *Journal of Materials Engineering and Performance.* 23(5), 1711-1717. https://doi.org/10.1007/s11665-014-0953-4.
[10] Tenerowicz, S., Suchoń, J. & Cholewa, M. (2010). Studies of the transition zone in steel – chromium cast iron bimetallic casting. *Archives of Foundry Engineering*. 10(1), 199-204. ISSN (1897-3310).
[11] Janerka, K., Szajnar, J. (2010). Methods of carburizing liquid cast iron and their effectiveness. In S. Pietrowski (Eds.) *Trends in the Optimization of Production Systems in Foundries* (pp. 111-124). Katowice: Archives of Foundry Engineering.