



The Influence of the Working Layer Thickness on the Quality of the Joint in Layered Castings

J. Suchoń * , M. Kondracki 

Silesian University of Technology, Department of Foundry Engineering,
Towarowa St. 7, 44-100 Gliwice, Poland

* Corresponding author. E-mail address: jacek.suchon@polsl.pl

Received 31.07.2026; accepted in revised form 27.09.2026; available online 30.09.2026

Abstract

Bimetallic castings are increasingly used as engineering materials. Their versatility demonstrates the significant need for their production. Bimetals are used in the mining, quarrying, cement, construction, and energy industries. Their advantages stem from the complementary nature of their various properties. For example, the combination of abrasive wear resistance and impact resistance allows for increased durability of machine components operating in extremely harsh conditions. Combining cast iron and steel allows for rapid disassembly and assembly of machine parts using welding, further increasing their popularity. The key to achieving a proper bond between two layers is carbon diffusion. For diffusion to be favorable, there must be a significant difference in carbon concentration and an adequate amount of heat to facilitate diffusion. In thick castings where the cast iron layer is several dozen millimeters thick and the carbon content exceeds 3%, the bond occurs almost spontaneously. This paper attempts to describe the effect of the amount of heat of crystallization on the quality of the bond in a bimetallic casting.

Keywords: Bimetallic casting, Stainless steel, Microstructure, Carburized layer, Heat of crystallization

1. Introduction

Bimetal is a material made of two different metal layers bonded together. The essence of bimetal casting is to combine two materials in a mold. These materials must differ in their properties and chemical composition. Therefore, bimetal castings are primarily made by combining steel and cast iron. [1]

The basic technology for bimetal casting is the mold cavity preparation method [2, 3]. It consists of two components: a support layer, usually a solid steel sheet insert, and a working layer cast from various materials depending on the desired performance characteristics. Figure 1 illustrates the concept of a layered casting.

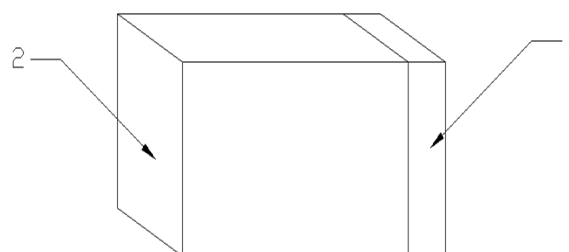


Fig. 1. Layered casting: 1) Supporting layer, 2) Working part

The most common method of making joints is based on diffusion bonding of the casting layers [4]. This process takes place



in a specially prepared mold and involves placing a steel sheet inside it, onto which liquid cast iron is then poured [5]. The resulting diffusion bond utilizes the ability of carbon atoms to diffuse at the interface between the two materials being joined. A diagram of the mold for a bimetallic casting is shown in Fig. 2.

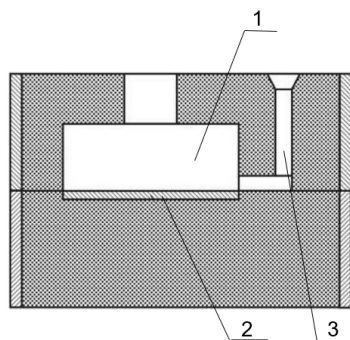


Fig. 2. Concept of layered casting: a) working layer, b) supporting layer, c) gating system [8]

To intensify the diffusion effect, an additional cavity under the sheet is often used for a so-called preheater. The preheater is poured before pouring the working layer [6, 7]. This can be done by more intensely heating the sheets to increase diffusion at the joint interface. A diagram of the mold for a bimetallic casting with a preheater is shown in Fig. 3.

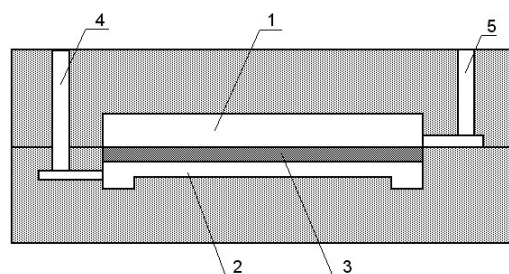


Fig. 3. Schematic diagram of a bimetallic casting in a solid-liquid system: 1 – cast iron layer, 2 – preheater layer, 3 – steel sheet, 4, 5 – gating systems [6]

Diffusion is a thermally activated process that occurs as a result of the movement of atoms in the material's spatial lattice. The direction of their movement is determined by the need for the mutual equilibrium of the component concentrations [8-10]. This process depends on time, temperature, and the concentration gradient of the diffusing elements [11-13].

2. Research Methodology

2.1. Castings

A supporting sheet measuring 105 x 4 x 105 mm was used in the tests. The working layer of the bimetallic casting was 100 x 100 mm, with thicknesses ranging from 1 to 5 times the sheet thickness. A drawing of the sheet and its thickness is shown in Figure 4.

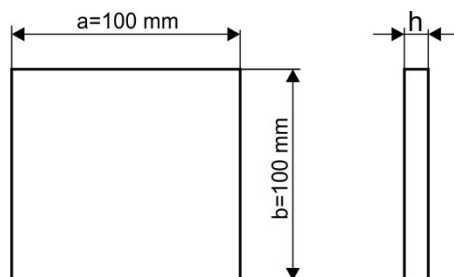


Fig. 4. Dimensions of individual sheets

Casting number	h [mm]
1.	4
2.	8
3.	12
4.	16
5.	20

Bimetal castings were made in two ways: with and without a preheater. The preheater is a recess under the sheet metal, measuring 80 x 80 x 10 mm. Five castings were made simultaneously in each mold to minimize the influence of pouring temperature on the formation of layered castings. Each set of bimetals was made in a separate melt. The chemical compositions of both melts are presented in Table 1.

Sheet metal with a 0.18% C content was used. Figure 5 shows the casting after ejection from the mold.

Table 1.

Chemical composition of the cast iron used

Alloying addition	Casting without heaters	Casting with heaters
	Percentage content	
C	3,85	3,62
Mn	0,239	0,301
Si	2,69	3,23
Cr	0,264	0,273
P	0,055	0,061
S	0,019	0,015



Fig. 5. Obtained castings: a) bimetal castings without preheaters, b) bimetal castings with preheaters (view from the preheater side)

2.2. Method for Assessing the Range of Carbon Diffusion

To determine the effectiveness and range of carbon diffusion, optical microscopy tests were conducted, and an image analyzer was used to measure the thickness of the decarburized cast iron layer and the depth to which carbon penetrated the steel sheet. Clear structural changes were observed in the diffusion zone. On the cast iron side, graphite disappears, while on the steel side, the structure changes from ferritic-pearlitic to pearlitic, with cementite precipitates appearing at the boundaries. An example structure of the bond zone, with the zones marked, is shown in Figure 6.

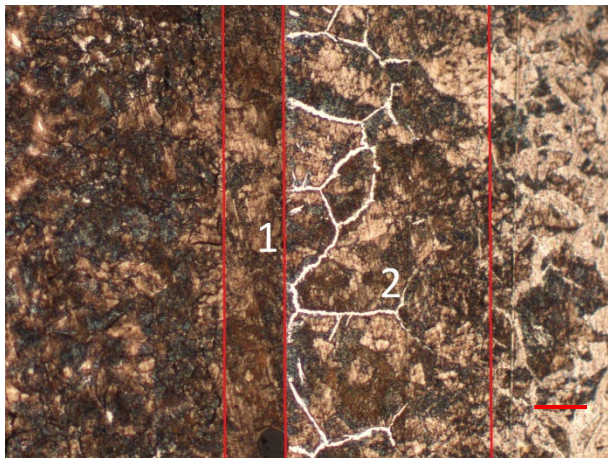


Fig. 6. Zone between sheet and cast iron: 1 – decarburized zone, 2 – carburized zone

The red marker in the photos measures 100 μm

The diffusion range was assessed using a computer image analyzer. The widths of the decarburized and carburized zones in the sheet were measured. The averaged measurement results are presented in Figures 7 and 8.

The sample designations used are as follows:

- W denotes the heat number (1 – heat without preheaters, 2 – heat with preheaters),
- P denotes the sample number (1 – working layer 4 mm, 2 – working layer 8 mm, 3 – working layer 12 mm, 4 – working layer 16 mm, 5 – working layer 20 mm)

The diffusion range is clearly related to the thickness of the bimetallic working layer. A significant increase is also observed when the sheet is preheated. As can be easily understood, this is related to the increase in the heat of crystallization released during the formation of the layered casting. For illustration, these heat amounts were determined for all casting variants. The MagmaSoft material database was used to obtain the necessary thermophysical data. GJL-150 cast iron was selected as the material because the cast iron used in the chemical composition tests is closest to this grade. The data used for the calculations were: liquid density: 6.745 g/cm³, heat of crystallization: 230 kJ/kg. Based on this data and the casting dimensions, the heat of crystallization released during the formation of individual castings was determined. The calculated heat of crystallization for each casting is summarized in Table 2.

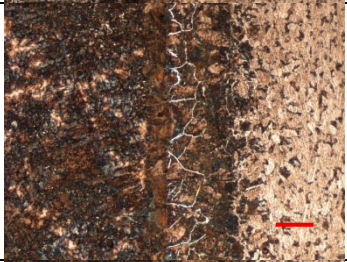
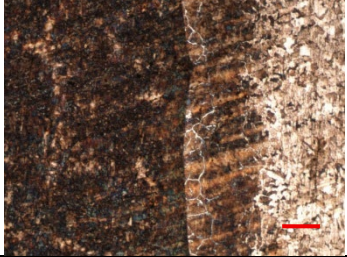
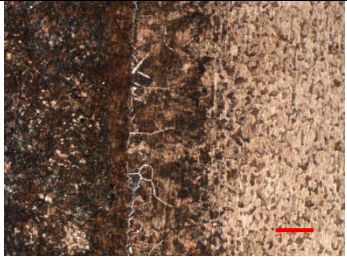
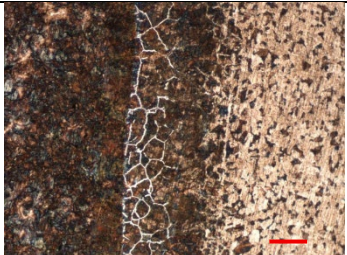
		Carburization depth of the sheet [μm]	Cast iron decarburization depth [μm]
W1P1		111	73
W1P2		307	95
W1P3		298	83
W1P4		358	127
W1P5		440	149

Fig. 7. Measurement results of decarburization and carburization zones in bimetal without preheater, along with sample structures
The red marker in the photos measures 200 μm

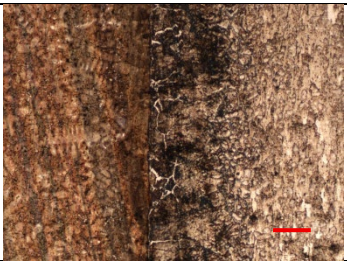
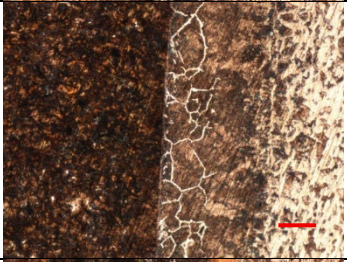
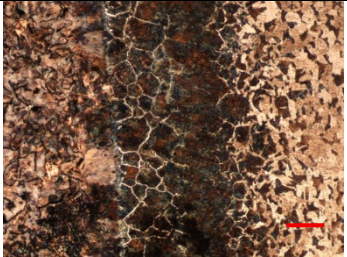
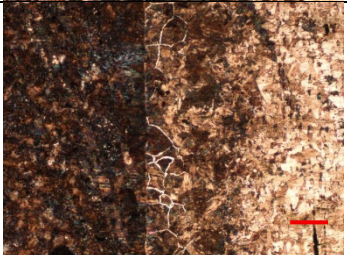
		Carburization depth of the sheet [μm]	Cast iron decarburization depth [μm]
W2P1		404	133
W2P2		496	121
W2P3		529	149
W2P4		723	188
W2P5		624	198

Fig. 8. Measurement results of decarburization and carburization zones in bimetal with a preheater, along with sample structures
The red marker in the photos measures 200 μm

Table 2.

Summary of calculated heat of crystallization for castings with and without a preheater

Thickness of the working layer [cm]	Volume of the working layer [cm ³]	Mass of the cast iron layer in the liquid state [kg]	Heat of crystallization of the working layer [kJ/kg]	Total heat of crystallization of the working layer and the heater [kJ/kg]
0.4	40	0.2698	62.1	161.3
0.8	80	0.5396	124.1	223.4
1.2	120	0.8094	186.2	285.4
1.6	160	1.0792	248.2	347.5
2	200	1.349	310.3	409.6

The calculated amounts of heat of crystallization allowed the preparation of graphs that relate the released heat of crystallization to the width of the carbon diffusion zones at the junction boundary in the bimetal.

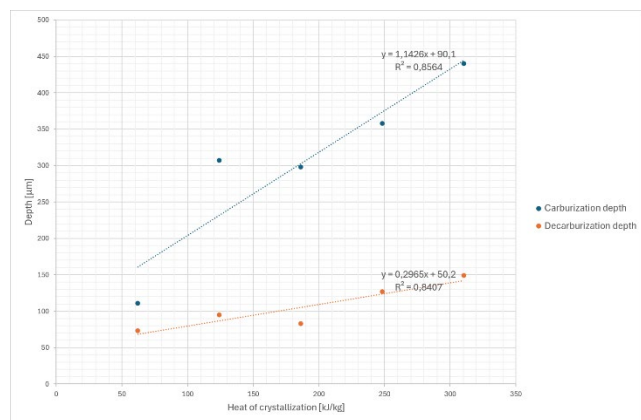


Fig. 9. The size of the carburizing and decarburizing zones in castings without a preheater as a function of the amount of crystallization heat

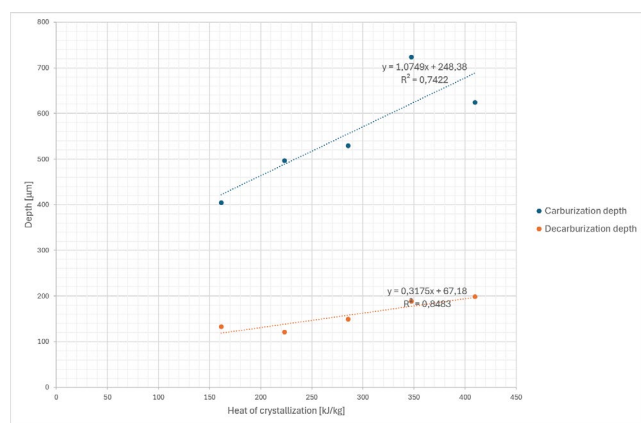


Fig. 10. The size of the carburizing and decarburizing zones in castings with a preheater as a function of the amount of crystallization heat

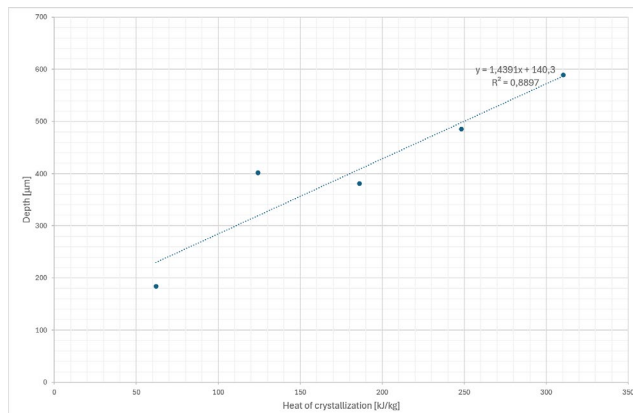


Fig. 11. Total diffusion depth as a function of the amount of heat of crystallization in castings without preheater

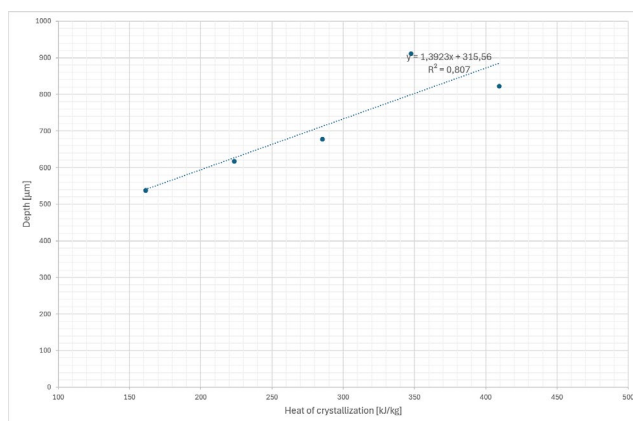


Fig. 12. Total diffusion depth as a function of the amount of heat of crystallization in castings with a preheater

3. Summary

The conducted research confirmed that the quality of the joint in bimetallic castings is decisively influenced by diffusion at the interface between cast iron and steel sheet. The factor that favors diffusion is the heat of crystallization. The larger the volume of solidifying cast iron surrounding the steel sheet, the greater the mass of the casting, and the greater the amount of heat released during crystallization, the greater the tendency for carbon exchange at the interface. The use of a sheet preheater significantly increases

the intensity of diffusion phenomena. The conducted research leads to the following conclusions:

1. Increasing the thickness of the bimetallic working layer increases the depth of decarburization of the cast iron and carburization of the steel sheet,
2. Due to the differences in carbon content between cast iron and steel sheet, the decarburized layer is always thinner than the carburized layer of the sheet,
3. The quality of the joint in a layered casting is related to the amount of heat of crystallization,
4. To improve the joint for castings with a thin layer of poured casting, the use of a preheater is recommended.

References

- [1] Górny, Z. (1987). Reinforced and multilayer castings. *Solidification of Metals and Alloys*. 11, 135-164. (in Polish).
- [2] Kilariski, J., Studnicki, A., & Suchoń, J. (2009). Iron alloys used for cast components exposed to abrasive wear. In *Advances in the theory and practice of foundry* (pp. 211–230). (in Polish)
- [3] Szajnar, J., Wróbel, P. & Wróbel, T. (2010). Multi-layers castings. *Archives of Foundry Engineering*. 10(1), 181-186. ISSN (1897-3310).
- [4] 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.
- [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., Dulaska, 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] Suchoń, J. & Kondracki, M. (2026). Interface carbon content and its influence on carburization of steel in bimetallic castings. *Archives of Foundry Engineering*. 26(2), 90-96. DOI: 10.24425/afe.2026.157993.
- [12] Przyszlak, N., Wróbel, T., Dulaska, A., Nuckowski, P.M., Łukowiec, D. & Stawarz, M. (2024). Microstructure of the working layer of X46Cr13 steel in a bimetal system with gray cast iron. *Materials*. 17(23), 5933.
- [13] Dulaska, A. & Przyszlak, N. (2025). Computer Modeling of Layered Castings Solidification: Analysis and Optimization. *Archives of Foundry Engineering*. 25(3), 213-220.