ARCHIVES
of
FOUNDRY ENGINEERING

ISSN (1897-3310)
Volume 11
Issue 1/2011

105 – 108

22/1

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

Bimetallic layered castings alloy steel – carbon cast steel

T. Wróbel [a,] *, M. Cholewa [a], S. Tenerowicz [b]
[a] Silesian University of Technology, Foundry Department, Towarowa 7, 44-100 Gliwice, PL
[b] Experimental-Implemention Foundry Division, Towarowa 7, 44-100 Gliwice, PL
* Corresponding author. E–mail address: tomasz.wrobel@polsl.pl

Received 14.02.2011; accepted in revised form 07.03.2011

Abstract

In paper is presented technology of bimetallic layered castings based on founding method of layer coating directly in cast process so-called method of mould cavity preparation. Prepared castings consist two fundamental parts i.e. bearing part and working part (layer). The bearing part of bimetallic layered casting is typical foundry material i.e. ferritic-pearlitic carbon cast steel, whereas working part (layer) is plate of austenitic alloy steel sort X10CrNi 18-8. The ratio of thickness between bearing and working part is 8:1. The quality of the bimetallic layered castings was evaluated on the basis of ultrasonic NDT (non-destructive testing), structure and macro- and microhardness researches.

Keywords: Bimetal; Cast steel; Steel; Austenite; Ferrite; Pearlite

1. Introduction

In the engineering industry noticeable is a growing demand for castings with special properties such as abrasive wear resistance, corrosion resistance at room or elevated temperature. Elements of this type often carried out entirely from expensive and hard to reach materials like of Ni, Co, Ti, or others. In many cases the requirements for high performance properties affect only the working surface of the casting. Especially if wear of an element leads to its destruction through exceeded the allowable main dimension decrease.

Among many methods for producing metallic coatings on materials for specific performance properties to be mentioned is founding technology so-called method of mould cavity preparation in which the element which is the working surface layer of the casting is placed in mould in form of monolithic or granular insert directly before pouring molten metal [1÷5]. This technology is the most economical way of enrichment the surface of castings, as it allows the production of layer elements directly in the process of cast. Therefore, this technology can provide significant competition for the commonly used technologies of surfacing by welding and thermal spraying [6÷8], because in addition to economic advantages do not generate opportunities for the development of cracks in the heat affected zone, which arises as a result of making layer by welding method.

The idea of the proposed technology of layered casting was taken from the relevant mining industry method of manufacture of composite surface layers based on granular inserts from Fe-Cr-C alloy and placed in mould directly before pouring molten metal. Obtained in this way working surface layers have a high hardness and metal-mineral wear resistance [1, 3 and 9].

Moreover in literature are present data about layered castings made on the basis of monolithic inserts, for example from carbon steel poured by liquid chromium cast iron [4] or from grey cast iron dipping into liquid hypoeutectic Al-Si alloy [10÷12].

2. Range of studies

In range of studies were made bimetallic layered castings, which consist two fundamental parts i.e. bearing part and working part (layer) (Fig.1). The bearing part of bimetallic layered casting is typical foundry material i.e. ferritic-pearlitic carbon cast steel, whereas working part (layer) is plate of austenitic alloy steel sort X10CrNi 18-8.

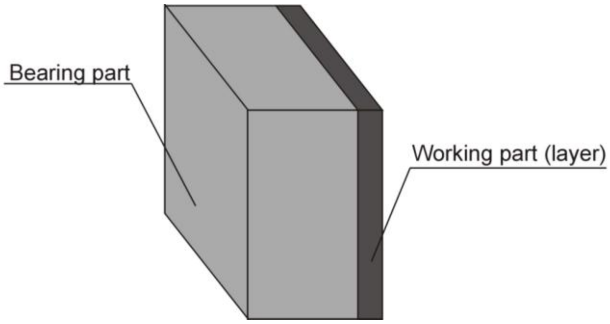
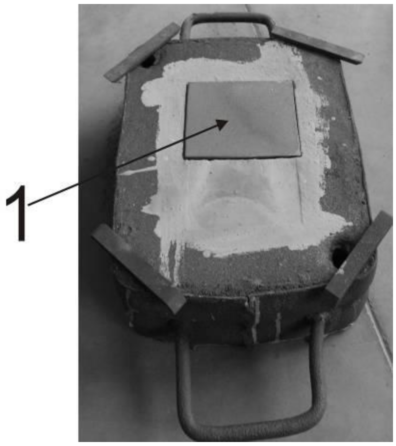


Fig. 1. Scheme of bimetallic layered casting

a)



b)

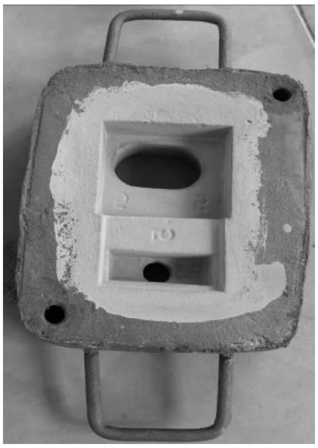


Fig. 2. View of sand mould with plate of austenitic steel (1) placed in its cavity: a – bottom half of mould, b – top half of mould

In aim of making a test bimetallic layered castings with dimensions 125 x 105 x 45mm, in sand mould with no preheating were placed plates of alloy steel sort X10CrNi 18-8 (Fig. 2), which then were poured by liquid carbon cast steel (C = 0,2 and 0,6%) from pouring temperature T_{zal} = 1550 and 1650°C.

On the basis of results of previous studies [13 and 14] were used steel plates with thickness 5mm, which surfaces staying in direct contact with liquid metal were covered by activator in form of boron and sodium compounds. These compounds favour the formation of a permanent joint between both materials of layered casting. Obtained in this way the ratio of thickness between bearing and working part about 8:1.

The quality of the bimetallic layered casting was evaluated on the basis of ultrasonic NDT (non-destructive testing) made using the DIO 562 flaw detector by STARMANS ELEKTRONICS. Next metallographic examination of macro-and microscopic was carried out. Metallographic specimens etched in the reagent Mi1Fe containing [15]: 3cm^3 nitrous acid and 100cm^3 ethanol and Mi19Fe containing [15]: 3g of ferric chloride, 10cm^3 hydrochloric acid and 90cm^3 ethanol.

Moreover measurements of macro- and microhardness were made using appropriately MIC2 Krautrkramer-Branson's and FM 700's Future-Tech.

3. Results of studies

On the basis of non-destructive ultrasonic testing it was found that only in bimetallic layered casting, which was made at pouring temperature 1650°C and concentration of carbon in cast steel amounting C = 0,6%, was obtained permanent joint between working part (layer) and bearing part, as the bottom echo was larger than the echo of the transition zone (head placed on the side of the plate) on 80% of contact surface of both materials. Moreover on residual 20% of surface was obtained partial joint, which is characterized by the presence of so-called “bimetallic connecting bridges”. Presence of so-called “bimetallic connecting bridges” also provides stability of joint and does not significantly reduce the application characteristics of the casting.

These results are confirmed by presented in Figure 3 example views of cross-section of test bimetallic layered casting.

Whereas in residual variants were obtained complete lack of joint between working part (layer) and bearing part i.e. variant of carbon cast steel contains 0,2% or 0,6%C at pouring temperature 1550°C or was obtained permanent joint between both parts of bimetal only on surface less than 5% of total contact surface of both materials i.e. variant of carbon cast steel contains 0,2% at pouring temperature 1650°C.

On Figure 4÷6 are presented microstructure of obtained bimetallic layered castings. It was found that obtained boundary between ferritic-pearlitic carbon cast steel (C = 0,6%) and plate of austenitic alloy steel, characterizes a high degree of nonlinearity (Fig. 4), which determines high strength of joint between working part (layer) and bearing part in bimetallic layered casting.

a) b)

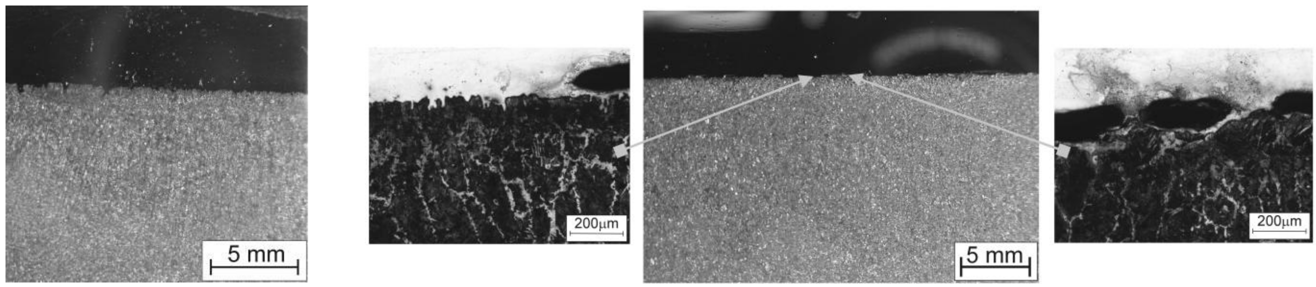


Fig. 3. View of cross-section of bimetallic layered casting in configuration plate of alloy steel sort X10CrNi 18-8 – carbon cast steel (C = 0,6%) made at T_{zal} = 1650°C: a) permanent joint, b) partial joint, which is characterized by the presence of so-called "bimetallic connecting bridges"

This joint has the character of diffusion which determines diffusion of carbon in direction from cast steel to steel plate. Proximate result of this diffusion is creation of pearlitic transition zone (δ) with thickness 15μm and hardness 230μHV (Fig.5 and 6).

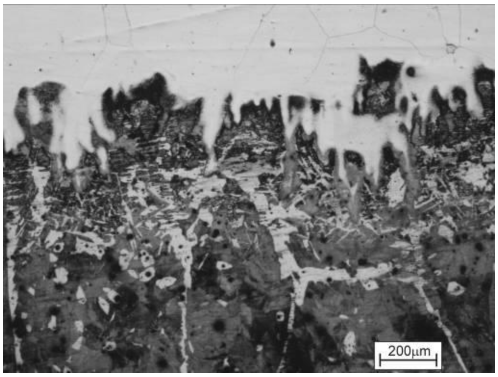


Fig. 4. Microstructure of joint area between austenitic alloy steel and ferritic-pearlitic carbon cast steel – etching Mi19Fe

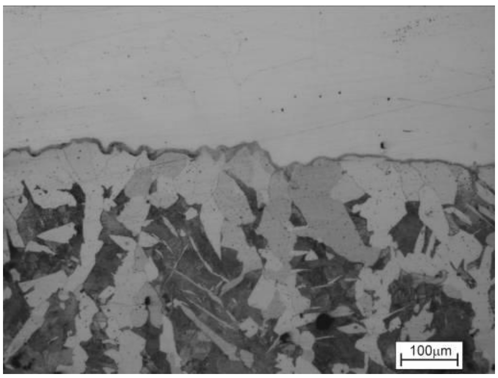


Fig. 5. Ferritic microstructure in decarbonizing, near boundary area of carbon cast steel – etching Mi1Fe

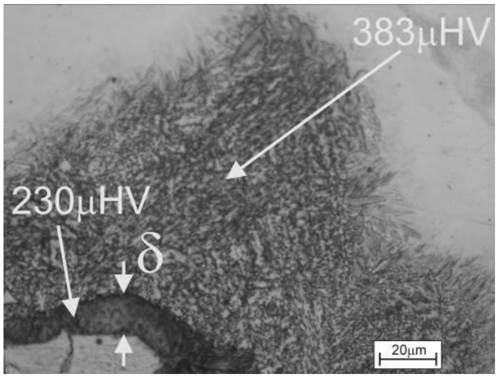


Fig. 6. Microstructure of diffusion joint area in bimetallic layered casting – in direction from cast steel (from bottom) to steel is visible following: ferrite, pearlite, martensite and austenite – etching Mi19Fe

Moreover, the result of the diffusion phenomenon is decarbonizing of cast steel in near boundary area and in consequence of this is creation in this zone ferritic microstructure with small amount of pearlite, considerably smaller than in the rest of bearing part of casting (Fig.5).

Additionally, the near boundary area of plate of alloy steel sort X10CrNi 18-8 is carbonizing by cast steel contains 0,6%C and in result of this is obtained in this zone microstructure of martensite with hardness about 380μHV (Fig.6). Besides carbonizing of the near boundary area of austenitic steel, also favors the creation of martensite cooling from high temperature to which the plate is heated, and whose source is the liquid cast steel poured into the mould. For the pouring temperature 1650°C of cast steel, the contact temperature T_s on the border of liquid metal - steel plate, fixed on the basis of dependence [16]:

$$T_s = \frac{\sqrt{\lambda_n \cdot c_n \cdot \rho_n} \cdot T_n + \sqrt{\lambda_r \cdot c_r \cdot \rho_r} \cdot T_r}{\sqrt{\lambda_n \cdot c_n \cdot \rho_n} + \sqrt{\lambda_r \cdot c_r \cdot \rho_r}} \qquad (1)$$

where:

λ_n, λ_r – coefficient of thermal conductivity, suitably for the liquid cast steel (bearing part of casting) and steel plate (working part of casting), W/(m·K),

c_n, c_r – specific heat, suitably for the liquid cast steel (bearing part of casting) and steel plate (working part of casting), J/(kg·K),
ρ_n, ρ_r – mass density, suitably for the liquid cast steel (bearing part of casting) and steel plate (working part of casting), kg/m^3,
T_n – temperature of the liquid cast steel, °C,
T_r – temperature of steel plate (working part of casting), °C,
is about 1100°C.

4. Summary

On the basis of obtained results was affirmed that obtaining necessary, permanent joint between plate of alloy steel sort X10CrNi 18-8 and carbon cast steel in bimetallic layered casting at assumed module of solidification, demands simultaneously of two conditions i.e. suitable, high pouring temperature of liquid cast steel poured into the mould in which is placed 5mm thick plate of austenitic alloy steel and also suitable, minimal difference in carbon concentration between the both joined materials. Fulfilment of only one of these conditions result in obtaining of defective casting, which has no application characteristics.

Therefore, the use of pouring temperature 1650°C and carbon cast steel with concentration of C = 0,6% on the bearing part of bimetallic layered casting, allowing on effective joint of this material with 5mm thick plate of alloy steel sort X10CrNi 18-8.

Prepared bimetallic layered castings according to work out technology can work in conditions, which require from working surface layer of element a high heat resistance and/or corrosion resistance in medium for example of industrial water. Moreover in case of application on working part (layer) the chromium-nickel steel is possible to obtain high abrasive wear resistance in result of increase in hardness of austenite from about 240HV to about 400HV. This increase of hardness following in operating conditions results from induced of plastic deformation martensitic transformation $\gamma \rightarrow \alpha'$ [13 and 17].

Acknowledgements

Scientific project financed from means of budget on science in years 2010 - 2012 as research project N N508 585039.

References

[1] J. Marcinkowska, B. Kusznir: Cast coatings on machine elements, Proceedings Materiale of Scientific Conference “Cast Form of Machine Elements”, Olsztyn (1979), 1-11 (in polish).

[2] T. Heijkoop, I. Sare: Cast-bonding – a new process for manufacturing composite wear products, Cast Metals, 3 (1989), 160-168.

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

[4] D. Bartocha, J. Suchoń, S. Jura: Layer castings, Solidification of Metals and Alloys, 38 (1998), 151-156 (in polish).

[5] M. Cholewa, S. Tenerowicz, T. Wróbel: Quality of the joint between cast steel and cast iron in bimetallic castings, Archives of Foundry Engineering, 3 (2008), 37-40.

[6] A. Klimpel: Surfacing and thermal spraying. Technologies, WNT, Warsaw (2000) (in polish).

[7] A. Klimpel, L.A. Dobrzański, A. Lisiecki, D. Janicki: The study of the technology of laser and plasma surfacing of engine valves face made of X40CrSiMo10-2 steel using cobalt-based powders, Journal of Materials Processing Technology, 175 (2006), 251-256.

[8] W. Xibao, W. Xiaofeng, S. Zhongquan: The composite Fe–Ti–B–C coatings by PTA powder surfacing process, Surface and Coatings Technology, 192 (2005), 257-262.

[9] J. Szajnar, P. Wróbel, T. Wróbel: Model castings with composite surface layer - application, Archives of Foundry Engineering, 3 (2008), 105-110.

[10] J. Viala, M. Peronnet, F. Barbeau, F. Bosselet, J. Bouix: Interface chemistry in aluminium alloy castings reinforced with iron base inserts, Composites: Part A, 33 (2002), 1417-1420.

[11] S. Pietrowski, T. Szymczak: Model of the alphinising coating crystallization on iron alloys, Archives of Foundry Engineering, 3 (2007), 123-128.

[12] S. Pietrowski: Structure of alifinising layer on the gray cast iron, Archives of Foundry, 11 (2004), 95-104.

[13] J. Szajnar, M. Cholewa, S. Tenerowicz, T. Wróbel: Enrichment of surface of low-alloyed cast iron with use of austenite layer, Archives of Foundry Engineering, 1 (2010), 187-190.

[14] M. Cholewa, T. Wróbel, S. Tenerowicz: Bimetallic layer castings, Journal of Achievements in Materials and Manufacturing Engineering, 43/1 (2010), 385-392.

[15] K. Sękowski, J. Piaskowski, Z. Wojtowicz: Atlas of structures of founding alloys, WNT, Warsaw (1972) (in polish).

[16] J. Taler., P. Duda: Solving direct and inverse heat conduction problems, Springer-Verlag, Berlin (2006).

[17] J. Adamczyk: Engineering of metallic materials, Publishers of Silesian University of Technology, Gliwice (2004) (in polish).