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Spatial Bimetallic Castings Manufactured from Iron Alloys

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Abstract

In this paper a conception for manufacturing method of skeleton castings with composite features was shown. Main application of such castings are the working organs of machines subjected to intensive abrasive and erosive wear. Skeleton geometry was based on three-dimensional cubic net consisting of circular connectors and nodes joining 6 connectors according to Cartesian co-ordinate system. Dimension of an elementary cell was equal to 10 mm and diameter of single connector was equal to 5 mm. For bimetallic castings preparation two Fe based alloys were used: L25SHMN cast steel for skeleton substrate and ZlCr15NiMo cast iron for working part of the casting. In presented work obtained structure was analyzed with indication of characteristic regions. Authors described phenomena occurring at the alloys interface and phases in transition zone. A thesis was formulated concerning localization of transition zone at the cast iron matrix – cast steel reinforcement interface. Direction of further studies were indicated.

Keywords: Casting, Skeleton, Bimetal, Composite, Structure

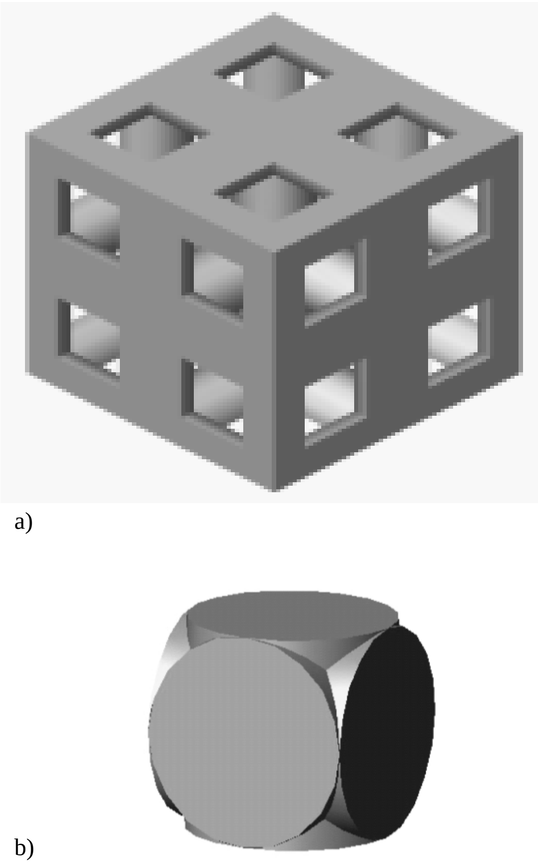
1. Introduction

Bimetallic castings are widely employed as working elements in winning machines which work in conditions of intensive friction wear. The main features of wear are: dynamic percussive loads, intensive abrasive wear caused by erosion and corrosion. Materials with high wear resistance usually have low ability for plastic deformation resulting from high hardness and brittleness. Moreover, differences in dimension changes caused by external loads and temperature increase tendency for fracture of brittle, wear resistant layers. Bimetallic castings are usually prepared from working part connected in diffusion process with plastic substrate which provides carrying abilities. Differences in thermal expansion of substrate and working alloys complicate proper casting manufacturing. Unfavorable phenomena cumulate at alloys interface. As an example of such technological problems working organs of water dredger can be given. Applied so far technology for connecting steel or cast steel plates with cast iron layer enabled yielding castings with good weldability and machinablity of the substrate material. But this technology requires heating of the substrate by flowing liquid cast iron what decreases output to 50% and clearly decreases massiveness and stiffness of the substrate. Application of cast steel skeletons poured with liquid cast iron (for example with chromium addition) can improve casting properties and eliminate other flaws. Increase of contact surface between working alloy and the substrate can be favorable for mechanical properties improvement of the final casting, which from properties point of view would be close to composite material.

2. Material and technological conception

In presented work some assumptions were made, agreeable with thesis that improvement of working part fracture resistance could be obtained by application of spatial bimetallic castings. During the studies a skeleton casting was manufactured from L25SHMN cast steel (substrate), poured in the next step with

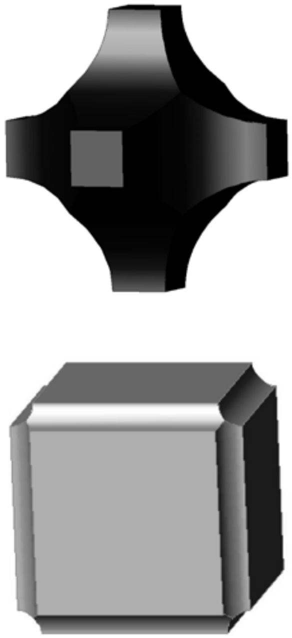
ZlCr15NiMo cast iron (working part alloy). In fig. 1 a geometry of skeleton casting was shown. In fig. 2 geometry of skeleton cells was shown for extreme cases of technological importance with different proportion of connector radius r and constant dimension of cube cell a. Connector radius was assumed as follows: r = 0,4·a and r = 0,1·a. Selection of characteristic dimensions of skeleton casting depends on mould cavity pouring conditions, solidification and cooling of the casting and on difference in thermal expansion of employed alloys, as well as on deformation caused by dynamic loads. Shape of the bimetallic casting solid resulted from working part shape. In conducted studies the simplest shape was taken into account, the rectangular prism. In fig. 3 assumed casting shape and cell dimensions were shown.



a)

b)

Fig. 1 Skeleton casting geometry: a) 8 cells with circular connectors b) node shape, in which connectors meet



a)

b)

Fig. 2. Extreme cases of internal cell shapes for different ratio of connector radius r and constant cube cell dimension a: a) r = 0,4·a, b) r = 0,1·a

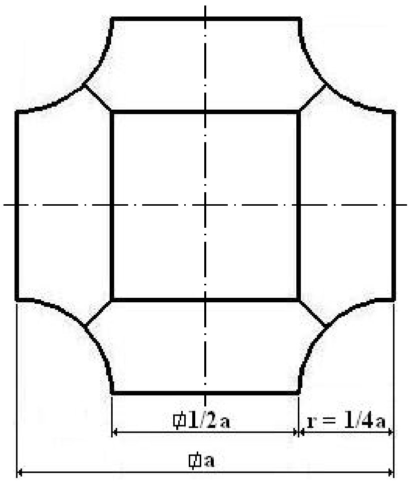


Fig. 3. Proportion of skeleton cell dimensions assumed for preparation of cast steel skeleton (substrate)

For shown in fig. 3 proportion ($r = \frac{1}{4}a$) volumetric content of blank space was equal to 59%. Blank space volume to metal volume ratio equals to:

$$\frac{V_p}{V_m} \approx 1{,}43 \qquad [1/1] \tag{1}$$

Blank space volume:

$$V_p = a^3 \cdot \left(1 - \frac{21 \cdot \pi}{160}\right) \cdot n \qquad [mm^3] \tag{2}$$

$$V_p = r^3 \cdot (64 - 8{,}4 \cdot \pi) \cdot n \qquad [mm^3] \tag{3}$$

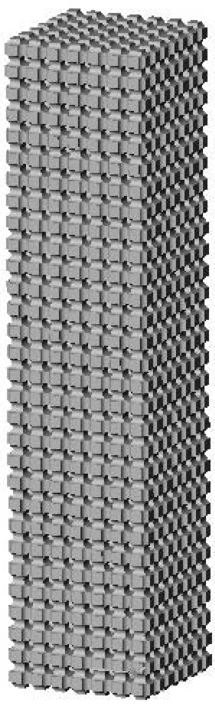
Alloy volume:

$$V_m = \frac{21}{160} \cdot \pi \cdot a^3 \cdot n \qquad [mm^3] \tag{4}$$

$$V_m = 8{,}4 \cdot \pi \cdot r^3 \cdot n \qquad [mm^3] \tag{5}$$

where:
V_m – metal volume in the casting; V_p – blank space volume in the casting; a – cube cell dimension; r – connector radius; n – cell number in the casting.

In prepared experimental castings cell dimension was assumed a=10 [mm] and connector radius r=2,5 [mm]. Casting dimensions was, as follows: 70x70x30 [mm]. In fig. 4 geometry of the cores applied for skeleton castings manufacturing was shown.



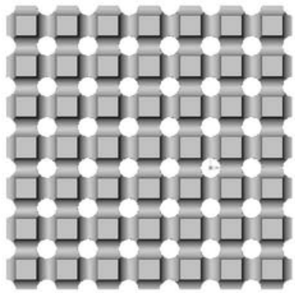


Fig. 4. Geometry of the cores for skeleton castings manufacturing (casting negative)

Additional aim of the studies was to optimize the design methodology for gating and feeding systems of the skeleton castings, which constituted an important issue for proper casting manufacturing

3. Results

In fig. 5 experimental castings were shown, which were then employed for bimetallic castings preparation.

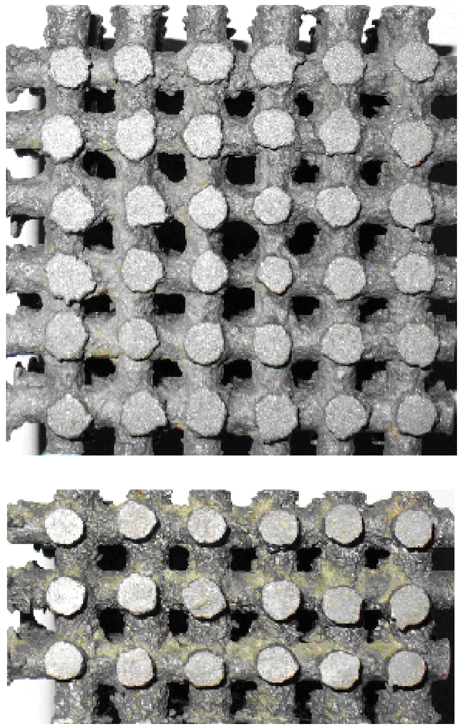


Fig. 5 Geometry of experimental skeleton castings made from cast steel

Before pouring liquid cast iron into the skeleton its surface was suitably prepared. The main aim of this treatment was to enable better wetting of the skeleton by liquid cast iron. The treatment consisted of removing the core sand and chemical activation of skeleton surface with use of aqueous solutions of flux-like-acting substances. After removing all the water from the skeleton surface, it was used as a pre-form (insert) and put inside the mould cavity poured with cast iron in the next step. Experimental castings manufactured during the studies enabled formulation of preliminary rules of technological parameters selection such as: thermo-physical properties of core and mould sands, pouring temperature as well as superficial phenomena description at alloys interface. These phenomena are analogical to phenomena occurring at metal matrix – reinforcing particle interface in metal matrix composites. Characteristic features of composite transition zone are concentration difference, mainly carbon concentration, but also differences in other elements concentration, time of contact in function of temperature, local elementary thermal capacities and conductivities in temperature range of connection creation.

During cast iron crystallization in cast steel skeleton neighborhood two effects of cooling can be observed. Cooling influence of the skeleton can be observed in macroscale of the casting (fig. 6) and in microscale at the interface (fig. 7).

In fig. 6 difference in structure of the riser head used for feeding of the skeleton region were shown. Feeder region was assumed as a monolithic cat iron casting. In shown micrographs it can be seen that dendrite cells decreased and carbide eutectic dispersion increased. Chromium carbides located at dendrite arms surface and in arm spaces. Boundary lines put on structure image showed region of radical change in alloy structure. In fig. 7. the alloys interface and transition zone typical for composite castings was shown.

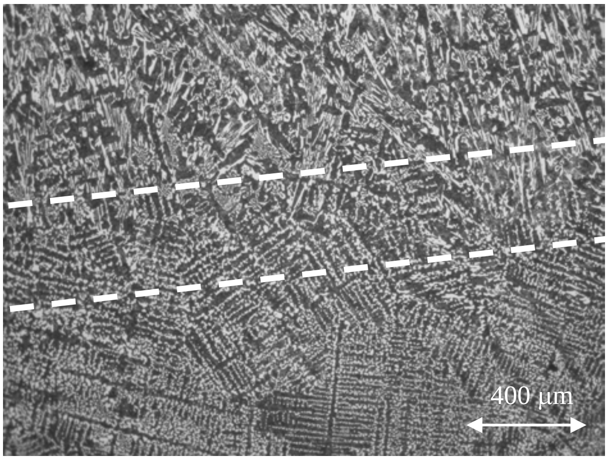
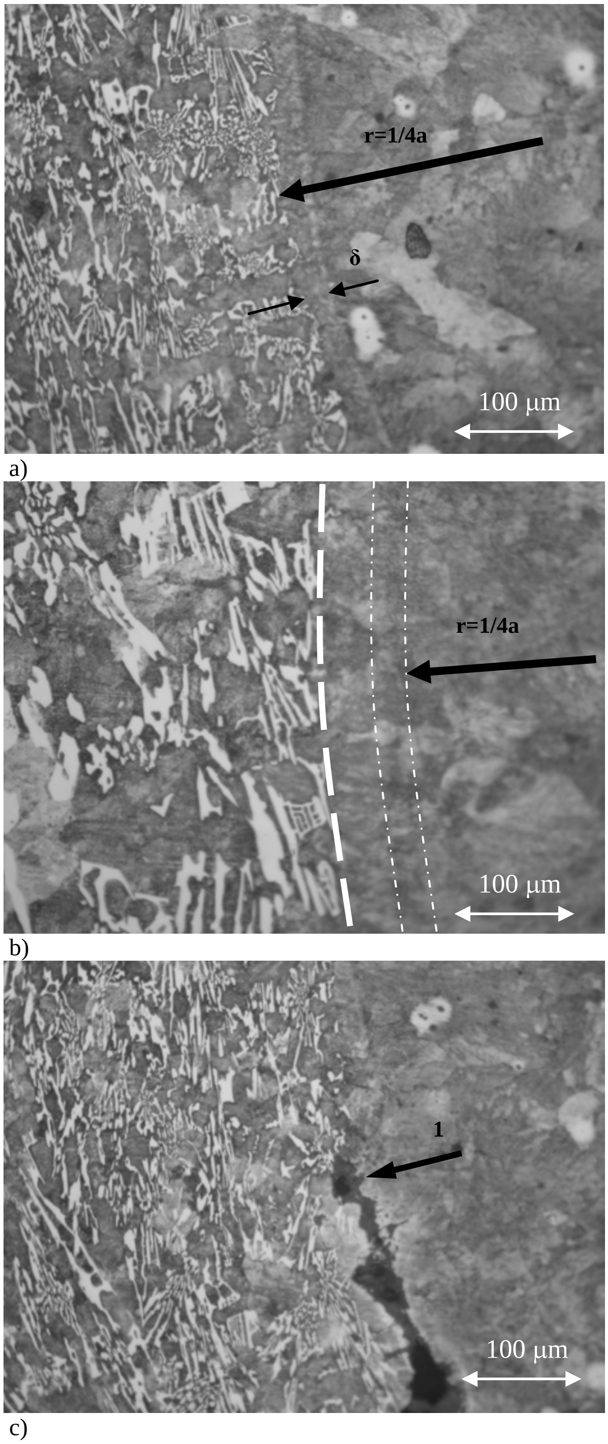
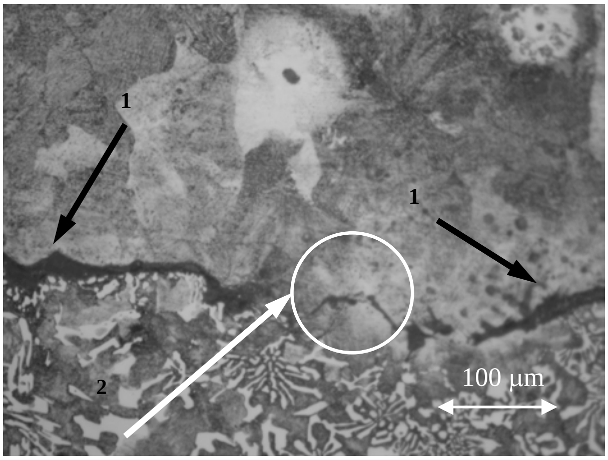


Fig. 6. Micrograph of cast iron structure showing structure refinement caused by heat flow kinetics in macroscale of bimetallic casting. Lines show boundary of transition between regions with different structure





d)

Fig. 7. Micrographs of transition zone between cast steel skeleton and cast iron; a) and b) examples of proper wetting with characteristic diffusion zone; c) and d) structural discontinuity regions resulting from incomplete wetting, d) micro-fracture caused by stress accumulation on notch resulting from incomplete wetting

Micrographs from fig. 7 a) and b) show proper transition zone at the interface. Size of diffusion zone δ delimitating characteristic structure was indicated in fig. 7 a) and is equal to 50 μm. Alloys structure differs from typical structure of these alloys in monolith castings. Differences concerns mainly dispersion of structural components and quantity of nonmetallic inclusions. In micrographs 7 c) and d) structural flaws connected with insufficient wetting were shown. Regions indicated as „1" show typical for composites structural discontinuities, probably caused by surface impurities, for example oxides. In region indicated with „2" a micro-fracture can be observed, probably caused by shrinkage. Near this region one can see fragment with retained continuity of connection. Secondary discontinuity could occur during stroke decrease of volume connected with liquid-to-solid transition. At the solidification temperature or during diffusion of, for example carbon to cast steel skeleton, the cohesion energy of a crystal was smaller than the adhesion energy of the connection. This caused local accumulation of stresses on notch caused by incomplete wetting.

4. Summary

Observed phenomena of transition zone, diffusion of mass and heat, differences in structure in respect to typical castings require further studies. Obtained results will be used for technological parameters optimization for bimetallic castings manufacturing. Conducted studies enabled indication and fundamental characterization of basic factors and range of its variation. Assumed material and technological conception was confirmed. Final verification will be obtained after tribological studies of obtained skeleton castings.

5. Conclusions

Conducted studies confirmed possibility of cast steel skeletons preparation and its employment for manufacturing of bimetallic castings having composite features.
Selection of proper skeleton geometry depends on specific needs connected with castings technology and exploitation.
Proper interface and transition zone between alloys selected for bimetallic castings manufacturing requires modification of superficial phenomena with use of physical and/or chemical factors.
For optimization of casting mechanical properties control of transition zone phases type and morphology is needed.
Proper bimetallic castings can be obtained only in cases of individually selected materials for cores and moulds and special feeding systems.

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