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Quality of the joint between cast steel and cast iron in bimetallic castings

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Abstract

The paper presents conception and production method of skeleton composite castings with use of cast steel G35CrSiMnMoNi skeleton casting and chromium cast iron EN-GJN-XCr15 filling. Working elements in winning machines and devices, which work in intensive aberasive wear i.e. liner of exhausters, percussive and ram hammers, are destination of bimetallic castings. Skeleton geometry was based on three-dimensional symmetrical 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. In range of studies were casted cast steel skeletons with chromium cast iron filling and based on metallographic research on light and scanning electron microscope was made quality assessment of joint in bimetallic castings. Moreover in range of studies was used microanalysis of chemical composition in transition zone of cast steel-cast iron joint.

Keywords: Composites; Skeleton casting; Bimetal; Cast steel; Cast iron

1. Introduction

In last years increase of demand of castings, which have high hardness and aberasive wear resistance with simultaneous high plastic properties, and so in roughly joint simultaneously properties of cast iron and cast steel [1÷4]. This solution lead to bimetallic casting in which part of cast steel is welded and worked mechanical with keep of high aberasive wear resistance of cast iron part. Moreover mechanical damages, which result from working conditions of bimetallic castings (application as working organ of mining machines, which works in conditions of intensive aberasive wear), do not cause a failure in whole volume because cast iron part is joint by diffusion with cast steel base.

Applied so far technology for connecting steel or cast steel plates with cast iron layer requires heating of the substrate by flowing liquid cast iron, what decreases output to 50% and clearly decreases massiveness and stiffness of the substrate [5 and 6]. Application of cast steel skeletons poured with liquid cast iron can improve casting properties and eliminate flaws of so far methods and makes possible [7 and 8]:

– joining of alloys in any place (core reproducing skeleton can be placed in any place of mould),
– carrying out of several joints in one casting,
– repeatedly increase of contact surface between cast iron and cast steel and additionally can possess any external shape, which meet a geometry of casting with diversified structure of skeleton.

2. Range of studies

The main aim of studies was to assess a quality of joint between cast steel and cast iron in bimetallic casting. Range of studies includes successively:

– pouring of cast steel G35CrSiMnMoNi skeletons with use of cores gometry as was shown on Figure 1,

- cast steel skeletons was poured with liquid chromium cast iron EN-GJN-XCr15,
- verefication of type and quality of joint in bimetallic casting with use of metallographic research on light microscope Nikon EPIPHOT-TME and scanning electron microscope Philips XL30 with microspectrometer EDAX to determination of chemical composition in transition zone between cast steel and cast iron.

Fig.1. Geometry of the cores for skeleton casting manufacturing (casting negative)

The key-meaning for quality of cast steel-cast iron joint have geometry parameters of skeleton. Geometry regularity of skeleton makes possible design of its mechanical properties and technological reproduction and pournig, also mutual thermal influence between skeleton and cast iron filling.

In Figure 2 geometry of skeleton cells was shown 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.

To advantages of first considered solution i.e. *r* = 0,4·a belong:

- large contact surface between cast steel and cast iron,
- easiness of manufacturing of skeleton casting,

however to disadvantage belong:

- difficulty at filling of skeleton by cast iron,
- proportions of heat capacity are unfavourable for joint by diffusion (skeleton can be unsatisfactory warmed).

Whereas to advantages of second considered solution i.e. *r* = 0,4·a belong:

- easiness of skeleton filling by cast iron,
- proportions of heat capacity are favourable for joint by diffusion,

however to disadvantage belong:

- small contact surface between cast steel and cast iron,
- technological difficulty at pouring of skeleton,

a)

b)

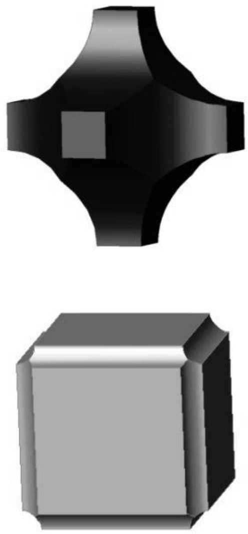


Fig.2. Extreme cases of internal cell shapes for different ratio of connector radius (r) and constant cube cell dimension (a): a) *r* = 0,4·a, b) *r* = 0,1·a

On the basis of introduced datas it was affirmed, that only proper technological compromise of geometrical features (a) and (r) permits on correct pouring of cast steel skeleton and next its filling by cast iron with obtaining of permanent diffusion joint.

To investigations following proportion was accepted:

$$r = \frac{1}{4}a \quad [mm] \qquad (1)$$

On the basis of dependance (1) in prepared experimental castings cell dimension was assumed a = 10 mm and connector radius r = 2,5 mm. Volumetric content of blank space was equal 59% and blank space volume (V_P) to metal volume (V_{SZ}) ratio equals 1,43.

3. Results and analysis

For introduced brief foredesign were made experimental castings of cast steel skeletons (Fig.3). Full reproducing of skeleton connectors was got, which next were cut on parts. Before pouring liquid chromium cast iron into the skeleton its surface was suitably prepared with use of borax.

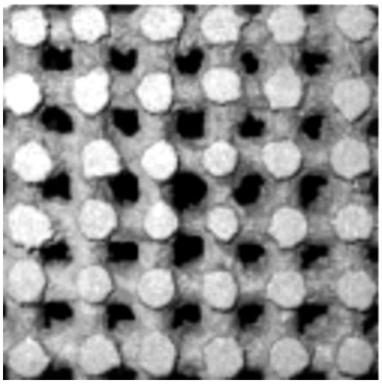


Fig.3. View of experimental skeleton casting made from cast steel G35CrSiMnMoNi

On the basis of metallographic research it was affirmed, that cast steel skeleton is a chill, which creating size reduction in chromium cast iron EN-GJN-XCr15 structure, near joint area. Size reduction of chromium cast iron contain decrease of dimensions of dendritc cells and increase of dispersion of carbide eutectic (ferrite + M_7C_3) (Fig.4). Presence and width of diffusion zone (δ) is important for quality of cast steel - cast iron joint.

Next proof on diffusion zone existence are results of microanalysis of chemical composition in transition zone (Fig.5 and 6). Mainly difference in Cr (which is the main alloy addition) and Fe concentration is observed. Difference in Fe concentration perhaps indirectly testify about diffusion of C, which is very intensive. It result from small atomic diameter of carbon. However determine of difference of C concentration, which result from mechanism of interstitial diffusion in transition zone, is difficult from point of view of research methodology.

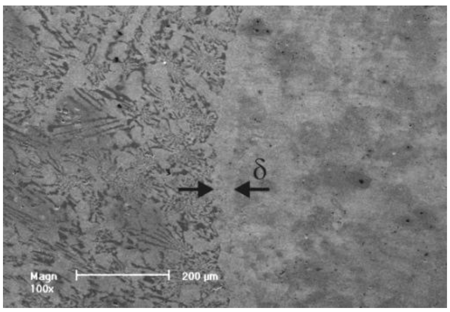


Fig.4. Structure of transition zone between cast steel G35CrSiMnMoNi and cast iron EN-GJN-XCr15 with evident diffusion zone (δ) with width about 50µm

a) b) c) d)

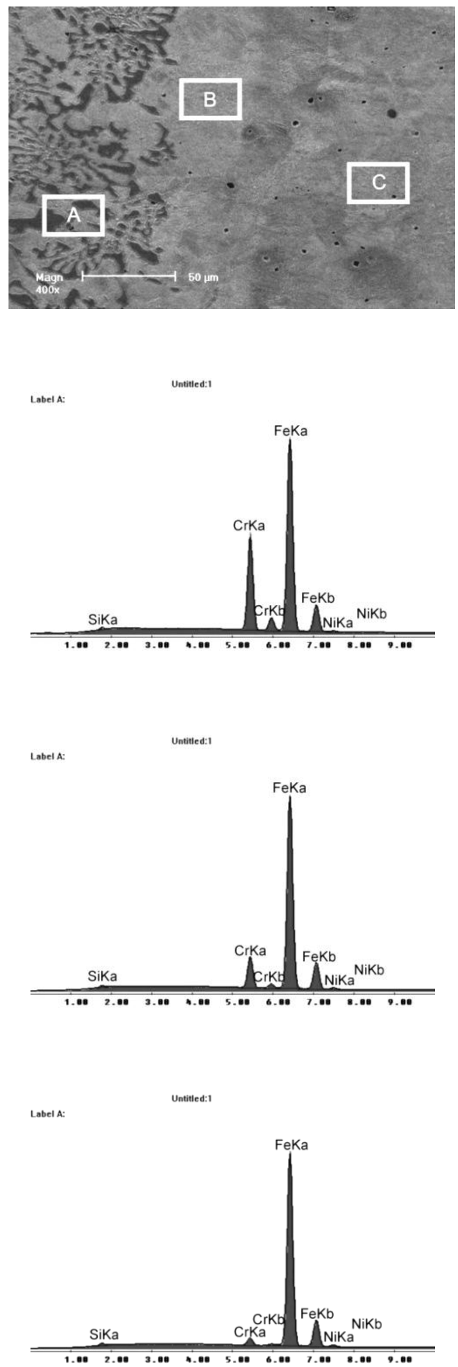
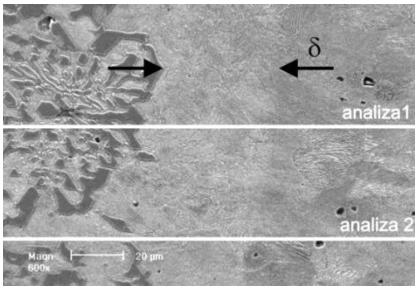
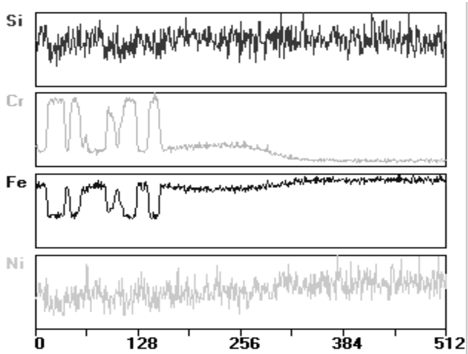


Fig.5. Distribution of Si, Cr, Fe and Ni in transition zone between cast steel G35CrSiMnMoNi and cast iron EN-GJN-XCr15 in bimetallic casting:
a) structure of research area,
b) pointwise microanalysis of chemical composition in point „A”,
c) pointwise microanalysis of chemical composition in point „B”,
d) pointwise microanalysis of chemical composition in point „C”.

a)



b)



c)

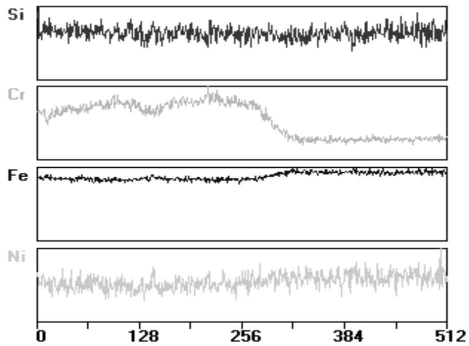


Fig.6. Distribution of Si, Cr, Fe and Ni in transition zone between cast steel G35CrSiMnMoNi and cast iron EN-GJN-XCr15 in bimetallic casting: a) structure of research area, b) linear microanalysis of chemical composition on line„analiza 1", c) linear microanalysis of chemical composition on line„analiza 2"

Moreover in diffusion zone occur favourable mild change of elements concentration for example Cr from suitable for chromium cast iron EN-GJN-XCr15 to suitable for cast steel G35CrSiMnMoNi. It probably provides to smooth transition of mechanical properties from cast steel to cast iron.

4. Conclusions

Based on conducted studies following conclusions have been formulated:

1. Geometrical features have key-meaning for quality of skeleton castings and their selection sholud result from individual useful and technological needs.
2. On quality of joint between cast steel and cast iron influences modification of superficial phenomena with use of physical factors i.e. borax, sand-blast cleaning or soaking.
3. For optimization of casting mechanical properties control of transition zone and diffusion zone morphology is needed. Width of diffusion zone provides to smooth transition of mechanical properties from cast steel to cast iron.
4. Presented technology requires of use of individually selected materials for cores and moulds and special feeding systems.

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