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The Effect of a Thin-Wall Casting Mould Cavity Filling Conditions on the Casting Surface Quality

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Abstract

The paper presents results of metallographic examination of faults occurring in the course of founding thin-walled cast-iron castings in furan resin sand molds. A non-conformance of the scab type was Observed on surface of the casting as well as sand buckles and cold shots. Studied the chemical composition by means of a scanning electron microscope in a region of casting defects: microanalysis point and microanalysis surface. Around the observed defects discloses high concentration of oxides of iron, manganese and silicon. A computer simulation of the casting process has been carried out with the objective to establish the cause of occurrence of cold shots on casting surface. The simulation was carried out with the use of NovaFlow & Solid program. We analyzed the flowing metal in the mold cavity. The main reason for the occurrence of casting defects on the surface of the casting was gating system, which caused turbulent flow of metal with a distinctive splash stream of liquid alloy.

Keywords: Thin-wall casting, Grey cast iron, Cold shots, Simulation

1. Introduction

The progress in the founding technology contributes to widening the scope of application for well-known casting materials in different branches of modern industry. This becomes possible thanks to new technological processes of alloying, casting, and thermal treatment. New technologies allow e.g. to replace castings of aluminium alloys with light-section cast-iron castings. This way, reduction of manufacturing costs and increase of casting strength is obtained at the same time [1–3].

Manufacturing of thin-walled castings carries also the risk of occurrence of casting defects typical for this type of products. Light section castings require the use of higher mould pouring temperatures which, in combination with the liquid metal stream thrust force, leads to erosion of the moulding sand and the related occurrence of dirt spots, sand buckles, scabs, etc. Measures preventing presence of non-conformances in thin sections of castings undesirable from the point of view of the customer requirements include, by correct selection of binding materials [4], special mould coatings, controlled compaction of moulding sands, and lowering the pour point [5-10]. Improving the mechanical properties is obtained by modifying the liquid alloy [11-12].

2. The test material

The subject of the presented study was a thin-walled casting made of cast iron with flake graphite and ferritic-pearlitic matrix, containing 3.3% C, 2.8% Si, and 0.5% Mn. The temperature at which the mould was poured with liquid metal (the pour point) was 1340°C. Microstructure of the cast alloy is shown in Fig. 1.

Fig. 1. An example microstructure of thin-wall casting. Note rosette pattern of flake graphite distribution and ferritic-pearlitic matrix. Etched with Nital (×100 magnification)

2.1. Metallographic examination

Examination of transverse sections of thin-walled casting was carried out with the use of electron scanning microscope VEGA3 (TESCAN). From a 8-mm thick casting wall, specimens for metallographic examination were taken. Fig. 2 shows example irregularities found on the casting's surface. A non-conformance of the scab type was observed on surface of the casting (Fig. 2a) as well as sand buckles and cold shots (Fig. 2b, c). Fig. 3 shows example views of transverse sections of a casting wall in the region of occurrence of casting non-conformances, where cold shots with a gas cavity can be seen adjacent to the casting surface, with a characteristic halo. On a selected cold shot, microanalysis of chemistry was performed by means of INCA x-act adapter for chemistry microanalysis (Oxford Instruments). Results of the analysis are presented in Fig. 4. Microanalysis of the surface (mapping) of the cold shot area (Fig. 4) revealed presence of a characteristic layer. In the material around the cold shot, eminent concentration of oxygen, silicon, and manganese was observed which is the evidence that the feature consists of oxides.

2.2. Simulation of flow and solidification

Presence of cold shots on casting wall surfaces has an adverse impact on aesthetic qualities of a casting. To determine the cause of occurrence of such undesired features, a computer simulation of the mould cavity filling and casting solidification was performed. The simulation was carried out with the use of NovaFlow&Solid program. It was assumed that the mould was made of furan resin sand. The wedge-shaped gating system was modelled for pouring from two ladles with an air venting system. The mould pouring temperature was assumed to be at the level of 1340°C. Results of simulation of the process of pouring the thin-wall casting's mould cavity are presented in Fig. 5.

The obtained results indicate that the flow of liquid metal from the main gate to the mould cavity is of turbulent nature with a characteristic spattering of the liquid metal stream (Fig. 5a, b). One can see isolated drops fall down deep into the mould cavity (Fig. 5b, c). The drops get cooled down, stuck to the mould surface, are then covered with liquid metal (Fig. 5c, d) with temperature lower than the pour point by about 150–200°C (dark-grey areas), and become "frozen". Cooler areas of the filled mould cavity are visible as early as after filling the mould cavity by 30% (Fig. 5c) and continue solidification increasing the area (Fig. 5d, e). From the beginning of pouring (Fig. 5b–e) and in the course of solidification, one can see areas (strips) running from lower to upper edge of the mould (Fig. 5f) where the metal has significantly lower temperature. Areas of these strips coincide with the areas of the most frequent occurrence of non-conformances (cold shots, scabs, sand buckles).

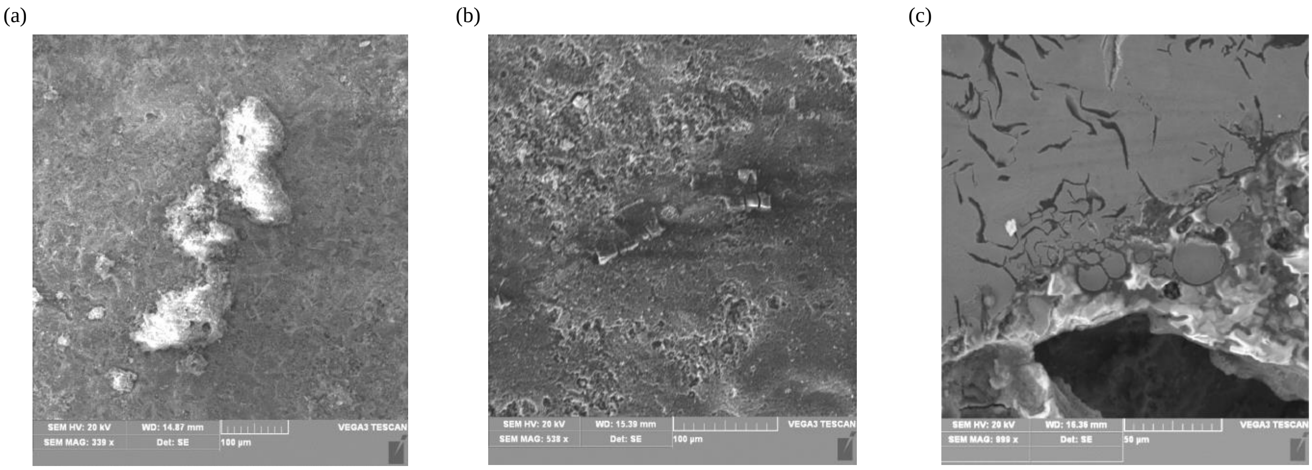

Fig. 2. An example view of a thin-wall casting non-conformity: (a), (b) on wall surface; (c) a view in transverse section — a cluster of cold shots at the casting surface

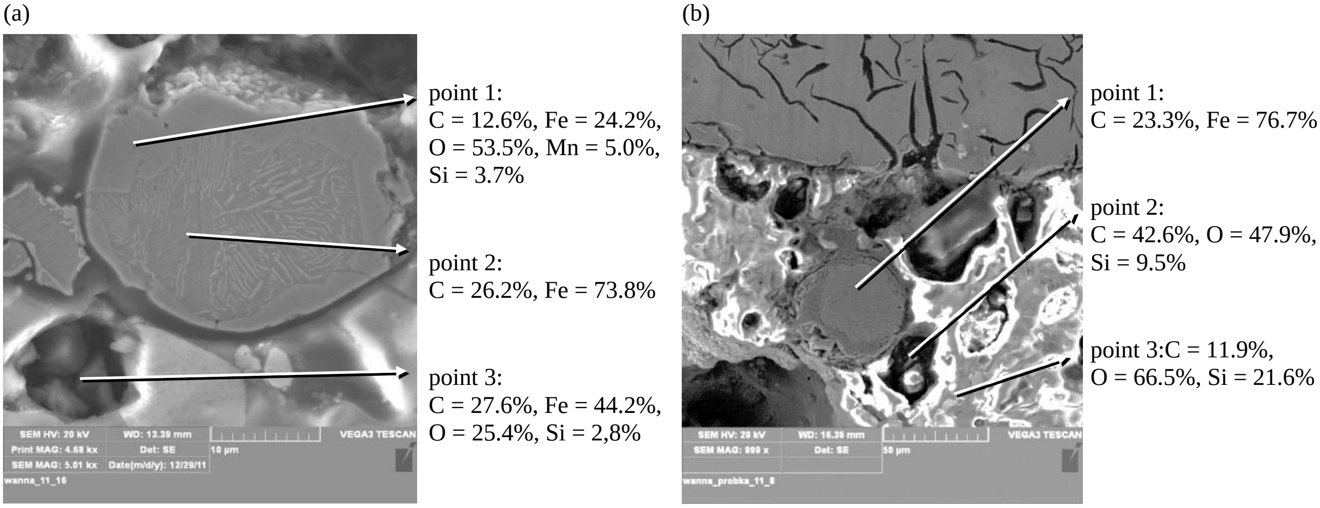

Fig. 3. Cold shots and oxides visible in the transverse section

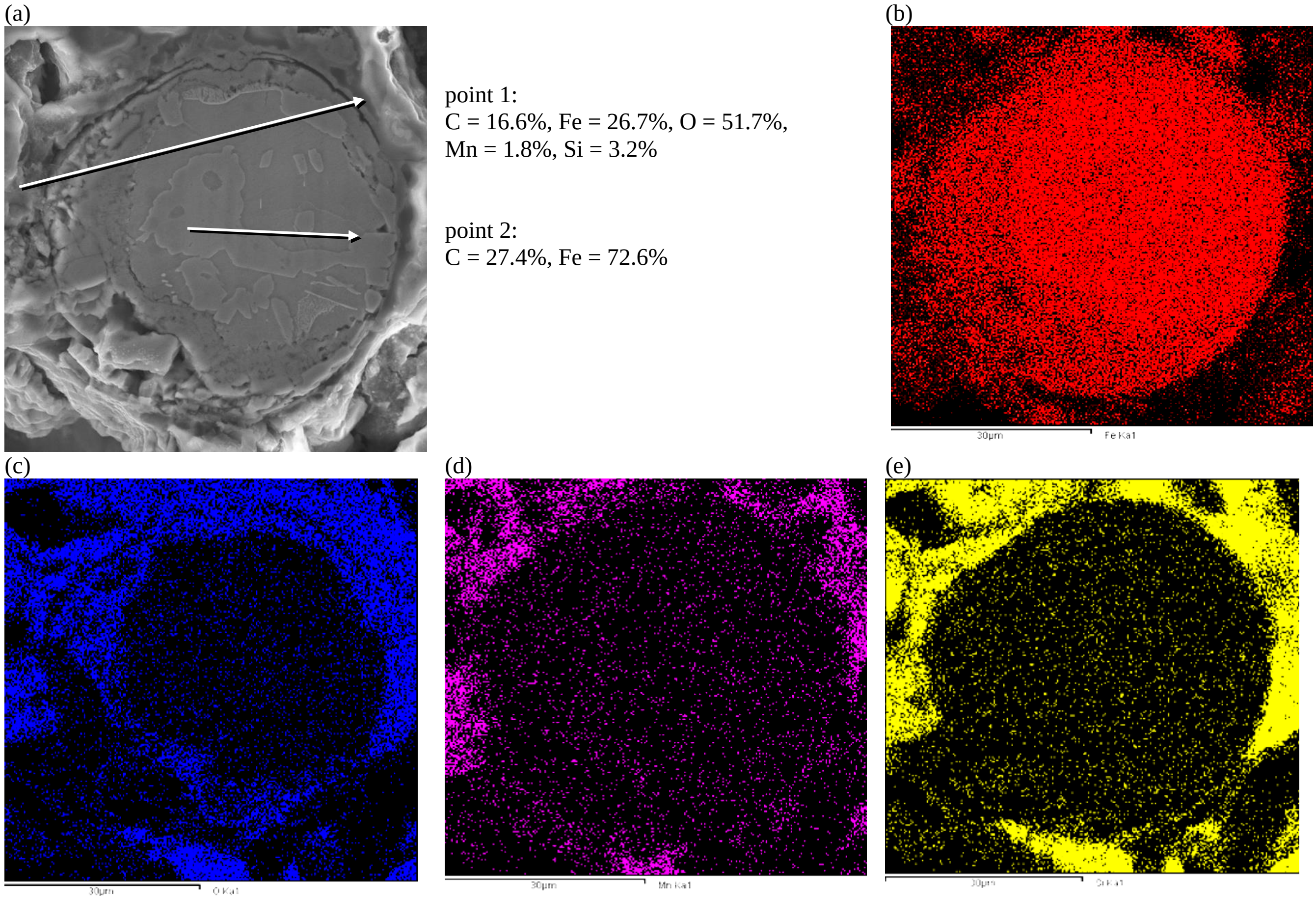

Fig. 4. Microanalysis: (a) point-like and (b)–(e) superficial

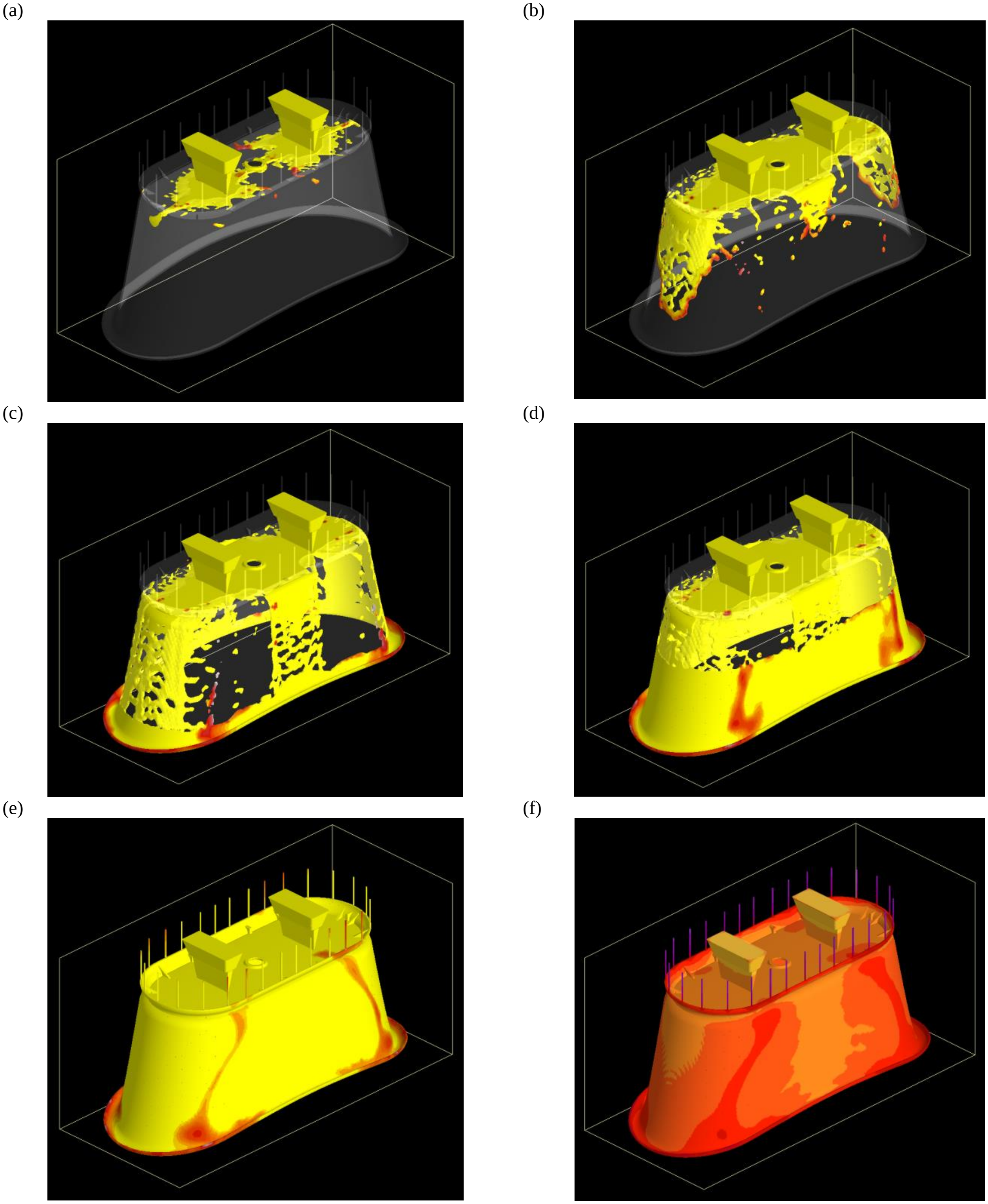

Fig. 5. Simulation of filling a thin-wall casting mould when filled in: (a) 15%; (b) 30%; (c) 50%; (d) 70%; (e) 100%; and (f) in the course of casting solidification

3. Analysis of results

Metallographic examination of sections taken from thin-wall castings of cast-iron with flake graphite revealed presence of casting non-conformances in the form of cold shots, gas cavities, and scabs. Cold shots are covered with a layer of oxides and this prevented them from fusing with the liquid metal. Once a cold shot is surrounded with liquid metal, the reduction reaction occurs as a result of with carbon oxide is generated in the form of gas cavities.

Simulation of the mould filling and casting solidification process with the design of the gating system used at the time of the experiment revealed that conditions for development of cold shots occurred as early as in the first phase of filling the mould cavity with liquid metal.

The employed gating system favoured breaking the liquid metal stream and creation of isolated large drops which were subject to oxidation when falling down into the mould cavity and were then hydrostatically lifted by the liquid raising in the cavity towards mould wall surfaces. As a result, clusters of cold shots were created on the casting surface which had an adverse impact on aesthetic qualities of the casting.

4. Conclusions

The above-described preliminary study on quality of a thin-walled casting of flake graphite cast iron allows to conclude that:

- on casting wall surfaces, one can observe occurrence of non-conformances of such types as cold shots, gas cavities, or scabs.
- the main cause of these non-conformances was an incorrectly designed gating system.
- the observed cold shots develop in the beginning of the mould cavity filling process, are then surrounded with the layer of oxides, stick to the mould surface, and remain unmelted by the inflowing liquid metal.

To reduce or eliminate non-conformances occurring on surfaces of thin-wall castings of cast iron with flake graphite, it would be necessary to redesign the gating system.

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