Tests and studies on improved innovativeness of sand reclamation units

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Abstract
The aim of the present study was raising the innovativeness of sand reclamation units through application of a new material - austempered ductile iron (ADI) - for elements exposed to abrasion wear and impacts. Methods used for casting of ADI blades for disk-type reclamation units were described along with the results of tests and measurements of the obtained hardness, strength and microstructure. The ready ADI castings of blades were next subjected to performance tests to compare them with the conventionally made cast steel blades operating under industrial conditions. The obtained results of the tests confirmed high properties and numerous benefits offered by ADI respective of cast steel used as a material for elements of sand reclamation units.

Keywords: Innovative casting materials and technologies, Installations for mechanical sand reclamation, Abrasion wear resistant alloys, Ductile iron, Heat treatment, ADI

1. Introduction
For a long time, in installations for mechanical reclamation of sand from the waste foundry moulding and core mixtures, the main operating elements exposed to abrasion wear and/or impacts have been made from alloyed cast steels \cite{1,3,7,8}. Recently, however, a very rapid development in production of ADI castings has been observed. This material ensures improved casting performance at lower production costs. The factors that enable cost-effective production include, among others, excellent castability and shape reproduction, reduced cost of casting machining and heat treatment, and reduced energy consumption during production. In many fields of its application, ADI is superior to steel forgings, welded fabrications, and elements made from carburised steel. Besides very high mechanical properties, ADI also offers very high abrasion wear resistance, which increases spontaneously during operation. Compared with steel, ADI is also characterised by 10\% lower density \cite{1}. In attempts at improving the innovativeness of sand reclamation units, and ensuring cost-effective production and longer performance life of parts exposed to abrasion wear with reduced costs of maintenance, the Foundry Research Institute in Krakow in cooperation with Metalodlew S.A., Krakow, have made the studies and carried out the tests on the performance life of ADI blades to replace the blades made from alloyed cast steel and used at present in RTL 10 disk-type reclamation units.

2. Manufacture and testing of ADI cast blades
In RTL 10 disk-type reclamation units, the main elements assigned for crushing the lumps of moulding sand and removal through attrition of the used binder from the sand grains are the blades and side plates, up to now made from the alloyed cast steel (e.g., L700H2GNM). The blades in disk-type reclamation units are mounted on rotor disks. During the process of reclamation, the crushed waste sand moves to the centre of the rotating disk, which bears the four mounted blades. The rotating blades are scraping the sand falling onto the disk and throw it onto the side plates. The sand hits the rotating blades and is moved by them, to hit next the surface of the side plates. During this process, the blades are exposed to mechanical impacts caused by the tramp metal
that is left in sand. Figure 1 shows a photograph of the used blade mounted on a disk operating in the reclamation unit.

Fig. 1. The used blade operating in a disk-type reclamation unit

Within the R&D program of Foundry Research Institute [1] tests and studies were made to explore the possibility of using ADI cast blades in operation of a RTL 10A disk-type reclamation unit.

2.1. Development of ductile iron chemical composition and casting of blades

Final chemical composition of ductile iron for cast blades (i.e. the composition after the spheroidising treatment and inoculation) was as follows: C - 3.6 - 3.8 %, Si – 2.2 – 2.4 %, Mn – 0.6 – 0.8 %, Mg – 0.04 – 0.06 %, Cu – 0.6 – 0.8 %, Cr – 0.6 – 0.8 %, Mo – 0.2 – 0.3 %

The castings of test blades were made and machined at METALODLEW S.A. Krakow. An example of casting made from the ductile iron of composition as stated above is given in Figure 2. In parallel with castings made from ductile iron, Metalodlew has cast a batch of blades in L700H2GNM steel to serve as reference sample for comparative purposes.

Fig. 2 A blade cast in ductile iron

2.2. Heat treatment of ADI blades

Ductile iron castings were austempered at the Foundry Research Institute in Department of Ferrous Alloys, using a prototype LT ADI-350/1000 technological line. The line includes the following elements: chamber furnace, type B-4-ENL, salt bath, type WS-4/450EL, device for washing and drying of castings, type WPSD-EL, charging unit, type LW-4E, charging-discharging post.

For austempering of cast blades, the following heating and cooling parameters were chosen:
1. heating of castings in furnace from ambient temperature to the temperature of austenitisation at 950°C for 5.5 h,
2. holding at the above mentioned temperature for 2 h,
3. austempering of castings in salt bath at 280°C for 2 h,
4. rinsing in hot water and drying.

Figure 3 shows the photograph of an ADI blade after heat treatment.

Fig. 3 Casting of blade made from austempered ductile iron ADI

2.3. Testing and measurement of mechanical properties, hardness and microstructure of blades cast in ADI

Hardness measurements and mechanical tests made on pilot castings gave the following values of the parameters:
1. as-cast condition - 40 HRC,
2. austempered 48 HRC,
3. tensile strength about 1572 MPa (PN-93/H-04357)

Microstructure examinations made on specimens of cast blades before and after austempering, designated as „0” and „1”, respectively, were carried out at the Complex of Research Laboratories of Foundry Research Institute.

Comparative method of research

Typical data:
- The examinations of graphite microstructure were carried out by comparison of the microstructure in unetched specimens with reference sample described in PN-EN ISO 945 1999.
The examinations of metallic matrix microstructure were carried out by comparison of the microstructure in etched specimen with reference sample described in PN – 75/H-04661.

Structure was examined and photographed under a NEOPHOT 32 metallographic microscope, using polished sections. The sections were etched in Mi1Fe reagent according to PN-61/H-04503.

The results of the examinations are compiled in Table 1; the images of microstructures are shown in Figures 4, 5, 6 and 7. The examinations have proved that after the austempering treatment castings have acquired the structure typical of ADI.

Table 1. The results of microstructural examinations

<table>
<thead>
<tr>
<th>No.</th>
<th>Sample designation</th>
<th>Microstructure of graphite acc. to PN-EN ISO 945</th>
<th>Microstructure of metallic matrix acc. to PN-75/H-04661</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>VA6</td>
<td>Pf1.P,C40,Cw6000</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>VA6</td>
<td>Ausferrite C40,Cw6000</td>
</tr>
</tbody>
</table>

Fig. 4 Specimen no. 0; 100x

Fig. 5 Specimen no 1; 100x; HNO3 etching

Fig. 6 Specimen no 0; 100x; HNO3 etching

Fig. 7 Specimen no 1; 100x; HNO3 etching

2.4. Evaluation of wear rate in ADI cast blades operating under industrial conditions

Under these studies, 50 pieces of blades for RTL 10A disk-type reclamation unit were cast and austempered to get an ADI material. In November 2006, these blades were sent for comparative performance tests to METALODLEW S.A, where they were assembled in a RTL 10A disk-type reclamation unit operating in a reclamation line for the waste self-setting sands with sodium silicate and alkaline resins. In this reclamation unit were alternatively assembled the blades cast from ADI (8 pieces) and from the L70H2GNM steel (8 piece). The blades were put in standard operation. Figure 8 shows a photograph of the reclamation disk with alternatively assembled blades made from ADI and L70H2GNM cast steel. The RTL 10A disk-type reclamation unit is an open structure. During tests it is opened once a month and a comparative analysis of the blades wear rate is carried out.

Figures 9 and 10 show successively the photograph of a cast steel blade and ADI blade after two month running (363 h with average reclamation output of 11.9 Mg/h).
A definitely better performance of the ADI blade, compared with the blade cast from L70H2GNM steel, is shown. The blades cast from ADI reveal a more uniform distribution of wear compared with their steel counterparts.

3. Conclusions

By analysis of the obtained results, the following conclusions were formulated:
1. The developed final (i.e. after spheroidising treatment) chemical composition of ductile iron enabled producing cast blades characterised by structure typical of the austempered ductile iron ADI.
2. The blades made from ADI were less prone to the abrasion wear and the distribution of wear was more uniform in them than in the conventional blades cast in L70H2GNM steel.
3. In view of a lower density of ADI, compared with that of steel, castings made in ADI can be designed in a more economic way and as rotating parts are easier in balancing.
4. Studies have shown that ADI offers very good abrasion wear resistance in contact with silica sand; its wider application is expected to improve the innovativeness of installations for the mechanical reclamation of foundry sands.

References