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SELECTION OF PROTECTIVE COATINGS OF MOULDS FOR CASTINGS OF HIGH-MANGANESE CAST STEEL IN DEPENDENCE OF THE APPLIED MOULDING SAND KIND

DOBÓR POWŁOKI OCHRONNEJ NA FORMY DLA ODLEWÓW ZE STALIWA WYSOKOMANGANOWEGO W ZALEŻNOŚCI OD RODZAJU STOSOWANEJ MASY

High-manganese cast steels are characterised by a high abrasion resistance under friction conditions with a simultaneous influence of pressure and impacts. This cast steel is especially suitable for castings of excavator's scoops, track links, streetcars crossovers, parts of crushers and mills for braking up of hard materials [1-4]. In order to obtain high quality castings of high-manganese cast steels in moulds on the high-silica sand matrices it is necessary to apply protective coatings, which prevent a direct contact between metal and matrix (SiO_2). Manganese after being poured into a mould can undergo a partial oxidation forming MnO, which reacts with silica. As a result low-melting manganese silicates are formed, which in a form of a tight layer adhere to the casting surface, significantly increasing a labour input related to cleaning. Three kinds of protective coatings were tested: zirconium, corundum and magnesite. As a base moulding sands on high-silica sand matrices with three kinds of resol resins were applied. The quality of the obtained casting surface was assessed in dependence of the protective coating and resin kind and also in dependence of the metallostatic pressure value.
Keywords: high-manganese cast steel, protective coatings, moulding sand, resins

Staliwo wysokomanganowe odznacza się dużą odpornością na ścieranie w warunkach tarcia z jednoczesnym działaniem nacisku i uderzeń. Staliwo to nadaje się szczególnie na odlewy czerpaków koparek, ogniwa gąsienic traktorów, krzyżownic tramwajowych, części kruszarek i młynów do rozdrabniania twardych materiałów [1-4]. Aby uzyskać wysokiej jakości odlewy ze staliwa wysokomanganowego w masach na osnowie piasku kwarcowego konieczne jest stosowanie powłok ochronnych, które zapobiegają bezpośredniemu kontaktowi metalu z osnową, a konkretnie z SiO_2. Mangan, po zalaniu metalu do formy może ulegać częściowemu utlenieniu tworząc m.in. MnO, który reaguje z krzemionką. W wyniku tworzą się niskotopliwe krzemiany manganu, które szczelną warstwą przylegają do powierzchni odlewu, znacznie zwiększając nakład pracy na oczyszczanie. Przebadano trzy rodzaje powłok ochronnych: cyrkonową, korundową i magnezytową. Jako podłoże stosowano masy na osnowie piasku kwarcowego z trzema rodzajami żywicy rezolowej. Oceniano jakość uzyskiwanej powierzchni odlewu w zależności od rodzaju powłoki ochronnej, rodzaju żywicy oraz wielkości ciśnienia metalostatycznego.

1. Introduction

The problem of the so-called chemical penetration occurs especially clearly at production of castings of high-manganese cast steels in moulding sands on the high-silica matrix, which is of a small fire resistance. This effect is quite small when chromite, zirconite or olivine sands are used as a matrix. After the mould pouring with liquid steel and the casting cooling, some times a certain moulding sand layer is strongly adhering to the casting surface and requires a significant labour input for its removal. In the cross-section of this moulding sand layer quartz grains are seen surrounded by glassy slag-similar substance, which binds them together. The most often it is caused by the chemical penetration effect, being the result of the chemical reaction between MnO and SiO_2, due to which manganese silicates of low melting temperatures are formed (manganese metasilicate $MnSiO_3$, melting point: 1564 K or manganese ortosilicate Mn_2SiO_4, melting point: 1618 K) [5, 6]. Therefore, when analysing reactions occurring on the mould cavity surface after pouring with liquid metal, the attention should be drawn to the character of the mould atmosphere. Generally it can be stated that, neutral or reducing atmospheres limit the penetration and contribute to eliminating of burnings, while the oxidation atmosphere increases this effect. Investigations on selecting the proper protective coatings for moulds and cores at the production of castings from high-manganese cast steels in moulding sands on the high-silica sands matrices – were performed in this work [7].

2. Materials applied for investigations

Three types of protective coatings were recommended for investigations, intended – according to the information of

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producers – for moulds and cores for heavy and very heavy steel castings:

- ► Protective zirconium alcohol coating: Zirconium S – produced by the Production – Trading Enterprise „KRATOS" S.C.
- ► Protective magnesite alcohol coating: VELVACOAT ST 802, produced by ASK CHEMICALS.
- ► Protective corundum alcohol coating: PROTECTA PKK, produced by PRECODLEW.

3. Testing of protective coatings under foundry plant conditions

3.1. Test melts

To assess the effectiveness of the investigated protective coatings the test melts were performed in the Experimental Casting of the Foundry Engineering Faculty, AGH. To this aim 3 experimental moulds were made of moulding sand used in the CEMA – MYSTAL foundry. This sand composition was: high-silica sand Biała Góra – 100 parts by mass, binder GEOPOL – 2.5 parts by mass, hardener SA 73 – 0.38 parts by mass.

The quality assessment of casting surfaces was carried out for 3 moulding sands (with resol phenol-formaldehyde resins) applied in the CEMA – MYSTAL foundry plant, as core sands (from each moulding sand cylindrical specimens were prepared (Ø50×50 mm) of a weight of app. 150 g, compacted by vibrations):

a) Moulding sand 1: quartz sand, resin: Rezolit AM, hardener: Prestal R1/5, (produced by MACHMAT MINERALS),
b) Moulding sand 2: quartz sand, resin: Estrofen, hardener: PR6, (produced by PRECODLEW),
c) Moulding sand 3: quartz sand, resin: Avenol, catalyser 7010 (produced by ASK CHEMICALS).

On three specially prepared plates four kinds of standard test specimens were formed (6 pieces of each) from each tested moulding sand (all together there was 12 combinations in a system: resin – protective coating) (Fig. 1) [8]:

1. specimens without a protective coating,
2. specimens with the zirconium protective coating,
3. specimens with the magnesite protective coating,
4. specimens with the corundum protective coating.

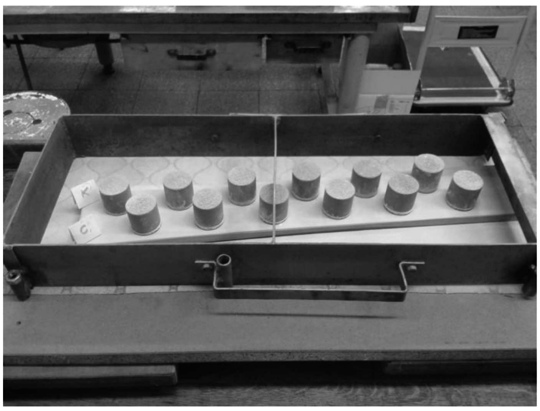


Fig. 1. Arrangement of specimens on the model plate (half of the mould) K – corundum coating, C – zirconium coating

Two layers of a protective coating were deposited. The first layer was deposited by painting (24 hours after making the specimen), then it was burned and the second layer was deposited on it (also by painting) and also burned.

The mould, prepared like that, was poured with high-manganese cast steel of the following composition: C – 1.27%, Si – 0.872%, Mn – 16.28%, P – 0.0123%, S – 0.0774 %, Cr – 1.08%, Ni - 0.495, Mo – 0.507%, V – 0.0668%, W – 0.0101%, Co – 0.0481, Cu – 0.149%, Al – 0.0100%, Ti – 0.00435%, Pb – 0.211%, Mo – 0.00421%, Nb – 0.0164%. A pouring temperature was 1480°C. After casting knocking out the casting surface was sand blasted and its quality assessed. The casting mass, after cleaning, was 10.7 kg.

3.2. Investigations of surface qualities of test castings at an application of various protective coatings

Mainly two factors influence the casting surface quality: chemical reactions between a matrix and alloy components (the so-called chemical penetration) and a metallostatic pressure (the so-called mechanical penetration). To eliminate the chemical penetration influence the protective coatings were applied, however they are effective only up to a certain metallostatic pressure. When the pressure exceeds a certain level the effectiveness of a protective coating can be quite low. Therefore investigations were focused mainly on assessing a metallostatic pressure influence. To this aim the test – in which the plate with a vertical mould joint was vertically poured – was selected [9-11]. The surface state of a rough casting was observed at six different levels of the metallostatic pressure. The tested metallostatic pressure range was from 10 to 70 cm of a metal. Some examples of test castings for moulding sand with the Rezolit resin are shown in Figure 2.

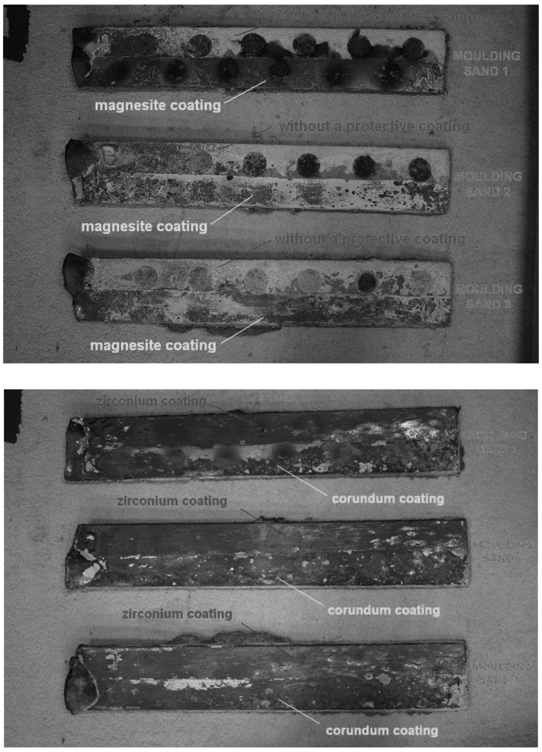


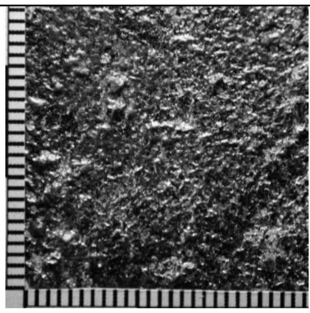
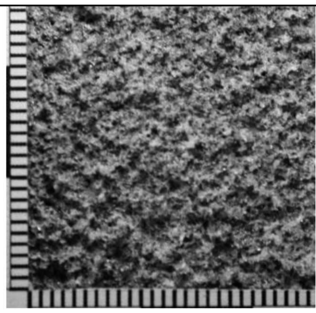
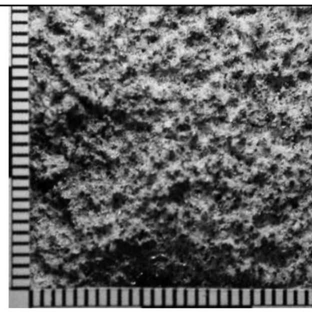
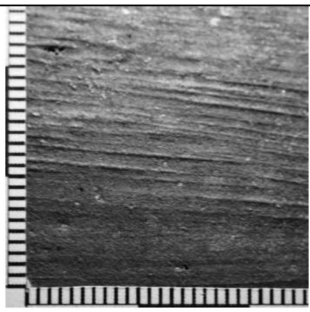
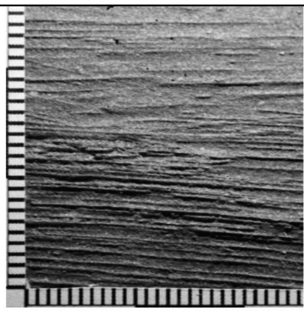
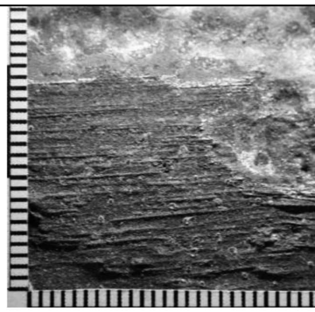
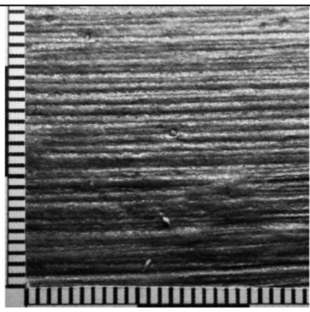
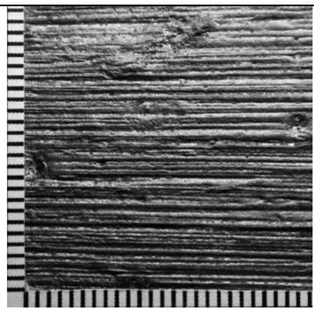
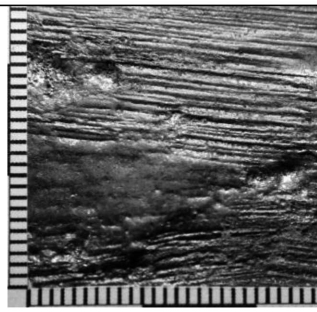
Fig. 2. Experimental castings after being knocked out from a mould (cores of a moulding sand with the Rezolit resin)

TABLE 1

Average values of the metallostatic pressure all tested coatings and moulding sands

Level of pressure	Value of the metallostatic pressure height, cm											
	Cast of plate 1- moulding sand 1 (with Rezolit AM resin)				**Cast of plate 2- moulding sand 2 (with Estrofen resin)**				**Cast of plate 3- moulding sand 3 (with Avenol resin)**			
	B	**M**	**K**	**C**	B	M	K	C	B	M	K	C
1	**16**	**10**	**12**	**15**	16	10	15	10	16	10	12	15
2	**27**	**21**	**22**	**26**	27	21	26	21	27	21	22	26
3	**38**	**32**	**32**	**36**	38	32	37	32	38	32	32	36
4	**48**	**42**	**44**	**47**	48	42	48	42	48	42	44	47
5	**59**	**54**	**54**	**58**	59	54	59	52	59	54	54	58
6	**70**	**68**	**66**	**67**	70	68	70	63	70	68	66	67

Symbols: B – without a protective coating, M – magnesite coating, K – corundum coating, C – zirconium coating.

Level of pressure	1	3	6
Without a coating			
With magnesite coating			
With zirconium coating			

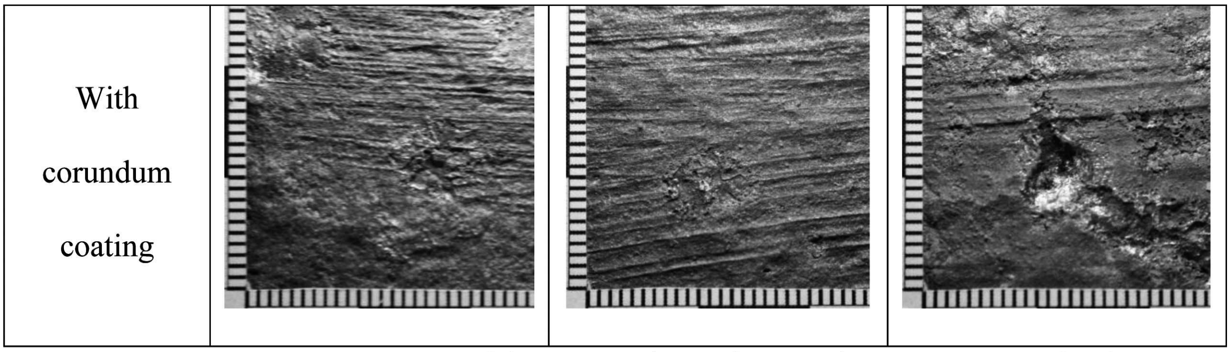


Fig. 3. Fragments of surfaces of the test castings of dimensions 25x25 mm, for the 1-st, 2-nd and 3-rd level of the metallostatic pressure

Analogous investigations were performed for cores made of moulding sands with three kinds of resins and for three different protective coatings. Average values of the metal column heights are presented in Table 1.

Sectors of experimental castings surfaces (25×25 mm), after sand blasting, for all levels of the metallostatic pressure for the moulding sand with the Rezolit resin, are presented in Figure 3.

The casting surface reflected by the tested mould without a coating indicates a roughness increase with a metallostatic pressure increase. In case of the moulding sand 1 the limiting penetration pressure was exceeded already at the 1-st level of the metallostatic pressure (metal height app. 10 cm) (Fig. 3). At pressure levels 5-th and 6-th the liquid metal penetrates the first layer of matrix grains.

The surfaces of castings reflected by the tested moulds with deposited protective coatings did not indicate specific differences caused by metallostatic pressure increases, within the tested range (Fig. 3). The casting surface quality depends, first of all, on the coating deposition accuracy. The tested coatings were deposited by painting with a swab (such technique is applied in the foundry plant, for which the presented here work, was executed). The most difficult was deposition, by this technique, of the zirconium coating and in effect the casting surface had visible folds. Flow marks occur on castings regardless of the metallostatic pressure.

On all casting surfaces, starting from the 4-th metallostatic pressure level, local burns of glassy sands adhering to castings were observed. The largest amount of these local burns occurred on the casting surfaces at the 6-th level of the metallostatic pressure.

4. Conclusions

Performing castings of the high manganese steel in moulding sands on the matrix of high-silica sands requires an application of the proper protective coatings of the mould cavity. 3 alcoholic protective coatings were tested: magnesite, zirconium and corundum. The obtained results lead to the following conclusions:

- ► The applied methodology allows determining the metallostatic pressure value, at which casting surface defects will occur due to the liquid metal interaction with moulding or core sands.
- ► During tests all three protective coatings behaved in a similar way and the surface quality – within the given range of metallostatic pressures – was satisfactory. However the possibility of applying the corundum coating (which is the cheapest) should be verified under the foundry conditions.
- ► The accuracy of the coating deposition is influencing the casting surface quality. The most difficult was depositing the zirconium coating, which caused that the casting surface had distinct folds on the surface.
- ► In order to perform the proper selection of the protective coating the tests should be carried out on large castings under industrial conditions.

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