

# Investigations of Protective Coatings for Castings of High-manganese Cast Steels

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## Abstract

When cast steel castings are made in moulding sands on matrices of high-silica sand, which has a low fire resistance the problem of the so-called chemical penetration is distinctly visible. Whereas this effect appears to a small degree only when moulding sand matrices are of chromite, zircon or olivine sands. Therefore in case of making castings of high-manganese cast steel (e.g. Hadfield steel) sands not containing free silica should be applied (e.g. olivine sand) or in case of a high-silica matrix protective coatings for moulds and cores should be used. Two protective coatings, magnesite alcoholic (marked as coating 1 and coating 2) originated from different producers and intended for moulds for castings of the Hadfield steel, were selected for investigations. Examinations of the basic properties were performed for these coatings: viscosity, thermal analysis, sedimentation properties, wear resistance. In order to estimate the effectiveness of protective coatings the experimental castings were prepared. When applying coating 1, the surface quality of the casting was worse and traces of interaction between the casting material (cast steel) and the coating were seen. When protective coating 2 was used none interactions were seen and the surface quality was better.

**Keywords:** High-manganese cast steel, Protective coating, Silica sand, Quality of surface

## 1. Introduction

When cast steel castings are made in moulding sands on matrices of high-silica sand, which has a low fire resistance the problem of the so-called chemical penetration is distinctly visible. Whereas this effect appears to a small degree only when moulding sand matrices are of chromite, zircon or olivine sands.

After filling the mould with liquid steel and cooling the casting, a change of properties in the moulding sand layer directly adjusting to the casting in relation to the layers situated at a further distance from the casting surface, can be observed. In some cases this layer is strongly connected with the casting surface and requires a significant labour input in its removal. Quartz grains, often surrounded by a glassy slag-alike substance

which is binding them to each other, are seen in the cross-section of this layer.

Presence of other elements in steel can favour a chemical penetration. Especially dangerous is manganese, which is easily oxidised to manganese oxide, MnO, and then reacts with silica forming silicates of a low melting temperature [1, 2].

In addition, liquid silicates are blocking intergranular spaces and can hamper transport of gases inside a mould.

At analysing reactions occurring on the surface of the casting mould cavity after pouring with liquid metal, the attention should be drawn to the influence of the atmosphere in the mould. Generally it can be said, that a neutral or reducing atmosphere limits the penetration and contributes to elimination of burn-on, while the oxidising atmosphere intensifies this effect [3-10].

Therefore in case of making castings of high-manganese cast steel (e.g. Hadfield steel) sands not containing free silica should

be applied (e.g. olivine sand) or in case of a high-silica matrix protective coatings for moulds and cores should be used.

## 2. Laboratory investigations of protective coatings

Two protective coatings, magnesite alcoholic (marked as coating 1 and coating 2) originated from different producers and intended for moulds for castings of the Hadfield steel, were selected for investigations. Examinations of the basic properties were performed for these coatings.

### 2.1. Viscosity investigations of protective coatings

Viscosity investigations were carried out by means of the rotary viscosimeter RHEOTEST 2. For viscosity determinations the set of measuring cylinders S/S<sub>1</sub> and water thermostat for assuring a constant temperature were used. Measurements were carried out at temperatures: 10, 20, 30 and 40°C. The dynamic viscosity dependence on temperatures for the tested coatings is presented in Figure 1.

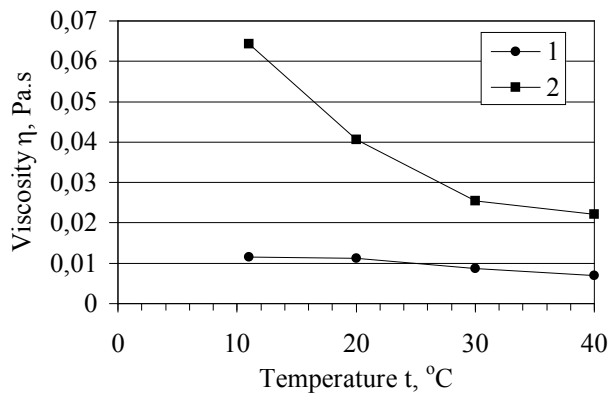


Fig. 1. Temperature influence on the dynamic viscosity of protective coatings

In the case of both protective coatings a viscosity decrease occurs with a temperature increase. For the protective coating 1 this drop is much softer (from 0.012 Pa·s in a temperature of 10°C to 0.007 Pa·s in 40°C) than for coating 2 (from 0.065 Pa·s in a temperature of 10°C to 0.022 Pa·s in 40°C). The coating 1 has several times smaller viscosity than coating 2.

### 2.2. Thermal analysis of the investigated protective coatings

The thermal analysis was performed for both protective coatings by means of the derivatograph of the Jota Company. Measurements conditions: heating temperature range from 20 – 1000°C, heating rate 10°C/min. The analytical results for protective coatings 1 and 2 are shown in Fig. 2 and 3, respectively.

In both cases the endothermic peak – with a maximum at a temperature approximately 100°C - with the corresponding mass loss was recorded. For the protective coating 1 the mass loss was 44.04%, while for coating 2 it was 30.39%. In both cases the mass loss is related to the evaporation of solvent - alcohol. This can be either ethyl alcohol or isopropyl one or their mixture. The boiling point of ethyl alcohol equals 78.30°C, and of isopropyl alcohol 82.3°C.

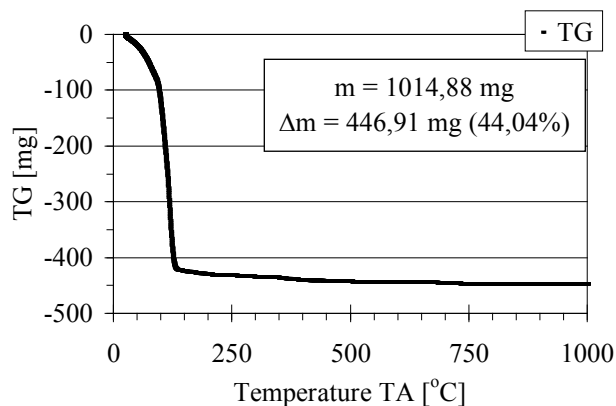


Fig. 2. TG curve for the protective coating 1, sample mass: 1014.88 mg, heating rate: 10°C/min

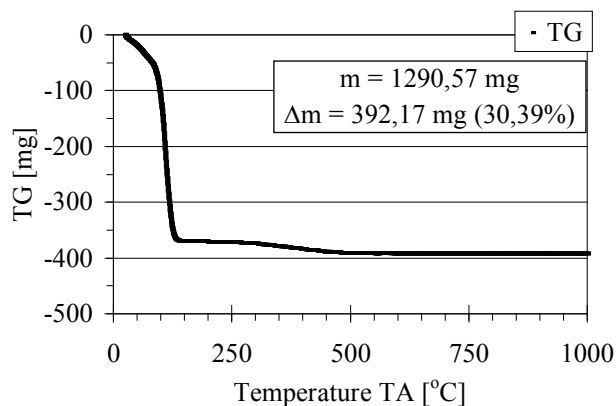


Fig. 3. TG curve for the protective coating 2, sample mass: 1014.88 mg, heating rate: 10°C/min

### 2.3. Sedimentation properties of protective coatings

In order to determine a tendency to sedimentation of the investigated coatings, which is important when these substances are stored for a long time, this parameter was checked according to the standard PN-H-11011. According to the standard the volume of a liquid above the suspension of coating in the 100 cm<sup>3</sup> measuring cylinder was checked after 24 hours. To obtain information concerning behaviour of coatings after shorter sedimentation times, measurements of volume were carried out after 1, 2, 3, 4, 5 and 6 hours from the moment of pouring a coating into the cylinder. The obtained results of the sedimentation tendency of coatings are presented in Figure 4.

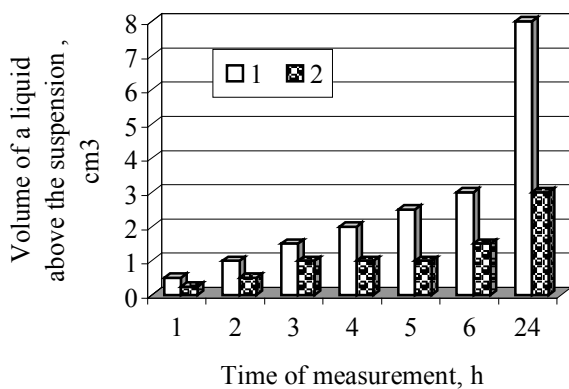


Fig. 4. Sedimentation tendency of the investigated protective coatings 1 and 2

It is clearly seen that the protective coating 2 is much less inclined to sedimentation than coating 1. This difference grows in time and after 24 hours the substance 2 exhibits twice smaller sedimentation tendency than coating 1.

### 2.4. Wear resistance of protective coatings

In order to assess the adherence degree to moulding sands and durability of the investigated protective coatings (resistance to erosion influence of liquid metal stream) the wear resistance was measured. The measurements were done by two methods, marked LS (LS apparatus) and HSW (apparatus produced by the Stalowa Wola Steel-Works).

Wear resistance measurements were carried out on roll shaped samples of dimensions:  $\phi$  50 x 50 mm. Shaped samples were made of a moulding sand of the composition (in parts by mass): high-silica sand – 100, resin: Permaset 839 – 1.0, hardener: Permacat 132 – 0.5. The samples compaction was performed by means of the vibratory device LUZ-2e of the Multiserw-Morek Company. Three layers of a protective coating were deposited on the shaped sample surface by immersing it in a liquid coating. After depositing each layer the sample was dried for 15 minutes at a temperature of 50°C. The measurement was performed 24 hours after depositing protective coatings.

The results of wear resistance of a protective coating are shown in Fig. 5. The test made by the LS method did show any essential difference between the investigated coating and the sample without any coating. However, in tests performed by the HSW method significant differences were seen. Wear resistance for shaped sample with coating 1 was 0.24%, with coating 2 was 1.41%, while for sample without any coating it was 0.62%. Thus, the coating 1 adherence was several times better than that of coating 2.

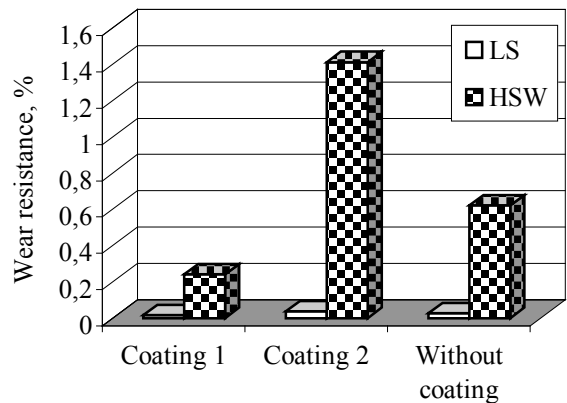


Fig. 5. Wear resistance of protective coatings

## 3. Investigation of protective coatings on test castings

The basic factor influencing the most intensely the surface quality of castings made in sand moulds is a metallostatic pressure [2, 3]. Thus, designing and performing of the technological test according to which the preparation of the experimental casting would be done under extremely difficult but controlled conditions seems justified [1, 4]. In order to estimate the effectiveness of protective coatings the experimental castings were prepared. The experimental mould was made of the moulding sand of a following composition: high-silica sand 100 parts by mass, Permaset 839 resin - 1 part by mass, Permacat 132 hardener – 0.5 parts by mass. On the specially prepared plate three kinds of standard samples were formed  $\phi$ 50 x 50 mm:

1. samples without coatings,
2. samples with protective coating 1,
3. samples with protective coating 2.

Shaped samples were made of the moulding sand of the same composition as the filling sand. A compaction of samples was done by the vibratory method in the apparatus LUZ-2e of the Multiserw-Morek Company. Coatings were deposited by the threefold submerging in the solution and drying after each deposition for 15 minutes at a temperature of 50°C.

All samples were placed on the model plate and then shaped. The view of the half of the mould with samples covered with coatings is shown in Figure 6. In a similar way samples without coatings were shaped in the second half (comparable) of the mould.

In addition, in between shaped samples with the given coating the same coating was placed on the mould by three-fold painting.

This was done to be able to assess the influence of the way of depositing coatings (immersing or painting) on the surface quality, after pouring with liquid metal. The mould prepared in such way was poured with the high-manganese cast steel of a tapping temperature of 1550°C and 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%. The mass of the casting after cleaning was 10.7 kg.



Fig. 6. View of the mould from the side of shaped samples with two kinds of protective coatings (marking: M – coating 1, P – coating 2)

The view of the casting after knocking-out - seen from the side of shaped samples without protective coatings – is presented in Fig. 7, while from the side of shaped samples covered with protective coatings – is presented in Fig. 8.



Fig. 7. Casting after being knocked-out – from the side of shaped samples without protective coatings

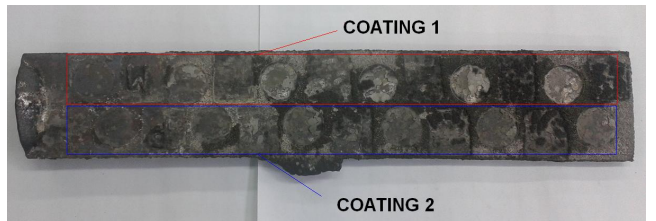


Fig. 8. Casting after being knocked-out – from the side of shaped samples with protective coatings

Below (Fig. 9) the casting surface without the protective coating and with coating 1 and 2 is presented as a function of the liquid metal height. The higher the metallostatic pressure the worse the casting surface quality. The application of protective coatings allowed to obtain the casting surface of a significantly smaller roughness. The casting surface quality depends on: the kind of coating, the way of mould preparation and the coating deposition method.

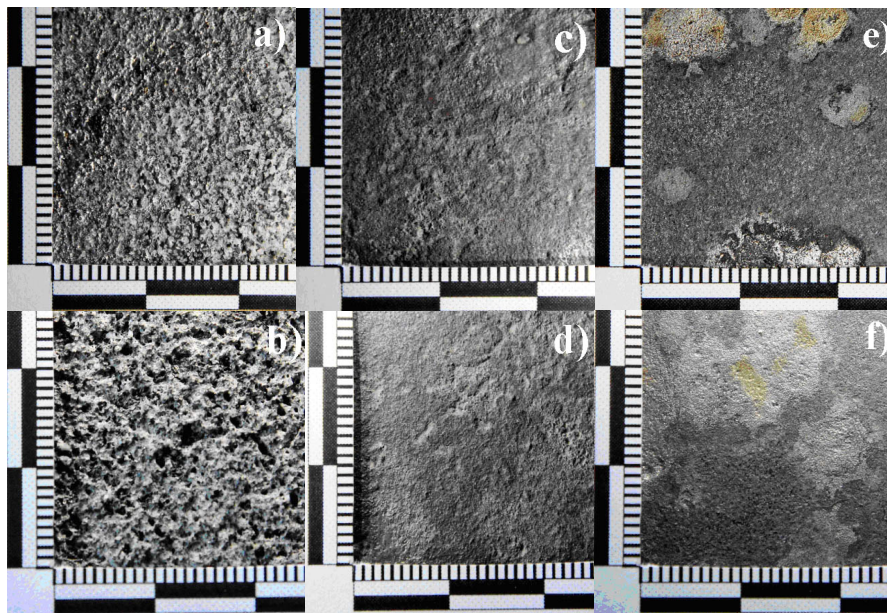


Fig. 9. Comparison of the surface quality of casting with protective coating and without protective coating for different metallostatic pressure: a) without coating, pressure 32 cm, b) without coating, pressure 67 cm, c) with coating 2, pressure 32 cm, d) with coating 2, pressure 67 cm, e) with coating 1, pressure 32 cm, f) with coating 1, pressure 67 cm

Photographs of the casting surface with the application of the coating 1 and 2 in dependence of the way of its depositing (3-times hand painting or 3-times immersing) and the metallostatic pressure value are presented in Fig. 10 and Fig.11, respectively.

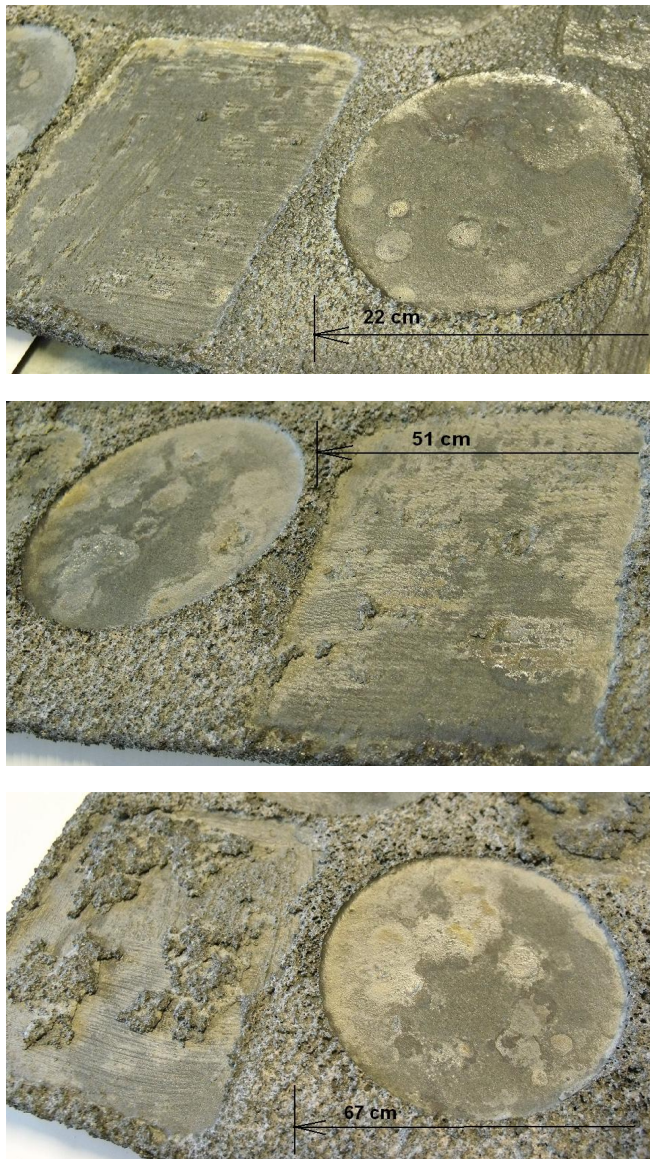


Fig. 10. Quality of the casting surface with the coating 1 deposited by brush and by immersing in dependence of the metallostatic pressure (circles – deposition by immersing, squares – deposition by painting)

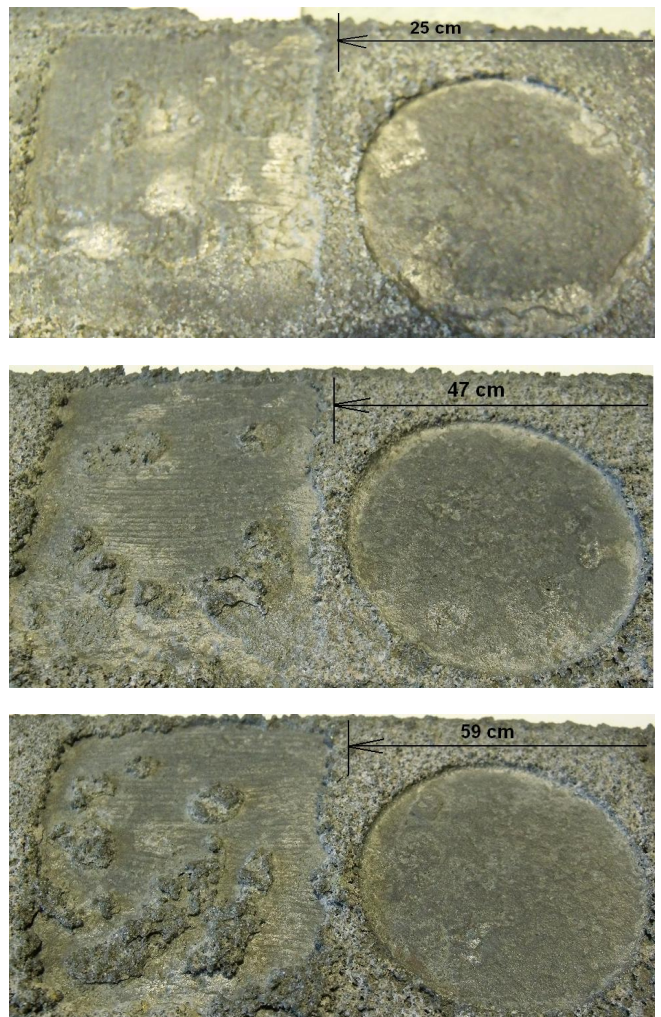


Fig. 11. Quality of the casting surface with the coating 2 deposited by brush and by immersing in dependence of the metallostatic pressure (circles – deposition by immersing, squares – deposition by painting)

The higher the metallostatic pressure the worse the casting surface quality. The application of protective coatings allowed to obtain the casting surface of a significantly smaller roughness. The casting surface quality depends on: the kind of coating, the way of mould preparation and the coating deposition method.

## 4. Conclusions

In order to obtain a sound casting of the high-manganese cast steel cast into moulding sands on the high-silica sand matrix **it is necessary to apply proper protective coatings** on the mould cavity. For this aim 2 protective coatings, magnesite alcoholic, originated from different producers but of a very similar composition, were investigated.

On the grounds of the obtained results it can be stated:

- Protective coating 1 has several times smaller viscosity than coating 2.
- The thermal analysis for both coatings indicated the occurrence of one endothermic peak, near a temperature of 100°C, originated from the solvent (isopropyl or ethyl alcohol). The mass loss for coating 1 was equal 44.04%, and for coating 2 - 30.39%.
- Sedimentation tests indicated that coating 2 after 24 hours exhibits more than two times smaller sedimentation tendency as compared to coating 1, which is important at longer storing of this substance.
- Examinations of the coating adherence to a moulding sand indicated that wear resistance of coating 1 was a few times smaller than of coating 2, thus showing that coating 1 was better adhered.
- To confirm the results of the laboratory examinations the testing of these two coating was also performed under experimental foundry shop conditions. When applying coating 1, the surface quality of the casting was worse and traces of interaction between the casting material (cast steel) and the coating were seen. When protective coating 2 was used none interactions were seen and the surface quality was better.
- Two ways of coatings deposition on the mould were applied. In case of painting by brush much larger foundry area is for the disposal. However, the deposition by brush painting provides worse results than immersing in the protective coating solution.

To achieve the proper selection of the protective coating, tests should be performed under industrial conditions on large castings.

## Acknowledgements

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