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A METHOD TO EVALUATE THE PERMEABILITY AND STRENGTH OF CERAMIC PROTECTIVE COATINGS APPLIED ON LOST FOAM PATTERNS

METODA UMOŻLIWIAJĄCA ŁĄCZNĄ OCENĘ PRZEPUSZCZALNOŚCI I WYTRZYMAŁOŚCI POWŁOK OCHRONNYCH STOSOWANYCH NA MODELE Z POLISTYRENU SPIENIONEGO W METODZIE PEŁNEJ FORMY

In lost foam process, application of protective refractory ceramic coatings on patterns made from foamed polystyrene plays a very important part and decides about the quality of produced castings. The coating should be made from a material of suitable strength and good permeability to give free way of escape to gaseous products which are formed due to the thermal destruction of a pattern. In this work an attempt has been made to determine the criteria for technological estimation of these coatings. A device cooperating with the apparatus for determination of the moulding sand permeability was designed and manufactured. To enable a comparison of the strength of various tested coatings, the relevant equations have been derived.

In the present investigation several types of ceramic coatings were applied and their composition was based on the following materials: quartz flour, zircon flour, mullite, hydrolysed ethyl silicate – 40, copolymer silicate binder, sizol 0–30. The thickness of the examined coatings was 1.0 ± 0.1 mm and 1.5 ± 0.1 mm for single-layer and double-layer coatings, respectively.

W technologii pełnej formy pokrycie modelu z polistyrenu spienionego ceramiczną powłoką ogniotrwałą odgrywa kluczową rolę i decyduje o jakości wykonywanych odlewów. Od powłoki wymaga się z jednej strony odpowiedniej wytrzymałości, z drugiej – odpowiedniej przepuszczalności produktów gazowych, powstających w wyniku destrukcji cieplnej modelu. W artykule podjęto próbę określenia kryteriów oceny technologicznej przydatności tych powłok. Skonstruowano i wykonano przyrząd, umożliwiający współpracę z aparatem do oznaczania przepuszczalności mas formierskich, do pomiaru przepuszczalności i wytrzymałości powłok ceramicznych. Aby umożliwić porównywanie wytrzymałości badanych, różnych powłok, opracowano odpowiednie wskaźniki.

Do badań zastosowano kilkanaście rodzajów powłok ceramicznych, których skład oparty był na następujących materiałach: mączka kwarcowa, mączka cyrkonowa, mullit, zhydrolizowany krzemian etylu – 40, spoiwo krzemianowo-kopolimerowe i sizol 0–30. Grubość badanych powłok wynosiła: jednowarstwowych – 1.0 ± 0.1 mm, dwuwarstwowych – 1.5 ± 0.1 mm.

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1. Introduction

Foundry technologies using patterns made from foamed polystyrene (or other similar materials) have a number of advantages, mainly of technological, economical and ecological character.

A characteristic of the full mould process, its variations and some selected problems determining the viability of this process have been discussed, among others, in [1, 5, 6, 7].

In full mould process, coating of a pattern made from foamed polystyrene with a refractory protective material plays a very important role and determines the quality of manufactured castings. A more comprehensive discussion of this problem was given in [3]. The present study describes a method developed recently to investigate some technological properties of these coatings and the obtained results of research.

2. Own research and results

The aim of the research was investigation of the technological properties, i.e. permeability and strength, of protective refractory coatings applied on patterns made from foamed polystyrene and used in full mould process.

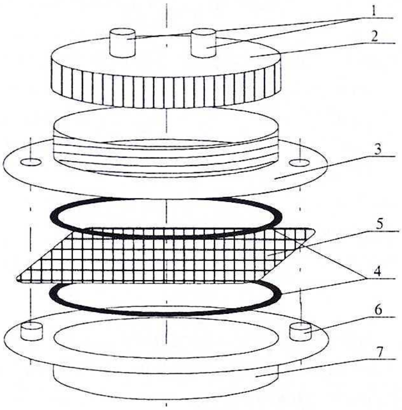

Fig. 1. Schematic representation of device for measurement of permeability and strength [4]: 1 – inlet and outlet pipes for compressed air, 2 – nut for strength measurement, 3 – upper body, 4 – packing washer, 5 – measuring grid, 6 – locating pins, 7 – lower body to fix the device in apparatus for measurement of permeability

The strength and permeability of coatings was examined using a method developed and described in [4]. A device has been designed and produced to be used jointly with an apparatus for determination of the moulding sand permeability (LPiR1 type or similar one). A schematic representation of the device is shown in Figure 1. The principle consists in applying by immersion a layer(s) of coating into a measuring metal grid (5) and in the successive hardening of this (these) layer(s). Then the grid is placed in a measuring device between its lower body (7) and upper body (3) – see: Figure 1, and the whole is mounted in an apparatus for the measurement of permeability. Having measured the permeability, into an upper part of the device a nut is screwed on; to one end of the nut a pipe for the supply of compressed air is connected, while the other end is connected to an air pressure gauge (*P*), measuring the air pressure inside the device. Then the air pressure supplied to the measuring chamber is gradually increased, and it acts into the coating placed on the grid. The destruction of coating even within an area of one single grid mesh makes the pressure growth stop first, and drop next (*P*) in the measuring chamber of the device.

To compare the strength of the examined different coatings, various coefficients have been developed:

$$W_R = P/A, \tag{1}$$

where: W_R – coefficient of the coating layer strength, calculated for an entire area of the grid meshes, MN;
P – pressure inside the measuring device, MPa;
A – total surface of all meshes in a measuring grid; for grid used in this research it amounted to about 13.0×10^{-4} m^2.

$$W_{R1} = P/a, \tag{2}$$

where: W_{R1} – coefficient of the coating layer strength, calculated for the surface of one single grid mesh, MN;
a – surface of one single mesh in a measuring grid; for grid used in this research it was about 0.004×10^{-4} m^2.

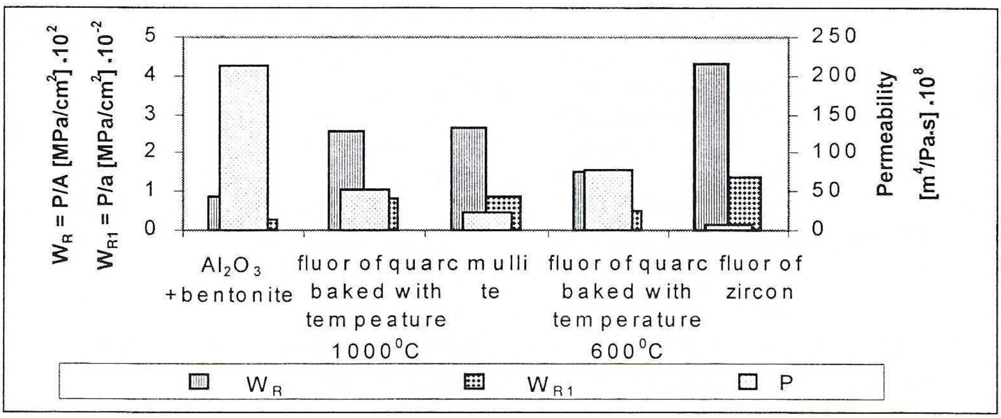

Fig. 2. Relationship W_R, W_{R1} and permeability in 1 – layer coating vs type of base material; binder: hydrolysed ethyl silicate – 40

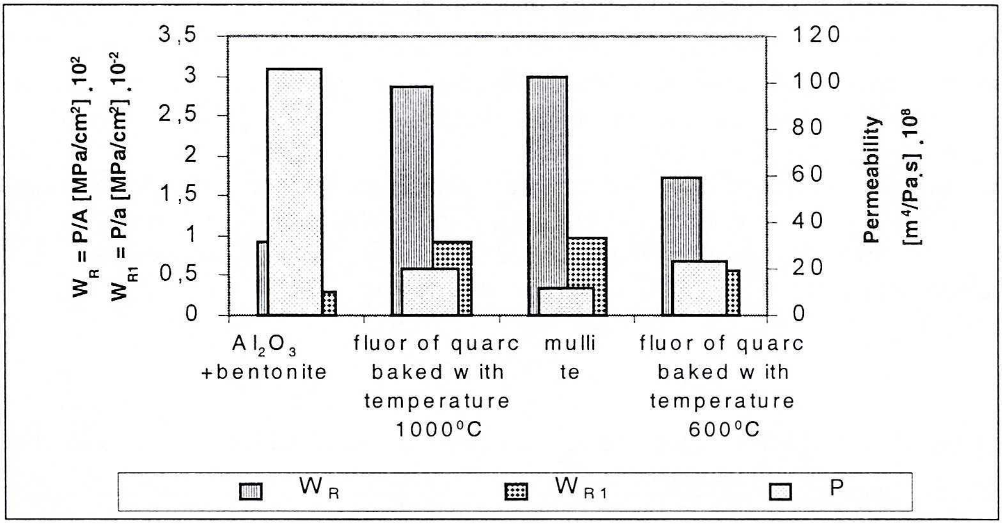

Fig. 3. Relationship W_R, W_{R1} and permeability in 2 – layer coating vs type of base material; binder: hydrolysed ethyl silicate – 40

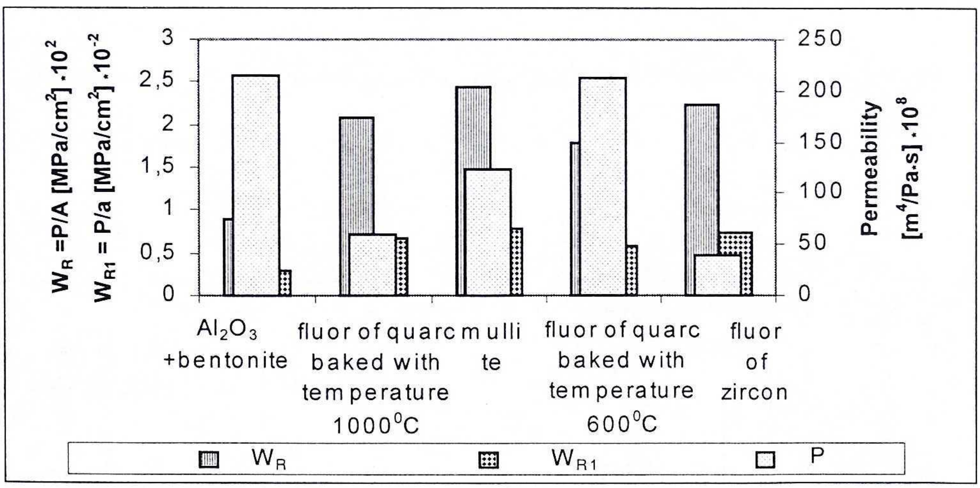

Fig. 4. Relationship W_R, W_{R1} and permeability in 1 – layer coating vs type of base material; binder: silicate – copolymer

The research was conducted on several types of protective ceramic coatings, the composition of which was based on the following materials:

1. Base sand
   - Quartz flour thermally treated at 600°C,
   - Quartz flour thermally treated at 1000°C,

- Zircon flour,
- Mullite.

2. Binder
- Hydrolysed ethyl silicate – 40,
- Silicate-copolymer binder,
- Sizol 0–30.

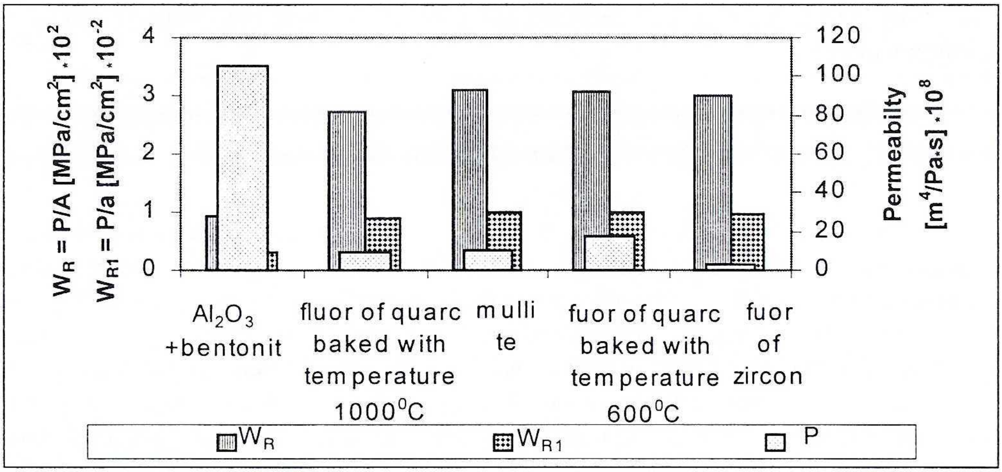

Fig. 5. Relationship W_R, W_{R1} and permeability in 2 – layer coating vs type of base material; binder: silicate – copolymer

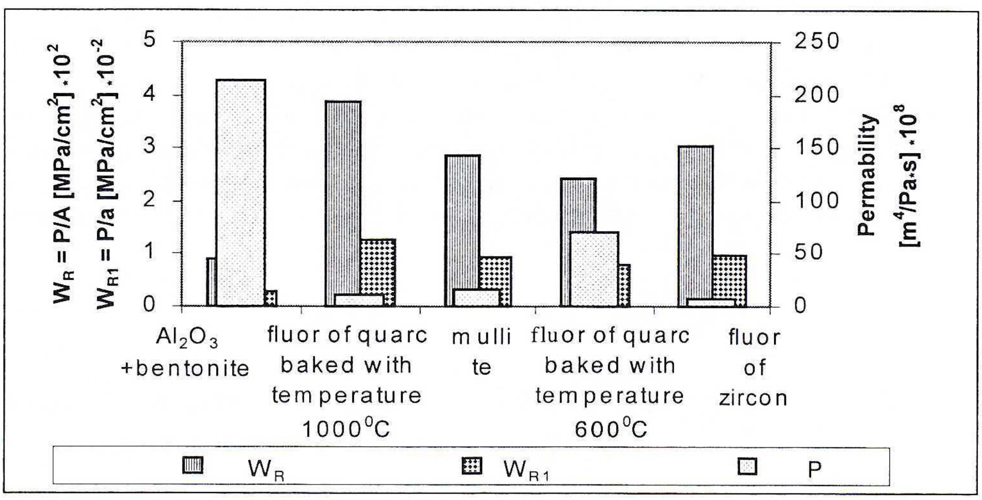

Fig. 6. Relationship W_R, W_{R1} and permeability in 1 – layer coating vs type of base material; binder: Sizol 0–30

3. Ceramic coating layers were also examined. Their composition was as follows [2]:
   - Al_2O_3 flour (90%) + bentonite (10%) with water-alcohol binder which was composed of water and ethyl alcohol mixed in a ratio of 1 : 1, added in an amount of 80–100% by weight in respect of the base material,
   - The thickness of the examined coatings was:
     - for single-layer coatings – 1.0 ± 0.1 mm,
     - for double-layer coatings – 1.5 ± 0.1 mm.

Figures 2 to 6 show plotted relationships used to compare the obtained results of measurements.

3. Conclusions

The conducted research has proved full applicability of the method and of the apparatus in determination of strength and permeability of protective layers of the refractory (ceramic) coatings applied on patterns made from foamed polystyrene used in full mould process. The measurement itself is easy and quick, not counting the time of application and hardening of the coating layers, which is the characteristic parameter of the technology.

The studies covered a few dozen of different coatings. They differed in the type of binder and in the type of the base material used. The coatings were applied as a single layer or as double layers. From the conducted investigation it follows that increasing the number of layers in a coating does not affect to a considerable degree the strength of the coating, while its permeability is reduced in quite a noticeable way.

In selecting of a coating for patterns made from foamed polystyrene, a very important role play the following factors : type of cast alloy, casting wall thickness and its geometrical configuration, which determines the possibility and advisability of application of a given coating. In view of these observations as well as basing on the results of other studies [8], it can be concluded that when full moulds are poured with alloys of lower pouring temperature, the lower gas volume is evolved from the polystyrene pattern than in the case of alloys characterised by higher pouring temperature. Therefore, coatings used in the former case can be characterised by lower permeability as well as strength, and then the factor which will decide about the choice of a given type of coating will be economy.

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