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The influence of organic fibre types on technological parameters in process of ceramic moulds making

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Abstract
The research being presented in this article has been set up with the aim of working out both the technology and starting up manufacturing process (in which a new generation of ceramic slips is employed) in "Armatura" precise foundry. There have been used "aqueous" Ekosil silicate binder and quartz ceramic material with addition of organic fibres for making slip in the new technological solution. In the presented research work has been achieved a quantitative and qualitative selection of composition for the ceramic slip. The selection has been based on testing of physico-chemical and technological qualities.

Keywords: Innovative casting materials and technologies, Investment moulding method, organic fibres, ceramic slips, ecology, precision castings.

1. Introduction

The following article presents an initial research that aims at starting the process of the precise castings production where slips of the new generation have been employed. Slips of the new generation contain "aqueous" inorganic siliceous binding agent, organic material of compound grade polydispersity and organic fibres.

The usage of this kind of slip remains in accordance with the Environment Protection Act (edited in 1997 by U.E.) applying to environment protection which imposes limit on emission of any kind of volatile organic component.

The "aqueous" binding agent, however, because of its specificity, has some infavourable technological proprieties (1,2,3) as for as it concerns to aspect of investment moulding technology.

There are following unfavorable proprieties:

- Poor wettability of model set surface;
- Prolonged drying time for consecutive layers of ceramic mould;
- Low mechanical resistance of raw mould and drop in permeability of ceramic mould;

The improvement in wettability, shortened drying time of consecutive layers and a partial improvement in mechanical resistance of raw ceramic mould has been archived by modification of binding agent's composition.

The further improvement in technological quality of the mould (like durability and permeability) should be provided by addition of organic fires to the slip.

The results of testing of the basic technological qualities of slips and ceramic moulds which were made with employment of organic fibre components have been presented in the article.

2. The Range of the work and methodology of research works

2.1. The range and methods of the research

There has been employed the same research methodology which had been developed and applied for determination of parameters of technical process for making of laminar ceramic moulds according to the investment moulding method witch has been used at Foundy Institute in Kraków.

During the research the following designations have been preformed.

- Dependence of slip viscosity on ceramic material content – measured by means of Ford's •6 cup;
- Wettability angle of the wetted by slips waxed modeling mass base.
- Reological parameters of ceramic slips -measured by means of rotary viscosometer Bohlin V88;
- Crushing strength of raw ceramic mass samples and of those heated at a temperature of 900°C samples;
- Permeability changes of ceramic mass samples during holding them at temperature between 20÷900°C, followed by cooling to the temperature of surroundings.

2.2. Materials for testing

The slips prepared for research consisted of Ecosil "aqueous" inorganic siliceous binding agent and mixtures of crystalline quartz flour including selected additional organic fibres. Quartz sands of two different size analysis have been used as materials for sprinkling of the sample ceramic mould produced. After initial testing four kinds of organic fibres have been selected for modification of ceramic slips. Their qualities are as follows.

Table 1.
Fibres characteristics

Cellulose fibre DOCEL	Cellulose fibre TECHNOCEL 165
Originated: hardwood: beech, ash Bulk density 30-60g/l Humidity max7,5% pH 5-9 - size analisys: - <1000ƒm-min.98% - < 800ƒm-min.60% - < 32ƒm-max.20%	Cellulose content 90% Bulk density 75g/l Humidity 6% pH 9 - size analisys: - <160ƒm-99% - < 90ƒm-80% - < 32ƒm-25%
Polyethylene fibre PE40	**Polypropylene fibre PP**
Homopolymer made of ethylene Density 0,93-0,97g/cm^3 Softening temperature 128°C Melting temperature 135°C Length of fibre 6mm Diameter of fibre 17dtex	Polipropylen C_3 H_6 Density 0,91g/cm^3 Softening temperature 145°C Melting temperature 165°C Length of fibre 2,2mm Diameter of fibre 2,2dtex

Ceramic slips have been prepared for testing. They consisted of Ekosil "aqueous" inorganic siliceous binging agent and mixture of crystalline quartz flour with addition of DOCEL and TECHNOCEL 165cellulose fibres in amount 1, 2 and 3% weight and polyethylene PE40 and polypropylene PP fibres – synthetic fibres in amount of 0,2 and 0,4% of weight.

3. Description of the results

3.1. Laboratory tests of physico-chemical and technological qualities

In the picture nr 1 and 2 there has been presented dependence of apparent viscosity (the thickness measured by means of Ford's cup), of ceramic slips, on mass fraction of quartz flour mixture with fibres in ceramic slips.

On the base of this determination the optimum binding agent's ratio to the mixtures has been established . These ratios have been applied during the further testing process.

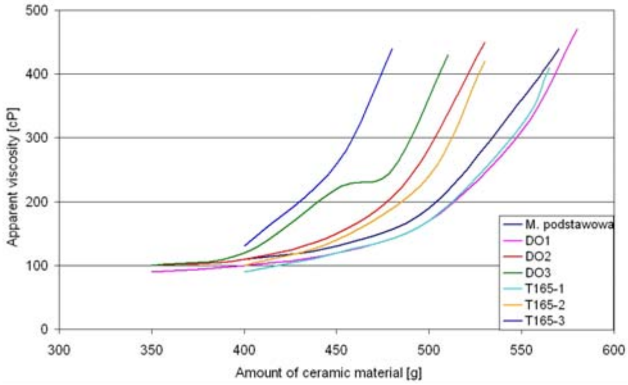

Fig.1. Dependence of apparent viscosity of ceramic slips, which contain cellulose fibres, on amount of ceramic material.

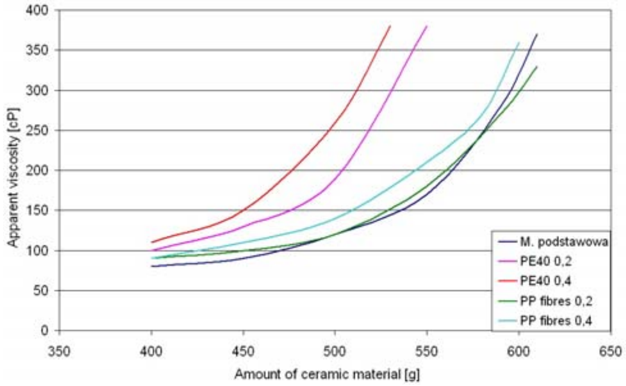

Fig.2. Dependence of apparent viscosity of ceramic slips, which contain artificial fibres, on amount of ceramic material.

After the initial tests had been done, there ceramic slips have been selected. Some with addition of 1 and 2 % DOCEL cellulose fibre some with addition of 0,2 and 0,4 % polyethylenole PE40.

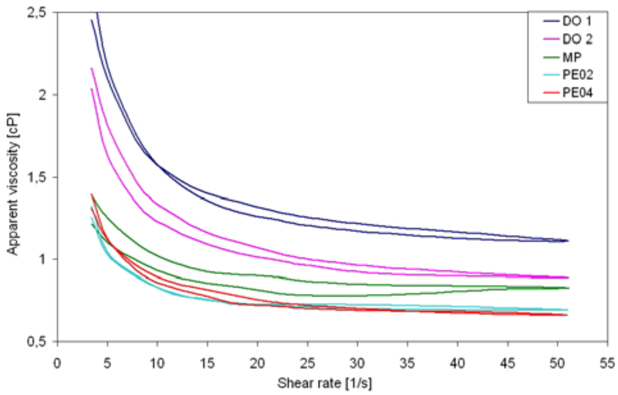

Fig.3. Comparison of apparent viscosity dependence on coagulation rate for slip containg natural and artificial organic fibres.

In the picture number 3 there are presented results of reometic marking in relation to slips containig and lacking of organic fibre. The addition of fibres causes increase in pseudoplastic quality of ceramic slips.

It indicates that there is an increase in susceptibility to structure creating in dispersive systems. Ratio of the follow n determined in accordance with rheological model amounts 1,0070 for basic mass without fibre addition. There is a drop in value caused by fibre addition. Accordingly to the a mount of 0,984 for cellulose fibres and to 0,984 for polyethylene fibres. The markings have been made for ceramic slips of equal apparent viscosity ranging about 300cP. (compare picture 1, 2). There has as well been measured the wetting angle of model surface.

Laminar mould samples have been made for resistance, permability and surfice roughness tests. The samples have been prepared by gradual spreading of 5 slip layers on wax moulds. Each time the layers have been sprinkled with fine-grained at first and with coarse-grained quartz sand later on.

Apparent viscosity of slip measured by Ford's cup is as follows.

- Towards the I coating 350÷400cP;
- Towards the II coating 150÷200cP;
- Towards consecutive coatings 250÷300cP;

Tabulation number 1 and picture number 4 presents the result of testing.

Analyze of results allows to come to the conclusion that addition of fibres causes:

- The overall, however, of different grade, decline in wetting angle. It testifies an improvement in wettability of wax base caused by ceramic slip's presence.
- An increase in resistance of raw sample and drop in resistance after burning. An extraorydinary resistance value of ceramic mass with edition of PE40 fibre is higher in both raw and incandescent samples while compared with samples made from basic mass.
- That quality of the sample surface is worsened by presence of DOCEL fibres and improved by addition of PE40 fibres, while compared with samples made from basic mass.

Table 2
Physico-chemical and technological qualities of ceramic slips containing fibres.

Type of fibre	Lack of fibre	DOCEL cellulose fibre		Polyethylene PE40fibre	
Mass fraction	0	1	2	0,2	0,4
Wetting angle	48	40	43	33	36
Crushing strength [MPa], raw samples	3,9	4,6	3,5	4,4	5,2
Crushing strength [MPa], incandescent samples	5,8	5,4	3,7	4,7	5,7
Roughness Ra, [μm]	2,83	3,79	3,2	2,38	2,22

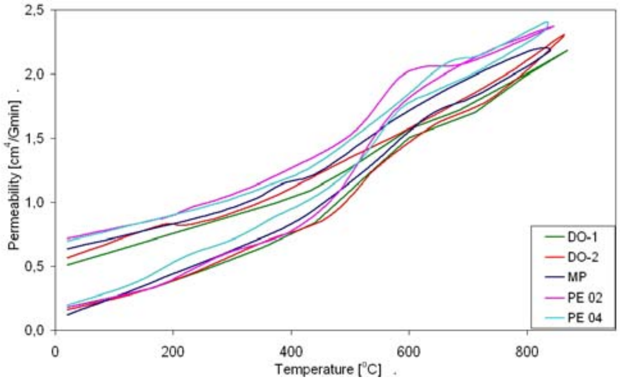

Fig. 4. Diagram of variation curves of sample ceramic form permeability, together with temperature changes.

In the picture number 4 have been shown curves of changes of a sample form permeability during, the process of hitting in temperature ranging between 20 to 900°C and between 900°C to 20°C. The highest increase in permeability of samples has been recorded in case of masses containing addition of DOCEL fibre. The best result have been achieved when there were used DOCEL cellulose fibre and PE 40 polyethylene fibres.

There is need for technical testing of the process of manufacturing ceramic forms in real conditions of "Armatura" foundry. This testing should be performed in order to verify the results and to reach the optimization of technological process.

3.2. Technical test done in conditions of precise foundry

The result of research, basing on testing of ceramic slips and laminar ceramic form samples, allows to claim that some of the organic fibres are useful for modification of ceramic slips, when improvement of technological qualities of laminar ceramic form is expected. There have been selected ceramic slips containing 0,2÷0,4% of weight PE40 polyethylene fibres and 1÷2% of weight DOCEL cellulose fibre for further test.

In case of PE 40 fibres is has been decided to spread the ceramic slip onto each of all the laminar coatings of the ceramic moulds. In case of DO-CEL fibres there shoud be applied a basic mass on the first coating and the mass with addition of fibre, in a recommended amount, onto the farter layers. There have been selected ceramic slips containing Ekosil binding agent, quartz flower, DOCEL cellulose fibres or PE40 polyethylene for tests. The tests were done with the aim of verification of results, which had been achieved in the laboratory surroundings. There have been used the following combinations of ceramic layers in further test runs (table 3) in "Armatura" precise foundry.

There have been prepared some experimental ceramic moulds and some samples made from, above mentioned, masses. They have been tested for crushing strenght and permeability. The results of technological quality tests are presented in table 2 and in the picture number 5.

Table 3
The results of crushing strenght test, performed on selected ceramic mass samples, in "Armatura" foundry surroundings.

Description of a ceramic slip sample	Crushing strength MPa	
	Raw samples	Incandescent samples
Ekosil binding agent with quartz flower, without any adition of fibre appled to all the coating	5,8	6,6
Ekosil binding agent with quartz flower, with adition of 1,5% DOCEl fibre. (1 coating without, the farter ones with addition)	5,5	7,2
Ekosil binding agent with quartz flower, with adition 0,4% PE40 fibre (1 coating without, the farter ones with addition)	5,8	6,0
Ekosil Luxor SK binding agent and etyl silicate used in an alternating way – version that , up to now, has been applied in "Armatura" foundry.	2,5	3,6

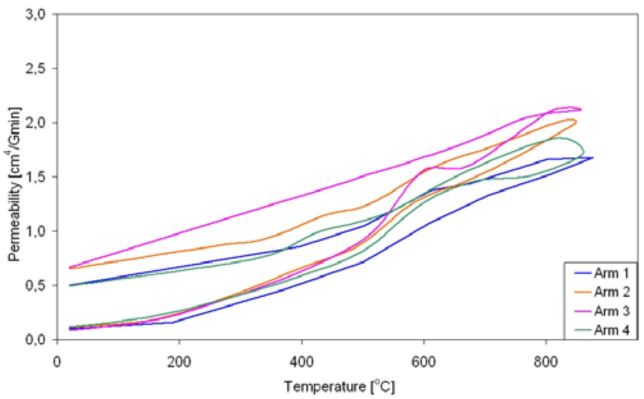

Fig. 5. Permeability dependence of the ceramic slip sample made in "Armatura" foundry on temperature.

4. Summary

It has to be stated that addition of cellulose fibre as well as synthetic ones causes increase in permeability and resistance of ceramic moulds. What is more it has been proved that addition of DOCEL fibre guaranties suitable homogenization of ceramic slip during the technical tests. To sum up it is to bee said that there has been selected a new generation of the slip witch contained EKOSIL binding agent quartz flower and addition of DOCEL cellulose fibre in amount of 1,5% in comparison with quartz filler. During the test run of the mould in the surroundings of "Armatura" foundry. The mass of the first coating should not contain addition of ceramic fibre.

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