Control of the Physical and Mechanical Properties of Mixtures Based on Liquid Glass with Various Fillers

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Abstract. The paper presents the results of a study of the main properties of mixtures with liquid glass (LG) and furfuryl oxypropyl cyclocarbonate (FOPCC) for mixtures based on various fillers (chromite compounds, mixtures of quartz sand with chromite and quartz sands). The parameters such as gas generation ability, compressive strength, gas permeability, friability, and residual strength were studied and determined by standard methods. The optimum content of the FOPCC multi-purpose additive in a mixture based on chromite and quartz sands was evaluated. The experimental results showed that the chromite sand-based mixture's compressive strength and gas generation ability is higher than those of the quartz sand-based mixture. The friability and gas permeability is higher with respect to quartz sand-based mixtures. It was found that the breakdown ability of chromite sand-based mixtures is better than that of quartz sand-based mixtures. According to the mixture process sample, the compressive strength value is 2,1 MPa; the gas generation ability of the mixture is about 11,7 cm^3/g; the friability of the mixtures is in 0,045%; the gas permeability is more than 400 units; the residual strength is 0,47 MPa for chromite-based mixtures. For mixtures based on quartz sands, the compressive strength is 2,074 MPa; the gas generation ability of the mixture is about 10,5 cm^3/g; the friability of the mixtures is 0,045%; the gas permeability is 500 units, and the residual strength is 0,97 MPa. A technological process for preparing cold hardening mixtures (CHM) based on chromite and quartz sands was developed. As a result, the surface quality of the molds was improved, and burn marks on the castings were reduced.

Keywords: Cold-solidifying mixture · Soluble glass · Furfuryl oxypropyl cyclocarbonates · Chromite sand · Quartz sand · Product innovation

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1 Introduction

The properties of molding sands, which depend on the starting materials, strongly influence the quality of the castings [2]. The amount of fillers in the mixture is on average from 90% to 98%. Fillers should be inactive to molten metal, have relatively high thermal stability, mechanical strength, refractory properties, lower coefficient of thermal expansion, minimum cost, and uniform grain composition [3].

Currently, quartz foundry sands are the most widely used; more than 90% of all foundry's sand is consumed by the foundry [4]. Quartz sand has a number of advantages: it has a high hardness, high melting point; chemical inactivity at ordinary temperatures; good wettability with water and with almost all binders used; in addition, it is used in the manufacture of castings from various alloys; and also mixes well with various components of mixtures [5].

Chromite sand is also used as a filler from facing and core mixtures for steel castings [6]. Highly refractory and chemically inactive chromite sands have also become more commonly used for turbomachinery needs [7].

Chromite sand has a high thermal shock strength and does not have any allotropic transformations at 575 °C. It is inert to iron oxides at high temperatures and is poorly wetted by liquid metal, preventing the formation of burn marks and improving the conditions for metal crystallization [8]. In addition, it has a high thermal storage capacity and thermal conductivity [9].

Therefore, the development and use of new mixtures based on quartz and chromite sands is an urgent task of the foundry.

2 Literature Review

There are a considerable number of ways to make molds [10] and cores [11] using numerous compositions of mixtures [12]. One of the most frequently used methods is obtaining molds and cores on liquid glass (LG). Liquid glass is an available, cheap, and non-toxic binder binding material. The use of liquid glass as a binder for the manufacture of core and molding sands makes it possible to obtain stronger molds, reducing the metal consumption of castings owing to the production of thinner-walled products [13, 14].

One of the main disadvantages of using mixtures on liquid glass that are cured with carbon dioxide is the formation of fusible silicates at temperatures 700 °C, leading to sintering of mixtures, an increase in residual strength, and consequently, to a deterioration in a knockout [15, 16]. Esters are used together with LG to improve the knock-out of molding and core sands.

The dependences of the increase in the compressive strength of mixtures with water glass for casting molds and cores on the composition and amount of ether hardeners were investigated and studied. The difference is in the composition and amount of technological additives with ether hardeners. This makes it possible to increase the compressive strength of mixtures on various fillers with water glass for casting molds and cores. A large number of on-air compositions were tested, based on which the most optimal for use were selected [17].

In this paper, it is proposed to use a multi-purpose additive of furfuryl oxypropyl cyclocarbonate (FOPCC) as an ether hardener in order to produce cores and molds based on liquid glass. When metal is poured into a mold, furfuryl oxypropyl cyclocarbonate, as a result of thermochemical destruction, releases carbon dioxide and water vapor in the volume of the resulting composition. That is why furfuryl oxypropyl cyclocarbonate is a cleaner material from an environmental point of view [18].

All cyclocarbonates in an alkaline environment are unstable and decompose while releasing carbon dioxide. In turn, carbon dioxide reacts with liquid glass and forms polysilicates in the volume of the composition formed.

The systems that have formed are classified as nanostructured composite materials because the processes of interaction between liquid glass and FOPCC occur in monomolecular layers on the sand surface.

When used as a binder, the Gel time or the sol-gel transition time is an important characteristic of a silica system. The main stage in gel formation is the collision of two silica particles with a reasonably low charge on the surface. During the interaction of such particles between them, siloxane bonds are formed that irreversibly hold the particles together.

Mathematical models were developed that serve to control the strength parameters of mixtures based on a chromite filler, the result of which is the ability to compare the properties of the mixture based on liquid glass with chromite sand, quartz sand, and a mixture of quartz and chromite sands [19, 20].

The study aims to analyze the properties of mixtures based on liquid glass with triethanolamine and FOPCC multi-purpose additive based on chromite sand, quartz sand, and a mixture of quartz and chromite sands to obtain high-quality molds and cores for foundry purposes.

3 Research Methodology

FOPCC is a clear, light yellow liquid. The mixture was obtained as follows: per 100 wt % of sand and 4 wt % of liquid glass.

Liquid hardener was added to the sand and stirred for 180 s, after which liquid glass modified with triethanolamine was added and stirred for another 120 s. The liquid glass was modified with triethanolamine. Triethanolamine was used from the total weight of furfuryl propyl cyclocarbonate. The mixture was made in a 9-seat mold. FOPCC was introduced in the amount from 0.4 to 0.6 wt %, liquid glass – from 4,5 to 5,5 wt%, and triethanolamine – from 2 to 10 wt % of the mass of furfuryl propyl cyclocarbonate.

Grade 2K1O102 GOST 2138-91 quartz sand and Grade AFS45-50 TU U 13.2-35202765-001: 011 chromite grains of sand were used as filler for the molding mixtures.

The paper investigated gas permeability, compressive strength, gas generation ability, and friability properties.

Molding materials must have a number of properties that correspond to a particular molding or core mixture. These include the conditions for the interaction of the mold with the liquid metal during the casting of the mold, cooling, and solidification of the casting.

The strength of the casting mold when it is made, filling it with an alloy, and solidifying the casting determines the mechanical properties. Compressive strength tests of the mixtures were carried out according to standards. For this purpose, to evaluate the ultimate strength of molding and core mixtures, a Model 04116U facility was used.

Technological properties determine the conditions under which high-quality molds and cores are obtained and castings with the lowest labor intensity and high surface quality (without cracks and surface contamination).

The friability rate of molding and core mixtures according to GOST standards was determined using standard cylinder samples. The samples were tested in a dry state. The crumbling was expressed as a percentage and was determined as follows. The sample was placed in a mesh ram rotating and was determined by the mass loss of the sample.

One of the most accessible methods for quantifying the breakdown ability was determining the residual strength of heated and cooled standard samples. Samples of standard sizes are made and kept for a day. After this time, they are calcined for 1 h in a muffle furnace at a temperature of 800 ºC. After they have cooled, they are tested for strength. This is the essence of the method.

The conditions for gas formation mainly determine the hydraulic properties.

Gas permeability is an essential property of molding and core mixtures and is characterized by transmitting gases. With poor gas permeability, it becomes more challenging to remove gaseous products from the casting mold cavity during its pouring. The gas permeability of the core and molding mixtures was carried as follows. Air was blown through a standard sample made from the core or molding mixture.

4 Results

The paper conducts a comparative assessment of the properties of mixtures based on liquid glass with triethanolamine and FOPCC multi-purpose additive based on chromite sand, quartz sand, and a mixture of quartz and chromite sand [21, 22].

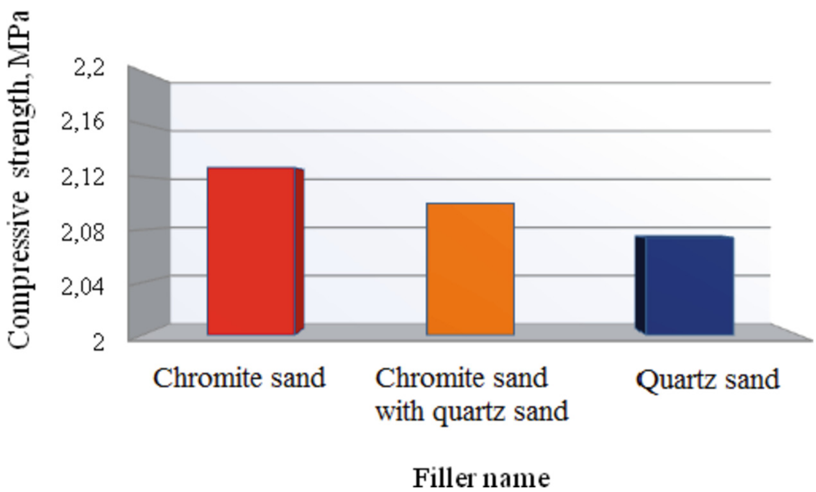

Fig. 1. Compressive strength of mixtures with various fillers.

The main mechanical, technological, and hydraulic properties of mixtures based on liquid glass and FOPCC additives were investigated by standard methods.

According to the mixture process sample, the compressive strength values are on average 2,127 MPa for chromite sands and 2,074 MPa for quartz sands. The gas generation ability of the mixture is on average 11,7 cm^3/g; the friability of the mixtures is in the area of 0,045%; the gas permeability is more than 400 units; the residual strength is 0,47 MPa for chromite-based mixtures.

For mixtures based on quartz sands, the gas generation ability of the mixture is 10,5 cm^3/g; the friability of the mixtures is in the area of 0,045%; the gas permeability is more than 500 units, and the residual strength is 0,97 MPa.

For clarity, the compressive strength, friability, gas permeability, and gas generation ability of mixtures with various fillers are shown in the form of histograms in Fig. 1, 2, 3 and 4, respectively.

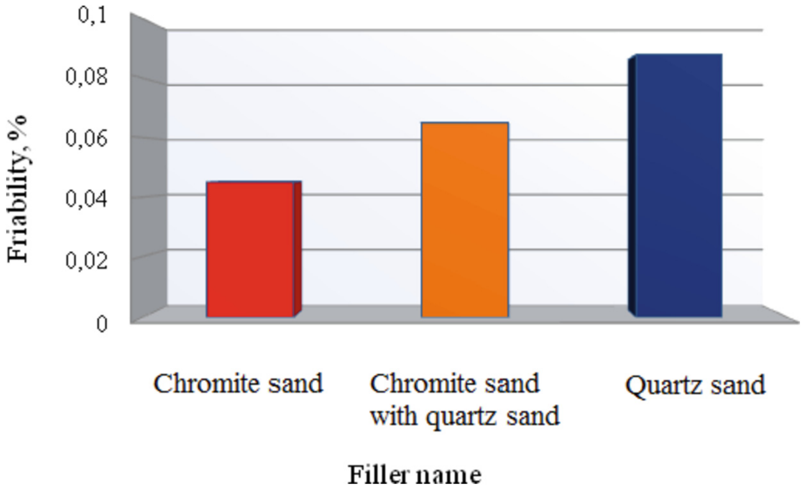

Fig. 2. Friability of mixtures with various fillers.

The review of the histograms shown in Fig. 1, 2, 3 and 4 showed that the compressive strength and gas generation ability of mixtures based on quartz sand are lower than those of the mixtures based on other fillers. The friability and gas permeability is higher in mixtures based on quartz sand.

Additionally, an experiment was carried out to determine the residual strength of mixtures on quartz sand, chromite sand, and a mixture of quartz and chromite sands. The findings of the experiment are shown in Table 1.

The review of the histogram data shows that the residual strength of mixtures based on chromite sand is lower than that of the mixtures based on other fillers.

The comparison of the main properties of mixtures based on chromite filler, on chromite and quartz sands, on quartz sand is reviewed. The investigations have shown the possibility of using chromite sands for cold-hardening mixtures based on LG with a multi-purpose additive of furfuryl oxypropyl cyclocarbonates in the foundry industry.

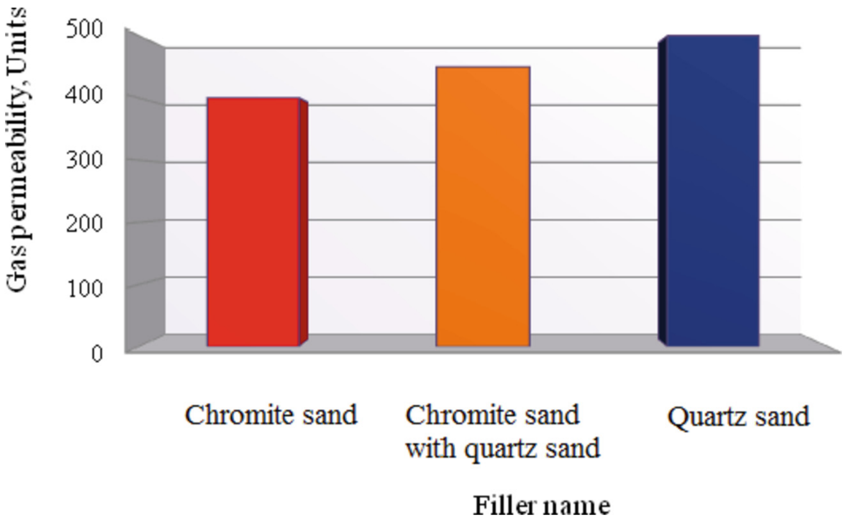

Fig. 3. Gas permeability of mixtures with various fillers.

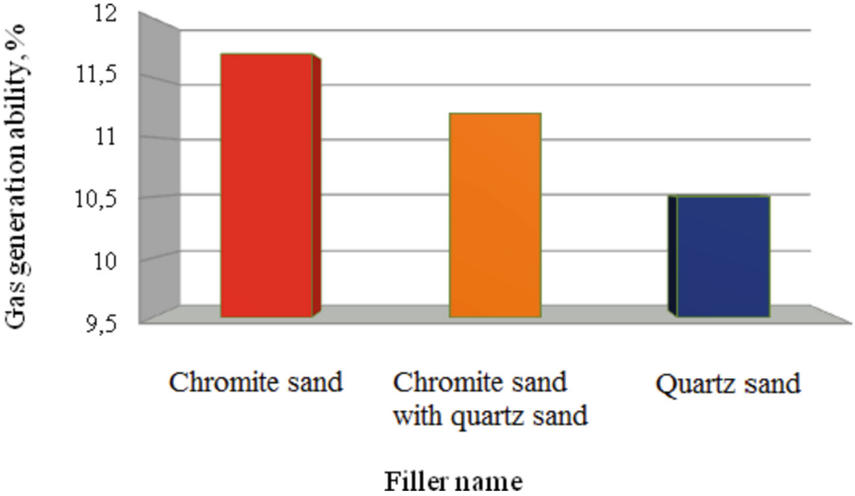

Fig. 4. Gas generation ability of mixtures with various fillers.

Table 1. Residual strength of mixtures with various fillers.

Item No.	Mixture name	Residual strength, MPA
1	Chromite sand	0,47
2	Chromite sand (10%) with quartz sand (90%)	0,53
3	Quartz sand	0,97

5 Conclusions

Technological processes for preparing core and molding CHM based on LG with FOPCC using quartz and chromite sands were developed to obtain high-quality castings from iron-carbon and non-ferrous alloys.

The main properties of CHM based on LG using a multi-purpose additive FOPCC based on quartz and chromite sands were determined, such as compressive strength, gas generation ability, gas permeability, friability, and residual strength. The quality of castings in sand casting depends on these properties.

According to the mixture process sample, the compressive strength values are on average 2,127 MPa for chromite sands and 2,074 MPa for quartz sands. The gas generation ability of the mixture is on average 11,7 cm^3/g; the friability of the mixtures is in the area of 0,045%; the gas permeability is more than 400 units; the residual strength is 0,47 MPa for chromite-based mixtures.

For mixtures based on quartz sands, the gas generation ability of the mixture is 10,5 cm^3/g; the friability of the mixtures is in the area of 0,045%; the gas permeability is more than 500 units, and the residual strength is 0,97 MPa.

The optimum content of the FOPCC multi-purpose additive the mixture based on chromite sand was evaluated. The experimental results showed that the values of the mechanical properties of the mixture based on chromite sand are higher than those of the mixtures based on quartz sand. The breakdown ability of mixtures based on chromite sand is better than that of quartz sand.

The studies have shown the possibility of using chromite and quartz sands for cold-hardening mixtures based on liquid glass with FOPCC in the foundry.

A technological process for obtaining CHM with FOPCC on chromite and quartz sands was developed. CHM with FOPCC based on chromite and quartz sands. As a result, the surface quality of the molds was improved, and burn marks on the castings were reduced.

It is planned to create new ethereal compositions for use in global production and test existing compositions as an opportunity to use with various fillers. The prospect is the organization of the production of essential compositions for widespread use in the foundry industry.

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