Artículo de investigación

The investigations of binder for investment casting

Las investigaciones del aglutinante para el casting de inversión
As investigações de ligante para fundição de investimento

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Abstract

The paper presents a study of binders of different composition for investment casting, which are safe from the point of view of ecology and safety for human life and health, have a long life-span, stable properties, provide increased gas permeability of forms and a lesser tendency to cracking, and as a result, ensure the production of quality castings. The proposed binder can be used on a par with the traditional, if you introduce spirit into it as a solvent. The introduction of acetone is impractical, because it promotes gelation of the solution, which makes it difficult to continue working with the binder. The gelling process is the coalescence of colloidal particles which causes an increase in the viscosity of the solution. The proposed binder has the following advantages over the traditional ones: it is water-based, non-flammable, non-toxic, environmentally safe; suspensions based on them have longer vitality, more permanent properties and require minimal maintenance; provide increased gas permeability of forms and their less tendency to cracking.

Keywords: casting, investment casting, binder, ethyl silicate, surface quality of castings.

Resumen

El artículo presenta un estudio de los aglutinantes de diferente composición para la fundición de inversión, que son seguros desde el punto de vista de la ecología y la seguridad para la vida y la salud humanas, tienen una vida útil prolongada, propiedades estables, proporcionan una mayor permeabilidad al gas de las formas y una menor tendencia al agrietamiento, y como resultado, asegura la producción de piezas fundidas de calidad. El aglutinante propuesto se puede usar a la par con el tradicional, si se introduce el espíritu como un disolvente. La introducción de la acetona es poco práctica, ya que promueve la gelificación de la solución, lo que dificulta el trabajo continuo con el aglutinante. El proceso de gelificación es la coalescencia de partículas coloidales que causa un aumento en la viscosidad de la solución. El aglutinante propuesto tiene las siguientes ventajas sobre los tradicionales: es a base de agua, no inflamable, no tóxico, seguro para el medio ambiente; las suspensiones basadas en ellas tienen una mayor vitalidad, propiedades más permanentes y requieren un mantenimiento mínimo; proporcionan mayor permeabilidad al gas de las formas y su menor tendencia al agrietamiento.

Palabras claves: Fundición, fundición de inversión, ligante, silicato de etilo, calidad de la superficie de las fundiciones.

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Resumo

O trabalho apresenta um estudo de ligantes de diferentes composições para fundição, que são seguros do ponto de vista da ecologia e segurança para a vida e saúde humanas, possuem longa vida útil, propriedades estáveis, proporcionam maior permeabilidade a gases de formas e menor tendência a rachaduras e, como resultado, garantir a produção de peças fundidas de qualidade. O fichário proposto pode ser usado em pé de igualdade com o tradicional, se você introduzir o espírito nele como um solvente. A introdução de acetona é impraticável, pois promove a gelificação da solução, o que dificulta continuar trabalhando com o aglutinante. O processo de gelificação é a coalescência de partículas coloidais que causa um aumento na viscosidade da solução. O aglutinante proposto tem as seguintes vantagens em relação às tradicionais: é à base de água, não inflamável, não-tóxico, ambientalmente seguro; suspensões baseadas neles têm maior vitalidade, propriedades mais permanentes e requerem manutenção mínima; proporcionam maior permeabilidade a gases das formas e menor tendência a rachaduras.

Palavras-chave: Fundição, fundição, aglutinante, silicato de etila, qualidade superficial de fundidos.

Introduction

The method of investment casting is a universal method of obtaining industrial and artistic castings of any size, weight and complexity from metals of any brand. Advantages of the method make it possible to approximate the casting to the finished product maximally, and in some cases to obtain it without mechanical treatment. Therefore, the method of investment casting is often used in turbine construction, mechanical engineering and where surface accuracy plays a huge role in the work of the most important details (Golovin, 2011; Yarushin, 2014; Kukuy, 2013).

The mold is obtained by layer-by-layer application of the suspension onto the model block, by sprinkling each layer with refractory sand followed by its drying (hardening). The number of layers depends on the quality of the suspension, the dimensions of the model unit and is usually four or more. Binders are used for the manufacture of shell forms. They turn into films of refractory oxides that firmly join the grains of the molding material as a result of chemical and physical processes during the drying of the layers and the calcination of the shell. In the initial state all used binders are liquids that should form stable suspensions when mixed with powders of a refractory base, wet the surface of models well without interacting with the model composition, dry as quickly as possible and harden on the surface of the model blocks without undergoing significant shrinkage and forming durable films with a high degree of adhesion to the surface of the refractory grains. These films should not form low-melting eutectics with the base material and weaken during calcination and also the pouring of shells. It is desirable that after solidification of the castings such softening occurs either spontaneously or when exposed to easily accessible means without compromising the quality of the castings (for example, under the action of water, steam, hot solutions of alkalis and vibration). Binders should be suitable for long-term storage, free from toxic and explosive substances, as well as from products capable of spontaneous combustion and be as cheap as possible. Most of these requirements are met by hydrolyzed organosilicon product solutions of ethyl silicate. Thus, ethyl silicate is a complex liquid consisting of a mixture of tetra-ethoxysilane and polymers formed as a result of hydrolytic polycondensation of the polymers, as well as the interaction products of ethoxysilanes with hydrogen chloride released during the esterification process of $SiCl4$. These products are subsequently hydrolyzed and the chlorine in them is replaced by hydroxyl groups.

The suspension consists of a binder fluid and a pulverized refractory material. In the industrial technology of investment casting various compositions of suspensions with various binders (hydrolysed ethylsilicate, liquid glass, silica, metallophosphates) are used (Kukuy et al, 2013; Gini et al, 2005).

Problem Statement

Ethyl silicate is a poor binder. It is necessary to convert the ethyl silicate to a colloidal state with its subsequent transformation into a sol for the formation of a solid mass that binds the filler grains. The conversion of ethyl silicate to sol is carried out by hydrolysis, in which the ethoxy groups are partially or completely replaced by hydroxyl groups. The result is a solution with a coagulation structure with plastic-viscous properties. The structures with resiliently brittle properties are formed and developed as moisture is removed. The solution turns into a gel with the gradual removal of water. A crystalline structure can be detected in the silicic acid gel after drying and calcining.

Now they try to replace ethyl silicate with modern binders, for example, Armosil, Ludex, etc. Ready binders like Armosil have the following advantages in comparison with ethylsilicate:

– they are water-based, non-flammable, non-toxic, ecologically safe;
– suspensions based on them have a longer lifetime, more permanent properties and require minimal maintenance;
– provide increased gas permeability of forms and a lesser tendency to cracking (Ivanov & Kazenov, 1984).

The drying of the water-based Armosil binder must be very intensive, because the binder itself dries for a long time, and a layer of cindery material may settle, as well as the appearance of surface defects. From the comparison chart for the drying of Armosil binders and ethylsilicate (fig. 1), it is evident that the forms based on the aqueous binder dry longer than the ceramic shells based on ethyl silicate. However, to accelerate the drying process, it is possible to introduce solvents, for example acetone or spirit.

Inadequate wettability by silicasols of domestic production of model compositions leads to the need for suspensions with ethyl silicate for the first layer applied to the model block. To increase the wettability of silicasols, surface-active substances are introduced into its composition, which in turn requires addition of antifoam additives (Safronov et al, 2015).

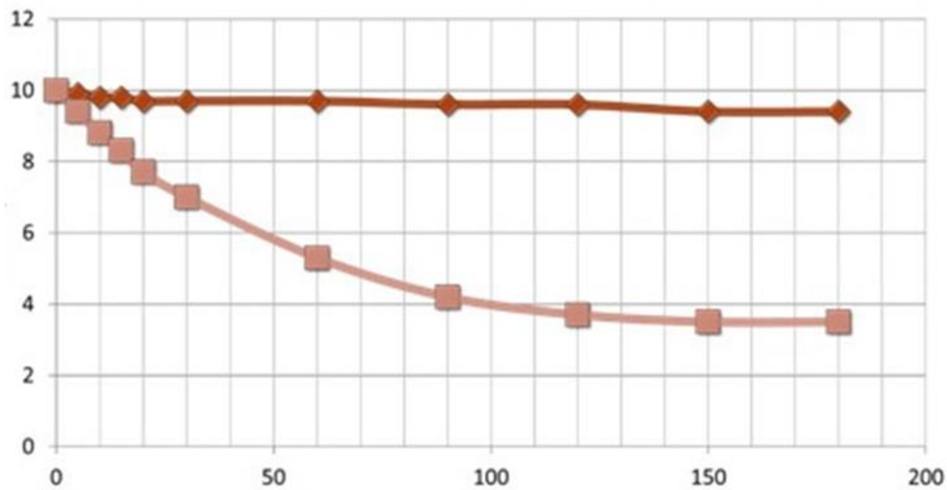

Figure 1. Change in mass (gr) depending on the duration of drying (min) of Armosil and ethylsilicate

In the work to increase the wettability it is proposed the introduction of solvents in the composition of silicasols, which moisturize the model compositions in combination with surfactants.

Particular attention should be paid to the evaporation processes of the binder. Dried form is a very critical indicator. The application of layers with insufficient drying of previous coatings leads to the destruction of the shape when the model composition is cut out.

Experimental Results and Discussion

The experiments were carried out during which the kinetics of evaporation processes of various binders was studied: ethylsilicate and Armosil and the influence of these solvents on these processes.

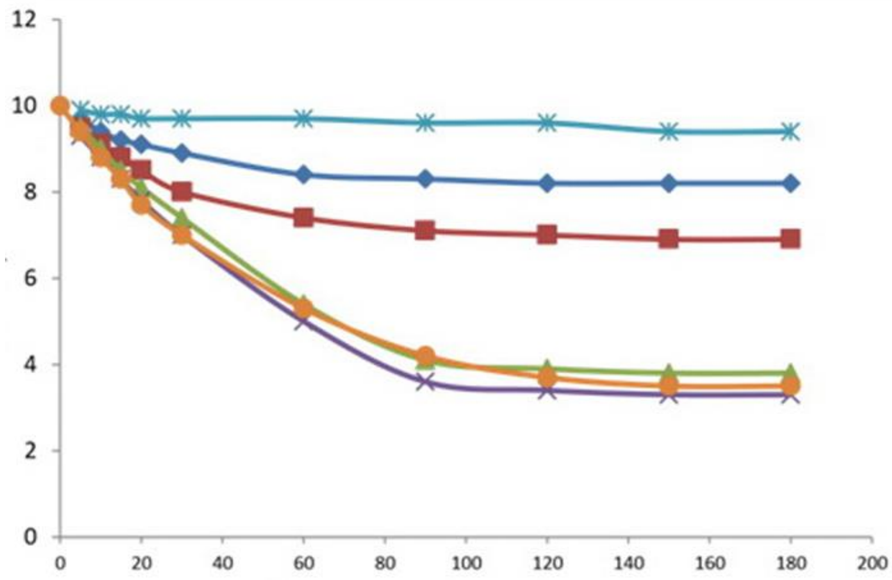

Figure 2. Change in weight (gr), depending on the duration of drying (min)

Armosil + 20% of the solvent;

Armosil + 40% of the solvent;

Armosil + 60% of the solvent;

Armosil + 80% of the solvent;

Armosil»;

Ethylsilicate

It was found (fig. 2) that the process of evaporation of pure Armosil is several times longer and, the more the solvent is introduced, the faster the drying process takes place. It is possible to replace ethyl silicate with Armosil" for the suspension applied to the model block of the first layer, if it is additionally injected with acetone or another solvent. Acetone evaporates rapidly, and as it is shown in the work (Yemelyanov et al, 2010), the proportion of the filler increases, and the viscosity of the suspension with the marshalite increases. This leads to an improvement in the surface quality of the first mold layer and, as a consequence, to the high quality of the casting surface.

The flow out of the binder is an important parameter, because there is no good wettability of the model without good spreadability, which results in poor quality castings. Figure 3 shows the Armosil spreading schedule depending on the addition of the solvent: the more the solvent is introduced, the larger the droplet diameter is. For example, if the droplet diameter was 8 mm in the absence of a solvent, when the 20% solvent is introduced into Armosil, the droplet diameter reaches 14 mm, i.e. spreading almost doubles. And the wettability of the binder models increases the same.

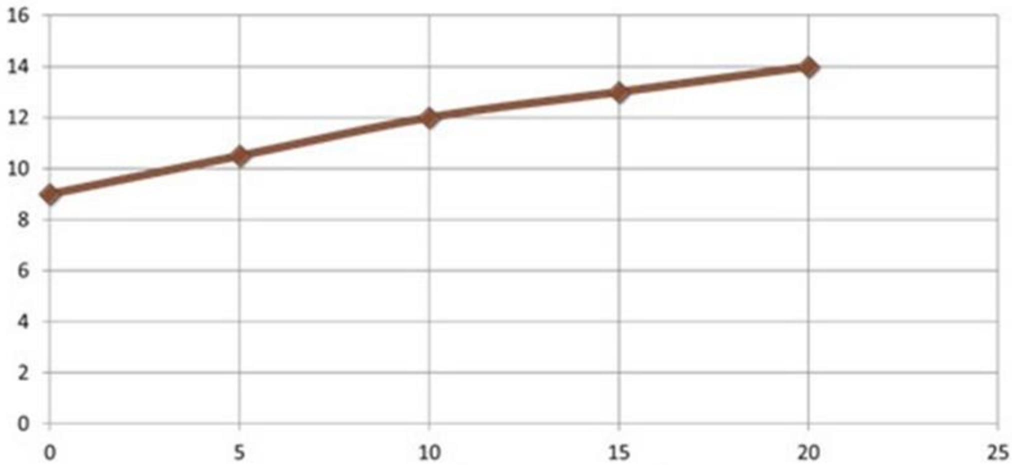

Figure 3. Flowability of Armosil (droplet diameter in mm) depending on the amount of solvent in percentage

Viscosity is one of the very important properties of the liquid state of matter. One can judge structural changes in the liquid by the nature of the change in viscosity. In this paper the Stokes method is used from the numerous methods for determining the viscosity, which is based on measuring the velocity of a ball falling in the liquid under the study.

Calculation formula for viscosity:

$$\eta = \frac{2}{9} \cdot \frac{\rho_1 - \rho_2}{V_0} \cdot r^2 \cdot g$$

where: ρ1 – the density of the ball material; ρ2 – the density of the liquid; r – the radius of the ball; g – acceleration of gravity; V0 = L / τ – the velocity of the ball in the fluid; L – the length of the path that the ball passes; τ – the time of passage of the path by the ball.

As a result of the study, it was found that the viscosity of Armosil binder without the addition of a solvent (0.99×10-3 Pa·s) is close in value to the viscosity of water (1.02×10-3 Pa·s).
The viscosities of the Armosil binder with the solvent were measured.

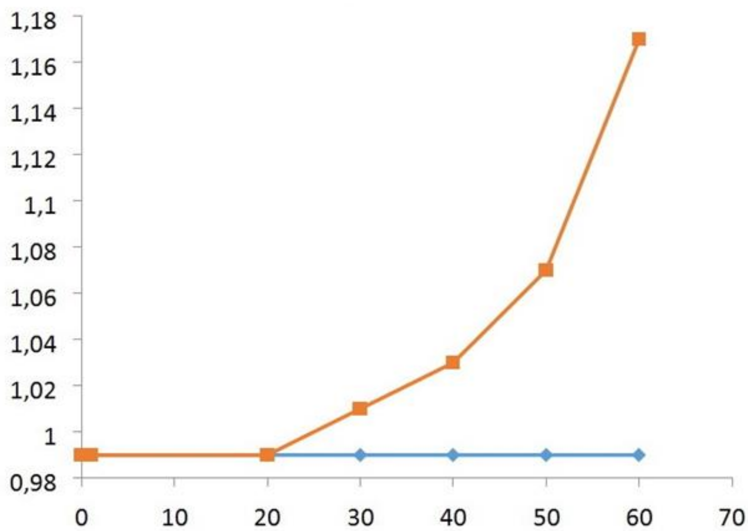

Figure 4. The dependence of viscosity (Pa·c) on time (min):
Armosil with 10% solvent —■— —◆—Armosil

It was found that when a 10% solvent is introduced into Armosil, the viscosity remains unchanged for 20 minutes (0.99×10-3 Pa·c), and then the viscosity increases to 60 minutes from 1.01×10-3 Pa·c to 1.17×10-3 Pa·c (fig. 4). This is due to the fact that the internal reconstruction of the aqueous solution of Armosil first occurs. Then the process of gelling begins, which is a coalescence of colloidal particles, enlargement of their dimensions, which leads to an increase in the viscosity of the solution. Thus, it can be concluded that it is possible to use Armosil as a binder with the addition of a solvent in the manufacture of castings by investment casting.

The study of the surfaces of forms on the basis of various binders was carried out. It is established that the use of "Armosil"is possible, but it is best to do the first layer on the basis of ethylsilicate, because the surface quality for ethylsilicate is better than for "Armosil". The granulometric composition of the filler of the refractory suspension and the covering material for all refractories was the same. Powders 5...50 microns, a covering of 0,16...1 mm for the first and fourth layer respectively. The graphs show that the initial permeability is different.

Figure 5. Microstructure of the surface of shell molds (×60): a) Armosil, b) Ludex c) ethylsilicate

The microstructure of the ethyl silicate surface has a lower roughness than Armosil and Ludex (fig. 5). This is due to the better wettability of the surface. Armosil and Ludex have practically identical data on the strength of forms (Yemelyanov, 2010). The contact surface of a ceramic mold based on Ludex is covered by pores by 40-50%. The pore size is from 20 to 100 µm. The pores of about 50 µm predominate. The pores are round in shape. The stretched pores are often curved, although they have a short length. The pores are placed from each other approximately at the same distance.

The contact surface of ceramic molds based on the Chinese binder GN-25 +10% latex is shown in fig. 6.

Figure 6. Contact surface of a ceramic mold based on a Chinese binder GN-25 (25% SiO_2 content) + 10% latex and quartz sand (×60)

The surface is covered with pores much less than the surface of the molds on the Ludex. The amount of pores occupies about 30% of the surface. The pore size is much smaller and is from 5 to 20 µm. The pores with a size of about 10 µm predominate. Pores also have a generally rounded shape. The stretched pores are curved, although they have a short length. The pores are placed from each other approximately at the same distance.

It was found that when the addition of 20% spirit as a solvent in an aqueous solution of silica powder, the surface quality of the shells on the Armosil binder is improved. In Fig. 7 shows the microstructure of the shell surface on Armosil with 20% spirit (Yakovleva et al, 2016; Safronov et al, 2017a; Safronov et al , 2015; Safronov et al, 2017b; Safronov et al, 2016).

Figure 7. Microstructure of the shell surface on Armosil with 20% spirit.

Conclusions

From fig.7 that the surface quality is very high, the roughness is small, therefore Armosil can be used on a par with ethylsilicate if a solvent, for example, spirit is introduced into it. The introduction of acetone is impractical, because it promotes gelation of the solution, which makes it difficult to continue working with this binder. When the gelling process begins, which is the coalescence of colloidal particles, the enlargement of their dimensions, the viscosity of the solution increases, which degrades the technological properties of the mixture.

Acknowledgements

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