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SYNTHESIS OF PHOSPHOSULPHATE SUBSTANCE AND PROPERTIES OF ITS STRUCTURED MIXTURE WITH QUARTZ SAND

Purpose. Creation of binder based on orthophosphoric acid and aluminum sulfate, study on its structure and physicochemical patterns of formation, determination of the properties of structured mixtures for the needs of foundry.

Methodology. In the work, X-ray qualitative and quantitative analysis was performed on the Rigaku Ultima IV unit, and differential thermal analysis was performed on the STA 449 C Jupiter synchronous thermal analyzer. Orthophosphoric acid, technical thermal, of 85 % concentration, 18-hydrous sulfate of aluminum $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ and quartz sand of brand 3K₅O₃025 were used. The strength of core mixtures was determined on the US-700 unit on standard cylindrical samples with a diameter and height of 50 mm. The roughness of the cast surfaces was determined on a profilometer model 107622 with computer processing of the obtained data and construction of profilograms. To determine the propensity of the core mixtures to form caking, a hexagon sample was used according to the method by M. Fedorov. Breakability was determined on standard cylindrical samples with a diameter and height of 50 mm according to the original method described in the text of the article.

Findings. For the first time, the mechanism of formation of aluminum phosphates with binding properties during the interaction of aluminum hydrate crystal sulfate $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ with orthophosphoric acid in the temperature range of 100–200 °C has been investigated. The formation is proved of an intermediate phase during heating – aluminum hydroxide $\text{Al}(\text{OH})_3$, which, in contrast to its sulfate, according to the results of thermodynamic analysis is able to interact with acid. Formation of aluminum in the system of ortho- and metaphosphates, which features binding properties and ensures high strength of samples based on quartz filler, has been established. The thermal transformations of the obtained binder, which consists of a combination of aluminum phosphates with its residual sulfate, are studied. Stages of gradual disintegration of crystal hydrates, formation of new aluminum phosphates and thermal decomposition of residual sulfate are recorded. The tendency to burn and knockout of the developed core mixtures was determined.

Originality. For the first time, a description has been developed of the mechanism of formation of aluminum phosphates with binding properties during the interaction of its sulfate crystal hydrate $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ with orthophosphoric acid in the temperature range of 100–200 °C.

Practical value. A new inorganic binder from orthophosphoric acid and 18-aqueous aluminum sulfate has been obtained for foundry production. The scheme of its preparation involves preliminary mixing and heating of the specified reagents with the resulting formation of a dry powder material which consists of phosphates and residual aluminum sulfate, and therefore it is called phosphosulfate. The binding has a long shelf life and is introduced into the mixture in a ready-made form while the technology of its production is less energy-intensive and long-lasting compared to the preparation of traditional metal phosphate binding.

Keywords: *binding, foundry core, orthophosphoric acid, aluminum sulphate, thermogravimetric analysis, phase analysis, aluminum phosphate*

Literature review. Foundry production is the basis of modern engineering and many other industries [1, 2]. Improving the quality and competitiveness of cast parts from traditional and new alloys [3], including composite ones [4, 5], is impossible without technical progress in developing molding materials and improving their properties.

The development of new binders and improvement of already known inorganic ones is relevant from a scientific and practical point of view [6, 7]. In recent years, interest has increased again in phosphate materials, the study on which began in the middle of the twentieth century. The most important scientific results belong to scientists of Massachusetts Institute of Technology – the work by D. Kingery and colleagues (USA, 1950, 1976) and Leningrad Technical Institute – the work by M. M. Sychev (1974), S. L. Golinko-Wolfson (1968), L. G. Sudakas (2008).

Phosphate binder materials, in particular new and improved forms, are used in many technical fields. For example,

a complex binder modified with aluminum, silicon and iron has found application in construction [8], aluminum phosphates – for the manufacture of porous ceramics based on silicon carbide [9].

The combination of such properties as high mechanical strength, thermal and chemical resistance, the ability to regulate curing processes with the formation of crystalline or amorphous structure led to the use of phosphate materials in the most extreme conditions, in particular for the manufacture of refractory products and casting cores.

Refractory products based on aluminosilicate filler and aluminophosphate or aluminum magnesium-phosphate binder are characterized by thermal stability of 1,400–1,600 °C [10, 11]. The addition of phosphates to calcium aluminate cement increases the strength and thermal stability [12].

By-products of other industries are often used to create phosphate compositions that harden when heated or at normal temperature [13, 14], in particular multicomponent inorganic materials [15].

The basis of the vast majority of complex phosphate binders is aluminum [16, 17]. However, the processes of prepara-

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tion of these binders are long and multi-operational, which increases the cost of finished products. In foundry production, where the use of materials is very significant, this is an important economic factor. Therefore, there is a need to simplify the process of synthesis of phosphate binders for foundry production.

Known schemes for the synthesis of phosphate binders converge on the fact that aluminum hydroxide is added to orthophosphoric acid, as well as oxides of chromium, magnesium, zinc, iron, etc. These technologies were introduced in the 70–80s of the twentieth century, but the latest developments in the field of molding materials [18, 19] and refractory products [20] are based on the same schemes.

A fundamentally new direction is the study on the interaction of orthophosphoric acid with inorganic salts of metals, primarily aluminum, in order to develop new schemes for the synthesis of phosphate binders. There is no such data in the literature.

Purpose. The purpose of our study is to create a binder based on orthophosphoric acid and aluminum sulfate, to study its structure and physicochemical patterns of formation, to determine the properties of structured mixtures for the needs of foundry production.

Research objectives are:

1. To analyze chemical and thermodynamic conditions of interaction of orthophosphoric acid H_3PO_4 with aluminum sulfate. To establish the theoretical preconditions for the synthesis of the phosphate binder in this system.

2. To investigate the chemical and phase composition of products formed after the interaction of orthophosphoric acid with aluminum sulfate.

3. To analyze the changes in the chemical and phase composition of the synthesized binder under heating conditions from 20 to 1,000 °C and to predict the possibilities of its use in the composition of molding and core mixtures for foundry production.

4. To check the developed core mixture in the conditions of practical application. To establish the complexity of extracting cores and quality parameters of cast surfaces of castings from iron-based alloys.

Methods and materials. A number of physicochemical methods for studying the structure and properties of materials are used in the work.

X-ray phase qualitative and quantitative analysis was performed on the installation “Rigaku Ultima IV”.

Differential thermal analysis was performed on a synchronous thermal analyzer “STA 449 C Jupiter”.

Orthophosphoric acid technical thermal of 85 % concentration was used. As the second component for the synthesis of

the binder in the work, 18-hydrous aluminum sulfate $Al_2(SO_4)_3 \cdot 18H_2O$ was used.

The strength of the core mixtures was determined on the installation of US-700 on standard cylindrical samples with a diameter and height of 50 mm.

The roughness of the cast surfaces was determined on a profilometer model 107622 with computer processing of the obtained data and construction of profilograms.

To determine the tendency of the core mixtures to the formation of burns technological test by M. Fedorov was used, which is a casting with different wall thicknesses from 5 to 40 mm, the sample scheme is shown in Fig. 1, a.

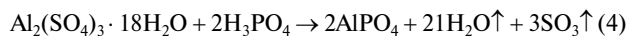
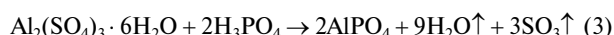
The knockout was controlled by the total work of extracting a standard cylindrical sample of a core mixture with a height and a diameter of 50 mm from a technological sample on a laboratory impact machine, whose scheme is shown in Fig. 1, b.

The work of knocking out was determined by the following formula

$$A = N \cdot m \cdot g \cdot h, \quad (1)$$

where A is work of knocking out the sample, J; N is the number of strokes of the copra spent on knocking out the sample; m is weight of the load, $m = 6.35$ kg; g is acceleration of gravity, $g = 9.81$ m/s²; h is the height of the fall of the load in the impact machine, $h = 0.05$ m.

Results. A prerequisite for the creation of a new inorganic binder is the study on physicochemical processes in the system of orthophosphoric acid and aluminum sulfate. Common forms of this inorganic salt are ordinary (anhydrous), as well as crystal hydrates with different numbers of moles of H_2O . At the initial stage, the isobaric-isothermal potential (Gibbs energy) for the following chemical reactions was analyzed



The change in Gibbs energy is calculated for normal conditions (293 K), as well as for reactions when heated to 200 °C (or 473 K) and 300 °C (or 573 K). Data [21] and the general formula were used for calculations

$$\Delta G = n_1 \cdot AlPO_4 + n_2 \cdot H_2O + n_3 \cdot SO_3 - n_4 \cdot Al_2(SO_4) - n_5 \cdot H_3PO_4 \quad (2)$$

where n_1 – n_5 are stoichiometric coefficients in the chemical reaction.

The results of calculations are shown in Fig. 2.

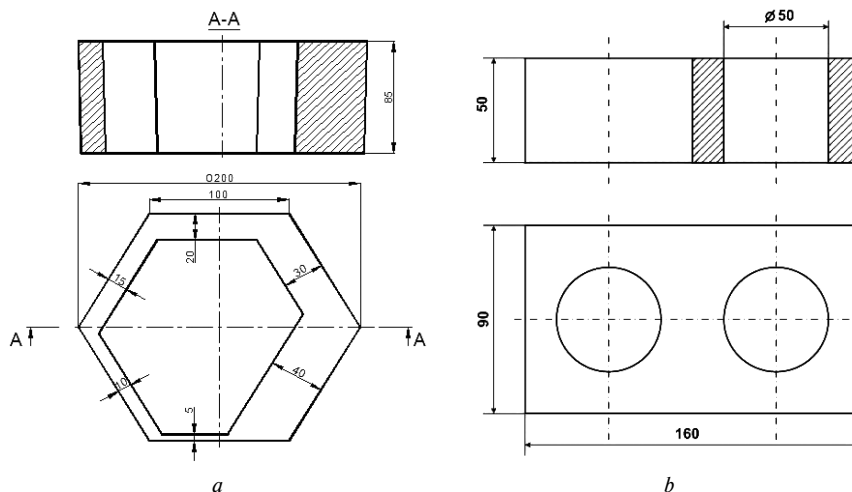


Fig. 1. Technological samples for the determination of the stability of the molding and shearing sums before burnout (a) and the work of shearing from cast parts (b)

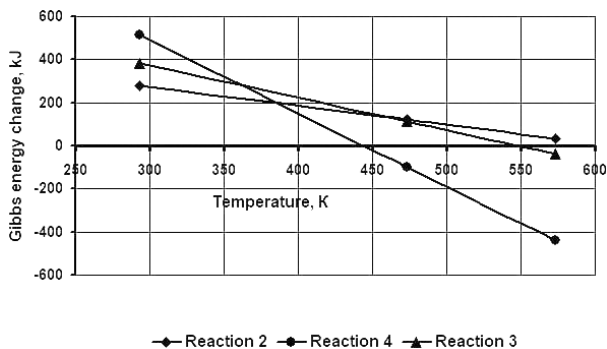


Fig. 2. Gibbs energy change in the range from 293 to 573 K for the reactions of interaction of aluminum sulfate with orthophosphoric acid

It was found that anhydrous aluminum sulfate cannot react with orthophosphoric acid in the considered temperature range. 18-hydrate sulfate is able to interact when heated in the range of 150–200 °C. Therefore, 18-hydrate aluminum sulfate was used in the experiments.

The experimental mixtures were prepared in two different ways. According to the first, they contained 3 % aluminum sulfate, 3 % orthophosphoric acid (85 % solution) and 2 % water. In this case, the addition of water is designed to simplify the process of making samples, reducing adhesion to the equipment.

According to the second method, aluminum sulfate (5 mass parts) and orthophosphoric acid (1 mass part) were mixed separately and kept for 1 hour at a temperature of 200 °C. The composition obtained after cooling was added to the mixture in an amount of 5 %, and 5 % water was added. In this mixture, the water ensures the dispersion of the dry composition in the volume of the mixture and the creation of adhesive bonds with the filler.

Standard cylindrical samples were made, which were kept at normal temperature, and also subjected to thermal drying at 100, 150 and 200 °C, after which the compressive strength was determined.

It is established that in the temperature range of 150–200 °C the samples of the mixture are strengthened, as evidenced by the course of the dependences in Fig. 3. In this case, regardless of the method of preparation, almost the same result is achieved in terms of strength.

Achieving a fairly high strength makes it possible to create a core mixture on the basis of this system. Accordingly, this sets the task of a deeper study on physicochemical processes in the system.

To determine the composition of the products of interaction between the components, X-ray phase analysis was per-

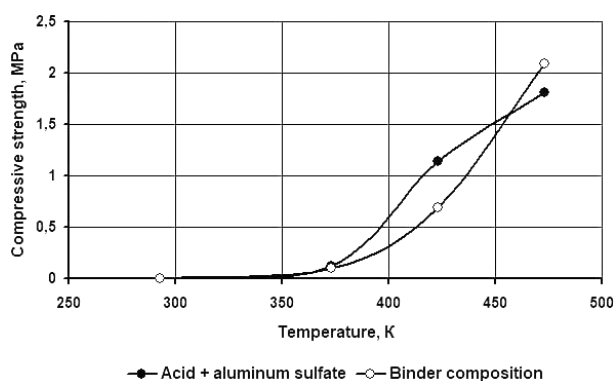


Fig. 3. The compressive strength of the samples of the mixture with orthophosphoric acid and aluminum sulfate depending on temperature

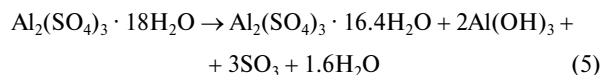
formed. The object of this study is a composition of 10 mass parts of aluminum sulfate $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ and 1 mass part of orthophosphoric acid with 85 % concentration. After mixing these components, the sample was kept in an oven at 200 °C for 1 hour.

The diffractogram of the composition is shown in Fig. 4.

According to the results of X-ray phase analysis, a number of new phases were identified in the composition, including those that have binding properties. In addition to the actual aluminum sulfate $\text{Al}_2(\text{SO}_4)_3 \cdot 16.4\text{H}_2\text{O}$, which differs from the original sulfate $\text{Al}_2(\text{SO}_4)_3 \cdot 18\text{H}_2\text{O}$ by the number of moles of water, two types of aluminum phosphates and aluminum hydroxide were found, which may be the product of partial decomposition of crystalline sulfate. Therefore, both aluminum phosphates and its residual sulfate, which predominates in the sample (78 %), obviously perform the role of a binder here.

From the analysis of the results of the performed research studies it is seen that at the first stage there was a partial decomposition of crystal hydrate aluminum sulfate. A similar process is described in the work by Kogan B. S., et al. (2005), which investigated all forms of existence of crystal hydrates of this salt and showed that 16.4-hydrate sulfate does exist, and the complete separation of all 18 moles of crystal hydrate water occurs gradually in a wide temperature range from 86.5 to 420 °C.

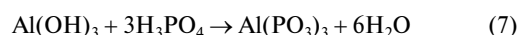
In this case, the chemical reaction is as follows



Using the molar masses of the components in reaction (5), it can be calculated that the decomposition of 1332 mass parts of 18-hydrate sulfate produces 637 mass parts of 16.4-hydrate sulfate and 210 mass parts of aluminum hydroxide.

Aluminum sulfate does not interact with orthophosphoric acid, as established thermodynamically. However, aluminum hydroxide at a temperature of 90–110 °C can interact with it. This principle is the basis for the preparation of well-known metal-phosphate binders.

Analyzing the phase composition of the sample, we conclude that the binding in the test sample were formed by reactions



For complete reactions (6 and 7) on 105 mass parts of hydroxide, 98 and 294 mass parts of H_3PO_4 are required, respectively. In the test sample, 210 mass parts of hydroxide (formed

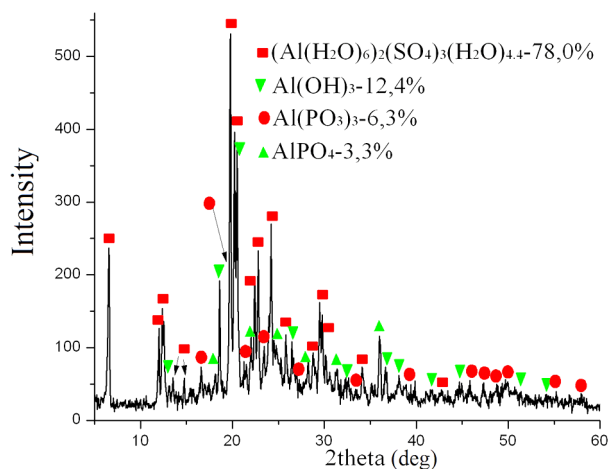


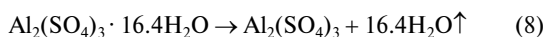
Fig. 4. Diffractogram of the composition of aluminum sulfate (10 mass parts) with orthophosphoric acid (1 mass part) after exposure to 200 °C

by reaction 4) account for only 133 mass parts of acid (1/10 of the amount of 18-hydrus aluminum sulfate), and taking into account the concentration – 112 mass parts of H_3PO_4 . Therefore, the aluminum hydroxide was in excess and could not fully react. This explains the fact that it was found in the sample (Fig. 4) together with aluminum phosphates.

After transformations (5, 6 and 7) the composition of the sample (by phase analysis) is as follows: 780 mass parts (or 78.0 %) of 16.4-aqueous sulfate, 124 mass parts (12.4 %) of hydroxide, 63 mass parts (6.3 %) of metaphosphate and 33 mass parts (3.3 %) of aluminum orthophosphate. Since the binder contains two types of inorganic salts (phosphates and sulfates), it should be assigned to a new class, previously unknown in the foundry industry – **phosphosulfate binder**.

In order to obtain information on the transformations in this binder during heating, differential thermogravimetric analysis (DTGA) of the same sample was performed. The results of DTGA composition of aluminum sulfate (10 mass parts) with orthophosphoric acid (1 mass part) after exposure to 200 °C are presented in Fig. 5.

Analysis of the data in Fig. 5 shows that aluminum hydrate crystal sulfate gradually loses moles of bound water as the temperature increases. At the same time, this process takes place in several stages (two large endothermic effects and one with insignificant intensity were detected on the DSC curve). In reality, these transformations should occur during the strengthening of the cores in the box (200–250 °C), i. e. they will not affect the quality of castings. In general, this process can be described by the equation



By the molar ratios of the components in reaction (8), we see that from 637 mass parts of crystal hydrate aluminum sulfate, 342 mass parts of anhydrous aluminum sulfate and 297 mass parts of H_2O are formed. Accordingly, in our case, from 780 mass parts of crystal hydrate, 417 mass parts of anhydrous sulfate and 363 mass parts (or 36.3 %) of H_2O are formed. The total weight loss along the DTG curve is 14.7 + 13.3 + 3.29 = 31.29 %, which is close to the calculated data.

The results of the phase analysis of the sample after heating to 400 °C (i. e. after the completion of all these transformations) are shown in Fig. 6.

Phase analysis shows the absence of crystal hydrates, as well as the absence of aluminum metaphosphate. Only orthophosphate is present in the sample. Thus, the transformation (8) did occur, but after it, given the presence of aluminum hydroxide in the sample, there is still a process of mutual conversion of phosphates

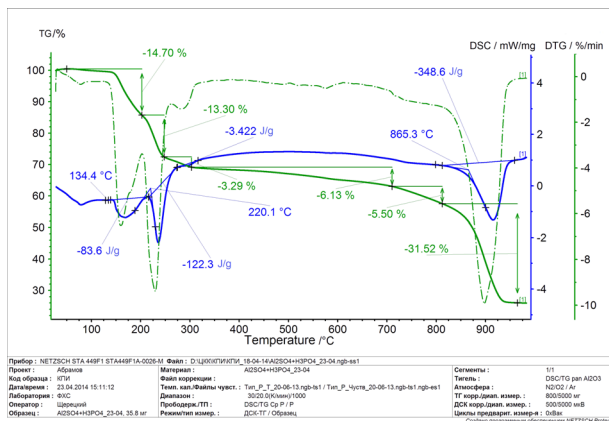
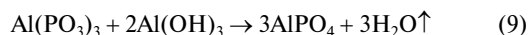


Fig. 5. DTGA composition of aluminum sulfate (10 mass parts) with orthophosphoric acid (1 mass part) after exposure to 200 °C

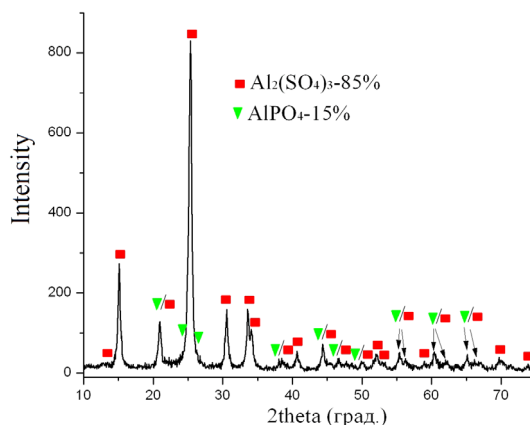
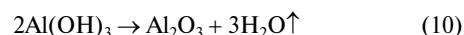


Fig. 6. Diffractogram of the composition of aluminum sulfate (10 mass parts) with orthophosphoric acid (1 mass part) after exposure to 400 °C

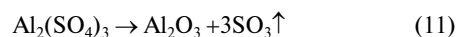
By molar ratios, we see that 264 mass parts of aluminum metaphosphate must react with 210 mass parts of aluminum hydroxide, which would result in 366 mass parts of aluminum orthophosphate and 54 mass parts of H_2O . In our sample there are only 63 mass parts of aluminum metaphosphate, so only 50 mass parts of hydroxide react, and there are 124 – 50 = 74 mass parts of $Al(OH)_3$. The result is 87 mass parts of aluminum orthophosphate and 13 mass parts of H_2O .

After transformation (9), aluminum hydroxide should remain in the sample, but it was not detected (Fig. 6), so it obviously disintegrated by the reaction



However, aluminum oxide was not detected by X-ray phase analysis. Apparently, it was completely converted to $AlPO_4$ phosphate. In this case, the stoichiometric relationship between aluminum and phosphorus will be violated, but such examples are widely known. For example, the TiS compound, depending on the conditions of formation, may contain from 1.0 to 0.3 titanium atoms, as shown in reference books by Samsonov G. V., (1963, 1970), Kosolapova T. Ya. (1968). Therefore, the formation of aluminum-saturated orthophosphate is quite likely.

Significant endothermic effect at a temperature of 865 °C is associated with thermal destruction of aluminum sulfate



According to the website wikipedia, this process should take place at 580 °C. In our case, the binder is complex – phosphosulfate. Aluminum phosphate acts as a mineralizer, significantly increasing the decomposition temperature of the sulfate component. From the casting point of view, this is very important: increasing the decay temperature of aluminum sulfate significantly reduces the gas evolution of the cores, in contrast to the sulfate binder.

The weight loss according to the DTG curve at 865 °C is 31.52 %, which confirms the implementation of reaction (11) with the release of a significant amount of gaseous product.

After the final conversion, only aluminum oxide and aluminum phosphate should remain in the sample. However, as follows from the diffraction pattern of the sample pre-calcined to 1,000 °C, shown in Fig. 7, there is no aluminum oxide in the sample. This means that all aluminum is contained in the supersaturated (non-stoichiometric) orthophosphate.

Therefore, it was found that the binder is formed not by direct interaction of aluminum sulfate with acid, but due to the formation of aluminum hydroxide, which is a by-product of the partial decomposition of sulfate during heating. It is aluminum hydroxide that reacts with phosphoric acid and forms a binder in the form of aluminum phosphates.

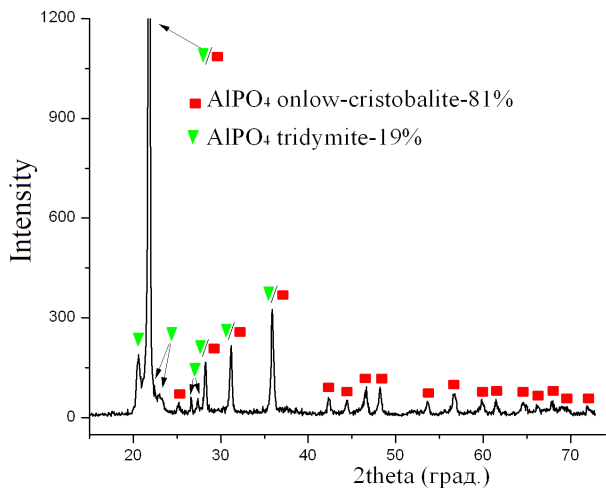


Fig. 7. Diffractogram of the composition of aluminum sulfate (10 mass parts) with orthophosphoric acid (1 mass part) after exposure to 1,000 °C

Foundry cores work in conditions of comprehensive heating, so most of the analyzed transformations can occur as part of the core mixture.

The release of gaseous products is undesirable, but it occurs mainly in the region up to 250 and more than 850 °C. Strengthening the cores in the equipment eliminates the risk of gaseous products due to the decomposition of crystal hydrates. In turn, only the surface layers of the cores are heated to 850 °C, and with sufficient gas permeability of the mixture, the formed gases can be easily removed into significant parts and further into the mold. Thermal decomposition of aluminum sulfate should reduce the residual strength of the mixture and significantly improve the knockout of the cores.

The phosphosulfate binder is used to make casting cores. Based on the data in Fig. 3, it provides a sufficiently high strength in combination with a refractory filler. But for the foundry technology, the required properties are also high thermal resistance, low chemical activity to the poured metal, as well as minimal work of extracting cores from cast parts.

The composition of the core mixture includes river quartz sand $3K_5O_3O_{25}$ (95 mass parts) and phosphosulfate binder (5 mass parts). The cores are dried at a temperature of 200 °C to give them strength.

The study on the developed core mixtures on the tendency to burn is carried out using technological tests, the appearance of which is shown in Fig. 1, a. The molds were filled with cast iron, which crystallized by a metastable system, i.e. with the formation of free cementite. The pouring temperature is

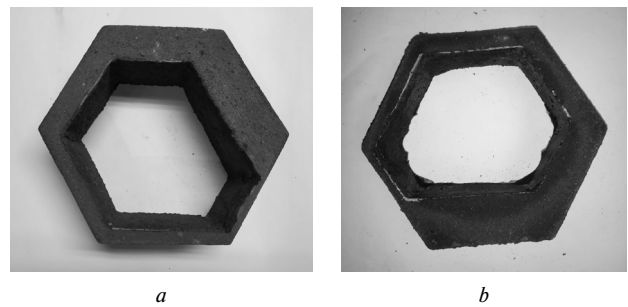


Fig. 8. Cast iron castings made using foundry cores with developed binder

1450 °C. The choice of alloy and its temperature is made in order to create the most dangerous conditions for the formation of burns.

The work of knocking out the cores from the castings was determined by the technological breakdown (Fig. 1, b), which is a prismatic casting with two cores with a diameter of 50 mm.

As a result of experimental fillings, it was found that the phosphosulfate binder is mainly resistant to physicochemical interaction with the melt. This is evidenced by the absence of burns on the inner surfaces of the castings (Fig. 8).

The extraction of cores from castings, as experiments showed, does not require any effort. The samples were removed from the technological breakdown already after the first impact of the impact machine, so that the work of knocking out is minimal – within 3 J. This is due to the phase transformations of the developed binder during heating: the decomposition of the sulfate component at 865 °C really ensures the low residual strength of the cores.

The roughness of the cast surfaces was determined on a profilometer model 107622 on samples obtained from parts of hexagonal technological breakdowns (Fig. 8) with a wall thickness of 20 mm. Three control measurements of roughness were performed, the length of the measuring section was 3–4 mm. Obtained data: 35.7; 38.1; 25.4 μm on the Ra scale. The average value is 33.1 μm , which corresponds to 14 degree of surface accuracy and 2 class of roughness according to GOST 26645-85.

In the end, the core mixture with the developed binder makes it possible to make castings with a length of 200 mm with holes with a diameter of 16 and 24 mm, photos of which are presented in Fig. 9. The cores were easily removed from the internal cavities, which could not be done using other inorganic binders.

Practical value. A new inorganic binder of orthophosphoric acid and 18-hydrous aluminum sulfate was obtained for foundry production. The scheme of its preparation involves pre-mixing and heating of these reagents with the formation of a dry powder material, which consists of phosphates and



Fig. 9. Castings made using the developed core mixture:

a – steel 30X25H02TJI, inner diameter 24 mm; b, c – cast iron C420, inner diameter 16 mm

residual aluminum sulfate, and therefore it is called phosphosulfate. The binder has a long shelf life, is introduced into the mixture in a ready-made form, and the technology of its manufacture is less energy-intensive and time-consuming compared to the preparation of traditional metal-phosphate binders.

Conclusions.

1. The analysis of physicochemical transformations that occur in the system of orthophosphoric acid with 18-hydrated aluminum sulfate, and the formation of a new for the technology of foundry production of a complex binder, consisting of a combination of phosphates and aluminum sulfate.

2. Thermodynamic calculation confirmed the impossibility of direct chemical interaction in the temperature range from 20 to 300 °C between orthophosphoric acid as an acid of medium strength and aluminum sulfate as a salt of a strong (sulfate) acid. The stepwise scheme of interaction in this system, which leads to the formation of the binder: partial decomposition of aluminum hydrate crystalline sulfate under slight heating with the formation of aluminum hydroxide and subsequent chemical interaction of hydroxide with acid with the formation of aluminum phosphates. This scheme of phosphate binder synthesis was implemented for the first time.

3. The dynamics of physicochemical transformations of the synthesized binder during heating within the range of 200–1,000 °C was studied, and the stage of gradual removal of crystalline water from aluminum sulfate and an increase in the relative content of aluminum orthophosphates was established. It was determined that at a temperature of about 865 °C, aluminum sulfate completely decomposes, which ensures a significant decrease in strength after heating the core mixture and minimizes the work of knocking out.

4. Practical studies have established that a core mixture based on quartz sand with a synthesized binder has sufficient strength, makes it possible to obtain cast iron and steel castings with a wall thickness of up to 40 mm without sticking, the roughness of cast surfaces corresponds to class 2.

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Синтез фосфосульфатної речовини та властивості її структурованої суміші із кварцовим піском

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Мета. Створення зв'язувального компонента на основі ортофосфорної кислоти й сульфату алюмінію, вивчення його будови та фізико-хімічних закономірностей утворення, визначення властивостей структурованих сумішей для потреб ливарного виробництва.

Методика. У роботі проводили рентгенофазовий якісний і кількісний аналіз на установці «Rigaku Ultima

IV», диференційний термічний аналіз – на синхронному термічному аналізаторі «STA 449 C Jupiter». У роботі використовували ортофосфорну кислоту технічну термічну 85 % концентрації, 18-водний сульфат алюмінію $Al_2(SO_4)_3 \cdot 18H_2O$ технічної чистоти та кварцовий пісок марки 3K₃O₃025. Міцність стрижневих сумішей визначали на установці UC-700 на стандартних циліндричних зразках діаметром і висотою по 50 мм. Шорсткість литих поверхонь визначали на профілометрі мод. 107622 з комп'ютерною обробкою отриманих даних і побудовою профілограм. Для визначення схильності стрижневих сумішей до утворення пригару використовували зразок шестикутника за методикою М. Федорова. Вибиваємість визначали на стандартних циліндричних зразках діаметром і висотою по 50 мм за оригінальною методикою, описаною в тексті статті.

Результати. Уперше досліджено механізм утворення фосфатів алюмінію із зв'язувальними властивостями під час взаємодії кристалогідратного сульфату алюмінію $Al_2(SO_4)_3 \cdot 18H_2O$ з ортофосфорною кислотою в інтервалі температур 100–200 °С. Доведено утворення при нагріванні проміжної фази – гідроксиду алюмінію $Al(OH)_3$, який, на відміну від його сульфату, за результатами термодинамічного аналізу здатен взаємодіяти з кислотою. Установлено утворення в системі орто- та метафосфату алюмінію, що наділені зв'язувальними властивостями й забезпечують високу міцність зразків на основі кварцового наповнювача. Досліджені термічні перетворення отриманого зв'язувального компонента, що складається

із поєднання фосфатів алюмінію з його залишковим сульфатом. Зафіксовані стадії поступового розпаду кристалогідратів, утворення нових фосфатів алюмінію й термічного розпаду залишкового сульфату. Визначена схильність до пригару й вибиваємість розроблених стрижневих сумішей.

Наукова новизна. Уперше розроблено опис механізму утворення фосфатів алюмінію зі зв'язувальними властивостями під час взаємодії його сірчанокислого кристалогідрату $Al_2(SO_4)_3 \cdot 18H_2O$ з ортофосфорною кислотою в інтервалі температур 100–200 °С.

Практична значимість. Отримано новий для ливарного виробництва неорганічний зв'язувальний компонент із ортофосфорної кислоти та 18-водного сульфату алюмінію. Схема його приготування передбачає попереднє змішування й нагрівання вказаних реагентів з утворенням у підсумку сухого порошкового матеріалу, що складається із фосфатів і залишкового сульфату алюмінію, а тому його названо фосфосульфатним. Зв'язувальний компонент має тривалий термін придатності, уводиться до складу суміші в уже готовому вигляді, а технологія його виготовлення менш енергоємна та тривала в порівнянні із приготуванням традиційних металофосфатних зв'язувальних компонентів.

Ключові слова: зв'язувальний компонент, ливарний стрижень, ортофосфорна кислота, сульфат алюмінію, термогравіметричний аналіз, фазовий аналіз, фосфат алюмінію

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