DOI 10.52209/1609-1825_2022_2_31 UDC 621.74.04

Manufacturing Shells with Investment Casting Excluding Formation of Pitting Spots on Castings

[1]***KVON Svetlana,** Cand. of Tech. Sci., Professor, svetlana.1311@mail.ru,*
[2]***OKISHEV Konstantin,** Dr. of Phys. and Math. Sci., Professor, okishevki@susu.ru,*
[1]***KULIKOV Vitaly,** Cand. of Tech. Sci., Professor, mlpikm@mail.ru,*
[1]***ATAMBAYEV Zhasulan,** doctoral student, Senior Lecturer, atambaev.jasulan@mail.ru,*
[1]***OMAROVA Aidana,** Mast. of Tech. Sci., Teacher, aidana_kartu@mail.ru,*
[1]NPJSC «Abylkas Saginov Karaganda Technical University», Kazakhstan, Karaganda, N. Nazarbayev Avenue, 56,
[2]South Ural State University, Russia, Chelyabinsk, Lenin Avenue, 76,
**corresponding author.*

Abstract. *The paper presents a method of manufacturing the shell with investment casting that helps avoiding the appearance of such a characteristic defect as pitting spots on the surface of castings. As part of the suspension for manufacturing a shell, it is proposed to use the Kazakhstan content clay as a refractory component and other components to ensure the required technological properties. As a preventive measure against the appearance of pitting, the integrated use of graphite and vibration treatment is proposed. Based on the data obtained, it was revealed that the method of manufacturing the shell allows to obtain castings with high surface purity, geometric accuracy and the absence of pitting spots. The results of the carried out studies have shown that as a result of such treatment the area of pitting spots is reduced by 30-35% while maintaining the previous indicators of surface cleanliness.*

Keywords: *investment casting, suspension, pitting, graphite, vibration, clay, heating, composition, analysis, vacuum treatment.*

Introduction. The investment casting method is widely used to obtain shaped castings with high geometric accuracy and surface cleanliness. To date, the IC method is not very common in the Republic of Kazakhstan (RK) due to a rather complex technology, however, given its promising potential, the presence of the existing fixed assets and equipment of foundries of the Republic of Kazakhstan, it seems very relevant to use it in manufacturing shaped castings, especially of materials that are difficult-to-machine.

An important stage in the investment casting technology is the stage of shell manufacturing. The properties of a shell largely determine the quality of the finished casting, as well as the possibility of exposure to external factors during the crystallization process.

The main part. The authors have proposed a technology of manufacturing casings using clay from the Kazakhstan Kumkeshu deposit and chamotte rubble. The mineral composition of the clay has been determined by X-ray phase analysis using a D2 PHASER diffractometer. Figure shows the results of XRF.

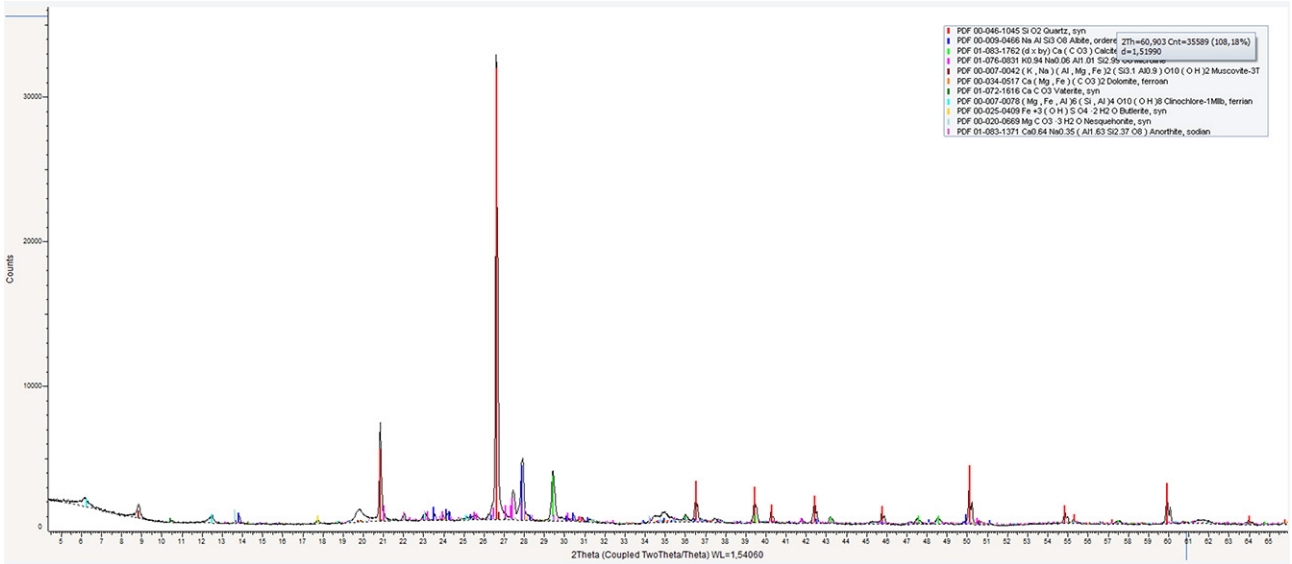
It is seen from the experimental data obtained that Kumkeshu clay does not contain kaolinite but it contains sufficient amounts of aluminosilicates such as muscovite (17.5%) and clinochlore (20.5%), as well as minerals, impurities: quartz in an amount of 37% and calcites in the amount of 7.4%.

When heated, muscovite undergoes several phase transformations in the temperature range from 125 to 1180°C, mainly associated with the oxidation of divalent impurity metals and the loss of water. Above the temperature of 1180°C, muscovite becomes stable [1], it does not undergo any phase and accordingly volumetric transformations.

The mineral clinochlore is poorly studied, one of its varieties is used as an ornamental stone, the characteristic feature is its low hardness, about 2 according to Mohs [2]. Quartz that is the prevailing phase in the clay of this deposit, is usually considered a mineral that degrades properties in the composition of clays, reduces the clay plasticity and pliability, while strength and hardness of the finished product increase [1].

Two refractory components are usually used for manufacturing a shell with IC: finely dispersed and larger ones for the formation of the frame. Dust from ferroalloy furnaces and finely dispersed silica SiO_2 are often used as the latter. Kumkeshu clay contains a large amount of quartz, so it is logical to assume that it can be used as a refractory component that forms the framework.

At the same time, it contains aluminosilicates of



XRF data of clay from Kumkeshu deposit

the same class as kaolinite, i.e. in a certain fraction it can be used as a refractory component filling the «frame gaps».

In other words, due to the unusual composition of Kumkeshu clay, it can be used as both refractory components, provided that the material is separated into coarse and fine fractions. The studies [3] have shown the possibility of using this clay for the manufacture of shells with investment casting.

Based on the results of the studies [4], the composition of the suspension has been proposed, consisting of the following components, wt%: silica sol 30-35; ethyl silicate 10; surfactant 1%; technical ethyl alcohol 10%; refractory filler the rest. It should be emphasized that the mixture of Kumkeshu clay with water (15% by weight of clay) is used as silica sol. This clay must undergo preliminary preparation: firing at 1200°C within 4 hours to ensure the occurrence of all possible phase and associated volumetric transformations; then grinding to the fraction of 400 microns to form a suspension. The use of clay with a high quartz content for obtaining silica ash but not quartz sand is caused by the fact that due to the content of other clay minerals (mullite, muscovite, clinochlore, kaolinite, etc.), the required viscosity, sedimentation stability and vitality of the suspension are provided. The minerals contained in clays belong to different groups of rocks, have different values of density, wettability coefficient, solubility in water and ethyl alcohol. Such a variety of physical properties of minerals contained in clays leads to the fact that a suspension based on them has higher sedimentation resistance. The solid phase of such a suspension is represented by a large number of components in comparison with a suspension based on quartz sand, and these components have various natural dispersion. All these factors determine the higher sedimentation stability of the suspension.

However, despite high attractiveness of the investment casting method from the point of view of the finished product quality, there is a significant specific drawback of the resulting castings. As noted in [5,6], one of the problems in the production of castings by investment casting is pitting: surface damage by point defects manifested as surface irregularities up to 1.5 mm deep and up to 5.0 mm in diameter. To prevent this defect, various methods of manufacturing and treating casings have been proposed.

For example, a method of manufacturing a shell with investment casting is proposed that includes making a shell by layer-by-layer deposition of a suspension based on a refractory material on an investment model using ethyl silicate as a binder, removing the model composition, placing the shell in a flask, filling the flask with a refractory material followed by calcining [7].

In works [8, 9], methods of treating shell molds based on artificial quartz (marshallite), preliminary application of a protective layer to the model, production of a mold shell and subsequent smelting the model are proposed, and celluloid with heat resistance of 40-70°C is applied as a protective layer.

The analysis shows that the most promising and adapted to production conditions is the method of manufacturing a shell proposed in [10]. This method of manufacturing the shell makes it possible to obtain castings with high surface cleanliness, geometric accuracy and the absence of pitting spots, the presence of which is characteristic of castings obtained by the investment casting method. A significant disadvantage of this method is the need for an expensive vacuum chamber with a sufficiently large capacity for the simultaneous placing all the flasks of the batch.

In [11], graphite is deposited on the outer surface

of the shell for the subsequent vacuum treatment as a preventive measure against the appearance of pitting.

Deposition of graphite on the outer layer of the shell leads to the fact that when liquid metal is poured into the shell due to increasing the temperature, carbon combustion occurs according to the reaction:

$$2C + O_2 \rightarrow 2CO.$$

As a result of this reaction, a layer of a weakly reducing atmosphere is formed in the region adjacent to the shell from the outside, which prevents the subsequent oxidation of the casting surface.

Subsequent vacuum treatment proposed in [10], makes it possible to increase the reduction potential of the medium, which ensures a high quality of the casting surface. However, it should be noted that a large vacuum chamber is quite expensive equipment, which limits its prevalence.

The authors propose vibration treatment as an alternative. The treatment with subsequent vibration of the shell leads to intensification of the gaseous products removal formed as a result of the interaction of the shell and the liquid metal.

The oxygen content gradient between the environment outside and inside the shell also promotes the transfer of oxygen to the outer region of the shell, which blocks the oxidation of the surface inside the shell.

Enhanced heat dissipation also prevents the development of the oxidation process and other processes of interaction of products with the casting surface. All these factors ensure the surface quality of the casting without oxidation and pitting. It should be noted that the vibrating table, in contrast to the vacuum chamber, is available in almost every area of the foundry, which makes the proposed method more affordable.

To test this assumption, the following experimental studies have been carried out. The above composition has been used as a suspension for making the shell. The wax model of the future casting has been immersed in the suspension for 3-4 seconds, then the model with the applied layer of suspension has been sprinkled with a dry mixture of fireclay of the -400 micron fraction.

The sprinkled model has been dried in a SNOL-100 drying oven at the temperature of 40°C until completely drying. The immersion – dusting – drying operations have been repeated 6 times, resulting in a shell with the thickness of about 7 mm.

The model has been removed by rinsing the shell with hot water. Then, on the outer side of the shell, crushed graphite with the fraction of -400 μm has been applied at the rate of 1 gram per 1 cm^2 of the casting area. The shell has been placed in a flask and reinforced with chamotte rubble. The upper part of the flask has been covered with chamotte rubble mixed with liquid glass to the creamy state. The top layer thickness has been 50 mm. The flask with a reinforced shell has been placed on a vibration table, cast iron of the AChS brand has been poured into the shell and subjected to vibration within 10 minutes, with an amplitude of 10 mm and a frequency of 120 Hz.

After the completion of crystallization and complete cooling, the resulting casting has been removed from the shell, its surface has been assessed for oxidation and the presence of pitting spots. The sample obtained by method [10] has been used as a comparison sample. The results of the experiment are presented in Table. The Table shows the average results.

It is seen from the data in Table 2 that the samples made by the proposed method show approximately the same surface cleanliness as the reference sample. At the same time, the area of pitting spots was reduced by 36%, which indicates the effectiveness of using graphite and vibration treatment as a preventive measure of protection against pitting during investment casting. It should be noted that the proposed method of manufacturing the shell makes it possible to simplify the technological process in comparison with the above by eliminating vacuum treatment and the need for an expensive vacuum chamber.

Conclusion. Thus, the studies carried out have shown the possibility of developing a shell with investment casting, which reduces or excludes the possibility of pitting spots the appearance on the casting surface. This is achieved by complex treating the outer surface of the shell with graphite of the -400 microns fraction in the amount of 1 g/cm^2 and subsequent vibration treatment of the shell. Clay from the Kumkeshu deposit (Kazakhstan) has been used as part of the suspension for manufacturing the shell, providing the necessary technological properties.

Surface parameters of prototypes

Sample characteristic	Surface roughness, Rz, μm	Tarnishing colors	Total area of pitting spots, %
Comparison sample	45	absent	12
Experimental sample	47	absent	7,6

REFERENCES

1. Назаратин В.В. Технология изготовления стальных отливок ответственного назначения. – М.: Машиностроение, 2006. – 234 с.
2. Минералы: Справочник / Главный редактор Ф.В. Чухров. – Москва: Наука, 1992. – Т. IV. Выпуск 2. – С. 179-186.
3. Квон Св.С., Куликов В.Ю., Щербакова Е.П. Использование глин некоторых месторождений Казахстана для изготовления оболочек при ЛВМ // Литейщик России. 2020. № 2. С. 18-23.
4. Щербакова Е.П., Исагулов А.З., Ибатов М.К., Квон Св.С., Куликов В.Ю., Аринова С.К. Исследование технологических свойств суспензии для изготовления оболочек при методе ЛВМ // Труды университета. – Караганда: Изд-во КарГТУ, 2020. – № 2. – С. 23-27, ISSN 1609-1825.
5. Гини Э.Ч., Зарубин А.М. Специальные технологии литья. – М.: МГТУ им. Н.Э. Баумана, 2010. – 367 с.
6. Гини Э.Ч., Зарубин А.М., Рыбкин В.И. Технология литейного производства: специальные виды литья. – М.: Академия, 2005. – 352 с.
7. Способ изготовления оболочковой формы. Патент RU № 2314891, МПК B22C 9/04 C1, 20.01.2008).
8. Способ изготовления оболочковой формы. Патент RU № 2285576, МПК B22C 9/04, 20.10.2006.
9. Способ изготовления оболочковой формы. Патент СССР. SU 1787651 A1.
10. Способ изготовления оболочковой формы. Патент RU 2505376C1.
11. Состав суспензии для изготовления оболочки. Патент RU 2191656.

Құймада питтингтік дақтардың пайда болуын болдырмайтын, балқытылатын үлгілер бойынша құю кезінде қабық жасау

[1]***КВОН Светлана Сергеевна,** т.ғ.к., профессор, svetlana.1311@mail.ru,*
[2]***ОКИШЕВ Константин Юрьевич,** ф.-м.ғ.д., профессор, okishevki@susu.ru,*
[1]***КУЛИКОВ Виталий Юрьевич,** т.ғ.к., профессор, mlpikm@mail.ru,*
[1]***АТАМБАЕВ Жасулан Нурбаевич,** докторант, аға оқытушы, atambaev.jasulan@mail.ru,*
[1]***ОМАРОВА Айдана Ержанқызы,** т.ғ.м., оқытушы, aidana_kartu@mail.ru,*
[1]«Әбілқас Сағынов атындағы Қарағанды техникалық университеті» КеАҚ, Қазақстан, Қарағанды, Н. Назарбаев даңғылы, 56,
[2]Оңтүстік Орал мемлекеттік университеті, Ресей, Челябинск, Ленин даңғылы, 76,
**автор-корреспондент.*

***Аңдатпа.** Жұмыста балқытылатын үлгілер бойынша құю кезінде қабық жасау әдісі ұсынылған, бұл құймалардың бетіндегі дақтар сияқты тән ақаудың пайда болуын болдырмауға мүмкіндік береді. Қабықты дайындауға арналған суспензияның құрамында отқа төзімді компонент ретінде қазақстандық мазмұндағы сазды және талап етілетін технологиялық қасиеттерді қамтамасыз ету үшін басқа да құрауыштарды пайдалану ұсынылады. Питтингтің пайда болуына қарсы алдын-алу шарасы ретінде графитті кешенді қолдану және дірілмен емдеу ұсынылады. Алынған мәліметтерге сүйене отырып, қабықты жасау әдісі бетінің жоғары тазалығымен, геометриялық дәлдігімен және питтинг дақтарының болмауымен құймаларды алуға мүмкіндік беретіні анықталды. Зерттеу нәтижелері көрсеткендей, мұндай өңдеу нәтижесінде питтинг дақтарының ауданы бұрынғы бет тазалығының көрсеткіштерін сақтай отырып, 30-35%-ға азаяды.*

***Кілт сөздер:** балқытылатын үлгілер бойынша құю, суспензия, питтинг, графит, діріл, балшық, жылыту, құрамы, талдау, вакууммен өңдеу.*

Изготовление оболочки при ЛВМ, исключающей образование питтинговых пятен на отливке

[1]***КВОН Светлана Сергеевна,** к.т.н., профессор, svetlana.1311@mail.ru,*
[2]***ОКИШЕВ Константин Юрьевич,** д.ф.-м.н., профессор, okishevki@susu.ru,*
[1]***КУЛИКОВ Виталий Юрьевич,** к.т.н., профессор, mlpikm@mail.ru,*
[1]***АТАМБАЕВ Жасулан Нурбаевич,** докторант, старший преподаватель, atambaev.jasulan@mail.ru,*
[1]***ОМАРОВА Айдана Ержанқызы,** м.т.н., преподаватель, aidana_kartu@mail.ru,*
[1]НАО «Карагандинский технический университет имени Абылкаса Сагинова», Казахстан, Караганда, пр. Н. Назарбаева, 56,
[2]Южно-Уральский государственный университет, Россия, Челябинск, пр. Ленина, 76,
**автор-корреспондент.*

***Аннотация.** В работе представлен способ изготовления оболочки при ЛВМ, позволяющий избежать появления такого характерного дефекта, как питтинговые пятна на поверхности отливок. В составе суспензии для изготовления оболочки предлагается использовать глину казахстанского содержания в качестве огнеупорного компонента и другие составляющие для обеспечения требуемых технологических свойств. В каче-*

стве превентивной меры против появления питтинга предлагается комплексное использование графита и обработки вибрацией. На основании полученных данных было выявлено, что способ изготовления оболочки позволяет получать отливки с высокой чистотой поверхности, геометрической точности и отсутствием питтинговых пятен. Результаты проведенных исследований, показали, что площадь питтинговых пятен в результате такой обработки сокращается на 30-35% при сохранении прежних показателей чистоты поверхности.

Ключевые слова: *литье по выплавляемым моделям, суспензия, питтинг, графит, вибрация, глина, нагрев, состав, анализ, обработка вакуумом.*

REFERENCES

1. Nazaratin, V.V. Tehnologija izgotovlenija stal'nyh otlivok otvetstvennogo naznachenija. [Technology of manufacturing of steel castings of responsible purpose]. – Moscow: Mashinostroenie, 2006. – 234 p.
2. Mineraly: Spravochnik / Glavnyj redaktor F.V. Chuhrov. [Minerals]. – Moscow: Nauka, 1992. – T. IV. Vypusk 2. – pp. 179-186.
3. Kvon Sv.S., Kulikov V.Ju., Shherbakova E.P. Ispol'zovanie glin nekotoryh mestorozhdenij Kazahstana dlja izgotovlenija obolochek pri LVM. [The use of clays from some deposits of Kazakhstan for the manufacture of shells at LVM]. Litejshhik Rossii. 2020. No. 2. pp. 18-23.
4. Shherbakova E.P., Isagulov A.Z., Ibatov M.K., Kvon Sv.S., Kulikov V.Ju., Arinova S.K. Issledovanie tehnologicheskih svojstv suspenzii dlja izgotovlenija obolochek pri metode LVM [Investigation of the technological properties of the suspension for the manufacture of shells using the LVM method]. Trudy universiteta. – Karaganda: Publ. KarGTU, 2020. – No. 2. – pp. 23-27, ISSN 1609-1825.
5. Gini Je.Ch., Zarubin A.M. Special'nye tehnologii lit'ja [Special casting technologies]. – Moscow: MGTU im. N.Je. Baumana, 2010. – 367 p.
6. Gini Je.Ch., Zarubin A.M., Rybkin V.I. Tehnologija litejnogo proizvodstva: special'nye vidy lit'ja [Technology of foundry production: special types of casting]. – M.: Akademija, 2005. – 352 p.
7. Sposob izgotovlenija obolochkovoj formy. [The method of manufacturing the shell mold]. Patent RU №2314891, MPK V22S 9/04 C1, 20.01.2008).
8. Sposob izgotovlenija obolochkovoj formy. [The method of manufacturing the shell mold]. Patent RU №2285576, MPK V22S 9/04, 20.10.2006.
9. Sposob izgotovlenija obolochkovoj formy. [The method of manufacturing the shell mold]. Patent SSSR. SU 1787651 A1.
10. Sposob izgotovlenija obolochkovoj formy. [The method of manufacturing the shell mold]. Patent RU 2505376C1.
11. Sostav suspenzii dlja izgotovlenija obolochki. [The composition of the suspension for the manufacture of the shell]. Patent RU 2191656.