эжекции атмосферного воздуха, кислород которого вступает в реакцию горения с избыточным горючим в основной струе горелки и образовании более мощной струи.

Ключевые слова: термоинструменты, горная порода, детонационное горение, топливные компоненты (бензин, керосин, воздух).

ТАУ ЖЫНЫСТАРЫН БҰЗУҒА АРНАЛҒАН ЖЫЛУ ҰРАЛДАРЫНЫҢ КОНСТРУКЦИЯСЫН ЖЕТІЛДІРУ

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Аңдатпа. Мақалада жану газдинамикалық үдеткіштерінде жоғары жылдамдықты алау оттығымен басталған соққы толқындарында отын қоспасын жағудың жаңа әдісін енгізу арқылы тау жыныстарын бұзуға арналған термодинамикалық жұмыс құрылғысының негізгі параметрлері қарастырылады. Тау-кен өнеркәсібіне жататын және тау-кен, тас өңдеу және құрылыс салаларында ыстық газ ағындарымен бұзылған кезде тау жыныстарына бағытталған әсер ету үшін қолдануға болатын тау жыныстарын термиялық бұзуға арналған құрылғы жасалды.

Түйінді сөздер: жылу құралдары, тау жынысы, детонациялық жану, отын компоненттері (бензин, керосин, ауа).

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APPLICATION OF ADDITIVE TECHNOLOGIES IN MODERN FOUNDRY PRODUCTION

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APPLICATION OF ADDITIVE TECHNOLOGIES IN MODERN FOUNDRY PRODUCTION

Abstract: The paper studies and analyzes the use of additive technologies in modern foundry production, determining their innovative development to create new products with high quality, reliability and determining its competitiveness in the world market of machine-building products. The essence of SLS-technology is defined as follows: model material - polystyrene powder with particle size of 50-150 microns - is rolled by a special roller on the working platform installed in a sealed chamber with an inert gas atmosphere - nitrogen. The laser beam "runs" where the computer "sees" the "body" in the given section of the CAD-model, as if "shading" the section of the part, as it is done by the constructor with a pencil on the drawing. In this case the laser beam is a source of heat, under the influence of which sintering of polystyrene particles takes place (working temperature - about 120°C). SLA, Polyjet and DLP technologies are the most widespread for metal casting. The first method involves sequential "running" of the laser beam over the entire surface of the layer to be formed where the model "body" is in the cross section. The second method of curing is performed by a beam in the form of a line in the process of layer formation due to radiation from a controlled ultraviolet lamp. The third way implies illumination of the whole layer simultaneously by creating the so-called mask - a "photo" of the current CAD-model section. Thus, additive technologies in modern foundry production have radically reduced labor intensity and costs of creating new products, which have high quality and reliability indicators and determine their competitiveness in the global market of machine-building products.

Key words: Additive technologies, nanotechnologies, prototyping, profitability of production, mechanical engineering, foundry production, synthesis molds, synthesis models, foundry tooling, three-dimensional CAD/CAM/CAE-technologies.

The development of industrial production in the modern world cannot do without the use of new technologies. Their use makes it possible to ensure the production of relatively cheap, high-quality and reliable products. Innovative development of modern foundry technologies is based on the application of computer, nanotechnologies and prototyping technologies which are reflected in modern additive technologies (Additive manufacturing or AF-technologies) based on manufacturing products according to a digital model (or CAD-model) by layer-by-layer addition and ensure the production of relatively cheap, high-quality and reliable products [1-3].

The use of additive technologies in various branches of modern mechanical engineering provides:

- manufacturing of complex and unique parts without the use of mechanical machining machines and expensive tooling;
- increase in profitability of production of small series and exclusive variants;
- eliminating the influence of the "human factor" in the production of parts: the construction of the part is carried out in fully automatic mode;
- Reducing the weight of parts by reducing the thickness of walls, elements, and creating honeycomb and other structures (the so-called bionic design). When using AF, raw material savings can be as high as 75 percent.
- Possibility to create complex, integrated parts in a single technological cycle;
- control of the physical and mechanical properties of the product being created.

The use of additive technologies in foundry production makes it possible to "grow" casting models and molds, which could not be produced by traditional methods, as well as significantly reduces the time of model tooling production. The use of molds and models produced by additive technologies in vacuum casting has made it possible to reduce the time for manufacturing pilot, prototype and, in some cases, serial products dozens of times.

The transition to digital product description - CAD and the resulting additive technologies have produced fundamental changes in foundry production, which is particularly evident in high-tech industries - aviation and aerospace, nuclear industry, mechanical engineering, medicine and instrumentation, industries where low-volume, piece production is typical.

The main advantage of using additive technology over others is "the short lead time for making castings from the moment the drawing of the cast part is received. A casting of a simple mold can be made within a day. These technologies are "increasingly being used in industries such as aviation and mechanical engineering to produce castings from Al- and Mg-alloys" [4].

The use of synthetic molds and synthetic molds production methods due to layer-by-layer synthesis technologies allowed to radically reduce the time of new product creation. For example, it takes at least 6 months to produce the first prototype part typical for automotive engine construction - cylinder block - using traditional methods, with the main time spent on creating the model tooling for casting "in the ground". Using Quick-Cast technology for this purpose (growing a casting model from photopolymer on a SLA-machine with subsequent casting using the fired model) has reduced the lead time for the first casting to 2 weeks. The same part can be produced by a less precise, but quite suitable technology for this purpose - casting in grown sand molds on machines like S-Max. A significant part of castings that do not have special requirements for casting accuracy or structure can be produced as a finished product within 3-4 days, taking into account preparatory and finishing times: direct cultivation of a wax model or Quick-cast model (1 day); molding + drying of the mold (1 day); mold hardening and casting itself (1 day) (Fig. 1).

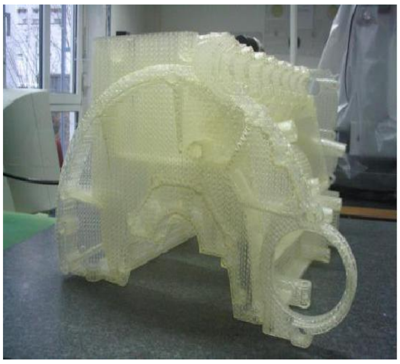

Рисунок 1 - Блок цилиндров: а – Quick-cast модель; б – чугунная отливка
Figure 1 - Cylinder block: a - Quick-cast model; b - cast iron casting

Quick-Cast technologies for the production of metal tooling and small batch castings are characterized by dimensional accuracy and surface roughness similar to that of melted and gasified models.

The technology of cryogenic casting is particularly effective when combined with the technology of extrusion 3D-printing, namely, to create casting molds with cores of clay or sand and clay mixtures placed in them on a 3D printer and then harden them by freezing. Given the technical capabilities of 3D printing, it is possible to ensure high geometric complexity of molds and cores and, as a consequence, produce complex shaped metal castings characterized by the presence of a variety of cavities. In such cases, however, the problem arises of removing cores from the cavities formed in the castings, for example when the cavities are in the form of tortuous channels or when the cavity inlets are smaller than the cavities themselves. A possible solution to this problem is to remove the cores from the cavities by washout. In order to comparatively evaluate the washout efficiency of the cavity materials used in experiments 1 and 2, these materials were tested by sealing samples in the form of 23×10×4 mm plates in plasticine containers that simulated castings, leaving one end surface open. This surface was oriented upwards and a free-flowing water jet was directed onto it, which had a volume flow rate of 1.2 ml/s and a temperature of 21 °C. The distance from the place of the outflow of the jet to the surface of the sample treated by it was 120 mm (12 cm). The tests showed that the samples from sandy-clay mixture were washed out with water in 9.5 minutes completely (i.e. to the depth of 23 mm), and the samples from clay were washed out only partially - to a depth of about 5.5 mm during the same time. Thus, the leaching rate of samples from sandy-clay mixture is approximately 4 times higher than the leaching rate of clay samples. This may be due to the less dense structure of sand-clay mixture compared to that of clay, due to which sand-clay mixture soaks up water more easily than clay.

Development of three-dimensional CAD/CAM/CAE technologies has led to a significant modernization of modern foundry and, first of all, pilot production. The aim of this modernization is to create conditions for full implementation of "paperless" technologies during the whole process of a new product creation - from designing and development of a CAD-model to the final product - to be an integral part of the design and production cycle for various purposes with a wide range of applied materials. For this purpose, foundries and sections are equipped with new equipment that gives a wide range of possibilities, but requires new knowledge.

Today, "trends in the development of modern foundry production are such that it is no longer only about creating exact copies (models) of machine parts, which are also important and are used in technologies" of investment casting, "but also about creating finished functional (gradient) products" [5,6].

Positive experience of using additive technologies for the production of parts of aviation units is available at JSC "OKB Sukhoi" (Russia), at this enterprise a set of equipment of the stereolithography technological line was installed, which was effectively used for obtaining unique in complexity precision cast parts of aircraft units from aluminum alloys, cast dies, flexible silicone forms and various tooling.

AF technology is especially important for accelerated production of castings. AF machines are used to produce: casting models; master models; casting molds and foundry tooling.

Casting models can be obtained (grown) from:

- Powdered polymers for subsequent casting on fired models;

- from photopolymer compositions, in particular, according to Quick-cast technology for subsequent casting according to burn-in models or according to MJ (Multi Jet) technology for investment casting.

Polystyrene is widely used as a modeling material for traditional burn-in model casting. Due to the development of layer-by-layer synthesis technologies, polystyrene has become especially popular in the field of prototyping, as well as for industrial production of piece and low-volume products. Polystyrene models are made on AF-machines working according to SLS-technology (Fig. 2). This technology is often used for the production of complex shape castings of relatively large dimensions with moderate accuracy requirements.

Рисунок 2 - Полистирольная модель и отливка головки цилиндра ДВС
Figure 2 - Polystyrene model and casting of the cylinder head of an internal combustion engine

The essence of SLS-technology is defined as follows: model material - polystyrene powder with particle size of 50-150 microns - is rolled by a special roller on the working platform installed in a sealed chamber with an inert gas atmosphere - nitrogen. The laser beam "runs" where the computer "sees" the "body" in the given section of the CAD-model, as if "shading" the section of the part, as it is done by the constructor with a pencil on the drawing. In this case the laser beam is a source of heat, under the influence of which sintering of polystyrene particles takes place (operating temperature - about 120°C). Then the platform is lowered by 0.1-0.2 mm and a new powder portion is rolled on top of the cured one, a new layer is formed which also sintered to the previous one. The process is repeated until the model is completely built, which at the end of the process is enclosed in an un-sintered powder mass. The model is then removed from the machine and cleaned of the powder.

The advantage of this technology is the absence of supports; during construction, the model and all its built-up layers are held by an array of powder.

Available on the market 3D Systems and EOS machines allow to build rather large models (up to 550x550x750 mm in size) without the need to glue separate fragments, which increases casting accuracy and reliability, especially for vacuum casting. At the same time, high detail of model building is possible: surface elements (part numbers, conventional inscriptions, etc.) with fragment thickness up to 0,6 mm can be built, guaranteed wall thickness of the model is up to 1,5 mm.

The InkJet technology from Voxeljet Technology GmbH (Germany) uses powdered acrylic polymer (polymethylmethacrylate - plexiglass, modified acrylic glass) as a modeling material. Used in this case machines VX500, VX800 and VX1000 have the size of the working area 500h400h300, 850h450h500 and 1060h600h500 mm respectively.

The advantages of the technology include the fact that the construction process is performed at room temperature, which reduces the risk of thermal deformations typical of SLS technology.

In the process of making castings, casting molds are sometimes grown from powdered polyamide, which is widely used for functional prototyping. Polyamide models are strong enough and in many cases allow to reproduce the prototype as close to the product as possible. In a number of cases, it is more economically feasible to use polyamide models as an alternative to wooden models. The model is grown in the same way as a polystyrene model. In order to minimize temperature deformations, it is made hollow, if possible, with the minimum possible wall thickness. An example of such a "fast" technological model of an internal combustion engine camshaft is shown in Fig. 3. This model was grown from two parts, in the manufacturing process the parts were glued together, filled with epoxy resin and fixed in the molding box. The duration of operations was 2 days [7].

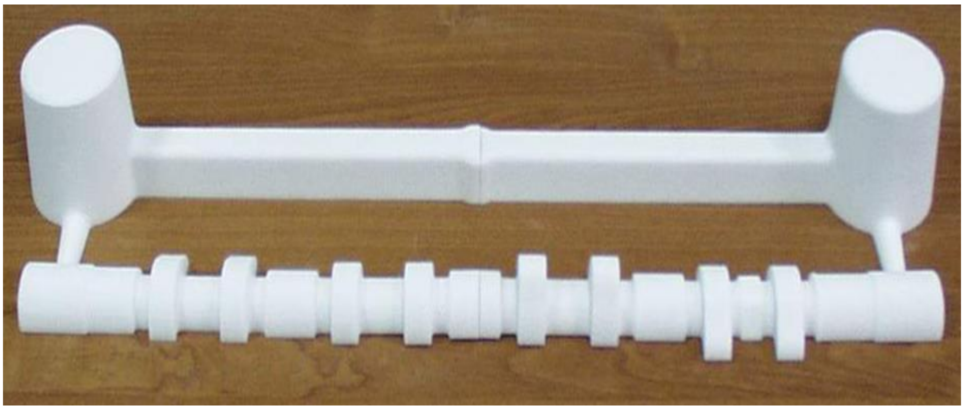

Рисунок 3 - SLS-модель распределительного вала
Figure 3 - SLS model of a camshaft

SLA, Polyjet and DLP technologies are the most widespread for metal casting. The first method involves sequential "running" of the laser beam over the entire surface of the layer to be formed where the model "body" is in the cross section. The second method of curing is performed by a beam in the form of a line in the process of layer formation due to radiation from a controlled ultraviolet lamp. The third way implies illumination of the whole layer simultaneously by creating the so-called mask - a "photo" of the current CAD-model section [8].

Non-laser "light" technologies with set exposure, used, for example, by Objet Geometry and Envisiontec, in many cases successfully compete with stereolithography, leaving a clear advantage in the speed of construction and cost of models. A number of production tasks can be successfully solved with AF machines of different levels.

Thus, additive technologies in modern foundry production have made it possible to radically reduce labor intensity and costs for creating new products that have high quality and reliability indicators and determine their competitiveness in the global market of machine-building products.

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ПРИМЕНЕНИЕ АДДИТИВНЫХ ТЕХНОЛОГИЙ В СОВРЕМЕННОМ ЛИТЕЙНОМ ПРОИЗВОДСТВЕ

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Аннотация. В статье исследовано и проанализировано использование аддитивных технологии в современном литейном производстве, определяющих их инновационное развитие по созданию новой продукции, имеющей высокие показатели по качеству, надежности и определяющих ее конкурентоспособность на мировом рынке машиностроительной продукции. Сущность SLS-технологии определяется в следующем: модельный материал – полистирольный порошок с размером частиц 50-150 мкм – накатывается специальным роликом на рабочую платформу, установленную в герметичной камере с атмосферой инертного газа – азота. Лазерный луч «пробегает» там, где компьютер «видит» в данном сечении CAD-модели «тело», как бы «заштриховывая» сечение детали, как это делает конструктор карандашом на чертеже. В этом случае лазерный луч является источником тепла, под воздействием которого происходит спекание частичек полистирола (рабочая температура – около 120°С). Наибольшее распространение для литья металлов получили SLA, Polyjet и DLP-технологии. Первый способ предполагает последовательное «пробегание» лазерного луча по всей поверхности формируемого слоя там, где в сечении «тело» модели. Второй способ отверждения производится лучом в виде линии в процессе формирования слоя за счет излучения от управляемой ультрафиолетовой лампы. Третий способ предполагает засветку всего слоя одновременно за счет создания так называемой маски – «фотографии» текущего сечения CAD-модели. Таким образом, аддитивные технологии в современном литейном производстве позволили радикально сократить трудоемкость и затраты на создания новой продукции, имеющей высокие показатели по качеству, надежности и определяющих ее конкурентноспособность на мировом рынке машиностроительной продукции.

Ключевые слова: аддитивные технологии, нанотехнологии, прототипирование рентабельность производства, машиностроение, литейное производство, литейные синтез-формы, синтез-модели, литейная оснастка, трехмерные CAD/CAM/CAE-технологии.

ҚАЗІРГІ ЗАМАНҒЫ ҚҰЮ ӨНДІРІСІНДЕ АДДИТИВТІ ТЕХНОЛОГИЯЛАРДЫ ҚОЛДАНУ

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Аңдатпа: Мақалада сапасы, сенімділігі бойынша жоғары көрсеткіштері бар және оның машина жасау өнімдерінің әлемдік нарығындағы бәсекеге қабілеттілігін айқындайтын жаңа өнімді жасау бойынша олардың инновациялық дамуын айқындайтын қазіргі заманғы құю өндірісінде аддитивті технологияларды пайдалану зерттелді және талданды. SLS технологиясының мәні келесідей анықталады: модельдік материал – бөлшектердің мөлшері 50-150 мкм болатын полистирол ұнтағы – инертті газ – азот атмосферасы бар герметикалық камерада орнатылған жұмыс платформасына арнайы роликпен оралады. Осылайша, қазіргі заманғы құю өндірісіндегі аддитивті технологиялар сапа, сенімділік және машина жасау өнімдерінің әлемдік нарығындағы бәсекеге қабілеттілігін анықтайтын жоғары көрсеткіштерге ие жаңа өнімді құрудың күрделілігі мен шығындарын түбегейлі азайтуға мүмкіндік берді.

Түйінді сөздер: аддитивті технологиялар, нанотехнологиялар, прототиптеу өндірістің рентабельділігі, машина жасау, құю өндірісі, құю синтезі-қалыптар, синтез-модельдер, құю жабдықтары, үш өлшемді CAD/CAM/CAE-технологиялар.

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EXPERIMENTAL AND LABORATORY STUDIES OF LOAMY SOILS OF THE PSKEMSKAYA HPP DAM

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Abstract. This paper presents the results of determining the maximum densities and optimal humidity of sandy loam-loam soils of the quarry of field No. 4 for the Pskemskaya HPP dam. These data were obtained using a standard compaction device using a special technique. Here, four standards were used, depending on the purpose, height and class of the structure, and various sealing works were applied. At the same time, the weight, the lifting height of the weight, as well as the number of layers of compacted soil varied mainly.

To determine the maximum density and optimal humidity, a graph of the dependence of the soil density on the humidity of the compacted samples is plotted. Find the maximum of the obtained dependence and the corresponding values of the maximum density of dry soil and optimal humidity.

Keywords: maximum density, optimal humidity, standard compaction, loamy soil.