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José María Pino Suárez 400-2 esq a Lerdo de Tejada. Toluca, Estado de México. 7223898475
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TÍTULO: El desarrollo y la investigación de la tecnología del bloque de cilindros de fundición.

AUTORES:

1. Denis I. Valeev.

2. Nikolay N. Safronov.

3. Lenar R. Kharisov.

RESUMEN. El artículo presenta una forma única de obtener moldes de fundición de bloques de hierro fundido gris sin el uso de equipos estándar. El artículo analiza el modo de operación de la fundición del bloque de cilindros, y se selecciona el material de fundición. La imposibilidad de fundir la obtención del bloque de cilindros R6 basado en la tecnología tradicional para V8 está comprobada. Se propone un nuevo método para formar cavidades internas y superficies externas de una pieza de fundición con el uso de residuos dispersos de empresas de construcción de maquinaria. Se ha desarrollado el modo de tratamiento térmico para eliminar tensiones internas y estabilizar el tamaño de la pieza fundida. Se proponen métodos para corregir defectos en piezas fundidas.

PALABRAS CLAVES: bloque de cilindros, barras para piezas de fundición, fundición gris, tratamiento térmico, corrección de defectos de piezas fundidas.

TITLE: The development and research of technology of the block of cylinders casting.

AUTHORS:

1. Denis I. Valeev.

2. Nikolay N. Safronov.

3. Lenar R. Kharisov.

ABSTRACT. The article presents a unique way of obtaining of cylinder blocks castings made of gray cast iron without the use of standard equipment. The technology makes it possible to produce castings in the small-scale production mode without significant capital costs, which is very important in the absence of long-term investments and sanctions for Russian defense enterprises and heavy engineering. The article analyzes the operation mode of the cylinder block casting, in accordance with this, the casting material is selected. The impossibility of casting obtaining of cylinders block R6 based on traditional technology for V8 is substantiated. The new method for forming internal cavities and external surfaces of a casting with the use of dispersed waste of machine-building enterprises is proposed. The heat treatment mode for removing internal stresses and stabilizing the casting size has been developed. The methods for correcting defects in castings are proposed.

KEY WORDS: cylinder block, rods for castings, gray cast iron, heat treatment, the defect correction of castings.

INTRODUCTION.

The cylinder block is the main part of the piston internal combustion engine. It is a solid piece, which unites the cylinders of the engine. There are support surfaces for installing the crankshaft on the cylinder block, the cylinder head is attached to the top of the block, the lower part is part of the crankcase [Grekhov L.V., Ivashchenko N.A., Markov V.A., 2013]. Thus, the cylinder block is the basis (housing) detail of the engine, to which the other units and assemblies are attached.

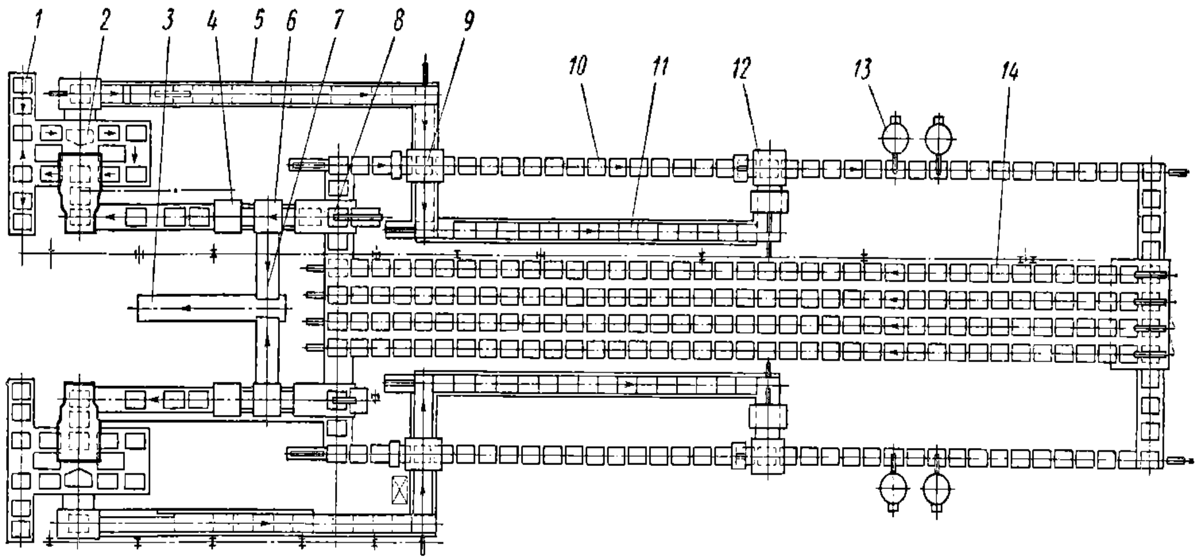
The cylinder operates under conditions of varying pressures in the supra-piston cavity. Its internal walls are in contact with a flame and hot gases with a temperature of 1500÷2500 °C [Dragiov B.X., Krugolev M.G., Obukhov V.S., 1987]. The average speed of sliding of piston rings along the walls of the cylinder in automobile engines reaches 12÷15 m/s [Yamanin A.I., Zharov A.V., 2003; Vyrubov D.N., Efimov S.I., Ivashchenko I.A., 1984]. Therefore, the material used to make the inner walls of the cylinders must have great mechanical strength, and the wall construction itself must have increased rigidity. The walls of the cylinders must resist abrasion against limited lubrication and have a general high resistance against other possible types of wear (abrasive, corrosive and some types of erosion) that reduces the service life of cylinders. In addition, the materials used to make the cylinders must have good casting properties and be easily processed on machines [Vanshejdt V.A., 1964; Ferguson C.R., Kirkpatrick A.T., 2016].

In accordance with these requirements, pearlitic gray iron with small additions of alloying elements (nickel, chromium, etc.) is used as the main material for the manufacture of cylinder blocks [Grudskii Yu.G. 182]. It has sufficient strength and hardness, provides rigidity of the cylinder block design, it is easily machined by cutting, forming brittle chips, and graphite inclusions provide a minimum coefficient of friction in the conditions of limited lubrication of the cylinder.

DEVELOPMENT.

Problem statement.

Fig. 1. The automatic molding line «SPOmatic» for molds measuring 1020×965×330 mm: 1 – the system of roller conveyors for circulation of models; 2 - the forming machine; 3 - the conveyor for castings; 4 – the flask unplugger; 5 - the zone of coloring and drying of half molds; 6 - the installation for knocking out forms by punching; 7 - the vibration separation grid; 8 - the transfer of the flasks to the knockout; 9 - the mechanism for installing the lower half mold; 10 - the installation area of the rods; 11 - the zone of advancement of the upper half-molds; 12 - the mechanism for covering the flasks; 13 – the filling area; 14 - the cooling of molds.

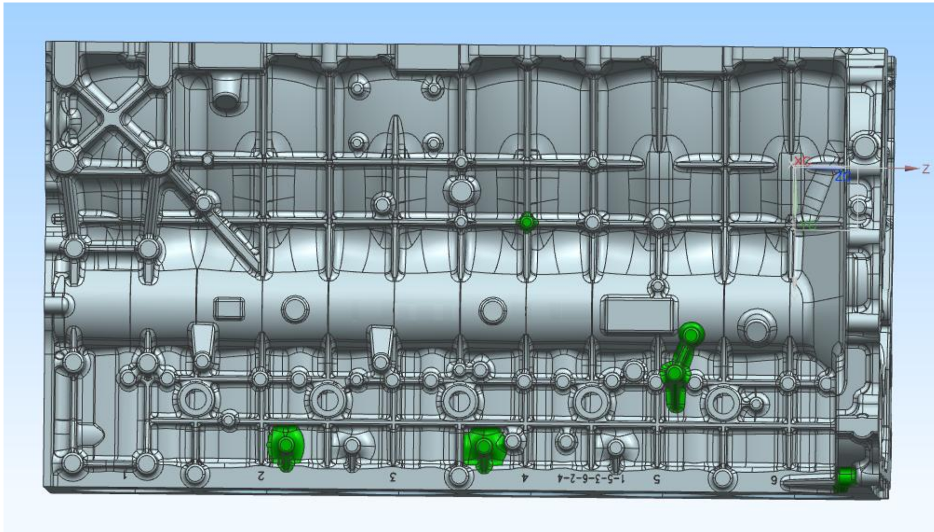


The traditional manufacture of cylinder block casting for trucks is carried out by casting into disposable sand and clay molds. The large dimensions and mass of the casting cause the use of automated machine mechanisms for molding, pouring and embossing operations. The automatic molding line "SPOmatic" [Henkin V.I., 2013; Shulyak V.S., 2008; Gorsky A.I., 1978] for molds measuring 1020×965×330 mm is shown in Fig.1.

The molds are moved on drive roller tables and trolleys. Each line is equipped with one molding machine, which alternately produces the lower and upper half molds. The system of submitting models is floating. The mixture is compacted by shaking with pressing a multi-plunger head.

The casting of the cylinder block R6 (Fig.2) has dimensions of 1018×534.5×705 mm. The permissible distance from the model to the wall of the flask for castings weighing up to 500 kg is 70 mm. This is the necessary wall thickness, capable of retaining the weight of the liquid metal in the mold. The obtained value of the minimum length of the flask is 1158 mm.

Fig. 2. The 3D model of the casting cylinder block R6.



According to GOST 2133-75 "Casting foundries, types and basic dimensions" the standard flask of similar size to the required one does not exist. Therefore, it was decided to use unique molds. This circumstance makes it impossible to use the automatic molding line "SPOmatic" for the casting of the cylinder block R6. In the absence of long-term investments and a sanctions regime for Russian enterprises, it is not possible to purchase a new molding-casting line or modernize the existing one. As an alternative, it is possible to consider the formation of the casting - its internal cavities and external surfaces by means of rods.

Experimental procedures.

At present, cold-hardening mixtures are widely used for the production of rods, which harden in the tooling under the action of gas-phase hardeners or catalysts (cold-box-process); mixtures with liquid hardeners or catalysts (no-bake process) [Budanov E.N., 2006; Zhukovsky S.S., 2010]. The cold-box-amin process was developed in the USA in 1968 by Ashland. The core mixture contains 100% quartz sand, 0.6...0.8% phenolic resin, 0.6...0.8% polyisocyanate. The rod is blown with a mixture of low-boiling liquid - tertiary amine (triethylamine, dimethylamine) vapor, with air, after the mixture is compressed in a box with a sand-blast or sand-shot method and the core acquires an initial strength that is 60% of its final value. The purge time is 2..5 sec, then 10...20 sec the rod is blown with air to purify it of the amine vapor. The catalyst consumption is less than 1.5 g per 1 kg of the core mixture. The solid polymer, polyurethane is formed, which ensures high strength of the rod, as a result of interaction of the binder components in the presence of a catalyst (amine).

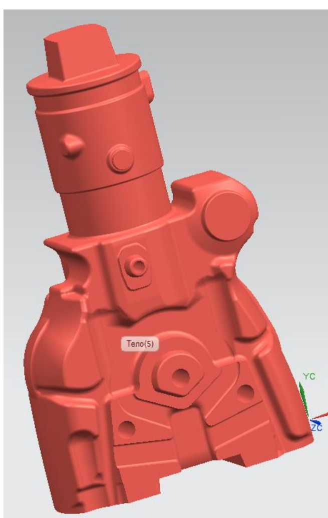
To prepare, dispense and feed the amine, special gas generators are used, which evaporate the amine, mix it with air and feed it into a core box. The mixture of amine with air, after passing through the core box, is sent to the neutralizer, where it is completely neutralized with dilute sulfuric acid to form a water-soluble ammonium sulfate salt. The degree of air purification in this system is close to 100%. Thus, the entire amine feeding path is completely sealed, which ensures the safety of the process. If it is necessary, the finished rods are painted with non-stick paint.

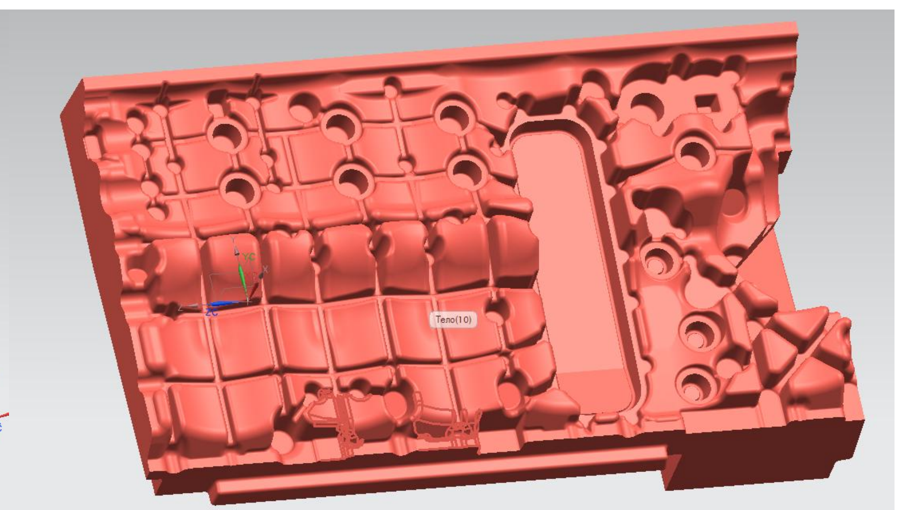
The strength of cold-box-amin rods depends primarily on the state of the macro and microstructure of the binder. At the initial moment of time after the manufacture of the rods, the least resistant region of the rod is the subcortical zone of the binder. The temperature regime and other purging parameters have a significant effect on the state of the macro- and microstructure of the binder, and consequently also on the strength characteristics of the cold-box-amin rods. To make the rods, a no-bake process will be used on the phenol-formaldehyde furan resin "Rezoform 8500". The resin practically does not contain free toxic monomers: the formaldehyde content is less than 0.7% (actually less than 0.5%), the content of free phenol is not more than 1.2%. It has good reactivity and provides high strength characteristics. The resin does not contain nitrogen, which reduces the likelihood of gas defects in the castings. This makes it possible to produce strong rods of any configuration, guaranteeing high quality of castings and easy knockout.

To form all the surfaces of the casting, 24 rods which are assembled into a package are required. The package consists of: a die, six center rods (Fig.3), two side (Fig.4), upper / lower left shirt, oil jacket, two ends, two water pumps, two springs, a water jacket box, a gating bowl, a boss and two mortises to the end rods. The individual parts of the package are glued together with synthetic polymer hot melt "Foundry TEC 501".

Visual inspection is carried out and small defects are brushed with 25A16PSM18KBKB (25x150) block and patched with repair paste by hand. Then the rod is painted by dipping in a spray bath with the composition "Arkopal 8367" – this is an aqueous non-stick coating based on aluminosilicates with the addition of graphite and iron oxide [Zhukovsky S.S. (1993) ;Vdovin K.N., Feoktistov N.A., Pivovarova K.G., Deryabin D.A., Khrenov I.B. (2016)].

Fig. 3 The center rod. **Fig. 4. The side bar.**





The painted package of rods is placed on a pallet on which a flask is mounted on the top. The flask with the package of rods is filled with the disperse waste [Safronov G.N., Safronov N.N., Kharisov L.R, 2015]. Casting of the mold with alloy SCH 30 GOST 1412-85 is carried out with a metal truck. The filling temperature is 1420...1440 ºC. Filling time is 30...45 sec. Before pouring, samples are taken for the amount of bleaching, for the chemical composition and the sample for mechanical properties. The chemical composition of the alloy is shown in Table 1.

Table 1. The chemical composition in % of SCH 30 material.

C	Si	Mn	S	P	Cr	Ni	Ti	Cu	Mo, V, Co, W, Nb, Sn (0.07%)
2.95	1.09	0.87	0.019	0.033	0.16	0.05	0.004	0.35	∑ 0.11

Experimental results and discussion.

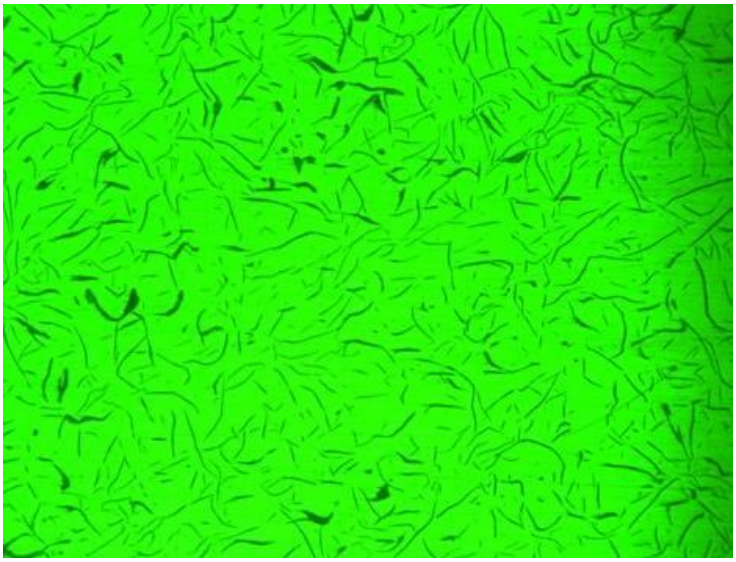
After casting, the casting is aged for 12 hours. Then the casting is knocked out of the mold, a molded flask is removed from the pallet with a bridge crane with a filled bag of rods for this purpose, the flask is installed on the grate and extracted. The casting is made by destroying the outer shell of the mold by hand using a scrap. The casting with the gating system is reloaded to a vibrating table with the help of a crane beam where the remnants of the core mixture are separated from the pockets and cavities of the casting. Then profits, gates and feeders are cut off. The casting (Fig.5) is cleaned by shot in the shot blasting chamber ES 1511 for 15 minutes, and it is necessary to double-rotate it 180 degrees manually with a crane beam [Ingo Gross, Frank Ioldert, 2010; Kanicki D.P., 1994; Popov A.A., 2002].

The pneumatic hammer chops off and peels off remnants of burrs and bays on the casting, and the channel under the camshaft is cut through. After cleaning the casting, its hardness is measured, mechanical properties and microstructure are determined. Measurement of the hardness of the cast was made on a hardness tester "FOUNDRAX BRINscan MkIII" [Dubrovsky V.A., Arbuzov I.A., 2002; Kolpakov A.A., Zuev M.P., 2002]. The hardness of the casting was 214 HB, which corresponds to the normative value in accordance with GOST 1412-85.

Fig. 5. The casting of the cylinder block R6.

The strength of the samples for mechanical properties filled with casting was 294 MPa, which corresponds to the grade of cast iron SCH 30. The microstructure of the sample is shown in Fig.6.

Fig. 6. The microstructure of the casting cylinder block R6, × 100.



The defects of casting in the form of shells up to 5 mm diameter and depth up to 8 mm, as well as cracks up to 100 mm long and up to 3 mm deep can be corrected by cold welding with copper-nickel electrodes. They do not dissolve carbon and do not form structures having high hardness after heating and rapid cooling. Whitening of the zone of partial melting with its small dimensions is practically absent. This is due to the fact that copper and nickel (the elements-graphiters) at the penetration have a positive effect. At the same time, nickel and iron have unlimited solubility, contributing to reliable fusion.

In the process of crystallization of a shaped casting of a complex configuration, such as a cylinder block, inevitably there are foundry stresses, due to braking shrinkage of the rods, as well as uneven cooling of the thin and massive parts of the casting. These voltages are eliminated by slow heating to 450÷550 ºC.

Depending on the size of the casting and the thickness of its walls, this temperature is maintained for 1 to 5 hours, followed by slow cooling. Internal stresses are relaxed and the casting size is stabilized at this annealing, no structural changes are observed. As coagulation of eutectoid cementite and its decomposition begins at a temperature above 550 °C, heating the casting above 550 °C leads to a decrease in the strength and hardness of the cast iron.

CONCLUSIONS.

Thus, the unique technology of obtaining the casting cylinder block R6, implemented without the purchase of new equipment and the lack of significant capital costs for the introduction, is presented.

Based on the operating conditions of the casting, an alloy of the optimum composition and service characteristics was chosen; the support fleet and other necessary devices for the production of castings were designed, the design and configuration of rods for forming external surfaces and internal cavities of the casting were developed.

The mode of heat treatment and methods for correcting defects in castings have been developed. The use of this technology will make it possible to successfully implement the process of localizing the production of foreign units and units on the territory of the Russian Federation within the framework of the import substitution program. Modern means of designing and modeling guarantee high quality of castings and short terms of technology introduction.

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DATA OF THE AUTHORS.

1. Denis I. Valeev. Kazan Federal University. Email: ln271@mail.ru

2. Nikolay N. Safronov. Kazan Federal University. Email: global@prescopus.com

3. Lenar R. Kharisov. Kazan Federal University. Email: info@prescopus.com

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