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ARGUMENT FOR RATIONAL TECHNOLOGY OF SHAPING FOR ARMATURE CASTINGS FROM IRON-CARBON ALLOYS

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Abstract: *This paper is the results of justification rational technology of making molds for casting of fittings of iron-carbon alloys with the improvement of working conditions and environment. Given data about the features of manufacturing of forms by various methods. The calculated material costs in the manufacture of 1 ton of the buildings of the rebar alloy 30B three variants of formation.*

Keywords: *rational technology, shaping, casting valves.*

1. INTRODUCTION

Modern armature construction is inconceivable without foundry production. Foundry production is the main base for the development of armature production. About 90% of the weight of the armature products are castings. The operating bodies and armature bodies are cast and then only the mechanical processing of the flanges is carried out. If the castings are of poor quality, especially in terms of geometric accuracy, then the enterprise bears significant economic losses associated with the marriage of the foundry. This way, the problem associated with the use of modern molding and rod equipment at enterprises, which makes it possible to obtain quality armature, is very relevant.
Reinforcing castings are liquid. Any investment quickly pays off and provides greater profitability. The equipment market offers a wide range of various molding lines. The choice of rational technologies and equipment for manufacturing reinforcing castings is very relevant. We will analyze various types of shaping: vacuum-film process, the process of pulse shaping, the SEATSU process [1].

2. RESULTS RESEARCH

On the basis of the literature [2] on the state and development of technologies shaping species found that until 80-ies of XX century main ways compaction molding compounds were shaking, pressing and combine them in various modifications.
In recent decades, there was a tendency of transition from static to dynamic compaction methods, because of the requirements that apply to casting quality, productivity, cost of materials and energy, safety and the environment.
Found that in today's world the most common are the following processes: vacuum process, pulse forming and sealing process air flow from the compression. At the same time then these methods are not widely used for a number of reasons, including economic, insufficiently studied patterns of densification; no sufficiently reliable data calculation methods strength by volume forms as a result of compaction, etc.

The aim is to identify and feasibility of forming a rational technology for armature casting of iron alloys with regard to improving the working conditions and environment.
Analysis densification with vacuum-envelope shaping (VES) showed that the main factor that determines the strength of the material forms with no binding is value dilution [3-8]. On the strength of molds and cores, which are made by vacuum forming is influenced by other factors such as the physical and mechanical properties of formative material, mold design, configuration and geometric dimensions of the working cavity forms.
Let's find the main factors that affect the process of compacting sand at VES [4]. Let's say is necessary to determine the maximum diameter D_r (round) for VES mold in which the mold is kept during transportation and vacuum is not destroyed. Pressure drop where:

$$\Delta p = p_a - p_b, \tag{1}$$

p_a and p_b – atmospheric pressure and remaining in shape.

From figure 1 shows that the equilibrium condition is that the strength of the external rubbing sand on the inner walls of the mold must be equal or greater than gravity of the sand:

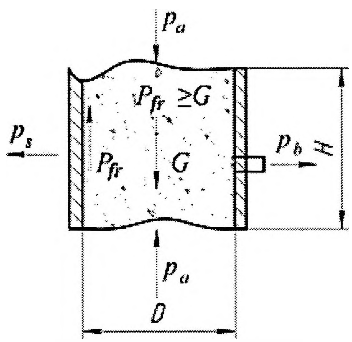

Figure 1: Calculation scheme

$$P_{fr} \geq G, \; P_{fr} = P_s tg\, f. \tag{2}$$

Power of the side pressure:

$$P_s = \xi(\Delta p + \gamma \cdot H)\Pi \cdot H, \tag{3}$$

where $\gamma \cdot H$ – specific pressure of gravity;
H, Π, S – height of the mold, its perimeter and area;
γ – density of sand;
f – factor external friction of sand;
ξ – coefficient of lateral pressure.

Then:

$$P_{fr} = \xi(\Delta p + \gamma \cdot H) tg\, f H \Pi\,; \tag{4}$$

$$G = S \cdot H \cdot \gamma\,.$$

As $S = \dfrac{\pi D^2}{4}$, and $\Pi = \pi D$, then if set formula (4) value of S and Π we will get:

$$D_r \le \frac{4\xi tg\, f(\Delta p + \gamma \cdot H)}{\gamma}. \tag{5}$$

From the formula (5) we see, the main factors are: pressure drop Δp; sand density γ; f, ξ – coefficient of friction and lateral pressure.

Coefficient f and ξ depends on sand grain size and its steepness:

$f = 28{,}5^\circ - 35^\circ$ – for small sands;

$f = 34^\circ - 46^\circ$ – angled sands;

$\gamma = 1600 \div 1700$ kg/m^3;

$\xi = 0{,}35 - 0{,}40$.

The higher the value ξ, f and Δp, the ceteris paribus D_r will be higher.

Let's look at VES scheme (figure 2) and calculate the pressure depended on height.

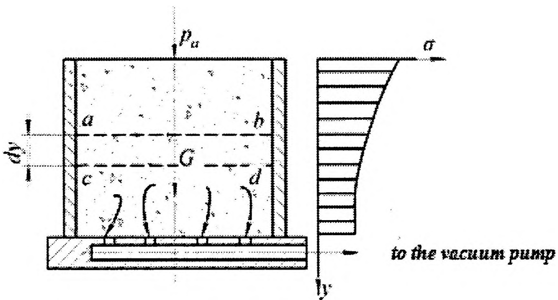

Figure 2: Stress-strain state in the form VES

For system and counter system operating voltage $\Delta p = p_a - p_b$, where p_a and p_b– atmospheric pressure and a residual form, that vacuumed.

At layer *abcd* thickness *dy* forces act on the upper limit of *GF*, the bottom *(G + dG)F*, on the side faces of the layers having specific strength τ rubbing sand on the walls of the mold, in the layer are gravity *G*, while shot semi shape of the model plate layer having a strength inertia *J*. Similar tensions are in $A^1B^1C^1D^1$ layer (in the scheme is not specified), but in the first case, the specific friction force τ are down, and the second τ^1 - up. Putting both layers differential equations and deciding them, we get:

$$\sigma = e^{Am}\left[\Delta p + n\frac{(g+a)}{A}\right] - n\frac{(g+a)}{A}; \tag{6}$$

$m = H - y; n = +1$ – for the lower layer;

$m = y; n = -1$ – for the higher layer.

$A = \frac{\xi f \lambda}{S}$; can be taken: $\gamma = 1600 \div 1700$ kg/m^3; $f = 0{,}3$ – coefficient of the outside pressure; $\xi = 0{,}4$ – coefficient of the side pressure; $a = 1{,}2$ m/s^2 – speeding semi shape of the forces of inertia.

From formula (6) shows that stress changes exponentially. It can be determined that the minimum allowable vacuum in the form to:

$$\Delta p_{\min} = \frac{\gamma(g+a)}{\xi \cdot f}\frac{S}{\Pi} \quad \text{or} \quad \Delta p_{\min} = \frac{D\gamma(g+a)}{4\xi \cdot f}. \tag{7}$$

Term (7) similar to (5), but takes into account the inertial forces.
From formula (7) shows that an increase in the coefficient of friction f and ξ pressure side pressure drop decreases with increasing density and γ sand, acceleration a and square mold S differential pressure should be increased.
The main factor in sealing compression of the airflow to the compression [6, 7] have the power filtering, which depend on air pressure, the initial mixture density and height of the mold.
To calculate the filtration of gas through the mold can be used depending same used in the mechanics of liquids and gases filtration to describe a porous medium.
The most famous equation for isothermal gas filtration in a porous layer is Leybenzon equation:

$$\frac{d\rho}{dt}=\frac{K_p}{m}\cdot\frac{\partial}{\partial x}(p\frac{\partial p}{\partial x}), \tag{8}$$

where ρ – density of air;
K_p – permeability coefficient layer;
m – porous of media;
p – air pressure;
x – coordinate direction filtering layer;
t – exact time.
With minor pressure differences in thickness of the porous layer of (8) has a solution:

$$p=p_1-\frac{p_1-p_2}{H_0}x, \tag{9}$$

where p_1, p_2 – gas pressure at the inlet and outlet of the layer under;
H_0 – the thickness of the mixture compacted.
Vaste of Q for this case:

$$Q=K_p\frac{\Delta p}{H_0}S, \tag{10}$$

where S – sectional area layer.
With increasing pressure drop (0,5-0,6 MPa) thickness is necessary to consider the ability to mix gas compression. Then the solution equation is carried out (8) for these conditions is as follows:

$$p=p_1^2-\frac{p_1^2-p_2^2}{H}x. \tag{11}$$

A gas flow filtered through a layer of the mixture described by the equation:

$$Q=K_p\frac{p_1^2-p_2^2}{2pl}S; \tag{12}$$

$$K_p=\frac{1}{270\mu}\cdot\frac{m^5d^2}{(1-m)^4}, \tag{13}$$

where K_p – coefficient of permeability to air, $K_p=2\cdot10^{-6}$ m^4/Ns;
μ – dynamic viscosity, air, $\mu=0{,}0182$ MPa·s;
d – average particle size of the solid phase.

The speed of air in filtering, in which the turbulent regime occurs is determined from the relationship:

$$\vartheta_t \succ \frac{100 \cdot m \cdot v}{d_e}, \tag{14}$$

where v – kinematic viscosity (with $t = 20^\circ C$; $v = 2,2 \cdot 10^{-5}$ m/s);

d_e – equivalent aerodynamic diameter, $d_e = \dfrac{4md}{6 \cdot (1-m)}$.

For filling mixed with quartz sand KO20 and porosity $m = 0,5$; $d_e = 0,75 \cdot 10^{-3}$ m.

When substituted into the formula (14) we obtain the numerical values of velocity above which there is a turbulent regime – $\vartheta_t > 14,6$ m/s.

Define filtration rate:

$$\vartheta_f = \frac{K_p}{m} \cdot \frac{(p_1^2 - p_2^2)}{2 p_2 H_0} x, \tag{15}$$

де H_0 – висота стовпу суміші, що ущільняється (опока з наповнюваною рамкою).
where H_0 – the height of the pillar that the compacted mixture (so far from filling the frame).

Maximum filtration rate at a value $K_p = 2 \cdot 10^{-6}$ MPa·s; $p_1 = 6 \cdot 10^5$ Pa; $p_2 = 1 \cdot 10^5$ Pa; $H_0 = 0,4$ m; $m = 0,5$ makes $\vartheta_\phi = 17,5$ m/s.

From the expressions (11) and (12) shows that the pressure of compressed air, the filtration rate and the height of the mold vary in a parabolic law, as confirmed experimentally.

In order form, as to be expected, there is major loss of pressure, which means most of the energy went into compression, as evidenced most important stress and consequently density at any values of initial pressure.

The final seal to forms determined by the pressure of after-pressing.

In the study of pulse techniques sealing molding sand note should note that the sand mixture - a complex rheological body, which has all three of its fundamental properties: viscosity, elasticity and plasticity. Rheological model of molding sand should really reflect all the physical processes that occur in molding the mixture under the influence of any seal.

When compression molding sand in box-form in the model tests it on himself two types of stress: compression and shear, and in different areas of the model-box-form fate of these strains are different at different times. There are also these two strain simultaneously.

In order to simplify the model of molding sand is advisable to introduce a two models: volumetric compression and pure shear. In this case, each model will consist of a small number of elements that are the most striking rheological properties of molding sand for in including another type of load. All this will reduce the accuracy of the results, but significantly simplify the cumbersome technology mix calculating rheological parameters [9-11].

Compaction mechanism with pulse shaping methods significantly different from the static compaction methods. Impulse sealing compressed air or gas combustion products is represented as follows. Front compression wave front, getting the mix, layer by layer gradually destroys base structure. There is a gap of cohesion linkages between the parts of the mixture, forming the bulk viscosity. Strain rate is so high that viscous membrane binding behave almost like a solid body. Structural air, concluded in the mixture directly compressed wave compression. Thus, the only body resists compaction H0 *, which describes the friction in a mixture with a volume compaction. After an active process of compaction, particle mixtures again connections are restored. Based on these representations, the rheological model with pulse compression can be proposed in the form shown in figure 3.

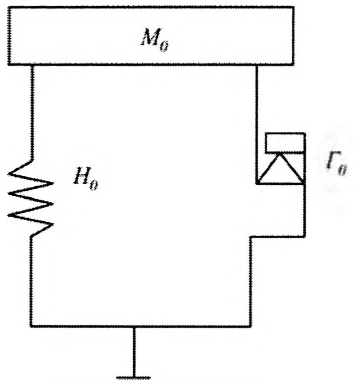

Figure 3: Rheological model of molding sand compaction methods for pulse:
M_0 – weight of the mixture; H_0 – Hooke elastic element; Γ_0 – mechanical stopper

Differential equations for this rheological model can be written based on Newton's second law in the form of:

$$M_0 \frac{d^2\varepsilon}{dt^2} = -3K\varepsilon, \tag{16}$$

where M_0 – weight of mixture;
ε – the relative volumetric deformation;
K – modulus of rigidity.
Decision of equation (16) looks like:

$$\varepsilon = \frac{1}{t_i}\sqrt{\frac{M_0}{3K}} \sin\sqrt{\frac{3K}{M_0}}t, \tag{17}$$

where t_i – pulse width.

Low pulse sealing mechanism different from the mechanism of impulse sealing pressure force nature sealing action, that value *dp/dt*.
At low air impulse, inertia acting in the mix is much higher than in high-pressure units. This provided much higher total passage area valve and extremely short time of its opening.
Molding machines that compact the molding mixture by direct action of the airflow can be renamed as airflow forming machines. Airflow forming machines include switching machines (air blow), pulse-shock machines are performing process Seatsu (air flow and after-pressing) process and a vacuum press machine [12, 13].
Energy consumption can be considered as an additional criterion for easy selection of a group of injection molding machines with similar technological capabilities. This factor is of paramount importance in terms of environmental and operational costs of machine. If the processes occurring in the airflow machines as there is a relationship between the operating parameters (indirect energy consumption) and the level of noise emissions.
Evaluation of energy required to seal molding compounds various ways forming a complex problem and leaves species implemented processes. Opinions about the impact of stress on growth rate effect compacting molding sand varied. According to some authors stress increasing the growth rate of molding sand leads to increase the degree of compaction. For others, the inverse is true phenomenon.
In light of the findings of the main action is the right choice of volume pulse heads, expanding the volume and initial pressure operation. Among the technological factors affecting the effects of air-stream compaction, bulk density is sand mixture before compaction process - pre-aeration of molding sand compaction increases. Using lower values of initial pressure can reduce power consumption

without compromising densification process effects. Thoughts on the impact of other properties on the molding sand compaction and pulse energy process often disagree, but there is no doubt influence the type of molding sand on energy densification. Results and analysis of air-flow molding process indicates the possibility of optimizing the aspect of reducing energy consumption of machines, with the correct choice of machine and process parameters. Progressive compaction reduces allowances for machining, which reduces the weight of the casting and increase savings. About 90% of the weight of reinforcing products make up the casting. Working bodies and buildings fittings casting and then get hold basically just machining flanges. Thus, all the costs of manufacturing reinforcing parts mainly attributable to casting. Buildings fittings (made from 30B weight 20kg) material costs for the sealing process in the manufacture of 1 ton given in table 1.

Table1: Price Calculation of 1 ton casting alloy enclosures fittings 30B

№	Articles of expenses	Costs, UAH*		
		Vacuum Process	Pulse forming	Seatsu -process
1	Basic payroll employees	1094	1300	1300
3	Basic materials	4220	4220	4220
4	Supporting materials	1168	1427	1427
5	Energy	3970	3970	3780
6	Cost	10452	10917	10927
7	Profit (20 %)	2090	2183	2185
8	selling price (+ 20 % VAT)	12542	13100	13112

*currency of Ukraine

Thus, the most economical in terms of cost to manufacture castings valves are vacuum process. This is because the excluded costs for connecting mixtures reduced costs and reduced sand plant number of personnel required for service of process.

Comparative characteristics data of shaping ways is shown in table 2.

Table 2: Comparative characteristics of airflow ways of shaping

Name of compact-tion method	Casting for using	Alloy	Approxi-mate weight of castings, kg	Mixture	Defects
Pulse forming	The head units for tractor engines wagon coupling housings, radiators and boilers	Cast Iron and steel	under 600	Sand and bentonite mixture of crude compressive strength σ_{cm}=0,16-0,22 MPa, with high initial power of the loosening 0,75-0,85 g/sm^3, density 40-45%, humidity 3-3,2%, gas permeability 70-90 .	Loosen in the upper corners of the model, burnt, gas sinks
VES	Castings for the railway industry, such as "beam", "frame"; semi tractor cities, pipe fittings, mold, cast iron bath, teeth excavator engine crankcase, casting cone crushers	Steel, cast Iron, Al	1 - 10000	Sand (1-2KO1B), zircon, chromite or olivine; humidity 0,1%	Gas Shells and porosity, burnt, geometry Violations included sand and film, clogging, of white in thin-walled cast iron castings

Seatsu process	The cylinder block. Motor housing, building heat exchanger section boilers and radiators, cast rear axle	Cast iron, steel, Al	Iron 700	sand and bentonite mixture of crude compressive strength σ_{cm}=0,15-0,2 MPa, density of 38-45% moisture 3,2-3,6%, gas permeability of at least 90	Burnt, sandy shells, gas shells

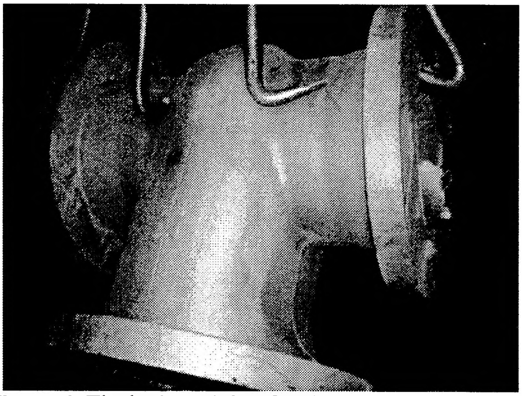

Figure 4: The body weight of 20 kg valves made of 30B

3. CONCLUSION

The best quality and cheap reinforcing castings (Figure 4)in the world are produced by modern vacuum-film molding technology. The best casting in 2005 was made by the vacuum process. The first place and the best prize at the congress of foundry workers in the United States was casting, weighing 1 ton, steel 4320, made by a vacuum process in ME Global, USA. The future of many not only reinforcing castings today, undoubtedly passes into the sphere of competence of the vacuum process.

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