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Conventional flow curves of liquid cast iron put on spheroidization

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Abstract

The purpose of the investigation was to confirm the hypothesis that the conventional flow curves of liquid cast iron put on sferoidization determined from the rod fluidity test are comparable to flow curves of liquids in environmental temperature. Moreover has been identified, that conventional flow curves for this liquid cast iron are similar to generalized non- Newtonian liquids curves.

For rods with the diameters 3-8 mm there are three various curves:

1 – the flow curve of liquid cast iron put on spheroidization overheated about 80 K resemble a shape adequately to a curve of densified liquid with shearing. This phenomenon can be caused by high overcooled and creation of crystallization nuclei;

2 – metal alloys overheated about 180 K resemble a shape adequately to Newtonian liquid;

3 – metal alloys overheated about 210 K resemble a shape of curve adequately to dispersed liquid with shearing. This phenomenon probably depends on influence of gas which creates on boundary of metal-sand mould.

Keyswords: Theoretical basis of foundry process; Flow curves; Cast iron.

1. Introduction

Rheology is a science about deformation and flow of matter. The “flow” means irreversible strain, which degree – under influence of force with limited value – grow with time expiration. The energy used to enforcement the flow undergo dissipation. The strain can cause changes of substance volume or changes its form. Characteristic rheological of liquid properties requires the flow curve tracing [1, 5]. The flow curve is rheological liquid graph presented on co-ordinate system in a function of: shearing stress and shear velocity, Fig. 1.

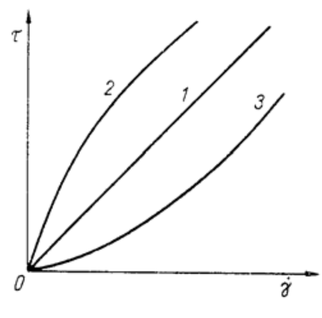

Fig. 1. Flow curves [1]: *1* – Newtonian liquid, *2* – dispersed liquid with shearing, *3* – densified liquid with shearing

Macrorheology treats a tested substance as continuous medium, that can be characterized by means of experimental definited rheological parameters, without penetrating the real molecular structure of body [1, 5].

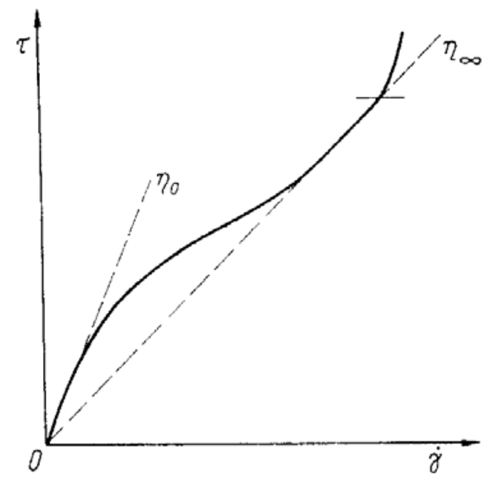

Fig. 2. The characteristic of generalized non-Newtonian liquid [1]

Generalized Newtonian liquid is dispersed with shearing system, that meets Newton's law for small and high shear speed. Flow curves for generalized Newtonian liquids, presented in fig. 2, has four characteristic ranges:

1 – At range of small shear speeds there occurs a constant ratio of shearing stress to shear speeds. Then, activity of system is similar to Newtonian fluid with constant viscosity η_o (equal to initial inclination).

2 – At range of average shear speeds there occur the non-Newtonian fluid region. The proportion of shearing stress to shear speeds (in this region) is not constant [1]:

$$\eta' = \frac{\tau}{\gamma} \neq \text{const} \tag{1}$$

In the testing region apparent viscosity of generalized Newtonian fluid decrease with the growth of shear speeds.

3 – At the high shear speeds there occurs a second region of Newtonian fluid. The inclination of flow curve is constant again.

4 – The characteristic growth of inclination of flow curve caused by turbulence occurs above limiting shear speed.

The results of research presents that in this zone, when shear speed grows an apparent viscosity decreases.

2. Analysis of model

At intake zone of channels of rod fluidity test the turbulent flow has appeared. The velocity distribution at the turbulent flow can be presented by equation in standard form (2). The basis for reasoning about the setting of universal velocity profile is dependence between shearing stress and braking distance, which was first defined by L. Prandtl [2, 3, 4, 7]:

$$\tau = \eta \frac{\mathrm{d}\upsilon}{\mathrm{d}y} + \rho \cdot l^2 \left(\frac{\mathrm{d}\upsilon}{\mathrm{d}y} \right)^2 \tag{2}$$

First element of equation is significant only at very small distances from the wall of channel and at larger distances predominantly is the second element. Then equation reduces (3):

$$\tau = \rho \cdot l^2 \left(\frac{\mathrm{d}\upsilon}{\mathrm{d}y} \right)^2 \approx \tau_w \tag{3}$$

where:

τ_w – value of shearing stress on the wall.

After transformation of equation (3) it has been received:

$$l \cdot \frac{\mathrm{d}\upsilon}{\mathrm{d}y} = \sqrt{\frac{\tau_w}{\rho}} \tag{4}$$

where:

$\sqrt{\frac{\tau_w}{\rho}} = \upsilon^*$ – dynamical velocity .

Both side of the equation have a velocity dimension.

It has been experimentally confirmed, that during the turbulent flow, the shearing stress on the wall of channel are proportional to density of fluid and to square mean velocity.

Highness of a rod obtained in fluidity test amount to a distance covered by liquid metal in sand mould channel of given diameter. When that covered distance is divided by pouring time then we receive the dimension of flow velocity, which is amounted to dimension of radicand: $\sqrt{\frac{\tau_w}{\rho}}$.

When in the second co-ordinate, the thickness of boundary layer is divided by pouring time, then we also receive a dimension of velocity.

The castability of metal is a parameter which determines a distance for metal flow in channel of sand mould before the stop of flow by the progressive process of solidification.

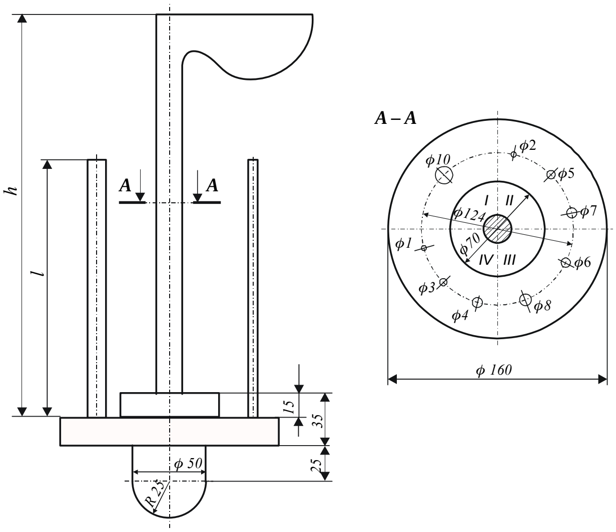

Fig. 3. The rod fluidity test [6]

Decisive factor of metal flow in sand moulds depends not only on chemical constitutions but also on pouring temperature and flow velocity. In earlier authors paper there are results of investigations of flow curves and rheological properties of grey cast iron [7, 9], Fig. 4.

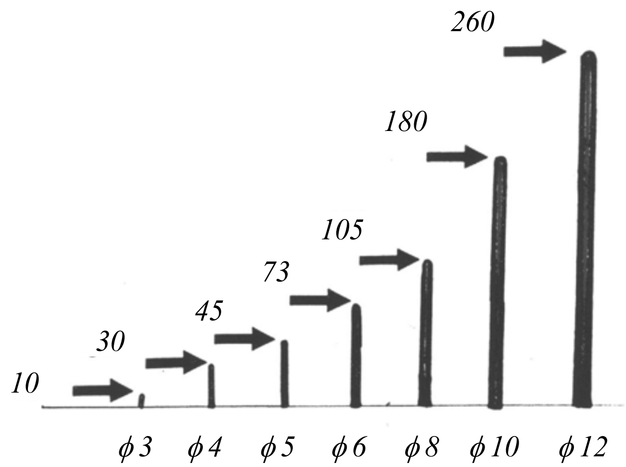

Fig. 4. Results of investigation rod fluidity test for grey cast iron with pouring temperature 1440 K (the depends high of rod from their diameter)

In the fig. 4, there has been shown, the highnesses of rods determine the flow curve which can resemble a shape of the flow curve adequately to curve densified liqiuid with shearing. The process of filling channels in sand moulds with liquid metal was a subject of investigations of many researchers [6, 7, 8, 9].

3. Results of testing

The rod fluidity test of spheroidal graphite iron (EN-GJS-400-15) was made in a big foundry. The metal alloy in induction furnace has been melted. Spheroidal process was realized by means of flexible hose by Pechiney Electrometalurgie. During this process temperature was about 1750 K. The results of chemical analysis of spheroidal graphite iron has been presented in the Table 1.

Table 1.
The results chemical analysis of spheroidal graphite iron after spheroidization process

Symbol element	C	Si	Mn	P	S	Cu	Mg	Sc
Content [%]	3,6	2,5	0,12	0,033	0,008	0,17	0,05	1,03

The results of rod fluidity test for cast iron put on spheroidization has been shown in fig. 5. The curves which are created by highnesses of rods has been called "conventional flow curves" which could be compare to flow curves of liquid substances at standard conditions.

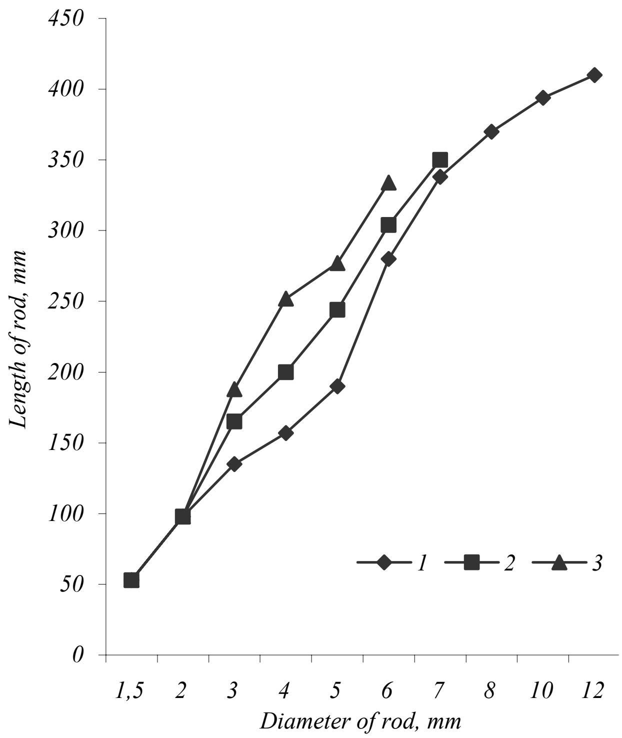

Fig. 5. Conventional flow curves of cast iron put on spheroidization: *1* – overheat about 80 K, *2* – overheat about 180 K, *3* – overheat about 210 K

During the flow of liquid cast iron put on spheroidization through the channels of fluidity test, mean velocity grows with the growth of diameter. The flow curves which can resemble a shape of the flow curve adequately to curve (fig. 2) of generalized non-Newtonian liquid.

For the diameters 3-8 mm there are three various curves:

1 – the flow curve of cast iron put on spheroidization overheated about 80 K resemble a shape adequately to a curve of densified with shearing liquid. This phenomenon can be caused by high overcooled and creation of crystallization nuclei;

2 – metal alloys overheated about 180 K resemble a shape adequately to Newtonian liquid;

3 – metal alloys overheated about 210 K resemble a shape of curve adequately to of dispersed liquid with shearing. This phenomenon probably depends on influence of gas which creates on boundary of metal-sand mould.

4. Conclusions

The results of investigation and analysis of the phenomena have been confirmed, that the curves determined by highnesses of rods from fluidity test amount to flow curves received for liquid substances at standard conditions. It has been identified, that flow curves liquid iron on put spheroidization are similar to curves of generalized Newtonian liquids.

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