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DEVELOPMENT OF THE PROCESS FOR STAMPING OF FORGED PARTS MADE OF GRANULES OF Al-Zn-Mg-Cu SYSTEM ALLOY

Belokopytov Vasilij I.[1], Gorokhov Yuruy V.[1], Konstantinov Igor L[1]., Uskov Igor V.[1], Lesiv Elena M.[1], Gubanov Ivan Y.[1], Zadvorny Alexander G.[1], Kirko Vladimir I.[1,2], Koptseva Natalia P.[1], Katryuk Victor P.[1]
[1]Siberian Federal University, Krasnoyarsk, Russia
[2]Krasnoyarsk State Pedagogical University named after Victor Astafijev, Krasnoyarsk, Russia
E-Mail: kopceva63@mail.ru

ABSTRACT

The influence of temperature and the speed parameters of the stamping process on the mechanical properties of forged parts have been studied. It has shown that in terms of the plasticity of the workpiece, stamping benefits most favorably from the mode improving the mechanical properties of the finished product. Similarly, but to a lesser extent, the stamp temperature influences the mechanical properties of the stamp. It has been established that the highest level of mechanical properties of stamped forged parts is achieved at stamp and workpiece heating temperatures ranging between 300–350 °C and intensity of shear strain speed $H = 5 \cdot 10^{-2}$–$1 \cdot 10^{-1}$ c^{-1}.

Keywords: granulated materials, stamped forged parts, quality, mechanical properties, structure, technology.

INTRODUCTION

The metallurgy of granules combining the production of micro ingots from a metal melt with high crystallization speed in the form of compact workpieces with a dense, pore-free texture is an important area of focus for improving the properties of structural materials in the fields where the traditional ingot casting and deformation technology to obtain semi-finished products has already exhausted its capacity [1].

The crystallization of a melt at high speeds enables the elimination of inevitable phenomena related to the casting of complex alloyed ingots, which cause defects in the process of their plastic deformation [2]. In addition, high-speed crystallization of alloys ensures abnormally supersaturated solid solutions, significantly expanding the limits of mutual solubility of alloying elements [3].

Thus, the method of granulating proves to be promising technology to manufacture metal products, inter alia from aluminum and its alloys, which allows not only to reduce labor costs in the production of stamped forged parts, but also to greatly improve their quality parameters [4].

The objective of this paper is the development of technological modes to manufacture forged parts of the "frame rail" type from a granular high-strength aluminum alloy of Al-Zn-Mg-Cu system.

METHOD OF PROCEDURE

To study the influence of the thermomechanical parameters of stamping on the mechanical properties of forged parts and their anisotropy under laboratory conditions, a stamp has been produced to enable the manufacture of articles (Figure-1), similar in their configuration to the forged parts of the "frame rail" type [4]. The stamp is equipped with silicon carbide heaters and is mounted on a hydraulic press PO 443 with the force of 20 MN. The temperature is measured and controlled using a thermocouple mounted directly onto the stamp strain, and is connected to a potentiometer. The mechanical properties were determined for samples taken from altitude 1a, 1b, 1c, longitudinal 2 and transverse 3 directions according to the diagram (Figure-2).

01969 alloy granules served as the feed material for obtaining the workpieces, which pertain to high-strength aluminum alloys of the Al-Zn-Mg-Cu system [5, 6]. Workpieces with cross-sections in the form of an isosceles trapezoid were manufactured by pressing with the elongation ratio $\lambda = 10$ of the granules fed into the container. These were heated in an electric furnace over two hours to the preset temperature before the stamping. The obtained forged parts were exposed to the final thermal treatment according to T1 mode, which includes quenching in water with a temperature of 475 ± 5 °C and subsequent aging at 135 ± 5 °C for 16 hours [7].

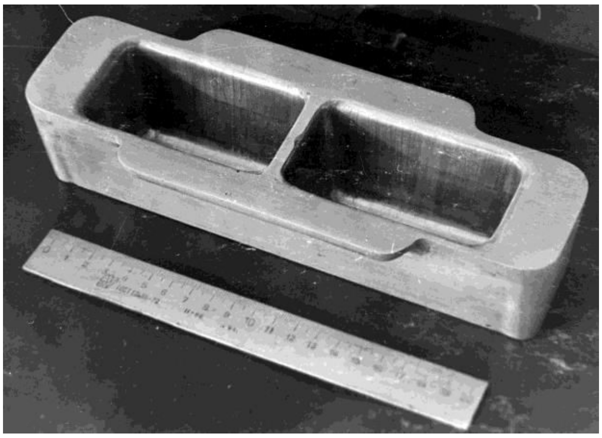

Figure-1. Model stamped forged part of the "frame rail" type.

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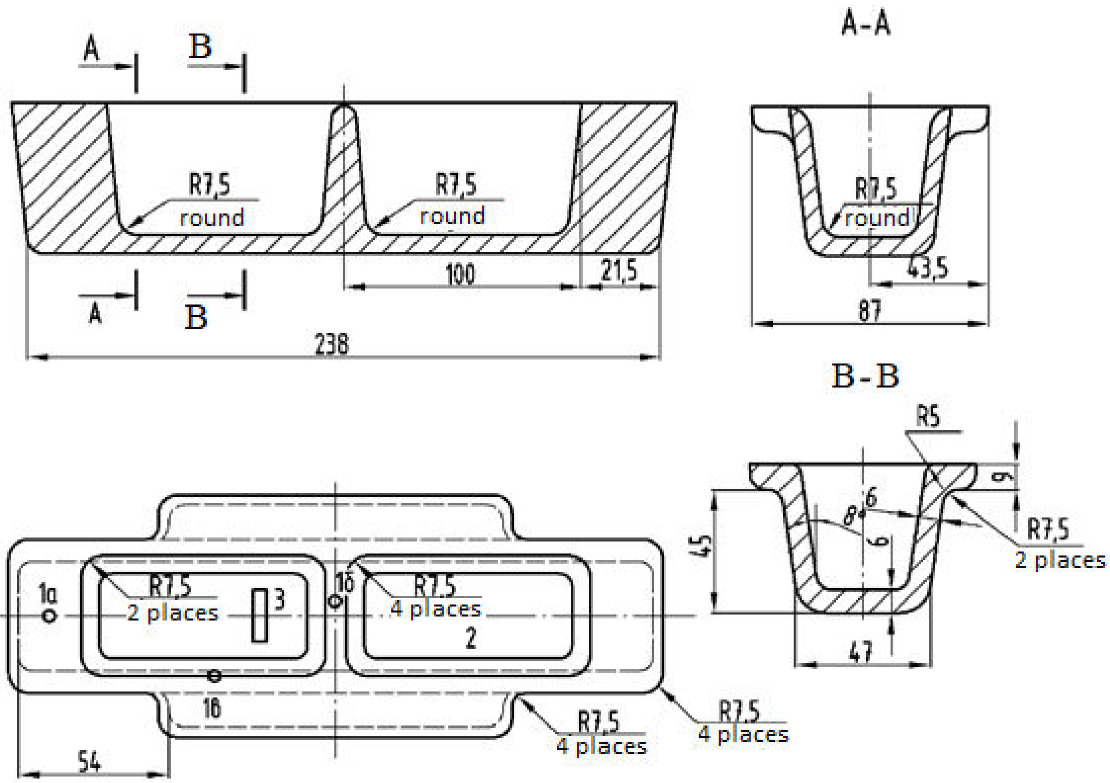

Figure-2. Sketch of a stamped forged part of the "frame rail" type 1a, 1b, 1c, 2, 3 - Diagram of sample taking.

RESEARCH RESULTS AND THEIR DISCUSSION

To determine the effects high-speed process parameters produced on the mechanical properties of forged parts, stamping was conducted at speed $v_0 = 0,05$; 0.10; 0.18; 0.60; and 1.80 mm/s. The deformation speed in the vertical direction was defined by the expression

$$\xi_z = \frac{v_0}{h}, \qquad (1)$$

where h - the thickness of the stamped forged part bottom.

Having taken the deformed state in the forged part bottom as flat, the intensity of shear strain speeds were calculated on the bases of the equation [8]

$$H = 2\xi_z . \qquad (2)$$

Table-1 gives the values of the deforming speeds, their respective deformation speeds and the intensity of shear strain speeds in the bottom of the forged part at the final stage of the stamping process.

Table-1. The movement speed of the traverse press and their corresponding deformation speeds and intensity of shear strain speeds.

v_0, **mm/s**	ξ_z, c^{-1}	H, c^{-1}
0.05	$8,3\cdot10^{-3}$	$1,7\cdot10^{-2}$
0.10	$1,7\cdot10^{-2}$	$3,4\cdot10^{-2}$
0.18	$3\cdot10^{-2}$	$6\cdot10^{-2}$
0.60	$1\cdot10^{-1}$	$2\cdot10^{-1}$
1.80	$3\cdot10^{-1}$	$6\cdot10^{-1}$

The heating temperature of workpieces $(t_{\text{заг}})$ and stamp $(t_{\text{шт}})$ in the stamping process were kept constant and equal.

Research results have shown (Figure-3) that the maximum values of yield strength and ultimate tensile strength of the samples taken from the forged parts as per diagram (Figure-2) correspond to the intensity of shear strain speeds $H = 5\cdot10^{-2} - 1\cdot10^{-1}\ c^{-1}$. Meanwhile, the coefficient of elongation varies slightly among the samples (Table-2).

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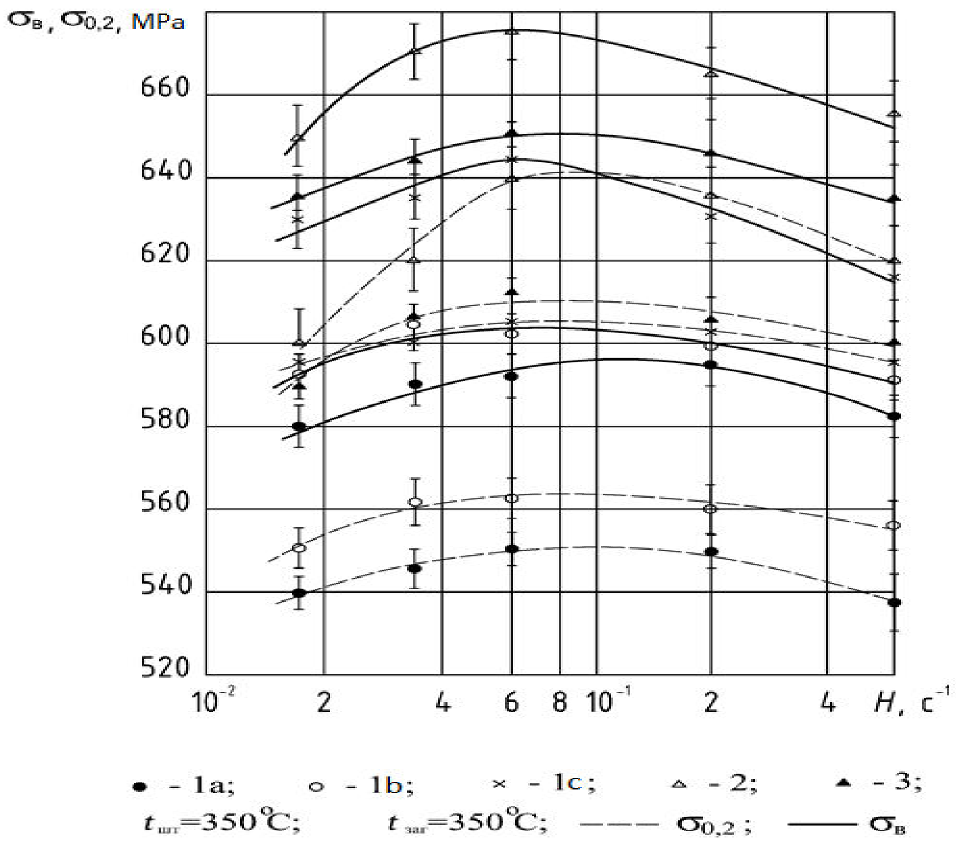

Figure-3. The relationship between the mechanical properties of samples made from forged parts and the intensity of shear strain speeds at stamping.

Table-2. The coefficient of elongation of the samples made from forged parts manufactured within different thermal mechanical parameters of the stamping process.

H, c^{-1}	$t_{шт}$, °C	$t_{заг}$, °C	The coefficient of elongation (δ, %) of samples made from forged parts according to the cutting diagram				
			1a	1b	1c	2	3
$1,7\cdot10^{-2}$	350	350	2.0	1.8	3.8	5.8	3.5
$3,4\cdot10^{-2}$	350	350	3.8	2.8	2.4	6.1	4.0
$6\cdot10^{-2}$	350	350	2.4	2.5	3.5	7.2	4.2
$6\cdot10^{-2}$	350	300	2.0	4.2	4.8	6.8	4.1
$6\cdot10^{-2}$	350	400	3.7	1.8	3.5	6.9	3.2
$6\cdot10^{-2}$	300	350	2.8	1.0	3.0	6.2	3.8
$6\cdot10^{-2}$	400	350	2.4	1.5	2.5	5.8	3.5

According to the graphs (Figures 4, 5) it is possible to define the stamping modes that ensure high-level mechanical properties in the finished product.

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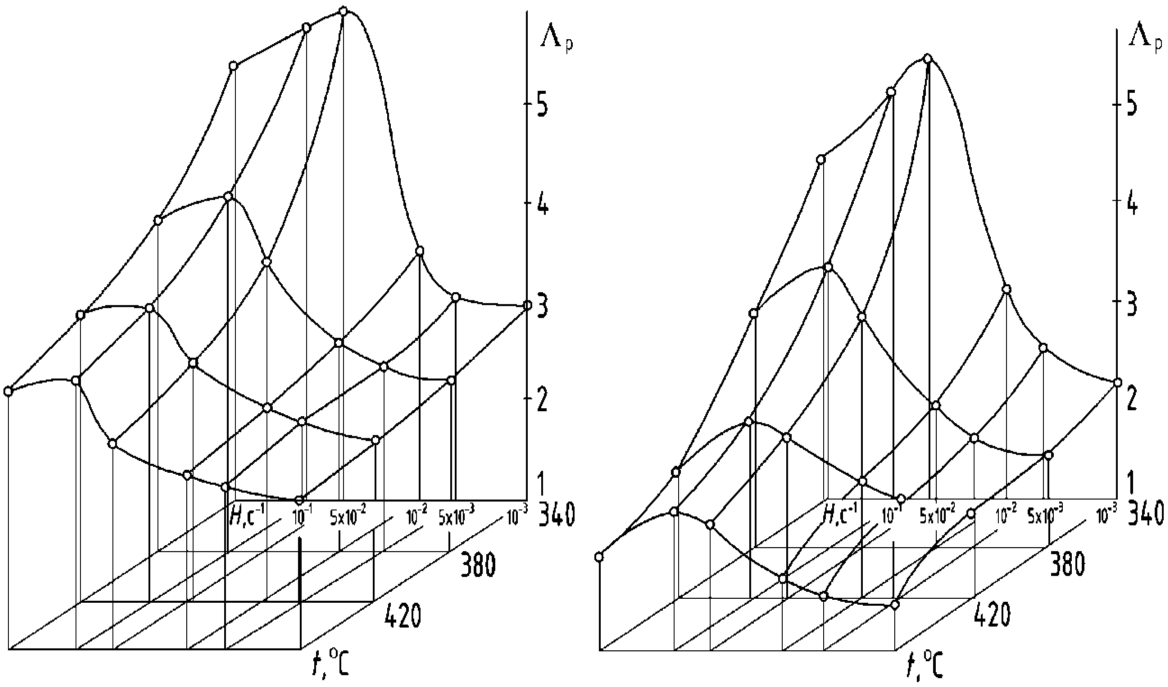
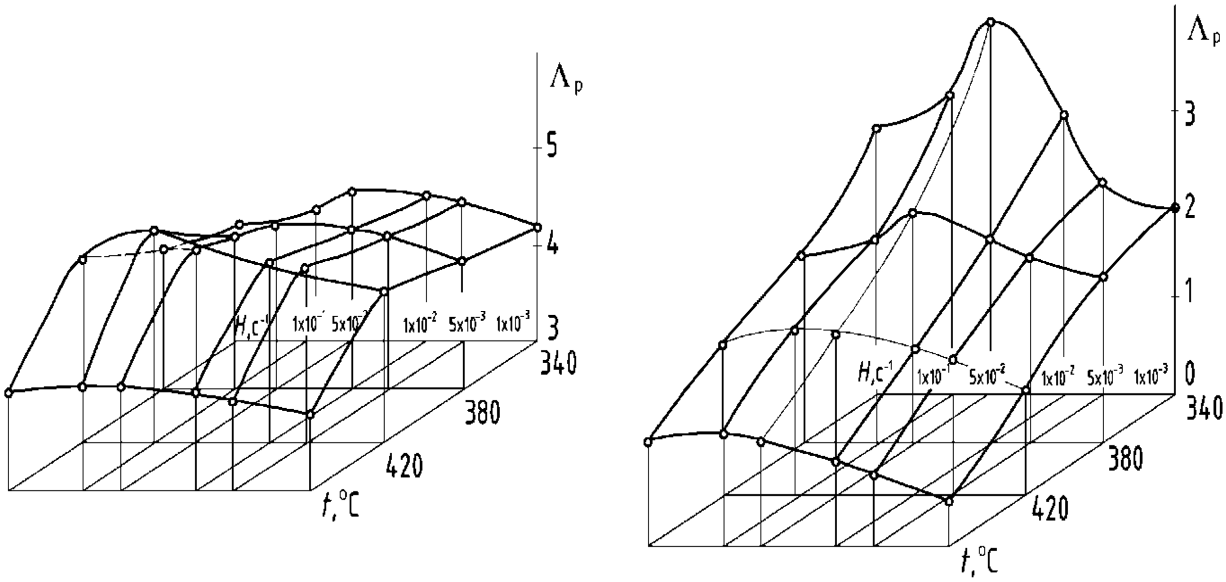


a b

Figure-4. Diagram of plasticity in the longitudinal (a) and transverse (b) directions of the extruded rectangular section profile made up of 01969 alloy granules obtained through torsional testing [9]



a b

Figure-5. Diagram of plasticity in the longitudinal (a) and transverse (b) directions of the extruded rectangular section profile made up of 01969 alloy granules obtained through tensile testing

Figures 6, 7 show the graphical relation of the mechanical properties of the selected samples to the workpieces heating temperature and the temperature of the stamp heating. They make it clear that an increase in the temperature of the workpieces in excess of 350 ^{o}C leads to reduced mechanical properties in stamp forged parts in altitude and transverse directions (Figure-6). Similarly, but to a lesser extent, the stamp temperature influences the mechanical properties (Figure-7).

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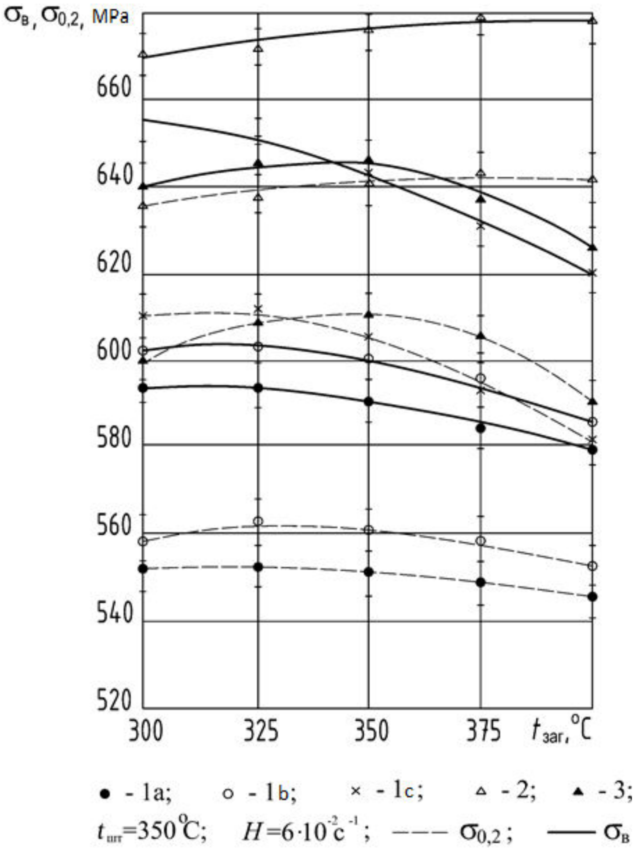

Figure-6. Relation of the mechanical properties of samples made of forged parts to the heating temperature of workpieces.

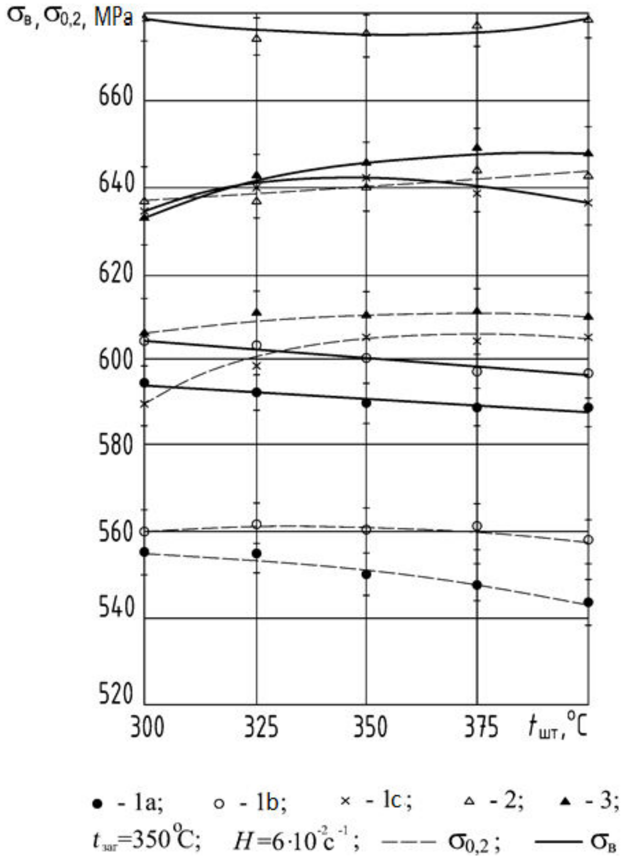

Figure-7. Relation of the mechanical properties of samples made of forged parts to stamp heating temperature.

In addition, the decrease in the workpiece temperature and the increase in the intensity of shear strain speeds significantly increase the stamping silk $P_{Ш}$ (Table-3) due to increased resistance to the deformation of the material.

Table-3. Relation of stamping strength to the workpiece temperature and the intensity of shear strain speeds at the stamp temperature of 350 °C.

$t_{заг}$, °C	H, c^{-1}	ε, %	$P_{Ш}$, MN
300	$6\cdot 10^{-2}$	22	2.24
		66	3.94
350	$6\cdot 10^{-2}$	22	2.02
		66	3.62
400	$6\cdot 10^{-2}$	22	1.91
		66	3.36
350	$1,7\cdot 10^{-2}$	22	1.86
		66	3.09
350	$3,4\cdot 10^{-2}$	22	1.96
		66	3.44

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Thus, the highest level of mechanical properties in stamped forged parts is obtained within the temperature range of stamp and workpiece heating from 300 to 350°C with an intensity of shear strain speeds of $H = 5 \cdot 10^{-2}$ $–1 \cdot 10^{-1}$ c^{-1}.

PRODUCTION TESTS

The calculation of the forming process for real stamped forged parts of the "frame rail" type according to the methodology described in the paper [10] enabled a stamp to be designed for preliminary stamping which ensures faultless forging at final stage of stamping. The preliminary and final stamping of forged parts under factory conditions was carried out on a vertical hydraulic press with a force of 150 MN. The workpiece was a pressed strip with elongation ratio $\lambda = 10$, thickness of 40, width of 250, and length of 1780 mm. Workpieces were heated up to the temperature of 300 and 350 °C over 2-3 hours. Soaking the workpieces in the furnace ensures the excessive phases' maximum liberation from the solid solution characterized by the high-level evenness of their distribution, which has a positive impact on the mechanical properties of the stamped articles [11]. Before stamping, the workpiece structure is over-crystallized and constitutes a ductile solid solution with uniformly distributed particles of intermetallic compound of principle alloying elements and aluminides from transition metals located mainly along the boundaries of subgrains [12–14]. The temperature of forged parts at stamping was 340-350 °C.

CONCLUSIONS

The stamping process for the forged part of the "frame rail" type from a granulated alloy of the Al-Zn-Mg-Cu system at the temperature of 340-350 °C in the isothermal mode and the intensity of the shear strain speeds $H = 2{,}5 \cdot 10^{-1}$ c^{-1} allowed products with relatively high mechanical properties to be obtained that meet technical specifications.

Nonetheless, the results of production tests revealed that the level of technology for casting, degassing and compacting granules should ensure a high-quality initial workpiece with a low level gas content to rule out the emergence of scaling in the form of point defects after hardening the stamped forged parts.

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