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Process research into metallic pipe wear of hot chamber die casting machines and methods ofincreasing wear resistance

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Abstract. The kinetics and reasons for metallic pipe wear of hot chamberzinc alloy die casting machines are established.Increasing metallic pipe wear components wear resistance is being achieved by means of die steelДИ – 22 with electroslag remelting modification and electron-beamremelting modification and after the processes of nitriding and boriding besides.

In the process of zinc alloys casting (modifications: Zamak - 4 - 1, Zamak - 10 - 1 and others) the most overloaded pressing unit features of hot chamber die casting machines typesCLT and IDRA appear to be metallic pipes components. Beta testing data carried out with KAMAZ PTCshow that metallic pipes componentsserviceability of IDRA machines made of steel 4Х5МФС doesn'texceed 2,5% ofzinc alloy die casting machinesmolding toolsaverage durability. Metallic pipes are being run at the temperature of zinc meltsequal to723±15К. High physicochemical interaction of zinc melts and steels influences on metallic pipe wire most of all, which depends on solution of metallic pipes componentsinternal channels[1 – 3].Consequently, processes research into metallic pipe wear of hot chamber zinc alloy die casting machines in order to increase wear resistanceis really actual.

To provide a quantitative law of tips internal parts damageability the investigation was held. The test disks had the following measurements: outer diameter - 30mm; internal diameter - 20mm; disk thickness – 5mm.Solutionintensity was estimated from the disk weight loss with regard to surface unit($\Delta P, g/cm^2$) during the period of planned investigations ($n = 1 \div 3\ 000$ cycleswith intervals 100 cycles).The results of tests on the solution kinetics of the metallic pipeactive faces are shown in Fig.1.Trend of a curve$\Delta P = f(n)$ is the evidence ofa compound dependence of steel 4Х5МФСsolution at various stages of operation.Conditionally, it is possible to distinguish 4 characteristic stages of the analyzed process. At the first stage ($n \leq 100$ cycles) the steel solution in melt Zamak - 4 - 1 increases insignificantly. The observed incubation period is associated with the increased resistance to oxide film solution on the metallic pipe surface. At stage *II* ($n > 100$ cycles), a sharp increase in solution rate was established. In the interval n ≈ 500-700 cycles (Stage *III*), the solution rate slows down. At stage *IV* ($n > 3000$ cycles) the intensified solution ofthe metallic pipe active face is again noted.

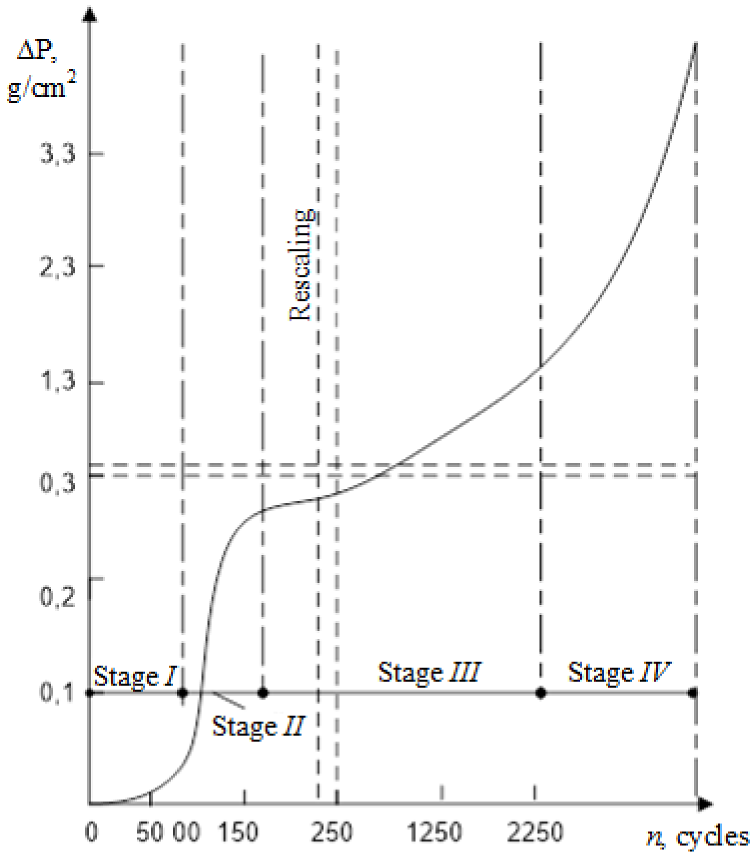

Fig.1 – The solution kinetics of the metallic pipe active faces made from steel 4X5MΦC in melt Zamak - 4 – 1 at 723K.

Metallographic and X-ray diffraction studies performed with DRON-3 installation established the formation of a transition layer on the tip channel surfaces being in contact withthe melt, consisting of the intermetallide phases $FeAl_3$, Fe_2Al_5, Fe_3Zn_{10}(Stage *II*) [4]. Identification of intermetallide phases was carried out according to characteristic radiation by scanning pulses at oblique cuts of polished sections. The structure of the layer is characterized by the presence of some defects in the form of pores, ruptures and cracks and by a strongsmall hardness H_μ ~ 1800, (Curve 3, Fig. 2).

As soon as *n* increases up to 1000 cycles, the intermetallide interlayer forms a continuous coating with thickness of ~ 0,08mm. The presence of these intermetallide phases causes an increased resistance to solution, (Stage *III*). Further accumulation of cycles (n>1000) has little effect on the transition intermetallide layer thicknessin the "steel-melt" system. At the same time, there is a slight decrease insmall hardness (Curve 4, Fig. 2), which is associated with the formation of an intermetallide layer with new characteristics (Fe_5Zn_2, $FeZn_7$, $FeZn_{13}$). Accordingly, the number of interference lines corresponding to iron-aluminum intermetallide elements such as $FeAl_3$ *and* Fe_2Al_5 decreases. At the end of this stage (n ~ 1300 cycles), the thickness of the layer increases, and thesmall hardnessdecreases noticeably (Curve 5, Fig. 2). At the same time there is an increase in the rate of the metallic pipe channel active face solutionalong with the disappearance of iron-aluminum intermetallide elements.

The obtained results make it possible to supplement the existing ideas about the causes for one of the most common types of technical failures in practice (the loss of the channel size and the implied danger of metallic pipes destruction or melt sputtering at the structural parts mating), and also implement a number of applied solutions aimed to increase metallic pipe wear components wear resistance.

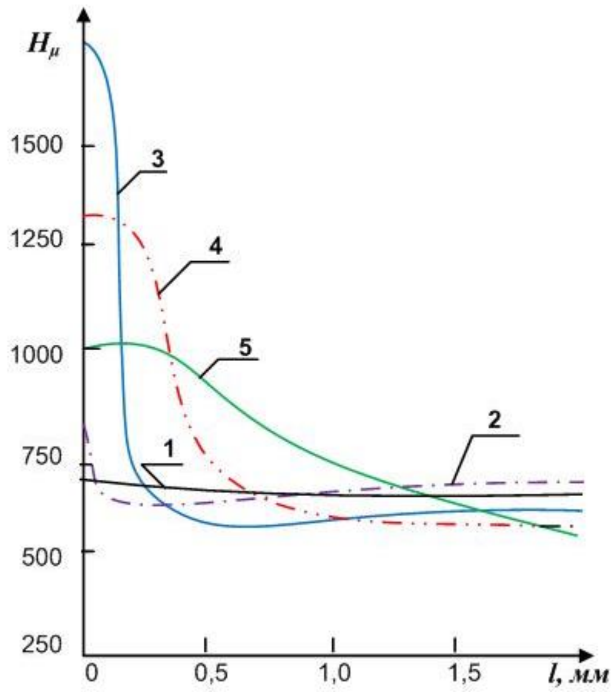

Fig. 2 – Change of small hardness in the surface layer of a metallic pipe material made from steel 4Х5МФС under the condition of interacting with melt Zamak - 4 - 1 at 723К: Curve 1 - initial state; Curves 2,3,4 and 5 after 5, 120, 1000,1300 pressing cycles respectively.

Along with steel 4Х5МФС widely used for metallic pipes manufacturing, such steel grades as 5Х4СВ4МФ, 4Х4ВМФС, 5Х3В3МФС, and steel 4Х4ВМФС (ДИ-22) received with the help of electric-slag and electron-beam remelting, and hardening by chemical heat treatment were subjected to research (Table 1). According to the solubility index (ΔP, *g/cm*^{2}) steel 4Х4ВМФС (ДИ-22) is promising for the manufacturing of metallic pipe elements of hot chamber zinc alloy die casting machines (from the number of materials studied). In accordance with the analyzed data the components serviceability reserve with the metallic pipes of die casting machines is based in the application of increased metallurgical purity material. The resistance of samples made of steel 4Х4ВМФСreceived with the help of electric-slag and electron-beam remelting to solution inZamak - 4 - 1 is 2.1 and 2.5 times higher on average than after conventional electric arc melting. The use of chemical-thermal treatment (nitriding and boriding) can significantly improve the serviceability of metallic pipes (Table 1).

Table 1 – The resistance oftool steel to solution in melt Zamak - 4 - 1 (melt temperature –723К, the period of planned investigations, *n* = 3 000 cycles).

Steel grade	Temper regime		Hardness, HRC, HB	Strengthening treatment	Hardness, HV	Relative resistance to solution in melt Zamak - 4 – 1
	$T_{hardening}$, K	T_{cast}, K				
4Х5МФС	1313	853	50-53			1
5Х4СВ4МФ	1393	873	52-54			1,28

4Х4ВМФС (ДИ – 22)	1333	853	50-53			1,2
5Х3В3МФС	1393	873	52-54			1,32
4Х4МФС (electric-slag remelting)	1333	853	50-52			2,52
4Х4МФС (electron-beam remelting)	1333	853	50-52			3,0
4Х4ВМФС	1333	853	50-52	Nitriding, 833K – 8 hours., 803K – 16 hours Layer depth 0,18 – 0,21mm	860 - 880	4,4
4Х4ВМФС	1333К (annealing – 2 hours)		160-180 HB	Boriding, 30%B_4C, 60%$Na_2B_4O_7$, 10%SiC, 1173K – 30 hours. Layerdepth 0,1 – 0,12 mm	1800	4,27

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