PLUNGER PRESSING SPEED LIKE THE MAIN FACTOR INFLUENCING OF THE MECHANICAL PROPERTIES OF DIE CASTING

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In the process of die casting the final quality of a cast is influenced by a great number of factors. The interpretation of the impact of the individual factors of die casting is based on the concept of the filling of a mould cavity. The issue of the filling of a die casting mould is complex due to the fact that the factors such as the cast structure and the mould thermal balance usually determine the real melt flow. High melt speeds in an intake port complicate the image of the flowing liquid because dispersive filling occurs at a specific speed. The main factors of die casting are: pressing speed, increase pressure, the melt temperature and the mould temperature. The presented paper deals with the experimental assessment of the impact of pressing speed on the mechanical properties and homogeneity of a die cast.

KEYWORDS

die casting, plunger pressing speed, mechanical properties

1 INTRODUCTION

The current consumption of aluminium alloys is constantly increasing by reason of demand in electrical engineering, aviation and particularly automotive industries. A current automobile includes parts of steel, cast iron and non-ferrous metal alloys, especially aluminium. Automobile manufacturers are trying to produce a lighter automobile not only in order to increase competitiveness but also by reason of a reduction in fuel consumption which would at the same time lead to a reduction in consumption of fossil fuels and thus to an elimination of carbon dioxide production as a greenhouse gas [Gaspar 2012]. Currently, aluminium alloys remain the most frequently used material in terms of the foundry industry owing to its specific weight, relatively good machinability and castability [Gaspar 2018].

Over the last ten years the consumption of aluminium castings has increased by 70%, out of which 60% of all castings are cast by die casting. The share of aluminium castings in an automobile has increased by over 160% in the course of last 30 years [Majernik 2019]. Components such as wheels, engine blocks, engine carrier systems, gearboxes, and braking systems are primary targets for reducing a vehicle weight, for their multiple-effect weight reduction which is reflected in reduction of wheel noise and vibrations, and in performance increase.

Costs of castings production and growing demands for mechanical load during operation play an important role which is associated with castings load. Requirements and difficulties of light alloy castings are increasing and will continue to increase [Krenicky 2008, Gaspar 2013].

2 DIE CASTING CHARACTERISTIC

Die casting is characterized by replacement of gravitational metallostatic pressure with a plunger force action upon the melt in a die casting machine filling chamber. The aforementioned is understood as a mechanical method of casting in which the molten metal is molded under pressure into a split metal mould by the action of a plunger on the melt in the filling chamber (Fig. 1). By means of plunger speeds, the units order in meters per second (10-100 m.s-1), the melt is being transferred from the filling chamber by means of the gating system into the mould cavity through the ingate. A total mould cavity filling period is very short – ones and tens of milliseconds. This method of the cavity filling allows the production of thin-walled shape-demanding castings with a high dimensional accuracy and an exact surface relief profiling of the mould cavity.

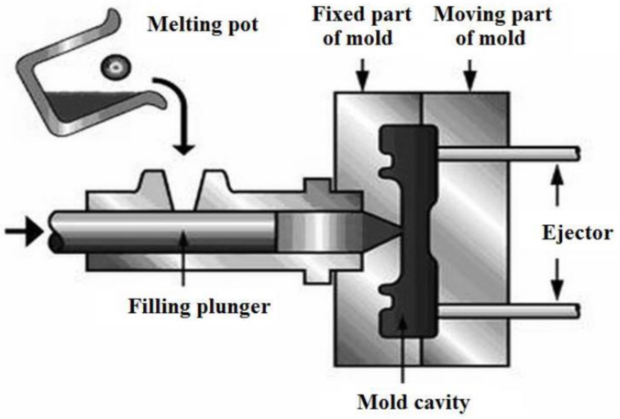

Figure 1. Scheme of casting metal under pressure

The quality of die castings is influenced by technological factors including [Gaspar 2013]:

- pressing speed in the course of casting cycle,
- specific pressure acting upon the melt, so-called resistance pressure,
- period of mould cavity filling,
- cast alloy temperature, filling chamber temperature and mould temperature.

In addition to the given factors the final quality of castings is also influenced by a proper structure of the casting mould which particularly includes the gating and venting and cooling systems of the mould [Majernik 2018]. The quality of castings is also influenced by other factors such as a die casting machine, a type of cast alloy and its metallurgical processing, the quality itself of the produced mould, the set technological parameters, and last but not least, the attendance of die casting machine [Murcinkova 2013]. In the production of die castings an increased attention is paid to the internal quality of castings which is characterized by the type and scope of foundry defects [Turtelli 2006]. Cavities are considered to be the main defects of castings. These cavities are determined as exogenous cavities arising as a result of gases and air capture contained in a mould by the turbulent melt flow [Mascenik 2012, Pavlenko 2017].

The most important factor in metal die casting includes the pressing plunger speed in the filling chamber of die casting machine. This speed determines a mode of the mould cavity filling and thus affects the internal as well the surface quality of castings. If the main technological parameters of die casting are focused on, then the quality of castings is influenced, in addition to parameters of the mould cavity self-filling, also by pressure affecting the solidifying casting in the final stage of the casting cycle - resistance pressure [Ruzbarsky 2014].

3 EXPERIMENTAL METHODS AND EQUIPMENT USED

A die casting machine with a type designation of Müller Weingarten 600 designed for casting of non-ferrous metals with a horizontal filling chamber was used to perform the experiments. The influence of changes of plunger speed the final quality of the casting made of ENAC 47100 (AlSi12Cu1 (Fe)) alloy, represented by mechanical properties, were monitored by permanent deformation "s" and hardness "HB" according to Brinell. Alternator flange castings (Fig. 2) cast in a quadrupled die casting mould with an automatic ejection was used for analysis. The mould treatment was performed automatically with an equipment by the company of Wollin by means of the agent Dascocast in the ratio of 1:100 and lubrication of a pressing plunger in the filling chamber by means of the lubricating agent Metalstar FE 82. Monitoring of technological parameters in experiments was allowed directly on the screen of die casting machine control system and with the dosing furnace control system.

Figure 2. Test casting

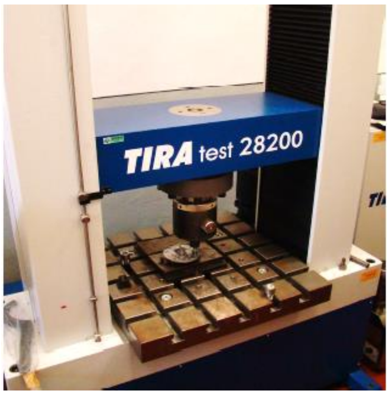

Figure 3. Equipment TIRAtest 28200

Chemical composition of the objective alloy was determined in the laboratory at the temperature of 22 ºC and 50% of relative humidity with a spectrometer SPECTROCAST. The static test in pressure (permanent deformation) was measured with the equipment of TIRAtest 28200 (Fig. 3). A term of permanent deformation means deformation measured with incomplete unloading. Permanent deformation tests were performed on a critical casting point and performed in accordance with GME 06 007 and GME 60 156 standards. Under these standards the initial loading force of Fa = 16 kN and loading speed of 10 mm.s^{-1} were defined. After reaching the maximum deformation value a subsequent unloading onto a half of the initial load force Fm = 8 kN occurred and thus the permanent deformation was developed. According to the standard prescribed values the permanent deformation at 50% of loading Fa is of value 0.150 mm.

Measuring of the hardness of cast samples was performed according to Brinell with the measurement equipment of HPO 250. Conditions of hardness measurements complied with EN 6506-1 standard: (a ball diameter D = 25mm, loading force F = 613N and loading period t = 10 s).

3.1 *Characteristic of monitored factors*

The casting quality within the performed experiment was represented by mechanical properties as follows: permanent deformation "s" and hardness "HB". When performing the experiment, the constant and variable technological factors were determined the influence of which upon the values of mechanical properties was monitored, particularly:

Constant technological factors:

- melt temperature: 710 °C
- mould temperature: 205 °C
- increase pressure: 25 MPa
- amount of metal residue in pressing chamber: 25 mm

Variable technological factors:

- plunger pressing speed: 1.9; 2.3; 2.6; 2.9; 3.2 m.s^{-1}

3.2 *Chemical composition analysis*

To perform a planned experiment, the melting with chemical composition given in Tab. 1 was carried out and it is in accordance with EN 1706 standard.

Table 1. Chemical composition of alloy according to EN 1706 standard

Chemical composition of the experimental cast of the applied alloy % of elements content					
Al	***Si***	***Fe***	***Cu***	***Mn***	***Mg***
85.27	12.02	0.71	1.19	0.21	0.13
according to EN 1706 standard					
rest	10.5 - 13.5	max. 1.5	0.7 - 1.2	max. 0.55	max. 0.35
Cr	***Ni***	***Zn***	***Pb***	***Sn***	***Ti***
0.02	0.02	0.35	0.02	0.03	0.03
according to EN 1706 standard					
max. 0.1	max. 0.3	max. 0.55	max. 0.2	max. 0.1	max. 0.2

4 ANALYSIS OF MECHANICAL PROPERTIES

With each adjusted technological parameter of die casting (either pressing plunger speed or resistance pressure) 5 pieces of castings were cast (from "a" to "e"). Overall, 25 pieces of castings were cast within the experiment. Tab. 2 shows the measured values of permanent deformation and hardness depending on the plunger pressing speed (category A).

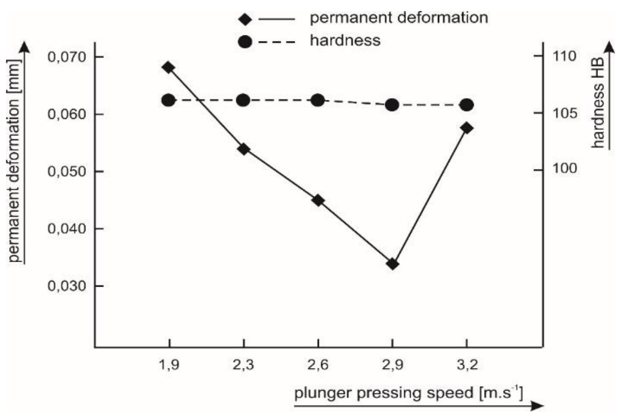

Figure 4. Dependence of average values of permanent deformation on the change of plunger pressing speed

Table 2. Chemical composition of alloy according to EN 1706 standard

Permanent deformation „s“ [mm]							
Sample No.	Plunger pressing speed [m.s^{-1}]	Sample No.					Aritmet. average
		a	b	c	d	e	
A.1	**1.9**	0.079	0.064	0.074	0.062	0.061	**0.068**
A.2	**2.3**	0.059	0.049	0.056	0.057	0.045	**0.053**
A.3	**2.6**	0.043	0.049	0.041	0.042	0.046	**0.044**
A.4	**2.9**	0.036	0.035	0.031	0.033	0.031	**0.033**
A.5	**3.2**	0.061	0.053	0.056	0.059	0.060	**0.058**
Hardness „HB“							
A.1	**1.9**	108	108	107	107	107	**107**
A.2	**2.3**	109	107	107	106	106	**107**
A.3	**2.6**	108	108	106	107	107	**107**
A.4	**2.9**	104	106	107	104	107	**106**
A.5	**3.2**	107	105	105	107	106	**106**

Fig. 4 interprets dependence of average values of permanent deformation on the change of plunger pressing speed and Fig. 5 interprets dependence of average values of hardness on the change of plunger pressing speed.

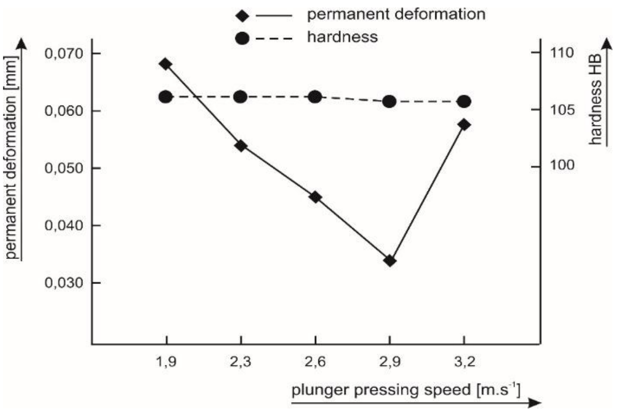

Figure 5. Dependence of average values of hardness on the change of plunger pressing speed

4.1 *Internal homogeneity analysis*

Internal homogeneity of castings was performed with the selected castings in points in case of which permanent deformation was measured in order to compare the obtained results of permanent deformation with RTG analysis. Fig. 6 documents the RTG picture without any obvious inner defect of the analysis of sample No. A.4-d which was included into a set of samples showing the lowest values of permanent deformation.

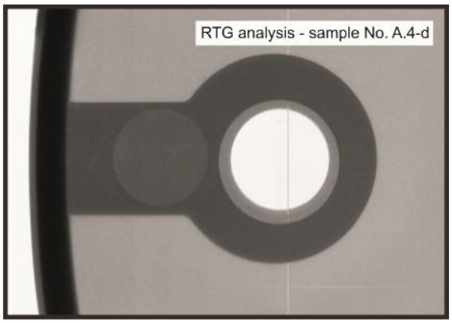

Figure 6. RTG analysis – sample No. A.4.d

RTG analyses of the sample No. A.1-a (Fig. 7) show inner defects documented by light spots. The presented samples were included into a set of samples showing the highest values of permanent deformation.

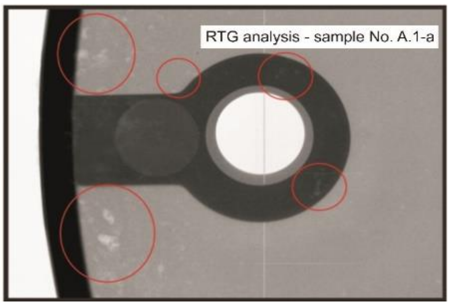

Figure 7. RTG analysis – sample No. A.1.a

5 EVALUATION OF MEASURED RESULTS

Evaluation of mechanical properties which involved permanent deformation "s" and hardness "HB" according to Brinell was performed by their monitoring on a critical casting point, i.e. in an assembly hole formed by means of the metallic core. Based on a set of measurements with the test equipment of TIRAtest 28200 the permanent deformation values depending on pressing speed were obtained. Hardness HB was evaluated depending on pressing speed with the equipment of 250 HPO. The RTG analysis of inner homogeneity was also performed which is the most common method of non-destructive checking reliably visualizing the point, shape and dimensions of inner cavities in order to relate the causes of worse values of permanent deformation of the experimental samples with these parameters.

The highest values of permanent deformation in terms of the pressing speed were observed with the analysed samples at the plunger pressing speed of 1.9 ms^{-1}. Further increase of the plunger pressing speed up to the value of 2.9 ms^{-1} causes decrease in the values of permanent deformation to the value of s = 0.033 mm. The highest quality castings were produced at this pressing speed. Based on the course of evaluation of permanent deformation depending on the pressing speed it can be concluded that the mould cavity filling depends on the speed of the metal flow in the ingate which determines a mode of the mould cavity filling. It is assumed that the filling mode transfers from turbulent to dispersion or a combination thereof. The cause of worse values of permanent deformation, as demonstrated by the RTG analysis, is the presence of inner cavities. These cavities are defined as the exogenous bubbles arising as a result of capture of gases and air contained in the mould by the turbulent melt flow. Hydrogen dissolved in the melt could diffuse in these bubbles. However, the process of hydrogen elimination is considered to be the secondary one. Stemming from the wall thickness of the analysed castings, of operating pressure etc., elimination of hydrogen out of the melt is unlikely.

A significant difference among the values of surface hardness of the casting in terms of changes of plunger speed and of resistance pressure has not been proved. The facts involved confirm the assumptions of the influence of plunger pressing speed upon hardness HB in the way that the die casting is characterized by a high degree of the melt subcooling when being in contact with a relatively cold wall of the mould resulting in the formation of the fine-grained structure in the peripheral walls of the casting.

6 CONCLUSION

By solution of experiments the results were achieved which shall represent the basis of technical preparation of production of castings in a pre-production stage in order to determine the correct values of technological casting parameters of a specific type of the casting. It has been proved that a determining factor in the production of high quality castings is particularly a correct adjustment of the plunger pressing speed which determines a mode of the mould cavity filling.
Knowledge of dependences between technological factors and mechanical properties of the die casting in terms of technological practice is an important aspect influencing the resulting casting qualities as well as the increase of the efficiency of production with respect to positive results in the economic field.

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REFERENCES

[Gaspar 2012] Gaspar, S., Mascenik, J., Pasko, J. The Effect of Degassing Pressure Casting Molds on the Quality of Pressure Casting. Advanced Materials Research, Vol. 428, No. January, 2012, pp. 43-46. ISBN 978-303785302-3.

[Gaspar 2013] Gašpár, S. and Paško, J. Influence of Technological Factors of Die Casting on Mechanical Properties of Castings from Silumin. Lecture Notes in Electrical Engineering, Vol. 240, pp. 713-722. ISSN 1876-1100.

[Gaspar 2018] Gaspar, S., Coranic, T., Pasko, J. Influence of Die Casting Factors and of Hardening Temperature upon Mechanical Properties of a Die Cast. MM Science Journal. Vol. 2018. No. December. pp. 2639-2642. ISSN 1803-1269.
DOI: 10.17973/MMSJ.2018_12_2018108.

[Krenicky 2008] Krenicky, T. Methods and means of eliminating sources of vibration for die casting machines. Technological Engineering, Vol. 5, No.2, pp. 58-59. ISSN 1336-5967

[Majernik 2018] Majernik, J., Kmec, J., Karkova, M. Analysis of the Impact of the Construction of a Gate on the Macroscopic Structure of a Casting and Its Influence on the Mechanical Properties of Castings. Manufacturing Technology, 2018, No. 3, pp. 439-443. ISSN 1213-2489.

[Majernik 2019] Majernik, J., Podařil, M. Evaluation of the Temperature Distribution of a Die Casting Mold of X38CrMoV5_1 Steel. Archives of Foundry Engineering, 2019, Vol. 19, No. 2, pp. 107-112. ISSN 1897-3310. DOI: 10.24425/afe.2019.127125.

[Mascenik 2012] Mascenik, J.: The Evacuation of Pressure Moulds as Progressive Developments of Die Casting Process. Acta Technica Corviniensis: Bulletin of Engineering, 2012, Vol. 5. No. 3, pp. 25-26. ISSN 2067-3809.

[Murcinkova 2013] Murcinkova, Z., Krenicky, T. Applications utilizing the damping of composite microstructures for mechanisms of production machines and manipulator devices. In: SGEM 2013: 13th Int. Multidisciplinary Sci. Geoconf. Vol. 1: 16-22 June, 2013, Albena, Bulgaria. Sofia: STEF92 Technology, 2013, pp. 23-30. ISBN 978-954-91818-9-0.

[Pavlenko 2017] Design of a program for calculation of forcing spring stiffness. MM Science Journal, 2017, No. December, pp. 1924-1928. ISSN 1803-1269. DOI: 10.17973/MMSJ.2017_12_201725.

[Ruzbarsky 2014] Ruzbarsky, J. Dynamics of core taking out at die casting. Applied mechanics and materials, 2014, Vol. 616, pp. 244-251. ISSN 1660-9336.

[Turtelli 2006] Turtelli et al. Magnetic and structural characterization of as-cast and annealed melt-spun Fe80-xSi20Crx. Journal of Magnetism and Magnetic Materials, 2006, Vol. 304, No. 2, pp. E687-E689.

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