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RESEARCH OF THE PQ-DIAGRAMS OF THE DIE CASTING PROCESS OF ALUMINIUM, COPPER, MAGNESIUM AND ZINC

***Abstract**: The processes comparison of die casting of aluminium, copper, magnesium and zinc by the calculated PQ-diagrams was performed in the article. The aluminium casting process is identical to the magnesium casting process, and the copper casting process is identical to the zinc casting process based on the performed analysis.*

***Key words**: melt, die casting, the piston, the casting, the diagram.*

***Language**: English*

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Introduction

The castings from non-ferrous metal alloys of the small and medium dimensions are mainly made by die casting on the special machines [1-10].

The various factors, such as the volume, material, and roughness of the casting must be considered for die casting. The configuration selection of the ingate system is performed for rational casting of the castings from various materials. Changing the number of the process parameters at implementation of the multi-factor experiment will allow to find the optimal option of die casting (from aluminium to zinc).

The PQ-diagram shows the actual process of melt injection. This data is necessary at the design stage of die casting, when the actual process parameters are not yet known.

Materials and methods

The die casting process was modeled under the following constant and variable conditions:

1. Materials.

Aluminium (Al), copper (Cu), magnesium (Mg), zinc (Zn).

2. The alloys database.

Density – 2500 kg/m^3 (Al), 8400 kg/m^3 (Cu), 1750 kg/m^3 (Mg), 6000 kg/m^3 (Zn); viscosity – 21×10^{-5} m^2/s (Al), 26×10^{-5} m^2/s (Cu), 26×10^{-5} m^2/s (Mg), 32×10^{-5} m^2/s (Zn); the constant – 0.35 (Al), 0.35 (Cu), 0.25 (Mg), 0.35 (Zn); the solidification factor – 3.8 (Al), 4.7 (Cu), 2.5 (Mg), 2.5 (Zn).

3. The casting weight – 1000 g.

4. The casting volume.

400 cm^3 (Al), 119.048 cm^3 (Cu), 571.429 cm^3 (Mg), 166.667 cm^3 (Zn).

5. Wall thickness – 2…5 mm.

6. The pouring temperature.

650 °C (Al), 1000 °C (Cu), 623 °C (Mg), 400 °C (Zn).

7. The minimal flow temperature.

540 °C (Al), 800 °C (Cu), 560 °C (Mg), 380 °C (Zn).

8. The die temperature – 180 °C.

9. Maximum filling time.

0.021/0.053 s (Al), 0.022/0.056 s (Cu), 0.008/0.021 s (Mg), 0.007/0.017 s (Zn).

10. Selected time – 0.03 s.

11. Flow through the ingate.

13333.333 cm^3/s (Al), 3968.254 cm^3/s (Cu), 19047.619 cm^3/s (Mg), 5555.556 cm^3/s (Zn).

12. The maximum ingate velocity, because of the die erosion.

40 m/s (Al), 56 m/s (Cu), 76 m/s (Mg), 56 m/s (Zn).

13. The selected ingate velocity – 30 m/s.

14. The ingate area.

444.444 mm^2 (Al), 132.275 mm^2 (Cu), 634.921 mm^2 (Mg), 185.185 mm^2 (Zn).

15. The minimal ingate velocity.

7.055/15.566 m/s (Al), 5.255/11.105 m/s (Cu), 6.928/15.374 m/s (Mg), 4.81/10.34 m/s (Zn).

16. The ingate dimension.

444.44×1 and 111.11×4 mm (Al), 132.28×1 and 33.07×4 mm (Cu), 634.92×1 and 158.73×4 mm (Mg), 185.19×1 and 46.3×4 mm (Zn).

17. The machine type – Buhler 600.

18. Selected casting pressure – 400 Bar.

19. Locking force – 600 ton.

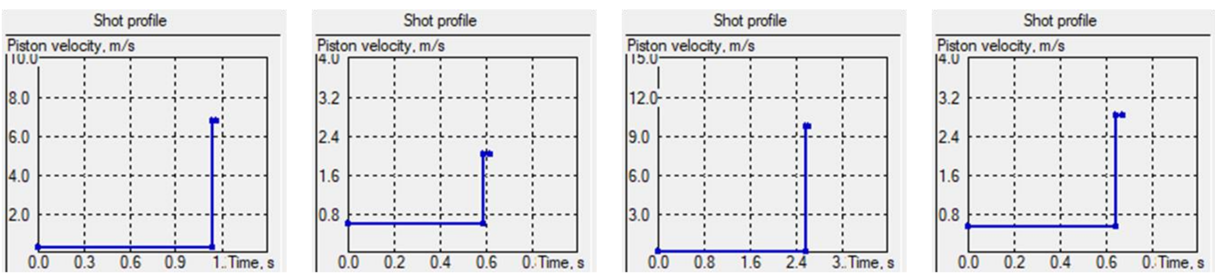
20. The projected area – 40000 mm^2.

21. Casting pressure – standard and pressure tight.

22. The surface finish – low and high.

Results and discussion

The calculated volume of aluminium melt, taking into account the ingate system, was 480 cm^3, the volume of copper melt was 199.048 cm^3, the volume of magnesium melt was 651.429 cm^3, and the volume of zinc melt was 246.667 cm^3. The shot profiles are displayed as the dependencies of changing the piston velocity of the machine from casting time (the Fig. 1). The piston diameter of the machine was accepted 50 mm in all cases.



A ***B*** ***C*** ***D***

Figure 1 – The dependencies of changing the piston velocity of the machine from casting time:
***A* – Al; *B* – Cu; *C* – Mg; *D* – Zn.**

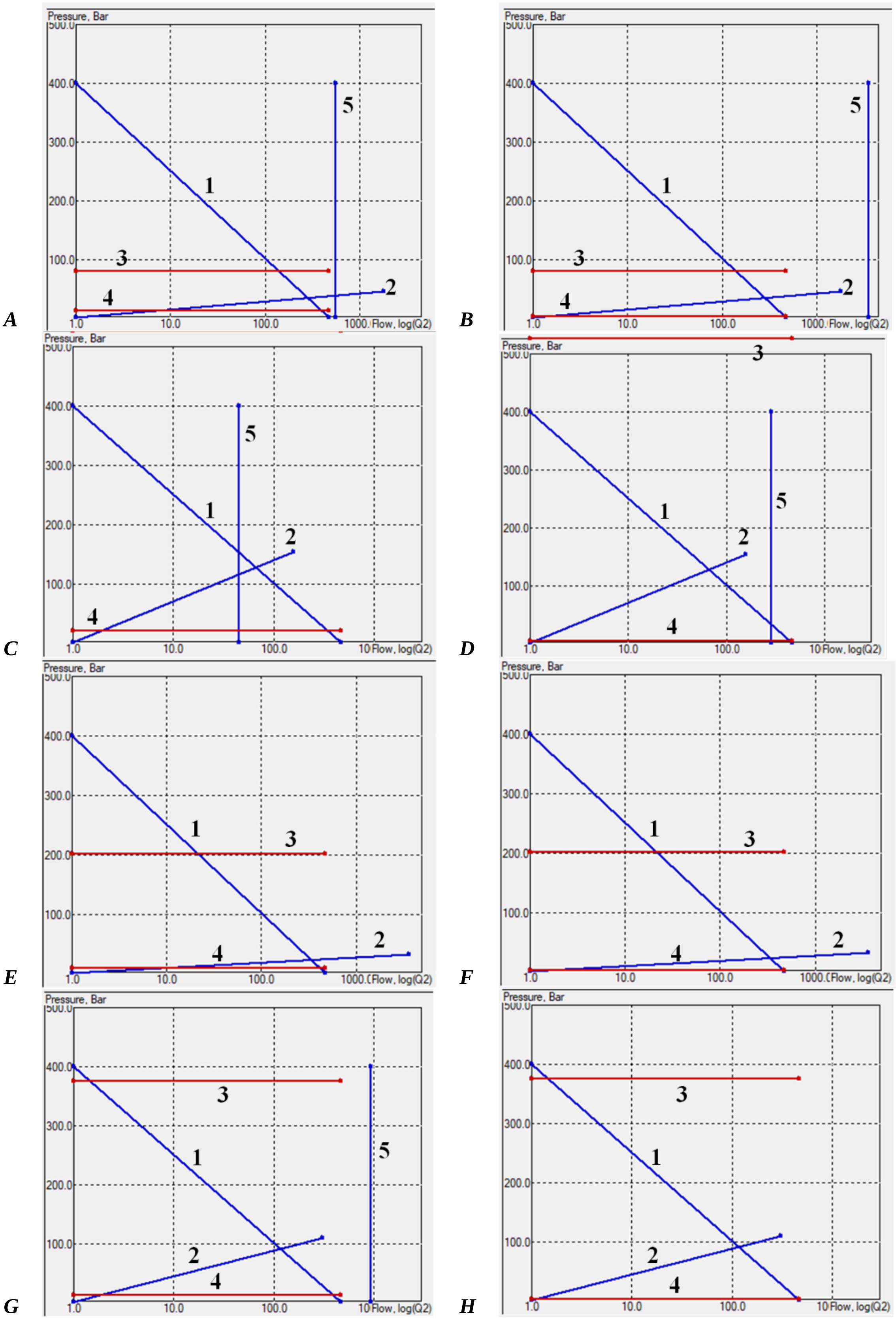


Figure 2 – The PQ-diagrams of die casting: *A* and *B* – Al; *C* and *D* – Cu; *E* and *F* – Mg; *G* and *H* – Zn.

Casting was carried out in two phases. The piston moves magnesium melt at low velocity in the first casting phase. Movement time of the piston in the first phase is 2.592 s, which is several times more than movement time of the piston at casting of other non-ferrous metals. The second phase of magnesium casting is characterized by instantaneous increasing the piston velocity to 9.701 m/s. The opposite process is observed at copper casting (high velocity of the piston in the first phase is replaced by low velocity in the second phase). The filling ratio of aluminium melt is 61.115%, copper melt is 25.344%, magnesium melt is 82.942%, and zinc melt is 31.407%.

The PQ-diagrams of die casting of aluminium, copper, magnesium, and zinc are presented in the Fig. 2. The graphs *A*, *C*, *E* and *G* were built at standard casting pressure, the low surface finish of the casting and the ingate thickness of 1 mm. The graphs *B*, *D*, *F* and *H* were built at tight casting pressure, the high surface finish of the casting and the ingate thickness of 4 mm.

The diagrams show: 1 – the machine power, 2 – the die line (the ingate area), 3 and 4 – the ingate velocity limits, 5 – theoretical fill rate. Changing theoretical fill rate is the main difference of die casting under the first and second conditions. Also, at tight casting pressure, the high surface finish of the casting and the ingate thickness of 4 mm, there is some increasing the range of the ingate velocity limits. The aluminium die casting process is similar to the magnesium die casting process. Theoretical fill rate of copper is in the range of the machine power, which indicates rationality of this process.

Conclusion

The lowest efficiency of the considered technological processes is observed at magnesium die casting with the same weight of the castings. High velocity of the piston movement in the second phase is required for reducing formation of casting defects during crystallization of the casting.

Theoretical fill rate changes approximately 1.5 times with the high casting requirements. The most efficient process was determined at copper die casting.

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