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POSSIBILITIES OF PRESSURE DIE CASTING OF IRON ALLOYS

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Abstract:
The current trends of production of casts are directed towards production of components disposing of higher accuracy, increased quality of surface and homogenous structure. In case of a thin-walled cast the development of speed of pressing and of pressure was observed inside the mould cavity during pressure die casting of ferrous alloys. In case of die casting of ferrous alloys the attention was paid to life service of a pressing piston and of a filling chamber. The optimal temperature of the steel casting ranges from 1600 to 1750°C and optimal mould temperature ranged from 220 to 260°C. The residues having occurred in gates reached the hardness of 38 HRC and in case of casts the value was of 45 HRC. Influence of acting of resistance pressure on the thin-walled casts only minimally. With the increasing resistance pressure the structure becomes more fine-grained and along with the increasing thickness of the wall the influence of the resistance pressure increases as well. Technology of pressure die casting of iron alloys can be compared with the pressure die casting technology of aluminium alloys. As standard, for pressure die casting the cast irons with carbon content of lower than 3% are recommended.

Key words: *pressure dies casting, specific pressure on metal, iron alloys, steel*

INTRODUCTION

Development of industrial production characterized by the increasing demands regarding the engineering products and other industrial sectors, requires modern structural designs of the mechanical systems with high performance parameters, service life and reliability.

RESEARCH TOPIC IN LITERATURE STUDY

The precondition to meet the requirements is availability of suitable material and production of the systems [9, 15]. The current trends of production of casts are directed towards production of components disposing of higher accuracy, increased quality of surface, homogenous structure and even mechanical properties with minimal energy intensity of their production. The high-quality casts should be produced by means of modern and effective technologies and a structural design should represent the starting point. The thin-walled casts are being trends for the future [1, 5, 7, 14]. Currently, observed can be considerable increase of production of casts from non-ferrous metals especially with regards to high productivity of work during pressure die casting of mass-produced casts. Mainly financial aspect plays significant role in efforts made to extend the field of ferrous metals by technology of pressure die casting in case of which it can be anticipated that more expensive aluminium casts, forged pieces and workpieces shall be replaced by the cases made of ferrous metals. Other reason refers to the fact that ferrous alloys during solidification under high pressure of up to 100 MPa improve their mechanical properties [10, 13, 19]. At the same time it can be assumed that ferrous alloy processed by the aforementioned technology could replace other steels in a number of spheres. To clarify the aforementioned objectives the experimental tests of pressure die casting of ferrous alloys were performed [12, 17].

METHODOLOGY OF WORK

In case of a thin-walled cast "blade" (Fig. 1) the development of speed of pressing and of pressure was observed inside the mould cavity during pressure die casting of ferrous alloys.

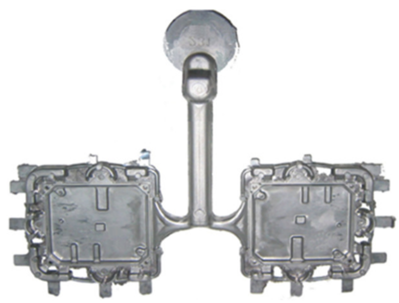


Fig. 1 Thin-walled cast

The tests were performed with the adjusted pressure die casting machine CLOO 100/16-B2 (Fig. 2).

Fig. 2 Pressure die casting machine CLOO 100/16-B2

The pistons were made of pearlitic alloy and the chamber was made of material 19552 hardened and tempered to 40-45 HRC. Contrary to clearance ranging from 0.03 to 0.05 mm between the piston and the chamber the respective clearance for the aluminium alloys were extended to 0.14-0.3 mm. The adjustment remained unchanged for the entire process of pressing unless the piston in the chamber was seized up.

RESULTS

In case of the thin-walled cast the development of pressing speed and of pressure inside the mould cavity was observed during pressure die casting of aluminium (Fig. 3) and of iron (Fig. 4). The individual pressure values of pressing were approximately on the same level. In case of aluminium alloy the value equalled to 11.4 MPa, in case of iron alloy the value equalled to 8.1 MPa. The time of solidification of iron alloy cast was of 30 seconds. The time of solidification of aluminium alloy cast was slightly shorter (of 25 seconds).

In case of die casting of ferrous alloys the attention was paid to life service of a pressing piston and of a filling chamber. In case of the adjusted pressure die casting machine CLOO 100/16-B2 achieved were 60-75 in-forcing before the piston was seized up contrary to original 6-7 in-forcing with die casting machine having not been subjected to adjustment.

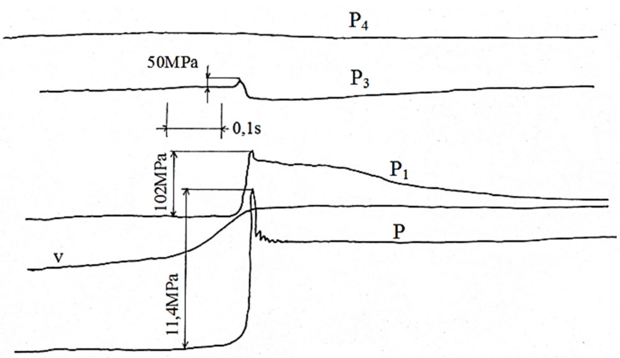


Fig. 3 Development of speed of pressure pressing inside the mould cavity in case of aluminium die casting
v – development of pressing speed,
P, P_1, P_3, P_4 – pressure inside the mould cavity in the course of the individual phases of the cast solidification

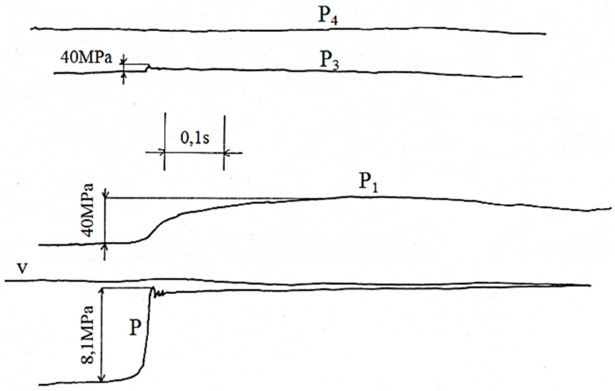


Fig. 4 Development of speed of pressing S and of pressure inside the mould cavity in case of die casting of iron
v – development of speed of pressing
P, P_1, P_3, P_4 – pressure values inside the mould cavity during individual phases of the cast solidification

Pressure die casting of iron alloys

Optimal temperature of cast iron casting ranged from 1450 to 1500°C and optimal mould temperature ranged from 200 to 240°C.

Figure 5 shows relation between volume weight and specific pressure acting upon metal at pressing speed of 0.4 m.s^{-1}.Volume weight of the iron cast reached 7600 kgm^{-3} contrary to value of 7200 kgm^{-3} without impact of pressure.

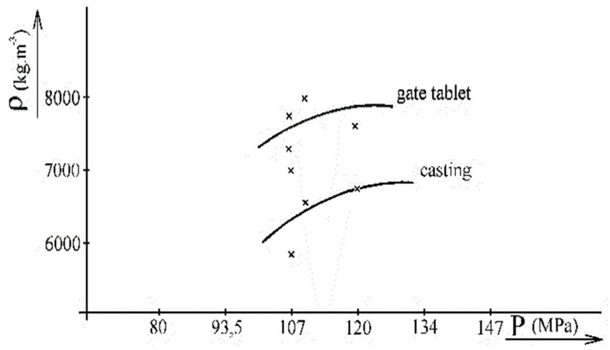


Fig. 5 Relation between volume weight and specific pressure acting upon metal at v = 0,4 m.s^{-1}

Optimal values of pressing speed in dependence on pressure acting upon metal were measured within the range from 1.7 to 2.0 ms^{-1} or 35-50 MPa. Increasing pressure results in a finer structure of the cast.

The surface of the cast reached hardness of 40-60 HRC. The casts cannot be machined mechanically only by means of grinding. With regard to considerable hardness, after being ejected from the mould the casts were inserted and cooled directly in the furnace. The casts being cooled in the free air reached the hardness of 60 HRC. The cast ejected from the mould at 1000°C and cooled in the furnace reached the hardness of 37 HRC and the cast ejected from the mould at 800°C and cooled in the furnace reached the hardness of 50 HRC. Thus in case of ejecting of such cast from the mould with temperature of over 1000°C and its consequent cooling in the furnace still machinable cast from iron alloy can be produced.

In case of pressure die casting of steel the temperature must not drop below 1550°C. The residues having occurred in gates reached the hardness of 38 HRC and in case of casts the value was of 45 HRC. At temperature of under 600°C in case of cast ejection the hardness of casts reached the value under 40 HRC with steel alloyed by *Cr* and with the steel 11373 the value was under 30 HRC in case of which the use of casts without thermal processing could be considered. Dependence of volume weight on pressing speed is shown in figure 6 for pressing speed of *v* = 0.5 to 1.5 ms^{-1}.

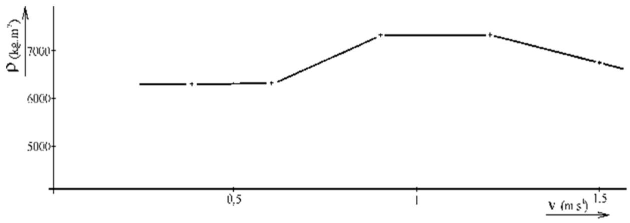


Fig. 6 Dependence of volume weight on pressing speed

Material 19552 and material on the basis of molybdenum were used for moulds. The material on the basis of molybdenum intended for the filling chamber ruptured due to fragility and exposure to operating temperature and thus could not be used further on. The mould cavity surface made of material based on *Mo* gradually sublimated for absence of protection layer during casting. The material removal was rather extensive and thus the mould could not be used further on. The service life of material 19552 amounted to 200 castings. With regards to costs related to production of mould designed for pressure die casting of metal the service life is insufficient, i.e. it is extremely short.

The highest values of specific weight ranging from7750 up to 7900 kgm^{-3} were reached by the residue in gate and the values in case of the cast ranged only from 7100 to 7300 kgm^{-3}. Dependence of the cast hardness on pressing speed is shown in Figure 7.

Fig. 7 Dependence of cast hardness on pressing speed

The sphere of higher hardness corresponds with the sphere of higher volume weight. The dependence of volume weight on specific pressure acting upon metal is shown in Figure 8 at pressing speed of *v* = 1 ms^{-1}.

Dependence of cast hardness on specific pressure acting upon metal is shown in Fig. 9.

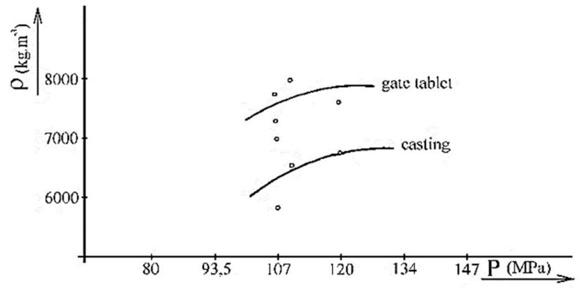


Fig. 8 Dependence of volume weight on pressure acting upon metal at v = 1 $m.s^{-1}$

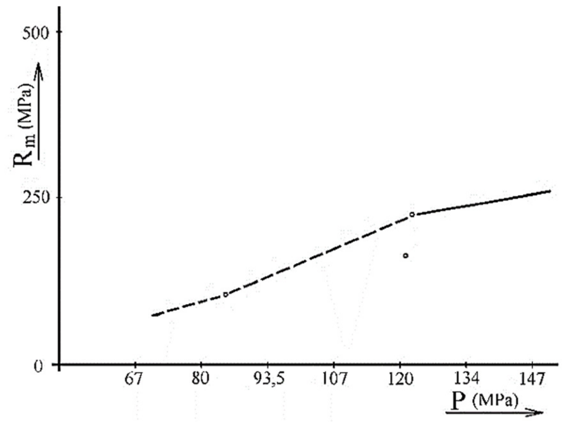


Fig. 9 Dependence of the cast hardness on pressure acting upon metal

Influence of acting of resistance pressure in case of pressure casting of iron alloys

When performing the pressure casting it was interesting to observe the pressure acting upon the crystallizing molten mass of the cast alloys. It is especially in case of the most widespread alloys such as Al-Si. Recently the research has proved that in case of casting of iron metals those can be also steel and cast iron Fe-C.

According to the researches performed by Batyšev [2] the diagram of Al-Si in Figure 10 during acting of high pressure shows the increasing eutectic temperature and the point of eutectic crystallization is shifted to higher content of silicium. After each 100 MPa the eutectic temperature increases by approximately 6.3°C and maximal dissolubility limit of silicium in aluminium at temperature of eutectic change is shifted by approximately 0.25 of weight % of Si.

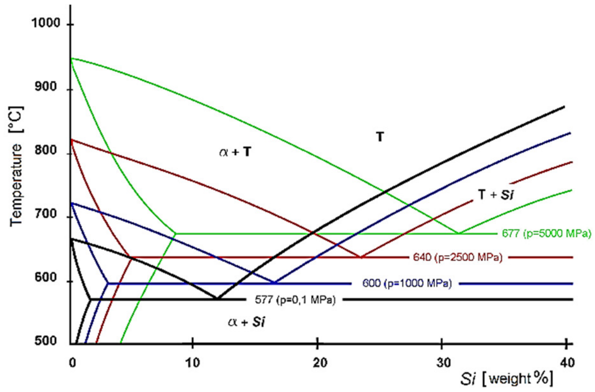
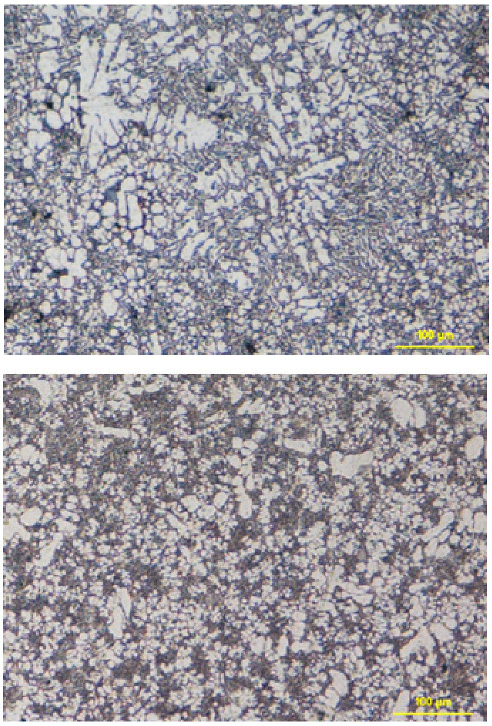


Fig. 10 Influence of pressure upon the appearance of equilibrium diagram Al-Si according to BATYŠEV
Source: [2].

References mentioned hereinafter support the tendency as well [3, 4, 8, 16].

Fig. 11 shows metallographic structure of alloy Al-Si 121 Cu 1 (Fe) in case of resistance pressure of 35 and 120 MPa. With regards to rather low values of resistance pressure and to thin-walled pressure casts the influence of pressure upon the structure was not considerable.



a)
b)

Fig. 11 Detail of metallographic structure of the thin-walled cast from alloy Al-Si12Cu1(Fe), x 100 ηm
a) resistance pressure of 35 MPa,
b) resistance pressure of 120 MPa

According to Ragan [5] the resistance pressure influences the thin-walled casts only minimally. With the increasing resistance pressure the structure becomes more fine-grained and along with the increasing thickness of the wall the influence of the resistance pressure increases as well [11, 18].

The optimal temperature of the steel casting ranges from 1600 to 1750°C and optimal mould temperature ranged from 220 to 260°C. The cast microstructure under pressure (Fig. 12, 13) the casting was of fine structure and the pearlite content reached over 50%, i.e. twice as high as it would refer to steel composition.

Fig. 12 Microstructure of pressure steel cast made of stell 11373 as viewed through the optical microscope, x1000 ηm

Fig. 13 Microstructure of pressure steel cast made of steel 11373 as viewed through the electron microscope, x1000 ηm

The shift of Fe-C diagram according to Figure 14 must be ascribed to the effect of the pressure during steel solidification.

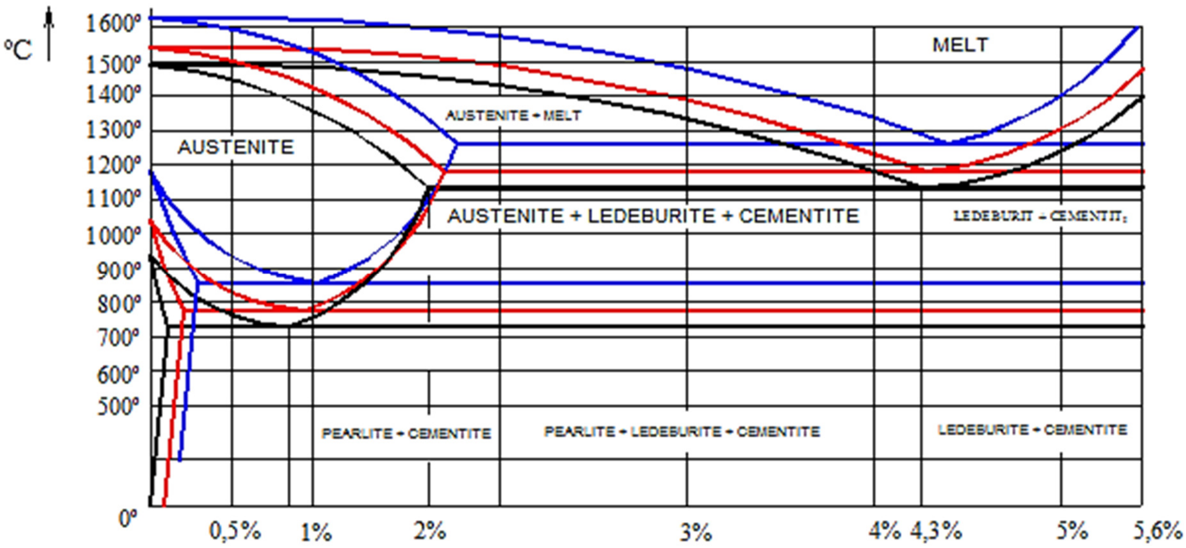


Fig. 14 Shift of Fe-C diagram in relation to resistance pressure

CONCLUSION

Technology of pressure die casting of iron metals can be compared with the pressure die casting technology of aluminium alloys. The particularities can be observed with regards to hardness of pressure casts in case of which the technology must be modified to be able to produce machinable pressure casts.

The economical issue is short service life of the mould which currently prevents the introduction of the aforementioned technology into the production unless the suitable mould material is found.

The pressure die casting of the cast iron has not been spread in the industry yet. The reason rests in difficulties related to removal of hardening in case of rapid cooling in a metal mould as well as to formation of hot cracking in case of thin-walled casts.

Certain hope in terms of the aforementioned issue are the testing casts ejected from the mould at temperature of 700°C directly into the furnace, their cooling in the furnace in which the defects were removed. However, prior to the introduction of the method into practice the improvement is required.

As standard, for pressure die casting the cast irons with carbon content of lower than 3% are recommended. To reduce the turbidity the company of General Electric employed a modifier which lowers the depth of the hardened layer twice [6, 19, 20]. Thus were produced the casts die cast under pressure from alloy with chemical composition of 3.7% C, 2.5% Si, 0.5% Mn and of Fe which represented the rest.

The temperature of the cast iron die cast in the filling chamber ranged from 1275 to 1330°C. The mould was made of molybdenum.

The casts made of grey cast iron are annealed during the period of 2 hours at temperature of 954°C. After the metal is annealed, the structure of deformable cast iron is formed. The grain is exceptionally fine, which is the result of considerable reduction of period of annealing contrary to standard annealing (48 hours) of the cast to deformable cast iron.

The use of modifiers and of short-term high-temperature annealing provides the possibility of utilization of cast iron with spheroidal graphite containing 3.8-4.4% of C for pressure die casting.

It is inevitable to continue in research of pressure influence upon the properties of alloy which shows its effects during pressure die casting in order to be able to obtain further comprehensive results in the field.

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