

# THE INFLUENCE OF SPIN CASTING PARAMETERS ON DIMENSIONAL ACCURACY OF CASTINGS CAST INTO SILICON MOULDS

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Preliminary notes

Spin casting is the technological process to produce metal, plastic and wax parts quickly from an existing master model. It is especially suitable for the manufacture of die casting parts since the manufacture of dies is normally very time-consuming and expensive. The paper deals with the influence of mould rotation speed and clamping pressure during spin casting into silicon moulds on dimensional accuracy of zinc alloy castings. The rotation speed was in range 200 ÷ 600 rpm. Clamping pressure was in range from 276 to 379,5 kPa. The results of experiments are curves of rotation speed and clamping pressure dependence on dimensional accuracy of castings.

**Keywords:** centrifugal casting, mould, rotation speed, silicon

## Utjecaj parametara centrifugalnog lijevanja na dimenzionalnu točnost odljevaka lijevanih u silicijskim kalupima

Prethodno priopćenje

Centrifugalno lijevanje je tehnološki postupak brze proizvodnje metalnih, plastičnih i voštanih dijelova iz postojećeg glavnog modela. Naročito je pogodno za proizvodnju dijelova tlačnim lijevanjem jer im je proizvodnja normalno skupa i zahtijeva puno vremena. Rad se bavi utjecajem brzine rotacije kalupa i pritiska stezanja tijekom centrifugalnog lijevanja u silicijskim kalupima na dimenzionalnu točnost odljevaka od legure cinka. Brzina rotacije je bila u rasponu 200 ÷ 600 okr./min. Pritisak stezanja je bio u rasponu od 276 do 379,5 kPa. Rezultati eksperimenta pokazuju ovisnost krivulje brzine rotacije i pritiska stezanja o dimenzionalnoj točnosti odljevaka.

**Ključne riječi:** centrifugalno lijevanje, kalup, brzina rotacije, silicij

### 1 Introduction

The centrifugal casting technologies utilize the centrifugal force to fill the mould cavities by molten material. The centrifugal force is generated by mould rotation [1]. The spin casting technology into silicon rubber moulds also belongs to these technologies. The rotation speed of casting mould is one of parameters that influence final quality of castings [2, 3]. Shape of runners and the method of mould cavity feeding by molten material are the next factors that influence the final products of casting process. The method of mould cavity feeding along with rotation speed influences the molten metal filling into the mould cavity, if it will be filled fluently, or the mould cavity will be filled by turbulence filling with severe stream collision [4, 5].

### 2 Methods and materials used for research

The aim of experiments was to determine the influence of clamping pressure and mould rotation speed on dimensional accuracy of zinc castings, cast by spin casting into the silicon rubber moulds. Four types of aluminium circular-shaped patterns were manufactured by CNC milling machine (Fig. 1). The patterns diameters were 60, 50, 40 and 30 mm. The thickness of patterns was 5 mm for each diameter. The experimental mould was manufactured using these patterns.

The distance, between the middle of each pattern and the mould rotation axis was 110 mm. Silicon rubber White SD THT with diameter 305 mm was used as

moulding material. The experimental mould is shown in Fig. 2.



Figure 1 Aluminium patterns

Experimental mould was vulcanized in Digital hydraulic 3-post vulcanizer – 50 TON/EA and the vulcanization time was 2 hours. Pressure of vulcanization process was 24,1 MPa and vulcanization temperature 170 °C.

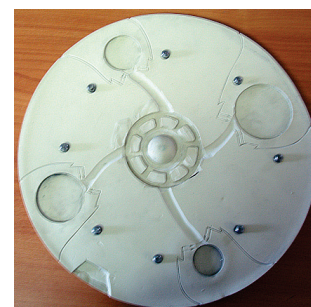


Figure 2 Experimental mould

Experimental castings were cast by Tekcaster Series 100D casting machine. Cast material was ZnAl4Cu3 zinc alloy. The chemical composition of cast alloy is shown in Tab. 1. Casting temperature of zinc alloy was 425 °C.

Table 1 Chemical composition of ZnAl4Cu3 (EN 12844) zinc alloy (wt. %)

Al	Cu	Mg	Pb	Cd	Sn	Fe	Ni	Si	Zn
3,7 ÷ 4,3	2,7 ÷ 3,3	0,025 ÷ 0,600	max. 0,005	max. 0,005	max. 0,002	max. 0,05	max. 0,02	max. 0,03	rest

Clamping pressure during casting was established to 276 kPa; 310,5 kPa; 345 kPa and 379,5 kPa. Mould rotation speed was established for each value of clamping pressure, in range from 300 rpm do 600 rpm, with step 100 rpm. Time of casting process was 35 s.

Experimental castings were measured by micrometers Schut 0 ÷ 25 mm, 25 ÷ 50 mm and 50 ÷ 75 mm, with accuracy 0,01 mm. Castings diameters, across the direction and in direction of molten metal flow, were measured (Fig. 3). Also casting thicknesses were measured, at nearest and most distant locations from ingate.

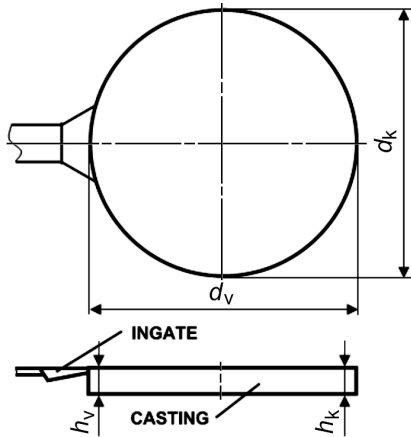


Figure 3 Measurement locations of experimental casting

### 3 Results and achievements

Average values of diameters were calculated for each combination of analysed parameters (Tab. 2). Graphs from calculated values are shown in Figs. 4 ÷ 11. Graphs show particular dependencies of diameters and thicknesses on clamping pressure and mould rotation speed, for each experimental casting diameter. The percentage value presents the deviation of casting diameter from pattern diameter.

Fig. 4 shows the dependency of  $d_k$  and  $d_v$  diameters on clamping pressure and mould rotation speed, for experimental casting with diameter 30 mm. From graph is obvious that increasing of mould rotation speed caused the increasing of  $d_k$  diameter up to 2,5 %. The  $d_v$  diameter increased about 1,5 %. Change of clamping pressure influenced the deviation of  $d_k$  and  $d_v$  diameters significantly only over 310,5 kPa.

Fig. 5 shows the dependency of  $d_k$  and  $d_v$  diameters on clamping pressure and mould rotation speed, for experimental casting with diameter 40 mm. It is obvious that increasing of mould rotation speed caused the increasing of  $d_k$  diameter deviation up to 2,5 %. The  $d_v$  diameter increased about 2,5 % only at rotation speed 600 rpm and clamping pressure over 345 kPa. Change of clamping pressure influenced significantly the  $d_k$  and  $d_v$  diameters accuracy only at rotation speeds over 500 rpm and about 345 kPa and 379,5 kPa.

Table 2 Average measured values of castings dimensions

	$d = 30 \text{ mm}$				$d = 40 \text{ mm}$				$d = 50 \text{ mm}$				$d = 60 \text{ mm}$			
$d_k / \text{mm}$	Rotation speed / rpm															
Clamping pressure / kPa	300	400	500	600	300	400	500	600	300	400	500	600	300	400	500	600
276,0	30,12	30,31	30,45	30,74	40,17	40,38	40,57	40,90	49,75	49,98	50,31	50,78	59,62	59,99	60,11	60,38
310,5	30,14	30,37	30,35	30,71	40,20	40,88	40,62	40,77	49,81	49,96	50,26	50,73	59,65	59,73	59,84	60,52
345,0	30,15	30,38	30,61	30,98	40,20	40,44	40,70	41,08	50,01	50,21	50,36	50,74	59,99	60,06	60,15	60,60
379,5	30,18	30,26	30,39	30,79	40,19	40,37	40,54	40,95	49,87	50,03	50,21	50,71	59,79	59,86	60,10	60,44
$d_v / \text{mm}$	Rotation speed / rpm															
Clamping pressure / kPa	300	400	500	600	300	400	500	600	300	400	500	600	300	400	500	600
276,0	29,86	29,95	30,07	30,31	39,68	39,82	40,05	40,33	49,66	49,81	50,17	50,38	59,56	59,78	59,98	60,25
310,5	29,77	29,89	30,18	30,18	39,73	39,78	39,99	40,48	49,59	49,63	50,02	50,41	59,57	59,65	59,76	60,26
345,0	29,91	30,03	30,45	30,41	39,71	39,84	40,15	40,51	49,66	49,76	50,25	50,41	59,74	59,74	59,82	60,37
379,5	29,96	29,98	30,03	30,46	39,69	39,66	39,87	40,86	49,53	49,18	49,81	50,36	59,61	59,63	59,77	60,13
$h_k / \text{mm}$	Clamping pressure / kPa															
Rotation speed / rpm	276,0	310,5	345,0	379,5	276,0	310,5	345,0	379,5	276,0	310,5	345,0	379,5	276,0	310,5	345,0	379,5
300	4,98	4,97	4,95	4,92	4,99	4,97	4,96	4,90	4,97	4,97	4,94	4,90	4,78	4,78	4,76	4,71
400	4,98	4,96	4,97	4,92	4,98	4,98	4,97	4,91	4,98	4,98	4,97	4,91	4,79	4,80	4,78	4,73
500	4,99	4,99	4,96	4,91	5,00	5,00	4,98	4,93	4,99	4,99	4,98	4,96	4,80	4,80	4,79	4,76
600	5,01	5,00	4,99	4,93	5,01	5,00	5,01	4,96	5,02	5,02	5,00	4,97	4,83	4,82	4,80	4,77
$h_v / \text{mm}$	Clamping pressure / kPa															
Rotation speed / rpm	276,0	310,5	345,0	379,5	276,0	310,5	345,0	379,5	276,0	310,5	345,0	379,5	276,0	310,5	345,0	379,5
300	4,98	4,98	4,95	4,91	4,99	4,98	4,96	4,92	4,97	4,98	4,96	4,92	4,79	4,79	4,77	4,74
400	4,98	4,97	4,97	4,92	4,98	4,99	4,97	4,93	4,98	4,99	4,98	4,95	4,79	4,81	4,80	4,78
500	5,01	5,01	4,99	4,98	5,02	5,02	5,00	4,98	5,02	5,01	5,00	4,98	4,82	4,80	4,80	4,78
600	5,06	5,04	5,03	5,00	5,07	5,03	5,03	5,01	5,08	5,05	5,03	5,01	4,90	4,86	4,84	4,84

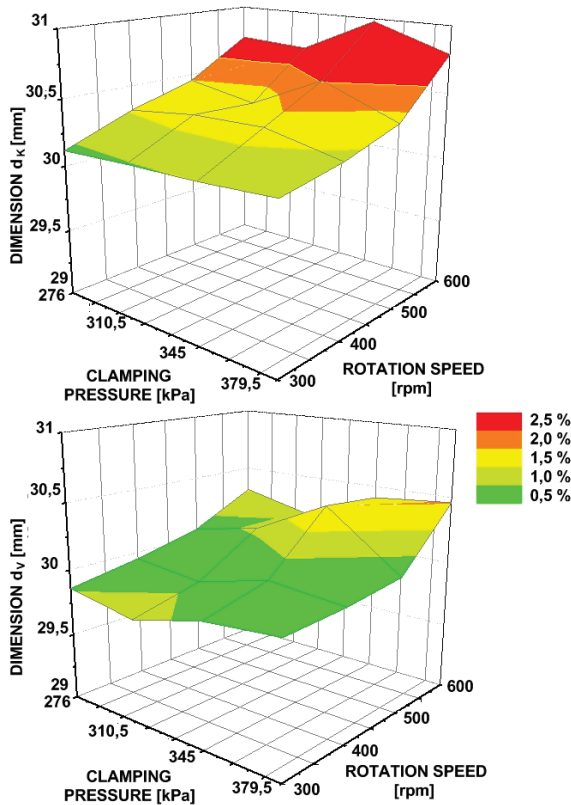


Figure 4 Dependency of diameters accuracy for casting diameter 30 mm

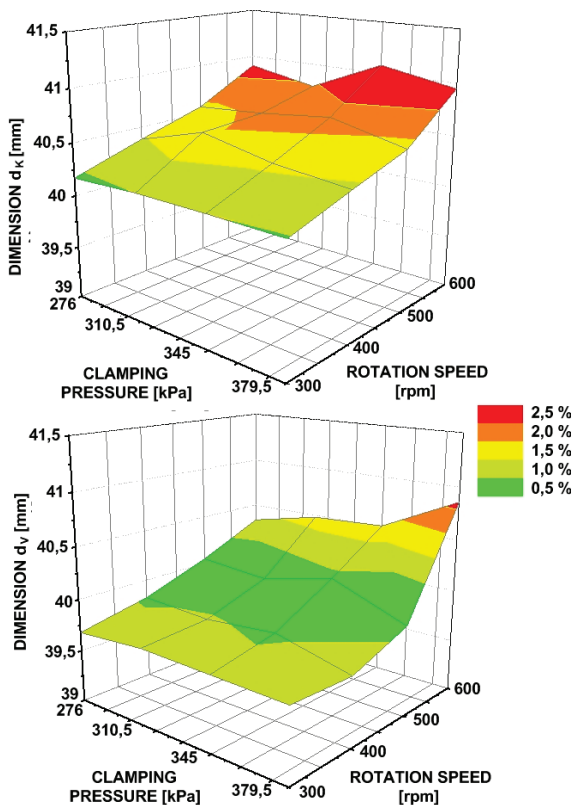


Figure 5 Dependency of diameters accuracy for casting diameter 40 mm

In Fig. 6 is shown the dependency of  $d_k$  and  $d_v$  diameters on clamping pressure and mould rotation speed, for experimental casting with diameter 50 mm. It was possible to observe that increasing of mould rotation speed caused increasing of  $d_k$  diameter deviation up to 1,5 %. Diameter  $d_v$  increased about 1 %. Change of clamping

pressure had no significant effect on casting accuracy. However, negative effect of high clamping pressure was observed only at 300 rpm and over 345 kPa.

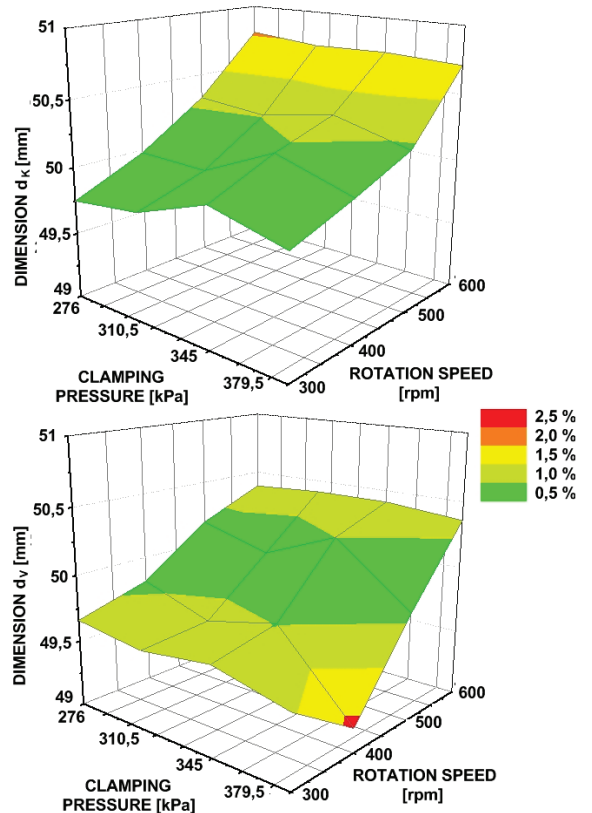


Figure 6 Dependency of diameters accuracy for casting diameter 50 mm

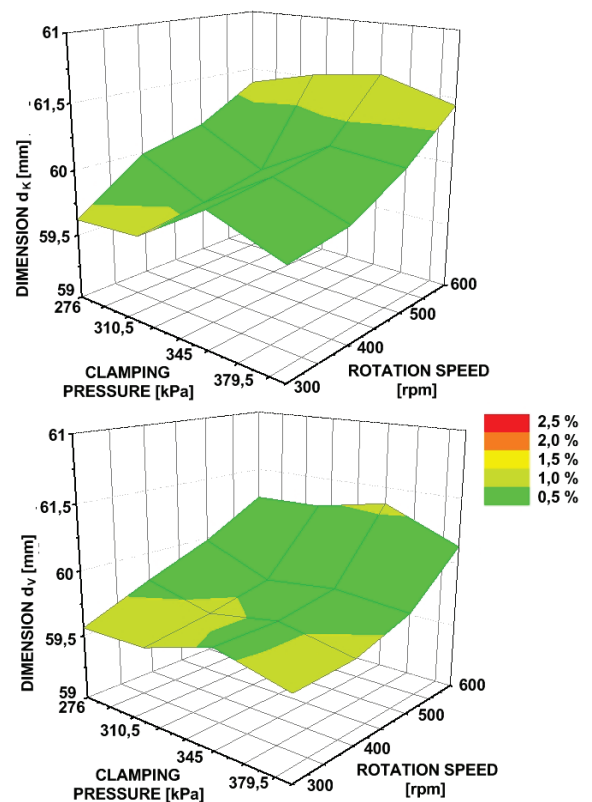


Figure 7 Dependency of diameters accuracy for casting diameter 60 mm

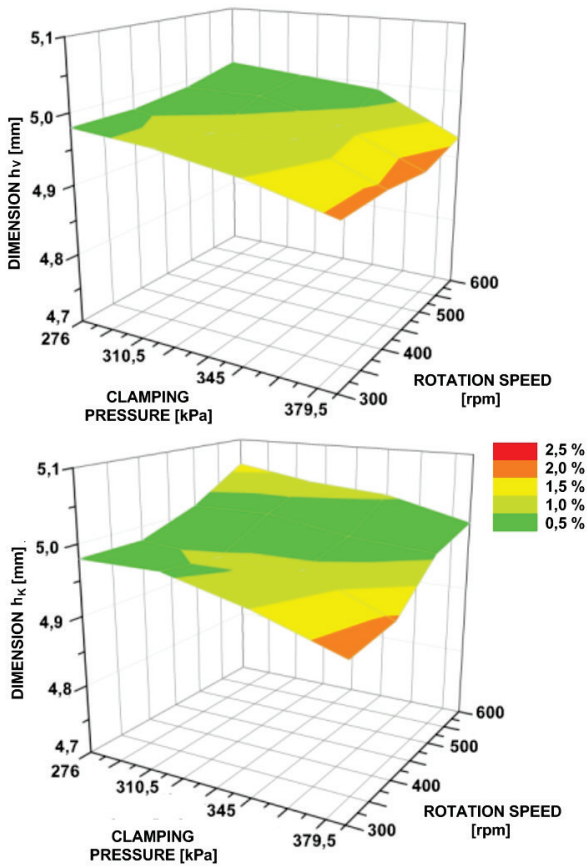


Figure 8 Dependency of thicknesses accuracy for casting diameter 30 mm

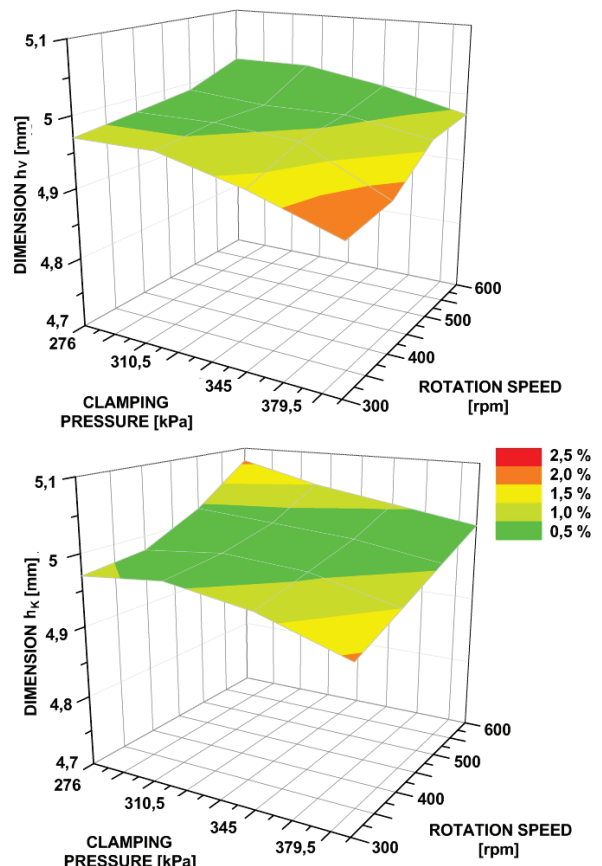


Figure 10 Dependency of thicknesses accuracy for casting diameter 50 mm

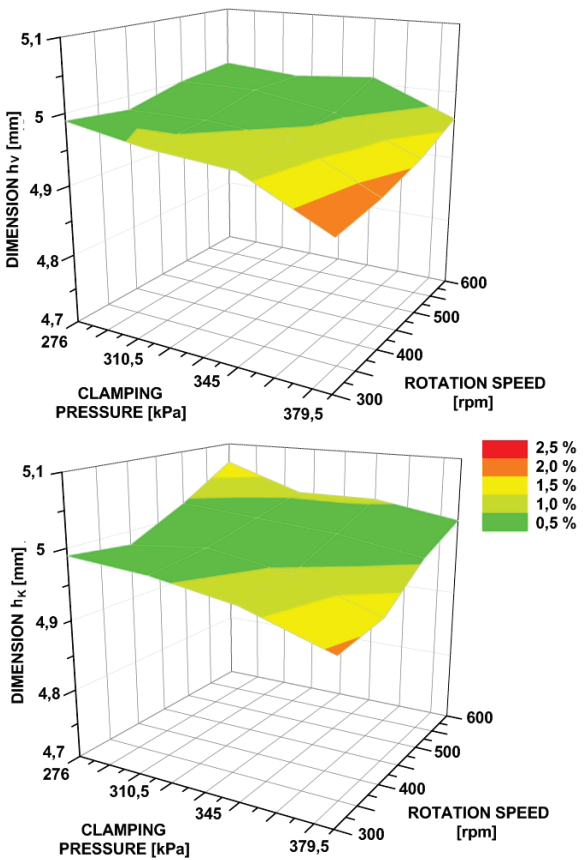


Figure 9 Dependency of thicknesses accuracy for casting diameter 40 mm

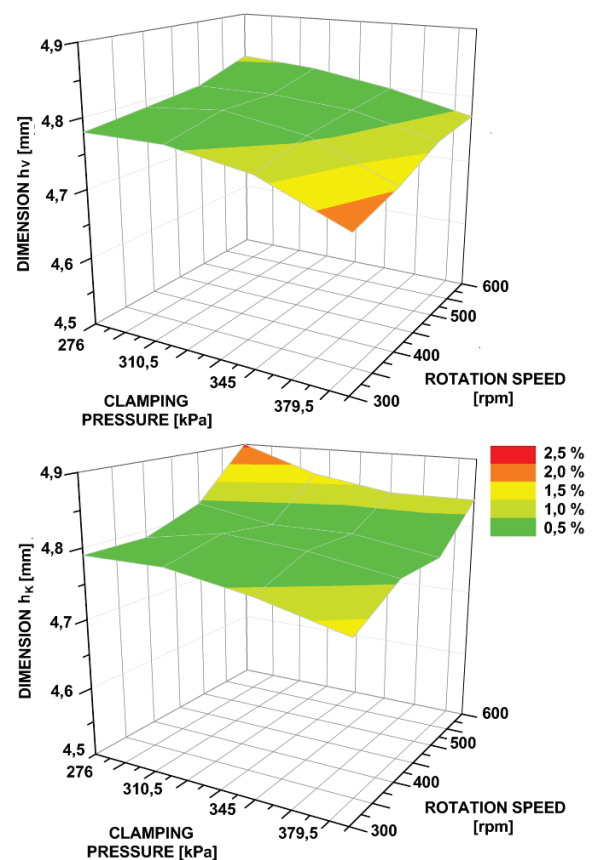


Figure 11 Dependency of thicknesses accuracy for casting diameter 60 mm

The dependency of diameters  $d_k$  and  $d_v$  on clamping pressure and mould rotation speed, for experimental casting with diameter 60 mm is shown in Fig. 7. In this case, the diameters increased only to 1 % for each combination of analyzed values of parameters. At rotation speeds in range from 300 rpm to 500 rpm, the deviation of  $d_k$  diameter was up to 0,5 %. The clamping pressure changed significantly the deviation only over 345 kPa, even though the increasing of diameters was only up to 0,5 %.

The small difference of accuracy of  $d_k$  and  $d_v$  diameters caused the effect of centrifugal force [4].

Fig. 8 shows the dependency of thicknesses  $h_v$  and  $h_k$  on clamping pressure and mould rotation speed for experimental casting with diameter 30 mm. For  $h_v$  thickness was the deviation up to 2 % at clamping pressure over 345 kPa in whole range of rotation speeds. However, the deviation for  $h_k$  thickness at clamping pressure 379,5 kPa is about 0,5 % at rotation speeds over 500 rpm. At low value of clamping pressure and rotation speeds over 500 rpm increased the thickness about 1,5 %. By clamping pressure increasing the casting thickness decreased. Regarding to thickness, most suitable for this casting diameter were values of clamping pressure to 310,5 kPa and rotation speed in range from 400 to 500 rpm.

For this combinations of parameters were the deviations  $\pm 0,5$  %.

Dependency of thickness accuracy for casting diameter 40 mm is shown in Fig. 9. It is possible to see that the highest increasing of deviation, up to 2 %, was for both thicknesses  $h_v$  and  $h_k$  at the highest value of clamping pressure and the lowest rotation speeds. Thickness  $h_k$  increased up to 1,5 % also at 276 kPa clamping pressure and rotation speed 600 rpm. In this almost ideal case with increasing of rotation speed also the value of clamping pressure increased. It is suitable to cast at clamping pressure up to 345 kPa and at rotation speeds up to 550 rpm. Most ideal was set of middle range of both parameters.

Fig. 10 shows the dependency of thicknesses  $h_v$  and  $h_k$  on clamping pressure and mould rotation speed for experimental casting with diameter 50 mm. Deviation of  $h_k$  thickness was 2 % only at combination of parameters 276 kPa and 600 rpm, or 379,5 kPa and 300 rpm. It was the combination of high clamping pressure with low rotation speed or contrary. For thickness  $h_v$  it was not very suitable to set clamping pressure over 345 kPa and rotation speed to 400 rpm. For this casting diameter are ideal lower values of clamping pressure and rotation speeds maximum 450 rpm.

Dependency of thickness accuracy for casting diameter 60 mm is shown in Fig. 11. For  $h_v$  thickness was increased the accuracy deviation more significantly by increasing of rotation speed. At clamping pressure 276 kPa and rotation speed 600 rpm reached up to 2 %. In this case the deviation increased also by increasing of clamping pressure. At the lowest rotation speeds the deviation was about 1,5 %. The highest clamping pressure in combination with low rotation speeds influenced the  $h_v$  thickness most negatively again. Value of deviation was about 2 %.

## 4 Conclusions

From obtained experimental results it was determined that rotation speed and clamping pressure influence the casting accuracy. The rotation speed has major influence on casting diameter accuracy. Increasing of rotation speed causes increasing of casting deviation at castings with diameter 30 mm and 40 mm. With increasing of casting diameter it is optimal to increase the rotation speed, in order to decrease the deviation.

Increasing of clamping pressure significantly influences the diameters accuracy only at higher rotation speeds.

For casting diameters 30 mm and 40 mm the mould rotation speeds at 400 rpm are the most optimal. The effect of change of clamping pressure is non significant at rotation speeds at 400 rpm. For casting diameter 50 mm the mould rotation speeds in the range from 400 rpm to 500 rpm are the most optimal. Change of clamping pressure does not change the accuracy significantly, only at values higher than 345 kPa. For casting diameter 60 mm rotation speeds in the range from 350 rpm to 550 rpm are the most optimal. Clamping pressure over 345 kPa is not very optimal.

From particular dependencies for casting thickness it is possible to conclude that high value of clamping pressure influences the deviation negatively, in some cases for the whole range of rotation speeds. The clamping pressure has the major effect on thickness deviation.

The effect of analyzed parameters on casting thickness is similar for each casting diameter. More significant difference is between  $h_v$  and  $h_k$  thicknesses. While for  $h_v$  thickness more suitable value of clamping pressure is up to 345 kPa and rotation speed over 350 rpm, for  $h_k$  thickness the most ideal is middle range of both parameters. At increasing of clamping pressure it is suitable to increase also rotation speed proportionally. Wrong combination of parameters resulted in different thickness in the cross section of casting. At higher values of rotation speeds it is necessary to make adjustments for effects of centrifugal force, mainly at lower clamping pressures [2, 6].

For each analyzed casting diameter it is suitable to set clamping pressure at about 310,5 kPa and rotation speeds in the range from 300 to 400 rpm.

It is necessary to note that the shrinkage of ZnAl4Cu3 zinc alloy is from 1,5 % to 4 % [7, 8]. The model is not made with the provision for shrinkage and measured values are the deviations from the model. It follows that the effect of centrifugal force compensates the decreasing of dimensions caused by molten metal shrinkage.

## 5 References

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