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EFFECT OF INJECTION PARAMETERS AND CAVITY POSITION ON MIM GREEN PART MASS

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ABSTRACT

This paper presents effect of the cavity position on green mass of metal injection (MIM) parts molded in a four-cavity split mold for different values of injection velocity, holding pressure profile and mold temperature. Test components where ring-shaped containing an external groove at the middle of height. It was found that the parameters that have greatest influence on part mass in single cavity are mold temperature folowed by holding pressure and injection velocity. Obtained experimental results also addres that the main source of variation in verticaly positioned runner system becomes cavity to cavity variation. In this case cavity to cavity variation increase is caused by separation and segregation supported by gravity effect.It was also found that in binder rich upper-cavity zone at sufficiently low mold temperature packing pressure increase cause decreasing of green part mass due to shift of glass transition temperature toward higher values.

Key words: cavity to cavity variation, gravity effect, metal injection molding

1. INTRODUCTION

The MIM process combines advantages of powder metallurgy and plastic injection molding through effective combination of metal materials in small and complex metallic components. The major technological phases of metal injection molding (MIM) are:

- mixing and granulating, where metal powder of typical size 1-22 μm and binder are mixed in a mixture (feedstock) at elevated temperature and then granulated.
- injection molding, where melted feedstock is transferred to the mold cavity forming green body then additionally pressurized to achieve sufficient density.
- thermal, solvent or catalytic debinding, where most of binder is removed from green (molded component) to get a shaped porous metallic part (brown body)
- Sintering, which consist of the thermal debinding of residual binder phase and final sintering to density of 96 % or more, followed by significant shrinkage 12-18 % to get pure metallic parts.

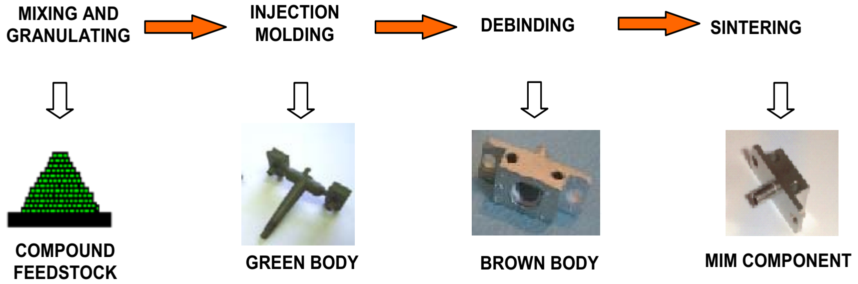


Figure 1: Scheme of Metal injection molding (MIM) process

Achieving narrow tolerance range 0.3 - 0.5% of nominal part dimension in MIM (1,4) requires understanding and reduction of variation sources in all process phases. Since there is a high correlation between green mass and sintered size variation (1), control of green mass variation after injection phase can be low cost and nondestructive approach to control final dimensions of MIM parts. Variation of the green part mass obtained from single cavity in MIM mostly depends on processing parameters stability and row material variation. Additional variation due to uneven filling, cooling or dimensional difference can occur when using a multiple cavity mold.

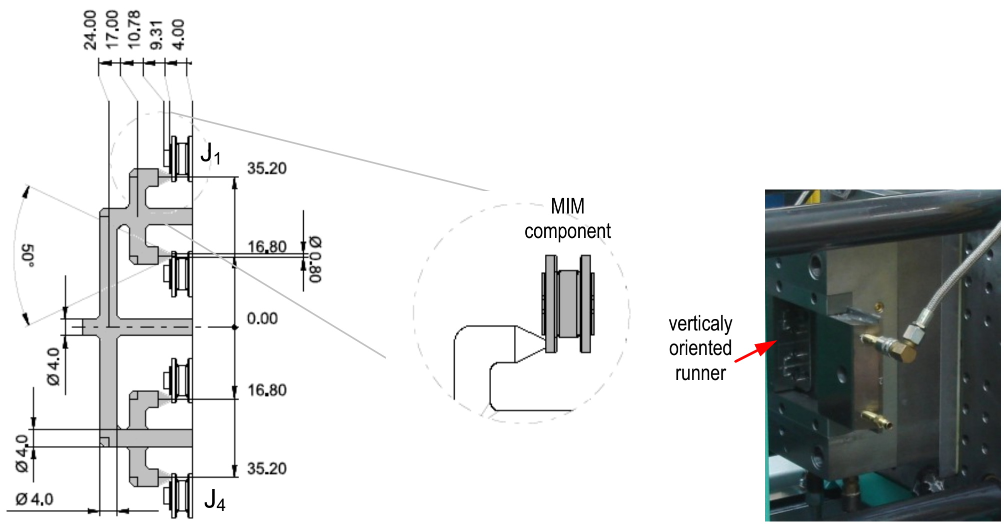
The aim of this paper is to evaluate the influence of gravity effect (cavity position) on green part mass variation using different values of mold temperature, injection velocity and packing pressure.

2. EXPERIMENTAL WORK

In order to evaluate gravity effect on green part mass an experimental split mold with verticaly positioned runner and cavities (Figure – a, c) was mounted on the Arburg 320C molding machine with ϕ=20 mm low compression screw adopted for MIM process. The parts studied were complex ring-shaped with an external groove and nominal mass of 1,27 g after sintering (Figure – b). Green part masses from top (J1) and bottom (J4) cavities were meassured by a precise electronic scale, while the coefficient of variation (CV) was used to express the normalized variation in mass.

Catalytic binder degradation was done in an Elnik debinding oven in nitric acid rich atmosphere, while sintering was done in an Elnik batch water cooled furnace using N_2 atmosphere at sintering temperature of 1310 ^{0}C.

The material used in this research was a highly viscous feedstock „Catamold 310N“ with polyacetal (POM) based binder and oversizing factor k =1,1669 ± 0,004. (k = tool dimension/ sintered dimension) that covers batch to batch shrinkage variation.



a) b) c)

Figure 2: The runner system dimensions, a); MIM component detail, b); and experimental four-cavity split mold, c)

The nominal parameter values and their levels used in injection experiments (Table 1) were chosen to comply with feedstock manufacturer recommendation and based on own experience. The injection velocity was held at 10 ccm/s until the melt reaches gates. Then, to avoid excessive shear heating, velocity was reduced and varied from 5 to 7 ccm/s. The packing phase was started with holding pressure value of 850 bar at the moment when the cavities are almost completely filled. Then, packing pressure was changed using rump-down (850-800 bar), constant (850-850 bar) and rump-up (850-900 bar) profiles during 2.1 sec.

Table 1: Overview of process parameters used in injection experiments.

Injection Parameter	Level 1	Level 2	Level 3
Injection speed (ccm)	5	6	7
Holding profile (bar)	850-800	850-850	850-900
Mold temperature (^{0}C)	115	125	-

Mold temperatures was varied in two levels, first value near glass transition point of the binder of 115 ^{0}C and second value was 125 ^{0}C according to feedstock manufacturer recommendation.

3. RESULTS AND DISCUSSION

Experimental results showed higher content of low density binder in upper cavity zone of vertically positioned runner system. Namely, binder at processing temperature is fluid and will flow more easily toward upper cavities because metallic powder accumulates on each flow obstacle and separates due to sudden directional changes and gravity effect.

According to expectation, green mass in both cavities increased with increasing pressure for almost all injection experiments. But, the experiments conducted using rump-up holding pressure profile (850-900 bar) at mold temperature 115 ^{0}C showed that green and sintered masses decrease in upper cavity (J1), despite comparativly higher pressure applied, Figure 3.

This can be explained by the fact that increased pressure rises the binder crystallization temperature (2,3) and reduces binder volume causing an increase in melt viscosity and heat transfer and consequently earlier gate sealing and lower packing. This effect takes place at the mold temperature close to glass transition point of polyacetal binder in binder rich area (upper cavity J1 zone).

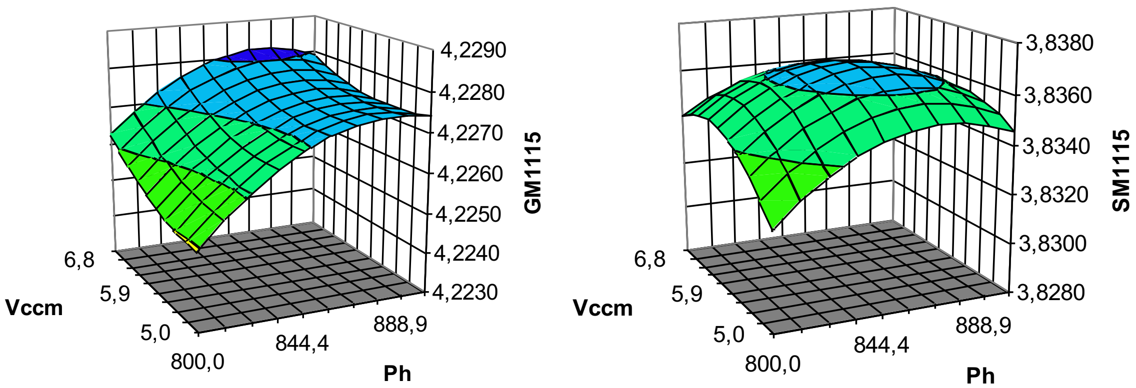


*Figure 3: Upper cavity green (left) and sintered mass (right) as a function of injection velocity (**Vccm**) and pressure profile (**Ph** – end packing pressure) at mold temperature of 115 ^{0}C*

The cavity to cavity coefficient of variation of green mass has value of 0.54% which suggests a ± 3 standard deviations dimensional precision of ±0.54%, if there are no other sources of dimensional variation and shrinkage is isotropic. The green mass CV caused by mold temperature change from 115 ^{0}C to 125 ^{0}C has vales of 0.07% and 0.1% for upper (J1) and lower (J4) cavity, respectively. The allowed mass variation range from 0.1 to 0.3% is reported by many firms in MIM (1).

CV due to injection velocity and holding pressure change has lower values compared to cavity to cavity variation and variation caused by mold temperature change. Table 2 compares green mass CV due to injection velocity and packing pressure for upper (J1) and lower (J4) cavity at mold temperatures 115 ^{0}C and 125 ^{0}C.

Table 2: Coefficients of variation due to injection velocity and packing pressure change.

Injection Parameter	Coefficient of Variation %	
	Cavity J1	Cavity J4
Mold temperature115 (^{0}C)	0,028	0,024
Mold temperature125 (^{0}C)	0,044	0,044

4. CONCLUSIONS

- In the vertically positioned runner system an additional cavity to cavity mass variation occurred due to phase separation and segregation supported by the gravity effect.
- Metal injection molding using high pressure can cause shift in binder cristalistion temperature and consequently lower green mass in binder rich areas such as upper cavities in vertically positioned runner system.
- Systematic cavity-to-cavity green mass variation has CV of 0.54% which is out of typical dimensional tolerance range of ±0.3 to ±0.5% for MIM.
- The variation range of injection velocity from 5 ccm/s to 7 ccm/s, mold temperature from 115 ^{0}C to 125 ^{0}C and packing pressure profiling from 800 bar to 800,850 and 900 bar produce coefficient of variation lower than 0.05%.

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