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COMPARISON OF PERFORMANCE OF THE HYBRID AND CLASSIC MOULD FOR INJECTION MOULDING

Damir GODEC
Mladen ŠERCER
Faculty of Mechanical Engineering and Naval Architecture
Ivana Lučića 5, HR-10000 Zagreb
Croatia

ABSTRACT
Application of prototypes becomes more and more important in product development process. The reason lies in development of number of automatic processes of Rapid Prototyping (RP) which enables direct prototype production based on CAD model of product within few hours or days. One of the basic disadvantages of RP processes is still limited number of applicable material for prototype production. On the other hand, if there exists appropriate material for prototype production, physics of prototype production is different than of for e.g. injection moulding. This leads to key differences in properties of prototypes and future products produced by injection moulding. Such state causes application of RP processes as processes for production of elements or whole moulds - Rapid Tooling processes (RT). Different properties of materials for RT mould inserts than classic mould materials could be main disadvantage of such processes. Therefore it is necessary to analyze differences in moulding properties caused by application of RT mould inserts. In this study a prototype (hybrid) mould and a classic mould are produced. Injection moulding was performed with both moulds and properties of moulding were compared.
Keywords: Rapid Tooling, hybrid mould, injection moulding

1. INTRODUCTION
Application field of rapid prototyping processes for manufacturing of mould elements is newer dated. Therefore the influence of materials of prototype (hybrid) moulds on moulding properties is still insufficiently explored. Many RT processes include use of non-metal or non-ferrous materials opposed to classic mould manufacturing processes. Mould material properties substantially determine final properties of manufactured moulding. [1] Recent researches on influence of metal prototype moulds on moulding properties are very limited. Nevertheless, often especially these moulds represent the most acceptable response to demands that are put for the product. Therefore it is necessary to understand the influence of metal hybrid moulds on moulding properties. [2]

2. RAPID TOOLING
The RT processes allow fast production of moulds enabling a quick response to the market requirements, which due to the segmentation is losing the characteristics of mass production and is turning more and more to the individual customer's requirements.[3] The requirements set on the mould for serial production by injection moulding and the possibilities provided by rapid prototyping processes are not completely harmonized at the moment, so that the direct usage of the rapid prototyping system for injection moulding in the industrial conditions still has not got the role which it should have in spite of the efforts invested in this field. [4,5] The RT processes are facing much stricter requirements than the RP processes. In case of RT processes, the produced moulds have to withstand over longer period of time the usual parameters of injection moulding, they have to be sufficiently wear-resistant, sometimes very close tolerances are required, and the surface quality must

be very high due to the aesthetic appearance of the moulded parts, as well as for easier demoulding. In spite of high prices of classic moulds and long times of their production, only few RT processes have found wider usage in the rapid production of moulds in small-batch productions. [3-5] For this paper *Indirect Metal Laser Sintering* (IMLS) process was used.

3. INDIRECT METAL LASER SINTERING PROCESS (IMLS)

For the production of mould inserts, the IMLS process uses primarily powder which consists of metal component as the building material and the polymeric component as the binder. After the first phase of the procedure the insert was made by the usual SLS process layer-by-layer based on the pre-developed computer model which is so-called *green* phase. The mechanical properties of such preform are not sufficient for the application in injection moulding. Therefore the *green* insert needs solidification which is realized by thermal treatment in the furnace at high temperature. The *green* insert is placed into the furnace where the process of sintering is initiated. The process in the furnace can be divided into three steps: debinding (at about 500 °C), final sintering (at about 700 °C - *brown* phase), and infiltration of bronze (around 1050 °C). The final mould inserts mainly have no cavities in their structure (the density of 95 to 98 % is achieved). They can be used for the production of over 100 000 moulded parts made of the common thermoplastic materials The IMLS procedure results in very good mechanical properties of the mould inserts. The result is the possibility of processing a greater number of moulded parts in the mould. This is at the same time the biggest advantage of the procedure since this does not only insure prototype production, but also the transition one (*bridge*), i.e. small-batch production of the moulded parts. [6-9]

4. EXPERIMENTAL SYSTEM

The research within the scope of the paper will encompass the influence of the hybrid mould on the properties of the thermoplastic thin-walled moulded part and the comparison with the influence of the classic mould on the properties of the moulded part. The study consists of the experimental analysis which allows making conclusion about the influences of the individual mould on the properties of the moulded part in thin-wall injection moulding in hybrid and classic moulds. For the needs of this paper, the thin-walled moulded part was developed, with a characteristic wall thickness of 1 mm. The material of the moulded part is adapted to the thin-wall injection moulding so that polypropylene (PP) was selected. Experimental mould with a single cavity was also developed. The replaceable parts are only the core and the cavity. The prototype mould inserts have been made by means of IMLS procedures of *LaserForm A6* material (Figure 1), and the classic ones of steel 1.2312.

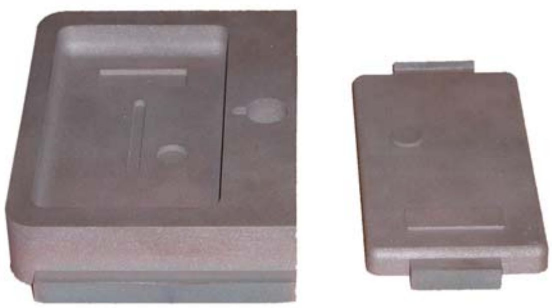


Figure 1. Prototype mould inserts

5. RESULTS OF EXPERIMENTS

The properties of the observed moulded parts were reduced to the mass, dimensional stability, deformation value and impact resistance (toughness) of the moulded parts. In order to analyse the influence of the mould on the properties of the moulded parts the central-composite design was used with three independent variables:

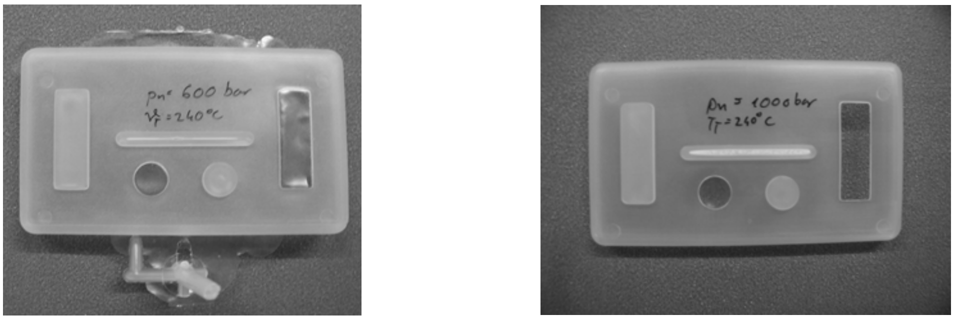
- melt temperature,
- injection time,
- packing pressure.

Average values of the monitored moulded parts properties and mould temperature field parameters are presented in Table 1.

Table 1. Mean values of moulded parts properties and mould temperature field parameters [2]

Property / Parameter	Value	
	RT mould	**Classic mould**
Mass	8,26 g	7,82 g
Dimension 1	100,22 mm	100,03 mm
Dimension 2	58,12 mm	57,97 mm
Deformation 1	1,59 mm	1,47 mm
Deformation 2	0,98 mm	0,93 mm
Impact resistance	96,6 kJ/m^2	123,5 kJ/m^2
Maximal mould cavity wall temperature	36,6 ºC	32,7 ºC
Mould cavity wall temperature gradient	5,8 ºC	2,5 ºC

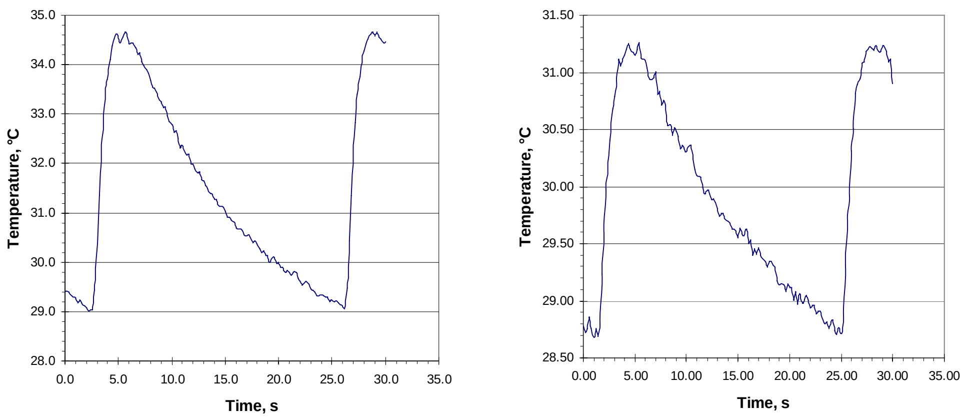
The resulting difference in the values of the mass of the moulded parts should be assigned to small differences in the dimensions of the prototype and classic mould inserts, but also to the higher compressibility of the materials of the prototype mould inserts. Higher compressibility of the prototype mould inserts can be proofed by the occurrence of flush on moulded parts at lower values of packing pressure than in case of classic mould inserts (Figure 2).



a) b)

Figure 2.Flush on moulded part: a - hybrid mould, b - classic mould; p_n - packing pressure, ϑ_T - melt temperature [2]

Higher values of deformations of the moulded parts can be explained by the fact that in the injection moulding as a rule higher cavity wall temperature was achieved in the prototype inserts (Figure 3). The moulded parts in case of prototype inserts left the mould cavity at higher temperatures which resulted in greater shrinkage of the moulded parts and greater resulting deformations.



a) b)

Figure 3. Mould cavity wall temperature field: a - hybrid mould, b - classic mould [2]

The reason for such difference lies in the lower heat penetration coefficient of the materials of prototype mould inserts. Lower heat penetration coefficient prevents fast conduction of heat into the interior of the mould, so that higher contact temperature of the cavity wall is achieved. Also the heating of such wall during a constant injection moulding cycle is faster, so that maximal mould cavity temperature is achieved faster than in the mould made of material of higher heat penetration coefficient (classic mould inserts).

Impact tensile resistance (toughness) of the moulded parts produced in the classic mould is much higher than the resistance of moulded parts made in the prototype mould (almost 50 % difference). The higher toughness of moulded parts made in the classic mould can be explained by lower temperature gradient of the cavity wall of the classic mould. In general, the heating and cooling of these mould inserts is slower than in the case of prototype mould inserts. The slower cooling of the moulded parts is at the same time suitable to acquiring higher values of toughness.

6. CONCLUSION

By comparing the prototype (*LaserForm A6* steel) and classic mould (1.2312 steel) for the production of thin-wall PP moulded parts, it can be concluded that the biggest differences in the properties of moulded parts result from higher compressibility of the prototype inserts (higher mass of moulded parts, bigger dimensions of moulded parts, occurrence of flush at lower values of packing pressure), and the difference in thermal properties of mould insert materials. The material of prototype inserts has a somewhat higher thermal conductivity coefficient than the material of classic mould inserts. The material of prototype mould inserts has a somewhat lower heat penetration coefficient, which results in achieving higher maximum cavity wall temperature but also higher temperature gradient than in the mould with classic inserts. Such condition causes higher values of shrinkage of the moulded parts and more difficult maintenance of the dimension stability of the moulded parts. Also, in the prototype mould lower values of tensile toughness are achieved. In order to achieve comparable properties of moulded parts made in both moulds, it is possible to define adequate corrections of the most influential parameters of the injection moulding in using the prototype mould.

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