Production injection moulds with additive technology by the HP MJF 4200 printer

Z Chval¹, K Raz¹, M Stepanek¹
¹University of West Bohemia, Regional Technological Institute, Univerzitni 8, 306 14 Pilsen, Czech Republic
zdhval@rti.zcu.cz, kraz@rti.zcu.cz, stepanem@rti.zcu.cz

Abstract. This paper is focused on the production plastic parts. It is describing two technologies— injection moulding and additive technology. The production process of the metal mould for the new parts takes about ten weeks. It is necessary to make some reductions after the mould is produced. It is increasing the time which is necessary for the prototype of products. This time (from the initial design of mould to the prototype of product) can take about six months. Additive technologies can be used for decreasing this time and for cost reduction. Moulds produced by the additive technology are mostly special inserts which can be implemented in the universal design of mould. It is also possible to produce whole moulds from plastic material. These moulds can have integrated cooling channels. There are high demands on the material of the mould with respect to the thermal resistivity, toughness and surface quality. There are really often used SLA technologies, which are considering the High Temp Resin and Material Jetting Digital ABS. Other options used in the factories are Somos PerFORM and Digital ABS Plus. This paper deals with the possibility of usage of the HP Jet Fusion technology with the material PA12 GB for the production of mould inserts and it is evaluating this process and repeatability of process.

1. Introduction
Production of prototype parts by usage of the additive technologies has already become a common production technology in many sectors of the industry. It is especially used in the prototyping of newly developed parts for further plastic injection technology. The idea of using 3D printing for serial (and small series production) is usually limited by the technological limits of the additive technology. It means the price of the printer and specific production time. The great advantage, of course, is that there is no need to produce an expensive mold. [1,2]

This paper deals with the description of the approach of usage of additive technology in production of injection mould for injection moulding press.

The production of the injection mould from the steel takes about ten weeks. There is often necessary to make two additional improvements of design (which each takes about one month). There is the final mold for the prototype after this process. It takes about six months from the beginning until the end of this process. There are additive technologies used in order to make this time interval shorter and in order to decrease costs of the mold. The final delivering time of the mould made by the additive technologies can be decreased up to five days. [3,4]

Usage of additive technologies in the production of the injection moulds is most suitable in following cases:
• Needs of the fast delivering time
• Lower number of products (50-100) [5]
• There will be changes of the geometry in the produced part
• Small size of parts (less than 150mm)
• Prototype parts and development of parts [6]

2. Current state of art in the field of injection moulding with usage of 3D printed moulds

Additive produced injection moulds are usually designed as inserts, which are placed into the aluminum or steel frames. There is also a way to produce whole moulds by additive manufacturing with internal cooling channels. It is suitable to place into the plastic mould some steel rods or tubes, which can work as and prevention against deformations and it helps with the heat dissipation. [7,8] There are specific requirements placed on the mould material in terms of temperature resistance, high rigidity and surface quality. Therefore, additive SLA technologies, using the High Temp resin and the material Jetting Digital ABS are often used in the industry. There are generally used products such as the industrial environment Somos PerFORM (SLA) and the Digital ABS Plus. Industrial SLA printers, preferred for the production of molds, should have a top-down print space configuration and they should have bigger print space and also there should be possibility to achieve a higher surface quality (considering now the SLA printers). Example of the 3D printed mould is shown in the following figure. [9,10]

![Figure 1. Injection mould with insert and with the final part](image)

The Stratasys company anticipates that molds made with their Material Jetting printers should be used for parts with a maximum volume of 165 cm³ and an injection pressure of 50-80 tons. The use of printed forms for small series or prototype production is already offered, for example, by the company Promolding B.V. (Netherlands). The example of this mould is shown in the Fig. 2. [11]
The material PA12 (glass filled) is also used for the production of injection molds. The Multi Jet Fusion technology is successfully used, for example, for production using the Reaction Injection Molding technology (RIM), which is used to produce, for example, covers for machines, medical devices, etc. [12]

3. Testing of 3D printed moulds
The main aim of the research was to verify the number of repetitions of the injection moulding process with usage of 3D printed inserts. The 3D printer HP Multi Jet Fusion 4200 and the material PA12GB were used for the production. It is a thermoplastic polyamide with glass filling. The material has according the ASTM D3418 following parameters: melting point of the powder material (for 3D printing) 186°C; the limits of thermal deformations of the products are determinated according the ASTM D648 standard (testing method A) as 173°C at a load 0.45 MPa. [13]

The material used for the injection moulding was polypropylene mainly because it has almost the best parameters for moulding and the melting temperature is less than 160°C. The lowest melting temperature of the material is suitable for the plastic mould.

There was designed and developed new innovative modular mould for testing plastic inserts. The injection moulding process was realized with usage of the press Arburg Allrounder 470E. This machine is a non-hydraulic experimental moulding device. Both devices are shown in the following figure. The mould is also shown in the Fig. 4.
Figure 4. The modular mould for testing of 3D printed inserts, cut of the CAD model (left), mold in the press (right).

For the first experimental testing of injection into a plastic (composite - PA12GB) insert was used a single form of tensile sample. The sample was designed for single inlet injection, as is shown in the following figure.

Figure 5. Modular mould with insert (left), various inserts from plastic material (right).

Injection molding into a plastic mould has various specifications which has to be taken into account in the technology of the injection molding process. The biggest limitation is the long cooling time of the molded part, due to the high insulating properties of the insert material (plastics). It leads to the higher cycle times and it is necessary to make a proper design of the inlet because the material should freeze in the inlet firstly.

Experimental verification of injection molding into a PA12GB insert showed the resistance and the durability of this material. It is necessary to notice, that testing was performed for simple parts without any complex geometries. It has been verified that it is possible to perform tens to low hundreds of
repetitions of the injection cycle without significant wear of the insert. The lower dimensional accuracy of the insert placement in the mold is the biggest problem of this technology. There was often a problem with accuracy resulting into overflows into the dividing plane. To eliminate this problem, it is necessary to print the insert with the allowance and, after inserting it into the mold, re-align it by machining. The experimental printed part is shown in the Fig.6 and different moulds are shown in the Fig.7.

![Image of injection molding result into a plastic mould](image6.png)

**Figure 6.** Result of the injection molding into the plastic mould

![Images of various inserts](image7.png)

**Figure 7.** Various inserts which can be used in the modular mould, from left: aluminum, SLA, PA12GB, PA12GB with machined upper surface.

4. **Testing of the plastic mould with more complex geometry**

The next step in testing of 3D printed inserts from the HP MJF 4200 printer was to test injection process into inserts with more complex geometries. For this purpose, an insert for injection molding of a real part for a specific engineering application was created in two different designs. The first design was simplified by removing the relief and the part was thus simplified to a volume with protruding thin-walled parts. The second design was designed as lightweight solution as an ideal solution for injection molding (see Fig. 8).
Figure 8. Inserts for injection moulding; left: solid design of the part, right: lightweight design of part

In the case of injection into the solid design of the part, there was no problem with ejecting the part from the modular mould. The problem occurred in the second - thin-walled design. In this case, it was no longer possible to remove the part from the insert. This problem is due to the significantly higher surface roughness of the 3D printed insert compared to conventionally machined insert from aluminum or steel. In case of too thin wall, the injected material is already pressed into the insert and due to the high friction, it is not possible to remove the part. It is shown in the following figure.

Figure 9. Results of injection moulding of more complex parts; - solid design after ejection (left), thin-walled design in the insert (right)

5. Further research
Following steps in the research will be:

- Verification of the possibilities of using a plastic mould for different degrees of complexity of the internal cavity of the plastic mold with respect to the minimum possible wall thicknesses and the minimum cross-section of the cavity. The goal will be to maximize the number of mold usability cycles for a given level of cavity complexity and to determine the minimum number of cycles for each level.

- Verification of the possibility of improving the properties of 3D printed plastic molds by application of commonly sold products based on sprays and thin coatings. For this purpose, a form for testing flowability in the form of an Archimedean spiral has already been printed (see following Fig. 10).
• Verification of the surface quality of moldings from 3D printed molds and comparison of the suitability of surface treatments of 3D printed parts used in the industrial sector.

• Determination of suitable materials for injection into the plastic mold insert with regard to the highest possible number of cycles of the injection process in one mold.

![Figure 10. Plastic inserts for testing the flowability; after the production by the HP MJF4200 printer (left) and after the chemical improvement of the surface (right)](image)

6. Conclusion
This paper is summarizing the research in the field of the usage of additive technologies for production of prototyping moulds. It was verified that this technology can be used without any significant problems for lower number of products and for simple geometry of parts. This approach will decrease price of some specific moulded parts.

The 3D printer HP MJF 4200 was used in this research and the moulded material was polypropylene. It is necessary to solve problems with moulding of thin profiles, where problems with ejecting can occur. It is also suitable to improve the surface roughness of 3D printed mould in order to decrease the friction coefficient between the mould and the product.

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