How to cite this article:

Authors: Przemysław Siemiński, Błażej Szulc

Title of article: „Analiza technologii przyrostowej FDM/FFF do wytwarzania wkładek formujących form wtryskowych" ("Analysis of FDM/FFF additive manufacturing production mold inserts of injection molds")

Mechanik, Vol. 91, No. 1 (2018): pages 53–55

DOI: https://doi.org/10.17814/mechanik.2018.1.11

Analysis of FDM/FFF additive manufacturing production mold inserts of injection molds

Analiza technologii przyrostowej FDM/FFF do wytwarzania wkładek formujących form wtryskowych

PRZEMYSŁAW SIEMIŃSKI
BŁAŻEJ SZULC *

The use of 3D printing for manufacturing mold inserts of injection molds has been described. The inserts were made by FDM/FFF from PLA polymer (two test cycles of several dozen). The selected items were measured using an accurate 3D scanner and aligned with the reference.

KEYWORDS: injection molds, additive manufacturing, 3D printing, FDM, PLA

The most popular method of manufacturing elements from thermoplastics is injection molding. For this purpose, injection molds [1] are used, which are usually very complicated tools. For this reason, they are used for large-scale and mass production. The main stage of the process is high-pressure polymer injection into a closed mold, the socket of which maps the shape of the manufactured element – moldings. The socket is made directly in the stamp and die plates or in mold inserts fastened in these plates. The seat during the injection is subjected to high mechanical and thermal loads and is wiped by the material, so they are usually made of special steel grades. Traditionally, the sockets are made by milling them on CNC machine tools or, optionally, by plunging. The costs of such treatment are high, so it is economically profitable to produce hundreds of thousands of moldings in them.

Mold inserts made by 3D printing

For over a dozen years, many companies in the world (also in Poland) have been testing and making inserts that form incremental technologies using SLS (Selective Laser Sintering) or SLM (Selective Laser Melting) - by EOS called DMLS (Direct Metal Laser Sintering) – from metal powders [2]. Steel inserts made with the SLS method usually require expensive infiltration with copper alloys [3] and are less durable than those made with SLM/DMLS methods. The mechanical strength and abrasion resistance of components obtained in SLM/DMLS processes from steel powders is comparable to those produced traditionally. In addition, incremental technologies allow you to make contributions from the so-called conformal cooling channels [4]. They can have very complicated cross-sectional shapes and transitions, impossible to achieve by classical methods [5]. Despite these advantages, SLM inserts are not commonly used in the construction of injection molds, which is due to economic reasons.

* Dr inż. Przemysław Siemiński (przemyslaw.sieminski@asp.waw.pl) – Wydział Wzornictwa Akademii Sztuk Pięknych w Warszawie; inż. Błażej Szulc (blazejsz1994@gmail.com) – Wydział Samochodów i Maszyn Roboczych Politechniki Warszawskiej

In the case of production of small series of moldings (up to several dozen pieces) [6], some companies propose to make mold inserts using 3D printing, using the stream method [7]. Descriptions of successful implementations have been available for several years [6, 8, 9]. Stratasys 3D printers (PJM method – polyjet modeling) or 3D Systems machines (MJM method – multijet modeling) are most often used. Examples of inserts made with incremental streaming technology are shown in fig. 1 and fig. 2.

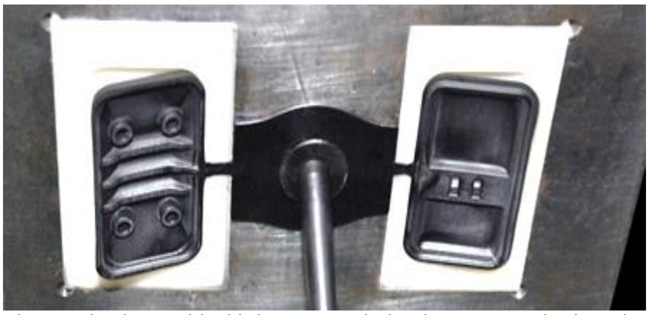

Fig. 1. Injection mold with inserts made by the MJM method on the 3D systems machine [6]

a) *b*)

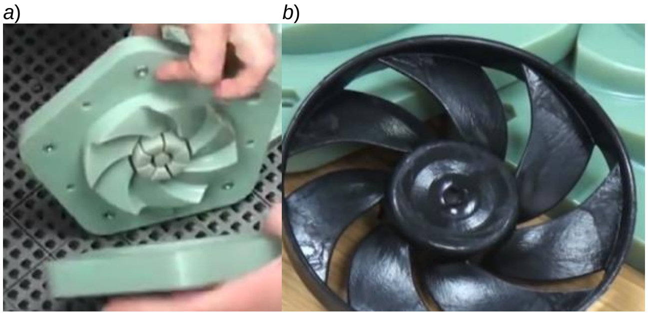

Fig. 2. Forming plates (*a*) made using the PJM method on the Stratasys machine and the compact obtained in them (*b*) [9]

Durability of the inserts or molding plates made with the PJM and MJM methods is not great, because the model material are photocurable resins. They deform under load at a temperature of 40÷60 °C, depending on the type (according to ASTM D648-07). For this reason, only thermoplastics with a lower plasticizing temperature, i.e. PP, PE and ABS, are injected into such mold inserts [6]. According to [6] inserts from MJM are subject to thermo-chemical treatment, which increases their resistance to high temperature and mechanical loads. It is also recommended to cool the compartments with compressed air after each cycle. However, guidelines for designing inserts from PJM are presented in [10].

The advantage of using incremental jet methods for the production of injection mold cavities is high smoothness (almost no visible layering) and therefore good quality of the surface of the molded parts (this also affects the ease of removing the molded parts from the nest).

Setting the problem and the purpose of the research

The authors did not meet with scientific publications and descriptions of implementations of incremental technology FDM/FFF (Fused Deposition Modeling – machines by Stratasys / Fused Filament Fabrication [RepRap]) [7] for the production of mold inserts for injection molds. The aim of this work was to examine the possibility of producing moldings in inserts made with the FDM/FFF method, and especially to check the suitability of PLA, which is considered a material more suitable for prototypes than engineering objects or tools, i.e. molds.

Description of tests

For the purpose of this work, 3D injection models were developed in the 3D CAD system, shaped like the logo of the Faculty of Automobiles and Working Machines of Warsaw University of Technology. The object was located in a circle with a diameter of 42 mm and had a thickness of 5 mm. Several versions of matrix inserts (with recesses for the inscriptions and smooth version) and stem inserts have been designed for this shape. The inserts were printed using the FFF method from PLA with 100% filling. The thickness of the layers was 0.2 mm. Steel fastening plates were designed and made for these punches and dies (fig. 3). A system for pushing the molded part out of the nest or separating the ingot from it was not designed.

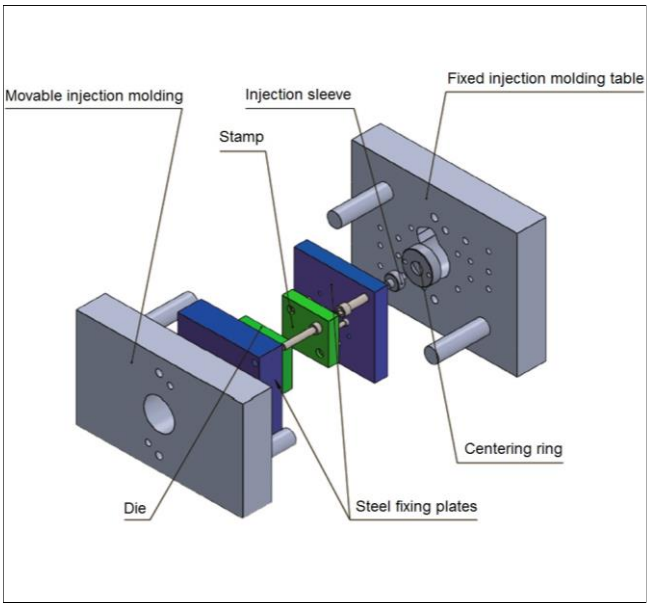

Fig. 3. Complex injection mold with the injection molding table used for testing. Green objects are mold inserts printed using the FDM/FFF method, and navy blue – steel fixing plates

Due to the courtesy of WADIM PLAST from Rule of Warsaw [11], the whole was mounted on the Dr Boy XS injection molder [12], the main parameters of which are: max. 100 kN clamping force and max. Injection volume of 8 cm^3. Several hundred injection tests have been carried out on this machine for several different sets of inserts. The injected polymer was Moplen HP500N polypropylene from Basell [13]. Two cycles of tests differing slightly in the shape of the seat and the applied stamp plate are described.

Tests No. 1

For tests No. 1, PLA inserts were installed with no inscriptions (fig. 4a), and the injected mass of colorless PP polymer was 6 g. In the injection system control the following process parameters were set: injection temperature of the polymer 180 °C, max. injection pressure (limitation) 400 bar, average mold closing time 60 s, average mold open time and free cooling about 120 s. The method of installing the inserts in the injection molding machine is shown in fig. 5a.

a) *b*)

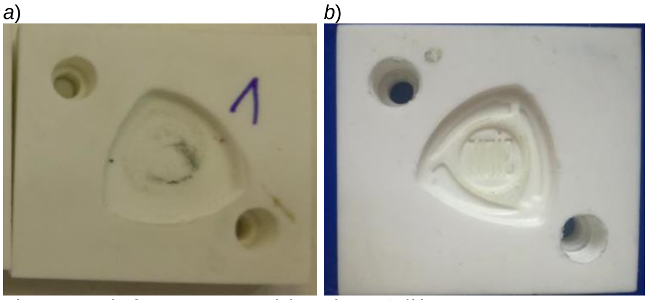

Fig. 4. Matrix for tests No. 1 (*a*) and No. 2 (*b*)

a) *b*)

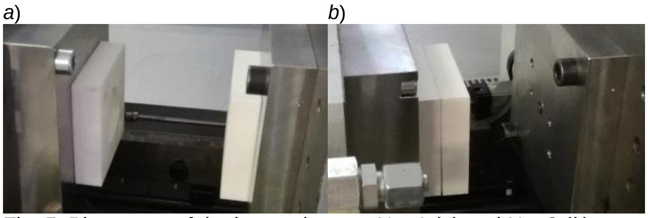

Fig. 5. Placement of the inserts in tests No. 1 (*a*) and No. 2 (*b*)

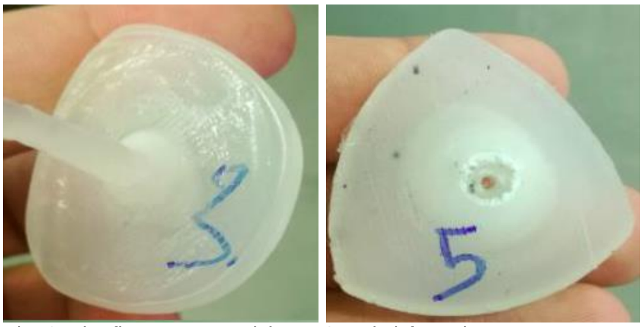

Fig. 6. The first compacts (pieces 3 and 5) from the test No. 1

In this way, the first six pieces of molded parts were produced (fig. 6). Unfortunately, the first compact was hard to remove from the nest. In order not to repeat this, hot air was used to smoothen the internal walls of the matrix, which caused a slight deformation of its bottom (fig. 4a) and left undulations on the moldings. In addition, an Ambersil silicone separator was sprayed onto the socket. Subsequent moldings were released without problems.

Then, cooling the socket with compressed air for about 50 seconds and the mold opening time was about 60 seconds. In this way, a further 30 pieces were produced – according to visual evaluation, their shape was constantly the same, so the process could be considered to be reproducible (fig. 7a).

Tests No. 2

Due to significant heating of the die and the punch, it was decided to disassemble the PLA punch and move the die to the steel plate (fig. 5b). A new PLA white matrix insert with inscriptions was used for the tests (fig. 4b) – 100% filling, thickness of 0.2 mm layers. The parameters were as follows: injection polymer mass PP 6.2 g, temperature of injected polymer 180 °C, max. Injection pressure (limitation)

400 bar, mold closure time 60 s, average mold open time approx. 30 s. This way, 60 pieces of moldings were produced (fig. 7b), the shape of which was repeatable, although difficult to assess due to the partial transparency of the material. Therefore, dark PP granules were used for further tests (fig. 8).

a)

b)

Fig. 7. Part of the test pieces No. 1 (*a*) and No. 2 (*b*)

Fig. 8. Appearance of test pieces No. 2 after the change of the granulate

a) *b*)

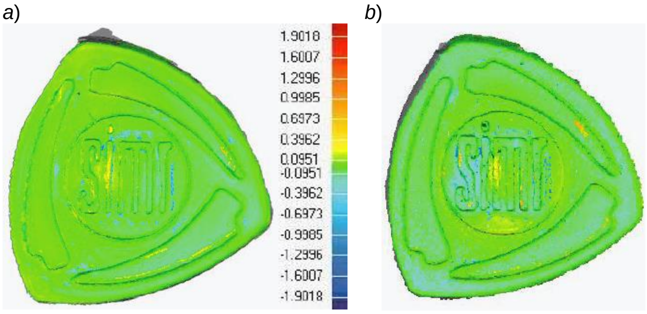

Fig. 9. Displacement map for moldings No. 30 (*a*) and 40 (*b*)

Smarttech structural light scanner with a certified uncertainty of 0.02 mm measurement made measurements of the external shape (only from the top) every tenth part. The impressions before the measurement were slightly covered with titanium white. Fig. 9 shows displacement maps for moldings No. 30 and 40 suited to the reference 3D model using the Best Fit method. The reference model was a scan of the molding made ten injections earlier, thus the deviation maps show first of all changes in the shape of the nest during production. Over 90% of the analyzed points were within ± 0.1 mm and this was the average deviation calculated by the system, while the average square error was 0.17 mm.

Conclusions

- Incremental thermoplastic extrusion technology (FDM/FFF) can be used to produce inserts forming injection molds.
- The research shows that the durability of the PLA matrix in the injection of PP polymer and simple shapes of the molding can amount to almost one hundred correct pieces – shape deviation about ±0.1 mm, on the sloping walls visible stepped effect, and on flat visible fibers. Such quality of the parts is sufficient for details are invisible to the user.
- The problem may be to remove the molded part from the socket – it is worth using the minimum inclination of the 5° walls and the stripping effect of the stepped effect remaining after 3D printing.
- In order to increase the durability of the socket and shorten the cycle time, the socket should be cooled after the compressed air has been removed.
- Replacing the printed plastic stamp with a steel plate results in a significant reduction of the cooling time of the mold and facilitates removal of the ingot.
- It is proposed to use printed cooling channels (for compressed air) in the matrix, which can significantly shorten the cycle time.

REFERENCES

1. Zawistowski H., Frenkler D. „*Konstrukcja form wtryskowych do tworzyw termoplastycznych*". Warszawa: WNT, 1984.
2. Stwora A., Skrabalak G. „Wpływ parametrów technologicznych procesu selektywnego topienia laserowego na wybrane właściwości elementów wykonanych z proszków stopu AlSi10Mg". *Mechanik.* 3 (2016): pp. 206–209, DOI: 10.17814/mechanik.2016.3.21.
3. Kumar S., Kruth J-P. "Effect of bronze infiltration into laser sintered metallic parts". *Materials & Design.* 28, 2 (2007): pp. 400–407.
4. Muszyński P., Mrozek K., Poszwa P. „Wybrane metody chłodzenia form wtryskowych". *Mechanik.* 8–9 (2016): pp. 996–1000.
5. Materiały informacyjne i strona internetowa firmy FADO: www.fado.info (dostęp: 26.11.2017 r.).
6. Materiały informacyjne i strona internetowa firmy I.J. Paliga: ijpaliga.pl/uslugi/formy-wtryskowe.html (dostęp: 26.11.2017 r.).
7. Budzik G., Siemiński P. „*Techniki przyrostowe. Druk 3D. Drukarki 3D*". Warszawa: Oficyna Wydawnicza PW, 2015.
8. Strona internetowa firmy Javelin Technologies: www.javelin-tech.com/3d/manufacture/molds/ (dostęp: 26.11.2017 r.).
9. Materiały informacyjne i strona internetowa firmy Stratasys: www.stratasys.com (dostęp: 26.11.2017 r.).
10. Bashor M. 3D Printed Injection Molds. Presentation Stratasys. www.moldmakingtechnology.com/cdn/cms/1%20stratasys.pdf (dostęp: 26.11.2017 r.).
11. Materiały informacyjne i strona internetowa firmy Wadim Plast: www.wadim.com.pl (dostęp: 26.11.2017 r.).
12. Materiały informacyjne na temat wtryskarki Dr. BOY XS: www.dr-boy.de/en/products/boy-xs/ (dostęp: 26.11.2017 r.).
13. Karta charakterystyki granulatu PP Basell Moplen HP500N: www.basellorlen.pl/assets/produkty/produkty/Moplen_HP500N_201410_PL.pdf (dostęp: 26.11.2017 r.)

Translation of scientific articles, their computer composition and publishing them on the website www.mechanik.media.pl by original articles in Polish is a task financed from the funds of the Ministry of Science and Higher Education designated for dissemination of science.

Ministry of Science and Higher Education
Republic of Poland