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EXPERIMENTAL EXAMINATION OF THE APPLICABILITY OF ADDITIVE TECHNOLOGIES IN THE FIELD OF RAPID TOOLING - INJECTION MOLDING

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Abstract: In this paper, an experimental examination/analyzing applicability and machinability of the polymer material's core and cavity formed using additive technology (rapid tooling) was conducted. Achieving the price reduction of the final product, as well as the price of the mold for plastic injection through the introduction of rapid tooling injection molding can be applied, not only to mass production, but also to small series production. This research is limited to obtaining plane parts of simpler geometry from polypropylene polymer material. Obtained results showed that, at this point, it is not directly possible to completely produce a core and cavity only through additive technologies. In order to achieve some tolerances at specific places, it is still necessary that the core and cavities are machined with conventional methods. On the other hand, it turned out that by using a polymer core and cavity, it is possible to produce a smaller series of the parts.

Key words: Rapid Tooling, Additive Technologies, Injection Molding, 3D Printing.

1 INTRODUCTION

Injection molding as the mass production method was introduced in late 19th century, by two American inventors J. S. Hyatt and J. W. Hyatt [1]. Up to this date, do

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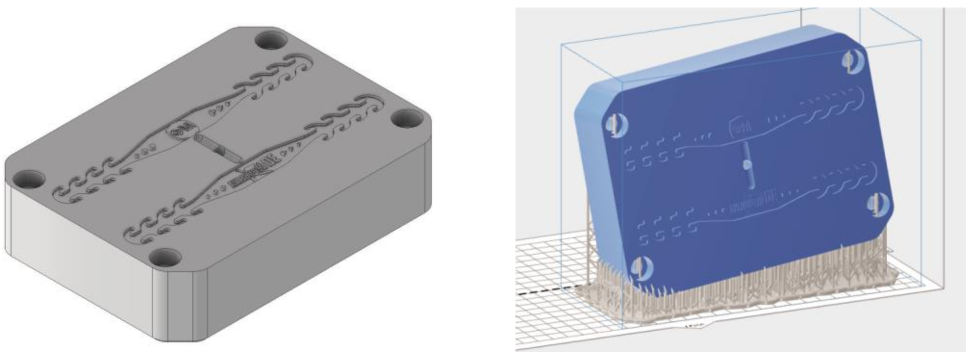
to cost effectiveness, injection molding is applicable only in the mass production. The main reason is production cost of the molding tool itself.

With introduction of the additive technologies, it is possible to completely review the application of certain methods of manufacturing parts. Some parts that require complex milling operations or casting operations can be produced in a simple and easy way using additive technologies [2-5]. In recent years, a large percentage of the research has been focused on examining the application of additive technologies in the field of rapid tooling for the needs of injection molding [6-13].

2 RAPID TOOLING

Rapid tooling as the as an area of application of additive technologies, is not only used for various auxiliary tools such as jigs and fixtures, but also has a huge application in the field of injection molding of polymer materials.

For the purposes of the experiments of this paper, a ČAD model of the mold (Fig. 1a) for a planar part representing a face mask carrier was created. Formed CAD model, in addition to the mold cavities, it contains channels for the flow of the coolant in order to temper the tool properly. The CAD mold model is formed in such a way that two face mask carriers should be formed during one injection molding process. The part is oriented in such a way that the part where the mold cavity is located has a better quality of surface, that is, that part of the mold is not in contact with the supports (Fig. 1b).

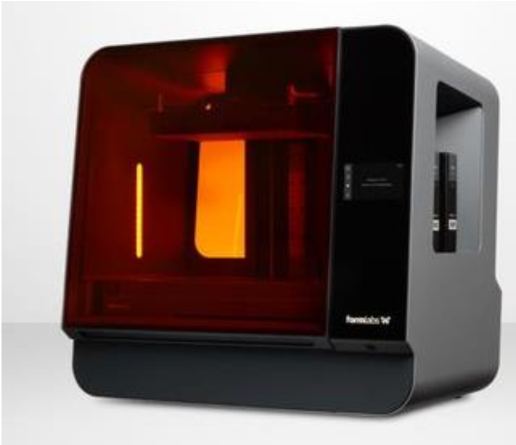


a) b)

Figure 1. *a) CAD model of the mold and b) production preparation*

The mold is produced on the Formlabs printer, on the model The Form 3L (Fig. 2a), using layer height 0.1mm. Photopolymer material that is used is Rigid 4000 V1. Printing time was estimated in approximately 25 hours.

In order to obtain optimal physical-mechanical properties of the printed part, in addition to cleaning rest of the photopolymer, the part was additionally postprocessed by additional irradiation under the UV light (curing).



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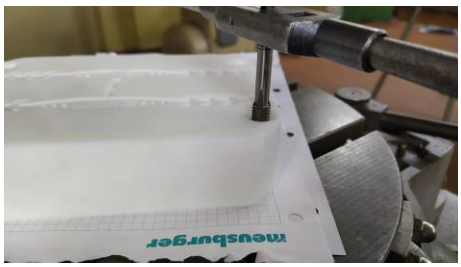
a)

Figure 2. *a) 3D printer Form 3L and b) printed part*

3 EXPERIMENTAL SETUP

As the tool for injection molding must satisfy certain criteria in the direction of production quality, that is, the quality of the processed surface, as well as dimensional accuracy, it is necessary to additionally post-process the printed part. This implies the subsequent treatment of the surfaces that were in contact with the supports, usually by the grinding method (Fig. 3a). It is also necessary to make technological threads for the later removal of the mold from the tool housing (Fig. 3b).



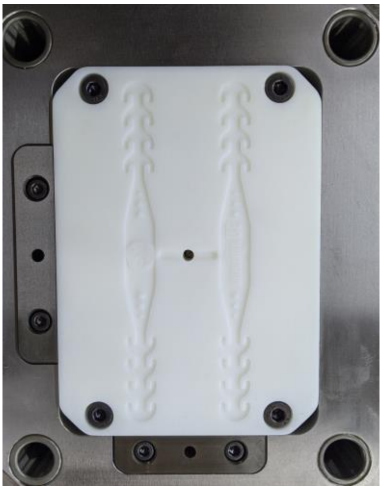
a) b)

Figure 3. *a) Tapping technological threads and b) grinding of the support surfaces*

As for the tool housing, standard modular tool was used from the manufacturer Meusburger. In order to achieve greater flexibility and reduce the cost of the tool, a plate used for positioning the ejector was also made using additive technologies (Fig. 4). The used standard modular housing is designed so that the complete sub-assembly consisting of the mold and ejector system can be replaced with great ease. In this way, if the mold is damaged, it can be replaced very efficiently.

Figure 4. *Assembling the ejector with the mold*

The mold in the sub-assembly with the ejector system is attached to the core side of the tool (Fig. 5a). In the cavity side of the tool, a flat insert (mold) made of aluminum is formed, in the center of which there is a sprue bush (Fig. 5b). Tool tempering was performed only on the side of the mold produced by additive technologies. The cooling system is formed so that the coolant passes through both - the modular housing and the mold.



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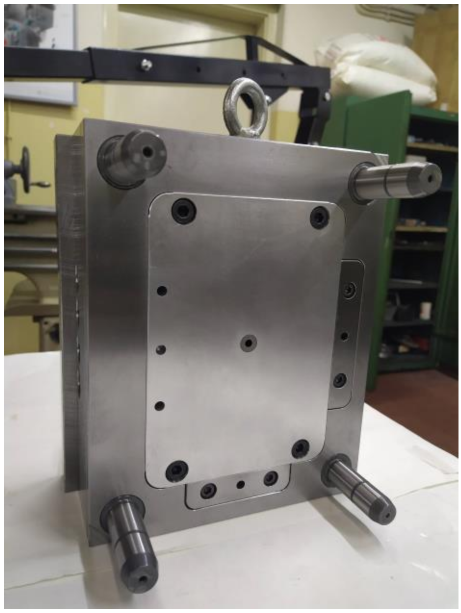


b)

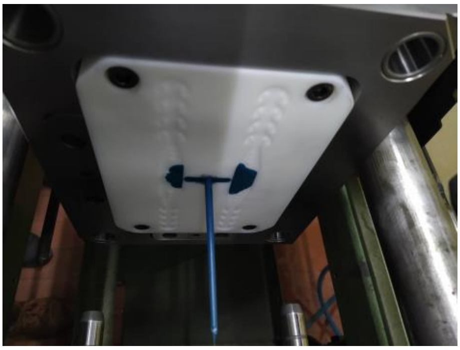
Figure 5. *a) Core and b) cavity side of the molding tool*

The injection molding experiments were formed so that polypropylene was chosen as the desired material for the face mask carrier.

4 RESULTS

Since working with polymer molds is still an unknown, the correct selection of injection pressure can be challenging. In the experiment.

After reaching the desired melting temperature (205 °C), as well as tempering the tool, the experiments were started with lower values of pressures, to establish the lower limit. This led to incomplete mold cavity filling (Fig. 6a). After the upper pressure limit was established, the injected melt volume was exceeded. As a result, there was flashing on the parting surface on a large scale (Fig. 6b).



a)

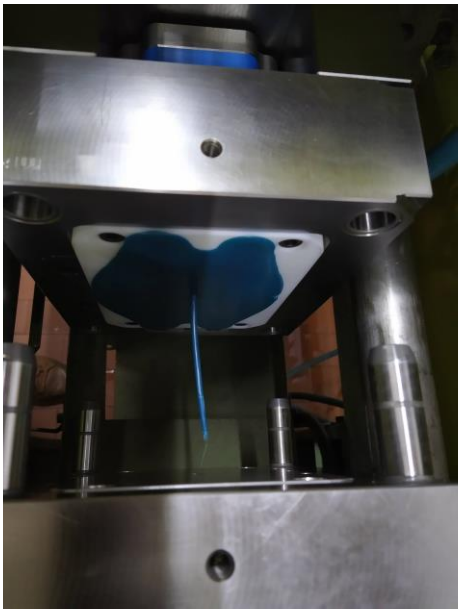


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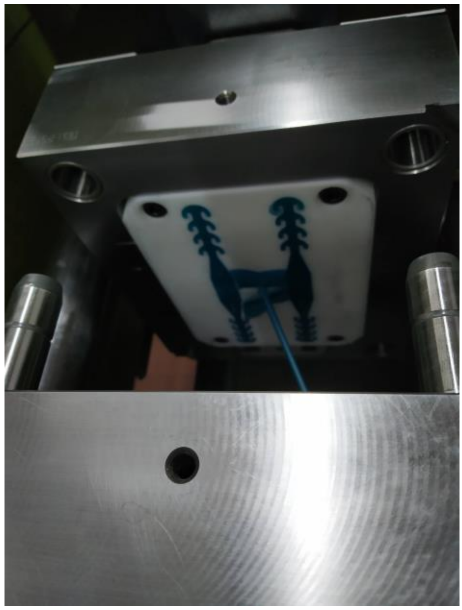
Figure 6. *a) Insufficient filling of the mold cavity and b) flashing on the parting surface*

After gradually adjusting the injection pressure (Fig. 7)., a part was obtained that fully meets the set criteria. After 100 injection cycles, where two parts are obtained in one cycle, there was no damage to the mold cavities.

When comparing the time necessary for the correct selection of the injection parameters in which the desired part is obtained (Fig. 8) and the cost of making the mold itself using additive technologies with the conventional way of making tools for injection molding, the conclusion is reached that the application of injection molding can be reduced to individual or small batch production.

a)



b)

Figure 7. *a) Insufficient filling of the mold cavity and b) flashing on the parting surface*

Figure 8. *Iterative reporting of obtained parts during the experiment*

5 CONCLUSION

The application of additive technologies with the appearance of newer materials, which have better and better physical and mechanical properties, plays an increasingly important role in production engineering as a whole.

When talking about the application of additive technologies in the field of injection molding, experiments have established that parts of the desired shape and dimensional accuracy can be obtained with great certainty.

The conclusion is that in the coming period, injection molding can not only be used in mass production, but will slowly take its place in individual and small-batch production, especially when a small mass of product is required.

REFERENCES

[1] J. S. Hyatt & J. W. Hyatt. (1872). U.S. Patent No. 133229. United States Patent Office.

[2] Williams, C. B., Mistree, F., & Rosen, D. W. (2011). A functional classification framework for the conceptual design of additive manufacturing technologies. Journal of Mechanical Design, 133(12).

[3] Rakov, D. L., & Sukhorukov, R. Y. (2021). Classification and analysis of additive technologies based on the morphological approach. *Journal of Machinery Manufacture and Reliability*, *50*(7), 616-621.

[4] Frandsen, C. S., Nielsen, M. M., Chaudhuri, A., Jayaram, J., & Govindan, K. (2020). In search for classification and selection of spare parts suitable for additive manufacturing: a literature review. *International Journal of Production Research*, *58*(4), 970-996.

[5] Kadir, A. Z. A., Yusof, Y., & Wahab, M. S. (2020). Additive manufacturing cost estimation models—a classification review. *The International Journal of Advanced Manufacturing Technology*, *107*(9), 4033-4053.

[6] Korotchenko, A., Khilkov, D., Tverskoy, M., & Khilkova, A. (2020). Use of additive technologies for metal injection molding. *Engineering Solid Mechanics*, *8*(2), 143-150.

[7] Lozano, A. B., Álvarez, S. H., Isaza, C. V., & Montealegre-Rubio, W. (2022). Analysis and Advances in Additive Manufacturing as a New Technology to Make Polymer Injection Molds for World-Class Production Systems. *Polymers*, *14*(9), 1646.

[8] Huang, R., Riddle, M. E., Graziano, D., Das, S., Nimbalkar, S., Cresko, J., & Masanet, E. (2017). Environmental and economic implications of distributed additive manufacturing: the case of injection mold tooling. *Journal of Industrial Ecology*, *21*(S1), S130-S143.

[9] Schuh, G., Bergweiler, G., Lukas, G., & Oly, M. (2020). Towards Temperature Control Measures for Polymer Additive Injection Molds. *Procedia CIRP*, *93*, 90-95.

[10] Garcia, J. L., Koelling, K. W., Xu, G., & Summers, J. W. (2004). PVC degradation during injection molding: Experimental evaluation. *Journal of Vinyl and Additive Technology*, *10*(1), 17-40.

[11] Rajamani, P. K., Ageyeva, T., & Kovács, J. G. (2021). Personalized mass production by hybridization of additive manufacturing and injection molding. *Polymers*, *13*(2), 309.

[12] Paganin, L. C., & Barbosa, G. F. (2020). A comparative experimental study of additive manufacturing feasibility faced to injection molding process for polymeric parts. *The International Journal of Advanced Manufacturing Technology*, *109*(9), 2663-2677.

[13] Dinu, E., Besnea, D., Ping, A. S., Spanu, A., Moraru, E., & Panait, I. (2020, September). Device for Injection Molding Realized by Additive Technologies. In *International Conference of Mechatronics and Cyber-Mixmechatronics* (pp. 139-148). Springer, Cham.