Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium, Volume 22, No. 1, ISSN 1726-9679
ISBN 978-3-901509-83-4, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2011
Make Harmony between Technology and Nature, and Your Mind will Fly Free as a Bird
Annals & Proceedings of DAAAM International 2011

RAPID PROTOTYPING THE FAST TOOL FOR MODEL PRODUCTION

**STANEK, M[ichal]; MANAS, M[iroslav]; MANAS, D[avid]; KYAS, K[amil];
PATA, V[ladimir] & SENKERIK, V[ojtech]**

Abstract: *Rapid prototyping technologies for easy production of prototype, parts and tools are new methods which are developing unbelievably quickly. The main objective of this paper is to give the basic introduction to this problem and describes the main differences between two commonly used methods: Fused deposition modeling (FDM) and 3D printing. Especially time and costs consumption on the same tested parts.*
Key words: *rapid prototyping, part, prototype, polymer*

1. INTRODUCTION

Successful product development means developing a product of high quality, at lowest cost, in the shortest time, in at a reasonable price. The development of the part and its introduction to market is time consumption process. But „time is money“and therefore could be said that money saving is greatest when time to market is minimalized utmost.

On principle, the conventional model making processes based on two-dimensional (2D) drawings. The rapid prototyping process is based on complete 3D models. The 3D geometric information from the CAD is split into layer information and the layers are gradually built directly with the aid of the computer. The advantage of the rapid prototyping technologies is the part building possibility using 3D CAD data only. All process by which 3D models and components are produced additively, that is, by fitting or mounting volume elements together (voxels or layers) are called generative production process. Rapid prototyping describes the technology of generative production processes. The application of rapid prototyping technology lays in solid imagining and functional prototyping. Prototypes are made from plastics (mainly ABS, PVC or special resins, metals or other materials that simulate one or more mechanical or technological functionalities of the final serial component. Often use word Rapid tooling describes a principles and technologies for tools and molds preparation. This prototypes are used for production of prototypes and preseries products. The rapid tooling uses the same processes as those used in rapid prototyping. Rapid manufacturing represent such a rapid prototyping applications that produce products with serial character. For these purposes can be used most of rapid prototyping methods. But the mechanical and other properties of materials used for the rapid prototyping do not reach mostly the characteristics of the serial products.

2. PRINCIPLES OF RAPID PROTOTYPING

Rapid prototyping belong to the additive production processes. In contrast to abrasive processes such a milling, drilling, grinding eroding etc. in which the form is shaped by material removing, in rapid prototyping the part is formed by joining volume elements. Most of used rapid prototyping processes work with layers where single layers are produced and joined to a final geometry. On principle, rapid prototyping processes are two and half D processes, that is tacked up 2D contours with constant thickness. But for layer creation 3D model is necessary. Rapid prototyping as the generative manufacturing processes are divided among two fundamental process steps:

- generation of the mathematical layer information,
- generation of the physical layer model.

Industrially are used many types of rapid prototyping systems working on different physical principles:

- solidification of liquid materials (polymerization process),
- generation from the solid phase:

- cutting from foils or paper (LOM),
- binder of powder or granules,
- powder sintering,

- generation form the pasty phase.

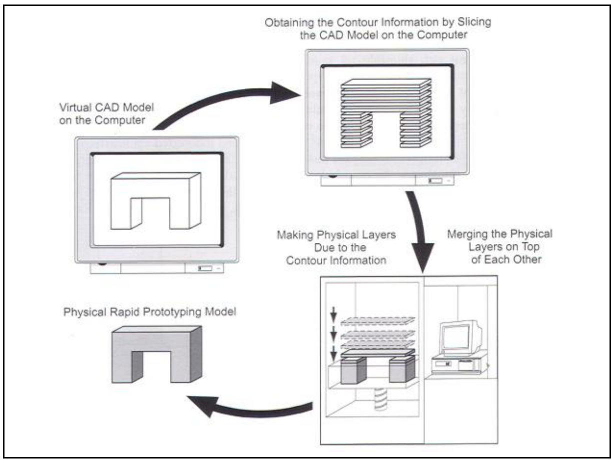

Fig. 1. Rapid prototyping principle

2.1 Fused deposition modeling (FDM)

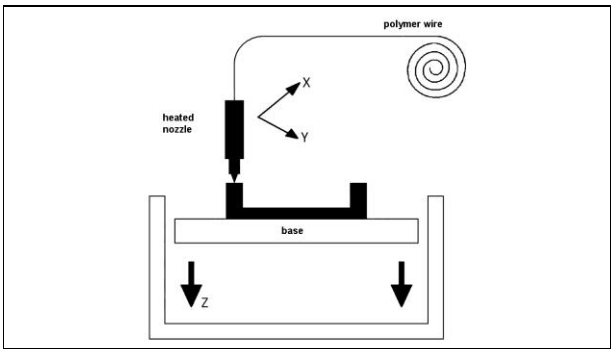

Fig. 2. Principle of Fused Deposition Modeling

Extrusion process is based on molted polymer which is extruded from nozzle system (extrusion die) and deposited geometrically defined onto a structure. The materials are deposited in layers as fine as 0,127 mm thick, and the part is built from the bottom up – one layer at a time. As building materials are used different types of polymers (ABS, PC, etc.).

2.2 3D printing

3D printing is very often used rapid prototyping method. The principle is very similar to 2D printing process of inkjet pointer. The injected material is a polymer which after cooling forms the required layer or binder which bonds powder particles. As in case of the inject printer, also 3D printer makes print the multicolor parts possible. The materials are deposited in layers as fine as 0,016 mm thick.

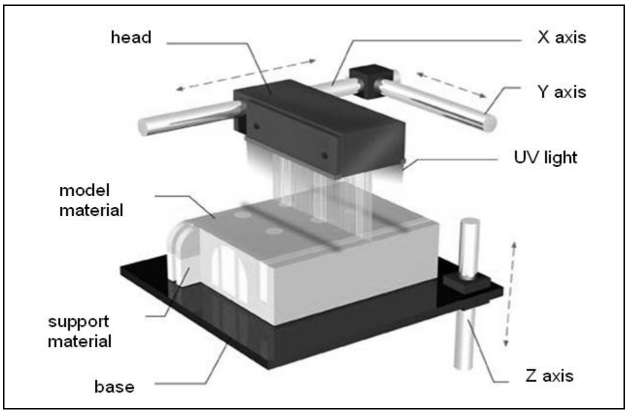

Fig. 3. Principle of 3D printing

3. EXPERIMENT

The mechanical properties, surface quality of prototypes and final cost with time of part building have been tested in comparison of both methods. Two machines has been used for the testing sample preparation: Stratasys Dimension SST 768 (FDM method) and Objet Eden 250 (3D printing method).

3.1 Mechanical properties

Five different methods have been used for the tensile testing sample production. 3D printing, injection molding (ABS) and three types from FDM (with horizontal, vertical and longitudinal orientation of layers). The best mechanical properties in tensile test can be seen on samples produced by 3D printing, see table 1.

Method of part preparation	σ [MPa]	A [%]	E-modulus [MPa]	Rb [MPa]
3D printing	1,37	5,75	1836	33,96
Injection molding	0,64	2,75	2302	26,31
FDM – horizontal	0,40	2,98	1774	20,03
FDM – longitudinal	0,49	2,71	1271	10,22
FDM – vertical	0,21	1,53	1631	19,31

Tab. 1. Tensile test

3.2 Total costs production and time consumption

The comparison of both methods is described in the table 2. There is shown differences between clear time printing, other time (pre-heating, part cleaning, etc.) and cost of part production (material, machine, etc.) in percentage.

Method of part preparation	Print time [min:s]	Other time [min:s]	Total time [min:s]	Cost [%]
3D printing	35:12	06:28	41:40	100
FDM	22:00	29:07	51:07	106,6

Tab. 2. Total costs production and time consumption

3.3 Surface quality

Surface quality of prototypes is one of the most important factors which can approach prototyped part to real part. It is specifying by the maximum layer thickness an orientation of part to base during its production (FDM layer: 0,254 mm, 3D print layer: 0,016 mm).

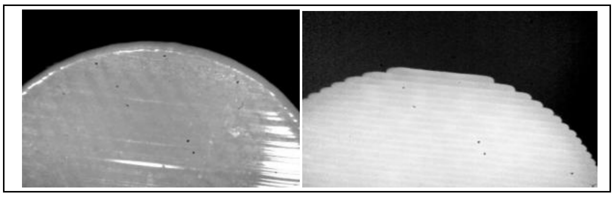

Fig. 4. Quality part comparison (3D printing – left, FDM – right)

4. CONCLUSION

Rapid prototyping method is very useful tool which can accelerate the way of product from the idea to market. Generative principle of rapid prototyping methods enables to produce parts of any geometry. These processes are practically unlimited in their ability to form complex shapes, they can produce both positives (parts) and negatives (dies and molds). The final conclusion of differences between mentioned methods is better for 3D printing because of shorten time, lower costs and better surface quality of part. On the other hand there are higher purchase costs of machine and support and model material.

5. ACKNOWLEDGEMENTS

This article is financially supported by the internal grant of TBU in Zlín No. IGA/10/FT/11/D funded from the resources of specific university research and by the European Regional Development Fund under the project CEBIA-Tech No. CZ.1.05/2.1.00/03.0089.

6. REFERENCES

Stanek, M.; Manas, M.; Manas, D. & Sanda, S. (2009). Plastics Parts Design Supported by Reverse Engineering and Rapid Prototyping, *Chemicke listy*, Volume 103, ISSN 0009-2770, pp.91-95

Manas, D.; Stanek, M.; Manas, M.; Pata V. & Javorik, J. (2009). Influence of Mechanical Properties on Wear of Heavily Stressed Rubber Parts, *KGK – Kautschuk Gummi Kunststoffe*, 62. Jahrgang, , ISSN 0948-3276, p.240-245

Stanek, M.; Manas, M.; Manas, D. & Sanda, S. (2009). Influence of Surface Roughness on Fluidity of Thermoplastics Materials, *Chemicke listy*, Volume 103, ISSN 0009-2770, p.91-95

Stanek, M.; Manas, M. & Manas, D. (2009). Mold Cavity Roughness vs. Flow of Polymer, *Novel Trends in Rheology III*, AIP, ISSN 0094-243X, pp.75-85

Kyas K.; Stanek M.; Manas M.; Manas D.; Krumal M. & Cerny J. (2010). *DAAAM*, p. 1081, ISSN 1726-9679, ISBN 978-3-901509-73-5, Zadar, Croatia

Rees, H. (2002). Mold engineering, Hanser Publishers, ISBN 3-446-21659-6, Munich, Germany

Kazmer, L. (2007). Injection mold design engineering, Hanser Publishers, ISBN 978-3-446-41266-8, Munich, Germany

Stanek, M.; Manas, D.; Manas, M.; Pata V.; Sanda, S.; Senkerik, V. & Skrobak, A. (2011). How the Filler Influence the Fluidity of Polymer, *Chemicke listy*, Volume 105, ISSN 0009-2770, p.303-305