Rapid Prototyping Methods Comparison

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Abstract: Rapid prototyping technologies for easy production of prototypes, parts and tools are new methods which are developing unbelievably quickly. 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. The main objective of this article is to give the basic introduction to this problematic and compare two different methods commonly used for prototype parts production. Especially cost and time consumption and final mechanical properties of the produced model.

Key-Words: Rapid prototyping, prototype, 3D printing, model, FDM, 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. These 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. [1-3]

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 (production) of the physical layer model.

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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.

The basic methodology for all current rapid prototyping techniques can be summarized as follows:

- A CAD model is constructed then converted to STL file format. The resolution can be set to minimize stair stepping.
- The RP machine software processes the .STL file by creating sliced layers of the model.
- The first layer of the physical model is created. The model is then lowered by the thickness of the next layer, and the process is repeated until completion of the whole model.
- The model and any supports are removed. The surface of the model is then finished and cleaned. [11]

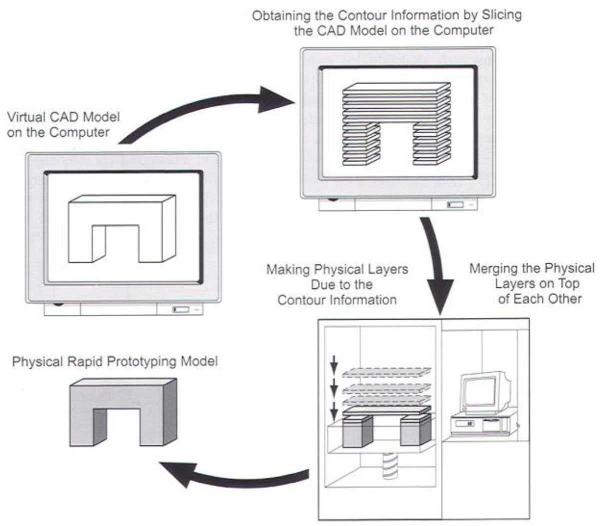

Fig. 1 Rapid prototyping principle

2.1 Fused deposition modeling (FDM)

Extrusion process is based on melted 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 (usually 0,17; 0,25, 0,35 mm) 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.). [5, 9]

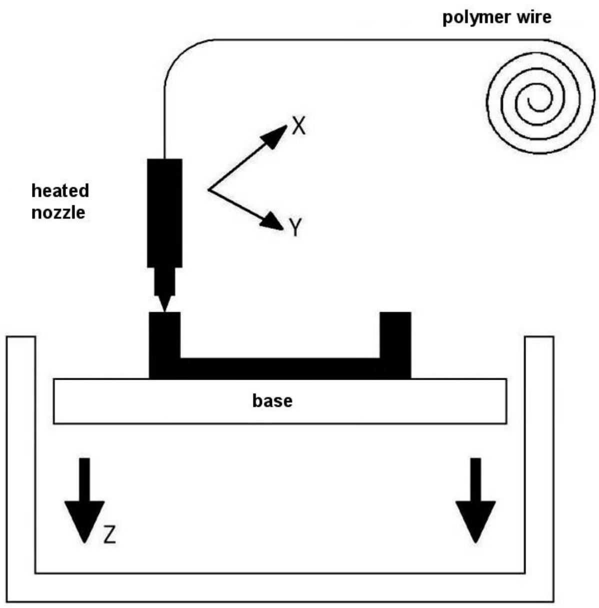

Fig. 2 Principle of Fused Deposition Modeling (FDM) method

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 (or multimaterials) parts possible. The small-footprint, exceptionally cost effective system uses a completely clean process, making it ideal for standard office environments. The materials are deposited in layers as fine as 0,016 mm thick (optionally 0,032 mm). [6-8]

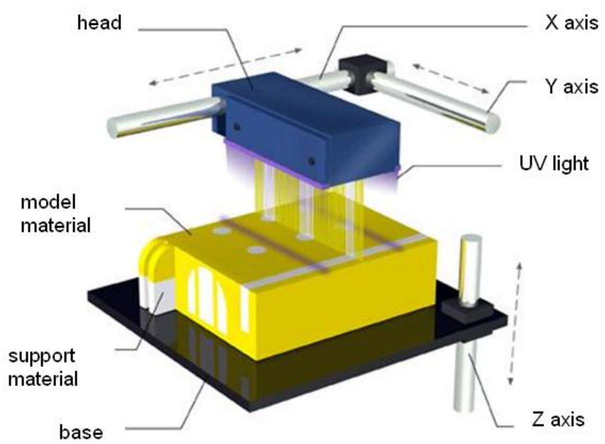

Fig. 3 Principle of 3D printing method

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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 – PolyJet).

3.1 Mechanical properties
Five different methods have been used for the tensile testing sample production: 3D printing, injection molding (ABS) and three types of from FDM (with horizontal, vertical and longitudinal orientation of layers).

A tensile test of the samples has been done by the standard CSN EN ISO 572-2 on the testing equipment ZWICK 1456. The best mechanical properties in tensile test can be seen on samples produced by 3D printing method, see Table 1.

Fig. 4 Testing sample (for tensile tests) production (3D printing)

Table 1 Tensile test

Method of sample 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

3.2 Total costs production and time consumption
The special part designed for this test has been used (Fig. 6). The comparison of both methods is described in the table 2. There is shown differences between clear time printing, other time (calibration, pre-heating, part cleaning, etc.) and costs of part production (material, machine time, etc.) in percentage.

Table 2 Total costs production and time consumption

Method of part reparation	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

The FDM method is faster in case of one model production because of bigger building layer (FDM – 0,25 mm vs. 3D printing – 0,032 mm). On the other hand the 3D printing method is faster in case of more than one part production if the lay in one row on the working plate.

Table 3 Time needed for multi part production

Number of models	OBJET EDEN 250 [h:min:s]	DIMENSION SST 768 [h:min:s]	Time diff. [h:min:s]
1 model	0:35:00	0:22:00	-0:13:00
3 models	0:42:00	1:06:00	+0:24:00
5 models	1:24:00	1:51:00	+0:27:00

Software of both machines are intuitive, easy to use and user friendly.

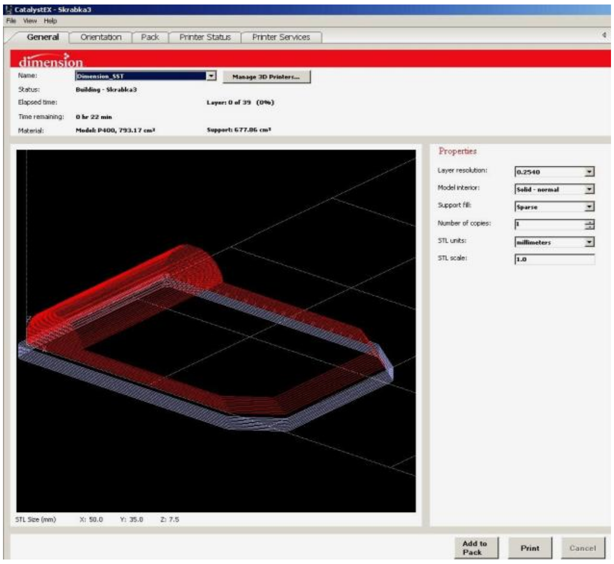

Fig. 5 Working desktop of SW (FDM)

3.3 Surface quality
Final surface quality of prototypes is one of the most important factors which can approach

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prototyped part to real part. It is specifying by the maximum layer thickness an orientation of part to base during its production (3D print layer: 0,016 mm; FDM layer: 0,254 mm).

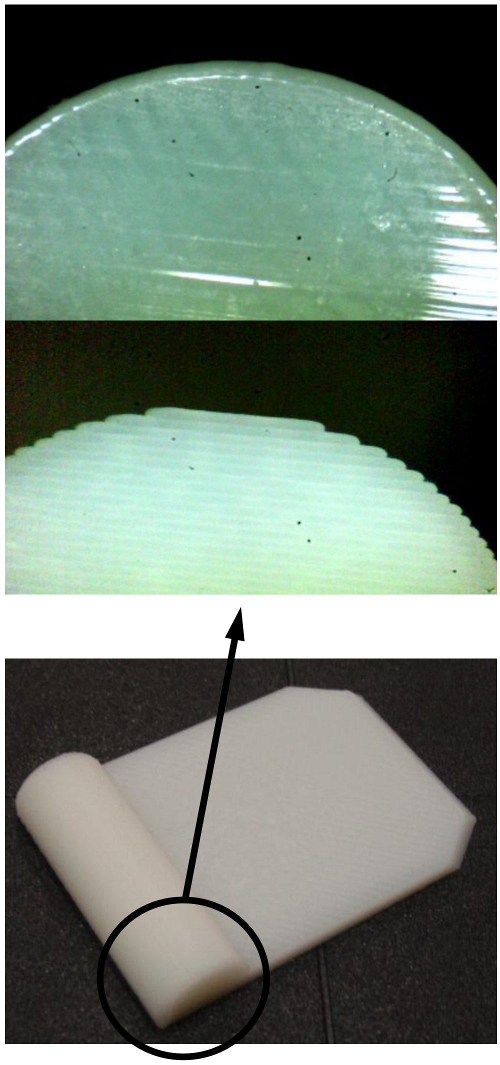

Fig. 6 Testing sample – upper from 3D printing, below – from FDM

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.

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