Experimental determination of surface roughness of parts obtained by rapid prototyping

R. UDROIU*, L. A. MIHAIL**
Manufacturing Engineering Department
Transilvania University of Brasov
29 EROILOR, 500036 Brasov
ROMANIA
* udroiu.r@unitbv.ro, ** l.mihail@unitbv.ro, http://www.unitbv.ro

Abstract: In the Rapid Prototyping / Rapid Manufacturing / Rapid Tooling process, surface finish is critical as it can affect the part accuracy, reduce the post processing costs and improve the functionality of the parts. This paper presents an experimental technique to determine the surface finish of parts built by the polyjet process. The experiment investigates the effect of the parameters: build orientation and surface type obtained by polyjet (mate or glossy). Experiments were conducted using a Taylor Hobson roughness checker and an ETALON TCM 50 measuring microscope. The results are focused on roughness and texture surface parameters for horizontal surfaces.

Key-Words: experiment, surface roughness, rapid prototyping, polyjet technology

1 Introduction

Rapid Prototyping (RP) can be defined as a group of techniques used to quickly fabricate products based on three-dimensional computer aided design (CAD) data. There are two main categories of RP technology: additive technologies and subtractive technologies.

Subtractive technologies use machining processes such as high speed milling to quickly obtain a rapid prototype. Additive technologies refers to a group of technologies used for building by adding layer by layer of physical models, prototypes, tooling components and finished parts, all from 3D CAD data or data from 3D scanning system. Additive systems, based on thin and horizontal cross sections taken from a 3D computer model, join together liquid, powder or sheet materials to produce plastic, ceramic, metal or composite parts.

Today's additive technologies offer advantages in many applications compared to classical subtractive fabrication methods such as milling or turning: objects can be formed with any geometric complexity or intricacy without the need for elaborate machine setup or final assembly; rapid prototyping systems reduce the construction of complex objects to a manageable, straightforward, and relatively fast process. However, compared to NC machining, a major disadvantage of RP processes is that they are currently restricted to specific materials that dependent on the method chosen.

Based on RP was development new terms that can be group under the umbrella of RapidX [6]: Rapid Product Development (RPD), Rapid Technology, Rapid Nanotechnology, Rapid Tooling (RT) and Rapid Manufacturing (RM).

Rapid Tooling [2], [3] is the technology that adopts RP techniques and applies them to tool and die making. RT can be divided into direct or indirect tooling. In direct tooling, the tool or the die is created directly by the RP process. In indirect tooling, only the master is created using the RP technology. From this master, a mould is made out a material such as silicone rubber, epoxy resin, soft metal, or ceramic.

Rapid manufacturing [3], [7] is based on rapid prototyping processes and methods and consist in fast production of functional parts of small series.

Today, there are a lot of rapid prototyping technologies. The most popular RP technologies [6] used worldwide are stereolithography (SL), selective laser sintering (SLS), 3D printing (3DP) and laminated object manufacturing (LOM). This paper is focused on 3DP technologies that represent 44.3% of all additive systems installed worldwide at the end of 2005 [7].

In the Rapid Prototyping\ Rapid Manufacturing\ Rapid Tooling process, surface finish is critical as it can affect the part accuracy, reduce the post processing costs and improve the functionality of the parts. The surface finish is important parameters for parts (RP), end parts (RM) and tooling (RT) obtained by additive technologies.

2 Surface finish of RP products

As we mentioned in the last chapter the surface roughness is a important parameters for RP, RM and RT. Regarding the quality of the surface in RP/RM we can mention that the roughness influence the aerodynamic data of the models tested in the wind tunnel [1]. A systematic approach for selecting the most suitable route for rapid fabrication of tooling (RT) for sand and investment casting processes was presented in [4]. Thus it was done a study regarding the surface roughness of the vertical wall for different RP processes (fig.1). The surface roughness was measured using a surface roughness tester (Mahr Perthometer).

.

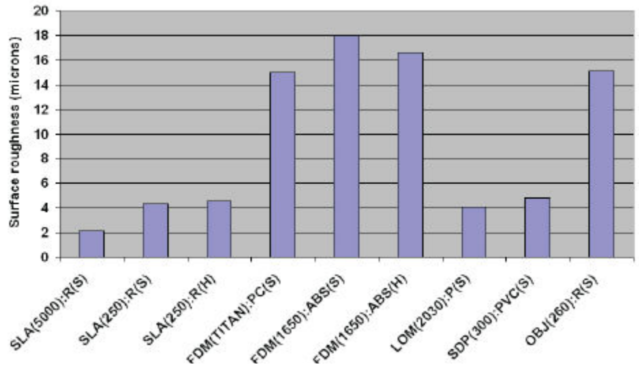

Fig. 1 Comparison of surface roughness (vertical) [4]

In this paper we were done an experimental investigation on surface roughness of rapid prototyping products produced by polyjet technology.

3 Polyjet building process

3D printing technologies [6] can be divided in the following: inkjet printing, fused deposition modeling, and polyjet.

Objet Geometries is a competitive player within the RP market with the Eden range of machines (Eden 250, Eden 350, Eden 500 and Connex 500) and Alaris printer. All Objet machines create parts layer by layer combining inkjet technology with photo-polymerisation (UV curing) process resulting polyjet technology.

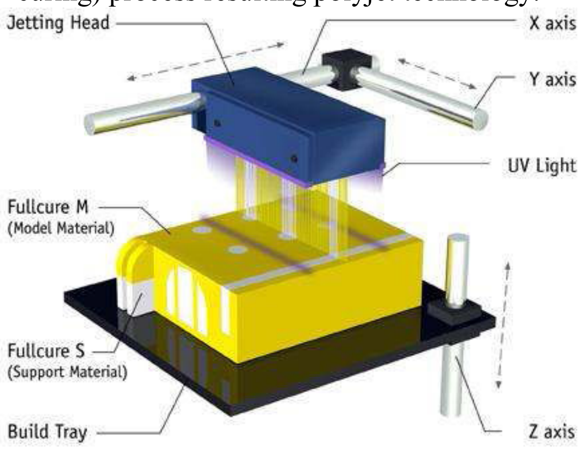

Fig. 2 Polyjet printing process

The polyjet printing process of EDEN 350 consists of the following main steps:

- jetting a photopolymer material in ultra-thin layers (16 micron) onto a build tray, layer by layer; The high-resolution 16 micron layers ensure smooth, accurate and highly detailed models
- curing of each layer using UV light, immediately after it is jetted; This step eliminates the additional post curing required by other RP technologies.

Two different photopolymer materials are used for building: one for the actual model, and another gel-like material for support. The geometry of the support structure is pre-programmed to cope with complicated geometries, such as cavities, overhangs, undercuts, delicate features, and thin-walled sections.

The RP part used in the following chapter to experimental determination of surface roughness is obtained using an EDEN 350 machine (fig. 3) from Manufacturing Engineering Department (Transilvania University of Brasov).

Fig.3 EDEN 350 (Manufacturing Engineering Department, Transilvania University of Brasov)

The part used for experimental investigation it was designed using Solid Works 2009 software. The digital model of the part is then converted to STL (Standard Triangulation Language) format file and imported within Objet studio software in order to be sending it to RP machine. Using Objet studio software (fig. 4) we optimized the model orientation, and defined the building parameters in order to minimize the building time and the material consumption.

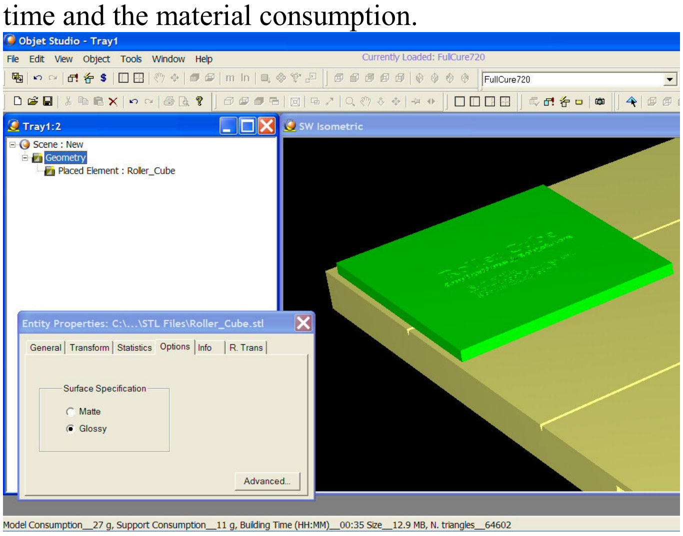

Fig. 4 Simulation of build part in Objet studio software

Regarding the surface specification there are two options: mate and glossy. In this case the upper surface will be printed in glossy mode and the lower surface in mate mode.
The materials used for RP process are in this case, Fullcure 720 resin [5] for the model and Fullcure 705 for the support.

4 Experimental determination of surface roughness of parts obtained by Polyjet technology

The surface roughness was measured using a "Surtronic 25" surface roughness tester (Taylor Hobson), as per DIN EN ISO 4288/ASME B461 and manufacturer's recommendations.
The "Surtronic 25" can be used either freestanding (on horizontal, vertical or even inverted surfaces) or bench mounted with fixturing for batch measurement and laboratory applications. This instrument calculates up to 10 parameters (fig. 6) according to the measurement application [8]:

- amplitude parameters (measures the vertical characteristics of the surface deviations): Ra (Arithmetic Mean Deviation), Rsk (Skewness), Rz (Average peak to valley height), Rt (Total height of profile), Rp (Max profile peak height), Rz1max (Max peak to valley height);
- spacing parameters (measures the horizontal characteristics of the surface deviations): RPc (Peak count), RSm (Mean width of profile elements);
- hybrid parameters (combinations of spacing and amplitude parameters): Rmr (Material Ratio), Rda - R Delta a (Arithmetic Mean Slope).

In the figure 5 it is presented the experimental instrumentation connected to the laptop.

Fig. 5 Calibration of the roughness checker

To measure the surface roughness it is necessary to calibrate the "Surtronic 25" roughness checker (fig. 5). The "Surtronic 25" stylus can traverse up to 25mm (or as little as 0.25mm) depending on the component. The Gauss filtered measurements were done for an evaluation length of 4 mm with a cutoff value of 0.8 mm.

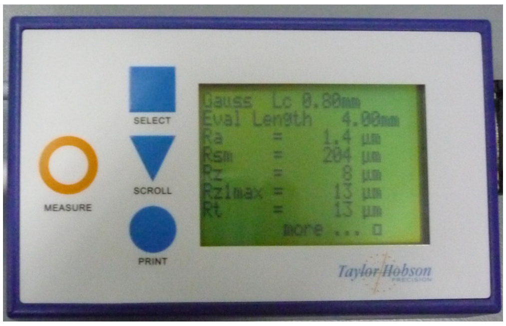

Fig. 6 The parameters calculated by "Surtronic 25"

To determine the surface roughness for the part designed in the previous chapter we proposed two sketches where we indicated the locations of measurement location areas on the surface part. The sketch presented in fig.7 was used for glossy surface and the sketch presented in fig.8 was used for the mate surface.

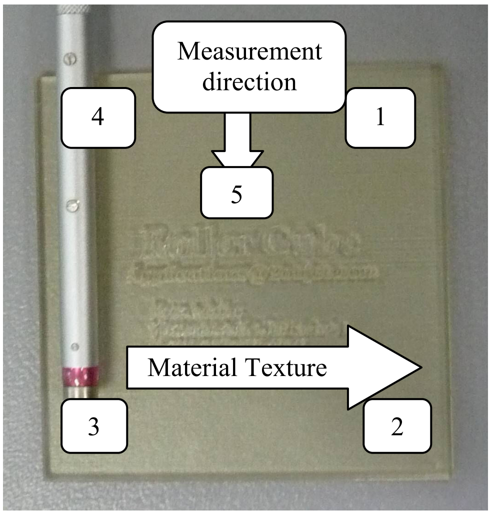

Fig. 7 Roughness measuring of glossy surface

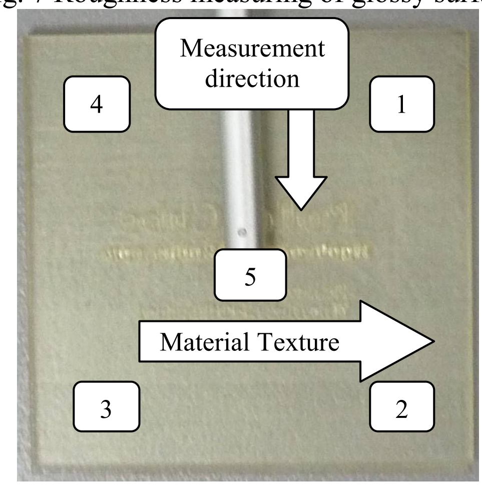

Fig. 8 Roughness measuring of mate surface

Five measurements were taken on each surface and the average values of Ra and Rz on horizontal surfaces (mate and glossy) were recorded (fig. 9 and 10). Four of these measurements (1, 2, 3 and 4) were taken in

ISSN: 1790-5117

ISBN: 978-960-474-139-7

transversal direction of the material texture and the last (5) in material texture direction.

	Measurement 1	Measurement 2	Measurement 3	Measurement 4	Measurement 5
Ra [µm]	1	1	0.8	1.4	0.4
Rz [µm]	5	6	6	8	3

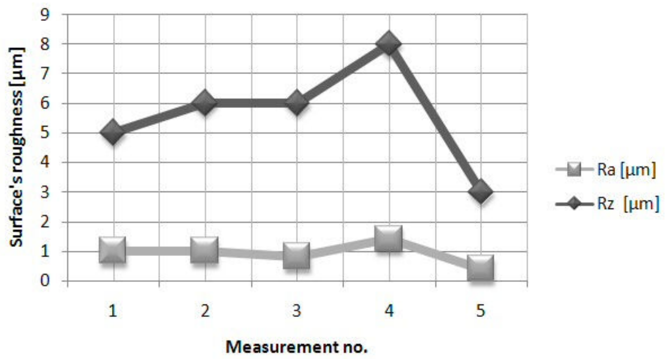

Fig. 9 Results for mate surface

	Measurement 1	Measurement 2	Measurement 3	Measurement 4	Measurement 5
Ra [µm]	1.2	0.4	0.6	1.8	0.2
Rz [µm]	6	2	3	7	1

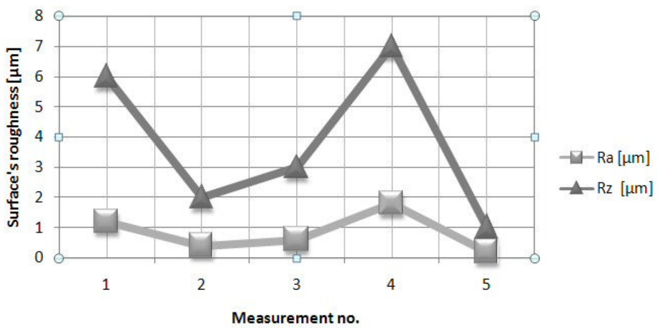

Fig. 10 Results for glossy surface

In order to estimate the surfaces roughness of parts fabricated by polyjet technology it was calculated the average value for mate surface (Ra_m=1.04 microns, Rz_m=5.6 microns) and glossy surface (Ra_m=0.84 microns, Rz_m=3.8 microns).

The surface texture was analyzed using an ETALON TCM 50 measuring microscope (fig. 11) that has an objective for 30x magnification.

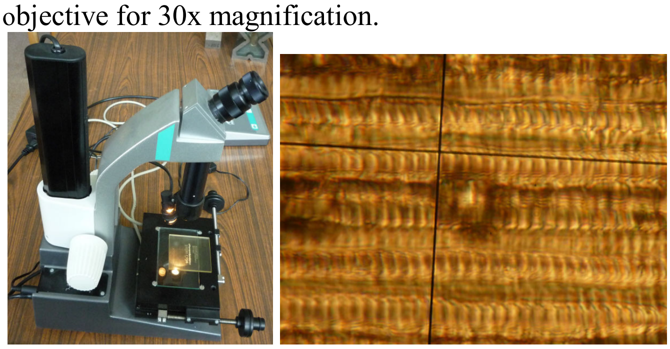

Fig. 11 ETALON TCM 50 measuring microscope and the texture of the polyjet RP surface

5 Conclusion

In this paper we were done an experimental investigation on surface roughness of rapid prototyping products produced by polyjet technology. The research has started within Manufacturing Engineering Department (Transilvania University of Braşov).

First of all it was designed a test part that was manufactured using the EDEN 350 RP machine. It is important to mention that in the polyjet process we can choose between two parameters that affect the surface quality: mate or glossy.

To experimental investigation of roughness we use "Surtronic 25" roughness checker from Taylor Hobson.

The average value for the mate surface are Ra_m=1.04 microns, Rz_m=5.6 microns and for the glossy surface are Ra_m=0.84 microns, Rz_m=3.8 microns.

The surface texture was analyzed using an ETALON TCM 50 measuring microscope.

As final conclusion, the quality of surface obtained by polyjet technology is very good and is not necessary a post processing of the RP part.

References:

[1] Adelnia, R., Daneshmand, S., Aghanajafi, S. (2006). Production of Wind Tunnel Testing Models with use of Rapid Prototyping Methods, *Proceedings of the 6th WSEAS International Conference on Robotics, Control and Manufacturing Technology*, Hangzhou, China, April 16-18, pp. 42-47

[2] Chua, C. K.; Hong, K. H.; Ho, S. L. (1999). Rapid Tooling Technology. Part 1 A Comparative Study. *The International Journal of Advanced Manufacturing Technology*, Vol., No.15, ISSN 0268-3768, pp. 604-608

[3] Kalpakkjian, S.; Schmid, S. R. (2006). Manufacturing Engineering and Technology, *Pearson Pretince Hall*, U.S.A. ISBN 0-13-148965-8

[4] Pal D.K. at al. (2007). Rapid tooling route selection and evaluation for sand and investment casting, *Virtual and Physical Prototyping Journal,* 2(4), pp. 197-207

[5] Park R. (2008). Utilising PolyJet matrix technology and digital materials, *TCT Magazine*, Vol.16, No.3, Rapid News Publications plc, UK. ISSN 1751-0333

[6] Udroiu, R.; Ivan N., V. (2008). Rapid-X Using 3D Printers, *Supplement Of Academic Journal Of Manufacturing Engineering*, No.2, Timisoara, Romania. ISSN 1583-7904, pp.199-205

[7] Wohlers, T. (2006). Wohlers Report 2006: Executive summary, Rapid prototyping & manufacturing. State of the industry, *TCT Magazine*, Rapid News Publications plc, UK. ISSN 1751-0333

[8] ***, 2009. Surtronic 25 Roughness checker, *Technical documentation*, Taylor Hobson.