



TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics and Mechanics

Vol. 56, Issue I, March, 2013

RESEARCH ON HOW TO CORRELATE THE ACCURACY OF THE PROTOTYPE MODEL, TOOLS AND PLASTIC INJECTED PARTS IN THE RAPID PRODUCT DEVELOPMENT PROCESS, USING THE SELECTIVE LASER SINTERING METHOD

Răzvan PACURAR, Ancuta PACURAR

Abstract: *The paper presents a Rapid Tooling (RT) technology that is suitable for Rapid Product Development (RPD) and for tooling preparation of the small volume production. A case study developed within National Center of Rapid Prototyping from Technical University of Cluj-Napoca (TUC-N) and Plastor SA company from Oradea, focused on the manufacturing of the injection moulding tools by selective laser sintering (SLS) technology is being analyzed, revealing the peculiarities and complexity of this technology, which involves different issues related to the correlation of the manufactured tools accuracy with the accuracy of CAD model and the injected plastic.*

Key words: *rapid tooling, rapid product development, selective laser sintering, SLS, accuracy.*

1. INTRODUCTION

It is well known the Selective Laser Sintering (SLS) process and technology, which can be used to produce complex parts from different type of materials. Beside the advantages of the SLS process, as compared to the classical manufacturing technologies, there are some disadvantages, as well [1], [2]. One of the major disadvantages of the SLS process is the accuracy, which is bellowing the accuracy provided by some well-known classical technologies, such as grinding. The use of the RP technologies has become more and more frequent in the manufacturing industry, because it offers a quick solution to produce prototypes of the very complex shapes, without being necessary any special tools [3]. Anyhow, there is a lot of work to be done in order to increase the accuracy of the SLS prototypes and injection moulding tools, as well [4], [5].

The research started within the technical university of Cluj-Napoca and Plastor Company from Oradea has proved the complexity of the technology in manufacturing process of the active elements for injection

moulding process. There are many important aspects to be taken into account when speaking about the accuracy of the SLS parts. CAD compensation factors have to be estimated, in order to get a good correlation between the accuracy of SLS plastic prototype and the accuracy of the injected plastic part obtained by using the SLS tools. This research is the first one made in Romania, trying to estimate and correlate the cad model accuracy to the accuracy of the SLS plastic prototype and metal tools, by taking into account the shrinkage phenomena that occurs in the SLS manufacturing process,

2. RAPID PRODUCT DEVELOPMENT USING SLS TOOLING METHOD

DTM SLS technology offers the possibility to rapidly manufacture prototypes from Polyamide plastic material and active elements tools from stainless steel material by using the same system, as well. The CAD prototype design is the first step when the development of a new product is rapidly needed. The CAD model is transferred to the Sinterstation 2000

equipment as an “.stl” file in order to manufacture the plastic prototype. Important corrections are done at this stage over the designed prototype and SLS tools (punch and die), as well. The active elements are manufactured further on, by using the same SLS equipment and finally, after some finishing operations are ready to be used in the injection moulding process. Even this normal itinerary seems simple at first look; there are some

important aspects that have to be solved in order to correlate the accuracy of the SLS tools with the accuracy of the SLS plastic prototype and the injected plastic part. By following this itinerary, too many finishing operations have to be done onto the SLS tools in the final stage, in order to adjust the dimensions, so as the injected part dimensions would be as closed as possible to the CAD prototype design.

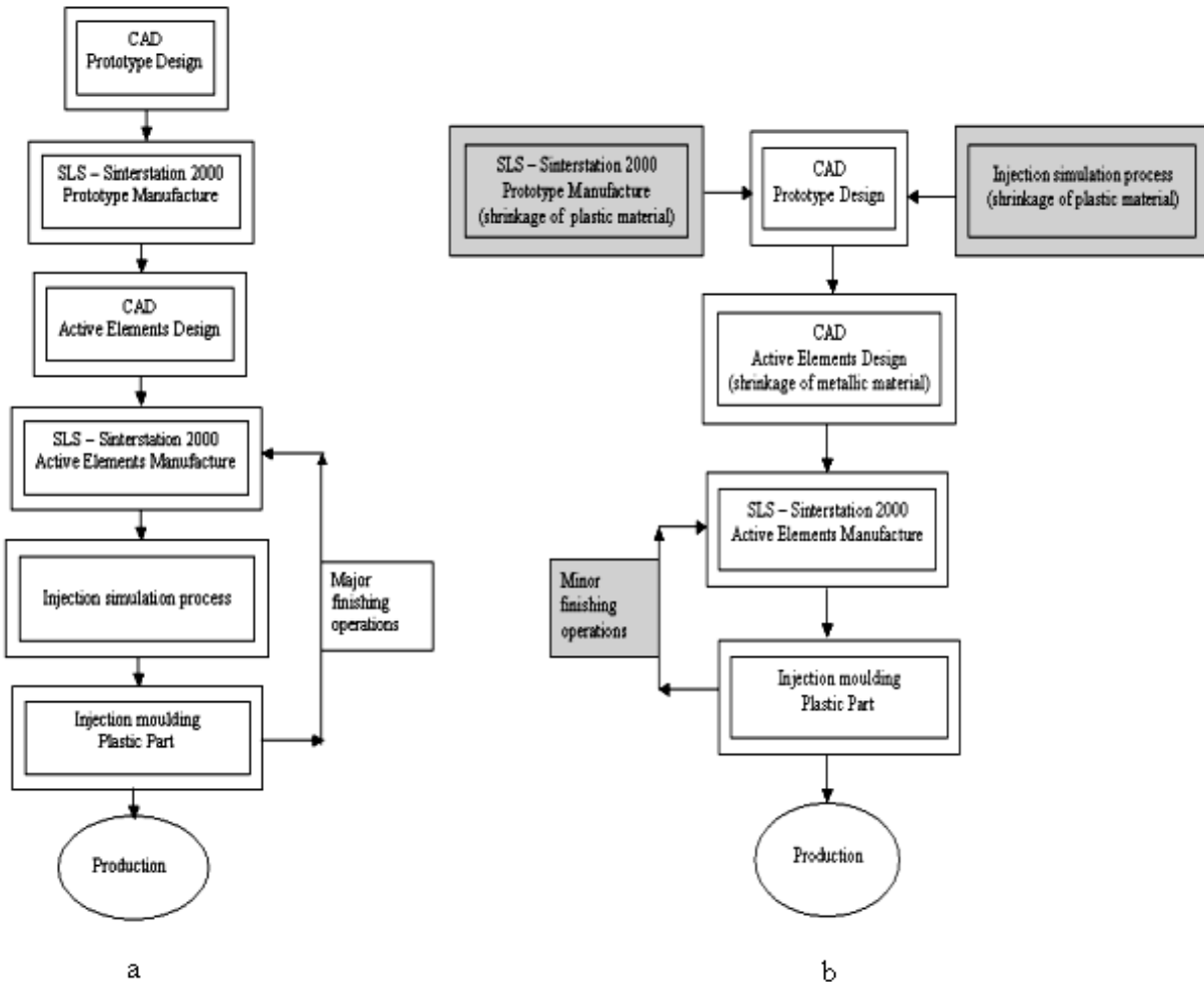


Fig.1. Rapid Product Development by using SLS technology
 a – normal itinerary; b – proposed itinerary (more efficient)

The itinerary could be much shorter, if we could estimate and take into account when designing the new product, the shrinkage of SLS polyamide plastic prototype, the shrinkage of injected plastic material and the shrinkage of SLS active elements tools (Figure 1). Taking into account those details will make not only the itinerary to be more efficient, but also will

significantly reduce time, by eliminating the major finishing operations of the SLS tools in the end. These considerations were taken into account when the case study (lid button of a grass-cutting machine) that was undertaken jointly by the Technical University of Cluj-Napoca and the Plastor Company from Oradea has been selected (Figure 2).

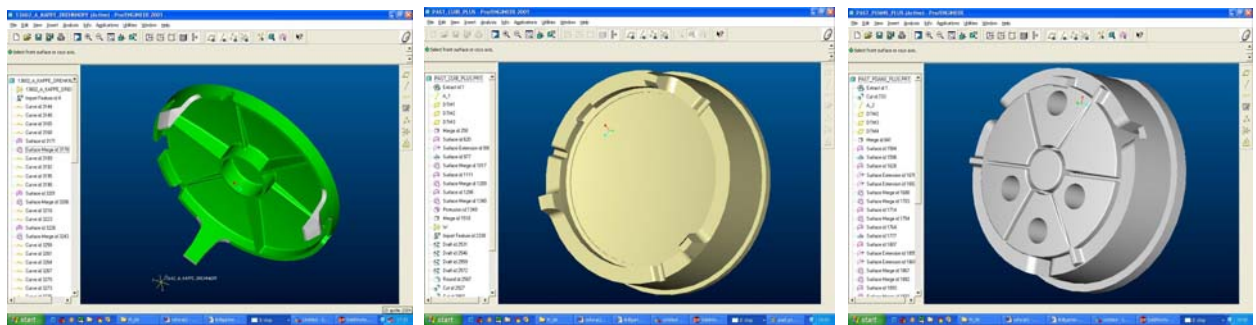


Fig. 2. CAD models – part prototype and active elements – punch and die

Regarding the Duraform polyamide plastic prototype, its shrinkage is around 0.1 mm, according to the material datasheet provided by the DTM Company that manufactures the SLS Sinterstation 2000 equipment. The prototype is manufactured in one stage on the machine and could be used as a finite part.

Regarding the active elements (punch and die) made from Laserform St-100 (stainless steel) material, the SLS process is done in two stages – the first one related to the selective laser sintering process on the machine, when so called “green part” is being obtained and the second one related to the post-processing stage in the oven, when so called “brown part”, fully dense metal part is obtained. The obtained accuracy of the manufactured SLS tools is mainly influenced on the second stage process, when at 1070 °C, bronze is being infiltrated into the part. That is why a more detailed analyze is needed in this case, as compared to the plastic prototype. In order to estimate the shrinkage that occurs in the post-processing stage in the oven, finite element analysis (by using CosmosWorks software) was needed.

The FEA consisted in a thermo elastic analysis. Two cases have been studied:

- Thermal expansion during the heating process from room temperature (20 °C) to 1070°C. In this case, the thermal expansion coefficient has been set to a higher value, due to the fact that the sintered material is in a powder state.
- Thermal contraction during the cooling process in the oven, from 1070 °C to the room temperature (20 °C). In this case, the thermal expansion coefficient has been set to a lower value, due to the fact that the part is already in a compact state.

As conclusion, the effects of the infiltration process can be modeled by modifying the value of the thermal expansion coefficient (α - coefficient). The estimated shrinkage is quite high (around 0.2 mm), as could be observed, mainly because of the post-processing temperature in the oven, which is around 1070 degrees (Figure 3). All deformations on X, Y and Z-axis are presented in Table 1.

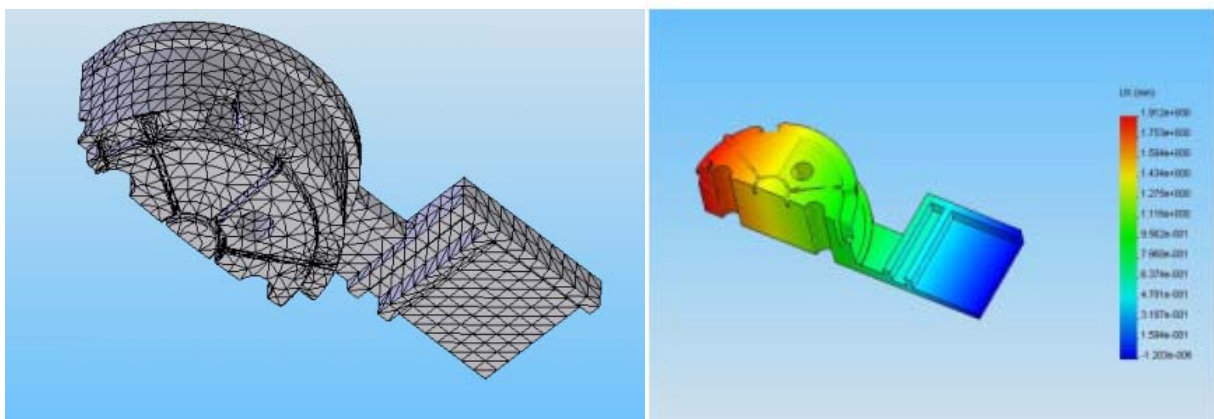


Fig. 3. Active elements - estimated shrinkage – CosmosWorks FEA analysis

Table 1
Estimated deformations, using the FEA

Deformation (mm)	X	Y	Z
Warming up	1,530	1,348	1,335
Cooling down	1,360	1,172	1,141
Residual deformations	0,170	0,176	0,194

Regarding the shrinkage estimation of the plastic part injected using the active elements

made by SLS, the MoldFlow finite element analysis software was used. The estimated volumetric shrinkage were around 1,2 %, which corresponds to approximate 0.1 mm in the ABS Terluran 867 M material case (with a melting point temperature of 264 °C) (Figure 4).

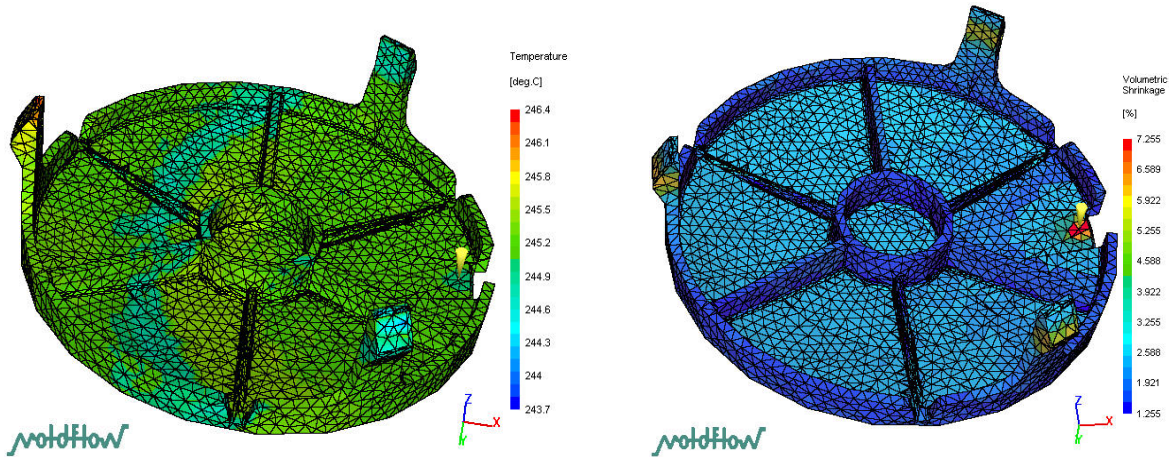


Fig. 4. Injected plastic part – estimated volumetric shrinkage MoldFlow analysis

All these collected data were further on post-processed and correlated accordingly, so as the dimensions of the finite injected part would be as closed as possible to the dimensions of the CAD parts, before the prototype and the SLS tools were manufactured on the Selective Laser Sintering equipment (Sinterstation 2000) at the Technical University of Cluj-Napoca (TUCN). The injection moulding tests, using the SLS tools manufactured at TUCN were made within the Plastor Company from Oradea.

3. EXPERIMENTAL RESEARCH

The virtual models of the parts were transferred to the SLS rapid prototyping equipment, via the *.STL files (Figure 5). The part prototype and the active elements - punch and die – were manufactured by SLS from dedicated materials (Duraform polyamide powder and Laserform St-100 powder) by using the technological parameters indicated in Table 2.

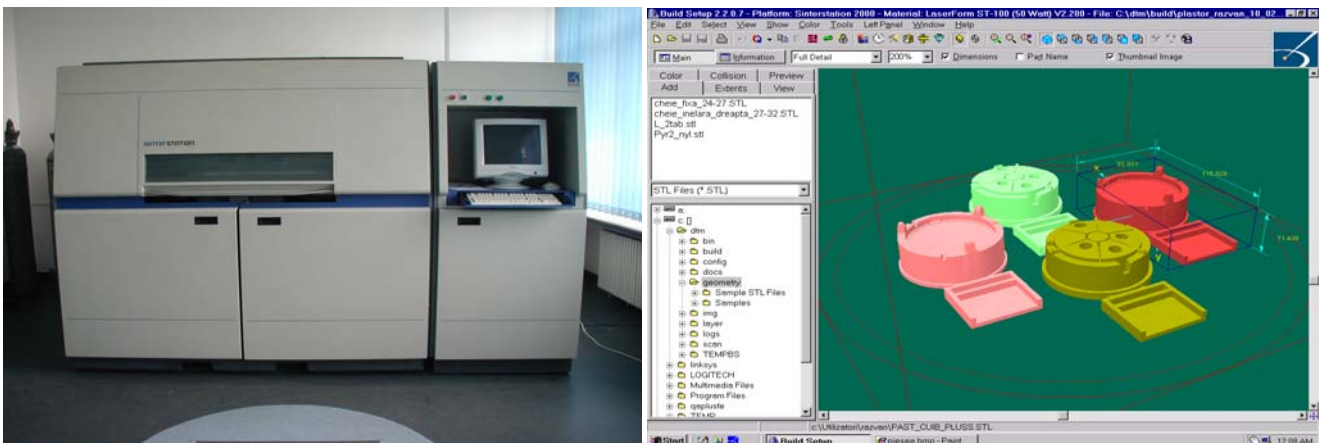


Fig. 5. SLS Rapid Prototyping equipment (TUCN)

Table 2

SLS Technological parameters

Parameter	Prototype (Duraform polyamide)	Punch and die (Laserform St-100)
Scale factors	X=1.03180, Y=1.03309, Z=1.01800	X=1.02054, Y=1.02144, Z=1.00950
Fill laser power	5 W	28W
Slicer fill scan spacing	0.15 mm	0.08 mm
Powder layer thickness	0.1 mm	0.08 mm
Manufacturing temperature	183°C	98°C

The tests of the SLS tools behavior were made at Plator Oradea, using a Krauss Maffei 90/340 a injection moulding machine. Finally, by using a Zeiss Eclipse Coordinate Measuring Machine (CMM) from the Technical University of Cluj-Napoca, some measurements

were made both, to the prototype and to the active elements manufactured by using the selective laser sintering technology and also to the injected parts obtained by using the SLS tools (Figure 6). The obtained results are presented in Table 3.



Fig. 6. SLS Prototype, tools and injected part measured on Zeiss Eclipse CMM

Table 3.

Obtained results

Punch		Die	
CAD dimension	Manufactured model by SLS	CAD dimension	Manufactured model by SLS
Exterior diameter $D_e = 56.6$ mm	Exterior diameter $D_{em} = 56.81$ mm	Exterior diameter $D_e = 56.8$ mm	Exterior diameter $D_{em} = 56.96$ mm
Interior diameter $D_i = 54.3$ mm	Interior diameter $D_{im} = 54.45$ mm	Interior diameter $D_i = 54.1$ mm	Interior diameter $D_{im} = 54.32$ mm

CAD model	Prototype made from Dur aform by SLS	CAD model	Injected ABS plastic part
$D_e = 56.8$ mm	$D_{em} = 56.7$ mm	$D_e = 56.8$ mm	$D_{em} = 56.65$ mm
$D_i = 54.1$ mm	$D_{im} = 54.05$ mm	$D_i = 54.1$ mm	$D_{im} = 54$ mm
$d_e = 15.5$ mm	$d_{em} = 15.42$ mm	$d_e = 15.5$ mm	$d_{em} = 15.37$ mm
$d_i = 13$ mm	$d_{im} = 12.88$ mm	$d_i = 13$ mm	$d_{im} = 12.85$ mm

4. CONCLUSIONS

The research started within the Technical University of Cluj-Napoca and Plastor Company from Oradea has proved the complexity of the manufacturing process when SLS technology is used to produce tools for the injection moulding process. This research is the first one made in Romania, trying to estimate and correlate the CAD model accuracy with the accuracy of the SLS plastic prototype and SLS tools, by taking into account the shrinkage phenomena that occurs during the post-processing stage, in the oven. The results of our research would underline and recommend that the compensation factors should be used, in order to get a good correlation between the SLS plastic prototype, the SLS tools (punch and die) and the injected part made by injection moulding using the SLS manufactured tools, in order to fit the dimensions of all these, with the designed CAD model dimensions. By doing so, the time needed for the Rapid Product Development process using the SLS tooling method will be significantly decreased.

5. ACKNOWLEDGEMENTS

This paper was supported by the project "Development and support of multidisciplinary postdoctoral programs in major technical

areas of national strategy of Research Development - Innovation" 4D-POSTDOC, contract no. POSDRU/89/1.5/S/52603, project co-funded by the European Social Fund through Sectorial Operational Programme Human Resources Development 2007-2013".

6. REFERENCES

- [1] Balc, N.; Berce, P., Pacurar, R.: *Active Elements Tools Made By Selective Laser Sintering* - Society Of Manufacturing Engineers, Rapid Prototyping Journal, pp.1-7, 2006.
- [2] Berce, P., Pacurar, R., Balc, N.: *Virtual Engineering for Rapid Product Development* - Proceedings of the WSEAS International Conf. on Engineering Mechanics, Structures and Engineering Geology, pp. 195-201, 2008.
- [3] Pham, D. T., Dimov, S. S.: *Rapid Manufacturing - the Technologies and Applications of Rapid Prototyping and Rapid Tooling* - Springer-Verlag, 2001.
- [4] Tang, Y.; Loh, Han Tong; Fuh, J.-Y.-H.; Wong, Yeow Sheong; Lu, L.; Ning, Y.; Wang, X. *Accuracy Analysis and Improvement for Direct Laser Sintering* -Int. J. of Machine Tools & Manufacture, Vol. 43, pp. 985-995, 2003.
- [5] Gu, P., Yan, M., Huang, X., Zhang, X., *Analysis of Machine Accuracy for Rapid Prototyping of Quality Components* – Proceedings SPIE, Vol. 3517, pp. 91-101,1998.

Cercetări privind modul de corelare a preciziei modelului prototip, elementelor active de matriță și pieselor injectate, în procesul de dezvoltare al produselor noi utilizând metoda sinterizării selective cu laser

Rezumat: În cadrul acestei lucrări sunt prezentate cercetările care au fost efectuate cu privire la corelarea preciziei modelului prototip și a elementelor active ale matrițelor fabricate prin metoda sinterizării selective cu laser cu precizia pieselor din material plastic injectate ulterior, utilizând aceste elemente de matriță. În urma cercetărilor efectuate, s-a ajuns la concluzia că o astfel de corelare a preciziei în etapa de proiectare a modelului prototip, prin aplicarea unor factori de scalare în această etapă (ținând cont de contracțiile rezultate în urma post-procesării matriței, respectiv de contracția pieselor injectate), ar simplifica în mod semnificativ itinerarul tehnologic necesar a fi parcurs în vederea dezvoltării rapide a unor noi piese prin metoda SLS.

Razvan Pacurar, Dr. Eng., Senior Lecturer, Technical University of Cluj-Napoca, Department of Manufacturing Engineering, B-dul Muncii, no.103-105, 400641, Cluj-Napoca, razvan.pacurar@tcm.utcluj.ro, 0040-264-401784.

Ancuta Pacurar, Dr. Eng., Lecturer, Technical University of Cluj-Napoca, Department of Manufacturing Engineering, B-dul Muncii, no.103-105, 400641, Cluj-Napoca, ancuta.costea@tcm.utcluj.ro, 0040-264-401721.