CONTENTS AUTHORS

15th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2011, Prague, Czech Republic, 12-18 September 2011

DIRECT HARD TOOLING PRODUCED RP METHODS

Adis Fajić
Federal ministry of development, entrepreneurship and craft
Ante Starčevića bb., Mostar
Bosnia and Herzegovina

Alan Topčić
University of Tuzla
Faculty of Mechanical Engineering
Univerzitetska 4, Tuzla
Bosnia and Herzegovina

Džemo Tufekčić
University of Tuzla
Faculty of Mechanical Engineering
Univerzitetska 4, Tuzla
Bosnia and Herzegovina

Edin Cerjaković
University of Tuzla
Faculty of Mechanical Engineering
Univerzitetska 4, Tuzla
Bosnia and Herzegovina

ABSTRACT
In order to increase competitiveness in conditions of open markets and the obvious trend of unification and reduction of number of products in series, more companies seek to reduce the development process and manufacturing of parts and tools maintaining the existing quality and prices of final products. The evolution of technology development of Rapid Prototyping in accordance with the requirements mentioned above has resulted in the creation of a series of processes that allow the direct hard tooling from 3D CAD files based on the principles of rapid prototyping, called Rapid Tooling and Manufacturing-RT&M. In this paper such RT&M processes are presented.
Keywords: rapid prototyping, rapid tooling, direct hard tooling

1. INTRODUCTION
Rapid tooling (RT) is a result of combination of the techniques of the rapid prototypes (RP) make with conventional make of tools in manufacturing of functional parts from electronic CAD data in shorter period and at relatively lower price from the methods of traditional mechanic make of tools. All the firms at the market of RT equipment and materials are permanently trying to meet the requirements that are related to improvement of the speed of equipment, punctuality and accuracy of measurement and shapes as well as in number of materials, which have a possibility to be adapted by RT procedures [1]. Besides that significant efforts are given to improvement of characteristics of usable materials, which additionally contribute to improvement of final quality of made RT products. Historically observed, most of the procedures of rapid tooling and manufacturing (RT&M) are based on the adaption of polymer materials, but in the last few years the use of metals in RT&M procedures takes more significant position. Immediate reason for the above mentioned situation is hidden in the fact that in the last years there is a higher number of newly developed RP systems that base their work on the adaption of more types of powder metal materials based on base of stainless steel, titanium, cobalt-chrome, aluminium, etc. Generally, rapid tooling as the area of the first and the most important application for rapid tooling of functional final products can be classified according to: the manner of make (direct and indirect tooling), duration of use of make tools (soft and hard tooling) and used materials (procedures based on: polymers, ceramics and metals, table 1.).

2. DIRECT HARD TOOLING

Direct hard tooling is related to manufacturing of tools and moulds directly through the RP systems where manufactured tools generally allow longer time period of exploration in manufacturing thanks to applied building materials. RP systems that are used for direct hard tooling due to characteristics of sintering process and implemented building materials (powder materials based on metal) require obtaining extremely high temperatures in primary process of tools manufacturing, which is mostly realised through the application of lasers or some other sources of intent energy. Such manner of the RP systems work assume the work of engine in extremely critical conditions that cause stochastic behaviour of those parameters that influence punctuality of the part that has been made. Further on in this paper the most familiar commercial methods for direct hard tooling are presented.

2.1 Direct Metal Laser Sintering – DMLS

The process of selective laser sintering-SLS developed by EOS (Electro Optical System – Germany) implemented in the direct hard tooling is known as a process of Direct Metal Laser Sintering-DMLS. This process are used in production of hard tools from powder base materials on the basis of bronze, steel, stainless-steel 316L, titanium, Al-30% Si, without the requirement for subsequent sintering of the produced parts because of the fact that parts are produced with 95% density. DMLS process with base material based on steel is mostly used for production of small geometrically complex parts which would be difficult to produce by classical methods. Depending on the required tool most molds for casting can be directly manufactured with cooling channels and can withstand manufacturing of several hundred thousand plastic molds. Moulds produced in this way can be used in metal injection molding with low melting point in a series of about a thousand pieces. In the case of production of molds from DMLS of materials based on bronze, it is necessary to perform infiltration of produced parts by mold resin or metals with low melting point (e.g. tin) to eliminate porosity of produced DMLS tools.

Table 1. RT procedures for different building materials

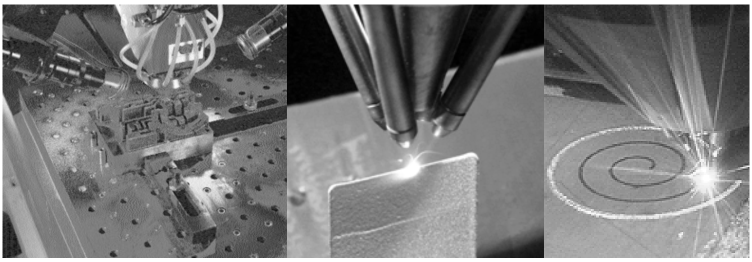
Building materials	RP process
Polymers	• *Direct AIM (3D Systems)* • *SL Composite Tooling (3D Systems)* • *RTV Tooling* • *Swift Tool (Swift Technologies)*
Ceramics	• *Direct Shell Production Casting - DSPC (Soligen)* • *Direct Metal Casting – ZCast DMC (Z Corp.)*
Metals	• *Three Dimensional Printing - 3DP (Prometal)* • *Direct Metal Laser Sintering - Direct Tool (EOS)* • *RapidTool (3D Systems)* • *„Kirksite“ Tooling* • *Space Puzzle Molding (Protoform)* • *Aluminum Filled Epoxy Tooling* • *Spray Metal Tooling* • *Direct Metal Deposition (Laser Engineering Net Shaping – LENS) (Optomec)* • *Electron Beam Melting – EBM (Arcam)* • *Laminated Object Manufacturing - LOM (Cubic)* • *KelTool (3D Systems)* • *Rapid Solidification Process - RSP* • *SprayForm (Ford Motor Company)* • *RePliForm*

2.2 Directed Metal Deposition– DMD

Laser Engineering Net Shaping technology (LENS) developed by *Sandia National Labs* has been commercialized by *Optomec company* as Directed Metal Deposition. DMD process is based on SLS process, the difference being that in the DMD process, instead of firming powdered materials on building platform in SLS process, powdered metal particles (less than 150 µm) are transmitting in gas flow through jets (figure 1.). Solid material are forming while solidification applied powder coating on locally melted area, creating individual layers full of density. The process is using very powerful laser (500 W - 4kW) and taking place in hermetic chamber that scrubs with argon to protect parts cleanliness and to eliminate contamination with oxygen or nitrogen. In DMD process it is possible to product molds full of density, with more material systems in one cycle allowing optimisation of tooling cost and thermal features of any location on the tool. Process is based on using those building materials: tool hammer H13, 304 and 316, stainless steel, nickel alloys, cobalt-chromium and Ti-6Al-4V alloys. By using DMD process, is possible rapid manufacturing huge tool-molds with controlling cooling, features that can't achieve with the conventional CNC technology, and fixes and modification persistent parts or molds that was made by conventional technologies.

2.3 Electron Beam Melting - EBM

In EBM process, metal parts are making layer by layer melting metal powder with strong electron beam (4 kW power) in under pressure chamber with elevated temperature (about 1000° C) which results stress relaxed parts with material features better than cast and wrought forging. The process is based on using high level energy that provides high melting capacity and high productivity. The EBM process is primarily developed for processing of refractory and resistant materials (tantalum, niobium, molybdenum, tungsten, vanadium, hafnium, zirconium, titanium) and their alloys, and it is characterized with high production speed, possibility tools production and parts of extreme complex geometries with mechanical features similar to heat treated materials.



a) b) c)

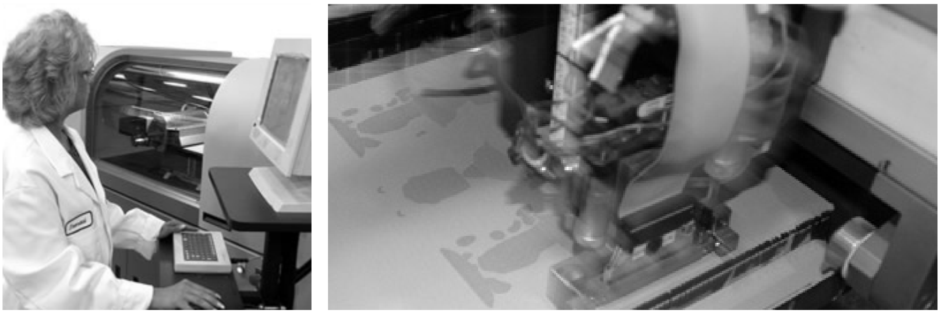
Figure 1. Directed Metal Deposition: a) RP workstation, b) i c) creating layers [2]

2.4 Laminated Object Manufacturing - LOM

As with other direct rapid tooling methods, lamination process begins with 3D CAD model, that divides on layers of certain thickness in application software. After that, laser beam of 5-axial CO_2 laser is directed with optical device and lead on defined cross-section of construction material in the form of metal foils where the thickness of metal foil corresponding to the thickness of the layer made of construction. LOM process is characterized by extreme speed, the possibility of producing, with low cost, high volume molds without internal stresses and strains (20% cheaper than in any other procedure for the direct production tool). Disadvantages of the LOM process are unsuitability for the production of tools with thin walls in the form of shells and necessity post processing - finishing tools, most whit conventional milling process.

2.5 Prometal 3DP process

Prometal three-dimensional printing process was developed by Extrude Hone Corporation in cooperation with Massachusetts Institute of Technology-MIT which has licensed the original 3DP technology. The process is based on a layered printing technique of work pieces using multiple inkjet printer electrostatic head for applying of liquid binder in the form of drops on building materials in the form of metal powders (figure2.). The manufactured parts are made at high speed (4000 cm3 / h) with the approximate thickness of the layers between 120-70 [µm], and possess about 60% density with 10% share of organic binder. Due to the poor mechanical properties of manufactured parts and thus achieving the full demands of the density of the parts, the densification of the parts trough processes of removal of thermal binder, sintering and infiltrating of other metal which has a slightly lower melting point (e.g. bronze) is required. With Prometal 3DP process extremely complex metal tools and finished metal products can be produced with high level of accuracy, flexibility and reliability which is why this procedure is represented in almost every industry. Great accuracy of this procedure positioned it close to the unconventional processing systems at approximately the final shape (Near Net Shape Forming) and in many cases Prometal 3DP process can produce components of complex internal geometries that would be impossible to make any other method.



a) *b)*

Figure 2. Prometal 3DP process: a) RP workstation, b) 3D printing [3]

2.6 RapidTool

The process of direct production of metal molds is based on a steel powder coated with thermoplastic binder as a building material. After primary SLS process, the influence of thermal energy of CO_2 laser causes the melting of polymer binder and fuses the particles of stainless steel and resulting "green part" is post-processed in industrial furnaces because of the porosity. During the process of overheating the binder blows and grains of metals are connected in the sintering process. After sintering phase part which structure reaches up to 70% density of stainless steel is obtained. In the final phase during the production of molds with full density, infiltration is performed with the bronze. These secondary processes are implemented in a single day, while the total processing time of mold takes 1-2 weeks [4] .

3. CONCLUSION

Direct hard tooling by application of process based on the technologies of rapid prototyping is a competitive alternative to conventional production of tools (high speed machining, electro erosion) which has significant potential for improvement as they surely guarantee a bright future. Currently available conventional processes of direct production of tools presented in this paper are mainly based on the implementation of the dust materials based on metals with or without additional binder components and direct or indirect application of concentrated energy sources, enabling the production of tools whose structure reaches 70 to 95% of the density of steel, which is for certain practical applications (plastic injection, injection molding and casting of metals with lower melting point) satisfactory.

4. REFERENCES

[1] Topčić A., Tufekčić Dž., Fajić A., Cerjaković E.: Implementation of Three Dimensional – 3DP printing process in casting, 5th International Symposium - Konstruisanje, oblikovanje i dizajn KOD 2008, Novi Sad, Serbia, October 2008.

[2] Hofmeister W., Wert M., Smugeresky J., Philliber J.A., Griffith M., Ensz M.: Investigating Solidification with the Laser-Engineered Net Shaping (LENS^{TM}) Process, JOM , vol. 51, no. 7, July 1999.

[3] http://www.prometal.com

[4] http:// home.att.net/