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A SEAT IN PREŠOV

APPLICATIONS OF 3D PRINTING
IN MOULD STRUCTURES

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Abstract

The submitted monograph is oriented towards application of 3D printing in a structure of a new generation of moulds. As to the content the monograph has been divided into two basic parts, i.e. theoretical and practical. The introductory chapters describe fundamental principles on the basis of which additive manufacturing works, i.e. seven principal types of additive manufacturing. Greater emphasis is laid on the DMLS technology serving as a base for practical part. The second part of theoretical overview deals with inner structure and its optimization. Consequently, the objectives were defined along with theses and methodology of elaboration. The introduction of the practical part offers analysis of the current state of the art as well as of the difficulties emerging in the course of manufacturing of the component parts by means of the DMLS technology. Further on, the monograph shows a case study analysing a shaping intermediate piece designed for plastic injection from the point of view of strength analysis and manufacturing process analysis in case of which the data serve as input information for verification of data after optimization of inner typology. The final chapters assess achieved results.

Key words

additive manufacturing, DMLS, topology, simulation, optimization.

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List of Symbols and Abbreviations

3D	Three dimensional
AM	Additive Manufacturing
CAD	Computer Aided Design
ISO	International Organization for Standardization
BJ	Binder Jetting
DED	Direct Energy Deposition
ME	Material Extrusion
MJ	Material Jetting
SL	Sheet Lamination
VP	Vat Photopolymerization
PBF	Powder Bed Fusion
UAM	Ultrasonic Additive Manufacturing
LOM	Laminated Object Manufacturing
LED	Light Emitted Diode
SLA	Stereolithography
SLS	Selective Laser Sintering
DMLS	Direct Metal Laser Sintering
EBM	Electron Beam Melting
RT	Rapid Tooling
IRT	Indirect Rapid Tooling
ABS	Acrylonitrilbutadienestyren
PA	Polyamide
PC	Polycarbonate

Introduction

Additive manufacturing frequently referred to as 3D printing is defined by ISO TC 261 standard as a process of adding layer-upon-layer of material with the use of data of the 3D model created in CAD system to manufacture final component parts by means of which it differs from subtractive and formative manufacturing.

At present additive manufacturing covers a number of machines differing by the applied manufacturing technology, means of added material and sphere of utilization. The main advantage of use of additive manufacturing is unquestionably a variance of structure design being incomparable with the use of other manufacturing methods. It offers opportunities especially in development and consequently in manufacturing of prototypes, in testing of functional samples, in utilization of modern alternatives of modelling and manufacturing of complicated geometries and structures, in reduction of weight, etc.

However, on the other hand, certain obstacles do exist in case of use of technologies of additive manufacturing ¹ such as high acquisition costs related to machines and material, slow manufacturing, insufficient quality and accuracy connected to inevitability of further machining. On the basis of rapid development of these technologies during last decades it can be assumed that some of the factors shall be eliminated in the near future. Reduction of machine and material costs and increase of manufacturing pace is expected. Regardless of the obstacles, the technologies are nowadays being used in the industrial practice. Following the aforementioned it is clear that the technologies are viable with particular specific applications even at present.

Unquestionably, one of the applications includes utilization in case of mould manufacturing. The main advantage brought into process of structure of moulds by additive manufacturing stems in so-called conformal cooling systems of moulds. Contrary to conventionally drilled cooling systems the conformal cooling offers more flowing distribution of temperature in the mould cavity resulting in reduction of annealing stress in a cast or in a moulded piece which is also connected with overall time of manufacturing cycle as no additive cooling in the mould cavity is needed and the final product can be thus moulded more quickly. However, the DMLS technology involves also certain difficulties in the manufacturing process. One of the serious problems refers to occurrence of annealing stress in the course of the manufacturing. Action of the annealing stress especially in marginal areas of the model causes clinks and cracks which in better case lead to inaccuracy of a final

product. The worse is the case in which the selected component gets completely detached from the machine platform resulting in its damaging and possible collision between the component and moving parts of the manufacturing equipment.

Shiomi et al. [2004] ranks among the first to have dealt with the issue of annealing stress with examination of the stress in case of selective laser sintering of chrome steel AISI 4140. On the basis of results it was concluded that to certain extent annealing stress can be reduced when the base plate is preheated. Merselis et al. [2006] took a different path and studied the influence of orientation of the laser move. The findings proved that the annealing stress was higher in case of samples manufactured by laser performing cyclic move in a single direction contrary to samples with changing laser trajectory direction. Leuders et al. [2013] studied resistance to formation of cracks due to annealing stress and on the basis of their results it can be assumed that annealing stress is accumulated in the marginal positions of the manufactured model and is considerably higher in the direction of manufacturing than in the direction perpendicular to this direction. Vrancken et al. [2014] examined the influence of orientation of the model upon occurrence of annealing stress. The results proved that the annealing stress represented the main factor in case of anisotropic behaviour of material of the component manufactured by the DMLS technology. The issue of occurrence and reduction of annealing stress remains unsolved and right that was the motivation to elaborate the monograph with the attention focused on areas of formation of annealing stress and its amplitudes. The practical part presents a proposal of alternative solutions involving optimization of inner structures with regards to preservation of functionality and service life of the manufactured component which was shaping intermediate piece designed for plastic injection. Other benefits of these alternative solutions include reduction of manufacturing time and material saving which eventually decreases the production costs and increases competitiveness of the company.