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OPTIMISATION OF RAPID PROTOTYPING PROCESS FOR ELECTRICAL VEHICLE MANUFACTURING

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Abstract: *In the case of three-dimensional (3D) printing complex products or big assemblies must be minimize the manufacturing process cost. Taking this into account, some printing parameters must be optimised, such as 3D printing time, post-processing time and material consumption. In this paper, a methodology regarding of design for additive technologies (DFAdT) and design for rapid prototyping/ rapid manufacturing assembly (DFA-RP/RM) is proposed, based mainly on separation of complex products in optimal sub-assemblies. A case study focused on a new concept of an electric vehicle (self-balancing scooter) is presented. The scaled prototype is manufactured using polyjet additive technology within the Industrial Innovative Technologies Laboratory, Department of Manufacturing Engineering from "Transilvania" University of Brasov, Romania.*
Key words: *Additive manufacturing, DFX, Design for RP/ RM Assembly, complex product, electric vehicle*

1. INTRODUCTION

Design for manufacturing (DFM) is a process to analyse the influence of the geometry and the choice of processes on costs focused on materials, methods of manufacture and tooling.

The main design for assembly (DFA) objectives are reducing the total number of pieces, reducing the number and cost of assembly operations and changing the geometry of parts to facilitate their assembly. The reduction of the number of parts in an assembly has the added benefit of generally reducing the total cost of parts in the assembly. Resuming the DFMA apply analytical techniques at the design stage to reduce costs and the difficulties of assembling and manufacturing products.

Three-dimensional (3D) printing represents a rapid prototyping/ rapid manufacturing (RP/ RM) technique enabling to obtain prototypes, tools or final products by additive manufacturing process. Theoretically, due to the additive way of manufacturing, RP/ RM can build shapes and products impossible to obtain using traditional manufacturing methods. However the practical experience shows that RP/ RM processes have some limitations which impose restrictions in the prototype design (Hague et al., 2003). Under the umbrella of Design for X (DFX) new concepts can be taking into consideration such as Design for RP/ RM (DFRP/ RM), Design for RP/ RM Assembly (DFA-RP/ RM), Design for additive manufacturing (DfAM) and Design for Additive technologies (DFAdT). These methods can be applied in the case of additive manufacturing of functional parts, big assemblies or parts and complex products. Some researches were development in the Design for RM (Hague et al., 2003) and Design for additive manufacturing field (David, 2007), (Gibson et al., 2010).

Additive technologies imply a number of parameters that must be taken into consideration in the design stage of RP/ RM products. The most important are the following:

- Ability to build parts with very small or large dimensions. For prototype with small dimensions or fine details, the designer must to do an analysis of wall thickness according with the RP machine performance. For large prototypes it is necessary a splitting or fragmentation of the computer aided design (CAD) model.
- Ability to build multi-component functional models.
- Best fabrication orientation of an individual part or many parts on the build platform. Some researches propose methods and rules to sole this problem.
- Ability to remove the support material.
- Mechanical characteristics of the RP/ RM material.
- Accuracy and the surface quality obtained by RP technologies and machines.

In the case of 3D printing complex products or big assemblies it is necessary to minimize the manufacturing process cost. Taking this into account, some printing parameters must be optimised, such as 3D printing time, post-processing time and material consumption. A main step in this direction is to separate the design into optimal parts or subassemblies and than finding the best manufacturing orientation of the components.

2. ELECTRIC SCOOTER DEVELOPMENT

In development of new special vehicle (electric or hybrid powered) it is necessary to manufacture a prototype (Valentan et al., 2007). In this paper a virtual 3D prototype of an electric vehicle (self-balancing scooter) is proposed and designed in CAD software Solid Works. A scaled model of the designed scooter is built by PolyJet technology in order to evaluate the shape, functionality and further aerodynamic testing in wind tunnel (Udroiu & Dogaru, 2009). But it is necessary the minimizing the cost of the prototype. Thus, we assume the following objectives: the minimization of the manufacturing time (printing and postprocessing) and the minimization of the material used. In the next chapter it is proposed a DFAdT and DFA-RP/ RM analysis wich is applied to the scooter model.

2.1 Case 1 – Redesign the wheel assembly using DFAdT method

In the first case, the scooter wheel (fig.1) is taken into consideration. The assembly of the scooter wheel is designed from three main components: the wheel, the cover and the electric engine (inside the wheel).

Starting with a DFAdT analysis we decided to build the wheel in one step, thus reducing the number of parts (fig.2). Thus the scooter wheel is necessary to be redesigned: assembly with new features. Some holes are added on the circumference of the wheel to allow and simplify the postprocessing process (removing wax support from inside the wheel).

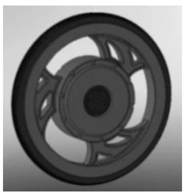

Fig. 1. Start design solution of the scooter wheel

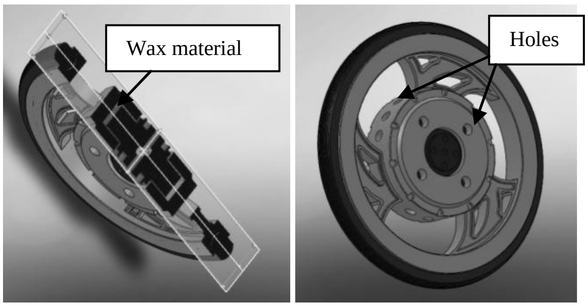

Fig. 2. New design of the scooter wheel (DFAdT analysis)

2.2 Case 2 – Dividing the scooter assembly model for optimal manufacturing using DFA-RP/ RM method

Finding the best fabrication orientation of the product can be a complicated task, especially for complex products. The methodology propose in this work is a two step procedure.

The first step consists in finding an optimal manufacturing scheme (OMS). Thus, following an iterative process, are analysed all the variants of manufacturing of the product:

- Can be printed the assembly on the built platform? It is difficult the postprocessing process?
- If yes, then is neccesary to divide the CAD assembly.
- It is chosen the best orientation for each component taking into accord the minimization of the manufacturing time and the prototype cost.
- Estimate the manufacturing cost.

In the second step, using the OMS calculated, it is search the optimally placement scheme (OPS) of the components on the RP build platform, thus minimising the printing time.

Following the proposed procedure, it is analysed the scooter assembly (DFA-RP/ RM analysis) and then virtually simulated the RP manufacturing process. Three cases are considered: case "A" (fig.3), case "B" (fig.4) and case "C" (fig.5-left). The estimated parameters of RP process are presented in the tab.1. The optimal solution is found in the case study "C".

	Model consumption	Support consumption	Building time
Case A	707 grams	1447 grams	33 h 45 min
Case B	525 grams	906 grams	21 h 02 min
Case C	394 grams	475 grams	13 h 38 min

Tab. 1. Estimated parameters of RP process

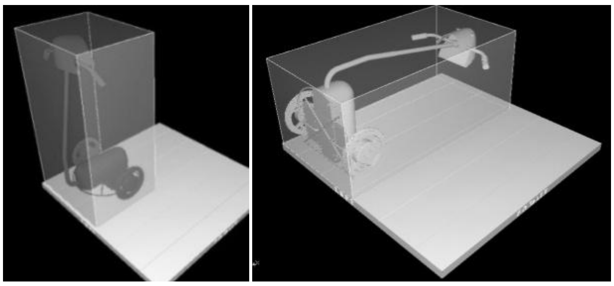

Fig. 3. Virtual simulation of the RP process. Case study "A"

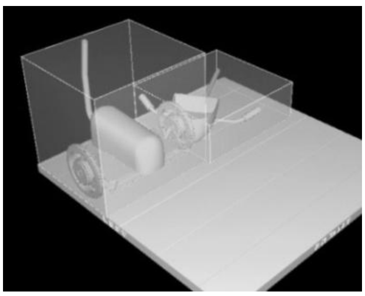

Fig. 4. Virtual simulation of the RP process. Case study "B"

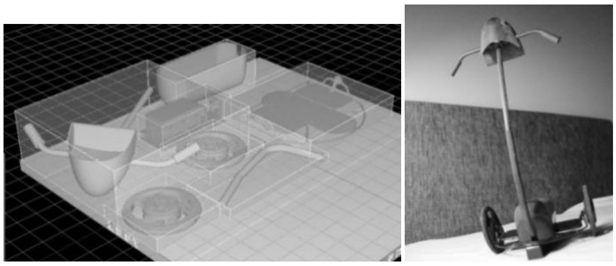

Fig. 5.Best fabrication orientation of the scooter parts on the build platform, Case study "C" (left) and the scaled prototype of the self-balancing scooter (right)

3. MANUFACTURING OF THE SCOOTER MODEL

Based on the optimal fabrication solution founded in the last paragraph, the scooter was manufactured by PolyJet technology on the EDEN 350 machine. After that all the components are assembled. The final assembly of the scooter is presented in the fig.5-right.

4. CONCLUSION

In this paper two DFX methodologies are proposed in the field of additive technologies. The first is focused on DFAdT and consists on reducing the number of pieces and the post-processing simplification (adding new design features). The second method proposed DFA-RP/RM is based mainly on optimal separation/ division of complex products in sub-assemblies. This method consists in two main steps: finding the optimal manufacturing scheme (OMS) and optimally placement scheme (OPS). Applying these DFX methods give possibility to optimising the material consumption and printing time, thus being minimised the prototype cost with 40-60%.

A case study regarding of a new concept of an electric vehicle (self-balancing scooter) is presented. The proposed methods are applied for a scaled prototype of this scooter, resulting 54% cost reduction of the prototype.

The next step will consists in the implementation of the proposed methods in a software module.

5. REFERRING

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