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EXPERT SYSTEM SUPPORT IN PRODUCT DESIGN FOR ADDITIVE TECHNOLOGY AND REVERSE ENGINEERING

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Abstract: The design for the domain of CAD/CAM systems is a process of decision making where technical solutions have been applied in order to achieve predefined objectives. There are many factors influencing the production of a part that can affect the quality. This paper presents an expert system that provides support for the analysis of CAD model design and its transformation in order to improve production parameters. The system provides multiple analysis as the basis for proposing optimal solution of manufacturing process. Validation of results of the system model is verified through the use of reverse engineering techniques.
Keywords: CAD, expert system, additive technology, reverse engineering

INTRODUCTION

The design process requires multiple phases of the product development[1]. The new parts, configurations and assemblies are presented by some kind of rules, equations and schemes. Each one represents something new and unique [2]. Different approaches have been taken with the aim to optimize the design of a product in additive domain [3-7]. A CAD model is under consideration in terms of his basic characteristic, where weighting factors are usually applied in selection or decision making process [8-11]. Mostly, the additive methods have a common way of production, but some differences between them make great potential for manipulation of a virtual model. Expert system support for additive manufacturing is based on the series of rules which define the procedure for optimal selection of the production parameters. Also, different measuring methods have been taken with the aim to control surface quality. The case study results of this paper is verified by reverse engineering process, where scanner converts the physical object into point cloud [12]. Reverse engineering is modern technology which provides a lot of benefits and possibilities in the CAD/CAM domain [13]. Some of them are including design reconstruction with impacts on shape analysis and prototyping [14, 15], quality control and inspection on certain parts [16], request for making clone of the original model [17], remanufacture of existing parts [18], and more. Very important fact about reverse engineering process is based on effort to eliminate inaccuracy in the proposed scan algorithm [19].

THE EXPERT SYSTEM DEVELOPMENT

Selection of manufacturing parameters is one of the most important tasks which a designer has to make in additive manufacturing process. In order to choose the best for product, designer need to compare more solutions and alternatives, and then make their assessment that is followed by certain constraints. Constraints are enforced by end-use of a product, so that a designer is forced to operate always within these constraints. Build orientation and layer thickness are imposed as the primary parameters in process defining of additive manufacturing. In order to determine properly, those parameters have to be analyzed in right direction. Certain number of criteria include manufacturing time, surface roughness, process errors, geometrical complexity, assembling, functional, ergonomic and aesthetic characteristics etc. [20].

In terms of the expert system building, the first of all, it has developed a structure of the basic variables that carriers of goals and recommendations for a tasks implementation. The development environment is based on the Java platform. A knowledge that is written in a knowledge base represents fundament of the expert system. It has grouped into units that make a logical blocks. A logical blocks are specific for a some data group. A production rules are used for a procedures execution and locomotion. Variables and production rules are distributed over a logical blocks. In expert system technology, each of the expert´s rule is a

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heuristic. The combination of all the heuristics allows the overall decision making problem to be solved. The example of basic IT/THEN production rule applied to accuracy of additive manufacturing, has the following format:

IF: *The model surfaces need to be produced with high accuracy:*
THEN: *Layer thickness has to be minimal.*

Definition of a production rule is a simple syntax that is suitable for reading and understanding of its meaning. If condition is Boolean operator that checks truthfulness or untruthfulness of the certain case. A rules are independent facts and there are no explicit links between themselves. Manufacturing of a part carries a lot of number of various factors that must be defined in development stage. These factors are defining the overall expediency arising from a part value improvement. Relate to the previous mentioned, it has been showed the expert system rule that provides this area of the part improvement:

IF: *Select improvement direction: Value improvement guidelines*
THEN: *Performance on aspects such as capacity, power, speed or accuracy.*
Freedom from breakdown or malfunction;
Performance under varying environmental conditions.
Secure, hazard-free operation.
Simple, infrequent or no maintenance requirements.
Except for disposable products, a long lifetime which offers good value for the initial purchase price.
Little or no unpleasant or unwanted by-products, including noise and heat.

Building of knowledge base is an important step of the expert system development, besides it is necessary to achieve connection between knowledge base and work prototype together. Also, a user interface must be created as structure of a system. In that circumstances, it has provided a real contribution of a production rules. The expert system work prototype is a program that interacts with experts or novices in order to solve problems. The end user provides an interactive input by selecting one or more answers from the list or by entering data directly. The built system is running as a Java Applet, where it generates an HTML page with Applet tag. This process is running by a local Web browser. Inference engine as the expert system brain checks a control block in order to see actions taken by the end user. Logical blocks are used for instruction implementing. The crucial moments in block executing are confidence variables. A system collects the necessary information from users through static and dynamic variables, and inference engine derives all confidence and collection variables.

Testing of a system accuracy and efficiency is carried out on the steering wheel. This model in interesting from design point of view (Figure 1). Process moves through several testing stages:

- Testing and evaluating knowledge base,
- Testing action of the inference engine,
- Testing interaction and ambiguity of an user interface,
- A system validation.

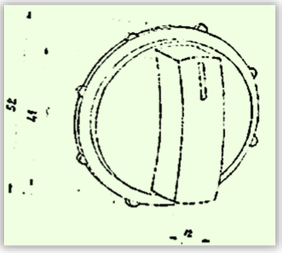

Figure 1. Sketch of the steering wheel

Note that, fulfillment of design requirements is reflected through obligatory tasks in terms of:

- Technical model requirements(Function, Form, Fit, Manufacturing Design, Assembling)
- Aesthetic model requirements (Visualization)
- Ergonomic model requirements (Ergonomic Design)

By detail analyze, there is no reason to divide model into specific zones in order to define layer thickness. For this possibility, it is not necessary to include model features, because layer thickness need to be uniform. So, model segmentation is not necessary, but individual treatment of surfaces is available. Following the system recommendations, model is viewed as integral object, where it is the most desirable to identify and highlight areas important from functional point of view. Such surfaces with a high degree of priority are reference to determine process parameters. Each of the model surfaces can be potential candidate to define process. The steering wheel has eleven candidate surfaces in total (Figure 2).

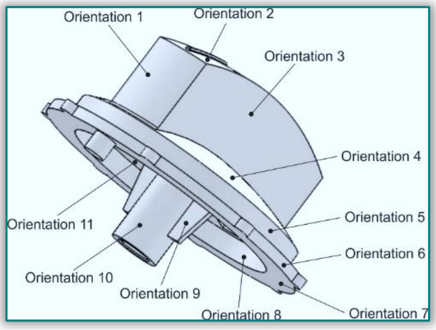

Figure 2. The surfaces as candidates to determine orientation

According to the presented rule (Figure 3), position control is achieved by confidence value definition. As evident from the rule, confidence value 30.0 is relevant mark for vertical orientation (Z axis direction), while confidence value 20.0 is not enough to be main orientation and represent horizontal orientation (X axis direction). All other marks in that diapason make a compromise between these two orientations values.

These values are results of individual treatment of a model surfaces. Also, a system recommendations are related on the layer thickness with respect to required production influential criteria. Graphical representation of the results is shown on Figure 4.

INFERENCE RESULTS:

(1) Build orientation along Z axis direction: Conf=30.0
(2) Build orientation along X axis direction: Conf=20.0

(1) Features axes of the highest values are parallel with Z axis of the machine!
(2) Features axes of the lowest values are perpendicular on the Z axis of the machine!
Consider layer thickness with respect to required production influential criterion.
Reduce height of the support structure at the minimum.

Figure 3. The inference results – analyze of geometrical complexity

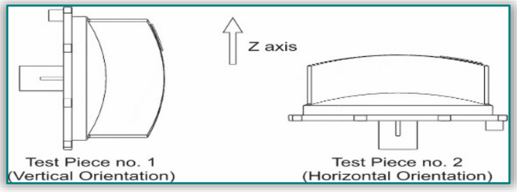

Figure 4. Graphical representation of solutions

SYSTEM VALIDATION THROUGH APLICATION OF REVERSE ENGINEERING

Quality control is a key factor in a modern approach to the process of product design. The ability to provide the geometry as it is actually designed, in its original dimensions and apply it as such is a major challenge in modern engineering. Trying to check the produced form, it's fitting and finally its function, most designers apply different measurement techniques. ATOS optical 3D scanning, based on the principle of border projection proved to be accurate in providing dimensional information in quality control and optimization and creating important measurement reports. Optical scanner delivers geometric data from an existing physical object. The obtained geometric data have been used to analyze the precision of surfaces on the model of the steering wheel of operating temperature of electrical device (Figure 4), made by recommendations of the expert system (Figure 3) by the method of 3D Print (Z450), by company ZCorp. ATOS software calculates complete polygonal grid of high-resolution area for the object by creating a smaller triangles in curved areas and larger triangles in flat areas, without decreasing the accuracy of the grid (Figure 5). The system uses a technique of the reference marking to merge data from different perspectives.

After the scanning is completed, the data supplied by the ATOS system is in arbitrary global coordinate system. To perform the comparison of scanned physical data and CAD original data, scanned data is converted into CAD data of coordinate position.

For the implementation of a detailed analysis, the scanned data is entered into the software GOM Inspect V7.5, where the alignment of compared models is done. For aligning models option prealignment was use (Figure 6). With this type of alignment, the system requires user first to define nominal point on the original CAD model, and then to select the Actual point on the scanned model.

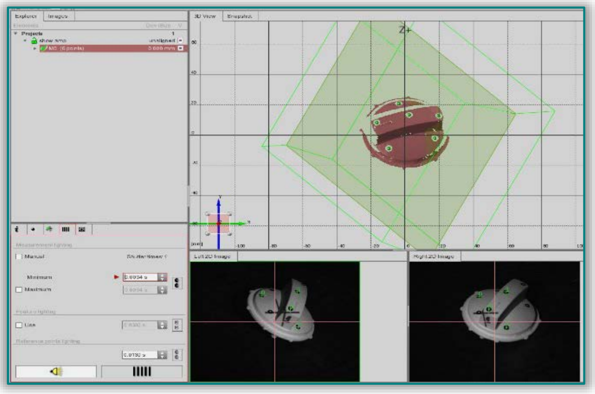

Figure 5. The scanning process of pieces that takes within the ATOS system

Based on the defined reference points, the system account the alignment for the given coordinates and proposes possible orientation of alignment. In other words, the prealignment aligns the scanned data (actual point) automatically according to the original CAD data (nominal point), regardless of the starting positions.

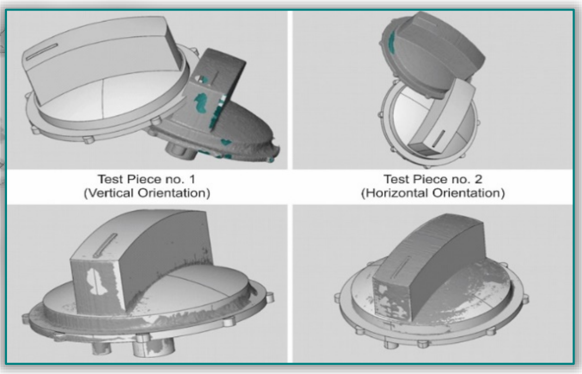

Figure 6. Alignment of objects to be compared

Figure 6 shows the alignment of scanned pieces with the original CAD model. It is immediately evident from the figure that the surfaces of the scanned pieces deviate from the original surface, i.e. the deviation at this stage is more than obvious. According to the analysis, it is concluded that the model made in the horizontal orientation has more accurate geometry than the model made in vertical direction and at this distinct degree has reduced the size of the stairs effect. In this way, the obtained results actually confirm the recommendations of an expert system in order to achieve high quality production of model surface, depending on the geometrical requirements. The process of product design shall not be retained only on the issue of the accuracy of the model, but may include an analysis of the material which is model made from. The models presented in this paper are made from ZP 150 powder. This type of powder is one of the best materials of company ZCorp., available for the use of methods of 3D printing. It provides a significant improvement compared to the previous types of powders, such as better visual impression, and of course the overall strength of the model. Therefore, it is a high performance composite material that provides very good performance for a model from which it is made.

CONCLUSION

Good design of planned product represents more than half of the successful work done. Therefore, the goal is to design a product that is simple and economical to produce. The literature states that the importance of the design process for the production is riddled with the fact that about 70% of the cost of production is determined by decisions made in the design process, while some 20% is determined by decisions made in the production process. However, successful design does not also guarantee an optimal design of a product. An important task of the design process represents a way to simultaneously reduce the cost of production and enhance the functionality and quality of product. Reducing the number of parts on the product is certainly the best opportunity for reducing production costs, because fewer parts means less wasted materials and time to develop.

Problems in the design can be reduced by using standard dimensions and shapes, because their availability and distribution contributes to the easy fitting within the functional structure. In general, the design process is a combination of a series of stages, each stage comprising a set of guidelines and recommendations in order to achieve a more optimal method of production, which ultimately improves the quality of product. Construction of the three-dimensional object at any stage of the design is of great importance especially for engineers and designers employed by the department of product development. In this way it is allowed access to various types of analysis of the model prototype, in order to ultimately conduct more effective engineering.

This way of work enables reducing the time required for product launching on the market. Therefore, the focus is on improving the part function and its task performing in assembly, but at the same time the visual impression and ergonomic design are in focus too.

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Note

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