Method of transition from 3D model to its ontological representation in aircraft design process

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Abstract. This paper proposes the method of transition from a 3D model to its ontological representation and describes its usage in the aircraft design process. The problems of design for manufacturability and design automation are also discussed. The introduced method is to aim to ease the process of data exchange between important aircraft design phases, namely engineering and design control. The method is also intended to increase design speed and 3D model customizability. This requires careful selection of the complex systems (CAD / CAM / CAE / PDM), providing the basis for the integration of design and technological preparation of production and more fully take into account the characteristics of products and processes for their manufacture. It is important to solve this problem, as investment in the automation define the company's competitiveness in the years ahead.

1. Introduction

Modern aircraft industry focuses, among other things, on a reduction of the production cost due to market demand. A cost reduction can be achieved by the design for the manufacturability (DFM) process. DFM practices are purposed to develop the product with the same quality that is more cost efficient [1]. This process requires extra knowledge and enough experience in choosing the appropriate equipment and techniques for parts production. Given the complexity of modern airplane design (3 million parts for a Boeing 767), it is hard to establish the right technique for each part, and as a consequence, design engineers often utilize patterns that have not changed for decades [2]. While this decreases the amount of time that is needed for the DFM process, it has a bad influence quality decisions. Design engineers do not choose the most cost-effective techniques and equipment. Thus, the problem is that common practice does not utilize fully the potential of modern equipment.

The information model in this paper comprises the assembly, parts, elements of construction, a semi-finished item, manufacturing operation, and the technological equipment required. This set-up sufficiently describes all the information needed for the DFM process [6]. The production environment objects described in this paper encompasses the set of entities in each node of the system (Fig. 1). The set describes the production capabilities of a manufacturer. This paper discusses an automation solution for design process phases, namely design engineering (Siemens NX) and the transition from design engineering to DFM (Siemens Teamcenter).
Figure 1. The ontology of the information model

The link between design engineering and DFM is made by data transition from the NX's 3D model to Teamcenter's system called an information model (Fig. 1). Such transition entails some difficulties because of different data formats. Each 3D model feature represents an element of construction (EC); therefore in practice, design engineers are manually creating each EC in Teamcenter based on the NX model features. The idea is to create a database containing both 3D model and EC. The benefits of having one database is to speed up the transition, accelerate the 3D design process due to utilizing standard features, and also to simplify customization of the 3D model.

Figure 2. The UI example and the typical 3D model
2. 3D model parts recognition approaches

One of the reasons for low automation level in the DFM process is due to poor formalization of the DFM process. In this paper, the authors have done some work on the formalization of the DFM process [6, 5] that led to the creation of the information model, the method of the DFM process and their implementation in DSS, “DFM analysis system.” This paper discusses the development of the method of the DFM process and the method of transition from a 3D model to its ontological representation in the aircraft design process.

The idea is to link UDF and EC and store them in one database. Design engineers create 3D models in Siemens NX utilizing the UDF from “DFM analysis system” or Teamcenter via the author's plug-in. The next technician to create the information model in “DFM analysis system” or Teamcenter can check its DFM acceptance. Owing to author's plug-in, technicians have the ability to automatically make a transition from a 3D model to its ontological representation. The design engineer can customize this 3D model in semi-automatic mode. Thereby, instead of recognizing parts, the plug-in utilize EC linked with a UDF dictionary that is highly customizable to fit any manufacturer's needs. The method provides precise recognition as compared with other solutions’ stochastic recognition. That is essential for DFM and following processes.

The method of transition from a 3D model to its ontological representation is based on a previously published paper [8] and includes the following steps:

1. To model UDF representing EC and add them to the database.
2. To link EC and UDF parameters.
3. To model aircraft parts utilizing UDF from the database.
4. To automatically link UDF on the 3D model and UDF in the database to create parametric ECs describing the 3D model.
5. To create the information model on the basis of the EC list.

All of the design elements of standard airframe parts consist of such primitives; if necessary, they can be broken down further into points, representing the lowest level of such hierarchies; however, such detailed characterization is rarely needed and can make data processing unnecessarily difficult. Linking the primitives in a single part helps to get the image of its contours; this is referred to as contour-based pattern recognition.

The design of airframe parts includes typical design elements such as wall, side, hole, flanging, and incision. To single out these design elements, one must apply the rules that specify the sequence and the conditions of connecting the lines for each design element. We, therefore, obtain a hierarchical system of geometric objects in CE, and each of these objects is selected on the bases of a previously determined classification.

Primitives can be used to determine the parameters of design elements, i.e. those of flanging, in the electronic model. Flanging is one of the design elements that make the walls of a part more rigid; the parameters of such elements are specified in GOST 17040–80. Flanging consists of several circles through which diameter $D$ of such flanging is determined; the distance between the centers of such circles determines height $h$ of the flanging; the surface of the transition between the wall and flanging $R$ (see Figure 3).

![Figure 3. Design element (Flanging)](image)

3. The method implementation

The author's plug-in for Siemens NX is based on the method of transition from a 3D model to its
ontological representation and focuses on simplifying the work of the design engineer and technologist. The plug-in user performs the steps represented below.

The plug-in is written in Java, using NX Open API for NX communication and RDBMS MariaDB as data storage. The UI example and typical 3D model are shown in Fig. 2.

Let us explain the workflow of the plug-in. The design engineer creates a 3D model utilizing UDF (which represent EC) in Siemens NX. In a semi-automatic way, the user creates compliance between the UDF and EC from the database. After that, the UDF is written into the database for the technician’s purposes, like automatic creation of the 3D model from EC list.

4. Conclusion

The paper examined modern software solutions for automatic feature recognition and discussed its modernization. Based on the analysis, the authors propose the method of transition from a 3D model to its ontological representation and implement it into the Siemens NX plug-in. The purpose of the work is to ease the process of data exchange between important aircraft design phases – engineering and design control, and to increase design speed and 3D model customizability.

Based on the research and development of an integrated recognition system, the authors are implementing the results that they produced in the automated process design system at the Aviation Plant. The system will bring the following practical results:

− software module for recognizing the structure of the CAD model of a product;
− software module for designing the product manufacturing route on the basis of the CAD model;
− information support for the technological design process;
− automating the development and regulation of processes on the basis of the CAD model.

Therefore, using the 3D model recognition system at the stage of concept design and technological preparation of manufacturing allows for making competitive products that feature better manufacturability and maintainability than their counterparts.

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