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Generative modeling in the SOLIDWORKS on the example of the furniture industry

Modelowanie autogenerujące w systemie SOLIDWORKS w przemyśle meblarskim

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The capabilities of CAx systems allow to expand CAD models with engineering knowledge. These are programmed models called generative or integrated models. Described is the usage of generative modeling in the SOLIDWORKS on the example of the furniture industry.

KEYWORDS: CAD, generative modeling

At the current stage of development of CAD systems supporting the design process, geometric modeling in the form of representation of 3D objects has become the obligatory standard. However, the needs of the modern industry and the variety of available solutions are associated with the growing demands placed on designers and constructors, which is why there is a need to automate work in CAD systems to enable rapid virtual product research [1]. This applies mainly to companies dealing in the production of variant products, including companies from the world-renowned Polish furniture industry.

In order to meet the changing market expectations, companies must demonstrate flexibility in production, which means readiness to introduce frequent design changes [2]. It is estimated that a significant part of labor-intensive design tasks (as much as 80%) are routine [3]. As a result, more and more importance is attached to the improvement of these processes.

In the classic approach, the designer determines the design features of the product based on knowledge and experience, while in the case of autogenerating modeling, the model is supplemented with knowledge and gains the "ability" to control construction features by changing the appropriate parameters. In the integrated model, input parameters are not determined directly by the designer, but by indicating the parameters or construction features with which the connection should take place [5]. Such design accelerates and facilitates the modification of the 3D model in the CAD system.

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Knowledge management in the design process

At present, there is a growing interest in knowledge engineering - an interdisciplinary department of science, which addresses issues including methods of collecting and formalizing broadly understood knowledge and utilizing its utilization, for example in counseling systems supporting decision making [6]. The formal assumption of engineering knowledge combined with modern IT systems allows the creation of so-called engineering systems based on knowledge, or KBE (Knowledge Based Engineering). KBE is a set of procedures and tools that facilitates the acquisition and recording of information on design and construction processes [7]. The collected and collected knowledge together with experience of experts (know-how), covering all aspects of the project, is processed by the computer, which improves its application in subsequent projects. The formal characterization of the rules of conduct developed by the constructors contributes to the standardization of the design process and the faster development of prototypes [3, 5]. KBE combines techniques of artificial intelligence, object-oriented programming and CAD programs by specifically taking into account the course of the engineering design process [4, 5].

In contrast to KBE, the auto-generative model only occurs in the CAD tooling environment and it is a geometric model with a high degree of parameterization, enriched with functions that automate the process of its generation. Functions that automate the creation of such a model are controlled by parameters, mathematical dependencies, design tables, templates, rules, reactions and conditional instructions representing knowledge. The connection between the knowledge base and the requesting module is not as clear as in the KBE systems. The process of self-generating modeling requires from the designer comprehensive knowledge about the design and construction process of the created product, 3D modeling techniques and CAD tool modules. The ability to formalize and implement knowledge using the given system is also very important. The process of knowledge implementation is related to the appropriate description of the values of features, relations between them, and the procedures that refer to the activities resulting from them [8].

Verification of the auto-generative modeling capabilities in the 3D CAD SOLIDWORKS system

SOLIDWORKS is a world-renowned CAD system for parametric three-dimensional modeling, which has also been used in the furniture industry. It enables the development of a product design consisting of solid models, welded constructions, sheet metal sheets and surface models, which gave the basis for verifying the modeling capabilities integrated in this system as part of the research.

Before the development of self-generating models, the process of gaining knowledge on the furniture design process, especially box furniture, was carried out. The basic classification, principles of designing the construction, used materials, joining methods, fittings and accessories have been familiarized with. The norm PN-EN 1116: 2006 describing the overall dimensions of furniture units used in the kitchen was analyzed. A number of self-generating models have been developed, including shelves, dressers, desks and kitchen furniture.

The construction of integrated models in the SOLIDWORKS system enables flexible management of the following features:

- geometrical relations between sketch elements and geometry elements of the same model and product model, thanks to which it is possible, for example, to change the geometry of the model with the change of one parameter dependent on it or change the dimensions of the entire furniture together with the change in the dimensions of the control skeleton - in the form of a sketch defined at the level of the assembly model (fig. 1);

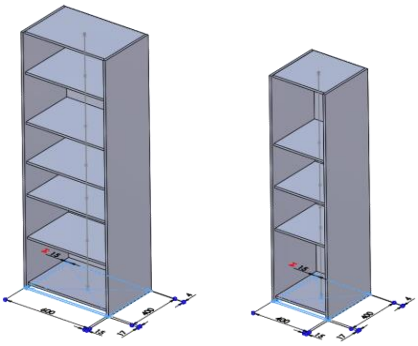

Fig. 1. Framework controlling the dimensions of the assembly model

- parameters that can be defined using numerical or descriptive values, depending them on model dimensions, operating states that create model geometry, global variables, materials and their properties;

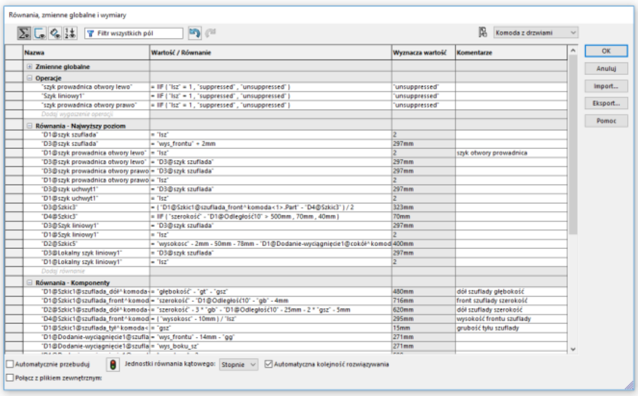

Fig. 2. Interface for programming the CAD model in SOLIDWORKS

- "equations" enabling defining dependencies based on (fig. 2): dimensions contained in parts and assemblies, global variables, file properties, mathematical functions and the results of other mathematical relations;
- "configurations", which are a tool for generating multiple versions of a given part or assembly within a single file (through the use of "configuration" you can get a family of models with different dimensions, parameters, properties, states of operations creating model geometry, materials and appearances; "configurations" in assembly files, you can develop product families using various configurations of components, dimensions and parameters for "assembly operations" or appropriate properties, there are three ways to create a "configuration" in SOLIDWORKS: manually, using a dialog box or configuration table developed in an MS Excel spreadsheet);
- special tools for modeling welded structures and parts made of sheet metal, but also useful in the case of furniture design, due to the automated trimming and lengthening of solid objects and obtaining information from the changing geometry of the model (fig. 3);

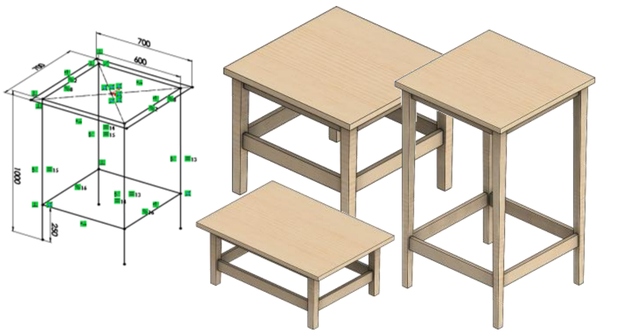

Fig. 3. Model of bar table made with the use of "welded constructions" and "sheet metal" tools

- open API (application programming interface) - an in-app programming interface that allows you to create scripts in the following languages: VB, VB.NET, VBA, C++, C#.NET, C++.NET, using SOLIDWORKS objects, functions, methods and procedures.

When building models for various types of furniture - including dressers, desks, bookshelves, kitchen furniture sets - assumptions limiting the possibilities of auto-generation were adopted (figs. 4-6).

Control parameters: height, width, depth, thickness of side panels, thickness of shelves, number of shelves, plinth height, number of middle panels, thickness of the back panel, rear panel offset;
Configurations: single-segment, multi-segment, multi-segment with plinth, multi-segment with door, multi-segment with furniture wheels

Fig. 4. Auto-generative model of the bookcase

Control parameters: height, width, depth, thickness of side panels, thickness of shelves, number of middle panels, plinth height, back panel thickness, rear panel offset;
Configurations: with a simple top, with a rounded top, with drawers, with a simple top and a fixed segment width, with a rounded top and a fixed segment width

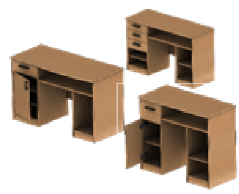

Fig. 5. Auto-generative model of the desk

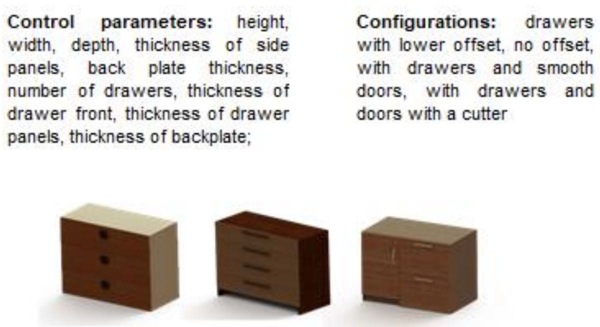

Fig. 6. Auto-generative model of the dresser

In order to be able to control the geometry of the model, parameters were defined for each of them, assigning them, in turn, the appropriate constructional features of the furniture with the determination of the dependencies occurring between them. Thanks to this, a specific modification of the parameters, while maintaining the relationship assumptions, results in the replacement of the model's geometry and the generation of a new variant of the furniture. In order to control the value ranges of individual parameters in a controlled and easy way, the interface in VBA was programmed for the auto-generative model of co-modulus (fig. 7).

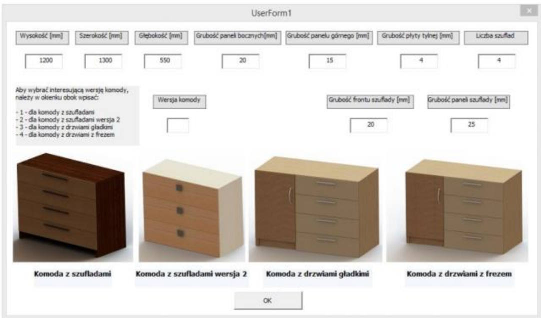

Fig. 7. Interface controlling the auto-generative model of a dresser

Conclusions

The auto-generative simulations of various types of furniture carried out as part of the research have confirmed that 3D integrated modeling is possible in 3D CAD SOLIDWORKS. What's more, it has been shown that model-autogenerating not only facilitates the work of the constructor, but should be its basic tool in the design process of furniture, and especially of the box furniture. This is due to the specific features of the structure, i.e.:

- defined forms of components,
- existence of fixed sets of configurations within a single class of structure,
- significant share of routine and repetitive activities of the design process of this type of products.

The discussed modeling gives the designer an opportunity to immediately introduce corrections, resulting, for example, from a change in project requirements or renewals at the client's request, which significantly affects the costs and production time of a given product.

It should be noted, however, that the development of the integrated model is labor intensive, because it is necessary to go through all phases of knowledge-based modeling, i.e.: acquiring knowledge, formalizing it, and then implementing it to the CAD model. In addition, the scope of the model being developed depends on the "amount" of knowledge to be introduced and the limitations applied. However, as a rule, the use of the auto-generative model in the design process facilitates and accelerates the construction of, above all, elements with the same basic structure, but differing in the values of individual constructional features. Therefore, before commencing design works, one should make a profit and loss account from the development of an auto-generative model.

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