DEVELOPMENT OF THE AUTOMATED SYSTEM FOR DESIGN SOLUTIONS' ANALYSIS AT CAD KOMPAS - 3D *

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This paper presents an automated system for CAD KOMPAS-3D-based design solutions' analysis and its main operation modes. The method of a structural-parametric analysis for CAD KOMPAS-3D-based design solutions is proposed. An algorithm of forming a sequence of optimal design operations is developed. An example of the design solution's analysis based on a specific detail performed at CAD KOMPAS-3D is given.

1. Introduction

There are various analysis subsystems in the computer-aided design of engineering objects, for example: a strength analysis. It consists of static calculation, stability calculation, calculation of natural frequencies and modes of natural oscillations, calculation of stationary thermal conductivity and thermoelasticity; the analysis of the dynamic behavior of machinery and mechanisms; subsystems for checking compliance with the design standards (the

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distance between dimension lines, a text arrangement, intersections in the dimension line, line styles and ticks, etc.), compliance with the company's restrictive lists (valid roughness values, quality grade, threads, etc.) , compliance with the rules on working in CAD (manual dimensions input, linking the position designation to the specification, the use of an axial object not lines with the axial style, etc.); calculation of dimensional chains and springs; optimization of gearing; selection of electric motors, reducers and coupling. At the same time, there is no analysis of designers' actions in CAD.

In practice, the project activities for developing 3D model engineering objects often encounter operations executed by designers, which lead to suboptimal design solution (in terms of the quantity and sequence of design operations). As a result, the design solutions' tree and the automated programs for CNC machines become complicated (unnecessary operations make these programs more complex).

CAD (KOMPAS, INDORCAD, Autodesk Inventor [1], CATIA, SolidWorks, T-FLEX CAD) and design solutions' analysis tools (KOMPAS-Expert, INDORCAD 10 [2], ANSYS [3]) are widely used in the production. There are no functions for determining suboptimal sequences of design operations. It is not possible to automatically rebuild a 3D model product based on the design solutions' analysis.

Thus, the topical task in the field of computer-aided design of engineering objects is the structural-parametric analysis of a design solution in order to identify suboptimal sequences of design operations, automatically restructure a model, and generate appropriate recommendations for a designer.

The paper deals with a new developed method of a structural- parametric analysis for CAD KOMPAS-3D based design solutions, the algorithm for forming recommendations to the designer. We have evaluated the developed method efficiency.

2. Problem

The research work describes the problem concerned with the quality improvement of engineering objects' design solutions performed at CAD.

The main objectives for developing an automated system for design solutions' analysis are.

1. Improve the quality of design solutions and simplify design solutions.
2. Increase CAD productivity by reducing the number of objects obtained in a model tree after design solutions' analysis.
3. Upgrade designers' skills and performance.

In order to achieve the above functional requirements, the following tasks have been completed.

1. A method of structural-parametric analysis for design solutions has been developed on basis of the design operations' sequence performed at CAD KOMPAS-3D, including the development of:

- models of the design operations' sequence, initial data for computer-aided rebuilding of an object 3D modeling, 3D model details, 3D model variables and parameters;
- algorithm of forming a design operations' sequence based on the design solutions' analysis [4];
- algorithm of searching for suboptimally executed design operations and their replacement by operations with fewer actions;
- rules for searching for suboptimal design operations and their replacement by operations with fewer actions.

2. The proposed models, method and algorithms are implemented as a software package.

3. Related works

In [5], the authors propose to use Siemens PLM Software's NX. It is a flagship product for CAD/CAM/CAE which offers integrated, automated design validation capabilities. Cimatron CAD/CAM software [6] designs complex details based on a mesh generation system for finite elements. In [7] describes the use of parametric control at both part and assembly levels and the ability to include technological information at all stages of product development in Creo Parametric. The end-to-end object-oriented system CADdy developed by the German company Ziegler (DataSolid GmbH) [8] provides standardization and unification of design solutions based on parameterization. In [9], the CATIA system is represented as a system that can effectively perform all product design engineering tasks: from conceptual design to drawings, specifications, wiring diagrams and control programs for CNC machines.

A common disadvantage of the above research works is the lack of search function of suboptimal sequence of design operations and automatic rebuilding a three-dimensional model of a product.

4. Solution

The method of structural- parametric analysis of design solutions is to search for design operations performed suboptimally by a designer. It differs from known methods in that the model tree of a design solution and 3D model objects' operations performed at CAD KOMPAS -3D are analyzed. The method allows designers to reconstruct the design solution's tree and to classify the products of engineering objects.

The model tree of the design solution displays a part (assembly) as a list of objects in accordance with the order in which they were designed. The History of Construction mode shows the assembly in the model tree of the design solution. This mode is used to represent the sequence of design operations, and it is used to correct operations in which the result of previous designer‘s actions influences on next ones. Each element of a model tree has certain properties and parameters: external parameters, coverage, material of manufacture, etc.

The sequence of design operations' analysis of 3D modeling objects executed in the CAD KOMPAS-3D environment is carried out on the basis of rules. The rule for the design operations' analysis consists of the following components: an operation type, a text description of the rule, a condition for triggering the rule. If the rule is found for the project operations sequence, a corresponding recommendation is given to a designer.

The initial data for CAD KOMPAS-based design solutions' analysis are the sequence of design operations performed by the designer. The model is given as:

$$PPrOperations = (Operations, TypesOperation, ParamsOp),$$

where $Operations = \{op_i | i = 1..k\}$ –a set of design operations,

$TypesOperation = \{o3d_i | i = 0..159\}$ – many types of operations at CAD KOMPAS (e.g., *o3d_fillet = 34* – the“Round” operation; *o3d_chamfer* = 33 –the “Chamfer” operation),

$ParamsOp = \{pr_i | i = 1..PR\}$ – is a set of parameters for operations with a value.

The operation model is given as:

$$Operation = (number, type, params),$$

where *number* – is the number of an operation in the operations' sequence,

$type \in TypesOperation$ – is a type of an operation,

$params \in ParamsOp$ – a list of operation's parameters with a value.

The model of the initial data for computer-aided rebuilding of a 3D model object is given as:

$$RebuildModel = (Details, Operations, Rules),$$

where $Details = \{dt_i | i = 1..k\}$ – a set of details included in the three-dimensional model of a CAD KOMPAS-based product,

$Operations = \{op \in Operation\}$ - a set of design operations,

$Rules = \{r_i | i = 1..k\}$ is a set of rules for searching for suboptimal design operations and their replacement by operations with fewer actions.

The model of details in a 3D model of CAD KOMPAS-based product is as follows:

Details = (id, class, attribute, material),

where *id* – a unique identifier of a detail,

class – a class of a detail (for example, "Ring", "Bush", "Flange", etc.)

attribute – a set of variables and parameters of a three-dimensional model,

material – material for the detail production (for example, "Steel 10 GOST 1050-88" (All-Union State Standard)).

The model of variables and parameters of a three-dimensional model is given as:

attribute = (name, value, note),

where *name* – a name of a variable or parameter of a three-dimensional model,

value –a value of a variable or parameter of a three-dimensional model,

note – a description of a variable or parameter of the three-dimensional model (e.g., "d = 24 – a diameter of a frame mounting surface")

The rule model is given as:

Rules = (template, result),

where $template = \{tpl_i|i =1..k\}$ is a first-order logic formula of searching for suboptimal operations in a design operations' sequence,

$resul\ t= \{res_i|i =1..n\}$, *res = (type, params)* – (type, params) is a set of optimal design operations (operation type, operation parameter with value), where the operation type is a constant, and the operation parameter with a value is a first-order logic formula.

The rule template in general terms has a following structure:

TPL = (id, type, txt, action),

where *id –an* identifier of a rule,

$type \in TypesOperation$ *–a* type of an operation,

txt- a description of a rule,

action - a rule's trigger condition.

Improving the quality of design solutions performed at CAD KOMPAS as well as increasing the designer's performance can be achieved through the search for suboptimally executed design operations and their replacement by operations with fewer actions.

The initial data for searching and analyzing the rules of an operations' sequence is ABC KOMPAS.

The algorithm of forming a sequence of optimal design operations consists of the following steps.

1.Start the designer's work with the project.

2. Generate operations based on an existing project (the initial data is the XML description of the assembly).
3. Add an operation to a sequence of operations.
4. Search for a rule that corresponds to an operation’s sequence.
5. Form the optimal set of operations.
6. Generate recommendations for replacing suboptimal operations based on sets of optimal and suboptimal operations.
7. Add a recommendation to the individual designer’s list of recommendations.
8. Replacing the set of suboptimal operations by a sequence with fewer actions.
9. Rebuild the design solution based on the sequence from step 8.
10. Save the design solution and display it in CAD KOMPAS.

5. Examples

Let us consider the rule of searching for suboptimal operations using the example of the "Round" operation. This rule has the following description:

"Do not use the" Round "operation for each edge individually. If it is possible, specify as many edges as possible, which parameters are the same."

Several "Round" operations with the same parameters are a condition of triggering the rule.

For example, the detail of "Casing" was considered, its model tree, prior to the design solution analysis, consists of 92 operations, 13 of which are forming operations, 72 - construction of geometric objects, and 7 - construction of sketches. The total number of actions taken in building is 395. The model tree contains 6 "Round" operations with the same parameters.

For this detail, the result of the design solutions’ analysis is the following recommendation:

«You have 6 identical operations ("Round: 5", "Round: 6", "Round: 7", "Round: 8", "Round: 9", "Round: 10"). Do not use the "Round" operation for each edge individually. If it is possible, specify as many edges as possible, which parameters are the same. This will result to 63% reduction in the number of actions.

If recommendations are fulfilled, the total number of actions will decrease from 395 to 380 or by 4%».

6. Experiment

As a measure of the designer's work effectiveness [10] we choose the number of actions (design operations) performed in CAD KOMPAS-3D when building a 3D part.

In order to assess the method of a structural-parametric analysis of design solutions, we analyzed assemblies developed in CAD KOMPAS-3D. The results are presented in the summary Table 1.

Table 1. Results of the analysis of product assemblies.

Assembly	Number of operations	Number of actions	Number of recommenda tions	Relative value of reducing the number of actions,%
Pump	830	3578	16	3,0%
Reducer	220	913	2	1,1%
Block	318	1330	7	4,0%
Suspension	937	3967	6	1,1%
Hud	162	742	4	1,0%
Assembly 1	46	212	3	20,8%
Assembly 2	123	542	1	3,1%
Assembly 3	58	287	1	5,9%
Assembly 4	119	552	3	3,4%
Assembly 5	1425	6075	6	0,9%
TOTAL	4238	18198	49	4,4%

The developed method of a structural-parametric analysis allows us to reduce the actions number performed by the designer on average by 4.4%.

7. Conclusion

The models of a design operations' sequence, initial data for computer-aided rebuilding of a 3D model object, details, variables and parameters of a 3D model are proposed.

Using the proposed models, we have developed a method for a structural-parametric analysis of design solutions based on the designer's action flow at CAD. It allows designers to increase their performance, as well as to improve the quality and simplify CAD-based design solutions.

References

1. T. Kishore, Getting Started with Autodesk Inventor 2018, *In book: Learn Autodesk Inventor 2018 Basics.*
2. V. Boykov. N. Mirza, D. Petrenko, A. Skvortsov IndorCAD 10 as BIM-tool for project analysis and conflicts detection. doi: 10.17273/CADGIS.2015.2.16

3. M. K. Thompson, J. Thompson, Interacting with ANSYS, *In book: ANSYS Mechanical APDL for Finite Element Analysis*.
4. A. Afanasyev, N. Voit, D. Kanev, Development of expert systems for evaluating user's actions in training systems and virtual laboratories, in *Proc. of The 11th IEEE International Conference on Application of Information and Communication Technologies (AICT-2017)*, (Moscow, Russia, 2017).
5. *NX for Design: Advantages and Benefits* (2018). https://www.plm.automation.siemens.com/en/products/nx/for-design/advantages-benefits.shtml.
6. *3D Systems Software* (2018). http://www.3dsystemssoftware.it/ShowProduct.aspx?ID=Cimatron.
7. *3D CAD Software Creo PTC* (2018). https://www.ptc.com/en/products/cad/creo.
8. *CADdy++ mechanical professional* (2018). http://english.datasolid.com/products/caddy-mechanical-design/caddy-mechanical-design-professional?showall=&start=1.
9. *CATIA Engineering* (2018). https://www.3ds.com/products-services/catia/products/v6/portfolio/d/digital-product-experience/s/catia-engineering/.
10. A. Afanasyev, N. Voit, I. Ionova, M. Ukhanova, V. Yepifanov, Development of the Intelligent System of Engineering Education for Corporate Use in the University and Enterprises. *In book: Teaching and Learning in a Digital World* (2018). doi: 10.1007/978-3-319-73210-7_84