MODELLING OF MECHANICAL ASSEMBLY STRUCTURE IN CAD ENVIRONMENT USING THEORY OF BASING

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Abstract. In this work the authors' concepts about modelling of structure of mechanical assembly, aimed to creation of an integrated CAD model, as well as reached results are presented. The model of structure is formed in virtue of the approach, developed by authors for integration the conceptual representation of geometry on level "structure" with the final geometrical model in CAD environment. An extended structural scheme, that includes the all components of the assembly and relationships between them, is used as an integrating element. This structural scheme is loaded up with additional engineering information that includes basing scheme of each component according to Theory of basing. This engineering information is used in the next stages of design process as embodiment design and creation of CAD assembly model.

The general principles of developed approach are: the structural scheme contains information about basing schemes of components and this extra information guarantees to stand by some of main suggestion of design theory in a formal manner; there are defined rules that allow part skeletons to be generated from the mentioned structural scheme in a formal manner; the part skeleton is used as base, on which part geometry is shaped up; there are originated formal rules that permit the definition of basing schemes to be transferred to CAD assembly model as geometrical constraints.

Key words: modelling, CAD, structure, assembly unit, basing

1. Introduction

Notwithstanding of attempt for an automaton of conceptual design, the results of conceptual stage don't be used directly in the embodiment design. Usually, the conceptual model is represented in symbolic form, as block chart or as graph model [3, 6]. Such kind of models doesn't allow achieving high level of automation in passage from conceptual model to embodiment design [5]. The consequences are decreasing of CAD effectiveness and increasing of tedious work respectively.

While CAD model of the assembly unit is created, the matting constraints usually are set formal, one doesn't give any meaning that descends from functions of different components. The structural scheme, which is created on conceptual stage of design process, usually represents abstract descriptions for relationships of kind of "is part of" or it is a hierarchical structure that doesn't carry information for the core of relationships between components [2, 4]. So, the investiture, still on the stage of conceptual design, with an engineering knowledge for the relationships character in the founded model and to use them in embodiment design, is a condition for integrating conceptual model with geometrical description of product [7].

As result of the precede investigations [7, 8] an approach for integrating results from stage of conceptual development of geometry on level "structure" with stage of final embodiment design in a CAD environment is developed. In accordance with this approach the structural scheme is loaded with extra engineering information, which includes basing schemes of parts under the terms of Theory of basing [1]. This engineering information is used in the next stages of embodiment design of parts and creation of the CAD assembly model.

The general principles of developed approach are as follows:

- the structural scheme incorporates information on basing schemes of parts; this additional information guarantees to stand by with some of main suggestion of design methodology in a formal manner;
- there are defined rules, which allow part skeletons to be formal generated from the so created structural scheme; the part skeleton serves as base for its embodiment design;
- there are created formal rules, which permit the basing scheme definitions to be transmuted as mating constraints in the CAD assembly model.

In this work the authors' visions on the further improvement and realization of mentioned approach through development a model of the structure of an assembly and a software implementation, aimed to building an integrated CAD model of product, are exhibited.

2. Description of structure of a mechanical assembly using Theory of basing

To introduce the description of structure of a mechanical assembly using Theory of basing, there will be quoted an example from [7].

Figure 1 shows exploded view of an assembly. The parts are noted as C_1, …, C_5. The process for formation of assembly structure, in accordance with mentioned approach, is shown on Figure 2. The symbols of Primitive (P) and Macros (M) are on the figure. Theirs meaning are:

Primitive (P) – a generalization of term part. The primitive is one or more assembled parts,

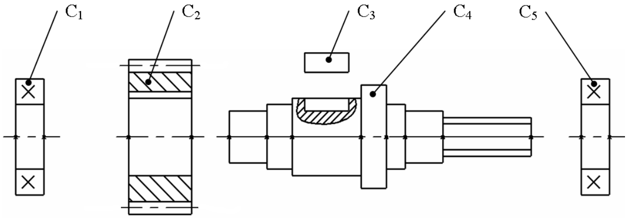

Fig. 1. An assembly unit (redrawn from [7])

which is considered as single component on the logical level.

Macros (M) – a primitive that includes two parts at least. Through trace of structural recursion, with which it is obtained, the full staffs of the macros is revealed as well as relationships that define theirs mutual disposition. These relationships are acquired through decomposition of complementary set of principal and subsidiary bases ant they specify relation "adjacency" and "hierarchy" between surfaces (the form elements) of the macros parts.

In [8] the rule ***R*** for building of a mechanical product structure is laid down as (with small emendation): "*Towards each basing primitive on particular level, in conformity with its sets of subsidiary bases and corresponded basing schemes, are based (assembled) one or more primitives from all the rest lower levels with appropriate sets of principal bases.*"

The structure of an assembly is formed in accordance with the next procedure [7]:

1. On "zero" level, parts (named primitives) are divided in two multitudes:
   - multitude "Basing primitives" (with sets of both principal and subsidiary bases);

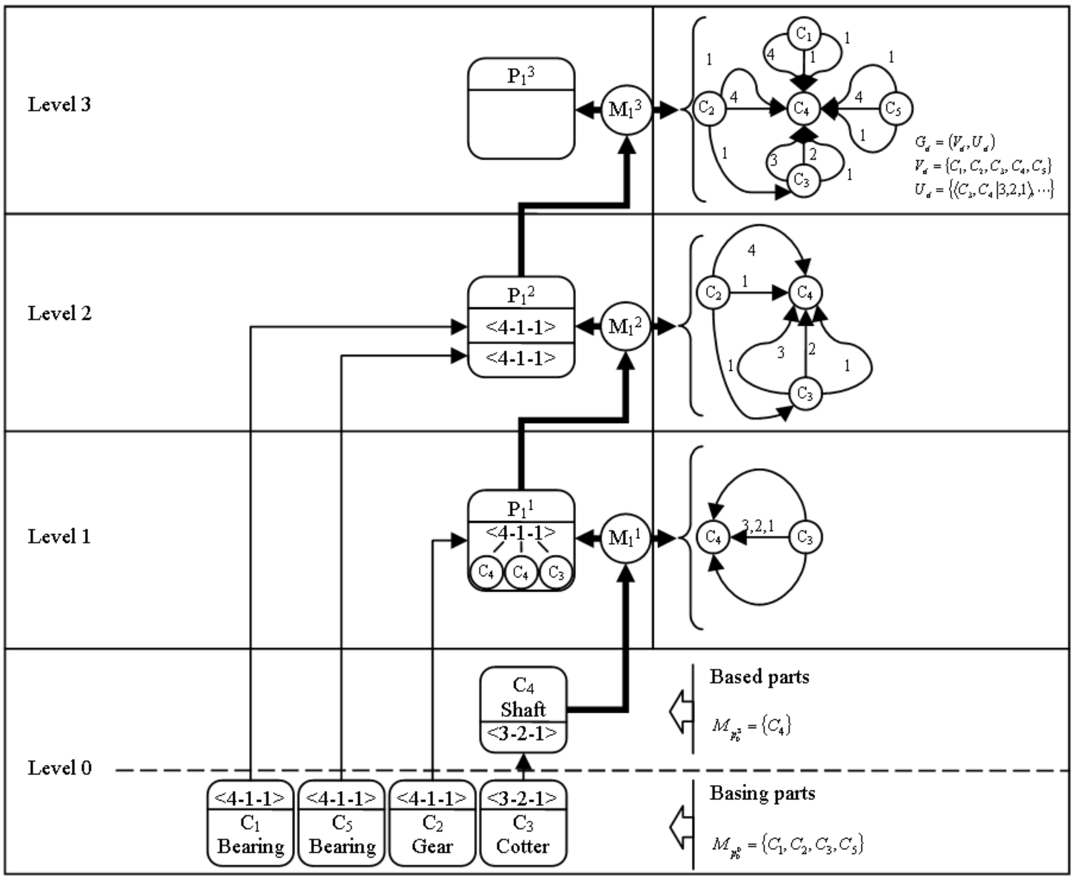

Fig. 2. Forming structure of macros for the assembly unit on Figure 1 (redrawn from [7])

- multitude “Based primitives” (with sets of only principal bases).

2. Towards every basing primitive in accordance with its set of exported features of kind “set of subsidiary bases”, the primitives that own corre-sponded “set of principal bases” is assembled.
3. The assembled through its complementary basing sets, basing and based primitives constitutes a new primitive, for which sets of primary and subsidiary bases are specified (the multitude of primitives are renewed).
4. On each upper level the available primitives are analyzed and the rule ***R*** for structure formation is performed.
5. On the last level the final primitive – the product is built. The product owns only a set of principal bases, by which it bases on environment (engine seating, foundation and etc).

The described procedure may be generalized as ***structural recursion***, fulfilled on arbitrarily *j*-th level, for which:

- the sets of basing and based primitive are defined;
- the rule ***R*** is performed.

On Figure 2 the primitives with symbols C_1, ..., C_5, P_1^1, P_1^2 , P_1^3 and the basing schemes with degrees of freedom, which the corresponding base is taken, are shown in rectangular frames. The basing schemes of the principal base sets are given in the upper side of the frame, while the subsidiary basing sets – in the bottom side. The macros are shown in circles and are marked with M_1^1, M_1^2 and M_1^3. The upper index of primitives and macros is the number of relevant level of structural recursion.

On the level “0” primitives (parts) are divided in two multitudes: Based {C_1, C_2, C_3, C_5} and Basing {C_4}. Let there traces the process of assembly structure, forming from level “0” (part) to level “3” (assembly unit – macros M_1^3).

On the level “0” the Cotter C_3 with principal bases <3, 2, 1> is connect with subsidiary bases <3, 2, 1> of Shaft C_4. The result is the macros $M_1^1 = \{C_3, C_4\}$.

On the level “1” the macros M_1^1 is looked at as primitive P_1^1 with set of subsidiary bases <4, 1, 1>. Towards him the part C_2 Gear with principle bases <4, 1, 1> is connected. The result is the macros $M_1^2 = \{C_2, C_3, C_4\}$.

On the level “2” the macros M_1^2 is looked at as primitive P_1^2 with two sets of subsidiary bases <4, 1, 1 >, to which the Bearings C_1 and C_5 are assembled through relevant complementary principal bases. The result is the macros $M_1^3 = \{C_1, C_2, C_3, C_4, C_5\}$.

On Figure 2 on the right, for each macros is shown its structure of parts that belongs to them. On the figure the relationships between parts also are shown. The relationships are loaded with taken degrees of freedom, which agree with the basing scheme.

3. Towards the implementation in a CAD environment

To make possible the implementation in a CAD environment, the mentioned approach for modelling of assembly structure will be elaborated in direction of concretization of theoretical outcomes and then binding them by an exist CAD system. As a result a software implementation will be created as an add-on for the CAD system. Thus the CAD system functionality will be extended towards modelling of mechanical assembly structure. The extended functionality will allows the CAD environment to integrate both conceptual design and embodiment design of parts as well as assembly unit.

The implementation includes solution of the next tasks:

- move from terms in the Theory of basing problem domain to terms in the CAD problem domain;
- design of user interface to mentioned model of assembly structure;
- implementation of the add-on of CAD system that fulfils user interface and that integrates the model of structure with the geometrical models of parts and assembly.

We plan to use the CAD system SolidWorks [9] for implementation of the developed theoretical model of structure. SolidWorks is a comparatively new CAD system, but it has rapid development and obtains more and more popularity.

The SolidWorks functionality covers the minimal requirements for implementation of the approach, namely:

- permits to be created abstract parts (parts without geometry), which may be included in assembly model;
- permits to be defined abstract geometry in form of geometrical datums, as axes and planes;
- permits in CAD model to present non-graphical information in form of attributes.

SolidWorks offers programming interface (API) for purpose of add-on making. The programming interface is offered in two, actually equivalent, variants – VBA (Visual Basic for Application) interface and C++ interface. VBA is incorporated in SolidWorks and gives a bigger flexibility. The experimental character of work is a reason, there to have a preference to VBA.

On the grounds of reached results and gain experience in this field there may be outlined the stages of progress of this work.

The first stage includes concretization of the theoretical model of structure with basing schemes with respect to SolidWorks features. The next tasks are envisaged:

- analysis of SolidWorks features concerning to define and work with abstract geometrical objects and non-graphical information;
- representation of terms of Theory of basin as fulcrums, primary bases, subsidiary bases, hidden bases, set of bases and etc. through primitives of SolidWorks;
- expression of parts basing, in the sense taken of degree of freedom, by means of constraints, which may be imposed in SolidWorks.

The second stage includes development of user interface to the model of assembly structure with basing schemes. Since the aim is to build an integrated CAD environment, the interface is design only with means, offered of SolidWorks, and incorporates the next:

- creation a comprehensively description of user interface: input, output, control, support, ready-to-use solutions;
- analysis of SolidWorks API with view of possibilities for implementation; probably adjustments in preliminary designed user interface, if there lacks way of realization.

The third stage includes the creation of the add-on for SolidWorks, which implements the specify user interface and realises integration of the model of structure with the parts geometrical models and the assembly model. On this stage we have the intention to make an analysis of the usefulness of the created integrated CAD environment.

4. Conclusions

The fulfilment of project tasks will lead to development of a model of the structure of mechanical assembly that includes basing schemes of parts. The created model will be described with means of contemporary CAD systems, which permits its implementation.

In the applied aspect an implementation of CAD environment will be created that integrates the model of product structure, which is developed on conceptual design stage, with its geometrical model. The implementation will be made as add-on for SolidWorks.

At last the directions for future investigations will point on. One of them is the development and the extension of the model of structure with a view to solution of wide range tasks that are bound with an analysis of the structure of the mechanical product. In the first place there is taken in account the task for analysis of dimensional structure and tasks, bounded with assembling process planning (assembling sequence, assembling scheme).

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