AN APPROACH TO INTEGRATE RESULTS FROM CONCEPTUAL DESIGN INTO CAD

***Abstract**: In this work it is assumed that the results of the conceptual design are presented in the form of extended structural scheme. The structural scheme allows to be supplemented with information that specifies the important decisions which secure the expected functionality of the product. There is a propounded approach to integrate structural scheme, loaded with additional design information, into CAD model. This approach allows to automatically generate CAD models of parts that include skeleton models and mechanical interfaces as well as CAD model of assembly in finished state. This way more realistic CAD models containing the actual geometric relationships between the components would be created. On the other hand, the decisions taken at the conceptual design stage are automatically transferred to the CAD model, which reduces the treadmill work associated with its creation.*

KEYWORDS: EXTENDED STRUCTURAL SCHEME, ASSEMBLY MODEL, CAD SYSTEM, CONCEPTUAL DESIGN

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1. Introduction

When mechanical products are designed there are generally meant to perform two main tasks:

- redesign of existing designs aimed at meeting the changed requirements;
- develop new products.

CAD systems offer tools for easy and fast changing of the geometric models of products as well as creating multiple configurations. With these characteristics, they provide a high level support for designers in solving problems of the first group.

With regard to the tasks of the second group, CAD systems can be used in the later stages of the design process, during which the final geometry of the product is created. The main obstacle CAD systems to be not enough useful during the conceptual design is they do not offer adequate support of abstract objects, that is, object which geometry is not yet defined. This is a reason results from conceptual design stage to be not fully integrated with the CAD model, which hinders the automation of the entire design process and increases the volume of the treadmill work which must be performed by the designer.

In this work is propounded an approach which allows the outcomes from conceptual design stage to be integrated into CAD model. This approach covers decisions connected with embodiment design such as positioning parts in the assembly and harmonizes mechanical interfaces between them.

2. Literature survey

There are many scientific studies which offer different representations of mechanical product which are designed to solve specific problems. According to [1] traditionally information about an assembly it is represented by directed or undirected graphs which represent components of the assembly and their relations. This is a compact representation of an assembly, but the information is not sufficient for the purposes of the study (assembly sequence planning). Therefore, it is considered a model that contains complete information about the assembly. As an advantage could be considered the possibility to convert and analyze the model by matrix operations. Definition of a single level of abstraction is a disadvantage. Lack of engineering information restricts the use of this model on the more abstract stages of design process such as conceptual design. Information about physical surfaces is also not available which prevents the model to be specialized to the level that makes generation of a CAD model possible.

In [2] are addressed issues which hinder closer integration of activities related to the development of a new product – from conceptual design to planning of its manufacturing. Various models are analyzed and their drawbacks in terms of integrating product data are outlined. The requirements for systems that manage product data throughout the design process, aka PDM systems, are formulated.

A model of connection in the product is suggested. A classification of mechanical relationships in the assembly is made as well as the rules for their creations are defined. The model supports various levels of abstraction and allows reuse of definitions that are entered at different stages of the life cycle.

The presented model includes basic information about the links between components of an assembly and it is focused primarily on the representation of the assembly sequence. From the viewpoint of developing geometric model of products there are have to be different levels of representation of the geometry which may be considered as flaw of the model under consideration.

In [3] the issues related to cooperative design within a large design project are examined. The main point of investigation is how to secure reliability of geometric description when inconsistent changes are made by various professionals that are involved in the design process. A model has been offered which allows to monitor the changes made and consequently to restore the consistency of the overall geometric data.

The model under consideration comprises the geometric description at low level and it is designed primarily to manage the proliferation of the changes. From the perspective of the entire design process this model may be part of a broader description that includes all levels of abstraction of product that is designed.

In [4] a geometric model that covers the conceptual stage of the design process is proposed. The basic idea is the skeleton of the assembly created in virtue of assembly sequence that is developed during the conceptual design stage. The skeleton is composed of abstract geometric elements and imposed on them geometric constraints for positioning.

The proposed in [5] approach is similar to those of [4]. The difference is in the abstract model the basing schemes of components are used for their positioning instead of mathematical geometric constraints. In that way geometric model contains engineering information that enables an analysis of positioning of components in the assembly from a functional perspective to be made.

The developed model offers a uniform description of the geometry of mechanical products at all stages of the design process – from abstract representations on the stage of conceptual design to final geometric delineations furnished by CAD systems. Therefore, this model was adopted in the subsequent reasoning.

3. Design process and CAD

The “top-down” design approach follows the natural course of development of the project – at first the requirements for the product are defined, which subsequently are specified to the establishment of its geometric model. The information flow in this case is shown on Fig.1. The figure shows only major stages that are directly related to the creation of the geometric model.

During the conceptual design there have been developed various schemes and conceptual drawings which help to specify mechanical interfaces of the parts and their positioning in the assembly. This information serves as a basis for developing CAD model at the stage of embodiment design.

Concerning the creation of abstract geometric model, CAD systems most often offer functionality as follows:

- model of an assembly can contain parts without defined geometry;
- can be created abstract models of parts, which are composed of reference geometry (skeletal parts);
- canbe imposed geometrical constraints on the reference geometry.

That functionality in many cases is not enough for presenting all information on the stage of conceptual design. Usually the conceptual model of a product is in a form that does not allow formalizing its transfer to the CAD model. This defines a large volume of tedious work because the information that is practically identical must be entered in the computer several times during design process.

To overcome these problems one must integrate information that had worked out at the stage of conceptual design with CAD model of the product. This would reduce tedious work associated with the creation of the CAD model and would cut back probability of errors as well as would increase information value and would allow creation of realistic models.

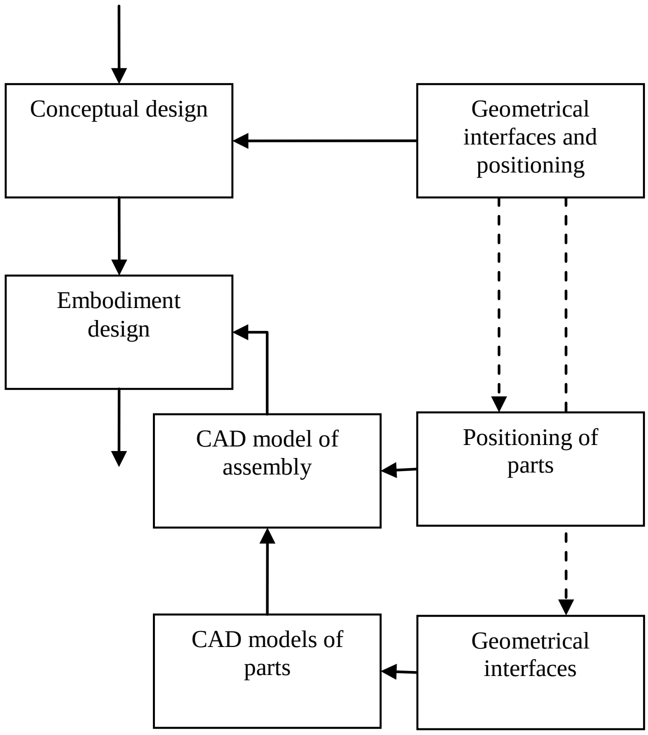

Fig.1 Information flow in “top-down” deign

4. Extended structural scheme as a way to integrate conceptual design into CAD

4.1. Extended structural scheme

In principle structural schemes contain only the basic functional parts of the product, their purpose and mutual relationship. In [5] the concept of “extended structural scheme” that contains all components of the product is introduced in order to solve problems related to embodiment design. Defined in that way, the extended structural scheme represents the concretization of the Part list of the product by adding mechanical relationships between its components.

On Fig.3 it is shown extended structural scheme of the assembly “Ring checker” – Fig.2. The scheme contains all the components of the assembly. The physical contact (contact of surfaces) between two parts is considered as a mechanical relation.

4.2. CAD model of assembly

In modern CAD systems parts geometry is defined in their geometric models. As a result, CAD model of an assembly contains no actual geometric description but only references to part models. In this case, the model of assembly is associated only with mutual arrangement of its components.

The mutual arrangement of components within a CAD model of assembly

The definition of mutual arrangement of the components within the CAD model of the assembled unit can be accomplished in two ways:

- fixing parts;
- imposing geometric constraints for orientation.

Both methods are used and the choice depends on the particular task. When parts are positioned by fixing geometric relationships between them are not created. In this case, the CAD model of assembly could be regarded as a kind of Parts list.

When the positioning of the parts in a CAD model is done by geometric constraints, the constraints impose conditions on the mutual disposition of surfaces belonging to two parts. These conditions can be regarded as creating mechanical relations between parts. This way there may define a structure of the model.

The second problem which is associated with the CAD model of assembly is how to coordinate parameters of mechanical interfaces of the parts. CAD systems offer various tools for automatic synchronization of the geometrical parameters which can generally be limited to two basic approaches:

- projected geometry;
- definition of mathematical function between them.

In the model of an assembly surfaces and edges belonging to the three-dimensional model of one part can be projected into a sketch and thereby to become elements of the model of another part. This creates associativity between geometric features of two parts – changing the geometry of one part automatically leads to a corresponding adjustment of the geometry of the second part. As a side effect there has been accomplished automatic coordination of the parameters of the mechanical interfaces. A disadvantage of this approach is that a sophisticated geometric model has been created and as a result of which problems may arise in subsequent modifications of the construction. There are also ~~are~~ troubles when one and the same part is used in different assembly models.

CAD systems allow to define mathematical functions (mathematical expressions) than involve parameters in the model. This way geometric parameters can be maintained in accordance with the required functional requirements. The concordance of geometrical interfaces in an assembly by implementing this approach frequently leads to the indispensability of a significant number of mathematical expressions to be defined, which is associated with a large amount of work that has to be done.

4.3. Extended structural scheme with additional information

The extended structural scheme contains names of all parts and mechanical links between them. This allows it to be loaded with additional information related to the relations in the geometric model. As previously mentioned, this information can be separated into two principal groups:

- mutual positioning of parts in assembly;
- coordinating parameters of geometrical interfaces of parts between which exist a mechanical connection.

In order to determine the positioning of parts in the assembly in [5] their scheme of basing are defined according to the Theory of basing. Here is offered the information that describes the mechanical interfaces of parts to be recorded in the extended structural scheme, which includes:

- geometrical configuration;
- mathematical equations that link geometrical parameters.

The extended structural scheme with additional information of the exemplary assembly of Fig.2 is shown on Fig.4. On the figure basing schemes are referenced through degrees of freedom that are withdrawn by the mechanical connection. Connections are directed according to their engineering meaning (based surfaces → basing surfaces). In terms of mechanical interfaces the following notations have been adopted:

- cc – cylindrical joint;
- pp – planar joint;
- cp – cylindrical surface tangent to planar surface.

On the scheme standardized threaded fasteners are considered as a part of the mechanical interface (denoted with +th).

4.4. Integration of extended structural scheme into CAD model

A similarity is shown when a comparison between the extended structural scheme of an assembly and its CAD model is made. On the structural scheme is shown a connection (mechanical interaction) between the components of the product. In the CAD model this interaction is specified with geometric constraints that are imposed between surfaces of different parts. The mentioned similarity allows unhindered integration between scheme and model.

The integration of the extended structural scheme in the CAD model assumed automatic conversion of information from the scheme in the model. With regard to the positioning of parts in [5] is shown how from defined basing schemes one would automatically generate skeletons of parts and how subsequently CAD models of assemblies are automatically created. In this case geometric constraints for positioning are imposed on reference geometry that belongs to skeleton of parts.

The mechanical interfaces can be represented as library features. In the structural scheme are defined geometrical interfaces of the two parts that form a joint and their parameters. These definitions are automatically appended to the skeletons of parts that are already ~~are~~ available.

5. Results of discussion

5.1. Extended structural scheme as conceptual description of assembly

Extended structural scheme contains only the names of the components of the assembly. It is created during the conceptual design, when the actual geometric description has not been invented. On the other hand structural scheme contains connections between components. These connections can be considered in various viewpoints and allow to assess whether the expected functionality of the device would be achieved.

The structural scheme gives an abstract idea for the finished product. This provides opportunities various aspects of the construction to be specified using the so-called conceptual sketches. The created in this way documentation provide a basis for the

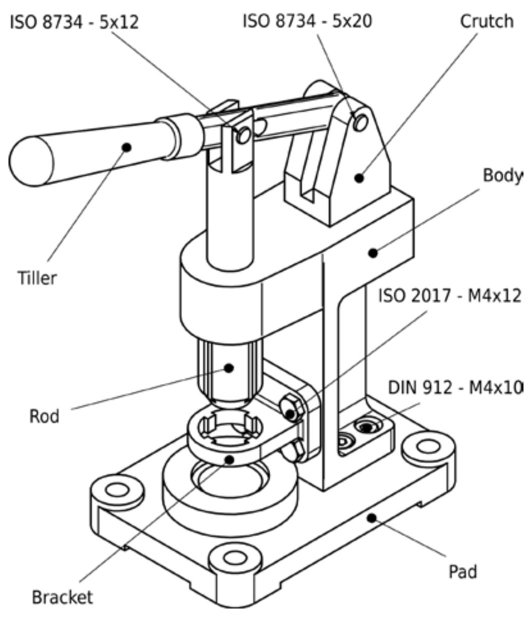

Fig.2 Exemplary assembly “Ring checker”

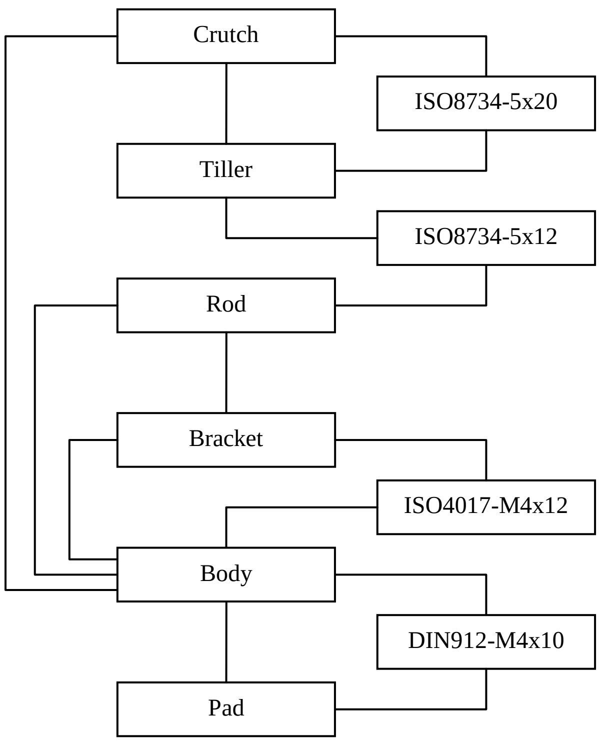

Fig.3 Extended structural scheme of the assembly in Fig.2

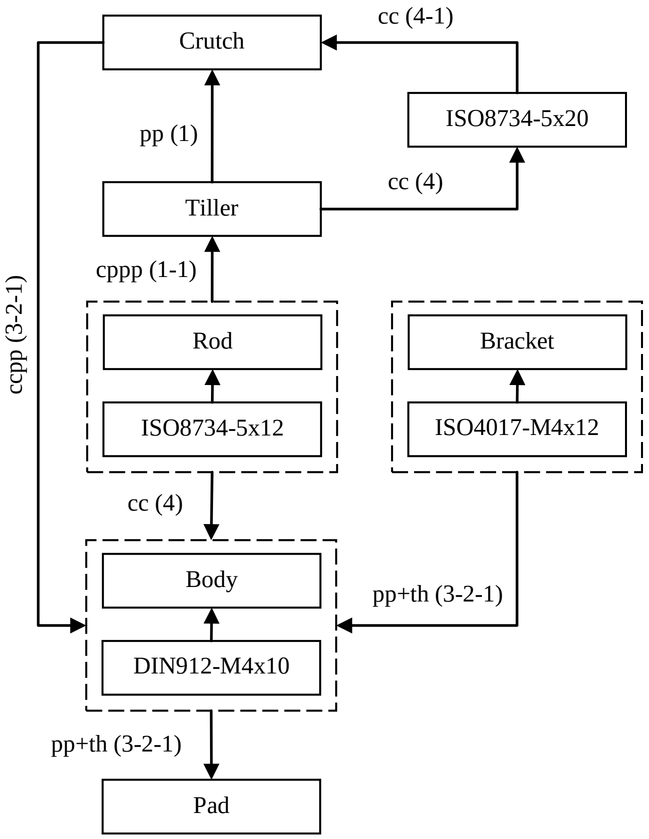

Fig.4 Extended structural scheme that contains decisions from the stage of conceptual design

embodiment design of the components during the next stages of the design process.

5.2. Imperfections of CAD model of assembly

As previously stated, there is a correlation between the structure of the CAD model of the assembly and its extended structural scheme. It should be noted that this similarity is largely dependent on the way in which the geometrical constraints are imposed. When creating a CAD model it is not necessary to set the geometric relationships that correspond to the actual mechanical links between components. In a number of cases, in order to cut down the work that has to be done to build the model or when the sequence of creating a model does not correspond to the sequence in which the product is assembled, there are imposed constraints that do not match the actual mechanical relations.

CAD models that contain no actual mechanical connections between components could create troubles when succeeding engineering analyzes are made or subsequent modifications which have to be carried out.

5.3. Approach to integrate results from conceptual design into CAD

Structural schemes can be considered as one of primary documents that are used for inventing concepts of products and making related with them important decisions that secure functionality that is specified. Because the extended structural scheme contains all the components and relations between them, it can be loaded with additional information and thus to become a framework containing the results of the stage of conceptual design.

Correspondence between information contained in structural schemes and CAD models allows their easy integration. The extended structural scheme is a higher level of abstraction of the assembly compared to its CAD model. When any decisions taken at the stage of conceptual design have been specified, it is automatically transferred to the CAD model. The outcome is a reduction of the volume of tedious work associated with developing the CAD model, creating a more realistic model and reducing opportunities for mistakes. The outcome is a reduction of the tedious work associated with developing CAD models, creating more realistic models and reducing opportunities for mistakes.

6. Conclusion

Structural schemes are developed on stage of conceptual design. The extended structural schemes may be supplemented with additional information that specifies the important decisions which provide the expected functionality of products.

There is a correspondence between the information contained in the extended structural schemes and CAD models. The structural schemes do not include geometrical information and therefore can be regarded as a higher level of abstraction of assemblies relative to their CAD models.

The extended structural schemes can easily be integrated with CAD models of assemblies. This way CAD models containing the actual geometrical relationships between the components have been created, which makes them more realistic. On the other hand, the decisions taken at the stage of conceptual design are automatically transferred to CAD model thereby the volume of treadmill work associated with their creation.

7. References

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