APPROACH FOR GENERATION OF EXTENDED STRUCTURAL SCHEME FROM CAD MODEL OF ASSEMBLY

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Abstract: *After the creation of a CAD model there may be required to do an analysis of its applicability to solve specific tasks. The conducting of this analysis is simplified considerably if the full geometry of the components is not seen but only imposed geometric relationships between them, which are the content of the structural scheme of the assembly. This paper proposes an approach for an automatic generation of the structural scheme of a mechanical assembly from its CAD model. It should be noted that the structural scheme, considered in the conventional sense, does not contain the actual properties of geometric relationships – in the structural scheme the components are of the same type when in the fact they are divided into basing and based. Therefore, there are generated the so-called extended structural scheme that contains all components and their basing patterns.*

Keywords: *CAD MODEL OF ASSEMBLY UNIT, STRUCTURAL SCHEME, BASING OF PARTS, CAD MODEL ANALYSIS, AUTOMATIC GENERATION OF STRUCTURAL SCHEME*

1. Introduction

To create a model of an assembly today's CAD systems provide geometric constraints with which the components are oriented in the space or relative to each other. The proposed geometric constraints are in fact mathematical constraints that have no direct connection with the actual geometric relations in the real product. For these reasons, when the designer models an assembly, it creates more or less formal geometrical relationships between the components. Because it is difficult to achieve the creation of a real model, the primarily goal is to achieve high efficiency, which means to reduce the time and effort required for the technical work associated with entering information into the computer.

Along with the above, after the creation of the geometrical model a number of engineering analyzes follow, proper or even the possibility of having their implementations depend on an adequate imposition of geometric constraints for orientation. There may be listed kinematic and dynamic analysis, and creation of various animations that require a geometric model that has necessary degrees of freedom and has adequate connections between its components.

From the above it follows that when a CAD model has been created there may be necessary to make an analysis of its applicability to solve certain tasks. Performing this analysis is significantly simplified if the complete geometry of its components is not considered but only the imposed geometric relationships between them, which are the content of the structural scheme of the assembly.

This work proposes an approach for an automatic generation of the structural scheme of a mechanical assembly from its CAD model. It should be noted that the structural scheme, at issue in the conventional sense, does not contain the actual geometric relationships – in the structural scheme components are of the same type, when in the matter of fact they are divided into basing and based. Therefore, there is generated the so-called expanded structural scheme that contains all components and patterns of their basing.

2. Approach for generating the extended structural scheme

The extended structural scheme of an assembly includes the following information [1]:

– the full list of the components;
– basing patterns of the components;
– primary and auxiliary bases of each of the components.

For the creation of an extended structural scheme there is developed an algorithm based on the Method of structural recursion [2].

The structure of the model of an assembly is represented as:

(1) $S=(M, W)$,
where set M (holder) contains all components and set W (signature) – imposed geometric constraints for positioning.

There are introduced the terms:

– primitive (P) – a component that is currently being analyzed how it is orientated;
– macros (M) – a conditional assembly from a lower level that is formed at a certain stage of the analysis of the model.

By introducing the concept of primitives holder of structure M is defined as:

(2) $M=M_P^o \; \dots \; M_P^i \; \dots \; M_P^n$,
where M_P^i is a set of components of the stage "i" of the analysis of the model.

The transition to each stage of the analysis of the model is carried out by applying the formulated in [3] **Rule R,** by means of which the sets of primary and auxiliary bases are replaced with the corresponding sets of geometric constraints for positioning.

The structure of the assembly is formed in accordance with the following procedure:

On the level "*0*" the parts (called primitives) are divided into two sets:

– set of "Basing primitives" (that have sets of primary and auxiliary bases);
– set of "Based primitives" (that have only sets of primary bases).

To each basing primitive in accordance with its set of exported features of type "set of auxiliary bases" there are joined primitives with the "sets of primary bases."

Linked by theirs complemented sets of bases, the based primitives are based in form of a new primitive, which are defined its own sets of primary and auxiliary bases (the set of primitives is updated).

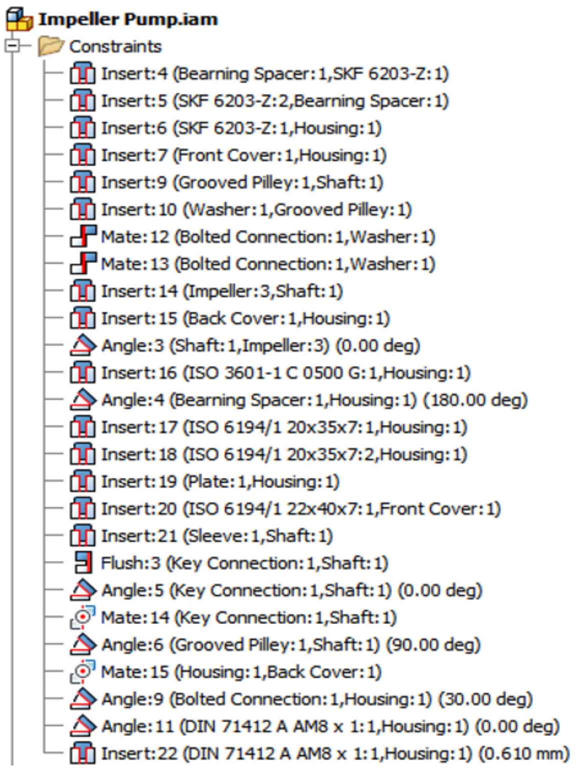

Figure 1 *Imposed geometric constraints in the CAD model of the assembly "Impeller Pump"*

On each higher level the available primitives are analyzed and the **Rule R** is performed for the formation of the structure.

On the highest level it is built the last primitive – the assembly that has only set of primary bases by which it is based in the environment (fundament, base, etc.).

The described procedure can be generalized as a structural recursion that is performed on the arbitrary level "*i*", for which:

– the sets of basing and based primitives are determined;
– the **Rule R** is performed.

In Figure 1 the graph of imposed geometric constraints in a model of an assembly is shown. If the imposed geometrical constraints meet the geometric relationship in the actual assembly, from the model can be generated its structural scheme.

Despite of the fact that the CAD system usually keeps the sequence by which the two components, which are involved in a geometric constraint, are selected they are considered as equivalent.

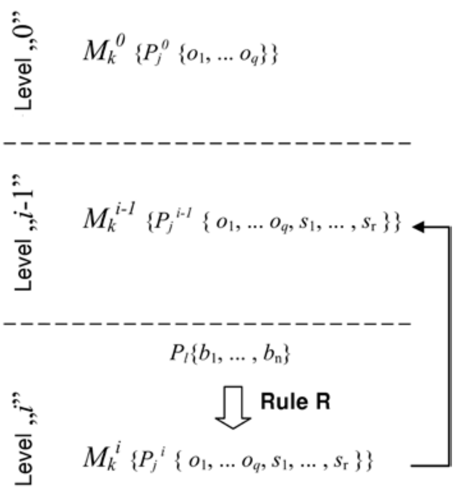

Figure 2 *The algorithm for automatic generation of the advanced structural scheme*

This means that from the CAD model cannot be made reliable conclusions about basing of parts.

For carrying out the engineering analysis of the structure of an assembly it is necessary to known how its components are based. For this purpose there must be known which geometric constraints fixate the component itself and which of them fixate other components to him. For example, on one component could have been imposed a number of geometric constraints for positioning, but it does not follow that the part is over constrained i.e. there are an availability of redundant geometric constraints.

The method of structural recursion is intended primarily for creation of the extended structural scheme of a mechanical product during the stage of the conceptual design. This work will illustrate an application of this method to recover the sequence of forming the structure of an assembly and the determination of the primary and auxiliary bases of the parts from the CAD model.

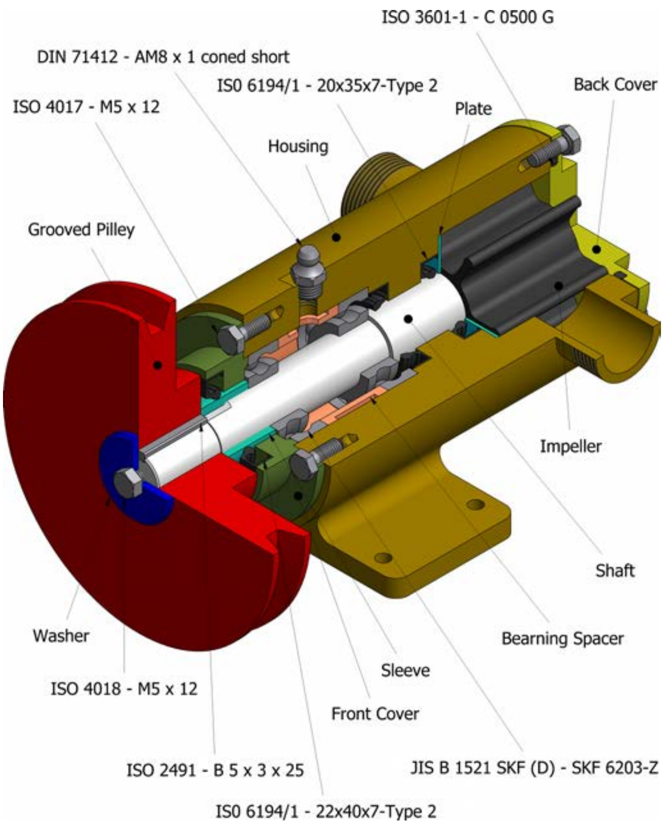

Figure 3 *CAD model of the assembly "Impeller Pump"*

With assumption that the geometrical constraints for the positioning of parts in the CAD model are imposed on the basing surfaces of the primitives, the definition of the primary and auxiliary bases is performed by the following procedure:

– from formal analysis of the CAD model for each primitive *Pj* are determined basing surfaces (surfaces over which geometric constraints are imposed) – $Pj\{b_1, \dots, b_n\}$;
– at the level "*i*" of the formation of the structure, the imposed geometric constraints between surfaces of the macro M_P^{i-1}, that is formed on level "(*i-1*)", determine the basing surfaces of the primitives P_k^{i-1} based on that level. So based surfaces of P_k^{i-1} are divided into primary, marked with "*o*" and auxiliary marked with "*s*" – P_k^{i-1} $\{o_1, \dots o_q, s_1, \dots, s_r\}$.

At level "*0*" the macro M_k^0 includes all fixed in the CAD model parts that have only main bases.

The proposed algorithm is illustrated in Figure 2.

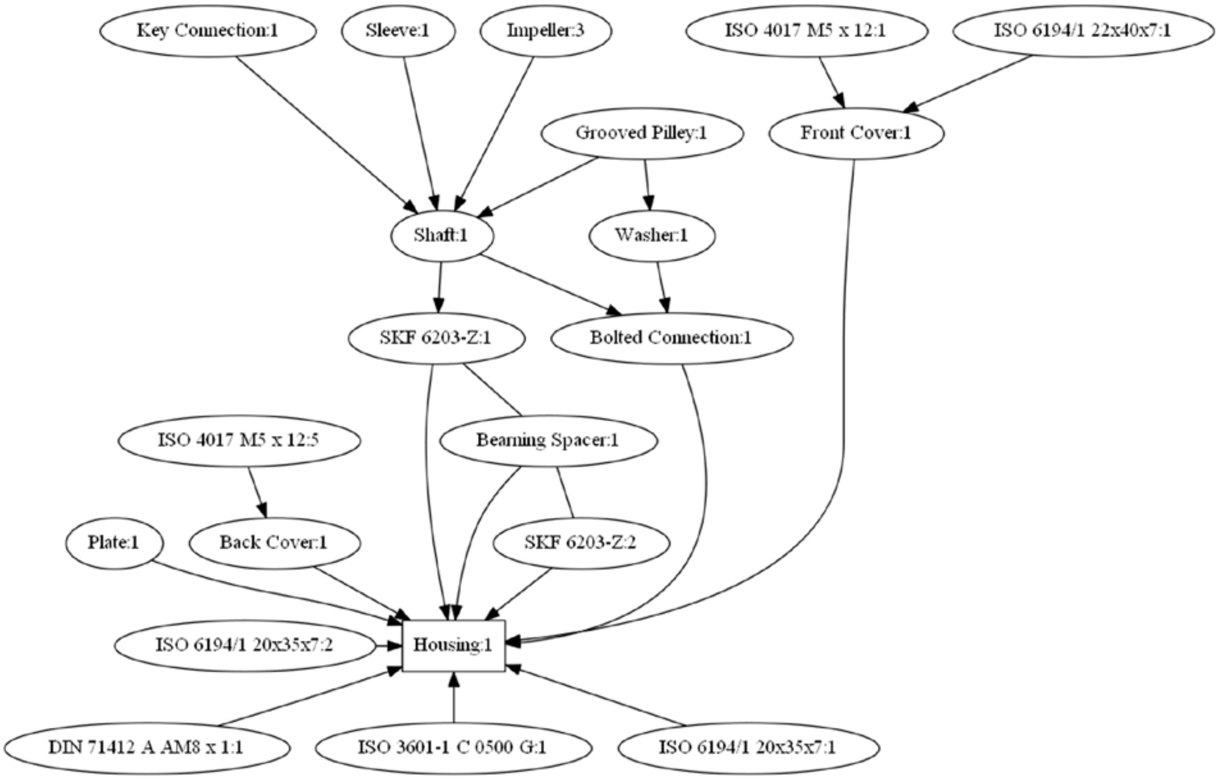

Figure 4 *Automatically generated extended structural scheme of the assembly in Figure 3*

3. Practical implementation

In order to verify the theoretical foundation it is made a practical implementation of the developed algorithm. A practical experiment was done with Autodesk Inventor, and for this purpose a VBA program is contrived, that performs the algorithm in Figure 2.

The created program has the following functionality:

– creates a list of all fixed components;
– creates a list of all pairs of parts over which geometric constraints for positioning are imposed;
– with extracted from the CAD model data performs the algorithm in Figure 2;
– the extended structural scheme is visualized using the package Graphviz [4].

As seen in Figure 1 on a pair of parts may be imposed more than one geometric constraint. This work does not take into account the type of restrictions, but the presence of geometric relationships between parts. Therefore, circumstances as this are ignored.

Experimental researches have been made with a random existing CAD model of an assembly, in this case the product “Impeller Pump” shown in Figure 3. Geometric constraints imposed in the model are illustrated in Figure 1. The structural scheme, automatically generated according to the proposed approach, is shown in Figure 4. On the structural scheme the arrows point from based to basing surfaces of parts.

4. Outcomes

An analysis of the automatically generated structural scheme in Figure 4 shows good consistency with the engineering meaning of the imposed relationships. Along with this there are also some exceptions.

It may be noted as an exception the relationship "Grooved Pilley" $\rightarrow$ "Washer" $\rightarrow$ "Bolted Connection", as the engineering logic suggests the opposite direction of the arrows. The reason for this is the imposed “cosmetic” relationship between "Bolted Connection" and "Housing" placed for the proper orientation of the screw head when a technical drawing is created. In the actual device such geometrical relationship does not exist.

Components “SKF 6203-Z:1”, “SKF 6203-Z:2” and "Bearing Spacer" are located on the same level of structural recursion so it cannot be identified which surfaces are basing and which are based. In this case it is necessary to be accomplished a further analysis of the imposed geometric constraints.

5. Conclusion

An approach for automatic generation of the extended structural scheme of an assembly from its CAD model is proposed. The preview of imposed geometric relationships allows easy to do an engineering analysis of both the structure of the CAD model and the actual product.

6. Literature

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