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THE INTEGRATED DEVELOPMENT OF A CONFIGURABLE PRODUCT

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Abstract

This paper presents an approach to the integrated development of a configurable product as a support tool to the designer during the product development process. To realize the integrated development of the configurable product, an information model of the configuration system is extended with an information model for the geometric representation of the product assembly in the CAD system. The objective of the extension is that a structure of the product variant is automatically created as a Feature Based Design CAD model. The entities of the information model have been developed according to the STEP standard 103003-214 and represented using the EXPRESS-G notation.

Keywords: configurable product, modular product architecture, CAD, STEP

1. Introduction

Numerous differences in customers' demands force enterprises to offer a wider spectrum of product variants in order to achieve the market competitiveness. Increasing the number of different parts and assemblies leads to higher diversity of the product variants but also to higher complexity of the product. The development of a configurable product is seen as a method which reduces the product complexity, keeping the market competitiveness of enterprises at the same time [1].

The configurable product is based on the modular product architecture that is a basis of the configuration process [2]. In contemporary research reports, the development of the configurable product has been researched to a high level of the product structure. The sells-delivery process has got the full benefit of these researches [4]. The collaboration with local companies has shown that very small numbers of companies use a configuration process as a tool for the improvement of the competitiveness on the market. Most companies which use a tool for the configuration process are not even engineering companies. The situation is different in the companies oriented to the global market. They have used configuration systems integrated in the ERP systems [3], but still there is a lack of implementation of the configuration systems in the design departments of small to medium enterprises (SMEs). One of the reasons is that existing CAD systems do not support the integration between CAD and configuration systems.

There are relatively few in-depth research reports which have focused on the research of a geometrical model of the configurable product [4]. This paper presents an approach to the integrated development of the configurable product as a support tool to the designer during the product development process. To realize the integrated development of the configurable product, an information model of the configuration system [5] is extended with an information model for the geometric representation of the product assembly in the CAD system. The objective of the extension is that a structure of the product variant is automatically created as a Feature Based Design CAD model, after which the technical documentation could be completed by the tools of a CAD system. The entities of the information model have been developed according to the STEP standard 103003-214 and represented using the EXPRESS-G notation. STEP (Standard for Exchange of Product model data) is an international standard that "provides a representation of product information along with the necessary mechanisms and definitions to enable product data to be exchanged" [6].

2. Previous work

The integrated development of a configurable product is represented by two information models: information model of the configuration system [5] and information model of a geometric representation of the product assembly in the CAD system. The first one represents the structure of a product variant to the level determined by individual demands of a customer within the limitation of product architecture. All variants of a configurable product are developed from a generic product structure defined for a configurable product. A generic product structure refers to the data description that represents modular product architecture, requirements and constraints [7]. The modular architecture of the generic product structure is described by generic modules classified in three module types: working, auxiliary and secondary modules [8]. Working generic modules exist in each product variant. Auxiliary generic modules comprise product variants listed in the customer's requirements. Secondary generic modules exist in the product variant only when the working or auxiliary generic modules need some additional modules to fulfil the customer's requirements.

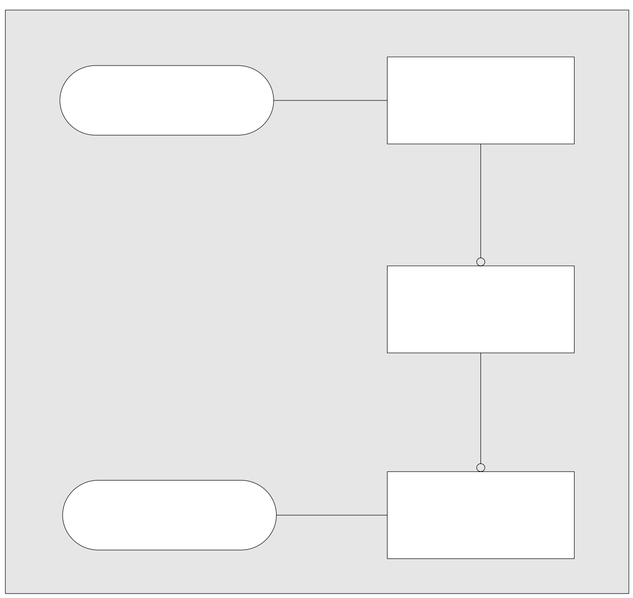

Figure 1. Entity diagram describing the structure of the product variant

The group of the entities shown in Figure 1 is described by an information model of the configuration system and represents the result of a configuration process – a structure of a product variant. The product variant is defined by the entity *complex_product* and consists of instances of generic modules defined by the entity *product_component*. The relationship between the product variant and the instances of generic modules is defined by the entity *product_structure_relationship*. This group of entities is a link to the second information model of a geometric representation of the product assembly in the CAD system.

3. Proposed information model

An information model for a geometric representation of the product assembly in the CAD system is based on the predefined assembly process in the existing feature based CAD systems. It describes an assembly model by which the geometric form is modelled based on the structure of the product variant. A limitation of the information model is related to the form of instances of the generic modules. All instances of the same generic modules have the equivalent geometric form and the differences between them are just in the scale of particular dimensions. But, an important advantage is in the geometrical representation of the product assembly for different product structures. Since the structure of the product variant is defined independently by the information model of the configuration system, the starting point for the proposed information model is a well defined structure of the product variant. Based on the defined structure of the product variant, the geometrical form of the assembly model differs according to different product structures. Therefore, the computer-aided system based on the proposed information model and described in Section 4 serves as a support tool to the designer helping him to achieve an automatic assembly process of the product variant in the CAD system. The "manual work" of the assembly process in the CAD system, a tiresome task for the designer, has been avoided.

3.1 The structure and entities of the information model

The information model is described by entities which represent the constituents of the assembly process: features of the 3D models, mates and their interrelations. The precondition for an assembly model is that each instance of the generic modules has exactly one 3D model (CAD file) made in the CAD system in which the assembly process will proceed.

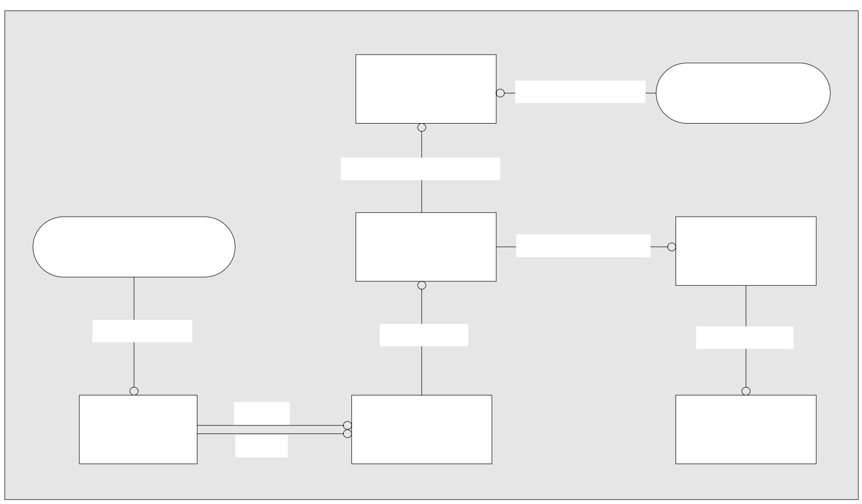

Figure 2. Entity diagram describing the features used in the assembly process

The entity *item_instance* represents the occurrence of the 3D model for an instance of generic modules. It is described by the following attributes:

- *id* – specifies the identifier of the *item_instance*,
- *definition* – specifies the name of the CAD file,
- *description* – specifies additional information about the *item_instance* (for instance, path).

The assembly model in the feature based CAD systems is defined by the features (surfaces, planes and axis) which are connected together and by the mates by which the type of connection is defined. For each instance of generic modules features of the 3D model which is used for connections in the assembly model should be defined. The entity *featured_shape* defines the shape of an item that includes a feature. It is described by the following attribute:

- *base_shape* – identifies the shape of the item.

A single feature can be oriented in many different directions in an assembly. The entity *feature_definition* defines a set of parameters and the type information representing a feature defined by the entity *feature_definition*. It is described by the following attributes:

- *is_defined_in* – specifies the shape of the feature,
- *location_and_orientation* – specifies the axis placement that defines the orientation of the feature.

Each 3D model consists at least of two or more features necessary for the assembly process. The association between the features and the 3D model is defined by the entity *shape_description_association*. It is described by the following attributes:

- *defining_geometry* – specifies the *feature_definition* that contains the shape information,
- *is_defining_shape_for* – specifies the object the *shape_description_association* is associated with.

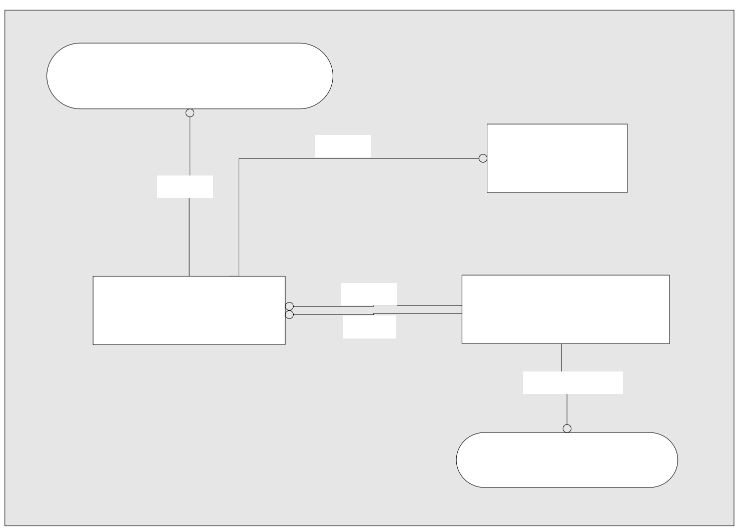

Figure 3. Entity diagram describing the mates between two 3D models

The entity *shape_element* defines the name of the connection for the feature that has to be identified and associated with another feature of a different 3D model in an assembly. It is described by the following attributes:

- *composition* – specifies the shape that the *shape_element* is part of,
- *description* – specifies additional information about the *shape_element,*
- *element_name* – specifies the word or group of words by which the *shape_element* is referred to.

In the assembly process, one connection can be realized only between two features of different 3D models. To define the connection between them, the values of the attribute *element_name* of the entity *shape_element* should be associated. That association is defined by the entity *shape_element_relationship* which defines the relationship between the two objects of the entity *shape_element*. It is described by the following attributes:

- *related* – specifies the second of the two *shape_element* objects related by the *shape_element_relationship*,
- *relating* – specifies the first of the two *shape_element* objects related by the *shape_element_relationship,*
- *relation_type* – specifies the meaning of the relationship.

The entities represented in Figure 2 are relevant for the connection of features between two 3D models. The mates between the features of the 3D models are defined by the entities presented in Figure 3. The entity *mating_definition* defines the type of mate between two features. It is described by the following attribute:

- *mating_type* – specifies the kind of mating, i.e., how the items will be mated together.

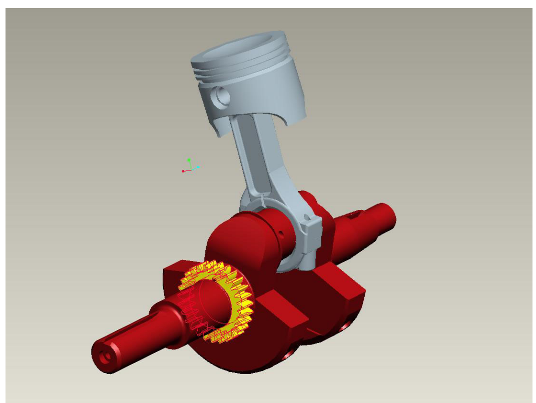

Figure 4. A test example - assembly of a crank shaft and piston

The entity *mated_item_association* defines the orientation of the mate defined by the entity *mating_definition*. It is described by the following attributes:

- *placement* – is used to orient the constituent of the *mating_definition*,
- *relating* – specifies the *mating_definition* that is a result of the mating operation.

The entity *mated_item_relationship* defines the association between the connection of two features and the mate which defines the mating type between them. It is described by the following attributes:

- *mated_shape* – specifies the *shape_element_relationship* that relates the two *shape_element* objects that form the area of mating contact,
- *related* – specifies the second of the two *mated_item_association* objects related by the *mated_item_relationship*,
- *relating* – specifies the first of the two *mated_item_association* objects related by the *mated_item_relationship.*

4. Example

A computer-aided support was developed based on the proposed information model. It consists of the entity relationship database, user interfaces and a CAD system. For experimental verification, a model of a crank shaft and a piston is used as a test example, Figure 4. The assembly of a crank shaft and a piston is used in many different types of engines. Each type of engine represents one product family. A product family in which the test example is used is for V2 engines. The test example consists of two assemblies: a crank shaft assembly and a piston assembly, Figure 5. It represents the instances of generic modules for a particular product variant. 3D models of the crank shaft and piston assemblies are made in the CAD system.

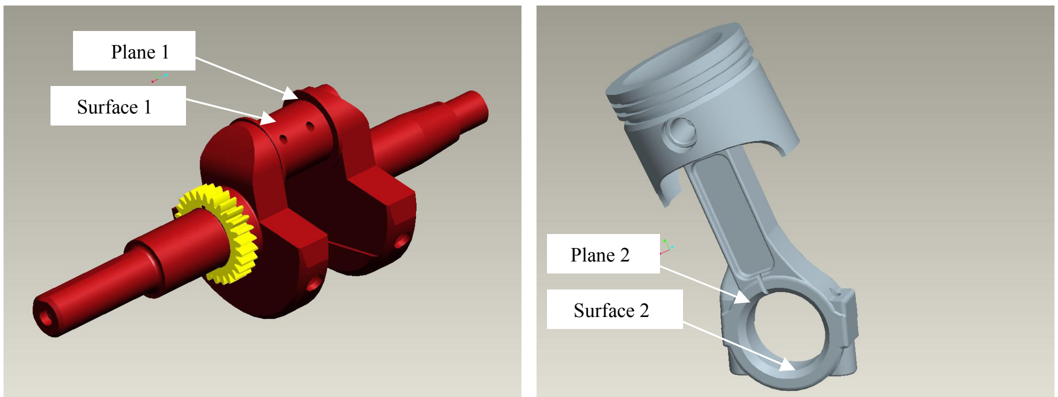

Figure 5. 3D CAD models of a crank shaft (left) and a piston (right)

An assembly model between these two components is defined by two mates. The first mate is between the Surface 1 and Surface 2, shown in Figure 5, and it defines the concentric mate. The second mate is between the Plane 1 and Plane 2, shown in Figure 5, and it defines the coincident mate.

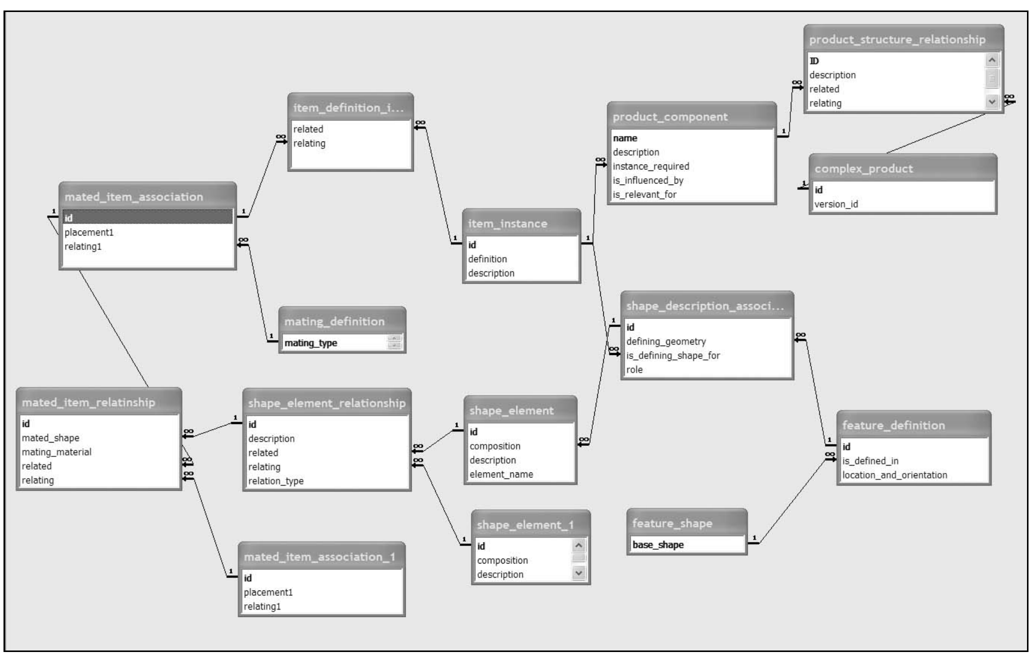

Figure 6. The structure of the entity relationship database

After the assembly process, the assembly is not fully constrained because the piston assembly can rotate around the crank shaft assembly. To get a fully constrained assembly, it is necessary to define an additional connection. Because of the experimental verification, additional connection will not be placed.

The data used in the assembly model is stored in the entity relationship database. The structure of the relationship database is presented in Figure 6. The assembly process is modelled by using a defined set of programming instructions. The result of the assembly process is the script file shown in Figure 7. The script file is ASCII file that can be imported into the CAD system in order to get a geometrical representation of the product. The structure of the script file is different for different CAD systems. Therefore, it is necessary to use different programming instructions for different CAD systems.

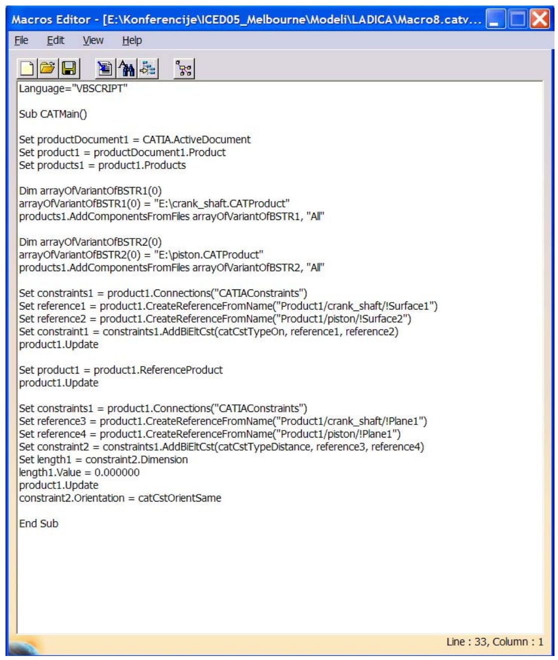

Figure 7. A script file as a result of an assembly process

5. Conclusion

The goal of this research is a time reduction in the design of product variants. The integrated development of the configurable product is realized as an extended configuration system which serves as a support tool to the designer. It covers the product variant development process from requirements to technical documentation.

A computer-aided support tool was developed based on the presented research. The tool is based on developed entity relationship database and existing CAD system seemingly integrated through user interfaces. From the designer viewpoint, it helped to create the geometric representation of a product variant as a Feature Based Design CAD model on the basis of the product variant structure which is adapted to the customer's requirements. Using the tools of the CAD system, the technical documentation is automatically updated. Therefore, the product variant development process is completed in a shorter time and the "manual work" of the technical documentation in the CAD system, a tiresome task for the designer, has been avoided.

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