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GENERIC PRODUCT STRUCTURE OF THE CONFIGURABLE PRODUCT

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1. Introduction

The competitiveness of today enterprises is achieved by the development of the products adapted to the customer demands. The driving forces which compel the development of adapted products are: shorter products life cycle, shorter delivery time and higher customers' demands. Meeting the customers' demands became a priority in the development of the product. It is considered that product incorporates functions which will satisfy customers' demands. More important is that customers expect the features of the product which will characterize the product as a unique one or the one that belongs to a special society group. The customers are very often identified with the product or groups to which it belongs. As the production of the unique products is very expensive and cannot satisfy the larger group of customers, the new type of production was developed - mass customization [Hales 1992]. Mass customization offers the adaptation of the products to the customer demands, keeping the mass production in the same time.

The main characteristic of the mass customization is the configurable product. In the development of configurable products, enterprises focus on the development of product family. A product family by definition consists of a set of related products [Tichem 1999]. The relationship between the members of the product family is explained in terms of the structure of these products. The structure of a product gives clear picture of the elements the product is made of and their relations. Here the elements of the structure are considered to be modules in order to keep generality Module represents the group of the structurally independent components clustered so that interactions between the components are localized within each module and interactions between modules are minimised.

This paper presents an approach for description of a product adapted to the customers' demands - configurable product. In this approach a configurable product is a product which is composed according to the demands of a particular customer order on the basis of a generic product structure. A data description that comprehends modular product architectures, requirements, constraints and their values forms the generic product structure. The entities of the generic product structure have been developed according to the STEP standard 10303-214 and represented using the EXPRESS-G notation. Modular product architecture is chosen as the product architecture of the configurable product, because promises the advantages of high volume production while at the same time, being able to produce a high variety of products that are adapted for individual customers. The electric motor is used as an example for the description of the generic product structure.

This article is a sequel to the [Pavlić 2003] in which the information model for the configuration system of the modular products has been described. The proposed information model has been developed according to the STEP standard 10303-214 as well. The entities of the information models are represented using the EXPRESS-G notation.

2. Product structure vs. product architecture

The terms product structure and product architecture are very often equally considered and interchanged. One of the reasons is that product structure and product architecture could have different meaning on different geographical locations. For instance, the term product architecture is more often used than term product structure in North America and it captures the meaning of the product structure. In Europe, these two terms have different meaning. According to [Tichem *et al.*, 1997] two main interpretations of the terms product structure are in use... In the first interpretation, the product structure is regarded as the result of design activities. According to this interpretation product structure defined by designer is a set of this the product elements and relations a between them. Depending on the type of the elements and relations that are considered, different structural views on one product could be defined. Often the product structure is viewed as the hierarchical structure of the physical components. The hierarchy of the components describes the part-of relationship between the components.

The second interpretation of product structure is referred to as the design data management interpretation of product structure [Tichem *et al.*, 1997].

Product architecture consists of aggregated units, following certain rules [Andreasen *et. al.* 2001]. The units are the elements which constitute the product when we have performed a restructuring of the product programme regarding market and product life cycle and regarding company internal activities like production and assembly [Riitahuhta *et. al.* 1998]. The result of the restructuring is the real (physical) product which is based on the accepted product architecture and consists of the particular components. The term product structure is used when the product consists of the physical components and their assembly relations. The term product architecture is used when the fictitious product consists of aggregated units.

2.1 Generic product structure

A product structure can be viewed according to different optics, e.g. supply, purchase, production, assembly, shipping, transport, sales, maintenance or recycling structures. Each of these structures describes the particular point of view of the product. In the available literature author did not found the description of the generic product structure which will comprehends all structures. Although [Van Veen 1991, Pulm 2001] described the generic structures, they are more considered on one or few product structures. This research is focused on the modelling of the part-of structure of configurable product, which we refer to as generic product structure. Generic product structure comprehends modular product architectures, requirements, constraints and their values.

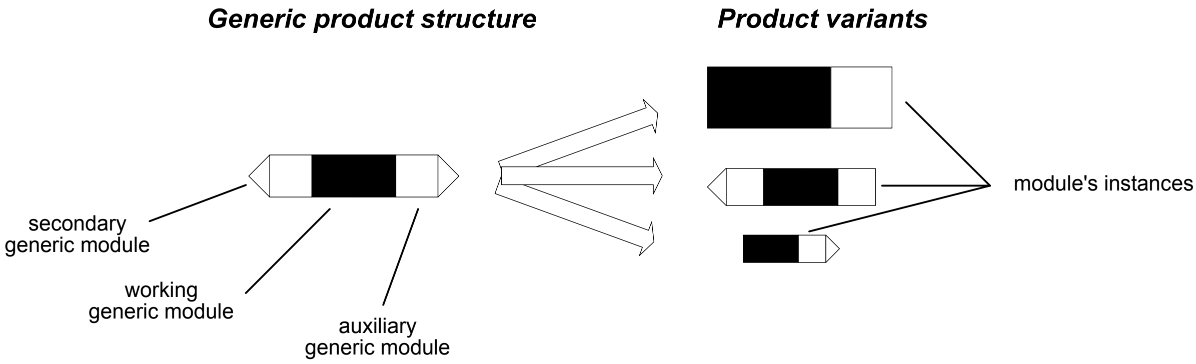

Figure 1. Product variants based on the generic product structure

Considering the different application of the variant in the generic product structure, the following forms of the variants will be used - product variant and variant of the generic module. The product variant represents the unique configuration of modules to be delivered to a customer. The instances of the generic modules represent the variants of the generic modules adapted to the customer demands in the product variant. Each product variants consists of the instances of the generic modules. The instances of the particular generic module coexist in the different product variants and the difference between them is in the difference of the structure attributes values.

Each product variant is configured upon the customer's requirements previously specified by the requirement list for that particular product family. All variants of the product family are developed from the generic product structure defined for that product family (Figure 1.). The generic product structure consists of generic modules classified in three module types: working, auxiliary and secondary module [Riitahuhta *et. al.* 2001]. Working generic modules exist in each product variant of a particular product family. Auxiliary generic modules comprise of product variants listed by the customer's requirements. Secondary generic modules exist in the product variant only when working or auxiliary generic modules need some additional modules to fulfil the customer's requirements.

3. The generic product structure concept

This chapter describes the generic product structure of configurable product and how the generic product structure can be applied to a real case of a modular product. The generic product structure is explained by the STEP entities and represented by the EXPRESS-G notation. The generic product structure concept is described through the example of three-phase high-voltage slipring induction motor (electro motor). Because of its modular architecture, the electromotor is chosen as an example for description of the generic product structure.

According to [Mortensen et al., 2000] there are two types of attributes, which are relevant when a product or product assortment is being modelled. These attributes are named structural and behavioural attributes. Structure attributes answer to the question "what is it?". The behaviour attributes answer to the question "what is it able to do?". The structure attributes are described by the name, description and value. Examples on the structure attributes for an electro motor are: shaft height = 350 mm, electric power = 400 W, type of electric current = alternate current, etc. Examples of the behavioural attributes are: reliability, exploitability, re-usability etc. In this article, only the structure attributes are used for the description of the configurable product, because the whole configurable product can be described by the structure attributes and the structural attributes can be determined directly during the configuration process.

As it was mentioned before, the configurable product is adapted to the requirements of a particular customer. Requirements are represent by the entity *requirements* and are directed to the determination of the structure attribute of the configurable product. It is important to emphasize that *requirement* describes only the definition of requirements, without a value immanent to a particular requirement. The value of a particular requirement is described by *property_value* and is linked to the requirement by *item_property_association* (Figure 2.).

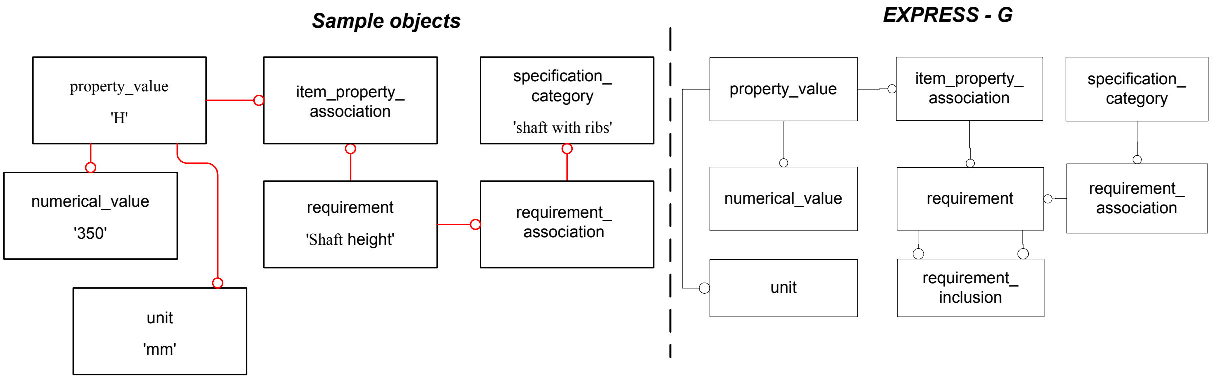

Figure 2. Example of requirement

The configurable product is defined by the entity *product_class* and represents the product family for which all product variants will be developed. A description of the product variant to be delivered to a customer is defined by the entity *product_class* as well. Due to different meanings the *product_class* entity takes, the entity *product_class_relationship* defines the association between them. On the figure 3, the description of the configurable product used as the example is "6 AKZ6 - electro motor". The descriptions of the product variants are "Electro motor 1" and "Electro motor 2". The product variants "Electro motor 1" and "Electro motor 2" belongs to the same product family "6 AKZ6 - electro motor".

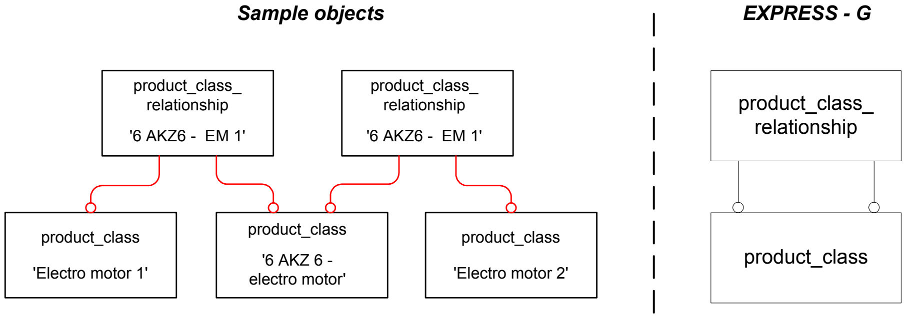

Figure 3. Example of product family and product variants

The modular product architecture applied in the generic product structure comprised the following modules: working generic modules, auxiliary generic modules and secondary generic modules. The entity *specification_category* identifies the generic modules. When working or auxiliary generic module can not fulfil the requirement by it self, the attribute *implicit_exclusive_condition* of the entity *specification_category* defines additional generic module to fulfil the requirement. The classification of the generic modules is defined by the entities *class_category_association* and *class_specification_association*. The entity *class_category_association* defines a working generic module in generic product structure. The entity *class_specification_association* defines an auxiliary or a secondary generic module. In the example of an electro motor the working generic modules are: frame, bearing assembly DE, bearing assembly NDE, shaft with ribs, rotor pack with winding, stator pack with windings and radial fan. Auxiliary generic modules are: air/air cooler and air to air heat exchanger. The secondary generic modules are: bearing end shield DE and bearing end shield NDE. All generic modules belong to the configurable product, e.g. "6 AKZ6 - electro motor", figure 4.

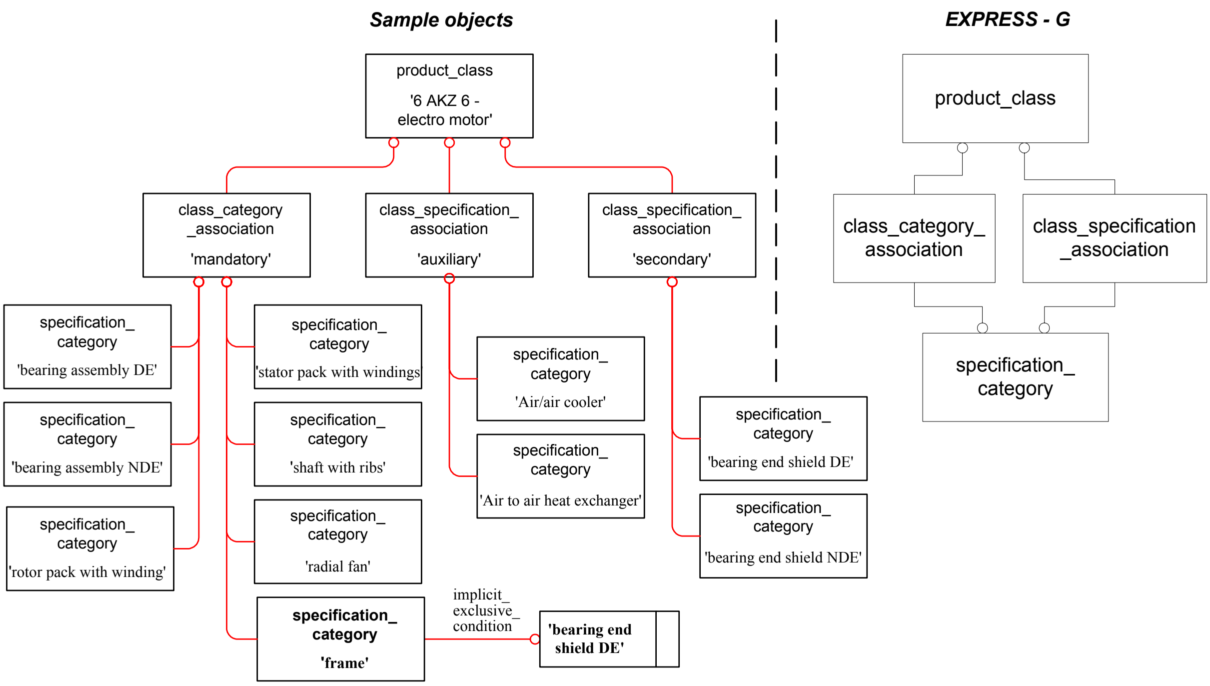

Figure 4. Example of generic modules

The generic module "frame" is a working generic module, but it needs the secondary generic modules "Bearing end shield DE" to fulfil the overall function of the module "frame" (Figure 4.).

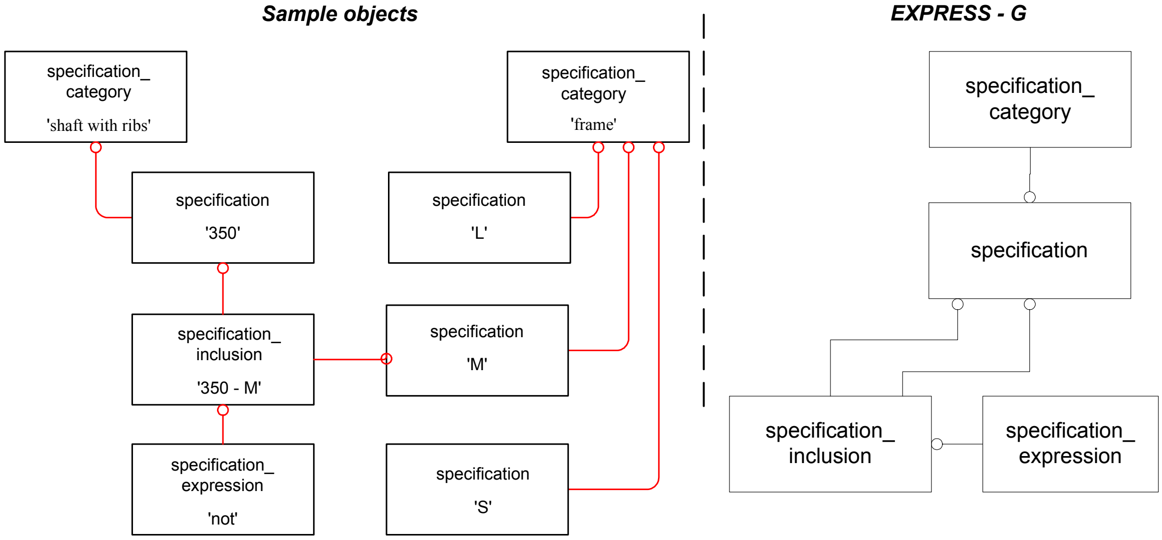

Figure 5. Example of compatibility statement between the modules' instances

The instance is derived from the generic module and it is defined by the entity *specification*. In present example, the generic module "frame" has the three instances: S (small), M (medium) and L (large), and generic module "shaft with ribs" has the instance "350". The entity *specification_inclusion* represent the compatibility statement between two instances of different generic modules. If the entity *specification_expression* has value "not", than the two instances defined by the entity *specification_inclusion* are not compatible. The compatibility statement between the two instances is established by the entity *specification_inclusion* only when it is not possible to define the compatibility statement by the attributes of the instances. E.g. the two instances of different generic modules are not compatible when the value of the same structure attribute is different. In some cases, it is not possible to define structure attribute for different instances but still the instances are not compatible. On the figure 5. the instance "350" of the generic module "Shaft with ribs" are not compatible with the instance "M" of the generic module "Frame", because these two instances are not working properly together what has been recorded in the practice.

4. Conclusion

This research is focused on the modelling of the product adapted to the customer's demands. Such product is called a configurable product. This paper concentrates on the generic product structure of a configurable product. A generic product structure comprehends the modular product architecture, requirements, constraints and their values.

The modular architecture used in the generic product structure is described by the generic modules. Modules' instances derived from the generic modules enable defining each module instance by the customer's demands, what in consequence results in the better adaptation of the product to the customer demands.

From the research of the real example in industry, an electro motor, requirements of the configurable product represent the structural attributes of the product. Therefore, the requirements in the generic product structure are described by the textual definition and value.

The presented approach can be seen as a beginning for the further research. The product variants which are based on the generic product structure have the same functions as the configurable product. Therefore, the generic product structure described in this article it is not suitable for the description of the product variants which functions differ from the functions of the configurable product. The further research should be directed to extend the present generic product structure to the product variants which will have different functions than the configurable product.

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