configurable products , B2B, knowledge database,
production planning, mass customization

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COMPUTER AIDED CONFIRMING ORDERS OF CONFIGURABLE PRODUCTS - CASE STUDY OF DATA PREPARATION

Abstract

According to requirements of the market a great number of small companies are forced to offer a wide product variety and often to respond to the market with customized solutions. At the same time, fast delivery is often a key to win orders. Recent developments in Information Technology (IT) made available also for small companies a class of software tools called product configurators. This paper presents a method of confirming orders for configurable products, focusing on data preparation for IT systems. The method enables efficient management of a large number of product variants. The empirical evidence suggests that, in order to exploit the full potential advantages of product configuration, changes in the organization and support IT systems are needed. This paper reports a case study of the implementation of a product configuration software in small and medium (SME) manufacturing enterprises. The example of the manufacturing roller shutter was chosen.

1. INTRODUCTION

For a long time, firms operating in on the contemporary market have been offering a wide variety of products, in order to fulfill the highly changeable demands of their customers. In many industries competitiveness requires efficient design and delivery of large numbers of product variants. One of a kind products or a large number of fixed products often lead to excessive amounts of design and customer specific engineering, or problems with the management of a large number of product variants. In this paper author presents a method for managing large product families as a configurable product.

The utilization of configurable products requires a systematic sales-delivery process and modeling the product family as a configurable product. Instead of explicitly defining a set of product variants in a product family, a configurable product has a configuration model that contains all the information on the possibilities of adapting the product to customer needs. Previously the primary source of competitive advantage for manufacturing companies in many industries used to be related with the price. Therefore all manufacturing strategies were driven by approaches to reduce the cost of products. Technological advances, in manufacturing as

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well as information, have provided the impetus for changes in many paradigms, including customer expectations. Customers have become more demanding and want products that can meet their specific individual requirements. Thus customization is turning out to be essential to maintain competitive advantage in many industries [23].

Producing customized products at a low cost, which seemingly is a paradox, is the purpose of many enterprises. Instead of the mass production the mass customization recently appeared. Mass customization relates to the ability to provide customized products or services through flexible processes in high volumes and at reasonably low costs. The concept has emerged in the late 1980s and may be viewed as a natural follow up to processes that have become increasingly flexible and optimized regarding quality and costs. In addition, mass customization appears as an alternative to differentiate companies in a highly competitive and segmented market [5].

This main purpose determined as fulfilling customer needs results production in the unit and small batch. In conditions of unit and small batch production a very important role is played by time of product availability for the customer. In the that kind of production enterprises win contracts playing with time of product availability for the customer. In such conditions confirming orders for customers is particularly important. Appearing the Internet and the cooperation B2B was a next challenge for many enterprises. Systems of the manufacturing became more opened and required intense IT support. According to appropriate accuracy to confirm orders availability of resources should be taken into consideration. For the correct production run a company needs some resources. They are especially machinery, materials, financial resources, information technology and human resources. One of the main resource's attribute is its availability which is most often constrained by many factors. In the production planning process, the main problem is to allocate resources to orders and jobs in such way to maximize resource utilization and shop-floor productivity as well as minimizing flow times, wastes and costs. The full utilization of resources in practice is very unlikely by reason of many constraints and unforeseen circumstances. So companies, particularly SME, need IT tools efficient solving the above problem not optimal but in the good enough way. This paper presents a case study of the implementation computer aided management system in SME for the roller shutter manufacturing.

2. PROBLEM BACKGROUND

Past research on product variety management explored multiple solutions to overcome these difficulties: some scholars focused on integrated approach for flexible manufacturing systems [17], others on product structure and specification [8], [2] , mass customization, part family manufacturing and group technology (GT). The concept of Mass Customization (MC) producing customized goods for a mass market has received considerable attention in the research literature [5]. The fundamental modes of operation for mass customization were given in [16]. A risk for mass customization termed as ‘‘mass confusion”, which is a metaphor of the burdens for the consumer as a result of attractive but probably overloaded options was also considered [10]. More and more, small and medium-sized enterprises (SME) are using software to augment the functionality of their products and offerings. Variability management of software is becoming an interesting topic for SME with expanding portfolios and increasingly complex product structures. While the use of software product lines to resolve high variability is well known in larger organizations, there is less known about the practices in SME [22].

Manufacturing based classification began to evolve in the 1940s. It is based on the idea that parts do not have to look the same to be similar. Although they may appear to be different, they can be manufactured in the same way. It becomes possible to develop a classification system that groups parts according to their manufacturing characteristics [9], [3]. The main problem in initiating a group technology based manufacturing system is to group parts into families. Three methods for accomplishing this grouping are [21]: visual inspection, parts classification and coding, production flow analysis. As the first step, the development of manufacturing groups requires some measure of parts classification. There is a lot of coding and classification systems that are now in the public domain.
Machine-part grouping problem was also considered in many publications [1], [11], [13], [18]. This issue is referred to as " part family & machine cell formation", "machine part grouping", "group technology manufacturing". The problem arises dividing the set of machines, into subsets and assigning to these subsets operations, in order to optimize a production organization quality criterion. In [18] the attempts to solve the problem with clustering methods were outlined.Conception of product configurators are described in literature among others in [10], [4]. Some scholars focused on optimization data preparing and modeling of product structure e.g. [14], [19], [7]. By product configuration process to the process through which the customer's needs are translated into the product information needed for tendering and manufacturing (typically product cost, bill of materials (BOM), production cycle, etc.). The attention management literature recently devoted to the issue of product configuration is also related to the important software applications. Advances have been incorporated in a new class of software products supporting the product configuration process called product configurators. The software applications are dedicated to web side users, for customers collaborating in B2B systems [15], [20], [6].
The paper is structured as follows. First, the studied company is shortly described, providing information about traditional and B2B business. Then, a description of the products family and the logic that is followed in generating product variants is provided. Then, the main product configuration-related problems faced by the company are discussed.. Next description of the main solutions the company envisaged in formalizing its product knowledge and then the changes in the operational management processes and in their performances are discussed. Finally, some concluding remarks are made.

3. **PROBLEM FORMULATION**

In this case study conducted a roller shutter manufacturing in a small enterprise two goals were included. The first goal is defined as order confirmation in B2B. The second goal is defined as operational management inside enterprise. Due to the lack of a comprehensive management Theory of Constraints were used to solve decision-making process for confirming orders. The paper focused on the mapping of the activities affected by product configuration before and after the implementation of the product configuration software.
To solve the problem a reply to the following question is performed:

- What data for configurable products are needed ?
- What data to confirm orders with appropriate accuracy must company based on ?
- Whether possible automatic confirming dates of delivery is for Internet customers (B2B)?
- How to build the automatic system of extracharge for individual options of choice (variant of the product)?

- What knowledge bases to extend the ERP system for the production of configurable products is necessary?

Effective company management requires the right quality data that can be provided by integrated information system. Therefore, the large number of SME have decided to introduced ERP class system although they have recognized that the introduction process is difficult and expensive. However, the alternative solution cannot be easily found [12]. In the majority of companies the introduced ERP systems were not fulfilling expectations in the area of operational production control. So, companies need efficient tools of decision-making process which could work in "on line" mode.

A given production system realizes "make to order" manufacturing. Due to the fact that the system resources are not wholly used, it is possible to accept additional orders. Prior to commencing the realization of these orders one should answer the questions: Do the resources possessed make it possible to realize the orders on time without exceeding the limitations?

Such the formulation of the problem serves to emphasize its decision-making nature.

The product configuration problem can be formally described as follows.

Definition 1. A configuration problem (CP) is formulated as:

$$CP := \{C, P, Cr, R\} \tag{1}$$

where:

C - set of components that may constitute a customizable product;

P - set of properties of components;

Cr - set of constraints imposed on components due to technical and economical factors.

R - set of customer requirements, which are usually specified in the forms of constraints.

Definition 2. A configuration Solution (CS) or a configuration is defined as:

$$CS := \{I, V, S\} \tag{2}$$

where

I - set of individuals, which are instances of components.

V - set of values, which are assigned to properties of individuals.

S - Boolean function defined as :

$$S : \{Cr, R\} \rightarrow \{T, F\} \tag{3}$$

The assignment of I and V makes the expressions Cr and R true.

Definition 3. A configuration engine (Ce) is a function that maps a configuration problem CP to a set of configuration solutions CS:

$$Ce : \{CP\} \rightarrow \{a\ finite\ set\ of\ CS\} \tag{4}$$

4. SOLUTION

4.1. About the company and products

The company's offer includes dozens of window covers' group products in interior and exterior systems, including: horizontal, vertical, rolled and pleated. Furthermore, the company as a producer of components to window covers offers a wide scope of details made of plastic,

aluminum, steel and wood. Modern, fully automated machine park allows us to maintain the highest, repeatable quality of ready-made element.

Fig.1. Roller shutters [25]

The care about the functionality, design, use of modern materials as well as the realization of products made for individual order gives our Clients the full comfort and unlimited arrangements possibilities [25]. Roller shutters are one among many of family products (Fig.1). In Tab. 1 was given technical specification.

Tab.1. Technical specification and features of roller shutters [25]

System	profile's height [mm]	profile's thicness [mm]	weight 1 m^2 [kg]	max width [mm]	max height [mm]	max surface [m2]
PA 39	39,0	9,0	2,80	2800	3000	6,0
PA 41	41,0	8,5	6,83	3800	4200	8,5
PA 45	45,0	9,0	3,00	2900	3500	6,5
PA 52	52,0	13,0	3,50	3700	3800	8,0

4.2 General conception

Given a set of predefined components, the task of product configuration is to find a configuration solution satisfying individual needs of customers without violating all constraints imposed on components due to technical and economical factors. Configuration models describing all legal combinations of components include knowledge about the structure of products and knowledge about technical and economical constraints. Additionally, user requirements can be specified in the form of constraints, such as constraints on properties of a component.

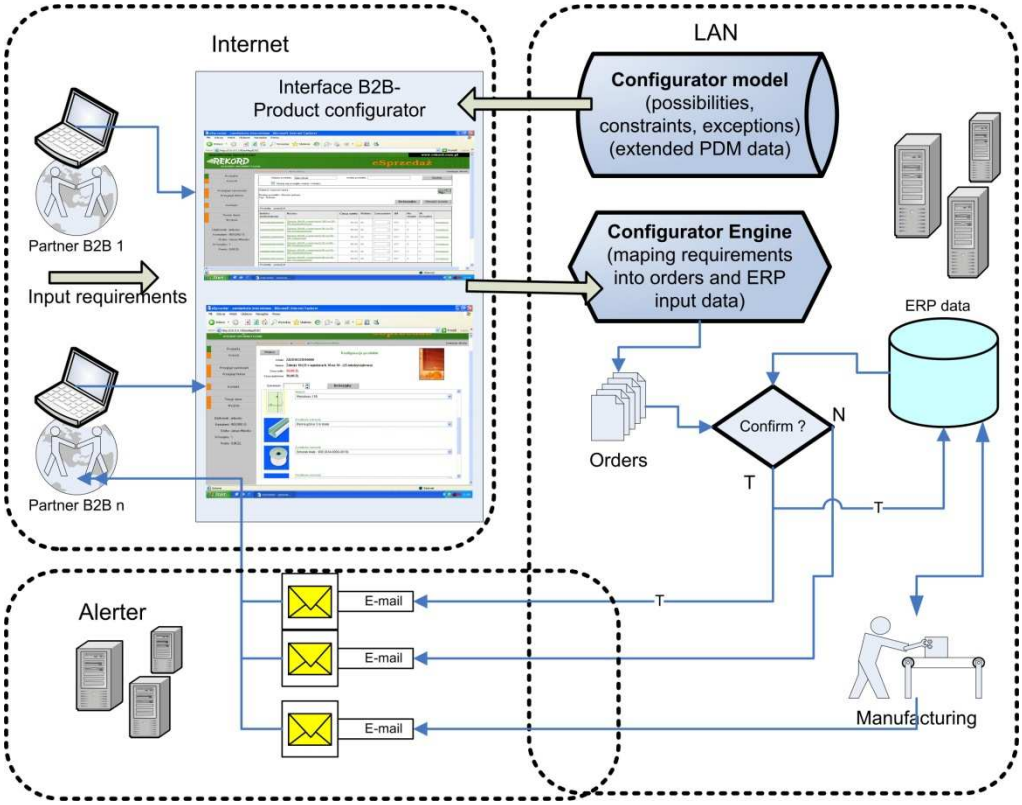

Fig. 2. General conception of presented solution

Using a problem-solving technology, configuration engines perform actual inference processes with both configuration models and user requirements as the inputs and then generate a configuration as the output. A configuration(or configuration solution) consists of the component individuals, the assignment of values to properties of these individuals and the connection relations among components such that all constraints and customer requirements are satisfied. The architecture of a product configuration system and integration with management information system is shown on Fig. 2. System consists from following elements: interface for B2B partners, configurator model, configurator engine, ERP system and alerter software.

4.3 Interface for B2B partners

Think of configurable products as made-to-order products dynamically developed last years. An Internet created new possibilities for submitting orders directly by the customer.
However, building the knowledge base for configurator was a real challenging. Not all companies in the business of roller shutter managed to cope with that problem. A configuration of products is based on the customer's requirements and defining it is the point issue.

The next problem constituted into the interface for submitting orders. The interface must be straight, transparent, dynamic, graphical and in correlation to changeable requirements.
For a better idea on how a product configurator works, imagine at the following shopping scenario:

1. A customer navigates through an electronics online catalog until finding a roller shutter that he is interested in. At this stage a search engine of products is needed.
2. Since the chosen product is a dynamic kit, it needs to be configured through an configurator.
3. The customer selects the "**Configure"** link (or a similar link) to interact with the configurator (see more in [26]). This interaction may be as simple as answering a series of questions or as complex as manually selecting detailed configuration options for the product. At this stage interface of configurator plays an important role.
4. When the customer has completed the interaction, the configurator returns a bill of materials that represents the grouping of items that make up the fully configured shutter. The customer can then decide to add this configured computer into the shopping cart.
5. The order is sent to the company by web page.
6. The company is confirming the order. The confirmation is visible on the web page. There is also sent alert about confirming or r rejection the order.

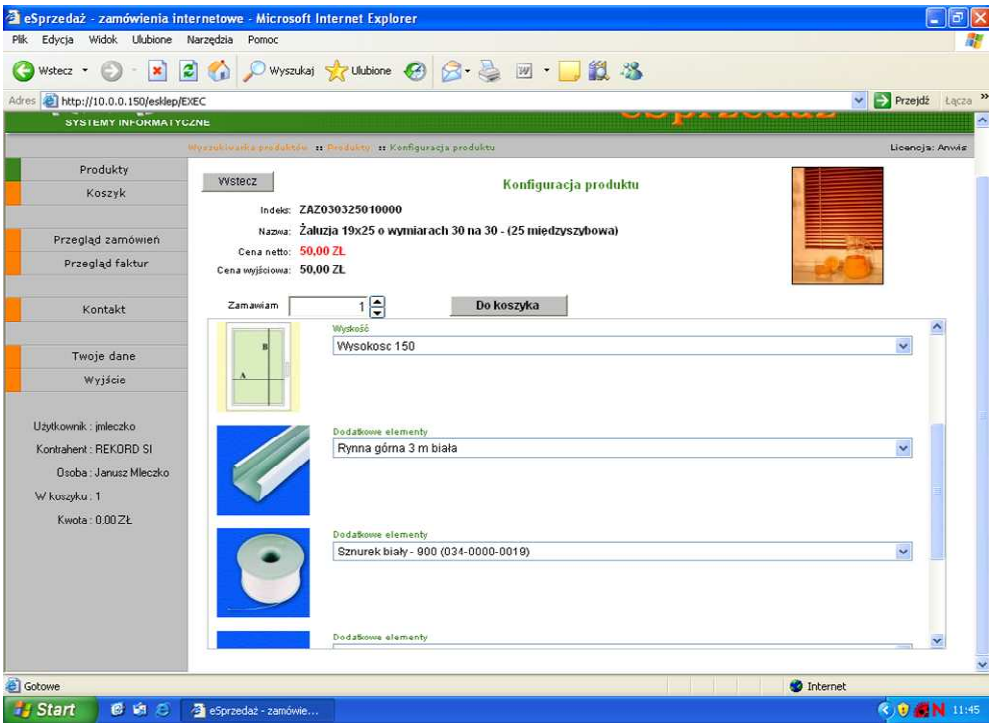

Fig. 3. Interface of product configurator

4.4 Configuration model

A configuration model is based on an analysis of the product to be modeled. First thing what user need to do is set-up attributes for the configurable products, like colour, size, kind of drive, etc. Therefore the modeler should have a good understanding of the product. The product should be modeled by product experts in the product development process. The configuration model is an abstraction of the real world product family that is specifically meant for configuration purposes. For example, it may suffice to model the different types of electric motors for rolling shutters as simple phantom (configurable module) and use it repeatedly in many structures. When kind of the drive (manual or electric) is configured, it is enough to decide the type of the engine.
A dependence of structures is a next problem. The main requirement for modeling is subjective and requires both practice and good understanding of the product to be modeled and of its usage. It is also evident that different needs lead to different models of the same product. So, modeler must configuration space create.

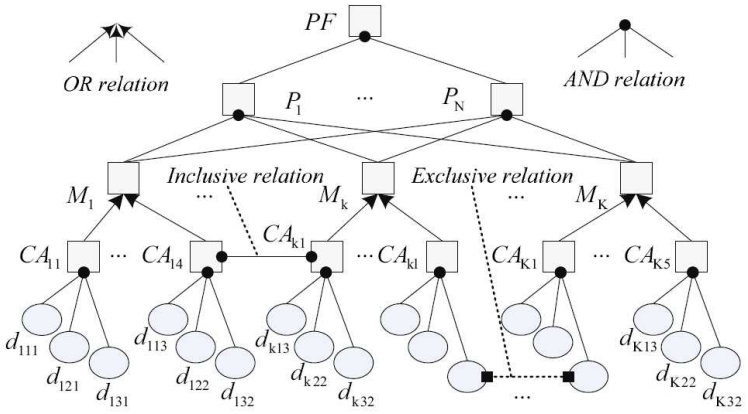

Fig. 4. AND/OR graph representation of configuration space [24]

In this case was implemented solution on the basis AND/OR graph representation [24]. As shown on Fig.4, configuration space is represented as a AND/OR graph with the root indicating product family (PF on Fig. 4.). The product family is composed of possible configuration solutions $P = \{P_1, P_2, \ldots, P_n\}$ with AND relation. Each solution $P_i | \forall i \epsilon [1, N]$ could be derived through configuring the configurable modules, $M = \{M_1, M_2, \ldots, M_n\}$.
Each configurable module $M_i | \forall i \epsilon [1, K]$ may possess several available module instances $M_k^* = \{CA_{k1}, CA_{k2}, \ldots, CA_{kL_k}\}$ with OR relation, among which, one and only one instance can be selected for a certain configuration solution. While customers always purchase products according to product performances, each module instance is characterized with corresponding product attributes $A = \{a_{kq}\}$, and their values $D = \{d_{kqr}\}$ where d_{kqr} indicates the r^{th} value of the q^{th} attribute associated with the k^{th} module.
Besides the hierarchical relations among these compositions, there are other relations needed to be considered due to their influence on product configuration. They are exclusive and inclusive relations, which could be used to check whether there are conflicts involved in configuration solutions thus enabling to rule out the infeasible solutions in configuration solving.

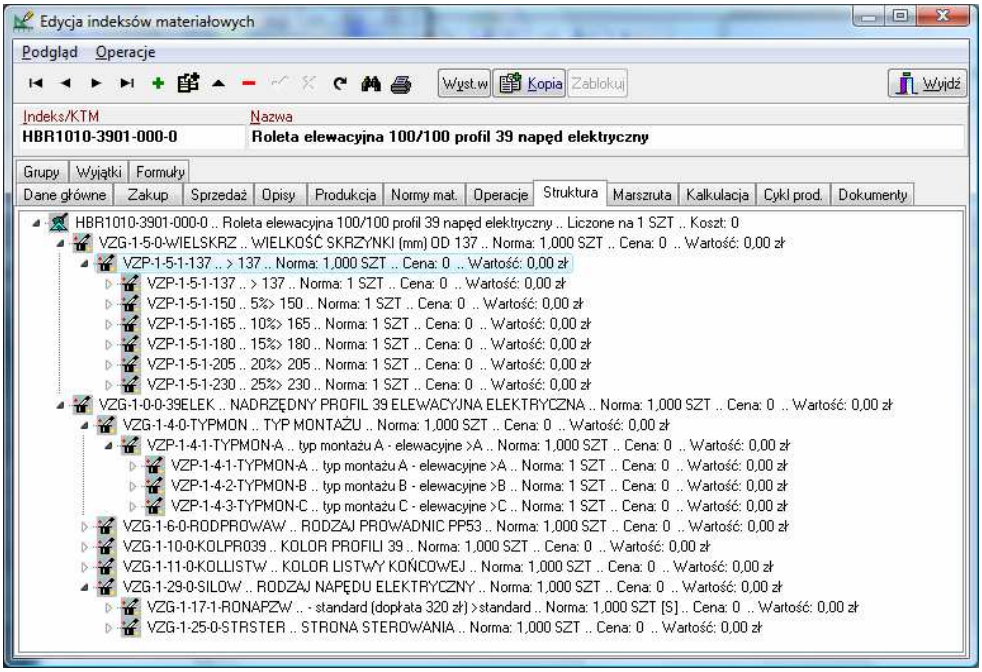

Fig. 5. Implementation of "AND/OR graph" in PDM module for roller shutter

In the configuration space, the inclusive relation between two compositions implies that when one of the compositions is included in a configuration solution, the other one should also be included. The inclusive relation can be represented as the "if-then" rule: if $C_i = p_{i1}$ then $C_j = p_{j1}$, where C_i and C_j refer to modules (or attributes) while p_{i1} and p_{j1} module instances (or attribute values) associated with $C_i$and C_j.

In the configuration space, the exclusive relation between two compositions means that these two compositions are not allowed to coexist in the same configuration solution if $C_i = p_{i1}$ then $C_j \neq p_{j1}$. In this way, the configuration space provides a straightforward way of combining module instances with higher efficiency and form the basis of configuration design for roller shutters manufacturing. Implementation of "AND/OR graph" in REKORD.ERP (see [26]) for roller shutter is shown on Fig.5.

Because there is a many of possibility for modeling the family of products it is hardly possible to choose the optimal variant. Unfortunately, in practice a big experience of the modeler is required. He must divide what components will be item, what will be configurator with "OR" relation, what will be configurator with "AND" relation and what will be an exception (exclusive relation). Additionally he should build the knowledge base for automatic selections of some parameters e.g. automatic type of the drive depending on the load. (Fig. 6.)

Procedure electric_motor_assortment

```
CREATE OR ALTER PROCEDURE
DP_SILNIK_SPREZYNA (
kategoria char(3),
rok smallint,
symbol varchar(10),
lp char(3))
returns (
indeks_silnika varchar(32),
indeks_sprezyny varchar(32),
opis varchar(90))
as
declare variable producent varchar(32);
declare variable rodzaj_napedu varchar(32);
declare variable spos_zabez varchar(32);
declare variable szerokosc double precision;
declare variable wysokosc double precision;
declare variable kgm2 double precision;
declare variable z1_kg double precision;
declare variable z1_obciaz double precision;
declare variable rodzaj_spr varchar(32);
declare variable profil char(3);
BEGIN
/* parametry  pod elektryczne */
if (:profil = '390') then KGM2 = 2.8;
if (:profil = '410') then KGM2 = 6.83;
if (:profil = '450') then KGM2 = 3 ;
if (:profil = '520') then KGM2 = 3.5;
if (:profil = '521') then KGM2 = 4.75;
if (:profil = '800') then KGM2 = 6.88;
if (:profil = '770') then KGM2 = 6;
select first 1 f_copymid(indeks,9,3) from
m_Zamobcepoz zk
where zk.KATEGORIA=:KATEGORIA and
zk.SYMBOL=:SYMBOL and zk.ROK=:ROK
and zk.LP=:LP
into :Profil;
if (:profil = '390') then KGM2 = 2.8;
….
select first 1 ind_zam from m_ZamobKonfig
zk join m_KimWsp kw on
zk.ind_zam=kw.indeks
where zk.KATEGORIA=:KATEGORIA and
zk.SYMBOL=:SYMBOL and
zk.ROK=:ROK
and
zk.LP=:LP and zk.indeks like "VZG-1-17-4-
PRODN%"
into :PRODUCENT;
select first 1 ind_zam from m_ZamobKonfig zk join
m_KimWsp kw on zk.ind_zam=kw.indeks
where zk.KATEGORIA=:KATEGORIA and
zk.SYMBOL=:SYMBOL and zk.ROK=:ROK and
zk.LP=:lp and zk.indeks like "VZG-1-29-0-
SILOW%"
into :RODZAJ_NAPEDU;
select first 1 ind_zam from m_ZamobKonfig zk join
m_KimWsp kw on zk.ind_zam=kw.indeks
where zk.KATEGORIA=:KATEGORIA and
zk.SYMBOL=:SYMBOL and zk.ROK=:ROK and
zk.LP=:lp and zk.indeks like "VZG-1-13-%-
SPZAB%"
into :SPOS_ZABEZ;
select first 1 wymiar_1 , wymiar_2 from
D_ZamobKonfig zk where
zk.KATEGORIA=:KATEGORIA and
zk.SYMBOL=:SYMBOL and zk.ROK=:ROK and
zk.LP=:lp
into  :SZEROKOSC,:WYSOKOSC ;
Z1_KG   =
WYSOKOSC*SZEROKOSC*0.000001*KGM2;
if(SPOS_ZABEZ= 'VZG-1-14-0-BRAK')
then Z1_OBCIAZ=Z1_KG*1.2;
else Z1_OBCIAZ=Z1_KG*1.2+5;
/* dobor silnika */
select first 1 IND_MAT, opis from
D_MATKONFIG where
Ind_zam_sil=:RODZAJ_NAPEDU and
Ind_zam_prod=:PRODUCENT and   :Z1_OBCIAZ
< OBCIAZ_DO AND :Z1_OBCIAZ >=
OBCIAZ_Od
and :SZEROKOSC between Szer_od and Szer_do
and   dostep='T'
order by kolejnosc into   :INDEKS_SILNIKA
,:opis;
suspend;
…..
END
```

Fig. 6. Example of knowledge database procedure

So, modeler's task consists on determining what should be an index of the product what configuration of "or/And" type and what components should be exceptions. It is particularly essential because of a huge amount of possible combinations at creating variants. So, inexperienced modeler can cause the failure in implementing the method. In the general case the number of the option is: $A_1^n * A_2^m * ... * A_l^x$, where $A_1, ..., A_l$ are nodes of the configuration, l is an amount of nodes and $n, m, ...x$ are amount of possible selection in individual nodes.

5. Conclusions

Managing product families consisting of a large set of product variants as configurable products requires defining a configuration model. We presented a conception for configuration models and gave short guide on using the concepts. The concepts and modeling guidelines for them were validated with success in SME for roller shutter. Information system support is necessary for modeling products, particularly for configurator available in the Internet for B2B partners. Modeling sets new requirements for the designer. In addition to having a good understanding of the product, a designer should be familiar with object oriented modeling. The main benefit there would be improving communication within the product development team and to other functions of the company, e.g. salesmen. The benefits also include the use of the knowledge database additional functions, structure and the related design constraints during the product development.

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