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PRODUCT CONFIGURATION USING KNOWLEDGE BASED SYSTEM

Product configuration is focused on achieving customer satisfaction. Configuration methods should use previous experiences related to product changes. One of the methods of storing experiences is elaboration of knowledge bases with the use of proper knowledge representation method. In the paper identification of customer needs was discussed, as well as product decomposition methods were presented. The Quality Function Deployment (QFD) method was suggested to be applied as a product and process data integration tool, where engineering characteristic of a product was combined with its trade characteristic. The paper shows that thanks to the application of knowledge based system in production preparation it is possible to support decision making connected with product selection and evaluation for a particular customer.

1. PRODUCT CONFIGURATION – GAPS ANALYSIS

One of the strategies adopted by several companies is to manufacture products according to individual customer requirements with low production costs.

Researchers focused on different aspects and methods supporting product configuration. Ming et al. [6] presented gaps analysis in the existing concepts supporting product configuration:

- collaborative design portal – lack of design of user friendly interfaces to enable real time collaboration,
- configurable design – lack of systematic ontology and processes on product configuration design,
- modular design – lack of systematic technology to represent, identify, reuse modules in new product development,
- platform-based design – lack of systematic technology to represent platform design,
- product knowledge management – lack of systematic way to represent, capture, organize, share, apply, create the design knowledge,
- lifecycle evaluation and optimization – lack of systematic way to evaluate life cycle efficiency at an early design stage.

For better, faster, cheaper product development it is necessary to reuse previously designed components and experiences related to their manufacturing process. Development

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of knowledge based system (KBS) can support product configuration. Storing products characteristic and product changes characteristic KBS helps to find the best solution for the particular client.

Customer needs identification is the first step of product configuration. Customer needs related to a B2B product can include engineering characteristics, as well as trade characteristics. The engineering characteristics include product attributes determining product usefulness, which include technical product attributes e.g. power, speed. The trade characteristics can include e.g. product prices, warranty and delivery time. Customer product characteristics should be transformed to the product characteristics made by producers and product structure comes from those characteristics. One of the concepts useful in creating product structure is modular design.

Modularity in product and process design is focused on reducing the range of product parts and manufacturing processes variation. According to this concept, the new product variant used common units. To satisfy customer needs it is necessary to analyse product functions, product structure and the production process. A change in the product structure causes several changes in the production system.

2. QFD AS A TOOL SUPPORTING PRODUCT CONFIGURATION

The theory helpful in complex product and process development is Quality Function Deployment (QFD), also known as house of quality. QFD supports meeting customer requirements in product and process design (Fig. 1).

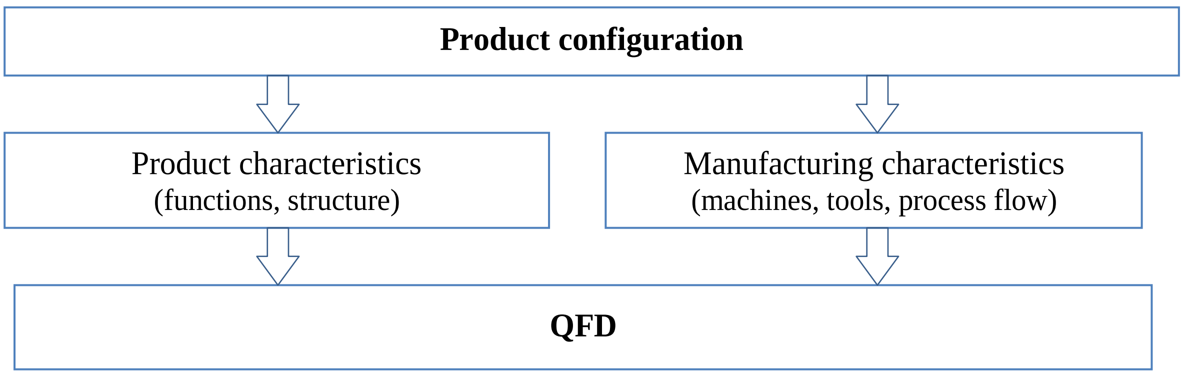


Fig. 1. Relation between product configuration and QFD

The QFD matrix (Fig. 2.) [4] determines the relationships between customer needs (denoted as “what’s”) and design characteristics (denoted as “how’s”). The top part of the matrix called a ‘roof’ indicates how design characteristics interact. The right part of the matrix includes assessment of the products. The target level of each design characteristic is presented at the bottom of the matrix [4].

QFD consists of series of matrices. The first one represents the relation between customer requirements and product characteristics. The second one describes the relation between product characteristics and product parts. The third QFD matrix gives information related to the production process. The fourth one provides information related to production process parameters. [1],[4],[7].

What? / How?			Design requirements				Importance	Rate		
								A1	A2	…
Customer requirements	**Functions / Attributes**	Value	p_{mk1}	p_{mk2}	…	p_{mkz}				
	f_1	f_{11}^{w}	c_{11}	c_{12}		c_{1k}				
	f_2	f_{22}^{w}	c_{21}	c_{22}		c_{2k}				
	f_n	f_{n2}^{w}	c_{z1}	c_{z2}		c_{zk}				
	Target level of design characteristic		p_{mk1t}^{woz}	p_{mk2t}^{woz}		p_{mkzt}^{woz}				
	Product alternatives		**Product parameters**							
	A1									
	A2									
	…..									

Fig. 2. QFD matrix

Product function deployment generates product structure which comes from detailed design. Product structure represents a product family from which a product variant can be generated. In product structure we can apply components and parts which are standardized and those which require to be redesigned. Components in the presented approach represent a set of parts which correspond to specific product requirements. That component can be also called a configuration item. To present product structure clearly, the graph method can be used (Fig. 3) [4].

A graph presents only the dependence between components, whereas product configuration needs more information. Each component can be described by a set of features called attributes which represent the most important component characteristic (Table 1) [4].

That product structure can be applied in QFD method. Customer requirements can be transformed into product characteristics with the use of the concept of product modularity. Each configuration item could be assessed separately according to the proposed approach.

Target product characteristics defined on the bottom part of the QFD matrix can be achieved by different alternatives. The alternatives in basic QFD are assessed by experts basing on their experience.

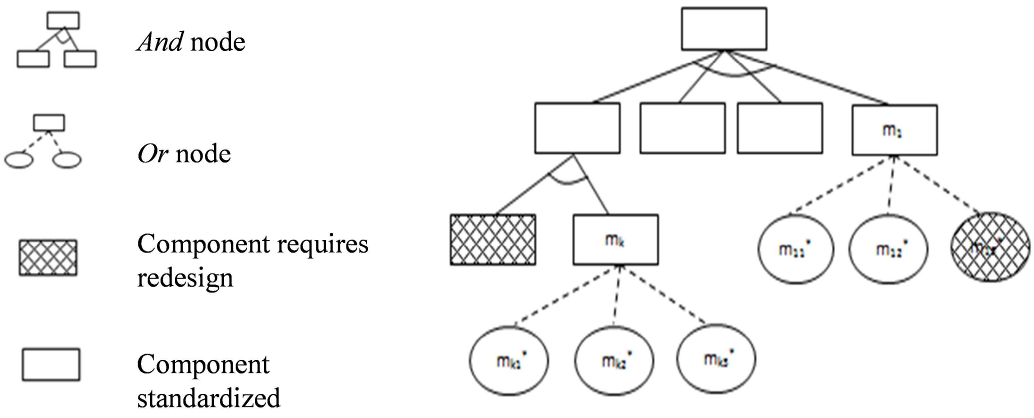


Fig. 3. Product structure

Table 1. Product components characteristics

Product components	Version	Product attributes			
		p_{mk1}	p_{mk2}	….	p_{mkz}
m_1	m_{11}^* m_{12}^* … m_{1l}^*	p_{m111}^w p_{m112}^w … p_{m11t}^w	p_{m121}^w p_{m122}^w … p_{m12t}^w		p_{mkz1}^w p_{mkz2}^w … p_{mkzt}^w
m_2	m_{21}^* m_{22}^* … m_{2l}^*	p_{m2121}^w p_{m212}^w … p_{m21t}^w	p_{m221}^w p_{m222}^w … p_{m22t}^w		p_{mkz1}^w p_{mkz2}^w … p_{mkzt}^w
….	….				
m_k	m_{k1}^* m_{k2}^* … m_{kl}^*	p_{mk11}^w p_{mk12}^w … p_{mk1t}^w	p_{m221}^w p_{m222}^w … p_{m22t}^w		p_{mkz1}^w p_{mkz2}^w … p_{mkzt}^w

The proposed approach to the configuration items assessment applies an evaluation indicator calculated according to the formula (1) and rules given in Table 2. The average grade used for overall variant assessment can be calculated according to the formula (2) [2],[3],[4].

$$w_{kzt} = \frac{\left| p_{mkzt}^{woz} - p_{mkzt}^{w} \right|}{p_{mkzt}^{woz}} \cdot 100 \tag{1}$$

Where:

w_{kzt} – assessment indicator for product k, attribute z, variant t;
p_{mkzt}^{woz} – target level of design characteristic;
p_{mkzt}^{w} – offered attribute value.

$$s_{kt} = \frac{\sum_{z} s_{kzt} \cdot k_z}{z} \qquad (2)$$

$$s_{kt} \in \{1,2,3,4,5\}$$

$$k_z \in N$$

Where:

s_{kt} – average grade assessment of requirements fulfilment for variant t, product k,
s_{kzt} – assessment grade of requirements fulfilment for variant t, product k,
k_z – importance weigh of attribute *z*.

Table 2. Proposed approach for assessment rules

Assessment indicator		Assessment grade	
if	$w_{kzt} \le o_{1z}$	then	$s^{kzt}=5$
	$o_{1z} < w_{kzt} \le o_{2z}$		$s^{kzt}=4$
	$o_{2z} < w_{kzt} \le o_{3z}$		$s^{kzt}=3$
	$o_{3z} < w_{kzt} \le o_{4z}$		$s^{kzt}=2$
	$o_{4z} < w_{kzt}$		$s^{kzt}=1$
Where $o_{1z}, o_{2z},\ldots,o_{4z}$ – bottom and upper values of parameter w_{kzt}			

What? / How?				Characteristics of configuration item			
Engineering characteristic	Product characteristics	Attributes value	Attributes meaning	m_1	m_2	…	m_k
	p_{mk1}	p_{mk1t}^{w}	k_1	c_{11}	c_{12}		c_{1k}
	p_{mk2}	p_{mk2t}^{w}	k_2	c_{21}	c_{22}		c_{2k}
	p_{mkz}	p_{mkzt}^{w}	k_z	c_{z1}	c_{z2}		c_{zk}
		Grade	1	m_{11}^{*}	m_{21}^{*}		m_{z1}^{*}
			2				
			3	m_{12}^{*}	m_{22}^{*}		m_{z2}^{*}
			4	…	…		..
			5	m_{1l}^{*}	m_{2l}^{*}		m_{zl}^{*}

Fig. 4. Grades for configuration of item variants

The presented approach helps to identify the importance of product attribute and compare product components. Assessment of product components helps to choose the proper components variant or the variant which needs to be redesigned. The presented approach is useful in knowledge-based system supporting decisions in product configuration.

The results of overall product assessment are given in the bottom part of QFD matrix (Fig. 4) [4].

3. KNOWLEDGE BASED PRODUCT CONFIGURATION SYSTEM

Knowledge is a combination of information, experience, context, interpretation and reflection [5]. Knowledge base configuration system is focused on supporting decisions related to product configuration.

Knowledge based system uses the QFD method as a tool for product variant identification and assessment. The presented approach helps to create KBS which supports product variant assessment.

The creation of KBS needs proper method of knowledge representation, user friendly interface, methods of knowledge acquisition and verification.

There are many methods of knowledge representation, e.g. rule based systems or neural network [5]. Rules can be formulated basing on expert knowledge or as a result of data analysis. Rule based systems are easy to apply in shell systems. A shell system is universal software which offered inference engine, user friendly interface and helps to create an explanation which gives additional information to system users. The use of a shell system needs knowledge loading related to a particular problem.

Another method of knowledge representation is neural network (NN). NN may be used for problem modelling where they can be trained via a dataset.

In the creation of KBS the problems are related to:

- what product characteristics should be offered to the particular client if enterprise portfolio does not include the needed product,
- which product from the product portfolio can be the base for changes,
- what kind of change it is possible to introduce to the existing products.

In the presented approach the following assumptions were applied:

- the KBS use rules for finding and assessing the most suitable product from the product portfolio,
- the manufacturing process is well known and a new manufacturing process requires small changes,
- NN was applied to estimate data related to the manufacturing process for a new product.

4. AN EXAMPLE OF TOOTHED GEAR CONFIGURATION

The aim of application is supporting decision making in the field of geared motors configuration. This KBS is dedicated to customer service.

The range of the presented knowledge base is limited to toothed gears which are components of geared motors.

The presented software used PC Shell and NN simulator from the Sphinx software packet and Exel. KBS was built with the use of chosen products offered by producers of toothed gears. This knowledge base system applied rule based approach, procedures for knowledge representation and NN. The problems solved by this KBS include [2]:

- selection of toothed gears work arrangement,
- selection of toothed gear work coefficients,
- selection of toothed gear variants,
- evaluation of toothed gears variants,
- time consumption estimation of chosen tasks.

Selection of toothed gears work arrangement is supported by a graphic classifier, which uses: work arrangement with two variants: a horizontal and vertical one, as well as type of product structure which distinguishes helical and bevel-helical reducers (Fig. 5) [2].

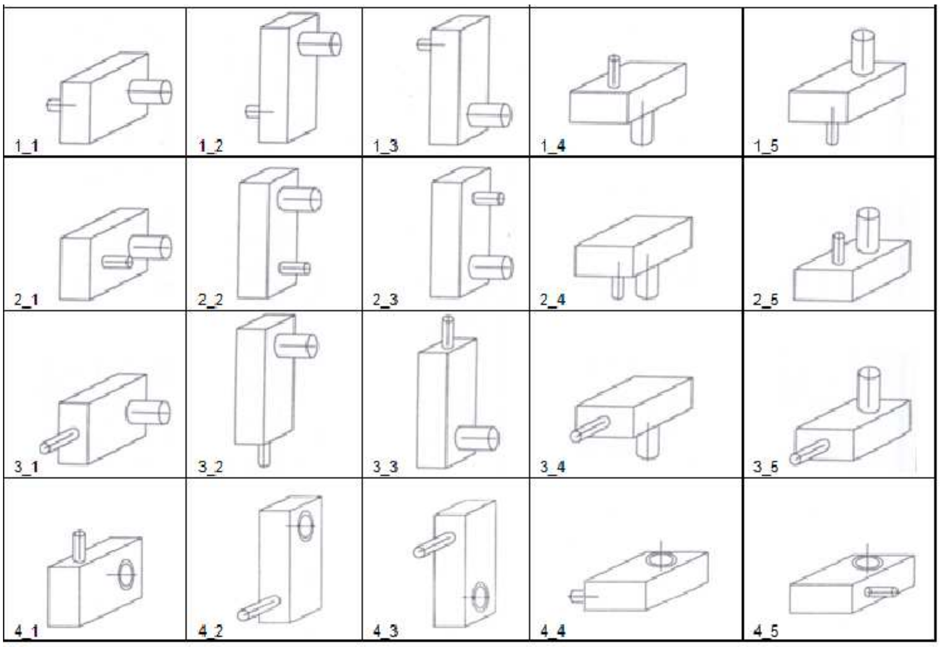


Fig. 5. Toothed gear working arrangement

The next step is focused on choosing the type of toothed gear reducers. For that purpose, the engineering and trade data should be submitted (Fig. 6) [4]:

- data needed for the characteristic of device's working environment,
- rotational speed of the driving device,
- rotational speed of the working machine,
- power transformed,
- delivery time,
- price,
- warranty.

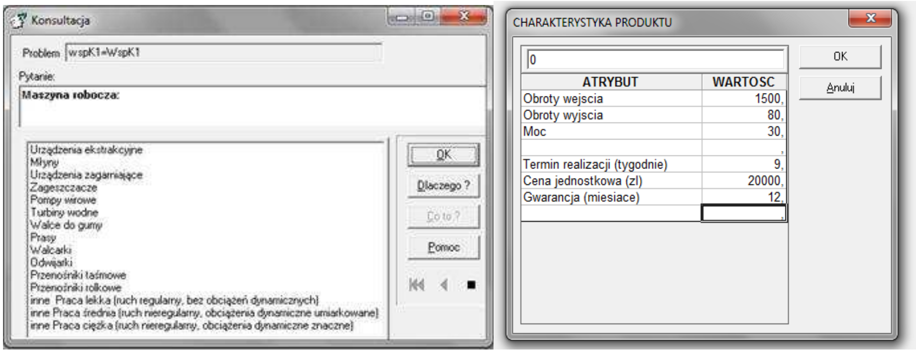
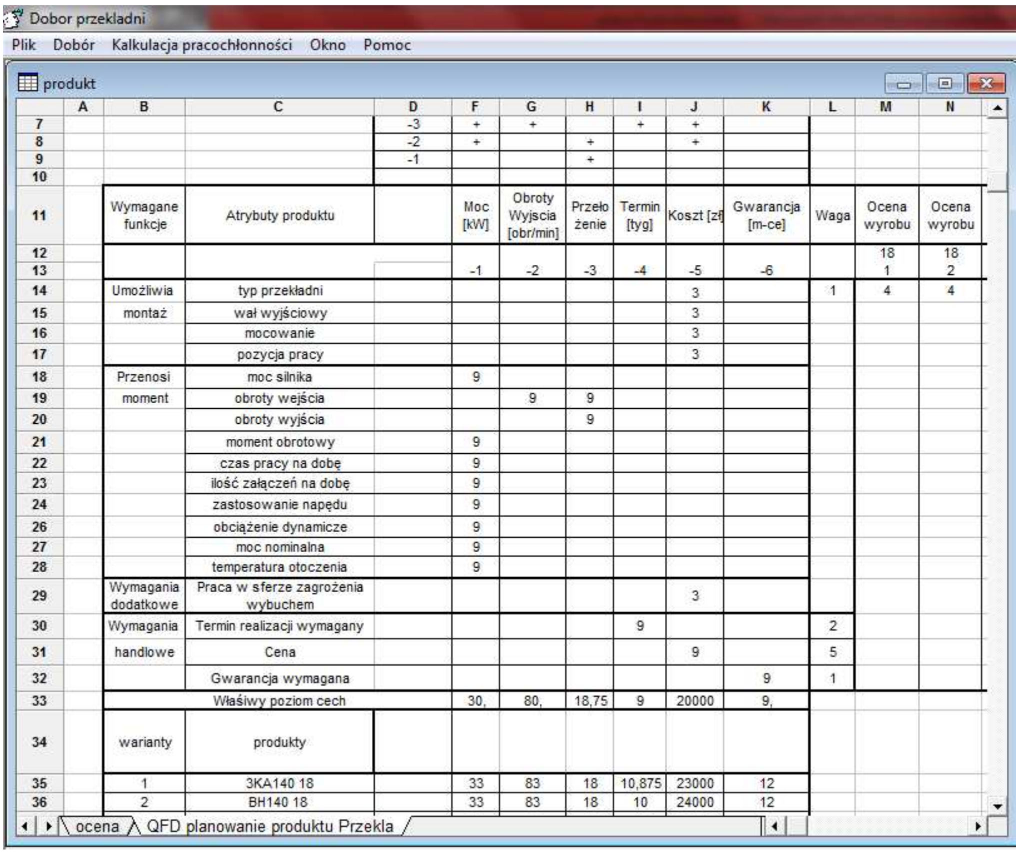


Fig. 6. Selection of toothed gear variants

Basing on the presented data, product variants are fixed (Fig. 7) [4]

Fig. 7. Product alternatives



	A	B	C	D	F	G	H	I	J	K	L	M	N
7				-3	+	+		+	+				
8				-2	+		+		+				
9				-1			+						
10													
11		Wymagane funkcje	Atrybuty produktu		Moc [kW]	Obroty Wyjscia [obr/min]	Przeło żenie	Termin [tyg]	Koszt [zł]	Gwarancja [m-ce]	Waga	Ocena wyrobu	Ocena wyrobu
12												18	18
13					-1	-2	-3	-4	-5	-6		1	2
14		Umożliwia	typ przekładni						3		1	4	4
15		montaż	wał wyjściowy						3				
16			mocowanie						3				
17			pozycja pracy						3				
18		Przenosi	moc silnika		9								
19		moment	obroty wejścia			9	9						
20			obroty wyjścia				9						
21			moment obrotowy		9								
22			czas pracy na dobę		9								
23			ilość załączeń na dobę		9								
24			zastosowanie napędu		9								
26			obciążenie dynamicze		9								
27			moc nominalna		9								
28			temperatura otoczenia		9								
29		Wymagania dodatkowe	Praca w sferze zagrożenia wybuchem						3				
30		Wymagania	Termin realizacji wymagany					9			2		
31		handlowe	Cena						9		5		
32			Gwarancja wymagana							9	1		
33			Właśiwy poziom cech		30,	80,	18,75	9	20000	9,			
34		warianty	produkty										
35		1	3KA140 18		33	83	18	10,875	23000	12			
36		2	BH140 18		33	83	18	10	24000	12			

Fig. 8. Evaluation of toothed gear variants

The relations between customer requirements and product characteristics were presented with the use of the QFD matrix made in an Excel sheet. On the bottom part of the matrix target values and products characteristic were put. On the right part of the matrix assessment grades for each evaluated product were presented (Fig. 8). [4]

The data related to time consumption estimation regarding product structure change was made with the use of NN. The learning process of NN and result of data modelling were presented on Figs 9 and 10.

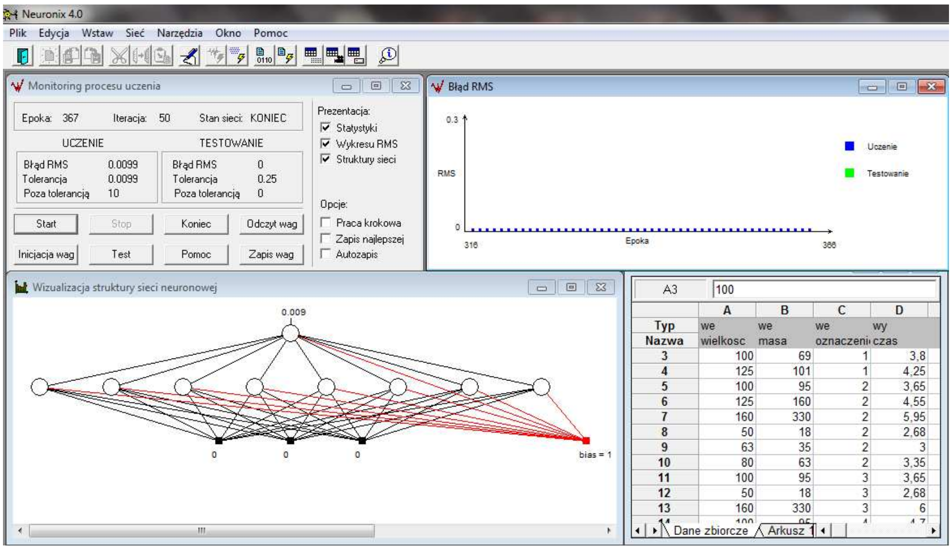


Fig. 9. NN learning process

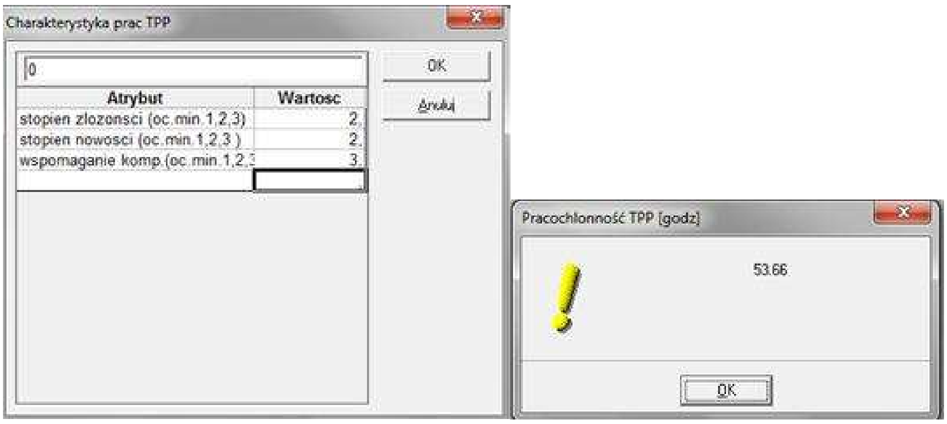


Fig. 10. Time consumption assessment

5. CONCLUSIONS

The decision process regarding product configuration which is focused on compatibility between customer requirements and functional and physical product features can be supported with the use of KBS.

Selection of the proper knowledge representation method determines the effectiveness of knowledge based system. Methods of knowledge representation, such as rules and NN are useful in the presented KBS.

Integration of the knowledge related to customer requirements, product structure and the manufacturing process helps in assessing product characteristics in make-to-order product offer preparation. The proposed approach uses the QFD method and performs the simplest searching, comparing, evaluating operations of different product variants as well as missing data estimation related to the production process of product redesign.

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