CODEN STJSAO
ZX470/1388

ISSN 0562-1887
UDK 658.512.2:004.42

Product Function Matrix and its Request Model

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Original scientific paper

A developed model of the first structural shape of the matrix of product function and its requests model have been shown in practice. It relates functions of the product and its requests model, and technical systems that solve them. Functions are described by parameters, determined by physical laws. The technical systems and functions are related among themselves through correlations that fill the field of the matrix. The correlations are determined through winning parameters. Winning parameters are determined from the set of parameters of each function that have the greatest importance and influence on a specific function. The model is implemented into a developed prototype computer system. The first structural shape of the product function matrix and its requests model for the stator of the electrical motor of the intake unit have been generated through the prototype computer system. By implementing the product function matrix and its requests model in the process of product conceptual design, it becomes possible for a designer to examine himself by comparing the possibilities of implementation of new ideas with previously built products.

Keywords

Conceptual Design
Design Synthesis
Functional Matrix
Functionality Matrix
Functional Modeling

Matrica funkcije proizvoda i njihovih zahtjeva

Izvornoznanstveni članak

U radu je prikazan razvijeni model prvog strukturnog oblika matrice funkcije proizvoda i model njezinih zahtjeva koji dovodi u međusobne odnose funkcije proizvoda i tehničke sustave koji ih rješavaju. Funkcije su opisane parametrima, određenim iz fizikalnih zakona. Tehnički sustavi i funkcije povezani su između sebe preko poveznica koje popunjavaju polja matrice. Poveznice su određene preko pobjednih parametara. Pobjedni parametri se određuju iz skupa parametara svake funkcije te imaju najveći značaj i utjecaj na određenu funkciju. Model je implementiran u razvijeni prototipni računalni sustav, pomoću kojeg je u ovom radu generiran prvi strukturni oblik matrice funkcije proizvoda i njezinih zahtjeva za stator elektromotora usisne jedinice. Primjenom modela matrice funkcije proizvoda i njihovih zahtjeva, u procesu koncipiranja proizvoda, omogućuje se konstruktoru preispitivanje samoga sebe uspoređujući mogućnosti realizacije novih ideja s već prethodno napravljenim proizvodima.

Ključne riječi

Funkcijska matrica
Funkcijsko modeliranje
Koncipiranje
Matrica funkcionalnosti
Sinteza konstrukcije

Received (primljeno): 2008-11-15
Accepted (prihvaćeno): 2009-06-10

1. Introduction

Within the lifetime of a product, the conceptual design is on the earliest phases, where the needs of the user and the technical requirements are translated into construction solutions through the design synthesis procedures [1]. User demands play a major role in increasing competitiveness of the product within the process of product development [2]. When user demands are finally defined, it is possible to define functional requirements and allocate goals of construction process [3].

In a construction process, the products, which represent technical systems, have a purpose and a reason for being, or in other words, their function. Functional modeling allows for an abstract approach, direction, understanding and a display of the complete product functionality [4]. The complete product functionality is divided into partial functions needed to complete the total functionality through the process of decomposition. The functional structure of the product that defines function as transformation of energy, materials and information is built in this way [5].

To accomplish the goal of standardizing the terminology in functional modeling, a standard dictionary is created, titled function basics. Kirschman and Fadel [6]

Symbols/Oznake

$P_{\mathrm{BB}j\,\mathrm{A}k\,i}$ - *j*-th building element BB*j*'s *i*-th parameter of the *k*-th auxiliary function A*k*
- *i*-ti parameter, *k*-te pomoćne funkcije, *j*-tog gradivnog elementa BB*j*

$P_{\mathrm{BB}j\,\mathrm{B}k\,i}$ - *j*-th building element BB*j* 's *i*-th parameter of the *k*-th binding function B*k*
- *i*-ti parameter, *k*-te povezne funkcije B*k*, *j*-tog gradivnog elementa BB*j*

$P_{\mathrm{BB}j\,\mathrm{M1}\,i}$ - *j*-th building element BB*j*'s *i*-th parameter of main function M1
- *i*-ti parametar glavne funkcije M1, *j*-tog gradivnog elementa BB*j*

$P_{\mathrm{BB}j\,\mathrm{S}k\,i}$ - *j*-th building element BB*j*'s *i*-th parameter of the supplementary function S*k*
- *i*-ti parameter, *k*-te dopunske funkcije S*k*, *j*-tog gradivnog elementa BB*j*

$PA_{\mathrm{BB}j\,\mathrm{A}k}$ - *j*-th building element BB*j*'s set of parameters of the *k*-th auxiliary function A*k*
- skup parametara *k*-te pomoćne funkcije A*k*, *j*-tog gradivnog elementa BB*j*

$PB_{\mathrm{BB}j\,\mathrm{B}k}$ - *j*-th building element BB*j*'s set of parameters of the *k*-th binding function B*k*
- skup parametara *k*-te povezne funkcije B*k*, *j*-tog gradivnog elementa BB*j*

$PM_{\mathrm{BB}j\,\mathrm{M1}}$ - *j*-th building element BB*j*'s set of parameters of main function M1
- skup parametara glavne funkcije M1, *j*-tog gradivnog elementa BB*j*

$PS_{\mathrm{BB}j\,\mathrm{S}k}$ - *j*-th building element BB*j*'s set of parameters of the *k*-th supplementary function S*k*
- skup parametara *k*-te dopunske funkcije S*k*, *j*-tog gradivnog elementa BB*j*

$WP_{\mathrm{BB}j\,\mathrm{A}}$ - set of all winning parameters of the *j*-th building element BB*j*'s all auxiliary functions A
- skup svih pobjednih parametara *j*-tog gradivnog elementa BB*j*, svih njegovih pomoćnih funkcija A

$WP_{\mathrm{BB}j\,\mathrm{B}}$ - *j*-th building element BB*j*'s all binding functions B set of all winning parameters
- skup svih pobjednih parametara *j*-tog gradivnog elementa BB*j* svih njegovih poveznih funkcija B

$WP_{\mathrm{BB}j\,\mathrm{M}}$ - *j*-th building element BB*j*'s main function M set of all winning parameters
- skup svih pobjednih parametara *j*-tog gradivnog elementa BB*j* njegove glavne funkcije M

$WP_{\mathrm{BB}j\,\mathrm{S}}$ - set of all winning parameters of the *j*-th building element BB*j*'s all supplementary functions S
- skup svih pobjednih parametara *j*-tog gradivnog elementa BB*j*, svih njegovih dopunskih funkcija S

$WP_{\mathrm{BB}j\,\mathrm{A}k}$ - *j*-th building element BB*j*'s set of winning parameters of the *k*-th auxiliary function A*k*
- skup pobjednih parametara *k*-te pomoćne funkcije A*k*, *j*-tog gradivnog elementa BB*j*

$WP_{\mathrm{BB}j\,\mathrm{B}k}$ - *j*-th building element BB*j*'s set of winning parameters of the *k*-th binding function B*k*
- skup pobjednih parametara *k*-te povezne funkcije B*k*, *j*-tog gradivnog elementa BB*j*

$WP_{\mathrm{BB}j\,\mathrm{M1}}$ - *j*-th building element BBj's set of winning parameters of main function M1
- skup pobjednih parametara glavne funkcije M1, *j*-tog gradivnog elementa BB*j*

$WP_{\mathrm{BB}j\,\mathrm{S}k}$ - *j*-th building element BB*j*'s set of winning parameters of the *k*-th supplementary function S*k*
- skup pobjednih parametara *k*-te dopunske funkcije S*k*, *j*-tog gradivnog elementa BB*j*

suggest a taxonomy made from four basic mechanical groups of functions. The papers [4, 7] conduct a classification of functions and flows into classes, which desire to achieve unambiguity in defining the terminology related to names of functions and flows. Žavbi, in papers [8-9] describes the functions by chaining physical laws. With the aim to accomplish unambiguity in function definition, rules are defined how to list function, functionality and product [10].

One of the primary goals of the previously mentioned synthesis, based on the paradigm of functional synthesis, is generating the structure of new technical systems by linking the functional models with existing technical systems that can realize them [11].

Functional synthesis uses numerous tools to relate functions and components, and functions and physical laws. Matrix methods like morphological matrices [12-13] are commonly used, as well as construction matrices [14] and houses of quality [15]. Morphological matrix as a tool was created by decomposing the total product function into partial functions, which are then listed in the matrix. The matrix then enables the recognition of technical systems that solve the functions in the matrix.

Computer-based tools can greatly contribute to a better and more efficient conduct of the construction process, to a reduction of the time used by a constructor in conducting activities within the process, and to a reduction of costs linked to the construction process. The development of computer-based tools in certain phases of the product development went in the opposite direction from the sequence of product development phase, as implicated in papers [16-17]. Because of the abstractness and undefined technical systems which present great obstacles and challenges for algorithm development that present the background of these tools, there is a great need for the development of new computer-based tools in the conceptual design phase [18].

The model of the first structural shape of the product function matrix and its requests model are shown in this paper. The model was developed based on the model shown in [3]. The model relates the functions and the technical systems that solve them. The functions that are set in the product function matrix and its requests model are described by parameters, because of their unambiguity. The physical laws are the basis for the definition of parameters. The parameters consist of: basic physical variables derived physical variables, geometric variables and physical constants. The parameters that have the greatest influence on a function are the winning parameters. The relations between functions and the technical systems that solve them are accomplished through winning parameters. By linking multiple product function matrices and their request models, through common linking function requirements, a matrix product structure is constructed. By linking matrices among themselves, a total functional and design structure of the product is generated. The rules defined in [10] are implemented in the model of product function matrix and its requests.

The first structural shape of the product function matrix and its requests model builds the lowest level of the matrix structure of the described product. This model is implemented into a developed prototype computer system. This paper demonstrates the first generated structural shape of the product function matrix and its requests model through the developed computer system. The matrix describes the technical system of the stator of an electromotor, from the intake unit of vacuum cleaner. The developed prototype computer system helps the constructor to generate the functional and design structure of existing and new products as variants of the previous ones, based on functional synthesis.

2. Product function matrix and its request model

Product function matrix and its request model is developed by an expanding model of function and functionality matrix, described in [3]. The product function matrix and its requests model is developed as a tool to aid the designer in the conceptual design phase to generate new variants of a product on the basis of previously made products. When functions are defined, the matrix correlates these functions on the one side and functionalities on the other side. Functionality is represented by technical systems [10]. The starting point in defining the product function matrix and its requests is the product functional structure which forms the input into the product function matrix and its requests. Thus the products at different levels must first be connected into a system. By system designing, functions and functional structure is defined. This procedure is described in detail [10].

The product function matrix and its requests model have two structural forms. In this paper the first structural form of product function matrix and its requests is presented. This structural form contains functions and technical systems that solve them. The form is placed on the last level of the listed system. The other, higher-level structural form refers to all other levels that are above the lowest level of the indexed system.

2.1. First structural form of product function matrix and its requests

First structural form of product function matrix and its requests is illustrated in (Figure 1). Within the product function matrix and its requests the functions are classified by types of functions in the following way: main function, designated by (M), supplementary function, designated by (S), auxiliary function, designated by (A) and binding function, designated by (B).

Building elements represent the technical systems, which form design models. Technical systems can be of different complexity. Functionalities are represented through building elements that solve the defined functions.

Aiming at the simplicity of the model, the names of building elements are designated by common marks: BB1, BB2,…, BB*j*: j = 1,..., m (Figure 1).

The column *description* contains the names of functions. For the sake of model simplicity the names are given by common marks. The main function's name is marked by (M1). Each building element can have only one main function. The names of the matrix model supplementary functions are marked by: S1, S2,…, S*k*: k = 1,..., p. Auxiliary functions are marked by: A1, A2,…, A*k*: k = 1,..., p.

A building element can have one or more supplementary and auxiliary functions. A building element may have no supplementary and auxiliary function. Binding functions are marked by: B1, B2,…, B*k*; k = 1,..., p. A building element cannot be without at least one binding function in its structure. The value p need not be the same for supplementary, auxiliary and binding function.

Owing to its being unambiguous each function is described by parameters. Depending on the function's complexity, the function can be described by varying number of parameters.

After all the parameters that unambiguously determine the functions have been listed, the winning parameters should be chosen. Winning parameters are determined for each function separately, and they represent those parameters that have the strongest impact on a particular function. A function can have at least one winning parameter. It is not possible for all the parameters that describe a particular function to be the winning parameters of the function at the same time.

To facilitate the explanation of the product function matrix and its requests model, in columns *parameters* and *winning parameters,* the parameters and the winning parameters are represented using sets for each particular type of function (Figure 1). A particular building element can have several supplementary, auxiliary and binding functions. Therefore, a set of winning parameters is defined for each supplementary, auxiliary and binding function.

Below the row *functionality* there are columns with the names of building elements listed in the table. It is possible to include j = 1,..., m of building elements in the matrix where a j appears in the name of the building element.

In general, the j-th building element BBj can be mathematically presented in the following way:

- **for supplementary functions:**

$$WP_{\mathrm{BB}j\ \mathrm{S}} = \left\{ WP_{\mathrm{BB}j\ \mathrm{S}1}, WP_{\mathrm{BB}j\ \mathrm{S}2}, \ldots, WP_{\mathrm{BB}j\ \mathrm{S}k} \right\}, \quad j = 1,\ldots,\mathrm{m}; k = 1,\ldots,\mathrm{p} \tag{1}$$

$$WP_{\mathrm{BB}j\ \mathrm{S}k} \subset PS_{\mathrm{BB}j\,\mathrm{S}k}, \tag{2}$$

$$PS_{\mathrm{BB}j\ \mathrm{S}k} = \left\{ P_{\mathrm{BB}j\ \mathrm{S}k\ 1}, P_{\mathrm{BB}j\ \mathrm{S}k\ 2}, \ldots, P_{\mathrm{BB}j\ \mathrm{S}k\ i} \right\}. \quad j = 1,\ldots,\mathrm{m};\ k = 1,\ldots,\mathrm{p};\ i = 1,\ldots,\mathrm{n} \tag{3}$$

- **for auxiliary functions:**

$$WP_{\mathrm{BB}j\ \mathrm{A}} = \left\{ WP_{\mathrm{BB}j\ \mathrm{A}1}, WP_{\mathrm{BB}j\ \mathrm{A}2}, \ldots, WP_{\mathrm{BB}j\ \mathrm{A}k} \right\}, \quad j = 1,\ldots,\mathrm{m};\ k = 1,\ldots,\mathrm{p} \tag{4}$$

$$WP_{\mathrm{BB}j\ \mathrm{A}k} \subset PA_{\mathrm{BB}j\,\mathrm{A}k}, \tag{5}$$

$$PA_{\mathrm{BB}j\ \mathrm{A}k} = \left\{ P_{\mathrm{BB}j\ \mathrm{A}k\ 1}, P_{\mathrm{BB}j\ \mathrm{A}k\ 2}, \ldots, P_{\mathrm{BB}j\ \mathrm{A}k\ i} \right\}. \quad j = 1,\ldots,\mathrm{m};\ k = 1,\ldots,\mathrm{p};\ i = 1,\ldots,\mathrm{n} \tag{6}$$

- **for binding functions:**

$$WP_{\mathrm{BB}j\ \mathrm{B}} = \left\{ WP_{\mathrm{BB}j\ \mathrm{B}1}, WP_{\mathrm{BB}j\ \mathrm{B}2}, \ldots, WP_{\mathrm{BB}j\ \mathrm{B}k} \right\}, \quad j = 1,\ldots,\mathrm{m};\ k = 1,\ldots,\mathrm{p} \tag{7}$$

$$WP_{\mathrm{BB}j\ \mathrm{B}k} \subset WP_{\mathrm{BB}j\ \mathrm{B}k}, \tag{8}$$

$$PB_{\mathrm{BB}j\ \mathrm{B}k} = \left\{ P_{\mathrm{BB}j\ \mathrm{B}k\ 1}, P_{\mathrm{BB}j\ \mathrm{B}k\ 2}, \ldots, P_{\mathrm{BB}j\ \mathrm{B}k\ i} \right\}. \quad j = 1,\ldots,\mathrm{m};\ k = 1,\ldots,\mathrm{p};\ i = 1,\ldots,\mathrm{n} \tag{9}$$

- **for main functions:**

As each building element can have only one main function, the above expressions are to be adapted in the following way:

$$WP_{\mathrm{BB}j\ \mathrm{M}} = \left\{ WP_{\mathrm{BB}j\ \mathrm{M}k} \right\} = \left\{ WP_{\mathrm{BB}j\ \mathrm{M}1} \right\}, \quad j = 1,\ldots,\mathrm{m};\ k = 1 \tag{10}$$

$$WP_{\mathrm{BB}j\ \mathrm{M}1} \subset PM_{\mathrm{BB}j\ \mathrm{M}1}, \tag{11}$$

$$PM_{\mathrm{BB}j\ \mathrm{M}1} = \left\{ P_{\mathrm{BB}j\ \mathrm{M}1\,1}, P_{\mathrm{BB}j\ \mathrm{M}1\,2}, \ldots, P_{\mathrm{BB}j\ \mathrm{M}1\,i} \right\}. \quad j = 1,\ldots,\mathrm{m};\ i = 1,\ldots,\mathrm{n} \tag{12}$$

The value n need not be the same for main, supplementary, auxiliary and binding function.

Connections between functions and building elements within the product function matrix and its requests are illustrated by the correlation elements in the matrix fields. If the connection between a function and a building element is not realized, the matrix fields are empty. The correlation elements are of two types interconnected in two ways:

- connection within the matrix,
- connection towards the matrices on the same level and the matrices on other levels.

Correlation within the matrix is performed between the main, supplementary, auxiliary and binding functions and the building elements that solve the given functions. When correlating main function and building element that solves it, the set of the main function winning parameters listed in the column *winning parameters* is to be equal to the set of all winning parameters for this type of function of this building element.

If this condition is not satisfied, connection between the main function and the building element cannot be realized. The j-th building element named BBj can be written as:

$$WP_{\mathrm{BB}j\ \mathrm{M}1} = WP_{\mathrm{BB}j\ \mathrm{M}}. \quad j = 1,\ldots,\mathrm{m} \tag{13}$$

Correlation between building elements and auxiliary functions are represented by the equation (14). In the case where the building element does not solve any auxiliary function, the fields of the product function matrix and its requests are empty. The j-th building element named BBj can be written as:

$$WP_{\mathrm{BB}j\ \mathrm{A}k} \subset WP_{\mathrm{BB}j\ \mathrm{A}}. \quad j = 1,\ldots,\mathrm{m};\ k = 1,\ldots,\mathrm{p} \tag{14}$$

The analogy with binding functions is the same as with supplementary and auxiliary functions. The condition for interconnecting the j-th building element named BBj and the binding function can be written as:

BUILDING BLOCK	FUNCTION	DESCRIPTION	PARAMETERS	WINNING PARAMETERS	FUNCTIONALITY											
					BB1				BB2				BB*j*			
					M	S	A	B	M	S	A	B	M	S	A	B
					$WP_{BB1\ M}$	$WP_{BB1\ S}$	$WP_{BB1\ A}$	$WP_{BB1\ B}$	$WP_{BB2\ M}$	$WP_{BB2\ S}$	$WP_{BB2\ A}$	$WP_{BB2\ B}$	$WP_{BBj\ M}$	$WP_{BBj\ S}$	$WP_{BBj\ A}$	$WP_{BBj\ B}$
BB1	M	M1	$PM_{BB1\ M1}$	$WP_{BB1\ M1}$	+											
	S	S1	$PS_{BB1\ S1}$	$WP_{BB1\ S1}$		+										
		S2	$PS_{BB1\ S2}$	$WP_{BB1\ S2}$		+										
		S*k*	$PS_{BB1\ Sk}$	$WP_{BB1\ Sk}$		+										
	A	A1	$PA_{BB1\ A1}$	$WP_{BB1\ A1}$			+									
		A2	$PA_{BB1\ A2}$	$WP_{BB1\ A2}$			+									
		A*k*	$PA_{BB1\ Ak}$	$WP_{BB1\ Ak}$			+									
	B	B1	$PB_{BB1\ B1}$	$WP_{BB1\ B1}$				+				+				
		B2	$PB_{BB1\ B2}$	$WP_{BB1\ B2}$				■								+
		B*k*	$PB_{BB1\ Bk}$	$WP_{BB1\ Bk}$				+								
BB2	M	M1	$PM_{BB2\ M1}$	$WP_{BB2\ M1}$					+							
	S	S1	$PS_{BB2\ S1}$	$WP_{BB2\ S1}$						+						
		S2	$PS_{BB2\ S2}$	$WP_{BB2\ S2}$						+						
		S*k*	$PS_{BB2\ Sk}$	$WP_{BB2\ Sk}$						+						
	A	A1	$PA_{BB2\ A1}$	$WP_{BB2\ A1}$							+					
		A2	$PA_{BB2\ A2}$	$WP_{BB2\ A2}$							+					
		A*k*	$PA_{BB2\ Ak}$	$WP_{BB2\ Ak}$							+					
	B	B1	$PB_{BB2\ B1}$	$WP_{BB2\ B1}$								+				
		B2	$PB_{BB2\ B2}$	$WP_{BB2\ B2}$				+				+				
		B*k*	$PB_{BB2\ Bk}$	$WP_{BB2\ Bk}$								■				
BB*j*	M	M1	$PM_{BBj\ M1}$	$WP_{BBj\ M1}$									+			
	S	S1	$PS_{BBj\ S1}$	$WP_{BBj\ S1}$										+		
		S2	$PS_{BBj\ S2}$	$WP_{BBj\ S2}$										+		
		S*k*	$PS_{BBj\ Sk}$	$WP_{BBj\ Sk}$										+		
	A	A1	$PA_{BBj\ A1}$	$WP_{BBj\ A1}$											+	
		A2	$PA_{BBj\ A2}$	$WP_{BBj\ A2}$											+	
		A*k*	$PA_{BBj\ Ak}$	$WP_{BBj\ Ak}$											+	
	B	B1	$PB_{BBj\ B1}$	$WP_{BBj\ B1}$				+								■
		B2	$PB_{BBj\ B2}$	$WP_{BBj\ B2}$												+
		B*k*	$PB_{BBk\ Bi}$	$WP_{BBj\ Bk}$												■

Figure 1. First structural form of product function matrix and its requests

Slika 1. Prvi oblik strukture matrice funkcije proizvoda i njezini zahtjevi

$$WP_{BBj\ Bk} \subset WP_{BBj\ B}$$
$$j = 1,.., \mathrm{m};\ k = 1,..., \mathrm{p}. \quad (15)$$

The product function matrix and its requests are composed of its sub-matrices within which the functions grouped in four types are correlated with the building element that solves them. It can be seen from (Figure 1) that the sub-matrices are positioned in the direction of the product function matrix and its requests main diagonal. Bindings for connection within the matrix and bindings for connection toward other matrices on the same level and toward matrices on other levels form the main matrix diagonal.

The product function matrix and its requests is square. It cannot be said that the matrix is completely diagonal due to the fields within which are found the correlation elements outside of the main diagonal. Over these correlations connection between building elements inside the product function matrix and its requests is accomplished.

3. Computer-based tool with the implemented product function matrix and its requests

The first structural design of the product function matrix and its requests model shown in this chapter was generated through the developed computer system. The technical system of the stator of an electromotor of the intake unit of vacuum cleaner is described in the matrix (Figure 2).

The matrix structure of the product describes the technical systems that are constructed from simple technical system by the first structural design of the product function matrix and its requests model. A simple technical system is made of binding elements. The products are structured in eight levels, ordered from simple to complex: *element*, *part*, *system*, *subassembly*, *assembly*, *machine*, *implement* and *object*. In this fusion, *part* and *element* are simple technical systems, which create the functional and design structure of a complex technical system through the matrix structure of the product. It is important to determine the context in which the product is examined by levels. For example, within a certain context an *assembly* can be considered a *subassembly* and vice versa. In the example of the first structural design of the product function matrix and its requests model (Figure 2), the stator of the electromotor of the intake unit, is observed in the context of a *system*. The electromotor is then a *subassembly*, the intake unit is an *assembly*, and the vacuum cleaner is a *machine*.

The simplicity and the complexity of a product should be viewed through the functional and design structure. If the functional structure is more complex, the design structure of the product is then more complex. The design structure is derived from the functional structure of the product. Design models create the design structure. The binding elements and components create the design model. The complexity of the design model depends on the complexity of the technical system. Depending on the complexity of the described product, the product function matrix and its requests model can have more or fewer rows and columns.

The product function matrix and its requests model, in the first and second design shape, have its name within the matrix structure of the product. The name consists the title of the technical system that is described and its main functions. The numbers in front of matrix names, placed in square brackets, show the level at which the matrix is found in the product matrix structure (Figure 3). Because of the complexity and the size of the matrix, (Figure 3) shows only a magnified and separated part of the product function matrix and its requests model for the stator of the electromotor. Within the product function matrix and its requests model the functions are divided into four types: main function marked with (M), supplementary function marked with (S), auxiliary function marked with (A) and binding function marked with (B). Every building element can have only one main function. It can also have one or more supplementary and auxiliary functions. A building element can not have either supplementary and auxiliary functions. In this case, the cells that contain names of functions within the product function matrix and its requests model are filled with a forward slash (/). Each building element has at least one or more binding functions.

The binding between functions and construction elements that solve them is done through bindings. If there is no established connection between a function and a building element, the matrix fields are empty. The bindings have two forms related to the way in which they connect: binding with the matrix () and binding toward other matrices on the same level and toward matrices on other levels (). Bindings for connecting within a matrix are located on the main diagonal of the matrix and also outside the main diagonal. The bindings that fill the fields of the matrix outside the main diagonal are a result of common binding functions, which have equal sets of winning parameters and building elements, and building elements where these sets of winning parameters are subsets of their sets of all winning parameters of binding functions. The connectivity between building elements within the product function matrix and its requests model is established through these binding functions.

Connectivity toward other matrices on the same level and matrices on other levels is established through common binding functions, to those building elements set within other product function matrices and their requests models. These bindings are found only in the main diagonal of the product function matrix and its requests model.

The developed prototype computer application allows for bindings to contain data on those winning parameters that are common to building elements and the functions with which the elements are connected to. The data is visible through floating menus over the bindings. The bindings toward other matrices on the same level and matrices on other levels are active links through which windows containing detailed data on the building element, through whose common binding functions establish bindings toward other product function matrices and their request models within the product matrix structure are opened. The data contains all binding functions of the building element, including the binding function that connects that building element with the building element in another product function matrix and its requests model. The window contains the name of the product function matrix and its requests model that the link leads to, the number of level for the matrix within the matrix structure, the winning parameters of the common binding functions of building elements which are inter-related and located at different product function matrices and their requests models, and the winning parameters of all binding functions of the building element that the link leads to (Figure 4).

4. Conclusion

Modeling products through functions has a major role in conceptual design and construction process, because it makes possible the abstractness, direction, understanding and display of the complete function of the product. In the construction process, all products that represent technical systems have a purpose and a reason for being, or in other words have their function.

The construction process is determined as a binding between product function and its design. After the construction task is defined, the main function and functionality of the future product is determined.

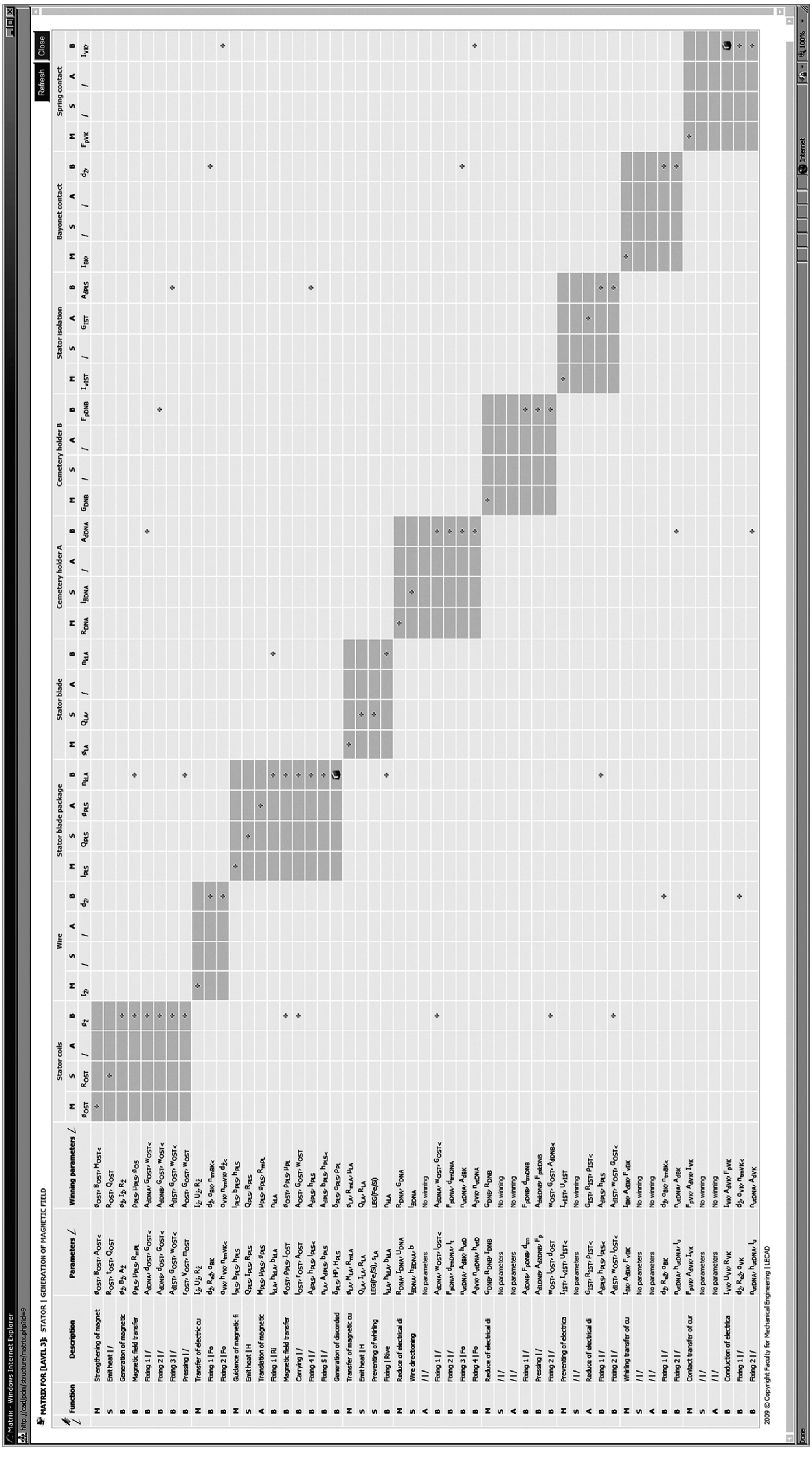

Figure 2. Product function matrix and its requests model for the technical system of the stator of an electromotor

Slika 2. Matrica funkcije proizvoda i njezinih zahtjeva za tehnički sustav stator elektromotora

The origin of the construction process are function requirements and wishes that can be shown in a descriptive form, through functions or functionalities and in a graphical form, through design models and known technical systems. Within the construction process, one of the most important phases is the conceptual design phase, during, which the user demands and technical requirements are translated into construction solutions. Conceptual design is therefore one of the earliest phases in the product lifetime, where the user's needs and technical requirements are translated into construction solutions.

This paper demonstrates the first structural form of the product function matrix and its requests model. The design process, as the binding between product function and its technical design, which is defined as functionality in details, is determined through the matrix. Each product described in the matrix creates functionality that is derived from main, supplementary, auxiliary and binding functions of the product. The product functions are described in more details by the parameters. The parameter list for specific functions is the novelty of this paper. The correlation between described functions and

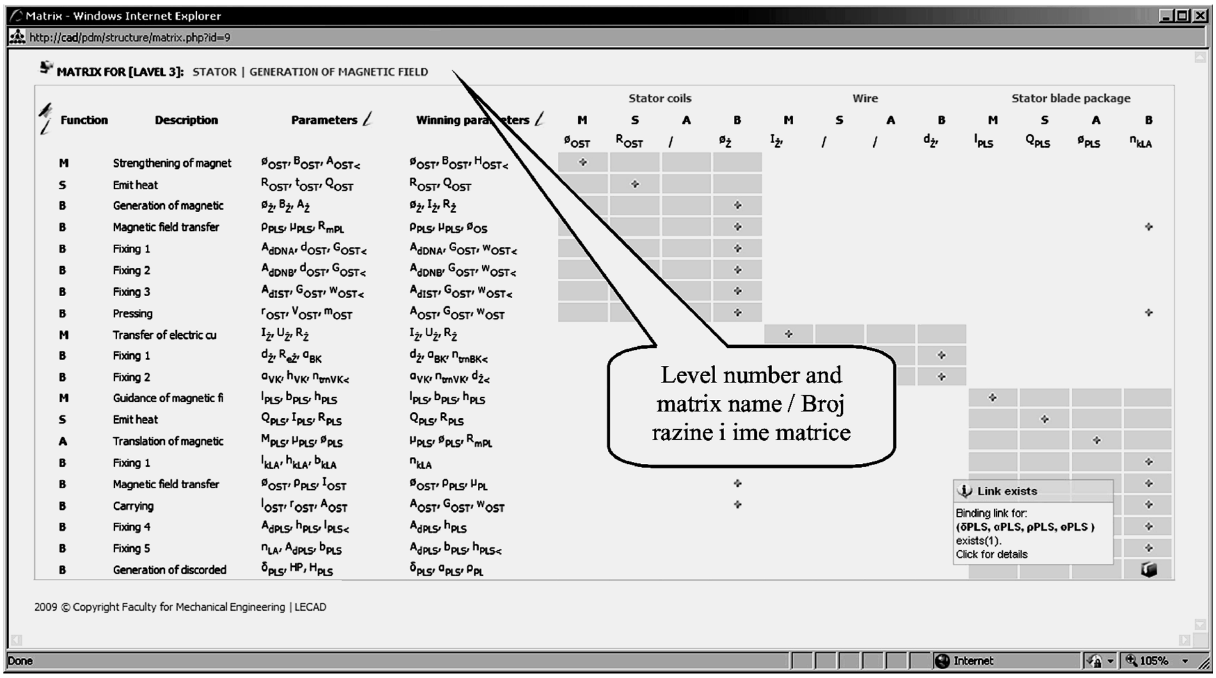

Figure 3. Bindings within product function matrix and its requests model

Slika 3. Poveznice unutar matrice funkcije proizvoda i njezinih zahtjeva

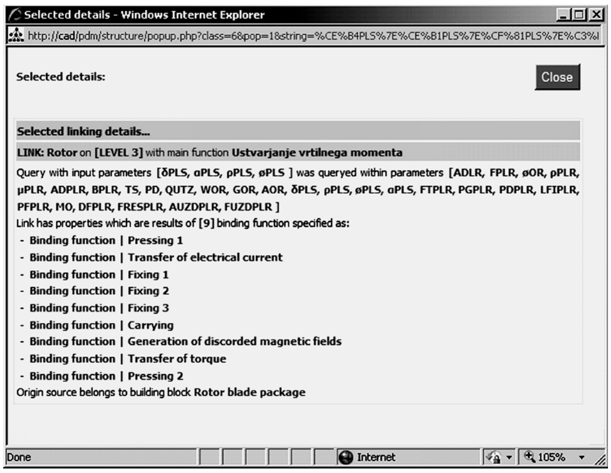

Figure 4. A window with data about binding functions of a building element

Slika 4. Prozor s podacima o poveznim funkcijama gradivnog elementa

technical systems that solve them is established through determination of winning parameters. The winning parameters have the greatest importance and influence on the defined functions. It is necessary to emphasize that intervals of numeric and descriptive values are generates in the description, meaning that the parameters gain a real meaning.

The model of the first structural form of the product function matrix and its requests model have been implemented into a developed prototype computer system. The first structural design of the product function matrix and its requests model was generated using the example of the stator of an electromotor of the intake unit of a vacuum cleaner.

The developed model of the product function matrix and its requests model is used as a tool through which the constructor generates functional and design structures of existing products during the conceptual design phase.

It also enables the constructor to build functional and design structures of new products, as variants of existing products described in the functionality and function matrix.

The basic idea for creating the product function matrix and its requests model is to enable the constructor to control himself within the construction process. By defining functions and their correlation into a single system, which can confirm an adequate physical system because it shows itself inside the matrix of the sub-matrix properties, the constructor can prove that he is on the right track. If the sub-matrix doesn't show, it can be states that the system of functions is upside down or that the functionality of individual technical systems is redundant and generally not applicable for use. In this way, the constructor can re-examine his idea, comparing it with previous construction solutions.

Acknowledgments

The work presented in this paper is financially supported by the Ministry of Higher Education, Science and Technology of the Republic of Slovenia and the Ministry of Science, Education and Sports of the Republic of Croatia through a bilateral project.

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