Program for Structural Synthesis
of the Multiple Fixtures

N. Seghedin, C. Zlati, and N. Zlati

Abstract—**This paper presents a program for structural synthesis -conception and design work-of the multiple fixture devices in the machine-tool structure. This program was created according to the principles of object-oriented programming. The program is also built upon two fundamental principles which characterize the evolution of the systems: the combination and the selection. The basic structural elements of the fixture devices are the clamping mechanisms. For this reason the program accomplishes clamping mechanism combinations, obtaining mathematically-possible combinations from which the combinations of technical incompatibility are excluded. Finally, the paper presents some fixtures functional structures obtained with the proposed program.**

Index Terms—**computer-aided planning and design, clamping mechanisms, fixtures, object-oriented programming.**

I. INTRODUCTION

The multiple fixtures are subsystems of technological systems of chip removal machine work and they are destined for the fixture (locating and clamping) of more pieces during one technological operation. The computer-aided synthesis of fixtures represent an important preoccupation for engineers in the manufacturing systems field.

Therefore, significant development was made in the field of computer-aided intelligent synthesis, and of fixtures out of modular elements [1]-[3]. Besides that, various automatic synthesis methodologies of the production system devices were structured [3]-[6]. Important advancements have been made concerning the genetic algorithms-aided synthesis of new fixtures [7]-[10]. Regarding clamping the pieces in devices, researches have been made concerning the determination of the optimum force of clamping [3], [9]. As far as the multiple clamping is concerned, researches have been made regarding the determination of the optimum force of clamping [10].

For structuring multiple fixtures, many researches have been made which primarily consisted in obtaining new structures of multiple clamping mechanisms in the construction of these devices [11], [12]. Furthermore, researches have been

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made concerning the possibilities of analysing the multiple clamping mechanisms, which is an essential condition for making an advanced synthesis of these mechanisms [13].

Analysing the literature of the field, one can notice that the multiple fixtures are characterised by important economical advantages. Thus, according to [14], these devices can lead to a time rate decrease of approximately 80 %. Therefore, when there are more pieces fixed in a device, the time rate decreases, among other reasons, because of: reducing the aiding time when fixing and detaching the pieces; reducing the basic time when using multiple tools; overlapping the basic time on the fixing-detaching aiding time, in the case of devices with charging-discharging stations.

These economical advantages determine the multiple fixture study have a great importance in the engineering theory and practice.

II. THE STRUCTURAL ANALYSIS OF THE MULTIPLE FIXTURES

Since the purpose of this paper is the structural synthesis of multiple fixtures, it is necessary that first and foremost a structural analysis of the multiple fixtures is made. After analyzing a large number of multiple fixtures, the result showed that the multiple fixture integrants can be reunited in various groups, named structural categories. Therefore, the basic structural groups that build a fixture are: Locating Elements and Mechanisms; Clamping (Alignment-Clamping) Elements and Mechanisms; Action Elements and Mechanisms; Division Elements and Mechanisms etc [11].

From all the structural groups composing the multiple fixtures, it was noticed that the group with the most influence on the structural aspect of the device is the Clamping (Alignment-Clamping) Mechanism group. This is due to the fact that these mechanisms are, generally, the most complex and multiple in the structure of the fixtures. These mechanisms are the ones which transmit the necessary energy for clamping the pieces, from the (manual, hydraulic, pneumatic, electromagnetic, electric etc.) action sub-system of the fixture.

III. THE STRUCTURAL ANALYSIS OF THE MULTIPLE CLAMPING MECHANISMS

The structural analysis of the multiple clamping mechanisms is aimed to track down the component elements of these mechanisms and the manner in which these elements combine.

The analysis of the multiple clamping mechanisms has been made on several levels.

On a first analysis level, as a consequence of the study of a

significant number of multiple clamping mechanisms, and according to the research papers [11]-[13], the result was that the general structure of multiple clamping mechanisms (for clamping the pieces P), contains three subsystems: the entry subsystem (In), the intermediary subsystem (Im) and the exit subsystem (Ie) (Fig. 1).
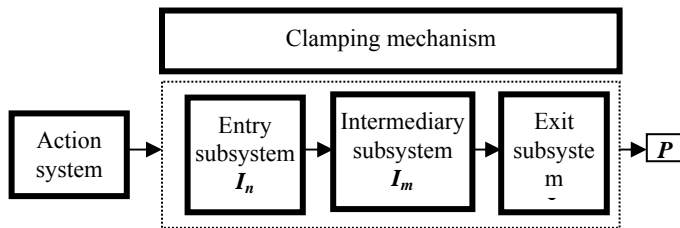

Fig. 1. The general structure of multiple clamping mechanisms

The entry subsystem contains those elements through which the energy is transmitted from the action system at the other multiple clamping mechanism subsystems. There are also cases in which the clamping is made directly through the entry elements, because the other clamping mechanism are missing or the entry subsystem makes a contact with the pieces P_1, P_2, ...P_n.

The intermediary subsystem contains the elements which change (amplify or reduce) the action forces.

The exit subsystem contains those elements which make close contact with the pieces–they are the elements which effectively assure the clamping of the pieces P into the fixture.

On a second analysis level of the multiple clamping mechanisms, the structuring means (the functional structures) of the three (entry, intermediary, exit) subsystems were settled. Thus, the following conclusions resulted:

— the entry subsystem is embodied by one single element, one of the multiple clamping mechanism characteristics being that the energy flux enters the mechanism through one single channel, after which there follows a dispersal of forces on more channels in order to simultaneously or gradually clamp more pieces;

— the intermediary subsystem can be missing from the multiple clamping mechanism structure or it can be embodied in one, two, three or four clamping elements;

— the exit subsystem can be missing, case in which it can be confused with the entry subsystem; this subsystem is embodied, almost always, by one single generic element, which is an element that can be found, at the same time, on more patterns of force transmission, patterns equal in number with the clamped pieces number.

In Fig. 2, there are examples of functional structures of multiple clamping mechanisms.

On a third analysis level of the multiple clamping mechanisms, clamping elements that are included in the entry, intermediary and exit subsystem structure were settled:

— entry subsystem (In): Screw - nut (simple, left-right); Hydraulic (pneumatic) cylinder rod; Cam (eccentric) (simple, multiple); Lever;

— Intermediary subsystem (Im): Ram (rod, pipe) (simple, special); Lever; Lever-hydrorubber; Cam (eccentric) (simple,

multiple); Ball (roller); Wedge (cone); Hydrorubber; Jointed bar; Rack-gear wheel; Screw–nut; Worm and gear; Gear wheel- gear wheel; Connecting rod;

— Exit subsystem (Ie): Lever; Ram (jaw, prism); Spring; Lever-wedge; Wedge; Roller; Chuck.
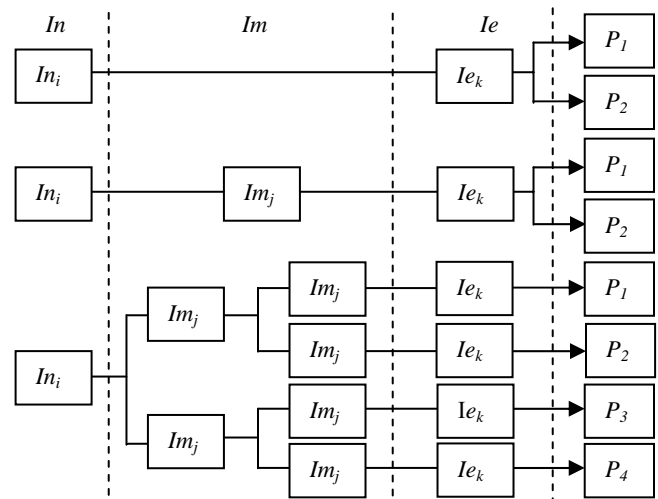

Fig. 2. Examples of functional structures of multiple clamping mechanisms (i=1... 4; j=1... 13; k=1... 7)

IV. THE STRUCTURAL SYNTHESIS PROGRAM OF THE MULTIPLE FIXTURES

The GENERATOR program, created in Visual C++ allows the obtaining of *new functional structures of multiple clamping mechanisms*, by the logical combination of the clamping elements in the entry, intermediary and exist subsystems. The program excludes the technically incompatible combinations and organizes the technically compatible combinations according to the extent to which these combinations meet certain appreciation criteria.

The GENERATOR program uses the elements of the C++ programming language for a class and object programming. The object-oriented programming (object-oriented techniques) is based on the concepts of *class*, object and a set of paradigms – the abstraction of the data and communication through messages, encapsulating, inheritance, polymorphism and dynamic binding.

In the object-oriented software engineering, the object-oriented analysis and the object-oriented design work-synthesis are very important. All remarkable methodologies of object-oriented software development impose, in the analysis stage, the identification and itemizing (attributes, behaviour, relationships) of the abstractions in the application field.

The premise of an object-oriented computational model is that the data nature of any application consists in a collection of objects as referrals to some classes. The architecture of the object systems is based on classes, objects, and the interactions between them.

In the case of multiple clamping mechanisms, the classes are represented by the three subsystems: the entry, intermediary and exit subsystems. The objects – the clamping elements –

consist in the component elements of the three subsystems. The interactions refer to the clamping elements combining manner etc. The referral objects of some classes have an inner structure and an outer behaviour defined by the class which they belong to. Therefore, the clamping elements are characterised by a certain number of entries and exits, as an expression of their inner structure. The outer behaviour is characterised by the value number which expresses the extent to which various criteria have been met. The same element can have various value numbers, according to the class (subsystem) which it belongs to. Essentially, an object has a state, a behaviour and an identity. As a first phase, to characterise these objects, with regard to the computer-aided synthesis, the following data must be pointed out: name, code, types of movement during the entry and the exit (rotation = R, translation = T), number of entries (I), number of exits (E). An example of a clamping element considered an object is presented in image three.

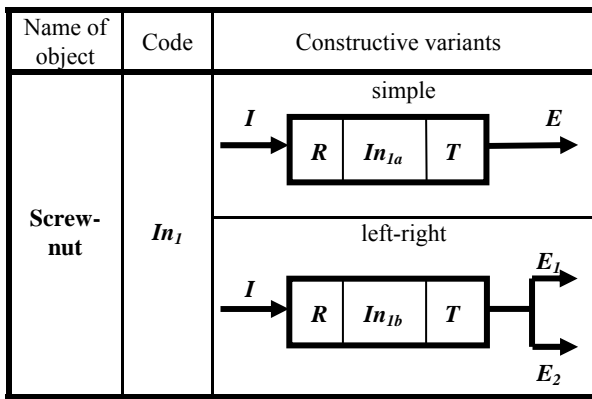| Name of object	Code	Constructive variants		
Screw-nut	In_1	simple		
		$I \rightarrow$	R In_{1a} T	$\rightarrow E$
		left-right		
		$I \rightarrow$	R In_{1b} T	$\rightarrow E_1$ $\rightarrow E_2$

Fig. 3. The screw-nut entry element as an object

According to object-oriented programming theory, every object must be described by a value. These values given to the objects (clamping elements) will be the base of the evaluation and regulation (arrangement) of the combinations that will be made by the GENERATOR program.

We opted for the determination, for each clamping element, of some value numbers obtained by implementing the imposed decision technique, from the value engineering. These value numbers are obtained according to the extent to which every clamping element meets certain appreciation criteria.

For the clamping elements which are entry elements the systematisation criteria are: operating mechanization possibility (OM); capacity of the forces distribution (FD); cost (C); selfbreaking characteristics (SB); capacity of the forces amplification (FA); efficiency (EF). The clasification criteria for the clamping elements from the intermediary subsystem are: capacity of the forces distribution (FD); cost (C); selfbreaking characteristics (SB); capacity of the uniform application of the forces (U); efficiency (EF); capacity of the forces amplification (FA). The clasification criteria for the exit clamping elements are: size of the contact tension between the clamping element and the piece (CT); efficiency (EF); capacity of the uniform application of the forces (U); capacity of the clamping of the different configuration pieces (DC); selfbreaking

characteristics (SB); capacity of the forces amplification (FA); cost (C).

We used the "imposed decision" technique from the value engineering for the global evaluation of the clamping elements. So, each clamping element will be characterized by a value (valuable) number (N_V) according to the way the appreciation criteria are solved.

First, a balanced sample of the appreciation criteria must be made. The criteria are compared one to the other and this is how the D decisions are obtained: 1-0; 0,5-0,5; 0-1. For example, in Table I the weighing of the appreciation criteria for the entry elements is presented.

Table I. Weighing the appreciation criteria for the entry elements

Appreciation criteria for the entry elements	DECISIONS D															Total decisions D	Weighting factor WN ($WN=D/15$)
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
OM	1	1	0.5	1	1											4.5	$WN_{OM}=0.30$
FD	0					1	0.5	0.5	1							3	$WN_{FD}=0.20$
C		0				0				0	0.5	0				0.5	$WN_{C}=0.03$
SB			05				05			1			0.5	0.5		3	$WN_{SB}=0.20$
FA				0				0.5			05		0.5		1	2.5	$WN_{FA}=0.16$
EF					0				0			1		0.5	0	1.5	$WN_{EF}=0.10$

Using this method, the appreciation criteria are re-arranging as in the following model:

a. The entry elements appreciation criteria (weights WN): 1-Operating mechanization possibility (OM) ($WN_{OM} = 0.3$); 2-Selfbreaking characteristics (SB) ($WN_{SB} = 0.2$); 3-Capacity of the forces distribution (FD) ($WN_{FD} = 0.2$); 4-Capacity of the forces amplification (FA) ($WN_{FA} = 0.16666$); 5-Efficiency (EF) ($WN_{EF} = 0.1$); 6-Cost (C) ($WN_{C} = 0.03333$).

b. The intermediary elements appreciation criteria (weigts WM): 1-Capacity of the uniform application of the forces (U) ($WM_{U} = 0.26666$); 2-Capacity of the forces distribution (FD) ($WM_{FD} = 0.23333$); 3-Capacity of the forces amplification (FA) ($WM_{FA} = 0.2$); 4-Selfbreaking characteristics (SB) ($WM_{SB} = 0.13333$); 5-Efficiency (EF) ($WM_{EF} = 0.13333$); 6-Cost (C) – ($WM_{C} = 0.03333$).

c. The exit elements appreciation criteria (weights WE): 1-Size of the contact tension between the clamping element and the piece (CT) ($WE_{CT} = 0.26190$); 2-Capacity of the uniform application of the forces (U) ($WE_{U} = 0.23809$); 3-Capacity of the clamping of the different configurations pieces (DC) ($WE_{DC} = 0.16666$); 4-Capacity of the forces amplification (FA) ($WE_{FA} = 0.16666$); 5-Efficiency (EF) ($WE_{EF} = 0.07142$); 6-Selfbreaking characteristics (SB) ($WE_{SB} = 0.04761$); 7-Cost (C) – ($WE_{C} = 0,04761$).

Next, the value numbers for each clamping element must be fixed. The value numbers for each element are obtained using the comparison, by all appreciation criteria, of the elements (which are components of each subsystem). For example, in Table II the comparison of the entry elements after the OM criteria, for obtaining the total decisions (D_{OM})is presented. The same way, the decisions D_{SB}, D_{FD}, D_{FA} are obtained etc.

Table II. Comparison of the entry elements after the *OM* criteria ($i = 1…4$)

Entry elements $\mathbf{I_n}$	DECISIONS *D*						Total decisions D_{OMi}	$D_{OMi}/6$
	1	2	3	4	5	6		
Screw-nut	0	05	0				0.5	0.83333
Hydraulic cilinder rod	1			1	0.5		2.5	0.41666
Cam (eccentric)		05		0		0	0.5	0.08333
Lever			1		0.5	1	2.5	0.41666

The value numbers (N_V) for these elements are established in order to the decisions (*D*) made after the comparison, one to another, of these elements using each of the criteria, the number of the decisions and the criteria weight. Thus, the general formula for the value numbers calculation for the entry elements (In_i, i=1…4) is:

$$N_V(In_i) = \frac{D_{OMi}}{6} \cdot WN_{OM} + \frac{D_{SBi}}{6} \cdot WN_{SB} + \frac{D_{FDi}}{6} \cdot WN_{FD} +$$

$$\frac{D_{FAi}}{6} \cdot WN_{FA} + \frac{D_{EFi}}{6} \cdot WN_{EF} + \frac{D_{Ci}}{6} \cdot WN_C.$$

The same way, each intermediary element (Im_j, j=1   13) will receive a value number, after the formula :

$$N_V(Im_j) = \frac{D_{Uj}}{78} \cdot WM_U + \frac{D_{FDj}}{78} \cdot WM_{FD} + \frac{D_{FAj}}{78} \cdot WM_{FA} +$$

$$\frac{D_{SBj}}{78} \cdot WM_{SB} + \frac{D_{EFj}}{78} \cdot WM_{EF} + \frac{D_{Cj}}{78} \cdot WM_C.$$

In a similar manner, the value numbers for the exit elements (Ie_k, k=1...7) are established using the formula:

$$N_V(Ie_K) = \frac{D_{CTk}}{21} \cdot WE_{CT} + \frac{D_{Uk}}{21} \cdot WE_U + \frac{D_{DCk}}{21} \cdot WE_{DC} +$$

$$\frac{D_{FAk}}{21} \cdot WE_{FA} + \frac{D_{EFk}}{21} \cdot WE_{EF} + \frac{D_{SBk}}{21} \cdot WE_{SB} + \frac{D_{Ck}}{21} \cdot WE_C.$$

In Table III, the value numbers of the clamping elements belonging to the three subsystems are determined.

The relations between objects, between classes, and between classes and objects represent, in fact, the essence of the computer based synthesis program of the multiple clamping mechanisms. In other languages, these relations are called rules and they underlie the structuring of the inference motors that characterize artificial intelligence. The relations have been stated, formulated and structured after many observations and analysis on multiple clamping mechanisms.

So, one of the first structuring rules is that multiple clamping mechanisms may have a liniar structure, as well as an arborescent, branched structure, and because of this, for each clamping element, the number of the convection tracks, for the input and output must be specified.

A very important rule or relation between objects is the on concerning the layout order of the clamping elements inside a combination. This rule is stated as the principle of the movement transmission compatibility: the imperative condition for a two-clamping element sequence to be technically viable is that the first element's output must coincide, concerning the movement form, with the second element's input.

Table III. The value numbers of the clamping elements belonging to the three subsystems.

Entry subsystem		
Code	Clamping Elements	*Nv*
In_1	Hydraulic (pneumatic) cylinder rod	0.32499
In_2	Screw - nut (simple, left-right)	0.26666
In_3	Lever	0.25277
In_4	Cam (eccentric) (simple, multiple)	0.19721
Intermediary subsystem		
Code	Clamping Elements	*Nv*
Im_1	Hydro-rubber	0.10208
Im_2	Lever-hydro-rubber	0.10033
Im_3	Lever	0.09285
Im_4	Ball (roller)	0.09285
Im_5	Wedge (cone)	0.08315
Im_6	Cam (eccentric) (simple, multiple)	0.08174
Im_7	Screw - nut (simple, left-right)	0.07824
Im_8	Worm and gear	0.07042
Im_9	Rack-gear wheel	0.06576
Im_{10}	Gear wheel- gear wheel	0.06149
Im_{11}	Jointed bar	0.05995
Im_{12}	Connecting rod	0.05837
Im_{13}	Ram (rod, pipe) (simple, special)	0.04999
Exit subsystem		
Code	Clamping Elements	*Nv*
Ie_1	Lever	0.16835
Ie_2	Chuck	0.15338
Ie_3	Ram (jaw, prism)	0.15146
Ie_4	Spring	0.14182
Ie_5	Ball(roller)	0.13093
Ie_6	Lever-wedge	0.12923
Ie_7	Wedge	0.12470

Computer instructions are structured in such a way that, if this condition is not achieved inside a combination, then the whole combination is deleted. This is the reason why the movement form of the input and output has been defined (rotation *R* and translation *T*) for each element inside the three subsystem structures (entry, intermediary and exit). In Fig.3 the use of the principle of the movement transmission compatibility is presented in a simplified way.
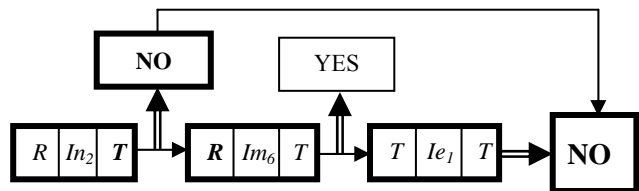

Fig. 3. The use of the principle of the movement transmission compatibility

The program allows structuring a data base that contains the elements inside the three subsystems. Inside this data base (Fig.

4), the name, the belonging subsystem, the motion form which characterizes the entries and the exits, the minimum and the maximum number of entries and exit, and the value number for each element are specified.

Fig. 4. The data base with clamping elements

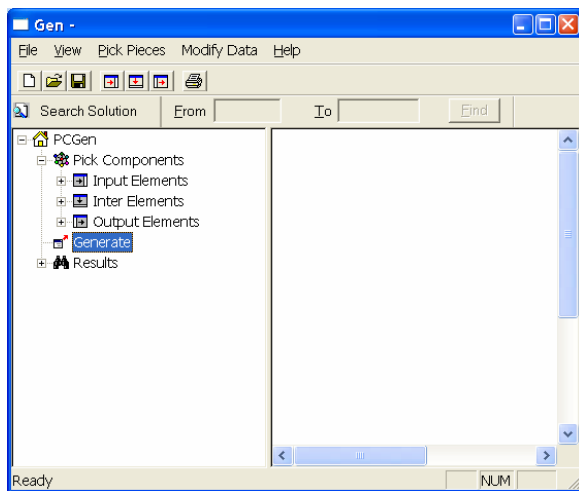In Fig. 5 the main window of the program is presented.

Fig. 5. The main window of the program.

To generate various functional structures of multiple clamping mechanisms, the elements that will embody the entry subsystem, the intermediary subsystem and the exit subsystem must be selected (Fig. 6, Fig. 7 and Fig. 8).

The program allows the visualization of the elements chosen for combination (Fig. 9). Another thing to be determined is how many levels (one, two or three) the contact elements must be set on, and then the combination, selection and arrangement process starts. The program arranges the obtained combination, according to the sums of the elements' value numbers. In Fig. 10 the arrangement of the obtained combinations is presented.

The program allows the visualization of the obtained combinations. These combinations can symbolize functional structures of some existent solutions concerning the multiple clamping mechanisms, or belonging to some new, unknown

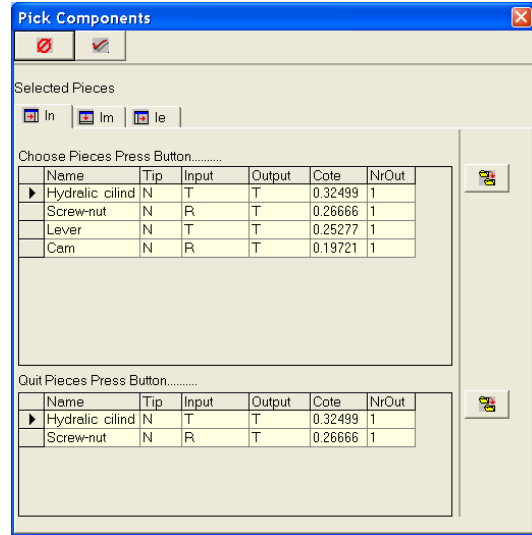solutions concerning these kinds of mechanisms.

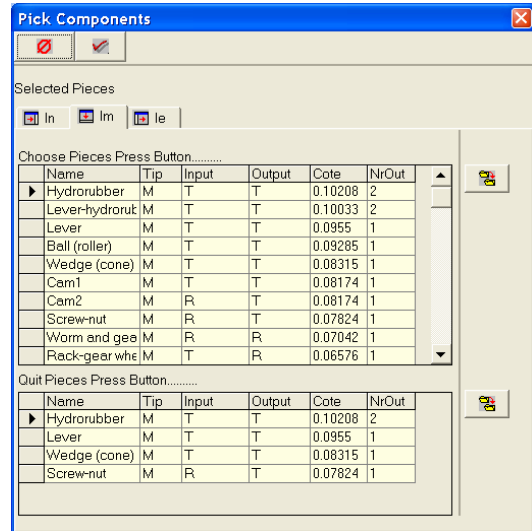Fig. 6. Choosing the entry subsystem elements.

Fig7. Choosing the intermediary subsystem elements.

In this latter case, the obtained combinations can underlie in making some creation themes in the multiple fixtures field. In Fig. 11 some functional systems obtained with the GENERATOR program are presented.

V. CONCLUSIONS

The GENERATOR program can be used as a means of obtaining new creation themes in the field of multiple fixtures, being at the same time, an efficient tool in stimulating technical creativity. The program can be improved by associating it with data bases containing graphical representations of clamping elements that combine in such a way that in the end structures of multiple clamping elements at the level of technical solution result, not only at the level of functional structure. Moreover, it

may forecast subprograms that can allow an automatic dimensioning of the obtained technical solutions.
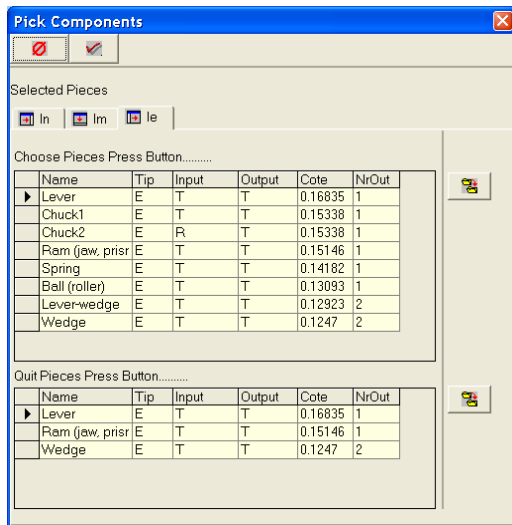

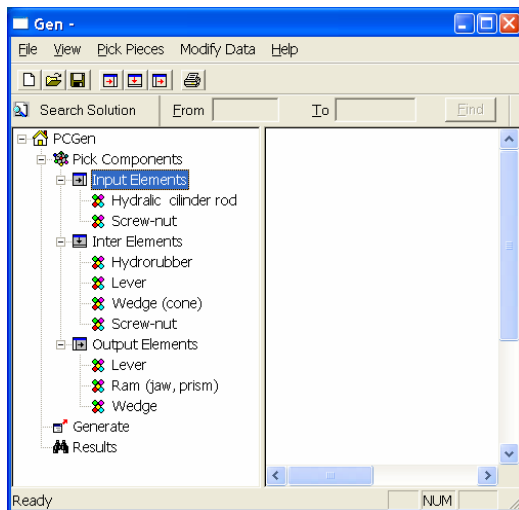Fig. 8. Choosing the exit subsystem elements.

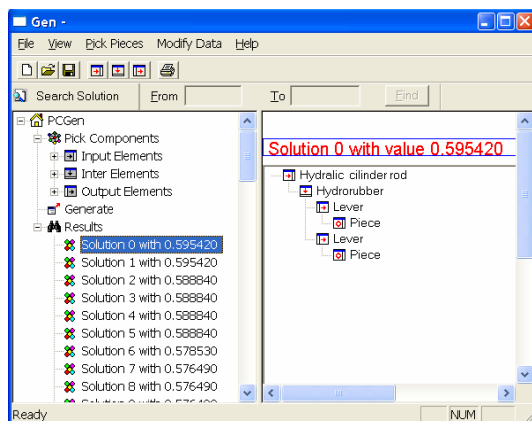Fig. 9. The visualization of the elements chosen for combination

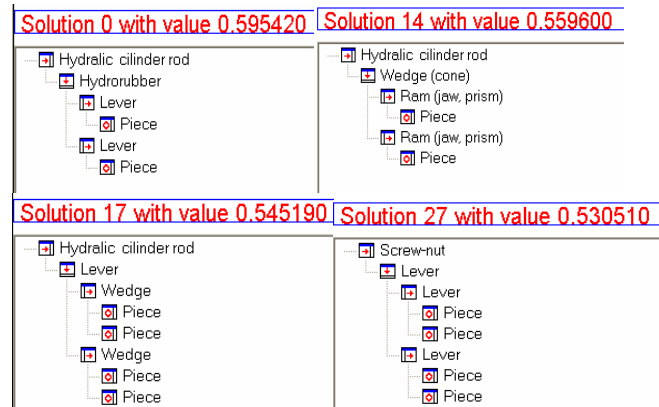Fig. 10. The arrangement of the obtained combinations.

Fig. 11. Functional systems obtained with the GENERATOR program

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