APPLICATION OF MULTILEVEL MORPHOLOGICAL ANALYSIS TO THE SYNTHESIS OF MECHANISMS OF FEEDING AND CLAMPING IN BAR MACHINES

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Abstract: *The basic principles of synthesis of feeders and bar grippers as the solution of multilevel, multivariate problems of finding ways of feeding and clamping, schemes to implement those methods, scheme design concepts for a given criterion using multilevel morphological analysis, are given here.*

Keywords: MORPHOLOGICAL ANALYSIS, FEEDING AND CLAMPING OF BAR, SYNTHESIS, LATHE AUTOMAT.

1. Introduction

Satisfaction of the variety of requirements to feed (FM) and clamping (CM) mechanisms of bar machines leads to a number of different schemes and designs, among which there are optimal to the appropiate quality criteria.

The process of optimal design of any target mechanism (M) is a multivariate, multilevel, multi-criteria analysis and synthesis issue (Fig. 1), the solution of which is associated with the choice of the best option [5, 11].

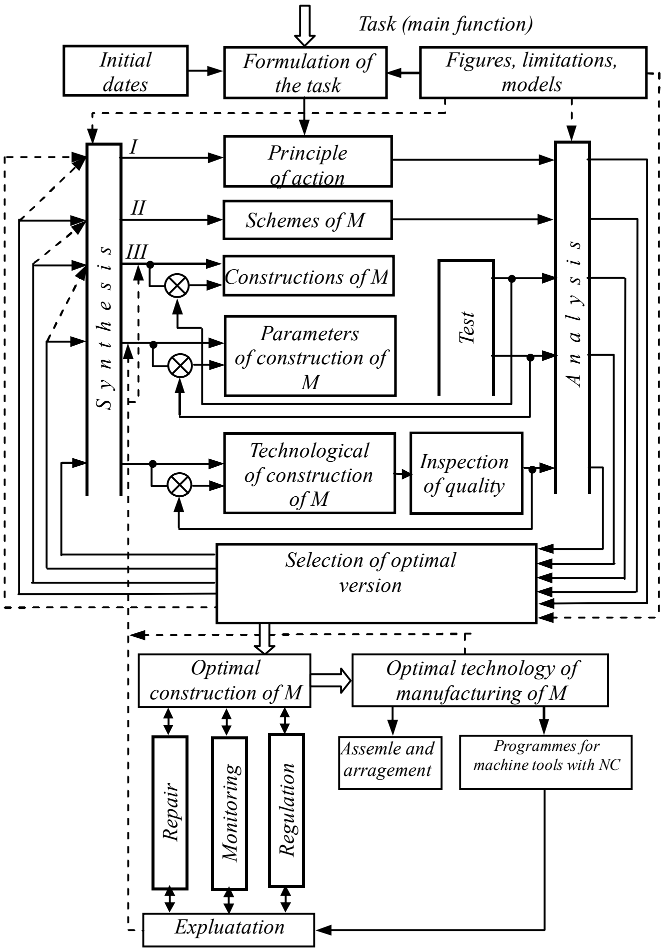


Fig.1 *The enlarged block diagram of the optimal design of targeted lathe mechanisms (M)*

Hierarchical separation of the design process into 4 levels, depending on the complexity of solved problems is conditional:

Level I - the synthesis and selection of action principle (method);

Level II - synthesis and selection of M schemes and its elements;

Level III - Synthesis and selection of M construction and its elements;

Level IV - Synthesis and selection of M rational design and its individual components.

Tracing the evolution of the FM and CM rod turning machines, as a technical system (TS) from the end of the XIX century. [4], to date, we can note the transfer of genetic information from the generating system, morphological traits that persist, and taking into account the advances in science and technology, knowledge not only in mechanics, but also Eother related sciences (physics, electrical, biology, genetics etc.) they are modified under the influence of purposeful human activity, systematic approach of the objective laws of development of different systems borrowed from nature. [1, 2, 3, 11, 14].

Morphology (from the Greek morpho - shape and logo - the doctrine), as the science of the structure of various organisms, organs, soil, from nature (morphology of stalk, morphology of bacteria, etc.). [2] was also applied to the TS [5, 8, 9, 10, 14, 17]. This gave impetus to the creation (synthesis) of new TS, which can be viewed at various levels of hierarchy (metasysytems, systems, subsystems) [7, 13].

2. Preconditions and means for resolving the problem

The method of morphological analysis can be applied at each level of issue solution. It creates a hierarcy of mulyvariate search of design solutions in designing the M, so FM and CM would be considered separately,

2.1. Feeding mechanisms synthesis

One can get a lot of options, using the aggregated (or mostly qualitative) criteria under incomplete information circumstances having the I-level morphological model principles (methods) of bar feeding on characteristic features (Table 1) [5]. The main indications for the morphological matrix (Table 1) are: the feeded object (type, method of storage, movement on filing), the location of the cohesive forces and the nature of the subject is moving (the place of filing, the clutch clamping elements with the object), the effect of creating cohesive forces, the number of locations of the cohesive forces, the location of moving and braking forces), the mechanism function, the presence of the stop limiting the movement of the object on feeding [6, 15, 16].

***Table 1:** Morphological table (M_1) containing principles (methods) of bar feeding*

Feeded (manipulated) object			The location of the cohesive forces and the pattern of object moving						
1.Type	2.Containment method	3.Moves during feed	4. Feed location	5.Coherence of FS and object	6.The effect of creating cohesive forces	7.Number of locations of the cohesive forces	8. The location of the moving and braking forces	9.Mechanism functions	10. Presence of the stop
1.1.Rounded rod 1.2.Sided rod 1.3.Tube 1.4.Detail-shaped profiled rod 1.5.Profiled detail-shaped tube 1.6. Rod and tube 1.7.Measured rods and workpieces	2.1.On the spindle line in the containment tube 2.2.On rollers along the spindle line 2.3.In a cartridge 2.4.In a bunker 2.5.In a drum 2.6.Combined	3.1.Translational 3.2.Rotary 3.3.Rotary and translational 3.4.No	4.1.inside spindle 4.2.Outside spindle 4.3.Inside and ourside 4.4.No	5.1 Jamming 5.2. Elastic 5.3.Combined 5.4. No	6.1.Mechanical 6.2.Electric 6.3.Magnetic 6.4.Electrostatic 6.5.Combined 6.6.No	7.1.One in front 7.2.One behind 7.3.Two in front 7.4.Two in front and behind 7.5.Along the entire length	8.1.In front 8.2.Behind 8.3.In front and behind 8.4.Along the entire length	9.1.Feed 9.2.Feeding and clamping 9.3.Support (momentum) 9.4.Confinement after cutoff 9.5.Нет	10.1.Present 10.2. Absent

The morphological model of bar feeding methods (except the morphological table) can be presented as morphological matrix:

Expanded

(1)
$$M_{PF} = \begin{vmatrix} 1.1 & 2.1 & 3.1 \\ 1.2 & 2.2 & 3.2 \\ 1.3 & 2.3 & 3.3 \\ 1.4 & 2.4 & 3.4 \\ 1.5 & 2.5 & \\ 1.6 & 2.6 & \\ 1.7 & & \end{vmatrix} \wedge \begin{vmatrix} 4.1 & 5.1 & 6.1 & 7.1 & 8.1 \\ 4.2 & 5.2 & 6.2 & 7.2 & 8.2 \\ 4.3 & 5.3 & 6.3 & 7.3 & 8.3 \\ 4.4 & 5.4 & 6.4 & 7.4 & 8.4 \\ & & 6.5 & 7.5 & \end{vmatrix} \wedge \begin{vmatrix} 9.1 \\ 9.2 \\ 9.3 \\ 9.4 \\ 9.5 \end{vmatrix} \wedge \begin{vmatrix} 10.1 \\ 10.2 \end{vmatrix}$$

Folded

(2)
$$M_{PF} = M_{FO} \wedge M_{FP} \wedge M_{FF} \wedge M_S$$

where M_{FO}, M_{FP}, M_{FF}, M_S – morphological matrix of: feedede object; feeding process; functions of FM; presence (absence) of the stop.

Having selected 1 or 2 methods of feeding implementation, we move to level II (pic. 2), where morphological models M_2' of shemes of bar feeding drive (FD), M_2'' scheme of feeding socket (FS), M_2''' bar stop shemes (S) are being built.

As an example, Table 2 shows the morphological table M_2'', where the main features are taken: the object of feed, the structure of FS (working part-feeding element, a body, the elastic part, auxiliary element); links feeding element (with the object of feed housing, the elastic part) and housing (with elastic part and the feed drive).

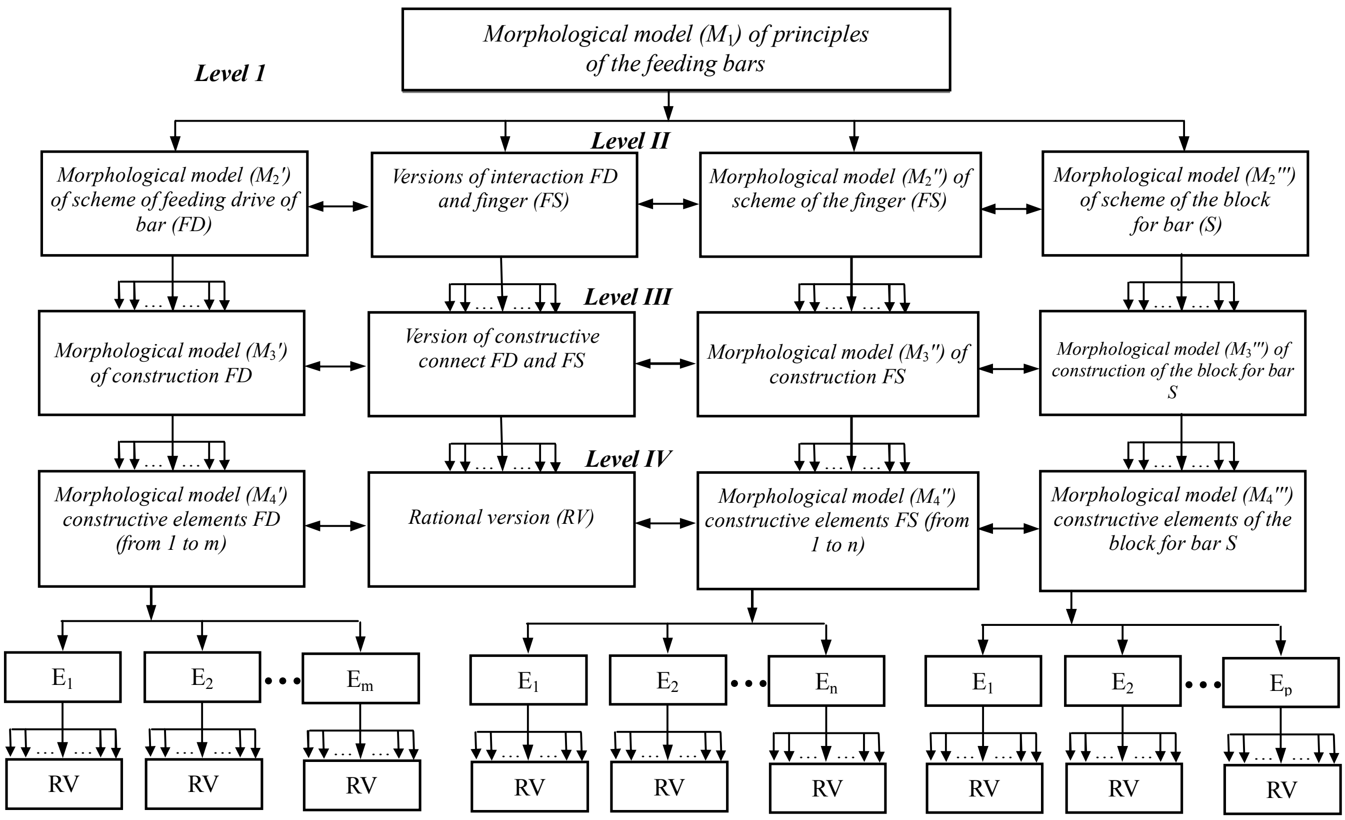


***Fig. 2** The hierarchy of multivariate search for design solutions in the design of the bar feeder using multilevel morphological analysis*

Table 2: *Morphological table (M_2'') containing schemes of feeding socket*

1. Feeded object	Structure (elements)				Links (relations)				
					Feeding element				Housing
	2. Working part - feeding element	3.Housing	4. Elastic part	5.Auxiliary element	6.With feeded object	7.With housing	8. With elastic part	9.With elastic part	10.С приводом подачи
1.1.Bar 1.2.Tube 1.3 Bar and tube 1.4.Measured rod 1.5.Measured tube	2.1.Jaw 2.2.Ball 2.3.Roler 2.4.Inclined disk 2.5.Compression spring 2.6.multy-petal disk 2.7.split ring	3.1.Elastic sleeve with slots 3.2.Solid cylinder 3.3.Composite cylider 3.4.No	4.1.console petal 4.2.Double-seat petal. 4.3.Screw 4.4.Celindrical spring 4.5.Split sleeve 4.6 No	5.1.Separator 5.2.Guiding ring 5.3.Guiding sleeve 5.4.No	6.1.Elastic effects 6.2.Force effects 6.3.Frictional 6.4.Fastening 6.5.Combined 6.6.Magnetic effects 6.7.No	7.1.Rigid 7.2.Elastic joint 7.3.Mechanical connection 7.4.Through a spring 7.5.Frictional 7.6.Combined 7.7.In one piece 7.8.No	8.1.Rigid 8.2.Elasic joint 8.3.Mechanical connection 8.4.Welded 8.5.Glued 8.6.In one piece 8.7.No	9.1.Through a spring 9.2. Rigid 9.3.On a cone 9.4.Through a carving 9.5.In one piece 9.6.No	10.1. Carving 10.2.Bayonet lock 10.3.Elastic lock 10.4.Frictional 10.5.No ....

Between the matrices M_2' and M_2'' a sign of the interaction of feed drive FD and supply socket (FS) is introduced.

Selecting 1-2 options from each of the II level matrix that better meet the complex quality criteria (both quantitative and qualitative), we move to Level IV design version of the feeder and stop bar where the same shall be chosen by the top 1-2 version of the matrices M_4', M_4'' и M_4'''.

Exact solution allows you to select the most promising (the best, or at least rational) version of created bar feeder mechanism in conjunction with the stop.

In the present paper the problem of multi-level synthesis of collets and sockets of increased durability is more particularly discussed.

Fig. 3 shows some variants that were synthesized using the morphological matrix M_2'' (table 2) of feeding collets (pos. 1, 3, 4) and sockets (pos. 2, 5). Unlike the standard collets (pos. 1, Fig. 3) with a certain combination of alternatives, some new variants are shown underlined, and give different non standard FC solutions.

Further processing of schemes into a design solution requires consideration of the following morphological matrix M_2''' (Fig. 2), which gives a number of constructive solutions. This is clearly seen even on the example of feeding collet with an elastic joint (position 4, Fig. 3) [6]. Variations of the elastic joint, which are connected to elastic part of the sponge-petal, are shown on Fig. 4, and the design of feeding collet is shown on Fig. 5.

The design of feeding collet (Fig. 4) is a cylindrical sleeve, in which, according to the standard (GOST 2877 – 80, BDS 6099-74) a variant of the interaction between a feed drive and executive part (feeding socket) as a metric thread (the connecting part 1) is made. For guiding and centering the socket is provided with guiding belt 2. The rest of the cylindrical part 3 has longitudinal sections 4, which form elastic petals and working jaws with longitudinal and transverse 5 sections, creating an elastic joint with conditional axis O-O (Fig. 4) in different versions.

Precompression of petals produced by force applied to the sponge in the location of the conditional axis of the elastic joint or a bit biased towards the sealing of petals (it is possible to make the precompression by two forces applied on opposite sides of the conventional elastic axis of joint). Then such condition of the collet is thermally fixed.

The feeding collet works as described later. During the feeding of the rod into the collet elastic deformation of the petals creates a force,which clamps the bars. This provides the necessary bonding strength. When the diameter of the rod is changed within its tolerance, or at least wear of the working hole rotates the end of the elastic part of the lobe adjacent to the elastic hinge. However, due to a small redistribution of contact pressures along the length of jaws that turn is compensated by oppositely directed rotation of jaws in an elastic hinge.

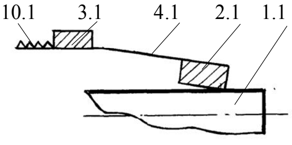
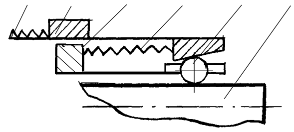
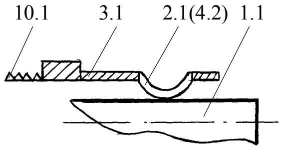
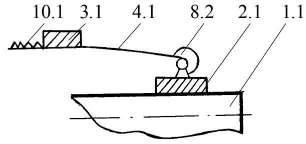
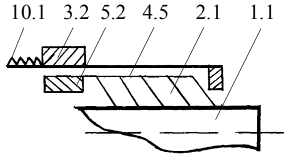
№	Scheme	Alternatives combination
1		1.1-(2.1+3.1+4.1+5.4)- -(6.1+7.7+8.6+9.5+10.1)
2		1.1-(2.2+3.2+4.6+5.1)- -(6.4+7.4+8.7+9.6+10.1)
3		1.1-(2.1+3.1+4.2+5.4)- -(6.1+7.7+8.6+9.5+10.1)
4		1.1-(2.1+3.1+4.1+5.4)- -(6.1+7.7+8.2+9.5+10.1) 8.2 - упругий шарнир
5		1.1-(2.1+3.2+4.5+5.2)- -(6.5+7.7+8.6+9.2+10.1)

Fig.3 *Synthesized schemes of feeding collets and sockets from the morphological model M_2'' (table. 2, matrix 1 and 2)*

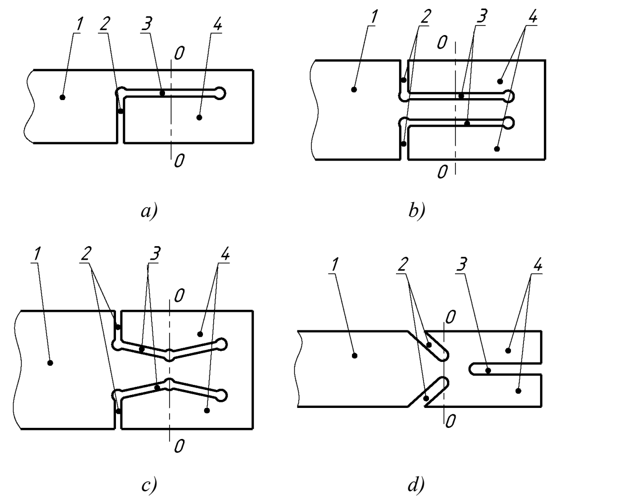


Fig.4 *Variants of connections (of elastic joint) collet jaws with petals (fig.2.6, pos.4): 1- elastic part; 2, 3 — slots ehich form elastic joint , 4 – collet jaw.*

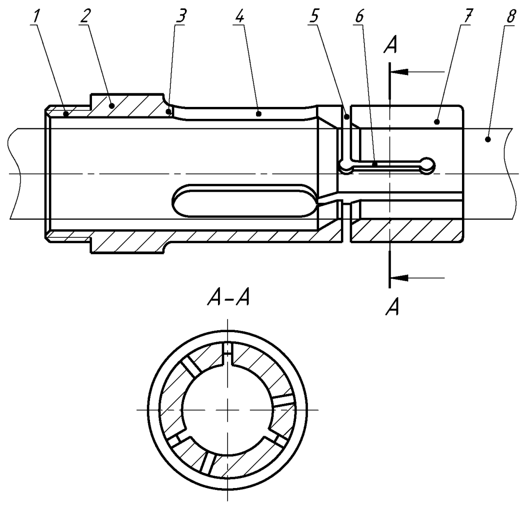


Fig. 5 *The design of feeding collet with elastic joints*

This ensures that the position of jaws is parallel to the bar when the diameter of rod is changed within some range or the working holes are worn. This reduces the specific contact stress in the sponge, to stabilize the point of application is equivalent to the current force applied to the sponge in place of conventional elastic joint axis, to increase uniformly wear long jaws to 0,5 and a total length of the petals.

Thus, in this feeding collet increase of durability is achieved by increasing the allowable amount of jaws wear and reduced intensity of its wear. Improved stability axial traction, as determined by the power propulsion is achieved by stabilizing the point of application of resultant force applied to the petal, changing the diameter of the rod and the magnitude of jaws wear .

The feeding colletis designed fo using in single-and multi-spindle automatic lathes.

2.2. Synthesis of clamping mechanisms

In analogy with feeding mechanisms (FM) a morphological model of principles (methods) of clamping (Table 3) is being developed. It has the characteristic features related to CM as a whole, to the drive clamp (CD), the executive object - the socket (CS) and different functions, providing the work and normal functioning of the CM as part of the whole machine, for example, a lathe machine.

Morphological model of clamping methods can be represented as a morphological matrix:

Expanded

(3) $$M_{PC} = \begin{vmatrix} 1.1 & 2.2 \\ 1.2 & 2.2 \\ & 2.3 \\ & 2.4 \\ & \end{vmatrix} \wedge \begin{vmatrix} 3.1 & 4.1 \\ 3.2 & 4.2 \\ 3.3 & 4.3 \\ 3.4 & 4.4 \\ 3.5 & \end{vmatrix} \wedge \begin{vmatrix} 5.1 & 6.1 & 7.1 \\ 5.2 & 6.2 & 7.2 \\ 5.2 & 6.3 & 7.3 \\ & & \\ & & \end{vmatrix} \wedge \begin{vmatrix} 8.1 & 9.1 \\ 8.2 & 9.2 \\ 8.3 & 9.3 \\ 8.4 & 9.4 \\ & \end{vmatrix}$$

Folded

(4) $$M_{PC} = M_{CM} \wedge M_{CD} \wedge M_{CS} \wedge M_F$$

where M_{CM}, M_{CD}, M_{CS}, M_F – morphological matrices of the clamping mechanism (CM) as the technical system as a whole, the clamp drive (CD) as a subsystem, clamping socket (CS) as a subsystem, the functions performed by CM.

Table 3: *Morphological table (MC_1) of bar clamping principles (methods)*

Clamping mechanism (CM)		Clamping Drive (CD)	
1.Energy conversion (input)	2.Power flow (input - output)	3.Locking	4.Structure
1.1.Primary 1.2.Secondary	2.1.Axial force – radial force 2.2.radial force – radial force 2.3.Torque - radial force 2.4.axial force and torque – radial force	3.1.Power inelastic 3.2.power elastic 3.3.Geometrical 3.4.Frictional (self-braking) 3.5.Combined	4.1.Constatnt 4.2.Variable self configurable 4.3. Variable auto configurable 4.4. Variable self and auto configurable

Clamping socket (CS)			Function of CM	
5.Number of clamping zones (seats)	6.Force contour	7.Clamping elements volume	8.Main for manipulation	9.Auxiliary
5.1.One on the working area 5.2.Two on the working area 5.3.Several in different places	6.1.Enclosed open 6.2.Enclosed closed 6.3.Combined	7.1.Constant 7.2.Variable 7.3.Combined	8.1.Clamping-bumming 8.2.Clamping 8.3.Bumming 8.4.Feeding and clamping	9.1.Balancing the centrifugal force 9.2.Stress reduction (withdrawal) 9.3.Characteristics stabilization 9.4.readjustment

Having selected 1-2 best variants of clamping methods for realization we move to level II (fig.2), where morphological models MC_2' of clamping drive schemes (CD) and MC_2'' clamping socket schemes are being built.

Further procedures are performed as seen on Fig. 6 which makes the original decision on the level of the inventions described by the authors [5, 8, 12].

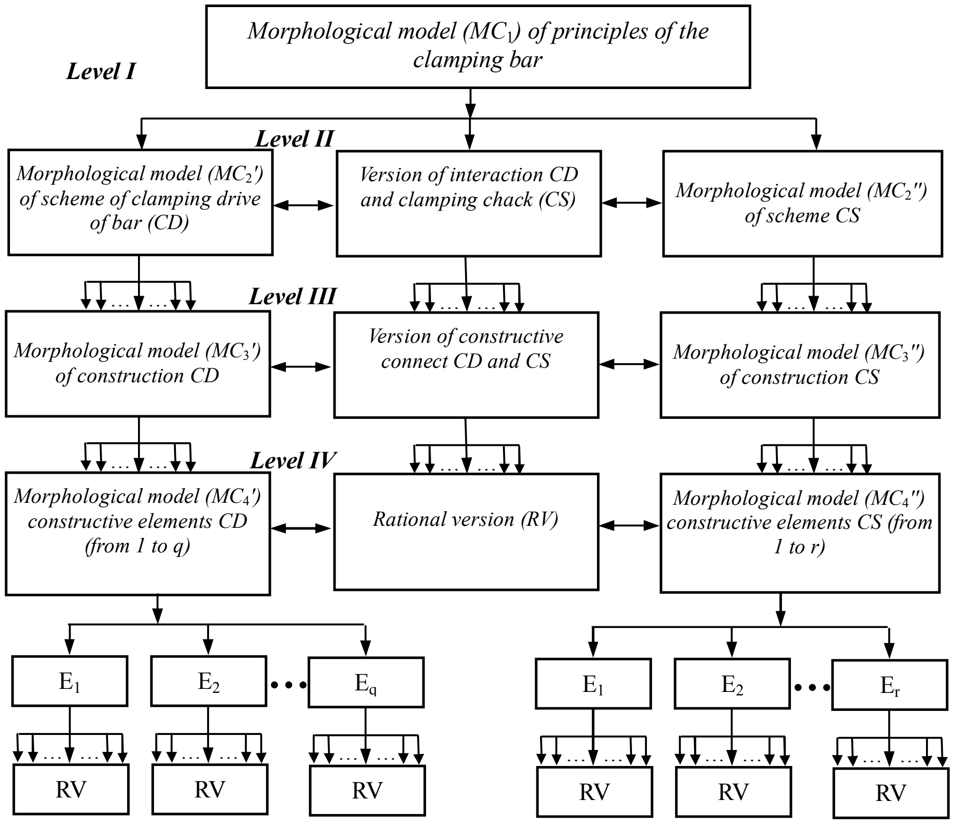


Fig. 6 *The hierarchy of Multivariate search for design solutions in the design of the clamps rods using multilevel morphological analysis*

3. Conclusion

Presented system-morphological approach as a multi-level is the basis for creating a database (funds) of elements images of the FM and CM that allow to implement computer-assisted design of feeders and clampers of rod machines.

4. Literature

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