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# NEW LOOK TO CREATION OF VISES FOR OBJECTS OF DIFFICULT FORM WITH THE USE OF MORPHOLOGICAL APPROACH AND THEORY OF FRACTALS

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ABSTRACT

*The paper proposes morphological formulas of universal vise from morphological set containing alternatives of new features of state, type of performance and mobility of clamping elements as well as prerequisites for using of the fractal theory to model the clamping process of complex shapes.*

## 1. INTRODUCTION

The challenges of the fourth industrial revolution «Industry 4.0» [1] and the approach of fifth fourth revolution «Industry 5.0» [2] require meticulous attitude to the production of machining tools for metal and woodworking machinery. Creation of advanced technological tooling allows to increase technical and economic indices and to expand technological possibilities of the equipment in conditions of mechanical assembly production [3,4]. Widely spread on the metal-cutting machine, in mechanical assembly production and everyday life are vices of various designs, which have mainly permanent structure and one kinematic chain from the motor (or manual drive) to clamping elements - jaws [3,4,6]. The presence of a single kinematic chain reduces efficiency (η) and requires additional energy consumption (with mechanized drive) or muscular work of worker (with manual drive).

The development of new universal vise with variable structure, which has two or more kinematic chains, makes it possible to significantly expand their functionality (wide versatility, wide range, adaptation to the object of any shape) [7]. This will contribute to reducing the number of tooling and technological operations, reducing the time to prepare for production and facilitating the labour of people during production processes, repair works and in daily life.

But the process of creating and designing such equipment requires new methodological approaches [13,14], advanced methods of structure-scheme synthesis in the search for new solutions and creation and use of effective mathematical models and algorithms with the help of computers.The direction of in-depth research can be related not only to the methodology of scientific and technical creativity, but also to a very interesting completely new in time theory of fractals, which has so far been recognized by mathematicians and physicists [8].

## 2. HISTORICAL INFORMATION

Analysis of previous studies shows the following [7,9-11]:

1. In practice, vises with two kinematic chains are already used, including differential helical gears. In these designs, the first kinematic chain is designed to select the gap between the workpiece and jaws by means of manual or mechanised drive, while hydraulic and electromechanical transducers are used as the second kinematic chain. But so far there is no theoretical basis for the creation of metalwork and machine vise, which are built using a genetic-morphological approach.

2. In practice there are few known vise’s constructions of the universal purpose [5], in which it is possible to clamp the workpieces of different shapes without changing the jaws. Invention [12] with manual drive and screw drive based on the principle used in the mathematical theory of fractals has been patented in the USA some time ago.

3 The known works performed in the KPI «Igor Sikorsky» [6,7,9-11] and TU-Gabrovo [20-22] on using the system-morphological approach and modern methods of searching new technical solutions for creating vices with given or improved functionality. Previous studies has been devoted to the force and rigidity characteristics of machine vices, as well as the use of fluid and bulk media in clamping elements, but there is no unified methodological approach to the design of universal vices.

## 3. NEW LOOK TO CREATION OF VISES

In order to search and predict new solutions for vise, a morphological model was developed in the form of a table, and to preserve confidentiality it can be represented in the

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form of a morphological set - a complete morphological matrix [13,14] Млщ = Мпз x Мпт x Мзе x Моз, where Мпз, Мзе, Мзе, Моз respectively matrix of the clamping drive ПЗ (sign 1), inverter ПТ (sign 2), clamping elements ЗЕ with signs of state (3), execution (4), mobility type (5), object clamp ОЗ with signs of quantity (6) and form (7).

$$M_{лщ}=\begin{vmatrix}1.1\\1.2\\1.3\\1.4\\1.5\\1.6\end{vmatrix}\wedge\begin{vmatrix}2.1\\2.2\\2.3\\2.4\\2.5\\2.6\\2.7\\2.8\end{vmatrix}\wedge\begin{vmatrix}3.1&4.1&5.1\\3.2&4.2&5.2\\3.3&4.3&5.3\\3.4&4.4&5.4\\3.5&4.5&5.5\\&4.6&\end{vmatrix}\wedge\begin{vmatrix}6.1&7.1\\6.2&7.2\\6.3&7.3\end{vmatrix}\qquad(1)$$

This is the total number of solutions Nлщ = 6 x 8 x 5 x 6 x 5 x 5 x 3 x 3 = 64800. A truncated matrix is proposed to reduce the search field and provide a convenient representation of the model, with a significant reduction in the number of solution options to N1лщ = 2 x 5 x 3 x 6 x 3 x 1 x 2 = 1080.

$$M^{1}_{лщ}=\begin{vmatrix}1.1\\1.2\end{vmatrix}\wedge\begin{vmatrix}2.1\\2.2\\2.3\\2.4\\2.5\end{vmatrix}\wedge\begin{vmatrix}3.1&4.1&5.1\\3.2&4.2&5.2\\3.3&4.3&5.3\\&4.4&\\&4.5&\\&4.6&\end{vmatrix}\wedge\begin{vmatrix}6.1\end{vmatrix}\wedge\begin{vmatrix}7.1\\7.2\end{vmatrix}\qquad(2)$$

For manual ПЗ which is used mainly in metalwork vises (alternative 1.1) and electromechanical ПЗ which is used in machine vises (alternative 1.2) with common screw ПТ (alternative 2.1), we write down the tuples of morphological sets in the form of morphological formulas (combination of alternatives for each sign) for ОЗ correct form (alternative 7.1) X1 - X8, and complex form of the type «articulated steering rod of car» (alternative 7.2) X9, X10 (Fig. 1):

$X_1$ = (1.1) – (2.1) – (3.1 – 4.1 – 5.1) – (6.1) – (7.1) – поз. а
$X_2$ = (1.1) – (2.1) – (3.1 – **4.2** – 5.1) – (6.1) – (7.1) – поз. б
$X_3$ = (1.1) – (2.1) – (**3.2** – 4.1 – 5.1) – (6.1) – (7.1) – поз. в
$X_4$ = (1.1) – (2.1) – (**3.2 – 4.2** – 5.1) – (6.1) – (7.1) – поз. г
$X_5$ = (1.1) – (2.1) – (**3.3** – 4.1 – 5.1) – (6.1) – (7.1) – поз. д
$X_6$ = (1.1) – (2.1) – (**3.3** – **4.2** – 5.1) – (6.1) – (7.1) – поз. е
$X_7$ = (1.1) – (2.1) – (**3.3** – 4.1 – **5.3**) – (6.1) – (7.1) – поз. ж
$X_8$ = (1.1) – (2.1) – (**3.3** – **4.2 – 5.3**) – (6.1) – (7.1) – поз. з
$X_9$ = (1.1) – (2.1) – (**3.3** – 4.1 – **5.2**) – (6.1) – (**7.2**) – поз. і
$X_{10}$ = (1.1) – (2.1) – (**3.3** – 4.1 – **5.3**) – (6.1) – (**7.2**) – поз. к

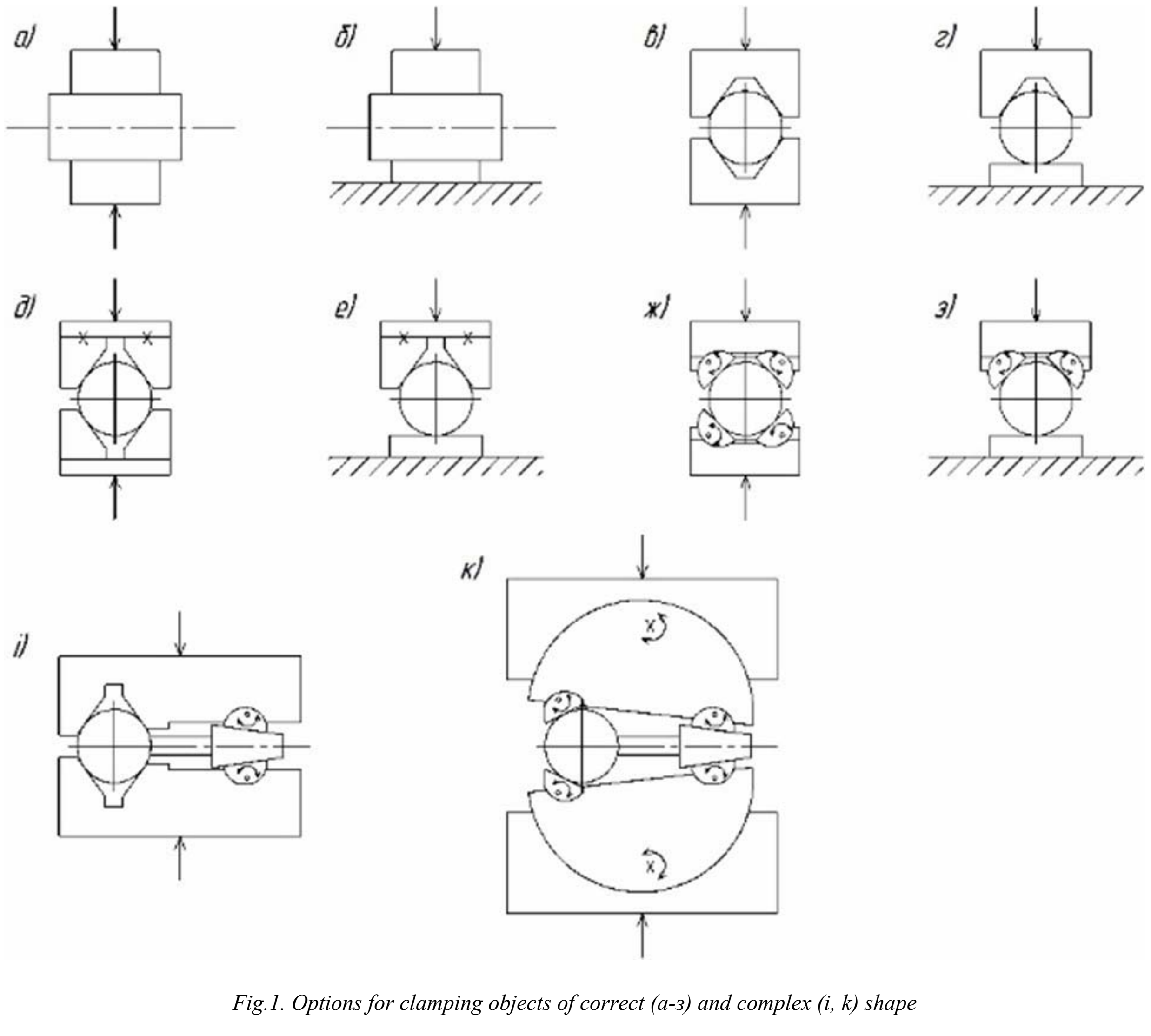

*Fig.1. Options for clamping objects of correct (а-з) and complex (і, k) shape*

Consider some of Sierpinski's structures that are well suited for creating and modeling universal vices such as "fractal vices".

Note: alternatives that different from option X1 are marked in bold.

The preliminary research and the US patent prompted the authors of this article to address the theory of fractals and the history of their origin [15]. Fractal (from Latin fractus - crushed, fractional) is often understood in common sense as some irregular, self-shaped structure. A more rigorous definition of fractal requires in-depth knowledge of algebra and mathematical analysis. A common understanding of a fractal is as a set that has the property of self-similarity (analogous to "matryoshka"), that is, such a set consisting of parts similar to itself. However, it should be noted that not all self-similar sets are fractal and not all fractal sets are self-similar. For example, any segment is a self-similar set, but at the same time it is not a fractal. At the same time there are fractal sets which are not self-similar. The term fractal was introduced in 1975 by French mathematician Benoit Mandelbrot (translated into English in 1977) [16, 17]. The Polish mathematician Wacław Sierpinski proposed frontal structures of different geometric forms [19], which can be successfully used in engineering. A convincing example was the work to create different antennas [18]. We will consider some Sierpinski structures that are well suited for the creation and modeling of universal vise-type «fractal vise».

Figure 2 shows the Sierpinski triangle obtaining from the following 4 cycles of construction:

An equilateral triangle is taken, which is the basis for constructing a fractal (iteration 0);

This triangle is split into 4 equilateral triangles and the central part is removed (iteration 1);

For each generated small triangle, the previous step is repeated (iteration 2, iteration 3, iteration 4).

*Fig. 2. Sierpinski triangle*

Interesting fractals resembling trees (Fig. 3, 4). They contain the same structure, the size of which decreases at each subsequent step (Fig. 3). There are several different types of such fractals in the form of Pythagoras tree (Fig. 4) and Cantor set (Fig. 5).

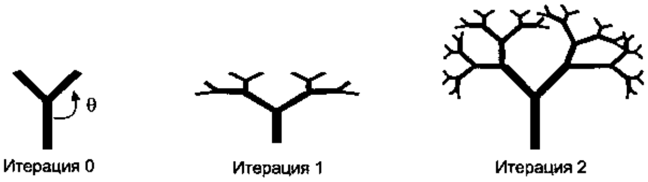

*Fig. 3. Construction of the fractal "Tree"*

To prove Pythagoras' theorem, a rectangle figure is constructed (iteration 0) with squares on one side of it so that they form a cavity triangle together with the side of the square (iteration 1). If the process is continued, a fractal is constructed (iteration 2, iteration 3) which is called the "Pythagoras tree" (Figure 4).

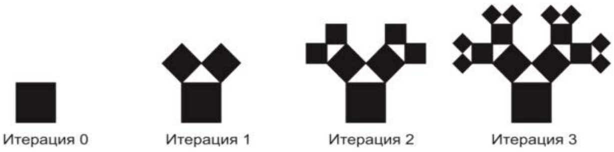

*Fig. 4. Construction of the fractal "Pythagorean Tree"*

A fractal (Cantor's set) was obtained by the German mathematician Georg Cantor. It is constructed from the segment [0, T] by successive removal of its central part of a certain size (e.g. a third). The operation is repeated for each of the two segments, and so on to infinity. Fig. 5 shows the Cantor set after the first six iterations.

The effectiveness of the developed morphological model (Table 1) is confirmed by the fact that US Patent No. 1059545 (Fig. 6) [12], which is described by a morphological formula, is also in the solution set space: **1.1-2.1-3.3-4.1-5.4-6.1-7.2,** and pos. 1,2,3,4 correspond to rotary 3E with rotation axes at angles a1, a2, a3, a4, in pos. 5 there is the screw 6 for gradual movement of the 3E.

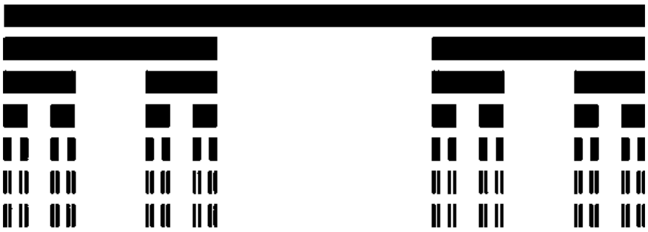

*Fig. 5. One-dimensional Cantor set*

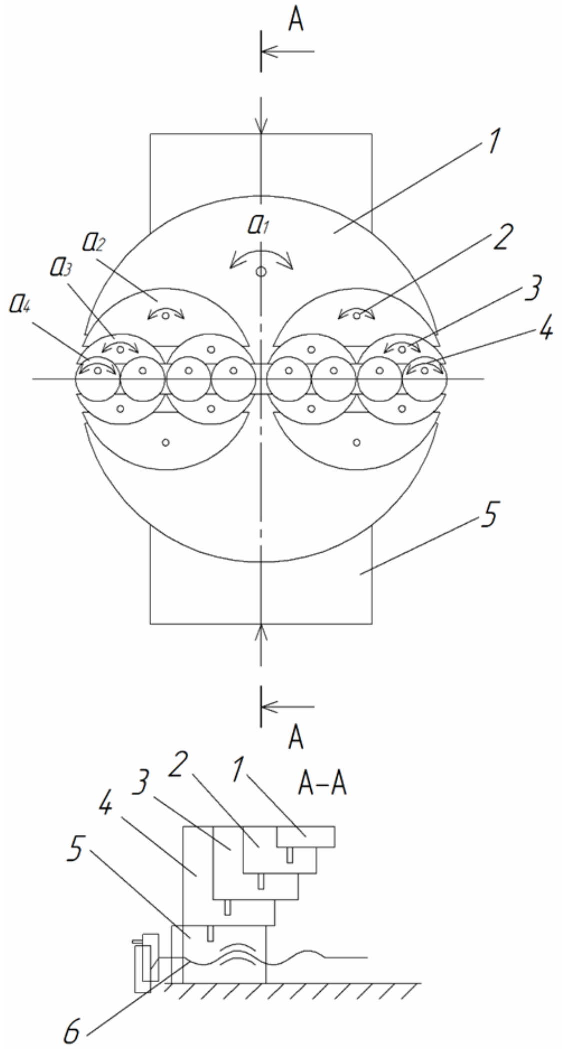

*Fig. 6. Scheme of fractal vise according to US Patent No. 1959545 with manual clamping drive (C) and screw transducer (ST)*

## 4. CONCLUSIONS

1. Metawork and machine vises are widely used in mechanical assembly and daily applications. But their functionality is limited by the fact that the vast majority of them are adapted to clamp cylindrical objects (parts) and objects with plane-parallel sides.

2. In mechanical assembly production, household and repair works in agro-industrial complex it exists a question of clamping objects of spherical, wedge, conic and irregular shape.

3. Various specialists and companies work on the creation of such vises, but so far this scientific and technical problem has not been solved and requires additional research, which determines their relevance.

4. For the first time the authors have proposed morphological formulas of universal vise from morphological set, containing alternatives of new signs of state, type of execution and mobility of clamping elements, as well as prerequisites for using fractal theory to model the clamping process of complex shapes.

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