# THE METHODOLOGY FOR CALCULATING THE DEGREE OF COMPLEXITY OF THE PARTS ORIENTATION IN VIBRATION TRAYS

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*The material from which the part is created has a decisive influence on the complexity and laboriousness assembly. Parts are still mostly delivered to assembly in disordered, chaotic state. The first theoretical work was focused on development of shape classifiers and sample solutions of automated orientation appropriate shape groups. Some works have appeared attempts for classification of components according the symmetrical. The most important assembly property of solid components from view of orientation is degree of symmetry. In this paper the developed methodology for calculating the degree of complexity of parts orientation in the case of parts orientation in vibratory tray.*

**Keywords:**
*design for assembly, grade symmetry, theory of orientation, vibrational orientation, alpha symmetry, beta symmetry*

## 1. Introduction

The material from which the component has been created has a decisive influence on the complexity and labour intensiveness of assembly. From the point of view of assembly, important features of components are those of handling. There are different methods of component manipulations depending on whether they are solid, fragile or flexible.

A special shapeless group of components are in a liquid, paste, granular or powdery state. A positive feature of these is that the assembly handling is simple. Agents need only to be fed into the assembly cavity by a volume dosage that fills the full cavity. Components with more than one material in different parts that are in different places are very progressive. In engineering, these are called composite materials. For example, we can vary the structure and density of the filler material (e. g. carbon fibres) in epoxy resins for use on a light aircraft's wing or a robot's arm with different strengths in different places.

In view of the assembly, it can be divided into three basic groups: 1. Group: Solid, 2. Group: with flexible surface 3. Group: Shapeless. The most commonly used components in mechanical engineering are solid. Their unpleasant feature is the specific shape of each component, which means a specific problem, particularly when being gripped or in orientation.

A representative of the product formed from elastic components is the cable bond of a domestic car. Flexibility of cables and the undefined shape of the product are almost entirely un-automated in installation. A solution to the problem is in finding a new invention that would allow the transfer of energy from the battery and signals from the panel, other than a wired way.

Other examples are wires that are difficult to handle and are orientated by machines. Development tends to replace them with solid parts (flat connectors, WIRE WRAP, technology, sandwich construction, etc.). Fragile and worn parts cannot be garbled or oriented by vibration (e. g. banks of light bulbs), which makes the possibilities of an easy and cheap automation more difficult.

## 2. Theory of orientation

The definitions of "symmetry" [Petrackova 1997], [Prochazka 1967] differ in details, but they are identical by the fact that the planes may be symmetrical according to the line, spatial according to the plane, while the line and the plane are the "mirror of the symmetry".

Symmetry reduces the number and amount of orientation movements. Furthermore symmetry is important for the assembly session between the contour width, thickness and body length – slenderness ratios. They have an impact on what percentage of the components, during the fall, land on the plane X, Y or Z area, etc.

Components are mostly delivered for assembly in a disordered, chaotic state. For these reasons work relating to the orientation of components is primarily concerned with automatic orientation [Boothroyd 1989, 1992], [Jurko 1988], [Mazag 1988], [Schraft 1982].

The first theoretical work was focused on the development of shape classifiers and sample solutions for automatic orientation of the shaped groups [Bassler 1988], [Holbrook 1988]. This work has been rather successful in cataloguing solutions [Łunarski 1991], [Mats 1989]. In some of these works attempts to separate components according to their degree symmetry.

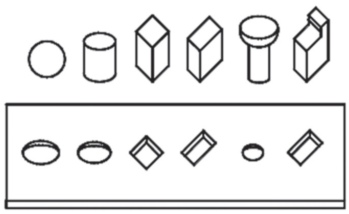
### 2.1 Boothroyd's theory

Boothroyd [Boothroyd 1982, 1983, 2005] is focused on slender parts. He found that they experience two kinds of symmetry, or non-symmetry – so called. α, β symmetry (asymmetry).

***Alpha symmetry*** – symmetry in respect of a plane perpendicular to the longitudinal axis of the component.

***Beta symmetry*** – symmetry in respect to the axis of rotation around the longitudinal x

These symmetries were later quantified by angles of displacement in degrees. (Fig. 2) [Boothroyd 1991].



| | | | | | | |
|---|---|---|---|---|---|---|
| α | 0° | 180 | 180 | 90° | 360 | 360° |
| β | 0° | 0 | 90 | 180° | 0 | 360° |

***Figure 1.*** *Boothroyd's theory of orientation [Boothroyd 1991]*

Before the evaluation of the component by Boothroyd, its longitudinal axis is pre-stretched in the direction of the "z" axis. This component rotates in the "gamma" symmetry, but its value is not evaluated.

### 2.1 Valentovic's theory

Valentovic [Valentovic 1996, 2000] found that for each (slender or non-slender) shape it is necessary to distinguish three types of symmetry, which results from three-dimensional space. Each of them can be measured by the number of revolutions (or fractions of one revolution). He created a theory valid for all possible shapes of components. This method is illustrated in Fig. 2.

Detection procedure of rotations around the axis x, y, and z axes are as follows: 1. Draw components in front view, side view and plan view. 2. Virtually rotating the drawn image around x whilst it is not being obscured by the original. The angle of rotation that we have covered is measured in revolutions and its value is Rx (e.g. 0.5

revolutions). If the image is studied from the concentric circles, the rotation is not needed Rx (Rx = 0). Similarly, we find values of Ry and in a side view and Rz in a plan view (Fig. 3).

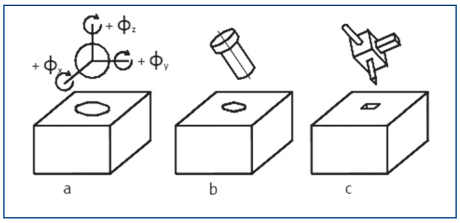



***Figure 2.*** *Component as an object of assembly. Valentovic's theory of orientation. Totally symmetric component (a), partially symmetric (b) totally asymmetric (c)*

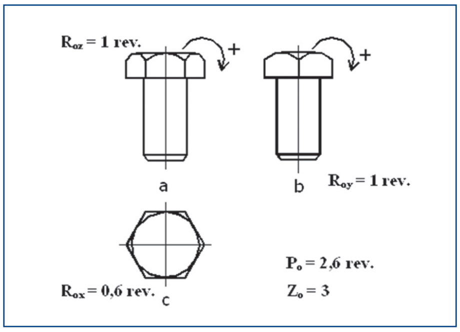



***Figure 3.*** *Complexity (Zo) labour intensity (Po) as objective indicators regarding orientation in assembly according to Valentovič*

Valentovic points to two objective indicators of orientation:

***Complexity of orientation*** $Z_o$ is the number need rotators (the axes for component orientation parts = $Z_{o\,=}\,\Sigma R$). Alternatively Z = 1 or 2, or 3 of the needed axes.

***Labour intensity of orientation*** $P_o$ is the sum of all rotations needed to find the orientation. The maximum may be 1 + 1 + 1 = 3 revolutions.

From these listed methods the correct method is Valentovic's. This method is inspiring in the sense that two similar indicators can be used for the assessment of complexity and labour intensity regarding the assembly of the whole product.

The method is applicable when evaluating the orientation of components freely scattered in a box, i. e. orientation with a completely chaotic state.

## 3. New methodology of component shape evaluation regarding vibrational orientation

The most frequent way of orientation is the so called vibrational orientation. It can essentially be explained by an example of a smooth prism orientation. Before switching on the vibration, the prism will have three possible positions on the horizontal bottom of the vibrational chute. (Fig. 4 position 1, 2, 3).

After turning on the vibrations, centrifugal force pushes the outer wall of the prism of the circular vibratory tray. [Stefanek 1997], [Senderska 2007], [Madarasz 2007] draws attention to other forces than gravitational forces of components during vibrations. Each "specialist for orientation" of the components is interested in a number $i_s$ (the number of permanent positions, which takes the body).

Speculatively, we found that after turning on the vibration, the prism has six stable positions (Fig. 4 1a, b, 2a, b, 3a, b) and leaves them in the output chute in only one desired position, others are thrown back to the container. Assuming that all of the above mentioned 6 positions –are located in the chute in equal numbers, the efficiency of orientation (ηo) will be:

$$\eta_o = \frac{1}{6}.100 = 16.66 \ [\%] \qquad (1)$$

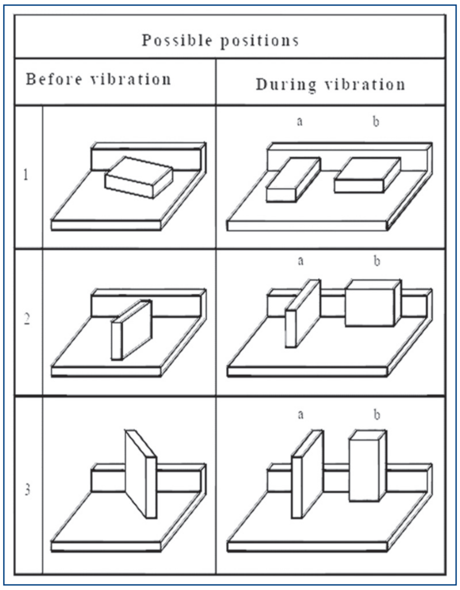



***Figure 4.*** *Examples of graphic-analytical examination of the number of stable positions is „common" prism in vibration chute during vibration.*

However, if the prism has a modified shape (Fig. 5), rather laboriously and speculatively, we find that the number of possible positions of the prism in the vibrating chute $i_{s\text{ will be}}$ 24.

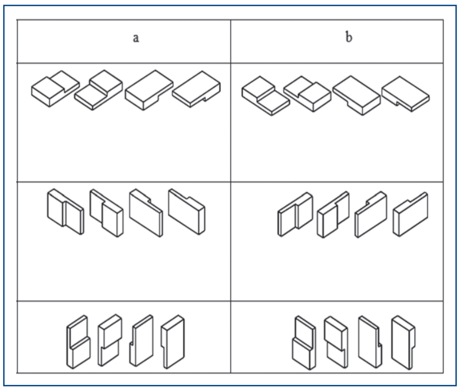



***Figure 5.*** *Examples of image-analytical examination of the possible number of stable positions of the body, which are displayed by the body which has the modified silhouette shape of prism*

In this case, efficiency of orientation ($\eta_o$) is very low:

$$\eta_o = \frac{1}{24}.100 = 4.16 \ [\%] \ ! \qquad (2)$$

Thus, we found that the effectiveness of orientation related to the number of stable positions of body silhouettes but especially with the modified shape of this silhouette. When speculatively surveying the amount of possible positions, it is difficult for the imagination and often leads to mistakes. The method used to date is very labour intensive.

The number of stable positions in the vibrating chute ($i_s$) is a number that characterizes the degree of complexity of the vibration-orientation, like the number "Z" (complexity) and "P" (labour intensity) examined by Valentovic's method for common non-vibrating orientation.

We derive a new method of testing locations of the components in the vibrating chute, which is characterized by elemental simplicity.

### 4. Indirect methods for the examination of the positions of the stated component in the vibrating chute

The investigated body shape is an equilateral triangle (Fig. 6). The body has 5 walls, which can be placed on a horizontal surface. Three of them (marked with a cross) are redundant.

The body only has positions on the horizontal support (Fig. 6 b, c). After turning on the vibrations from the position (Fig. 6 b, d) four alternative positions are created. Of these, two are redundant (marked with a cross). Two stable positions only arrive from this fact.

From the position (Fig. 6 c, e), after turning on vibrations, three possible positions are created and two are redundant, i.e. They arise from only one position (Fig.6 c, e). Altogether, the redundant positions $i_s$ will be $i_s = 3$.

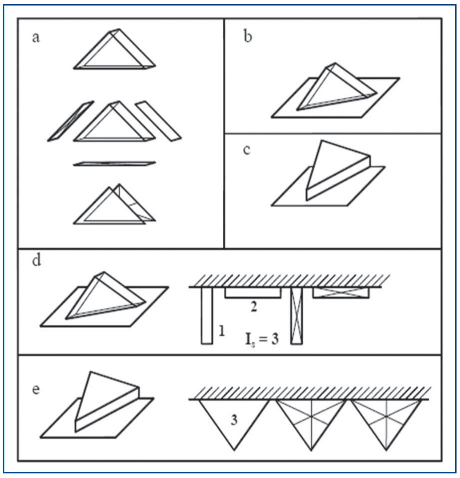



***Figure 6.*** *Investigates possible stable position of the body shape of the stated shape in the vibration chute with orientation (equilateral triangle). Indirect method. a – examined the body, b, c – possible positions of the body on a horizontal support, d, e – Possible location of the body after switching on vibration.*

It is slightly more complicated when the examined body has a triangular silhouette, which is otherwise a modified shape (Fig. 7).

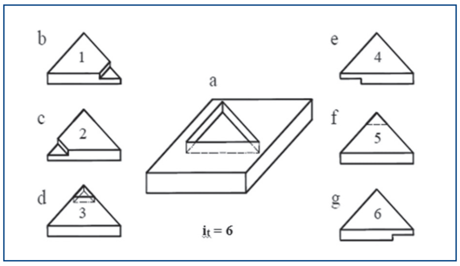



***Figure 7.*** *Examination of possible in the body's silhouette (shape of equilateral triangle with a recess). Indirect method. a – template of body's silhouette, b, c, d, e, f, g – possible positions of examined body in the template of its silhouette.*

In this case the number of possible positions will be:

$$i_m = i_s \cdot i_t \ [-] \qquad (3)$$

where:

$i_m$ – complexity of vibrational orientation,

$i_s$ – number of possible stable positions which takes stated body,

$i_t$ – number of possible positions, which takes the modified body in its own silhouette (Fig. 7 b,c,d,e,f,g).

In our case it will be:

$$i_m = 3.6 = 18 \text{ possible positions} \qquad (4)$$

Value $i_m$ shows the complexity of the vibrational orientation.

The number of these stable positions ($i_{m)}$ is an important objective indicator of the complexity of the orientation of the vibrating shape. For bodies that have curved walls, proceed accordingly.

### 5. Conclusions

The most important assembly characteristic of the solid parts is the degree of symmetry which relates to the complexity and effortlessly (labour intensity) orientation.

Often the behaviour of some of the components' shapes is estimated subjectively (subjective evaluation). We have shown that the shape's characteristics of component are more preferable to evaluate by objective indicators calculated on the basis of the laws of mathematics and mechanics. For evaluating the shape's properties of the components in terms of its random orientation to the desired position using Valentovic's complexity indicators (Zo) and labour intensity (Po) orientation.

For evaluating the effect of component's shape in respect of the complexed vibrating orientation, it is preferable to use the indicator Im (number stable positions, equation 3).

We have shown that vibration orientation options are limited mainly to the low efficiency of orientation (equations 1 and 2) so that the components often fall back into the bowl until it "succeeds" in being orientated.

In this paper the developed methodology for calculating the degree of complexity of parts orientation in the case for parts orientation in vibratory tray.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