ANALYSIS OF THE LOCATORS POSITIONING FOR PRISMATIC WORKPIECES

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Abstract. The paper analyse the way of applying the 3-2-1 principle of positioning – orienting of the prismatic work-pieces, considering the particular case of a work-piece with the following dimensions 176×86×50. For establishing the relation between the value of the cutting force and the necessary clamping force, are taken into consideration the position of the locators, the way of applying the clamping force, the way in which the cutting force acts on the work-piece. Were also determined the reaction forces on the locators from the secondary plane when are located at different distances from the applying point of the clamping force and are generated the corresponding variation graphics, for establishing the clamping configuration which are not valid.

Keywords: clamping device, adjustable locators, modular system, clamping force, optimization

1. Introduction

A processing device, for fulfilling the functional role of orientation and fixing of the work-pieces for processing, must contain in them structure orientation elements, supplementary locating elements, clamping elements or subassemblies, adjustment and guiding elements for the tool, contact elements with the machine-tool [1].

The clamping system must assure a sufficient clamping force in order, durring processing, the work-piece must keep iti positon on the locators in conditions in which on it acts various forces and torques (cutting forces and torgues, mass forces, auxiliary forces etc.) which have as concequesce the removal of the work-piece from the equilibrum position by breaking the contact with the locators, which has as principal inconvenient the obtaining of different dimensions or the snatching of the workpiece from the device [2].

The application point, the directions and the sense of the clamping force are established in a way to maintain the equilibrum of the working piece on the locators and to avoid its deformation in the contact points [3]. Aspects that are taken into consideration when it is realised a clamping configuration are related to the processing type (milling, boring), the shape and the workpiece dimentions (rectangular, cilindrical) and its material (steel, aluminium, bronze), because the work-piece needs different design strategies for the clamping configurations, beeing necesary in most of the cases the canceling of six freedom degrees [4].

The elaboration of the clamping configuration involves the establishment of the locators and the rigid fixing on the workpiece, taking into consideration it’s shape and dimensions, the material and the processing requests [7]. A general methodology for determining the optimal clamping force and of the factors that are taken into consideration is represented in figure 1 [5].

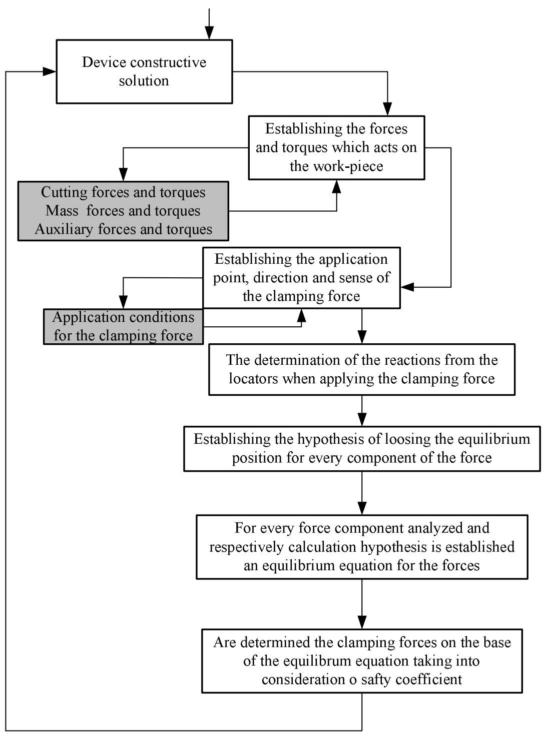

Figure 1. Methodology for the optimal clamping force determination

Performance analysis of the devices supposes going through a methodology that comprises the following steps: the study of the work-piece, analysis of technologic procedures and process parameters, determining the necessary clamping numbers for processing the work-piece, establishing the orientation surfaces and production type.

2. The analysis of locators positioning on a surface perpendicular on the cutting force

For the prismatic work-pieces a well-known method from the literature [1] and very often used for the prismatic work-pieces positioning is the principle 3-2-1 [4]. The work-piece is positioned using three perpendicular planes, the principal one being the one on which the work-piece is laid, and which assures the cancellation of three freedom degrease.

For the orientation and fixing device realised in modular variance [6], with interchangeable and reusable components, which are part of the modular elements set SEM 64, existent at of the Machine Construction Technology Department, Faculty Enginery and Technological System Management, University Politehnica of Bucharest, represented in figure 2. Every component element has a functional role in the respective subassembly. The principal laying plane it is materialised with the help of the modular motherboard (2), with T channels. The secondary plane come in contact with two lateral locators, R_1 and R_2, (3), and the tertiary is the one that contains a single support (4).

The element, which assures the clamping of the work-piece, it can be used in different positions on its surface. The first case is on the surface parallel with the one of the locators R_1 and R_2. Other situations are that when is parallel with the one of the locator R_3, perpendicular on the surface parallel with one that the work-piece lays or at a specific angle with the surfaces for the lacators R_1, R_2 and R_3

The supporting elements are mounted in special bodies (4), which are fixed on the motherboard (2) with the help of the screws and of the T chocks (5), which can be fixed in the board channels. The clamping is done with the help of the mechanism screw-nut (6), figure 2, this being mounted in a special body (7) fixed on the mother board (2), with the help of the T chocks (5) [5]. By used fixing configuration are cancelled six freedom degrees.

On the device can be generated some adjustments imposed by the cutting parameters, the shape and the dimensions of the work-piece, its positioning on the machine table, adaptation from dimensional point of view, because of the multidimensional modular elements.

In addition, by attaching sensors and command systems it can be realised the force control, them adaptation to the optimal values and the inclusion of the device in a technological system tool-work-piece machine tool-manipulation system autonomous.

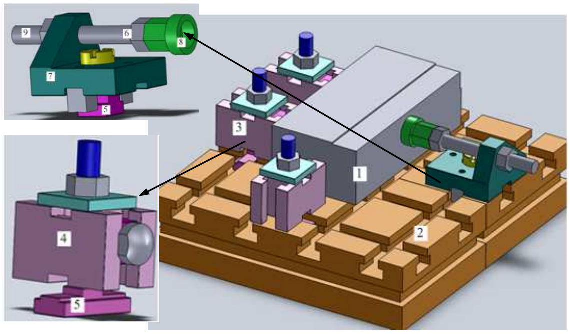

Figure 2. 3D model of the analysed device

Further it will be analised the case when the clamping force is perpendicular on the cutting force, in the same plane or in parallel one [5].

In figure 3 is represented a prismatic work-piece, orientated and fixed on the principle 3-2-1. The locator R_3 is opposite to the proccesing force, which is considered to be the cutting force F_c.

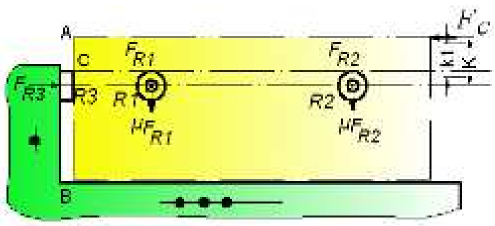

Figure 3. Upper view of the workpiece in the device

The cutting force F_c transmit to the work-piece an overturn moment around point C, the begining point of the locator R_3.

For the processing of the prismatic work-piece, figure 4, the locators R_1 and R_2 are positioned at length l, respectively m, from the line AB that marked the lateral surface of the work-piece.

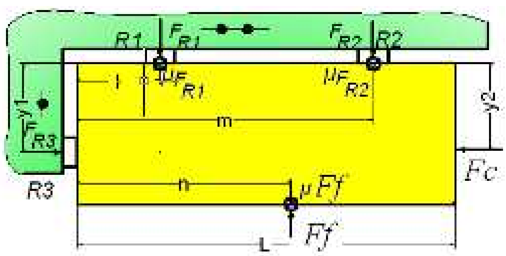

Figure 4. Frontal view of the workpiece in the device

The locator R_3, positioned at the length y_1, and the cutting force act at the distance y_2. The work-piece clamping it is realised on the surface parallel with the locator elements R_1 and R_2, at distance n.

In figure 5 is represented the forces diagram which act on the work-piece, when it is considered simplified with a bar shape.

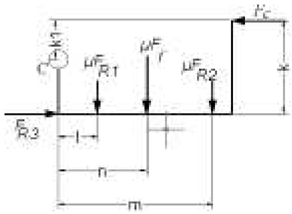

Figure 5. Forces position

Appling the methodology presented in figure 1, the first stage in determining the optimal clamping force is the establishing of the forces and torques, which acts on the surface of the work-piece.

After establishing the application point, the direction and the sense of the forces, the next step in the analysis of the fixing system represents the determining of the value of the reaction forces from the locators R_1, R_2 and R_3. The reactions forces are determined as a function on them position respect to the work-piece, the value and the mode of applying the clamping force.

It follows then the determination of the necessary clamping force, F_f, as a function of the cutting force, F_c, the position of the clamping point and of the locator R_3, from the tertiary plane.

For the considered case, it will be follow, the general methodology stages in two hypotheses, namely:

I. The hypothesis when the application point of the cutting force is at the same distance from the end of the work-piece as the locator R_3, $y_1 = y_2$;
II. The hypothesis in which $y_1 \neq y_2$.

I. Establishing the dependence relation for the clamping force in the hypotheses $y_1 = y_2$

1. Determining the reaction force from locator R_3:

For determining the reaction force F_{R3} it is used the force equilibrium equation on x direction.

$$\sum F_x = 0\,, \tag{1}$$

$$F_{R3} = F_c\,. \tag{2}$$

2. Determining the reactions forces from the locators R_1 and R_2:

It can be write the torques equation related to the locators R_1:

$$\sum M_{R1} = 0\,, \tag{3}$$

with the form:

$$F_f \cdot (n-l) - F_{R2} \cdot (m-l) + F_{R3} \cdot y_1 - F_c \cdot y_2 = 0\,, \tag{4}$$

when $y_1 = y_2$, the relation (4) becomes:

$$F_f \cdot (n-l) - F_{R2} \cdot (m-l) = 0\,. \tag{5}$$

From which results the reaction force in the locator R_2:

$$F_{R2} = \frac{n-l}{m-l} \cdot F_f\,. \tag{6}$$

For determining the reaction force in the locator R_1, it can be write the torque equation related to the locator R_2:

$$\sum M_{R2} = 0 \tag{7}$$

with the form:

$$F_{R1} \cdot (m-l) - F_f (m-n) + F_{R3} \cdot y_1 - F_c \cdot y_2 = 0\,. \tag{8}$$

Using the same hypothesis, $y_1 = y_2$, the relation (8) becomes:

$$F_{R1} \cdot (m-l) - F_f (m-n) = 0\,, \tag{9}$$

from which results:

$$F_{R1} = \frac{m-n}{m-l} \cdot F_f\,. \tag{10}$$

3. Determining the clamping force as a function of the cutting force:

It can be write the torques equation given by the forces that acts on the surface of the work-piece and produce the rollover around point C:

$$\sum M_c = 0\,, \tag{11}$$

with the form:

$$\begin{aligned} &F_c \cdot k_1 + F_{R3} \cdot (k-k_1) - \mu \cdot F_{R1} \cdot l - \\ &\quad - \mu \cdot F_{R2} \cdot m - \mu F_f \cdot n = 0. \end{aligned} \tag{12}$$

Replacing in the anterior relationship (12) also the variation functions for the reaction forces F_{R1} and F_{R2} it can be obtain:

$$\begin{aligned} &F_c \cdot k_1 + F_c \cdot k - F_c \cdot k_1 - \mu \cdot \frac{m-n}{m-l} \cdot F_f \cdot l - \\ &\quad - \mu \cdot \frac{n-l}{m-l} \cdot F_f \cdot m - \mu F_f \cdot n = 0, \end{aligned} \tag{13}$$

$$F_c \cdot k - \mu \cdot F_f \cdot \left(\frac{m-n}{m-l} \cdot l + \frac{n-l}{m-l} \cdot m + n\right) = 0\,, \tag{14}$$

$$\begin{aligned} &F_c \cdot k = \mu \cdot F_f \times \\ &\quad \times \frac{m \cdot l - n \cdot l + n \cdot m - l \cdot m + n \cdot m - n \cdot l}{m-l}, \end{aligned} \tag{15}$$

$$\begin{aligned} F_c \cdot k &= \mu \cdot F_f \cdot 2\frac{m \cdot n - n \cdot l}{m-l} = \\ &= \mu \cdot F_f \cdot 2\frac{n \cdot (m-l)}{m-l} = 2 \cdot \mu \cdot n \cdot F_f\,, \end{aligned} \tag{16}$$

from which results:

$$F_f = \frac{k}{2 \cdot \mu \cdot n} \cdot F_c\,. \tag{17}$$

It is consider the particular case of a prismatic work-piece, with the dimensions 176×86×50 mm. The cutting force F_c and the reactions force from the locator R_3 acts at the same distance from the end of the work-piece, namely at 43 mm.

It is also considered the clamping force F_f acts at the middle of the work-piece, in point n = 88 mm, and the position of the locators R_2 is R_3 at 25 mm from the sitting plane of the work-piece.

So, for k = 25, n = 88 mm, F_c = 580 N, by applying the formula (17) it can be determined a clamping force F_f = 823 N.

Considering the determined force when the cutting force and the reaction force from the locator R_3 acts at the same distance for the work-piece end, the reaction forces from the locators R_1 and R_2 can be determined with the relations:

$$F_{R1} = 823 \cdot \frac{m-n}{m-l}, \tag{18}$$

$$F_{R2} = 823 \cdot \frac{n-l}{m-l}. \tag{19}$$

Taking into consideration that the position of the clamping force was anterior established (by choosing the value for n), the value for the reaction force from the two locators R_1 and R_2 is function of them position.

For the first case of analysis it is considered that the position of the locator R_2, given by the value of m is variable, from 88 to 176 mm, and the locator R_1 can have different positions which are indicated by the l value (12,18, 24, 36, 48 and 60 mm).

For these positions are calculate the reactions values from the two locators, R_1 respectively R_2. The variation graphs are represented in figures 6 and 7 for R_1 and, respective R_2.

By analysing the figures, it can been said: as the locator R_2, is further from the application point of the clamping force, the value of the reaction force F_{R1} grows.

In the same time when the locator R_1 becomes closer to the application point of the clamping force, the reaction force on it decreases.

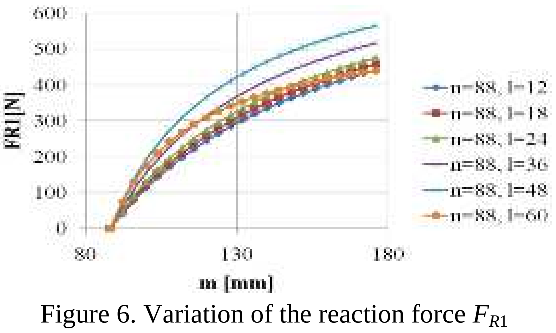

Figure 6. Variation of the reaction force F_{R1} corresponding to the locator R_1

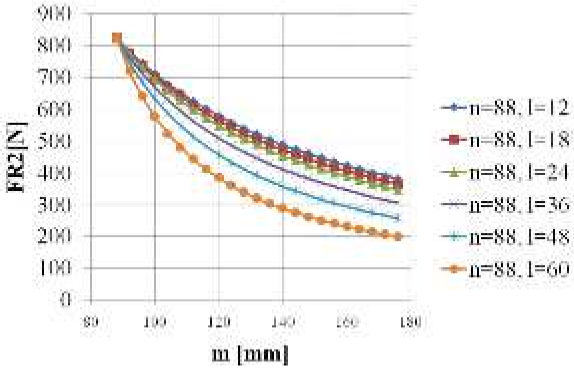

Figure 7. Variation of the reaction force F_{R2} corresponding to the locator R_2

In the same time, as the distance between the locator R_2 and the application point of the clamping force decreases, decreases the also the value of the reaction force in this locator. In this way have been demonstrated the reactions forces from the locators R_1 and R_2, F_{R1} and respectively F_{R2}, are functions of the value of the clamping force, its position and the position of the locators R_1 and R_2.

If are represented of the same diagram the variation of the reactions forces from the locator R_1 and the locator R_2, for every case, it can be found that at the intersection of the two curves, is obtained them position, when the reaction force are equal on the locotrs R_1 and R_2.

In figures 8 ÷ 13 is represented the variation of the reaction forces F_{R1} and F_{R2} for n = 88 mm, and for different values for l (12, 18, 24, 36, 48 şi 60 mm) when m = 88 … 176 mm.

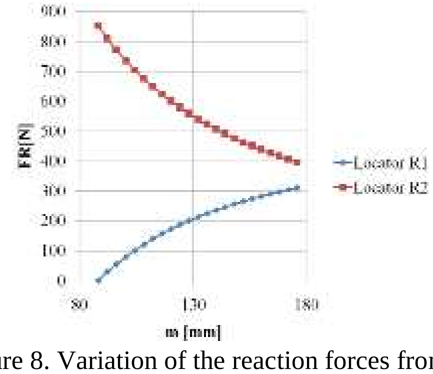

Figure 8. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 12 mm

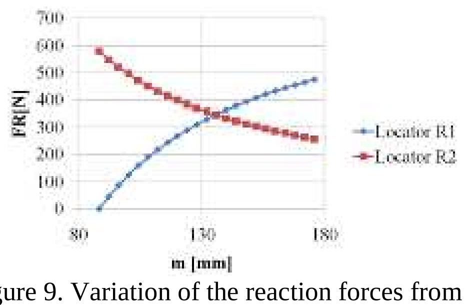

Figure 9. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 18 mm

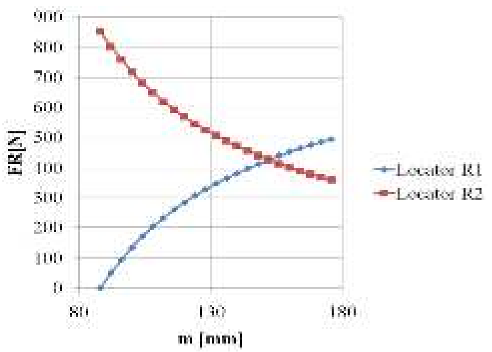

Figure 10. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 24 mm

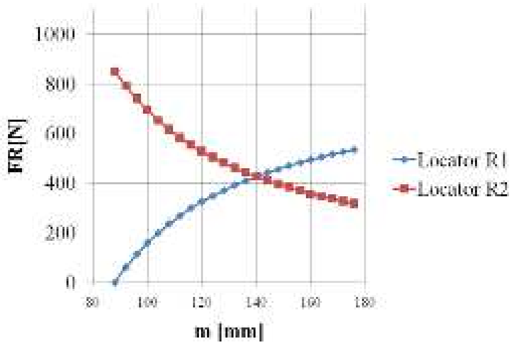

Figure 11. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 36 mm

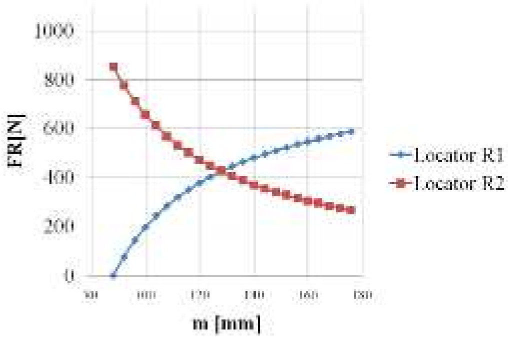

Figure 12. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 48 mm

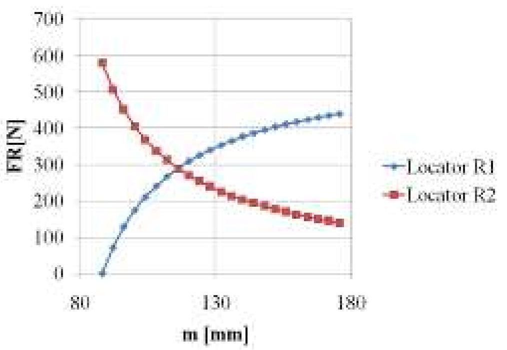

Figure 13. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 60 mm

The intersection point offers information related to the posotion of the two locatos when the values of the reaction forces F_{R1} and F_{R2} are equal on the two locators and the variation mode of the reaction force, as a function of the locators position.

II. The calculation of the clamping force dependence in the general case in which $y_1 \neq y_2$

Are followed the same steps for the methodology as in the precedent case:

1. Determining the reaction force from locator R_3:

Appling the same equilibrium equation as in the precedent case, is obtained $F_{R3} = F_c$.

2. Determining the reaction forces in the locators R_1 and R_2:

It can be replaced the value of e F_{R3} with F_c.

$$F_f \cdot (n-l) - F_{R2} \cdot (m-l) + F_c \cdot (y_1 - y_2) = 0\,, \tag{20}$$

from which

$$F_{R2} = \frac{n-l}{m-l} \cdot F_f + \frac{y_1 - y_2}{m-l} F_c\,. \tag{21}$$

It can be written the torque equation in R_2:

$$\sum M_{R2} = 0\,, \tag{22}$$

with the form:

$$F_{R1} \cdot (m-l) - F_f (m-n) + F_{R3} \cdot y_1 - F_c \cdot y_2 = 0\,, \tag{23}$$

replacing $F_{R3} = F_c$ results:

$$F_{R1} \cdot (m-l) - F_f (m-n) + F_c \cdot (y_1 - y_2) = 0\,, \tag{24}$$

or

$$F_{R1} = \frac{m-n}{m-l} \cdot F_f - \frac{y_1 - y_2}{m-l} F_c\,. \tag{25}$$

So the reactions forces from the locators R_1 and R_2 are functions of the values and the positions of the clamping and cutting forces.

3. Determining the clamping force:

The clamping force is a function of the value and the position of the clamping force and can be obtained, as in the precedent case, from the torque equation around point C:

$$\sum M_c = 0\,, \tag{26}$$

with the form:

$$\begin{aligned} &F_c \cdot k_1 + F_{R3} \cdot (k - k_1) - \mu \cdot F_{R1} \cdot l - \\ &- \mu \cdot F_{R2} \cdot m - \mu F_f \cdot n = 0. \end{aligned} \tag{27}$$

Replacing in the anterior relation $F_{R3} = F_{as}$ and the variation functions for F_{R1} and F_{R2} it can be obtained:

$$F_f = \frac{k - \mu \cdot (y_1 - y_2)}{2 \cdot \mu \cdot n} \cdot F_c\,. \tag{28}$$

For exemplification, it is considered the particular case of o prismatic work-piece with the dimensions 176×86×50 mm.

Are studied two possible cases regarding the relation between y_1 and y_2.

a. *Case I* – in the first stage is analysed the case when the application point of the cutting force is closer to the work-piece end then the position of the locator R_3, so $y_1 < y_2$.

It is considered that the position of the locators R_2 and R_3, related to the piece high is k = 25 mm. Also, the clamping force acts, in the ideal case, namely at the half of the work-piece, at n = 88 mm.

The friction coefficient steel-steel is μ = 0.1.

For example if it is considered y_1 = 43 mm, y_2 = 60 mm and F_c = 580 N, then the necessary clamping force is F_f = 781 N:

$$F_{R1} = 781 \cdot \frac{m-n}{m-l} - 580 \cdot \frac{y_1 - y_2}{m-l}, \qquad (29)$$

$$F_{R2} = 781 \cdot \frac{n-l}{m-l} + 580 \cdot \frac{y_1 - y_2}{m-l}. \qquad (30)$$

For the analysed case it is considered the position of the locator R_2, given by the m value is variable, from 88 to 176 mm, and the locator R_1 can have different positions, which are indicated by the l value (12, 18, 24, 36, 48 and 60 mm).

For these positions is calculated the reaction values F_{R1} and F_{R2}, from the two locators R_1 respectively R_2.

The variation graphs are represented in figure 14 for locator R_1 and in figure 15 for locator R_2.

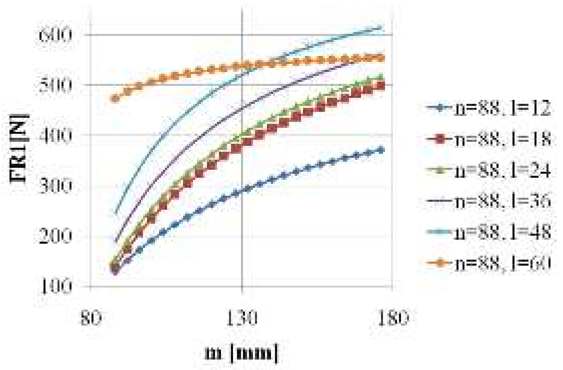

Figure 14. Variation of the reaction force F_{R1} corresponding to the locator R_1

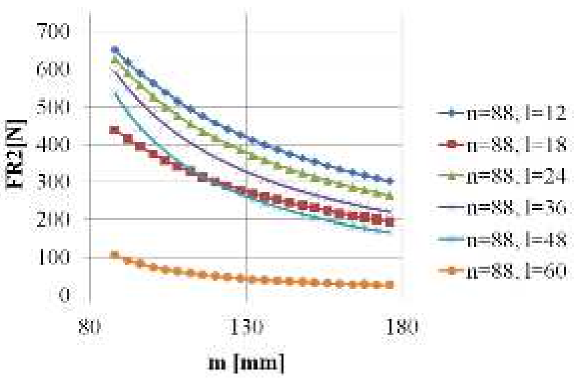

Figure 15. Variation of the reaction force F_{R2} corresponding to the locator R_2

For the analysed case it is considered that the position of the locator R_2, given by the value for m, is variable, from 88 to 176 mm, and the locator R_1 can have different positions, which are indicated by the value for l (12, 18, 24, 36, 48 and 60 mm).

For these positions are calculated the value of the reaction forces from the two locators F_{R1} and F_{R2}, for the locator R_1 respectively R_2.

The variation graphs are represented in figure 14 for R_1 and in figure 15 for R_2.

From the analysis of figures 14 and 15 it can be established that when the locator R_2 goes further from the application point of the clamping force, the value of the reaction force F_{R1} grows, together with the enclosing of the locator R_1 to the clamping point.

In the same time, when the distance between the locator R_2 and the point of application for the clamping force grows, the value of the reaction force from this locator decreases.

In this way was demonstrated that the values for the reaction forces F_{R1} and F_{R2}, reactions from the locators R_1, respectively R_2 are functions of the value of the clamping forces, its position and the position of the locators R_1 and R_2.

In figures 16 ÷ 21 are represented the variations of the reactions forces F_{R1} and F_{R2} for n=88 mm, and different values for l, when m=88…176 mm.

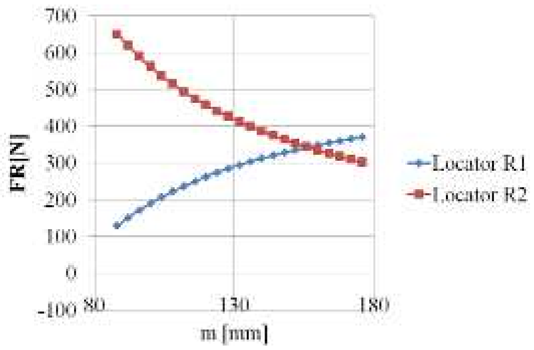

Figure 16. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 12 mm

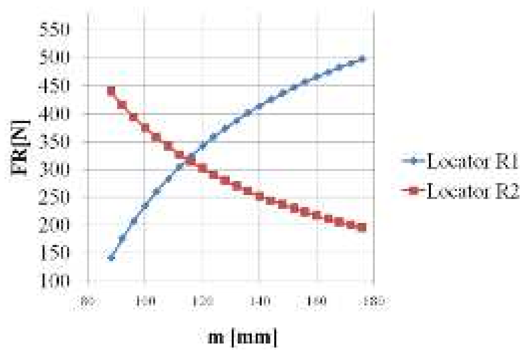

Figure 17. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 18 mm

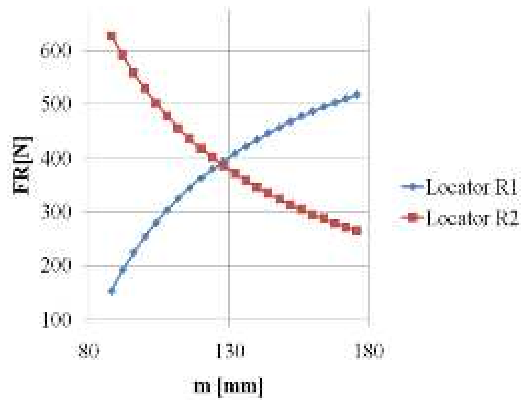

Figure 18. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 24 mm

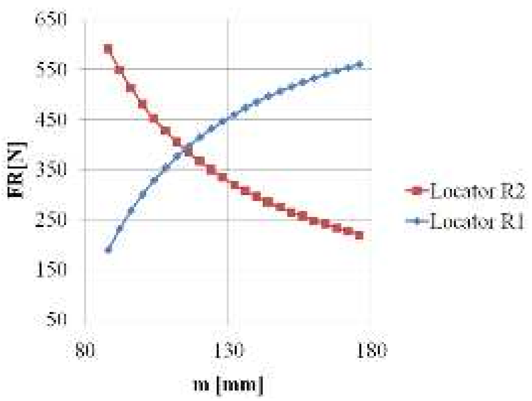

Figure 19. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 36 mm

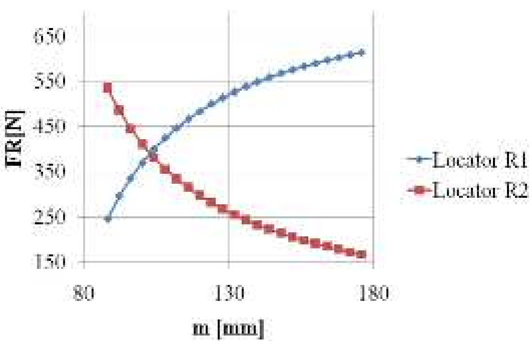

Figure 20. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 48 mm

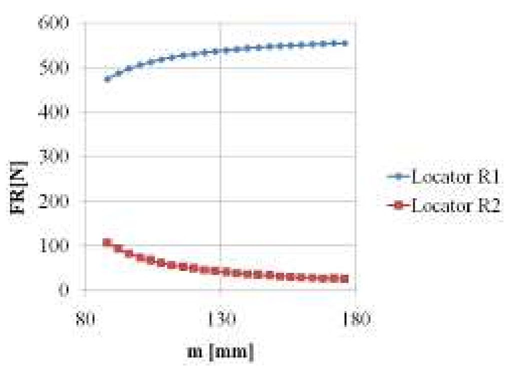

Figure 21. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 60 mm

The intersection point offers information related to the posotion of the two locatos when the values of the reaction forces F_{R1} and F_{R2} are equal on the two locators and the variation mode of the reaction force, as a function of the locators position.

b. Case II – the analysed case is the one in which the application point of the cutting force is more away from the end of the work-piece then the locator R_3, $y_1 > y_2$. It is considered that the application point for the locators R_2 and R_3, related to the work-piece high is k = 25 mm.

Also, the clamping force, acts, in the ideal case, namely at the work-piece half, at n = 88 mm.

The friction coefficient steel-steel is μ=0.1.

For example if it is considered y_1 = 43 mm, y_2 = 20 mm and F_c = 580 N, then the necessary clamping force is F_f = 781 N:

$$F_{R1} = 781 \cdot \frac{m-n}{m-l} - 580 \cdot \frac{y_1 - y_2}{m-l}, \qquad (31)$$

$$F_{R2} = 781 \cdot \frac{n-l}{m-l} + 580 \cdot \frac{y_1 - y_2}{m-l}. \qquad (32)$$

For the analysed case it is considered the position of the locator R_2, given by the m value is variable, from 88 to 176 mm, and the locator R_1 can have different positions, which are indicated by the l value (12, 18, 24, 36, 48 and 60 mm).

For these positions is calculated the reaction values F_{R1} and F_{R2}, from the two locators R_1 respectively R_2.

The variation graphs are represented in figure 22 for locator R_1 and in figure 23 for locator R_2.

From the analysis of figures 22 and 23 it can be established that when the locator R_2 goes further from the application point of the clamping force, the value of the reaction force F_{R1} grows, together with the enclosing of the locator R_1 to the clamping point.

In the same time, when the distance between the locator R_2 and the point of application for the clamping force grows, the value of the reaction force from this locator decreases.

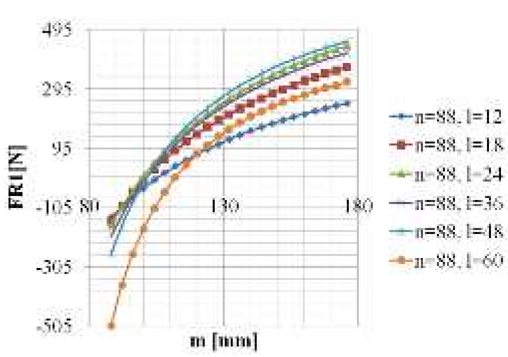

Figure 22. Variation of the reaction force F_{R1} corresponding to the locator R_1

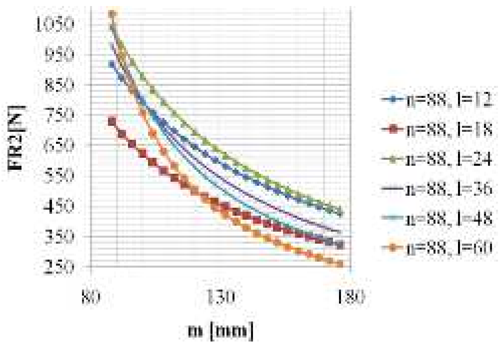

Figure 23. Variation of the reaction force F_{R2} corresponding to the locator R_2

In this way was demonstrated that the values for the reaction forces F_{R1} and F_{R2}, reactions from the locators R_1, respectively R_2 are functions of the value of the clamping forces, its position and the position of the locators R_1 and R_2.

In figures 24 ÷ 29 are represented the variations of the reactions forces F_{R1} and F_{R2} for n = 88 mm, and different values for l, when m = 88…176 mm.

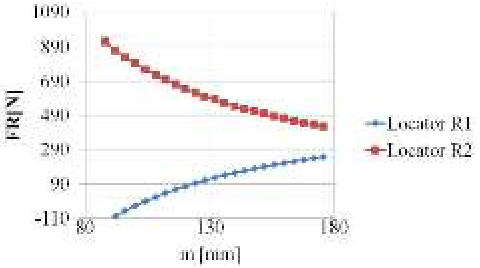

Figure 24. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 12 mm

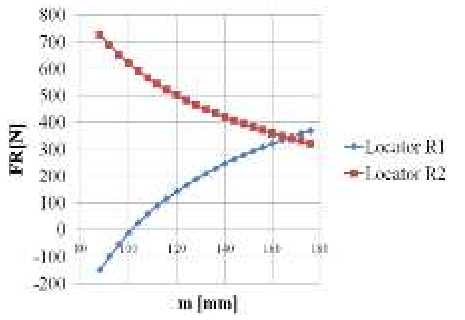

Figure 25. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 18 mm

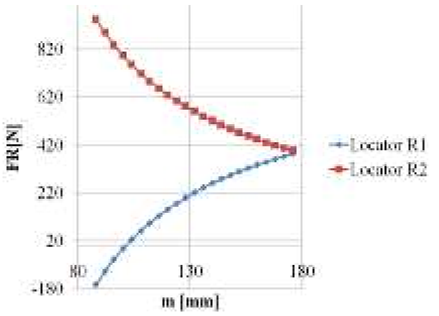

Figure 26. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 24 mm

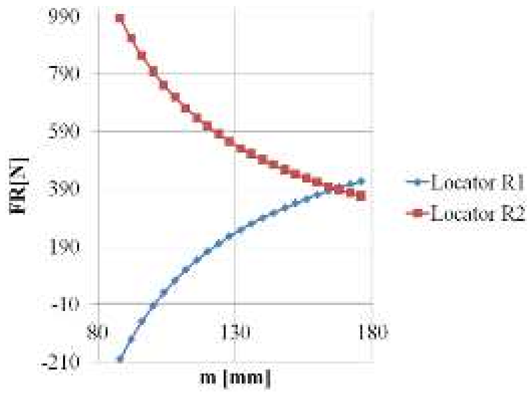

Figure 27. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 36 mm

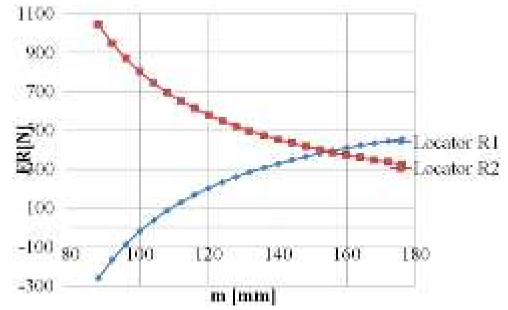

Figure 28. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 48 mm

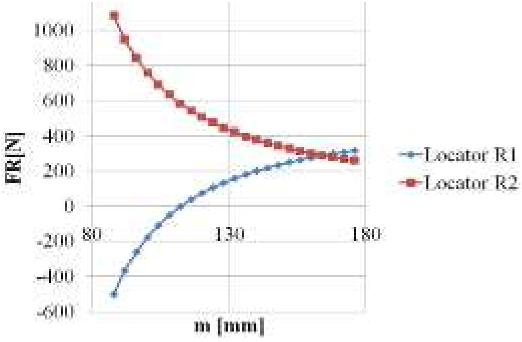

Figure 29. Variation of the reaction forces from the locators R_1 and R_2, for n = 88 mm and l = 60 mm

The intersection point offers information related to the posotion of the two locatos when the values of the reaction forces F_{R1} and F_{R2} are equal on the two locators and the variation mode of the reaction force, as a function of the locators position.

Anlising figure 24 it can be found that in the case when the position of the locator R_1 is at 12 mm from the end of the work-piece, the one of the locator R_2 can not be at a distance smaller than 106 mm.

In a contrat case it could result an invalid fixing configuration because a negative value on the locator R_1 indicates the fact that the work-piece slides on the locators. This fact is in contradiction with one with the fundamental principles of the orientation and fixing of the work-pieces in a device.

Following were elaborated the diagrams from figures 25 ÷ 29, for every studied case, for determining the invalide fixing configurations and the positions of the locators R_1 şi R_2 in a way in wich the reactions forces F_{R1} and F_{R2} to be equal.

From the analisys of the variation of the graphs for the reactions from the locators R_1 and R_2 was founded that if the position of the locator R_1 is at 18 mm from the end of the work-piece can result a valida fixing configuration only if the position of the locator R_2 is at least at 106 mm from its end, figure 25.

3. Conclusions

The paper analyse the way of applying the 3-2-1 principle of orientation and positioning for the prismatic work-pieces, in the devices for machine-tools.

Related to this principle the work-piece is being positioned using three perpendicular planes, the laying plane being the principal one, and the one, which assures the cancelling of three degrees of freedom for the work-piece.

For establishing a relation between the cutting force value and the necessary clamping force, are taken into consideration the locator's position, the way of applying the clamping force, the way in which the cutting force acts on the work-piece.

It is analysed the way of applying the clamping force when the clamping surface it is perpendicular on the cutting force, in the same plane or in orthogonal plane.

For this were determined the reactions forces on the two locators when they are placed at different distances from the point of application of the clamping force and realised the coresponding variation graphs.

The study was realised for three different cases: cutting force acts at the same distance, at a bigger or at a smaller distance from the end of the work-piece as the singular locator.

Regardless the position of the clamping force related to the position of the singular locator, the value of the reaction force on it is only function of the cutting force.

For the locators opposite to the surface on which it is done the clamping the value of the reaction force it is function of the clamping and cutting force, the position of the cutting force, related to the singular locator, the locators position related to the clamping point.

Also, with the help of these calculations and graphic representations, were determined the not recommended zones for positioning the locators.

If these zones were used, it will results the work-piece sliding on locators, fact that is inadmissible, because will lead to the total compromise of the processing process.

These researches will be continued with the establishment of the optimal locators position when the clamping force is applied at a specific angle with the locators R_1 and R_2, respectively R_3.

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