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# STATIC STIFFNESS OF TURNING TOOLS

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*Lucrarea prezintă sintetic, pe baza unor cercetări experimentale privind rigiditatea statică (proprie şi de contact), comportarea, din acest punct de vedere, a unei noi soluţii constructive de cuţite de strunjire, brevetată, în raport cu soluţia clasică. Brevetul de invenţie a fost premiat cu o medalie de aur la Salonul Internaţional al Invenţiilor de la Geneva, ediţia din anul 1995.*

*Based on experimental research on the static stiffness (own and contact), the paper presents the behaviour of a patented solution of tools for the turning processes, in comparison with the classic solution. The patent has received a gold medal at the International Inventions Convention from Geneva in 1995.*

**Keywords:** static stiffness, exchangeable tool, elastic deformation, turning processes

## 1. Introduction

The processing precision and productivity in any technological system depend on its stiffness.

The processing productivity also depends on the stiffness of the technological system used in processing. As a result, the parameters of the processing operation must fulfil restrictions imposed by the allowable value of the elastic deformation resulted from the interaction force –stiffness during processing.

The stiffness of the processing technological system is influenced by the sum of its elements. Knowing the stiffness of each element is very important, as it allows identification of the elements with low stiffness and taking the necessary measures as a result.

Mounting the cutting tools on normal lathes can be made using various methods. Because usually the advantages and disadvantages regarding the mounting precision, the tool exchange time, the cost [1] are known, it is important to know the stiffness of these cutting tools associated with their mounting methods.

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## 2. Experimental models

Throughout the evolution of cutting tools and of the tool mounting devices on normal lathes, several cases can be taken into consideration, three of which are presented in fig. 1, as follows:

-classic tool *2* oriented and clamped in classic stationary device *1*– (fig.1,a);

-classic tool *3* secured in an exchangeable device *2* installed in a base device *1*– (fig 1,b);

-turning exchangeable tool *2*[2] oriented and clamped in a special device *1*– (fig. 1,c.).

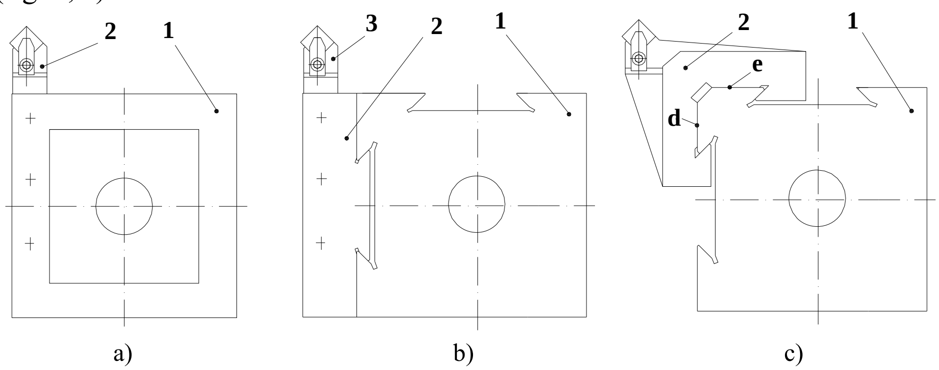


Fig. 1. Experimental models

The classic tool *2* is clamped in a stationary classic device *1* by screws fig 1.a). Four different tools can be mounted on the stationary classic device.

For machining operations with more than four active phases it is necessary to use a flexible tool mounting system. As a result, an exchangeable device *2* is presented in fig. 1.b on which the classic tool is clamped by screws. The exchangeable device *2* is quickly installed through a trapezoidal railing assembly to the device *1*.

In fig. 1.c, an exchangeable turning tool *2* which is assembled on the *d* and *e* sides of the special device *1* is presented, and the installation is performed through a special wedge diagonally located.

These three methods for mounting the classic and exchangeable tools will be named generically in “1, 2, 3 study cases”.

## 3. Determination of the tool stiffness

The determination of the tool stiffness for the three cases, was made by taking into consideration the following criteria.

*a. Equivalent working conditions.* In order to determine the tool stiffness, considering the mounting method for the three cases, it is necessary to create equivalent working conditions [3, 5].

The equivalent working conditions are considered to be the working conditions that is identical or very close regarding the system/subsystem status with the load characteristics etc. if a series of requirements are fulfilled.

•The system structure must be identical or very close (material, overhang length, etc.), see fig. 2, 3, 4:

$$l_1= l_2= l_3= 25 \text{ mm}. \quad (1)$$

•The physical devices (marked with *1*) and geometric references must be identical:

$$RF1= RF2= RF3; Ox_1y_1z_1= Ox_2y_2z_2= Ox_3y_3z_3= Oxyz. \quad (2)$$

•The F force load features (magnitude, direction, starting point) are identical or close.

•The features imposed for the determined elastic deformation U (direction, measurement point) are identical.

*b. Load-measurement schemes*. The load-measurement schemes must fulfil the load requirements: load type (force, torque, load, unloading; static, dynamic), direction, application point, magnitude.

The measurement scheme for a deformation must allow the measurement of the fundamental deformations ($U_x$=X, $U_y$=Y, $U_z$=Z) in the point taken into consideration.

Considering all of the above, a load-measurement scheme was considered for the three cases. The turning tool is loaded with a static, spatial force ($\alpha$ =$45^0$, $\beta$=$30^0$) with the point of application $A_F$ at *l*=25 mm. The tool deformation is determined on the X direction, with the application point $A_F$ in the tool top.

As a result, a load-measurement scheme identical for the three cases (fig. 2, 3, 4) was realized.

Figures 2, 3, 4 present the common elements: *1* – the device with respect to which the elastic deformation is determined; *2* – the tool clamping elements; *3* – the tool; *4* – the magnetic support for measuring device.

In the first two presented cases the tool clamping force is approximately 2000 daN, while for the third case the force is about 400 daN.

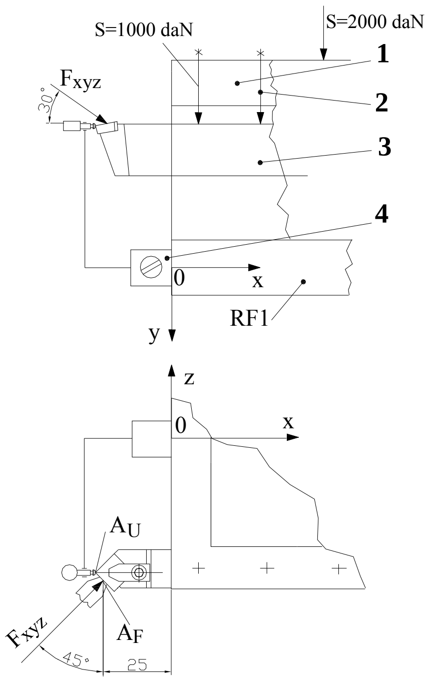


Fig. 2. Deformation load and measurement schemes for case 1

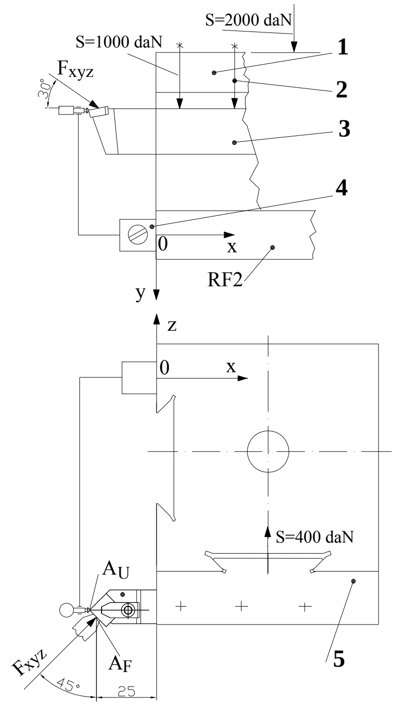


Fig. 3. Deformation load and measurement schemes for case 2

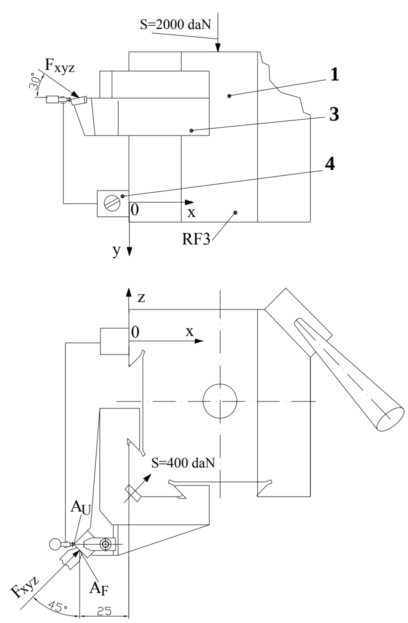


Fig. 4. Deformation load and measurement schemes for case 3

## 4. Experimental setup

The experimental bench (fig. 5) consists of a base stand *1* on which an intermediate stand *2* is mounted for the successive installation of tools and a sub-assembly *3* to support the force loading system *6*.

On the intermediate stand *2,* the tool *5* mounting devices *4* are installed (the experimental models are those presented in fig. 1).

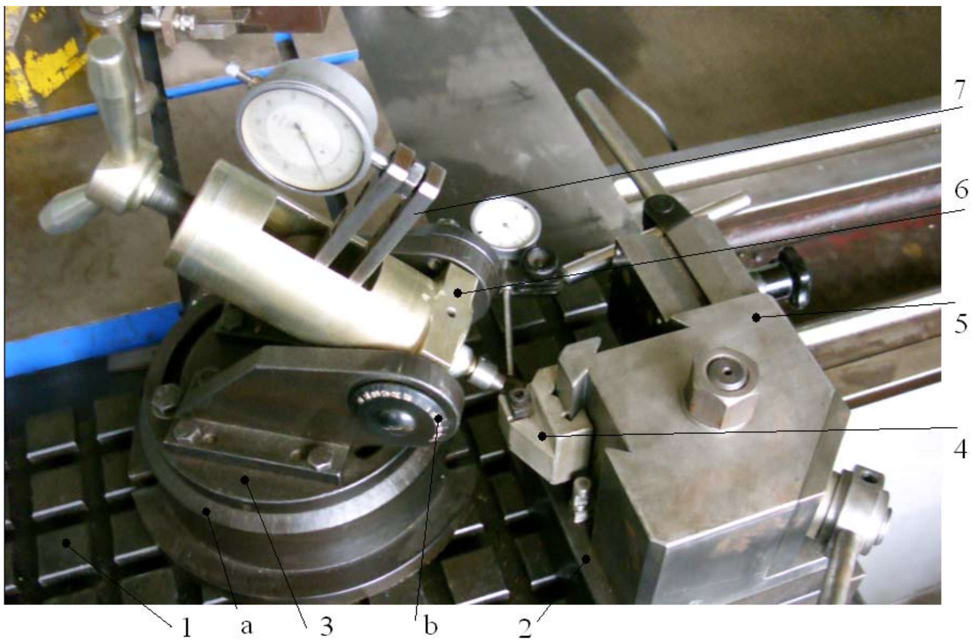


Fig. 5: Bench for measuring the turning tools forces and deformations

The force load device *6* allows the application of a smooth loading with forces on all three axes. In order to create the various angular positions, the device has *a* and *b* scales. The measurement of the force is made with a dynamometer *7* endowed with a measurement device. The measurement of the deformations is made on the X direction with a measurement device having a precision of 0.001 mm. The measurement device is supported by a magnet.

## 5. Experimental results

Experimental data regarding the load and the deformation of the tools used on the cases 1, 2, 3 are presented, by taking into consideration the following general working conditions as follows:

•System status: repose.

•Loaded element = deformed element ($E_F$=$E_U$).

•Physical reference: base stand of the base device, geometric reference: $Ox_1y_1z_1$ or $Ox_2y_2z_2$ or $Ox_3y_3z_3$.

•Force application point ~ point for measuring the deformation ($A_F$~$A_U$).

•The load force is static, spatial F =Fxyz, α =45$^0$, β=30$^0$, F [daN].

•The deformation is static and measured on the x direction, X [µm].

The experimental data regarding the deformation of various types of spatially loaded tools is presented in table 1. The presented experimental data is the average of 20 loading-unloading cycles.

*Table 1*

**Results of experimental research**

| Force $F_{xyz}$ [daN] | | Case 1 | | Case 2 | | Case 3 | |
|---|---|---|---|---|---|---|---|
| | | X Deformations average [µm] | | | | | |
| Load | Unload | Load | Unload | Load | Unload | Load | Unload |
| 0 | 0 | 0 | 0.25 | 0 | 0.5 | 0 | 0.2 |
| 63 | 63 | 0.25 | 1.25 | 0.5 | 3 | 0.10 | 0.4 |
| 125 | 125 | 0.5 | 1.75 | 1.5 | 5 | 0.25 | 0.6 |
| 200 | 200 | 1 | 2.50 | 3.5 | 7 | 0.40 | 0.75 |
| 250 | 250 | 2 | 3.25 | 6 | 9 | 0.60 | 0.8 |
| 325 | 325 | 3 | 4 | 8 | 10 | 0.75 | 1 |
| 395 | 395 | 4 | 4 | 10 | 10 | 1 | 1 |

The force vs. deformation plot, which corresponds to the data presented in table 1, is presented in fig. 6, 7, 8.

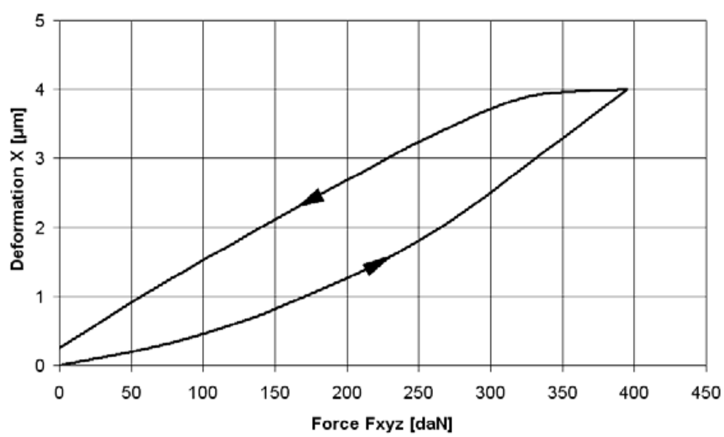


Fig. 6. Deformation – loading function, X(Fxyz), case 1

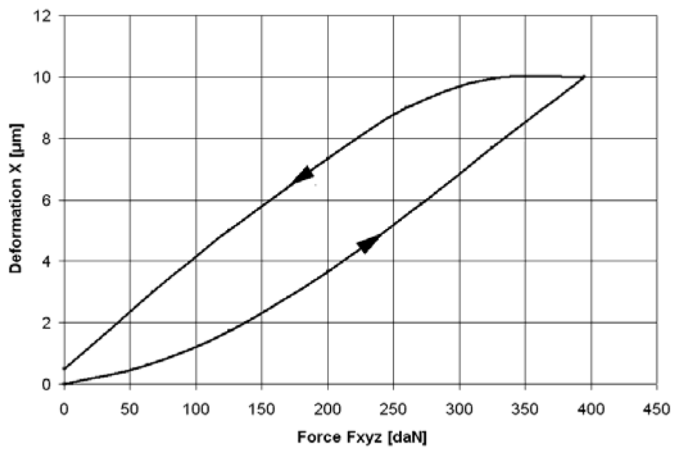


Fig. 7. Deformation – loading function, X(Fxyz), case 2

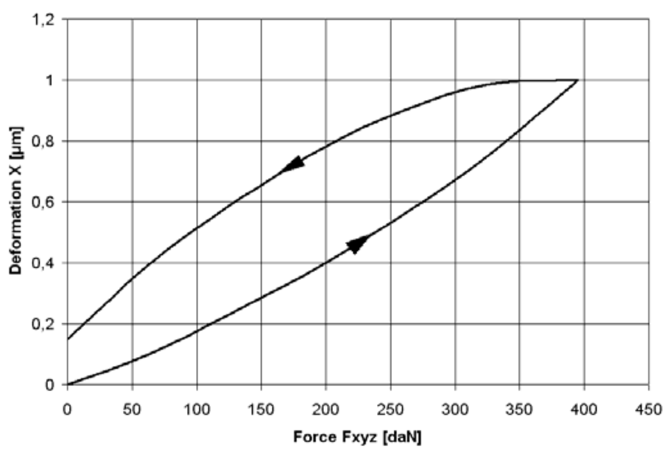


Fig. 8. Deformation – loading function, X(Fxyz), case 3

The stiffness [3, 4, 5] of various types of tools loaded with a spatial force $F_{xyz} = F_s$ on the x direction is, for the three cases:

1) Case 1 $$Ksx_1 = \frac{Fxyz}{X_1} = \frac{395}{0.004} = 98750 \text{ daN/mm}$$

2) Case 2 $$Ksx_2 = \frac{Fxyz}{X_2} = \frac{395}{0.010} = 39500 \text{ daN/mm} \quad (3)$$

3) Case 3 $$Ksx_3 = \frac{Fxyz}{X_3} = \frac{395}{0.001} = 395000 \text{ daN/mm}$$

The ratios between the stiffness of the exchangeable turning tool and the stiffness of the classical tool secured through the two presented methods – in the classical stationary device, and the exchangeable device are the following:

$$\frac{K_{sx3}}{K_{sx1}} = \frac{395000}{98750} = 4; \quad \frac{K_{sx3}}{K_{sx2}} = \frac{395000}{39500} = 10. \tag{4}$$

## 6. Conclusions

Based on the stiffness feature the hysteresis effect occurs. The surface of the hysteresis cycle between load and unload branches characterizes the mechanical work consumed for the contact deformations on the joints, overcoming the friction forces. The area of the surface for the hysteresis cycle depends on the type of tool and its magnitude decreases in the following order: case 2, case 1, and case 3. As a result, the contact deformation is the lowest for case 3. The classic tool secured in the exchangeable device (case 3) which in its turn is mounted in the base device presents an additional joint compared to the classical tool (case 1) mounted on the stationary device. Cases 1 and 2 also present a screw joint to mount the tools.

The greatest stiffness for the spatial load on the X direction is presented by the exchangeable tool (case 3) which has the lowest number of joints and presents a constructive and dimensional shape which provides a very high stiffness. It is followed by the classical tool and by the classical tool mounted on an exchangeable device.

The ratios between the stiffness are 10:1 and 2.5:1, which means that the processing errors caused by the stiffness in case 3, are very low.

The exchangeable turning tools have a static stiffness approximately 4 times higher than the classic tools mounted in a classic device and approximately 10 times higher than the classic tools mounted in an exchangeable device. By using the exchangeable tool mounting devices, a substantial increase of the system stiffness is observed.

The exchangeable tools present the above mentioned features for clamping forces approximately five times lower compared with classic tools.

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