ANALYSIS OF THE FACTORS THAT INFLUENCE THE PROCESSING PRECISION AND THE EFFECTS OF THE VIBRATIONS FROM THE CUTTING PROCESS ON IT

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ABSTRACT: Turning processes are currently widespread, making the issue of processing accuracy resulting from their development to be intensively studied.
By establishing the processing precision, it is desired to make parts that respect the quality standards of the processed shape and surfaces. By this is meant the way of satisfying the requirements and technological specifications imposed by the functional requirements of the mechanical elements that will make up a subassembly together with the parts made. Due to the interactions exerted between the subassemblies of the component elements of the technological system as well as to the influences of the different process factors, the criteria imposed for the precision of the processing are not always observed. In order to highlight the observance of the precision processing conditions in the case of cylindrical semi-finished products processed by turning, it is required to specify the basic conditions necessary to carry out the cutting operation.
The precision of the mechanical processing performed by means of cutting processes aims at respecting the degree of correspondence of the characteristics (dimensional and geometric) of the machined parts, with the same characteristics specified in their execution drawing.
The aspects regarding the fulfillment of the precision conditions of the processing are: aspects of the dimensional precision; precision aspects of geometric shape; aspects related to the relative position of the surfaces of the machined parts (with reference to the macrogeometric characteristics of the machined parts).

Keywords: machining accuracy, factors influencing machining accuracy, vibration, placement angle, clearance angle,

Introduction.

In order to include as many factors as possible that influence the processing accuracy, we start from the structure of the technological system. Such an approach mentions the existence of three main factors that determine the degree of accuracy of the surfaces obtained after processing, namely:

- incorrect choice of the values of some parameters of the working regime;
- the inaccuracy of the fixing position of the workpiece in the clamping device of the machine;
- processing deviations resulting from the basic process and certain:
  - inaccuracy of the theoretical calculations performed in order to choose the optimal processing parameters;
  - the low value of the rigidity of both the machine tool and the cutting tool;
  - elastic deformations of the processing system under the action of cutting forces;
  - thermal deformations of the technological system;
  - internal deformations of the machined part;

Of course, each of the above elements acts in given situations.
However, it is not excluded that at some point multiple interventions will appear, with negative influences on the accuracy of processing.

Another approach of the main factors that influence the precision of turning processing [4];[9], captures two aspects, namely:

- Study of factors dependent on the cutting regime;
- study of factors independent of the

cutting regime.

The first category includes:

- thermal deformations of the technological system;
- wear of cutting tools,
- elastic deformations of the MUSDP system;
- internal stresses that occur during the processing,
- vibrations
- cutting force
- parameters of the cutting regime.

Within the second category of factors that do not depend on the cutting regime are:

- machine tool geometry;
- dimensional deviations (variations of the cutting depth);
- placing-fixing the part in the device;
- internal stresses of the material blank.

Due to the separate or considered influences of the factors belonging to one or both of the mentioned categories, it results in favoring the occurrence of processing errors.

Each of the above factors does not have a controlled evolution, but evolves differently, being necessary to know the laws of variation and action of each individually or separately, depending on the case.

The influence of the vibrations of the technological system on the processing precision.

As already mentioned, the rigidity of the technological system is one of the factors that influence the maintenance and control of the values of dimensional accuracy and the quality of surfaces processed by cutting.

At the same time, it is necessary to analyze the lack of rigidity, which leads to an increase in the vibration level of the technological system [8].Vibrational motion is characterized by amplitude (increasing simultaneously with speed) and frequency.

Vibrations affect the following:

- Quality of processed surfaces,
- Decreased dimensional accuracy,
- Rapid wear or even breakage of tools made of fragile material large (diamonds, ceramic materials, some metal carbides),
- Defects of machine tool components due to vibration,
- Generating noises above the allowed limits.

The main causes of vibration in the technological system come from:

- Internal sources of the processing process:
  - Non-uniformity of processing addition and material structure,
  - Radiated beats of the tool holder mandrel,
  - Non-uniform entry of the edges of the cutting tool into the material,
  - Phenomena inside the cutting process (formation and evacuation of chip elements).

- Sources external to the processing process:
  - Vibrations transmitted by the foundation from appropriate equipment,
  - Vibrations caused by unbalanced masses in rotational motion,
  - Vibrations produced by different shocks.

During the processing operations in the technological system three types of vibrations appear:

- Forced vibrations,
- Self-vibration (self-excited vibration),
- Relaxation vibrations.

Depending on the ratio (μ) between the frequency of vibrations and the frequency of rotational movement (of the tool / semi-finished product) there are 3 distinct situations:

μ > 1-results errors in the cross section, (fig.1.).

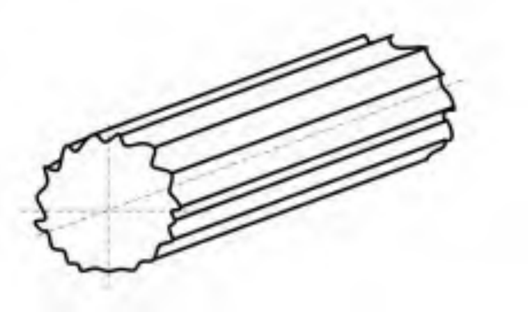

Figure.1. Cross section errors [7].

μ =1- results in errors in the cross section (oval piece in cross section), (fig.2).

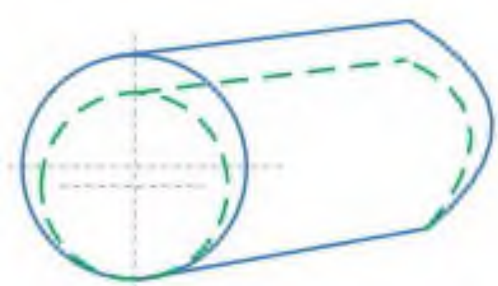

Figure. 2. Errors in the cross section (oval piece in cross section. [7].

μ <1 => cross and longitudinal section errors. when grinding the inner cylindrical bores with small and very small diameters (fig.3.).

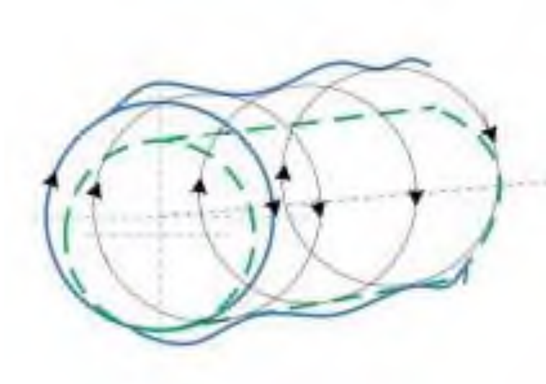

Figura.3. Cross and longitudinal section errors, [7].

The appearance of vibrations in the cutting process can be explained based on several theories / hypotheses [7]:

Taylor's hypothesis.

The cause of self-vibrations is the variation of the cutting force during the 4 stages of chip deformation: elastic deformation, plastic deformation, hardening, breaking [7].

Kashirin's theory.

The cause of the self-vibrations is the variation of the frictional forces on the tool release face [7].

Sokolcvsky's theory.

The cause of the self-vibrations is the continuous variation of the effective geometric parameters during the traverses of the irregularities of the processed surface [7].

Harnis and Grig's theory.

The cause of the self-vibrations is the continuous variation of the cutting depth between the irregularities of the previous processing and the oscillations of the current processing which determines the appearance of the cutting force and implicitly the appearance of a self-vibrating effect [7].

Toblas's theory.

The cause of self-vibrations is the variation of the cutting forces when the tool enters the undeformed material and when it is rejected by the hardened material.

Vibrations in the cutting process create a corrugated surface on the part that will not meet the specified requirements. The aim of deepening the study is to investigate the cause of vibrations and to investigate the problems created by vibrations that occur in the cutting process to reach conclusions about their source but also to find solutions to alleviate or even eliminate this problem [7].

There are a lot of parameters that need to be changed when dealing with vibrations in the cutting process. The most important parameters are: feedrate, speed, cutting depth and feedrate, but also the geometry of the cutting tool must be changed in many cases.

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Lindström (2003) summed up several parameters and their influence on the cutting process, fig.4 for the geometry of the cutting tools [14].

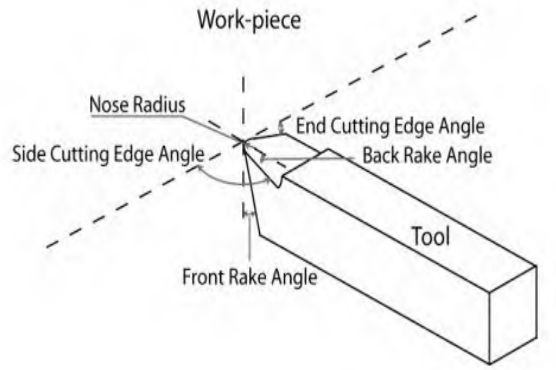

Figure. 4. Geometry of the cutting tool [14].

The lateral cutting angle has a large influence on the radial component of the cutting force and can therefore be set to minimize it, because, in general, the dynamic stiffness is lower in this situation. Lateral cutting angles, other than 90º, have a negative influence on the quality of the machined surface [14].

The tip radius can also be used to reduce the radial cutting force component. The back (Rake Angle) can be used to reduce dynamic forces, choosing a positive angle. The reason for the vibration is the fluctuation of the shear forces. The low shear forces keep a small deviation and the system has less energy in it.

The cutting force can be decomposed into components corresponding to the tangential, radial and axial directions, fig. 5.

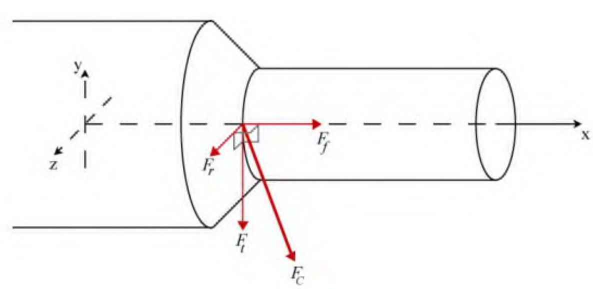

Figura.5. Cutting force components [14].

In Fig. 5, FC - is the cutting force, Ft - is the tangential component, Fr - is the radial component, Ff is the axial or supply component.

Tobias (1961) reports, among other things, a shorter tool life when vibrations are present during operation. This is due to the high-impact loading of the cutting edge. The article also reports that in some cases the increased life of the cutting axes was gained by oscillations.Numerous researches have been done on tool failure and various ways to detect it, for example by acoustic emission or analysis of radiated sound[14].

In fig.6. it can be easily seen that the relative displacement between the cutting tool and the workpiece is of particular importance for optimal cutting.

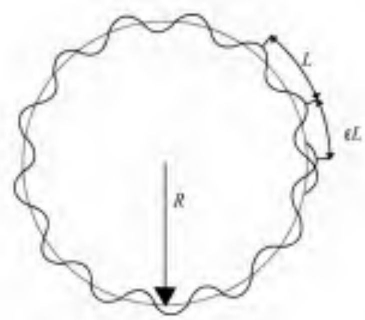

Figure. 6. Corrugated surface of the workpiece with wavelength L and phase shift ε due to vibrations [14].

Vibration reduction can be done by changing the cutting parameters and the geometric parameters of the cutting tool or by damping, either passive or active. Both passive and active depreciation have been used successfully and have different advantages and disadvantages.

Passive damping is based on a damped structure / damped cutting tools or a clamp / shaft workpiece. The basic theory is that a viscous elastic material is added to the structure and follows the critical motion for the limiting frequencies. Depreciation can be added to the tool, tool holder, cutting tool support structure, workpiece clamp or shaft bearing. Different tightening conditions give different results, because the properties of the structure can be changed a lot.

Passive depreciation is limited to the intended purpose, as it can only be notable frequencies

amortized. A great advantage of passive damping is that very small changes in the operation of the machine must be made [14].

Active damping uses online data recorded during the operation and adjusts the instrument to create anti-resonance. Active damping can be used for a number of different frequencies in a wide range of settings. The disadvantage of active damping is that it requires expensive equipment and changes in the installation of machinery [14].

Analysis of errors caused by the vibrations of the technological system.

During the processing process, under the action of factors of different nature, the technological system can move from a stable state to a state of dynamic instability which is manifested by the appearance of vibrations.

The appearance of vibrations involuntarily generates, within the technological system, a series of negative effects such as:

- overloads (due to applied overloads);
- premature wear of machine tools and tools;
- worsening the quality of the processed surface;
- limiting the productive capacity of the machine tool by using work regimes not correlated with the optimal ones.

In machining, vibrations are mostly produced by the cutting force [4]. By means of the MUSDP system, they affect the workpiece, having as a consequence, uncontrollable values of the quality parameters of the processed surfaces. In other words, the final shape of the part results in numerous imperfections due to random shifts from the ideal cylindrical shape of the cutting tool. For this reason, the problem of stability in processing processes, becomes increasingly closely related to the quality of the finished product [10]; [11]; [12]. In the theoretical research as well as in the experimental ones undertaken until the present moment, it is observed that the realized pieces present a multitude of imperfections at the level of the surface, most presented by means of random deviations from the cylindrical profile of the surfaces to be processed. calculation models, undertaken for this purpose, in order to highlight as much as possible the influence of vibrations that occur during processing.

To avoid the occurrence of own or forced vibrations, action must be taken on the causes that produce them. Therefore, it is recommended [8]:

- balancing the masses in rotating motion
- increasing the rigidity of the machine tool by eliminating the games in the bearings;
- use of seamless transmission belts;
- avoiding a processing with wide and thin chips;
- the use of those working speeds that are not included in the vibration zones, knowing that low and high speeds are best;
- using tools with optimal geometry;
- the use of elastic elements to insulate machine tools if vibrations occur transmit through the ground.

Although so far we have only talked about the vibrations produced within the technological system, it should be noted that they can also come from sources outside the system. They influence only by high values of vibrations the elastic structure of the technological system.

The influence of the geometric parameters of the cutting part of the tools on the cutting process.

The following parameters influence the optimization criteria:

- seating angle α,
- clearance angle γ,
- main angle of attack K an secondary angle K ',
- tilt angle λ,
- peak connection radius r,
- sharpening radius ont,
- the shape of the seating and clearing faces,
- the lateral and longitudinal fragmentation channels of the chip and the parameters of the resistant part of the tool.

Knowing the influence of each mentioned parameter on the optimization criteria allows the establishment of the optimal geometry for each concrete case of processing [4].

The influence of the laying angle on the cutting process.

Increasing the seating angle reduces the contact surface between the seating face and the machined surface by decreasing the normal force on the contact and friction surface, decreasing the unit energy load and thereby increasing durability.

This positive effect is counteracted, in case of exaggerated increase of the seating angle, by the decrease of the heat evacuation capacity, due to the decrease of the tooth mass [4].

On this basis, the durability variation curves T = f (α) present maxima at different values of the angle α, depending on the type of tool, the tool material and the processed one, the cutting regime, etc. (fig. 7). Curve 1 refers to the case of machining with a high-speed steel knife of a carbon steel, and curve

3 of an alloy steel; curve 2 refers to the processing of a carbon steel with a milling cutter reinforced with sintered carbide; curve 4 refers to the case of a high-speed steel corner cutter for processing an alloy steel, and curve 5 to the case of a cutter for cutting alloy steel. In general, the maximum durability moves to high values of the laying angle with the decrease of the chip thickness (Fig. 8).

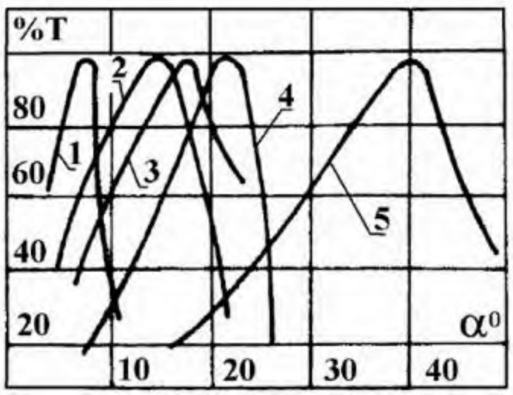

Figure.7.Durability depending on the clearance angle [4].

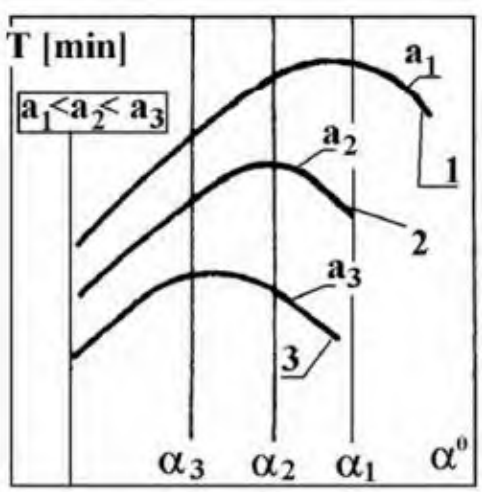

Figure.8.Variation of durability depending on the clearance angle [4].

This is explained by the fact that when the thickness of the chip decreases, the weight of the friction phenomena on the placement face increases, becoming efficient the increase of the placement angle.

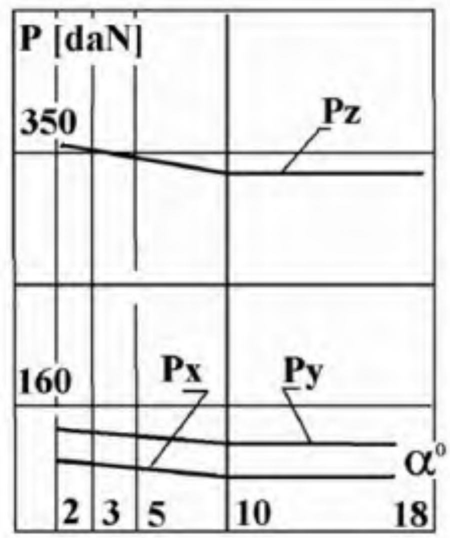

Figure.9.Forţele de aşchiere în funcţie de unghiul de degajare α [5].

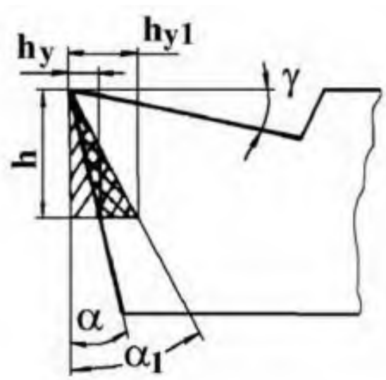

Figure.10.The influence of the seating angle on the wear [2].

Increasing the settling angle causes a decrease in the cutting forces by decreasing the normal forces and the friction forces on the seating surface.

The shape of the experimental curves of variation of the cutting forces in relation to the laying angle are represented in Fig.9.and shows that the decrease in cutting forces is pronounced only up to a value of the setting angle of 10 ° - 12 °.Regarding the quality of the processed surface, it improves slightly with the increase of the laying angle, as a result of the decrease of the friction phenomena on the laying surface [4-6].

The angle α influences the surface quality and indirectly, through vibrations; experimental research has shown that, if within the limits of 8 ° - 16 ° of the seating angle, it does not influence the amplitude of the self-oscillations, at low values of the seating angle, the amplitude of the self-oscillations decreases.

This conclusion is valid only as long as no significant wear of the seating surface occurs.In the case of tools with a small installation angle, the appearance of wear determines the increase of the contact surface with the part and the intensification of the self-oscillations.

The setting angle has a pronounced influence on the machining accuracy, especially by means of wear in the longitudinal direction hy; for the same size of wear ha on the seating face, the radial wear hy increases intensely with increasing angle α, Fig. 10.

To increase the dimensional stability of the tool against wear, the initial practice by sharpening a facet with a zero, wide angle of installation is indicated by sharpening the placement face, h_f = 0.1 - 0.2 mm, which causes wear to evolve slowly even on a new tool.

The practice of the zero facet determines, in addition to a high dimensional stability and a more uniform evolution of the wear, as well as an increase of on average twice the durability. The roughness Rz in the case of machining with tools that have a zero facet on the placement face is significantly lower [4].

The influence of the clearance angle on the cutting process.

Research in the field of cutting has led to the conclusion that the clearance angle influences the cutting process both directly and indirectly.The direct influence is manifested by changing the direction of chip release; increasing the angle γ brings the release direction closer to the direction cutting V, Fig.11 that is, to reduce the plastic compression, to reduce the cutting forces and the unit energy load and therefore to increase the durability [4].

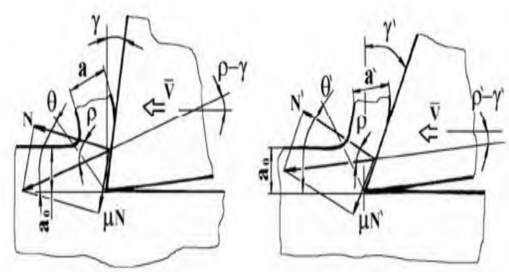

Figure .11. Changing the direction of chip release as it grows. [4].

The clearance angle influences the quality and precision of the processing by means of vibrations.

The amplitude of the self-oscillations and the undulations produced by vibrations on the processed surface increase with the decrease of the clearance angle, this increase being particularly pronounced in the area of the negative values of the clearance angle, Fig.12.

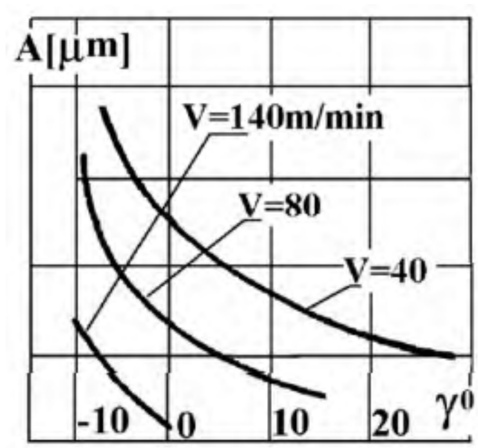

Figure.12.Vibration amplitude depending on the clearance angle and cutting speed [4].

The explanation consists in the fact that, with the decrease of the clearance angle, the disturbing forces Fz increase and, in particular, Fy, the friction phenomena on the clearance face and the deposition phenomena on the edge intensify. According to Fig.12, there is also a decrease in the influence of the clearance angle on the amplitude of the self-oscillations, with the increase of the cutting speed, which is normal, since the increase of the cutting speed leads to an increase of the temperature in the cutting area. from this area at a temperature at which the influence of the release angle is greatly diminished, both in terms of plastic compression and in terms of cutting forces and moments.

Conclusions.

The analysis of the literature highlighted the fact that the issue of processing errors generated during the turning process was a concern from the earliest stages of research on the accuracy of machining.

The analyzed researches aimed at identifying the sources generating processing errors, sources classified in two main categories: the characteristics of the technological system and the parameters of the cutting regime.

This research has been carried out systematically, especially with regard to the influence of cutting forces, cutting tool wear, cutting depth and less systematically on the influence of the rigidity of the technological system on machining accuracy.

The analysis of the researches showed that the rigidity of the technological system is a feature that significantly influences the accuracy of turning processing, by increasing machining errors as the rigidity of the elements in the structure of the technological system decreases -piece blank). At the same time, it is necessary to analyze the lack of rigidity, which leads to an increase in the vibration level of the technological system. Also the vibrations appeared in the cutting
process influence the surface quality of the parts.

The vibrations in the cutting process occur due to the interaction of all the components necessary to carry out the cutting process (machine tool-tool-semi-finished product).

In machining, the vibrations are mostly produced by the cutting force. By means of the MUSDP system, they affect the workpiece, having as a consequence, uncontrollable values of the quality parameters of the processed surfaces. In other words, the final shape of the part results in numerous imperfections due to random shifts from the ideal cylindrical shape of the cutting tool. For this reason, the problem of stability in processing processes is becoming increasingly closely related to the quality of the finished product.

The systemic analysis performed provides a clear view of the elements that influence the machining accuracy pursued in the turning process. The weight of the rigidity of the technological system in the occurrence of processing errors is highlighted, both as a direct source of their generation and as a factor that modifies the influence of other input parameters on the occurrence of processing errors.

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