ANALYSIS OF THE POSSIBILITIES OF REDUCTION AND MEASUREMENT OF CUTTING TOOL VIBRATIONS DURING THE CUTTING PROCESS

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ABSTRACT: Vibration occurring during machining is a major limitation to the productivity and quality of products. The dynamic interaction between the cutter and the workpiece during a turning process causes self-excited vibration.

If the level of vibration is sufficiently high, poor surface quality of the workpiece and excessive tool wear can occur.

The role of machining is to generate surfaces that must meet the requirements imposed by the designer through the execution drawing of the part.

During machining, a continuous process of transporting material from the tool faces takes place which causes changes in the mass and geometry of the active part and which constitutes the wear process of the cutting tool.

In the case of cutting, the wear of the cutting tools is favored by the particularly high pressures in the tool-chip-part system (which can be 300 ÷ 400 times higher than in mechanical joints), by the conditions of dry or semi-dry friction on the contact surfaces.

As a result, the wear of the cutting tool is much more intense than the similar process in the case of general-purpose machine parts. In turning operations, the cutting tool is subjected to a dynamic excitation during the cutting operation. The dynamic movement between the cutting tool and the workpiece will affect the machining result, especially the quality of the workpiece surface. Thus, vibration problems are of great interest in turning operations.

The vibrations involved during the processing operation influence the surface quality.

Keywords: machining precision, turning, vibration, cutting tool wear, machined surface quality.

Introduction.

During a metal turning process, complex dynamic interaction takes place at the interface between the workpiece and the cutter. As a result, chatter may occur. Analytical solutions for turning chatter are mostly based on the regenerative chatter mechanism: as the cutter encounters a wavy surface of a workpiece left from the previous cut, the undulations generated in the previous revolution affect the cutter–workpiece vibration and may cause dynamic instability[9].

Several theories have been proposed to explain the occurrence of chatter instability for optimizing certain combinations of process parameters, i.e. feed rate, depth of cut, rotational speed, variation of chip thickness and variation of cutting force[3].

The analysis of research conducted in the literature showed that the rigidity of the technological system is a feature that significantly influences the accuracy of turning processing, by increasing processing errors with decreasing rigidity of elements in the structure of the technological system (machine tool carriage, fixed doll / doll furniture, tool, semi-finished part). 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 study of the main factors that influence the precision of machining on turning, captures two aspects, namely: [3];[4];[5];[6];

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

The first category includes:

- thermal deformations of the system technological;
- wear of cutting tools,
- elastic deformations of the system MTDPT;
- internal tensions that occur during processing process,
- self-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 cutting depth);
- placing-fixing the part in the device;
- internal stresses of the material blank.

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 the processing processes becomes more and more closely related to the quality of the finished product, Fig.1 [3; 4; 5; 6];.

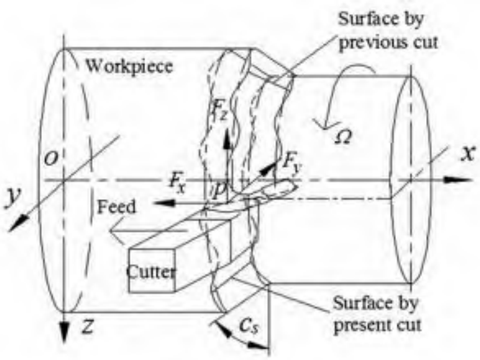


Figure 1. Analysis of regenerative chatter[9]

Analysis of the possibilities of reducing the vibrations of the cutting tool.

An active vibration control project in external turning operations was initiated in 1997. It referred to external longitudinal turning operations and a project was created at the Department of Mechanical Engineering, Lund Institute of Technology, LTH.

A working solution was developed in which vibrations were reduced by about 40 dB and led to a doctoral thesis for Lars Hakansson. However, the magnetostrictive model was not suitable for industrial purposes, so further improvements were needed [7].

A schematic image of the first test model developed at LTH is shown in Fig.2.

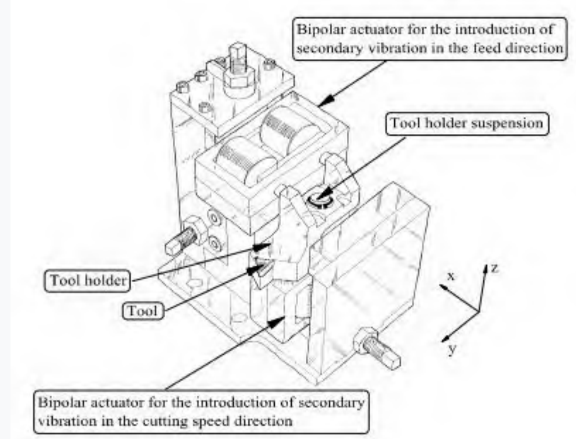


Figure .2. The first working model developed at LTH [7].

The first working model developed at LTH was not possible to incorporate into a standard lathe used in industry without severe changes. The model also needed improvements and soon showed defects. A solution was found using piezo-ceramic attenuators, being created generations of active processing tools whose supports contained piezo-ceramic plates Fig 3. It had good potential, but unfortunately did not withstand the forces appeared during the cutting operation [7].

Figure 3. The first attempt at an active tool holder solution using the piezo-ceramic technique [7].

The piezotronic PCB was also involved in the development of the cutting tool holder with piezoceramic plates and was contacted to develop a stronger cutting tool holder, the unsatisfactory result being shown in Figs. 4.

This tool holder was weak, both the holder and the vibration attenuator had insufficient average operating time [7].

Figure 4. Piezotronic PCB solution of the active instrument using a piezo ceramic attenuator [7].

The solution of having built-in vibration dampers was abandoned at this stage. Figure 5. presents the first external solution based on piezo ceramic attenuators developed at BTH. This solution was possible for incorporation into the lathe used in experiments without modifications.

The experiments that were performed showed that the vibrations were reduced by about 40 dB and the surface quality improved. significant.

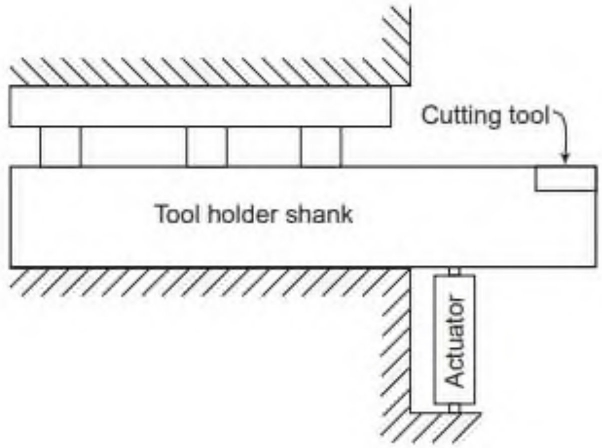


Figure 5. The first solution developed at BTH using a piezo-ceramic actuator mounted outside the tool holder [7].

From now on, it's time to try again to get back to the idea of having the built-in attenuator. The attenuator used in the previous model was small enough to fit a standard tool holder. By incorporating the attenuator into a standard instrument, the holder allows the use of the active vibration control technique in a standard lathe in industry. Then an accelerometer was also incorporated in this model [7].A CAD model of this project is shown in Fig. 6.

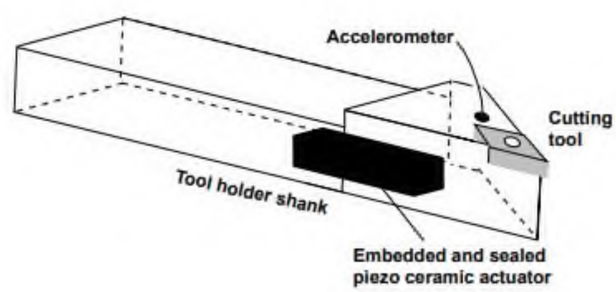


Figure 6. A standard tool holder with a built-in piezo-ceramic actuator [7].

The design of the tool holder has been improved by incorporating a socket in the tool body and is being designed in cooperation with Active Control Sweden AB, a company that is trying to develop and market active control technology in turning operations. The socket connects to a servomotor and the accelerator signal from the accelerometer with the amplifier and the control system. The result is called ActiCut ™ and is shown in Fig. 7.

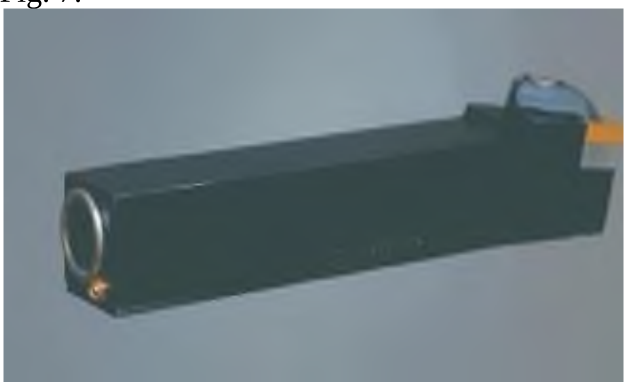


Figure 7. The active tool holder called ActiCut ™ with a built-in piezo-ceramic, attenuator and accelerometer [7].

Analysis of the possibilities of measuring the vibrations of the cutting tool.

The most important characteristic property of the vibrations occurred in the cutting process is that they are induced not only by the periodic external forces, but rather by the cutting forces that appear to remove the addition of material. It was observed that the thickness of the chips removed differs due to vibrations that affect the cutting process, vibrations that occur due to dynamic forces, which in turn, increase the amplitude of vibrations [4].

Vibrations in the cutting process occur due to the interaction of all elements components necessary to carry out the cutting process (machine tool-tool-semi-finished product), fig 8.

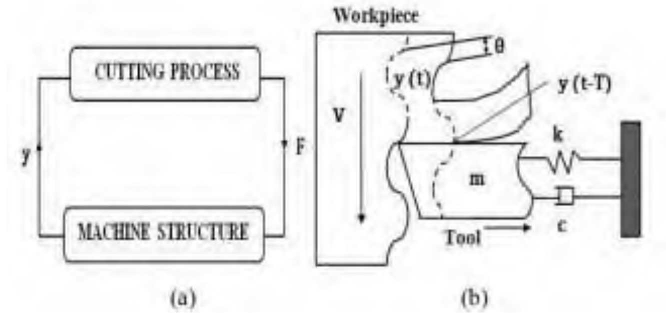


Figure 8. (a) Machine tool, cutting process interaction;
(b) Result of vibration [8].

Experiments were performed on the measurement of vibrations that occur in the cutting process. The cutting forces were measured with a piezoelectric dynamometer, Kistler 9257A components, together with PCB 462 load amplifiers for each force channel, fig. 9.

PCB 333B piezoelectric accelerometers were used in conjunction with an internal ICP conditioning amplifier built to measure the amplitude of vibrations in the Y and Z directions.

The microphone is used with an internal amplifier built to measure the acoustic signals in the cutting process.

All signals measured by the sensors are transmitted to the computer.

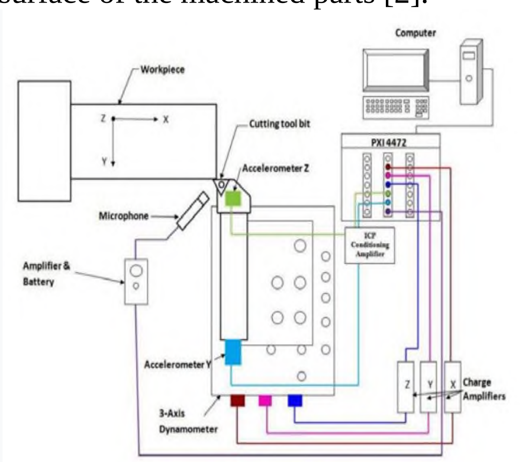
Each signal is then filtered and analyzed on the computer using NI LabVIEW [8].

Based on the above, experimental research is required both by the need to verify the theoretical models for determining the rigidity of the machine tool analyzed (static and dynamic models) and by the need to determine the actual values of dimensional and geometric parameters to obtain machined parts, in order to establish the influence of the rigidity of the technological system used on the precision of the processing.

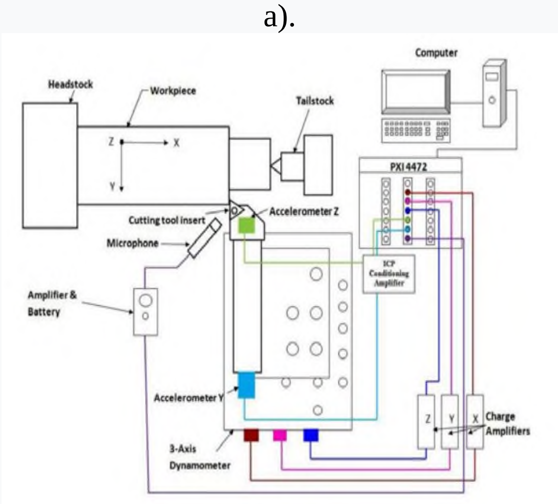
It is known that the turning process involves the chip removal of the processing additive. The forces that appear during processing tend to take the system out of the equilibrium state in which it is at a given moment.

To their action the technological system, characterized by a certain value of rigidity, responds with a set of forces of opposite and equal direction.
in size with the deformers. Thus, from a theoretical point of view, there is the establishment of a static and dynamic balance of forces acting within the processing system.

All the effects of the interactions between the technological system and the cutting forces will be transposed on the surface of the machined parts [2].



a).



b).

Fig. 9. (a) and (b): Experimental scheme used to determine the influence of vibrations [8].

Conclusions.

Based on the analysis of the current state of scientific and technical research in the field, the following conclusions were highlighted:
- study of the influence of low rigidity and the occurrence of vibrations in the technological system have an effect on the precision of machining on turning.
- low rigidity of the system (MUDSP) leads to an increase in the vibration level of the technological system.
- vibrations occurred in the process of cutting influences the surface quality of the parts.
- vibrations in the cutting process they appear due to the interaction of all the component elements necessary to carry out the cutting process (machine tool-tool-semi-finished product).
- a working solution has been developed in which vibrations were reduced by about 40 dB and led to a doctoral thesis for Lars Hakansson. However, the magnetostrictive model was not suitable for industrial purposes, so further improvements were needed.
- in cutting operations, 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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