THE POSSIBILITIES TO USE A SIGNAL FOR DESCRIBING THE ELASTIC DEFLECTION BEHAVIOUR OF A WORKPIECE PROCESSED BY TURNING

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Abstract: Today, the processing centers used for different kinds of cutting processes have built in a series of sensors which are capable to monitories some of important causes of processing errors as force variations, chatter and so on. In the absence of such equipment, some research can be performed using the method and the equipment presented in this present study. Thus, this study presents a method which can be used for measuring some processing errors as elastic deflection, radial deviation and roughness evaluation, as it will be showed. The measurement equipment can be attached easily on a lathe, as it is in our case; also, it is presented a sensor which provides a signal convertible into a displacement. The obtained data provided by the equipment used, not only data concerning the elastic deflection of the analyzed work piece, will offer significant results for the roughness measured in several section of it. Furthermore, the obtained values both, for the elastic deflection and the roughness, can be easily used in any kind of manufacturing device for compensate the processing error. This fact recommends this method to be used with minimal features in the cutting processes domain.
Key words: deflection, signal, turning, roughness

1. INTRODUCTION

One of the causes which lead to processing errors during turning processes is represented by the elastic deflection of the processed workpiece. Even if the depth of cut is severely controlled in order to suppress some possible issues at the end of the process, on transversal section and on the longitudinal direction, several deviations which does not corresponds with the expected one are discovered. Especially, when the accuracy requirements concerning the surfaces roughness are strictly established, each elastic deflection could conduct to a processing error [1, 2]. This fact is caused mainly by the low stiffness of the work piece and secondly, by the cutting force variations, chatters phenomena and so on [3]. Beside this, the roughness parameter also can be influenced by the errors which occur during processing. Therefore, the accuracy conditions expected doesn't accomplish the requirements.

Based on the mentioned aspects presented above and considering the actual conditions with the support of the assisted measuring devices to solving some issues, a strategy for measuring other accuracy parameter as roughness is proposed. The method used supposes to measure values of the roughness and other parameters on different workpiece shapes [4].

Today, most of the processing centers offering high services concerning the monitoring of several technical parameters during the cutting process [5]. But, each processing center comes with significant values considering the budget. There are some studies which has treated such situations [2, 3, and 6]. As an alternative, the described method presented in this paper, comes with an appropriate solution to know some data about the elastic deflection of the work piece, especially related to the roughness values, as it could be observed. Also, the presented methods could be used further on other cutting processes and on other different machine-tools. Beside this, the presented stand is placed near of the machine-tool in order to maintain the initial conditions of processing in case of the processed work piece and it is easily to adapt to any machine-tool [9].

2. PROBLEM DESCRIPTION

This present study is using an experimental stand placed near of a lathe in order to determine, on-machine, some aspects concerning possible errors which can occur during processing. The main issues which have to be solved consist into reveal if the measured method, trough the measured data, based on the experimental stand described below, provides another data besides the elastic deflection of the considered work piece [8]. It is desirable to know if the values obtained correspond with the roughness parameter. If the signal contain much information that we expected, for example the value of the roughness, it will be studied the possibility to separate those information using some mathematical method, as signal filtering [9].

3. METHODOLOGY AND EXPERIMENT SETUP

Into a previous study it was treated some aspects concerning a way to estimate the behaviour of a slender bar [2]. The first measurement step has analysed the radial error of the considered work piece, basically, the deviation measured on radial direction. This aim it was achieve using an experimental stand placed near of a lathe (Figure 1). The bases of the concept consist into determining a signal which will provide the path of the cutting tool during processing. Therefore, after the work piece processing step was completed, a measuring stage was performed. Thus, it was measured the considered work piece along the longitudinal direction of these, in order to follow the same path as the cutting tool, this time replacing the cutting tool with an optical sensor. Of course, it was preferred a non-contact measuring sensor instead of a contact one, in order to avoid any kind of touch positioning error.
For this present study was used a normal lathe with 500x1500mm possibility of processing. An optical sensor type OptoNCDT2000 it was used to generating the signal which provides data concerning the elastic deflection and roughness parameters of the work piece. An S235 it was used as material for the considered work piece. The measured/analysed length was delimited between the sections A (x coordinate axis value =0) and B (x=687.5), chosen depending by the clamping setup conditions (Figure 3). The work piece was clamped between chuck and the pick of the tailstock. As main parameters for the cutting regime were chosen: rotations n=500 rot/min, depth of cut: d_c=2mm.

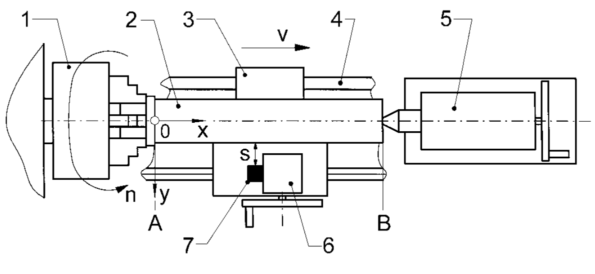

Fig. 1. The optical sensor placed on the machine-tool (lathe): 1- chuck with 3 jaws; 2- workpiece; 3- cross-slide rest; 4- table slides; 5- tailstock; 6- tool head;7- optical transducer

For signal analyzes process provided by the optical transducer was used a numerical oscilloscope, type ADC212/50-PicoTechnology and a personal computer (Figure 2). With support of the Matlab software was possible to filter and highlight, in numerical form, the data obtained.

The principle of measuring consists into analyzing the cylindrical helix obtained combining the rotation movement of the work piece with the feed movement.

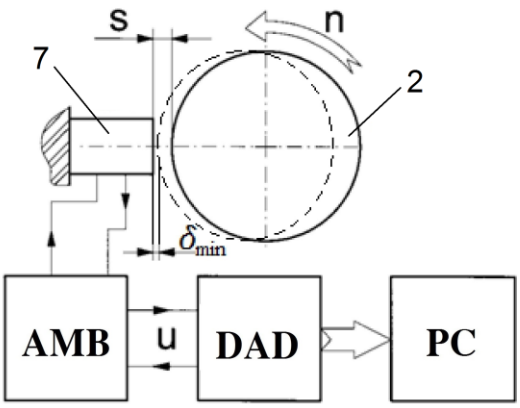

Fig. 2. Experimental stand used in this present study AMB - acquisition measurement bridge, DAD - Acquisition Data's Device, PC – personal computer

The obtained data were used forward in order to make a graphical representation of the work piece shape. The difference obtained by comparing the initial graphical shape with the last one obtained after processing offers the value of the radial deflection error.

4. EXPERIMENTAL ASPECTS

The signal description was made considering the distance related in time, between the work piece and the optical sensor (1), where *s* is the distance and *t* represents the time.

$$s=s(t) \tag{1}$$

The movement was registered between the limits A and B, for a period equal with 20s. The data acquisition was made on a continuous domain of ±100 mV.
In the Figure 3 is presented the temporal evolution of the measured signal transposed in registered period of time. It can be observed that the graph highlights 4 measurement areas/lengths:

- Z1 –a calibration length being as necessary, with a greater diameter than the all part of the work piece;
- Z2 - a length used for describing the measured signal, with fast pick variations;
- Z3 – the end of the work piece; the optical sensor has left the measurement range;
- Z4 – length without importance but which give clues about the end of the measuring length.

As main details presented in the figure can be highlighted the starting and the ending time measurement, booth with the real speed of the workpiece. The speed value was obtained from the same measured signal, considering the parameters of distance and time elapsed.

A first question which arises is if the measured signal gives true data about the real distance between the work piece and the optical sensor. The answer is affirmative, fact proved in the study [9]. Now remains only the question if the measured signal can provide data about the roughness values which corresponding to the measured work piece.

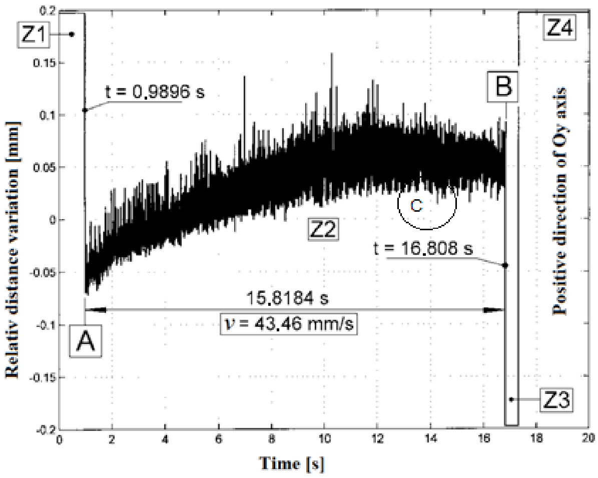

Fig. 3. Temporal evolution of the signal s(t)

On the Figure 4 is presented a detail from the Figure 3 in which supposed that:

- the detail D presents a harmonic evolution of the measured signal, with an amplitude around 25 µm, due to the radial deflection, according to the study [8];
- over the main component of the signal from the detail D it is observed a second component which is show also in the E detail; this last component is assumed to the work piece roughness;

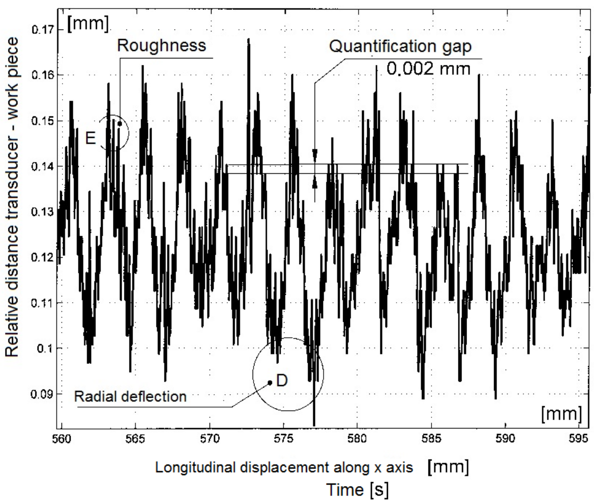

Fig. 4. Representation of the detail C from the Figure 3

Figure 4 presents also a quantification gap which is assumed to the minim distance between two lines of alignment corresponding to the range of the optical transducer used.

The numerical filter used for separation those two components of the signal, which cuts only the components by low frequencies. The autocorrelation function applied has revealed the existence of an evolution, having the period evolution (8 period registered on 20mm distance), equal with the measured helix (same value as the feed rate) (Figure 5).

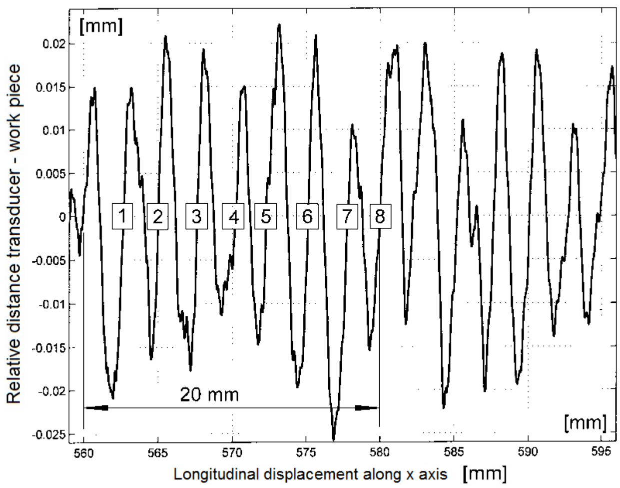

Fig. 5. Highlighting the components from the signal presented on detail C

Further, the measured signal was interpolated in order to determine the mathematical expression, used lather in the Matlab software in order to obtain the graphical representation of the roughness parameter.

Thus, Figure 6 presents the graphical result of the numerical interpolation applied. It is observed that there is a difference pick to pick related to an amplitude equal with 30.2 µm, which represents the radial deflection transposed on the processed work piece.

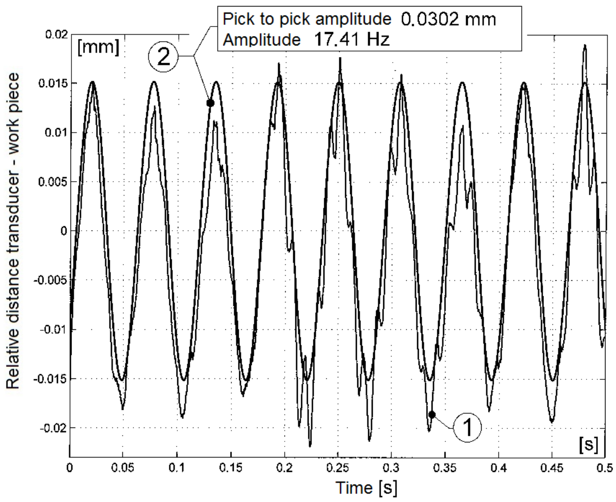

Fig. 6. Graphical result of the numerical interpolation (1- experimental curve, 2- numerical interpolation)

Other significant detail is represented by the frequency of the interpolation curve, which is equal with the rotation frequency of the work piece f_{rot}= 17.41 Hz.

Based on the interpolation curve, can be analysed and determined the value for the helical exploring step p_{ee}.

$$p_{ee} = \frac{d_{A-B}}{n_{rot}} = \frac{d_{A-B}}{f_{rot} \cdot t_{A-B}} = 2.496 mm/rot \quad (2)$$

The relevance of the obtained value is certified by the estimation made with autocorrelation function. The mentioned function applied to the signal demonstrates that the signal has repeatability and is not periodically. The periodicity of the signal can represent a vibration of the measured component, translated as a noise, which cannot give a true measured signal. Further, it was represented a part of those 7 periods specified in the Figure 5. It was found that the main component of the signal presents a second component overlapped over the main component of this.

In order to demonstrate if the measured signal offer booth aspects concerning the elastic deflection and the roughness surface of the processed workpiece, a larger scale representation will highlight these issues. For this purpose a sequence of the measured signal, noted with letter E, will be increased. On Figure 5 can be seen a second component of the measured signal transposed on the main component signal. Were identified and noted starting with 1 to 7 the all small curves identified on main component signal. It is observed that the step between two micro curves, noted with p_{sc}, is equal with 0.357mm, value obtained splitting the pee in 7 intervals. Considering the rotation frequency, the frequency for the secondary component becomes:

$$f_{cs} = 7 \cdot f_{rot} = 121.87 \text{ Hz} \quad (3)$$

Using a cut-down numerical filtering (with elimination of the components of high frequency) it is possible obtain a new graphical representation of the graph from the Figure 4 (Figure 5). Each curve is considered as being a roughness characteristic transposed over the main component of the signal, the radial deflection of the considered workpiece. In this case, the created issue should be solved by study the roughness surface evolution of the considered work piece. Thus, a confirmation methodology of the mentioned hypothesis was used. The work piece measurement was performed using a Handysurf E35-A roughness device. The value of 12.5 mm was used as a measurement distance (Figure 7).

The measurement data have been processed using the Matlab software. Based on the numerical filter used, has been detailed the work piece profile presented into the Figure 6.

For the study was considered only a sequence of the measured signal, due to presence of a periodical component reveal by amplitude pick to pick, with a value around of 80 µm.

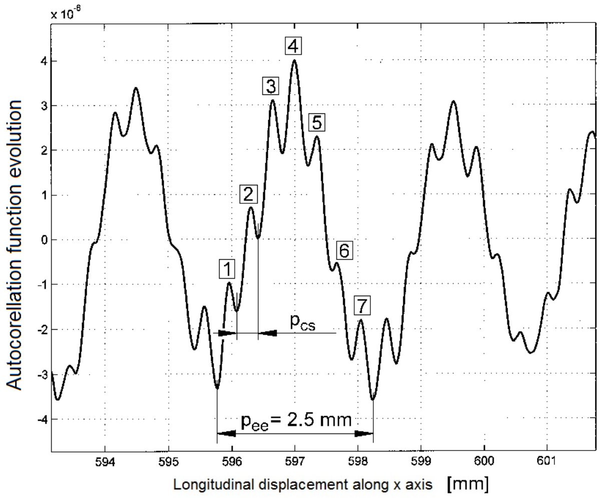

Fig. 7. Representation of the detail C. Aspect of a new component signal identification

After a series of numerical filters was applied in order to process the measured signal, the low frequency component it was possible to be eliminated. It is observed that the parameter p_r can be defined as $1/f_r$ [mm/rev] and it is coinciding with the feed tool used for the processing the surface. Forward, the interpolation procedure, made with the Matlab software, assumes to obtain a sum of the difference between the modulus, point with point of the experimental and approximate curve (Figure 9). It is expected that this one should be minimum and his value approximate the feed rate 0.416 mm/rev. The result obtained is different from the step of the secondary component equal with a value of 0.35mm/rev.

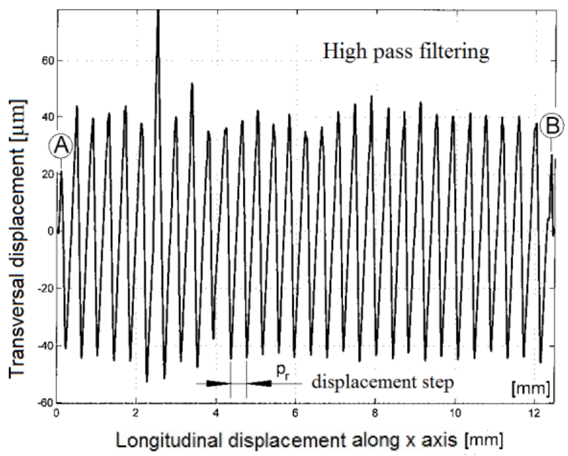

Fig. 8. A detail with the roughness measured of profile. High pass filtered evolution

This means that the first measurement highlights the result of measuring the part on the generators (p_r), the second parameter being represented by the step helix (p_{ee}).
Otherwise, the cylindrical helix is generated through the work piece processing (highlighted by the roughness of the remaining section), which have the sense against the measuring helix obtained with the optical transducer.

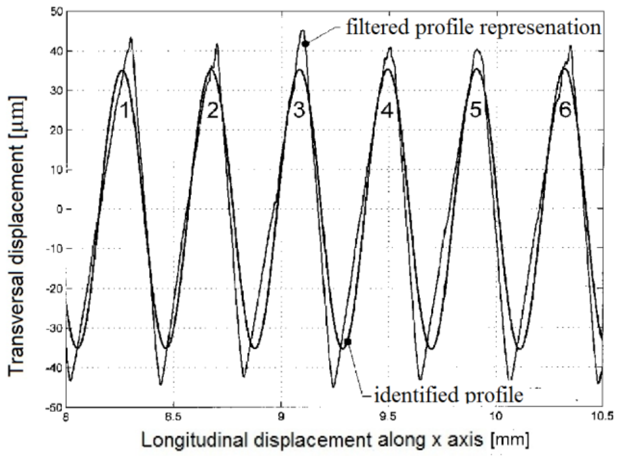

Fig. 9. Representation of the roughness filtered signal

Thus, the first one is generated by clockwise spinning with the feed oriented to the chuck and the second one is on the right side, generated by clockwise rotation with the feed oriented to the tailstock (Figure 10).
The representation of the measurement presents with the p_{ee} parameter the distance f of the measured helix, with AB the generator and with B'B the circumference of the transverse circle. Each arch included in one measured step becomes a_{ee}. The measurement arch contains six complete helixes associated to the roughness (because $p_{ee}/p_r=6$), thus will have a_{er1}, a_{er2}....a_{er6} segments. From Figure 8 representation it can be highlighted the connection between p_{ee}, p_r and p_{cs} as following:

$$p_{ee} = 6 \cdot p_r = 7 \cdot p_{cs} \quad (4)$$

that means:

$2.5 = 6 \cdot 0.41(6) \approx 7 \cdot 0.3571$

Based on geometrical analogies, can be writing following expressions:

$$\frac{p_r}{p_r - p_{cs}} = 7 \quad \text{Respectively} \quad \frac{p_{cs}}{p_r - p_{cs}} = 6 \quad (5)$$

In such conditions, if the measurement helix has the same sense of traveling with the roughness helix, based on the geometrical representation presented above, it can be easily represented trough a mathematical expression between p_{ee}, p_r and p_{cs} as it is presented above.
On the Figure 10 it was represented the straight segment corresponding to the measurement helix is developed, by joining the points A and B'. In such conditions, the origin of the second component of the signal is well explained and used as the second purpose of this paper: to highlight the way to use all the aspects which concerning the information provided by a measured signal.

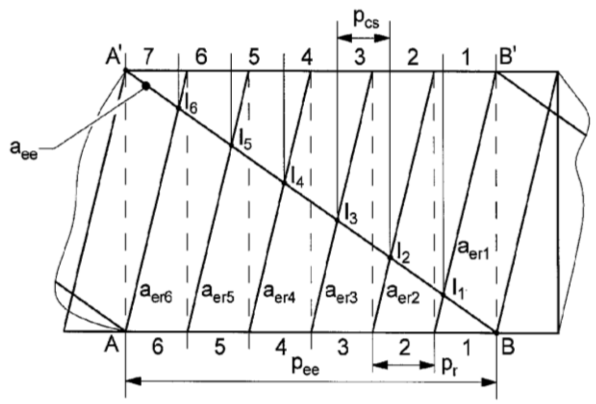

Fig. 10. A detail concerning the measured periods of the identified signal

The same profile it is encountered also, in case of making the flat surfaces on the helical teeth of the cylindrical tools (at the so-called propeller detailing). This aspect was highlighted and described in the study [10]. Also, the quality of the signal which gives the secondary component is not accurately defined do to the measurement principle used. In this way, the measurement focused area provided by the optical transducer used is overlapped (Figure 11).
According to Figure 11, the focused LASER area is not precisely defined (as a point) and its area being doubled in comparison with the measured step distance. Hence, the effect used to mediate the signal.
Of course, a secondary factor which has a severe influence on the obtained result it is represented by the incidence profile defined trough the surface roughness.

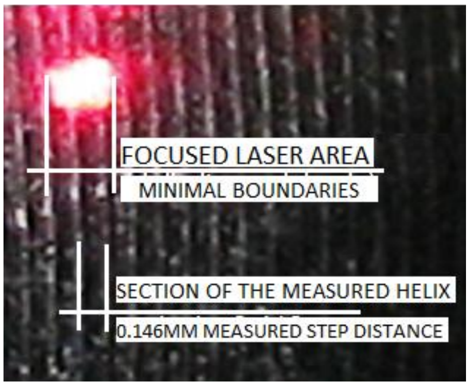

Fig. 11. A detail concerning the measured surface of the work piece. Statically representation. Measurement boundaries defined

5. CONCLUSIONS

The most processing centers have a series of sensors able to determine processing parameters. However, in some cases, these sensors are sold separately. In this case, the measurement method presented above comes as an advantage in this way. More than that, the experimental stand used can be easily used on other kind of machine-tool, booth in other cutting processes. This fact offers the possibility to measure, directly on the machine-tool used for processing the work pice, the interest parameter without modifying the initial parameters (work piece modes of orientation and clamping).

The obtained values sustain the initial hypothesis: measuring the work piece errors by using a measured signal to detect two of most important parameters: radial deflection and roughness parameter. Also, it is observed that the second component of the signal, identified as the roughness parameter, which could be extracted from the main signal in order to provide significant data about the surface accuracy. With other words, it could be observed that the described numerical evolution of the signal leads to separate not only the studied phenomena, but also as other important data as the one assigned to the roughness.

The Matlab software used in this study has shown its usefulness trough it possibility to separate the signal components, booth with the cut-down filtration/removing the useless part of the signal.

A possible further step will follow to compensate the errors identified during the work piece processing. This aspect being achieved using a software which will act in opposite direction to the deforming forces.

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