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CONTRIBUTION CONCERNING THE PROCESSING OF EXPERIMENTAL DATA OBTAINED THROUGH SUPERFINISHING OF STEEL

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ABSTRACT

An experimental research on the fundamentals of the superfinishing process is reported here. This work presents some of the experimental results obtained for 3 types of steel, OLC 45, 13CrNi and 41MoCr11 using the superfinishing process. This work intends to present several experimental results obtained through the processing of the experimental data obtained, considering the process as a dynamic series in discreet time, because the roughness is a dynamic series formed from a multitude of n discreet for whom it exists a function x (t), its argument t representing the discreet time.

Keywords: superfinishing, analysis in frequency, dynamic series, roughness

1. INTRODUCTION

Superfinishing is a fine machining process which uses abrasive grit that are bonded together, to form a stone as cutting medium. The process was first conceived in 1936 [1], and since then has become widely used as a subsequent operation after grinding to enhance finish and remove any chatter marks from the work piece. When applied to rolling element bearing surfaces, the process is claimed to enhance wear resistance and to increase fatigue life [2, 3]. Although not being primarily used for stock removal, superfinishing also corrects size and shape deviations, improves roundness, and provides better blending of the profile radii [3]. Despite its widespread use, the fundamentals of the process are not well understood. Selection of superfinishing conditions is mainly based upon trial-and-error methods. The present research was undertaken to prove the importance of working-parameters and their relative importance in the process. The experimental research had in view the evolution in time of the roughness of OLC45, 13CrNi and 41MoCr11 steel grades, and for each of them 27 samples were used. The roughness of all these samples was measured at the beginning of the experiment (t = 0 s), after 60 s, after 120 s, and finally, after 180 s. For each sample, 4 values of the roughness R_a were determined. Therefore, a total number of 108 values for each one of the three above-mentioned grades of steel were obtained. The experiments were made using different speeds n_a of the main shaft, different number of double strokes f of the tool, and different pressures P. The variations of the sizes can be depicted on a chart in the discreet area (the time has values in the whole numbers) or in the contiguous area (the time has values in real numbers). In the sense of those presented above, there must be mentioned 4 major benefits offered by the discreet representation: the computer works in the discreet area for the processing of the experimental data; the accuracy of the calculations is maximum; one can better perceive the real way of variation of the value under analysis; and the establishing of mathematical models based on experimental data appeals to the discrete domain. Experimental data in the discrete domain constitutes a finite series which, as a rule, cannot be expressed as a equation of the general term. For this reason, the discrete domain calls for recurrence relations and regression; if a recurrent procedure is used with just the values of the series under analysis, then auto-regression will be used, that is, auto-recurrence. The utilization of the analyse in time of the experimental data permits, mainly: appreciation about the character of the temporal variation of the dynamic series; establishing of the values of the terms had in view; the determination of the statistical parameters for different sizes; the effectuation of the temporal correlation analysis of the data.

2. ANALYSE IN TIME OF THE EXPERIMENTAL DATA

The statistical characteristics describe the functioning in the presence of an aleatory process. A dynamic determinist series can be seen as a realization of an aleatory process and, therefore, the processing of the results is similar. Charts obtained through the processing of the data shows that the statistical sizes of the roughness are various, thus for a time of t = 60 s the most important diminution takes place, for the 60-120s interval the diminution is less visible and for the interval of 120-180 s, even if the average values of the roughness are the smallest, practically the diminish of the roughness is very little. One can observe from figure 1 that the roughness of those 27 samples of the OLC 45 steel does not enframe in Gauss and Weibull distribution law, existing deviations of the curves against the straight line afferent to the repartitions had in view, fact confirmed through the Smirnov-Kolmogorov test, whereat is obtained the acceptance of the hypothesis H1 with a threshold of signification of 0.05. Form figure 2a can be noticed that the values of roughness, at t = 0s, of 41MoCr11 steel does not enframe in Gauss distribution law; in exchange, in figure 2b, is remarked a better proximity of the curve of roughness experimental data, for t= 180s, to the ideal straight line of the normal repartition.

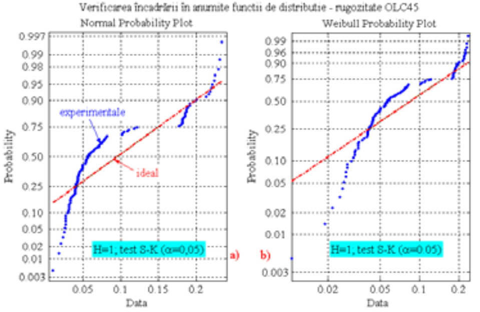

Figure 1. Gauss and Weibull distribution law for roughness

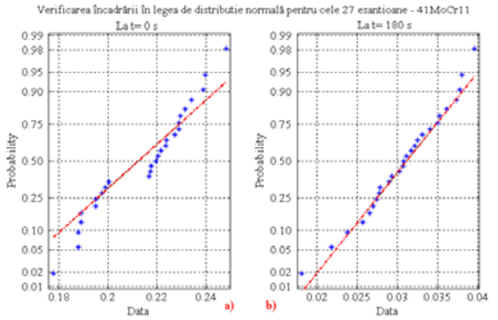

Figure 2. Normal distribution

3. STATISTICAL CHARACTERISTICS OF THE 2ND ORDER. ANALYSIS IT OF CORRELATION

Analysis of correlation, which uses statistical characteristics of 2nd order, allows: appreciation of the temporal correlation of the experimental data, for having the guarantee of their utilization in subsequent calculus; appreciation on the non-linear characters of the dynamic experimental series.

Although the statistical features of the 1st order presented previously, which use the probability density of 1st order, are used frequently, yet these don't give a complete image of the intern character of the aleatory process or of a dynamic determinist series; indeed, for instance, two dynamic experimental series can have the same average and dispersion, but their character of variation can be different. To characterize the intern structure of a certain dynamic series *x(t)*, therefore to appreciate the connections among its sections, the auto-correction function is used, which represents a non-aleatory function (analytic), which for a pair of arbitrary selected values *(t1, t2)*, is equal with the mathematical hope of the product of two aleatory centred sizes, corresponding to the two section. The auto-correlation function shows the degree of temporal correlation of experimental data. A symmetry on the axis of time on the graph of the auto-correlation function shows the existence of auto-correlation both on the presented data and on future identical experimentations. The greater the tendency of the function of auto-correlation to the average value (the null value if the process is centred), the weaker is the temporal correlation of the data. In figure 3 and fig 4 are presented the functions of auto-correlation for the OLC45 steel ,respectively for the 13CrNi steel, for the values mentioned in the graphs: the roughness Ra, pressure P, frequency of the cutting tools *f*, and speed of the main shaft of the machine tool n_a.

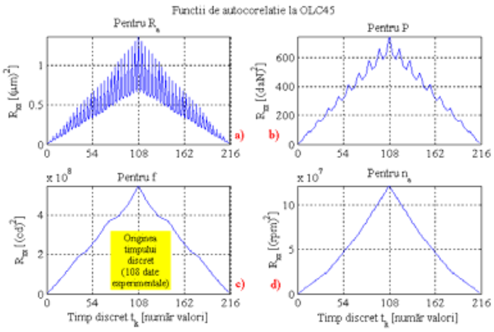

Figure 3. The functions of auto-correlation for OLC 45

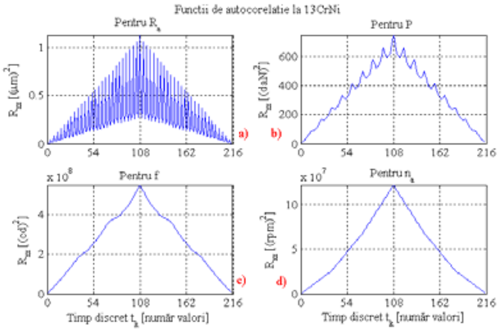

Figure 4. The functions of auto-correlation for 13CrNi

The variation character of the curves of the auto-correlation functions is in concordance with the one of the respective sizes (most pronounced variation belongs to the roughness); the curves have an acceptable symmetry, and do not suddenly tend to null values. The function of inter-correlation characterizes the statistical connection among two aleatory process $X(t)$ şi $Y(t)$ in different moments of time, which are at the distance τ in time from one another. The value $R_{xy}(0)$ characterize this connection at the same moment of time. If the aleatory process $X(t)$ şi $Y(t)$ are statistical independent and the average value is null, then their inter-correlation function is zero; the opposite affirmation in not always true. If the inter-correlation chart is symmetric and tends slow to the average value (respectively the null value), then exists a good temporal inter-correlation of the experimental data and, therefore, exist the guarantee of their subsequent utilization.

4. ANALYSIS IN MONO-SPECTRAL FREQUENCY OF THE EXPERIMENTAL DATA

The analysis in mono-spectral frequency, permits the establishing of the frequency spectrum for different sizes (roughness, pressure), the establishing of the harmonic components with high energetic contribution from the experimental series, comparing of spectral pictures for different steels, the determination of the sampling frequency for the determination of the mathematical models which describes the behaviour in dynamic regime in contiguous time, therefore differential equations. The processing of the experimental data is made using the classic Fourier transform which considers the processes as linear, neglecting the non-linearity of any nature. The practice proved that the real processes are non-linear, fact confirmed in the frame of this paper. Two simplifying hypothesis are adopted: the studied process (evolution in time of the roughness) is considered a *linear process* and the spectral analyses of the dynamic experimental series is done, the series being considerate stationary, with the frequency spectrum invariable in time.

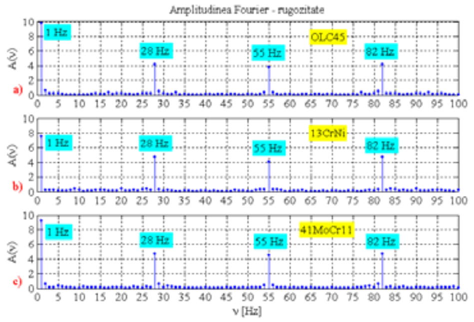

Figure 5. Fourier amplitude for the roughness

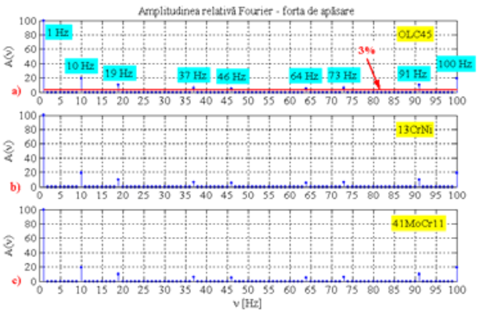

Figure 6. Fourier amplitude for the pressure

In fig. 5 is presented the Fourier amplitude for the roughness of all three steel grades used, and in fig. 6 for the pressure. The charts point out the harmonic components with high energetic contribution from the experimental series; the frequencies of these components are mentioned on chart, being different for roughness and pressure. Fig. 5 shows that these frequencies are the same to all steels grades used, fact that confirms that the samples were tested under the same conditions. The chart from fig.6 shows the necessity of adopting a sampling frequency of 200 Hz, being detailed the case is which is accepted the neglect of harmonic components with energetic contribution less than 3% from the maximum value; for this reason, the chart contains the relative values of the amplitude.

5. ANALYSIS IN POLY-SPECTRAL FREQUENCY OF THE EXPERIMENTAL DATA

Analysis in poly-spectral frequency assures the discovering and the separation of linear components and of the noises from the dynamic experimental series obtained through calculation, as well as the settlement of non-linear mathematical models of the evolution of a process. Poly-spectral analysis uses statistical moments of superior order and consists in the generalization of auto-correlation of the dynamic series through the use of cumulators, which represents non-linear combination of these moments. Bi-spectral analysis is utilized for discovering and the separation of the non-linear part from the experimental series and the tri-spectral analysis is used for the separation of the noises that accompany any real process. In fig. 7 is presented the bi-spectrum for roughness afferent to the OLC45 steels. Similar, in fig. 8 is shown the bi-spectral analysis afferent to pressure, for the same steel grade.

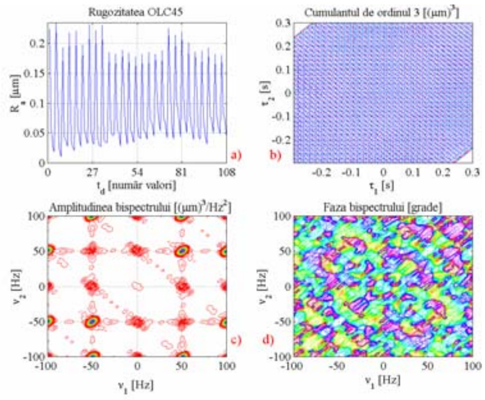

Figure 7. Bi-spectral analyses for roughness

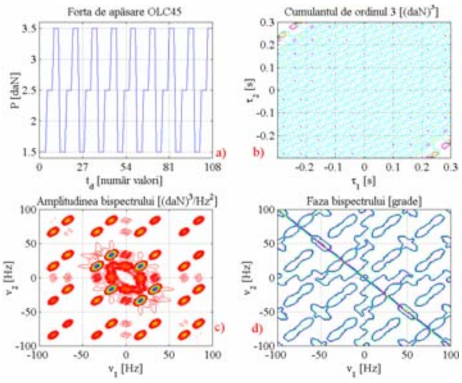

Figure 8. Bi-spectral analysis for pressure

Base on those shown above (in graphic the band of frequency f_1 is allocated to the linear components and f_2 to non-linear part), as well as from the results obtained from another experimental researches, it result: charts point out the existence in all dynamic experimental series of a non-linear component, with a weight more or less important, but which anyhow cannot be neglected (if there won't be non-linear components then their image in the afferent graphs would not exist); from charts is noticed the existence of different spectral pictures for diverse sizes; conclusion is valid too for the same size, but to different steels.

6. CONCLUSIONS

The charts of the Fourier amplitude for the roughness of the three steel grades studied and of the relative Fourier amplitude for pressure, points out the harmonic components with high energetic contribution at high frequency, up to 100 Hz, what drives to the necessity of adopting the sampling frequency of 200 Hz, the neglecting of harmonic components with energetic contribution less than 3% from the maxim value being accepted. The use of poly-spectral analyses in the frame of this study confirms the fact that the real processes are non-linear and it can be noticed that the relations are expressed in discreet time and refers to the afferent dynamic series y[n]. Bi-spectral analysis is utilized for discovering and the separation of the non-linear part from the experimental series and the tri-spectral analysis is used for the separation of the noises that accompany any real process

7. REFERENCES

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