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Measurement of a superficial texture by applying the alpha parameter on the profile P, for measuring a manual transmission gear

Saraiva, Q. M.[1] ; Magalhães Junior, P.A.A.[2]

[1]Me Student, Mechanical Engineering Department, Pontifical Catholic University of Minas Gerais, Belo Horizonte, Brazil
Email: Querlem.saraiva@hotmail.com
[2] Professor, Mechanical Engineering Department, Pontifical Catholic University of Minas Gerais, Belo Horizonte, Brazil
Email: paamjr@gmail.com

Abstract*— *The objective of this work is to demonstrate the P Profile application in the measurement of superficial texture of the cone seat of the synchronization ring gear of a Mechanical Transmission.

It is known that this superficial texture is an essential factor for the good performance and durability of a Mechanical Transmission, since the variation of this texture is directly linked to the synchronization failure, premature wear of the synchronization ring coupling guides, gear and sleeve.

Keywords*—*Superficial Texture, P Profile, Manual Transmission Synchronization.

I. INTRODUCTION

The term surface integrity cannot be defined only by superficial texture or geometric shape. The characteristics of layers below the service surface must also be considered because the process to obtain a machined surface is very broad, considering plastic deformation, rupture, elastic recovery, heat generation, vibrations, residual tension and even chemical reactions in some cases [1].

The superficial texture of a machined component is the result of the combination of several factors, that can be divided into roughness, waviness and faults [2].

It is characterized as roughness the irregularities or micro geometric errors existing on a surface due to the cutting process, such as tool wear, tool advance marks and APC fragments [1]. The waviness are superficial irregularities or geometric errors for which the spacing is bigger than the irregularities considered as roughness, usually caused by vibrations, tool flexing (due to shear forces), temperature, tool or tool fixing errors. In addition, faults are defined as interruptions in the typical topography of a surface. They can be caused by defects inherent to the material, such as inclusions, cracks, voids, or may also arise during the cutting process [1].

The superficial roughness expressed in thousandths of a millimeter (μm), is the measure of the texture of a surface quantified by vertical deviations of a real surface from its Ideal geometric form, which is that prescribed in design, as shown in figure 1 [3].

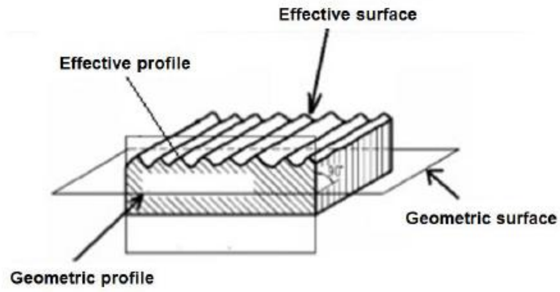

Fig. 1: Geometric surface and Effective surface

We can find in the literature several parameters of roughness, but by convention, 2D roughness is represented by "R" followed by additional characters that indicate the mathematical and statistical method used for its calculation. In Brazil, this parameter is based on the depth of the roughness measured according to the midline system (M) [4], according to figure 2 [3].

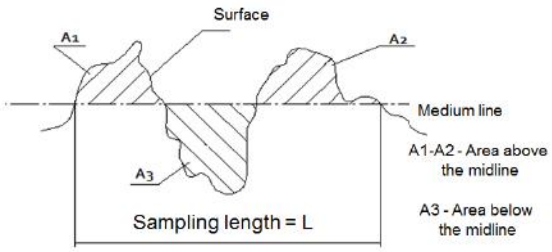

Fig. 2: Roughness Measurement System - Midline

The Ra parameter is the most widespread and the most used. This parameter is calculated from the arithmetic average of the profile deviations, taking as reference the midline and it is defined over a sampling length "l" as shown in FIGURE 3 [5].

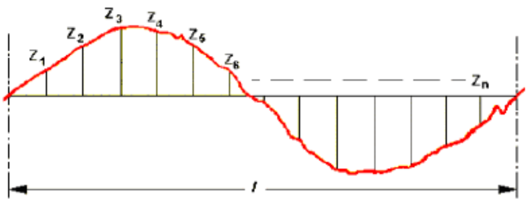

Fig. 3: Ra - Roughness Average

Ra is mathematically expressed by the following equation:

$$R_a = \frac{Z_1 + Z_2 + Z_3 + \cdots + Z_n}{n} \rightarrow Ra = \frac{1}{l}\int_0^l |Z(x)|\,dx$$

It is characterized as Tp, the percentage of the contact area generated by the truncation of the peaks to a certain depth [6], configures figure 4.

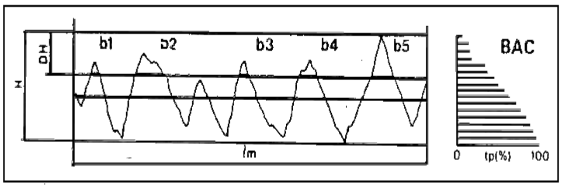

Fig. 4: Tp representation

Tp is mathematically expressed by the following equation:

$$Tp = \frac{b_1 b + b_3 + \cdots + b_n}{lm}\ x\ 100(\%)$$

The analysis of superficial texture can be demonstrated as follows: analysis without filtering (profile P), roughness analysis (profile R), waviness analysis (profile W) and shape analysis. Profile P contains roughness, shape and waviness. The profile R only contains roughness and the profile W only contains waviness. The form is a macrogeometric analysis and is analyzed separately [5].

This work has the objective of analyzing two gears, one of those has presented a problem in the final operation due to the failure of synchronization (difficult to engage gears) and on the other one this fault has not been verified. Through comparing the measured characteristics according to the standard drawing between the two gears, we studied the values found and proposed other possibilities using the analysis in the R and P profile in the surface texture, as well as a mathematical interpolation, in order to define the ideal parameter P for the application.

II. EXPERIMENTAL PROCEDURES

Two second speed driving gears for the C513 manual transmission were used. Both forged on 19 Cr Mn material, cemented and tempered. These two parts were grinded in the NOVA grinding machine, built in 1994 year, using a conventional aluminum oxide grinding wheel, with 0.30 mm over material to be grinded. In the end of the grinding machining process, expected to obtain a cone roundness of 4.0 µm, Ra of 0.45 to 0.75 µm and Tp of 1.8> 50%, according to Figure 5.

Ra	0,45 a 0,75 µm
Tp	1,8 > 50%
Roundness	4,0 µm

Fig. 5: 3rd speed conductive gear with finishing parameters

The roughness was measured in a Taylor Hobson rugosimeter, TalySurf Series model.

The experiments with the gears were performed with production vehicles, driven by a test driver, using the plant test track.

III. METHODOLOGY

The two tested gears, one of which presented a problem in the final operation due to the failure of synchronization (difficult to coupling gears) and another on which this failure was not verified were submitted to the measurements specified by design.

We compared the macro and micro geometric differences between two gears to define what characteristic was linked directly with the problem. This way of comparation between OK and Not ok parts to define the root cause problem, resemble to the stage of RedX methodology, called *Component Search*. This stage proposes the change between OK and Not ok components, individualizing the component that is linked to the problem for further in-depth analysis for the discovery of the real characteristic that turns the problem on and off.

IV. RESULTS

Measuring the standard gear drawing specifications regarding the Not OK gear rejected in the test track due to synchronization problems, we found the following results, according to the table below:

Characteristic	Specification	Real
Roundness	4µm	3,23 µm
TP 1,8	> 50%	99,98%
Ra	0,45 to 0,75 µm	0,62

We observed that the gear, despite presenting a synchronization problem in the test track, was in accordance with the drawing specifications.

We needed to define a superficial finishing parameter that would serve as a reference for the machining area to define good and bad parts. As the synchronization problem is related to the three previously mentioned parameters (Ra,

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Tp and Roundness), we proceeded to analyze the possible variables of these three parameters. Applying the measure of Tp in the profile P that we will call it from now on alpha parameter due to being intellectual property of the company, we obtained the following results:

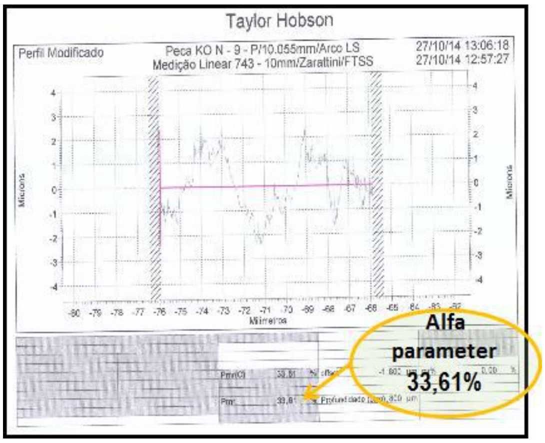

Fig. 6: Alpha parameter control result of the gear that presented synchronization problem - Alpha = 33,61%

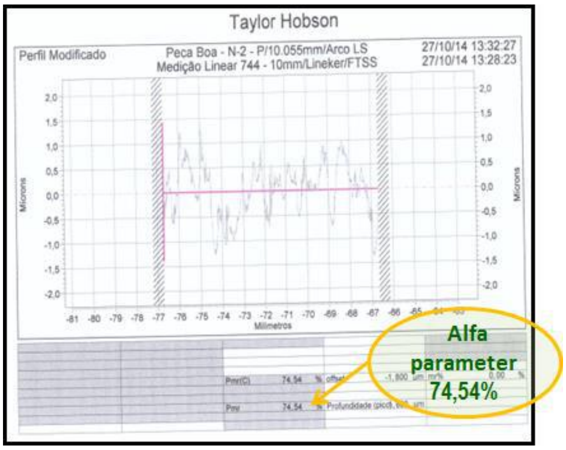

Fig. 7: Alpha parameter control result of the gear that do not presented synchronization problem - Alpha = 74,54%

As we can see, the Not ok part had all the characteristics provided for drawing accordingly. When applying the new control parameter (Alpha) for the Not ok part, presented value of 33.61%. For an OK part the value found was 74.54%. In this way we find a value that differentiated a good part from a bad one based on Profile P.

Considering that the practical result showed that for an alpha parameter of 33.61% we have a Not ok part and for 74.54% we have an ok part, we applied a mathematical modeling to define what would be the minimum alpha parameter for terms only good parts.

In figure 8 we have the mathematical calculation used for the adequacy of the curve with the alpha parameter data available.

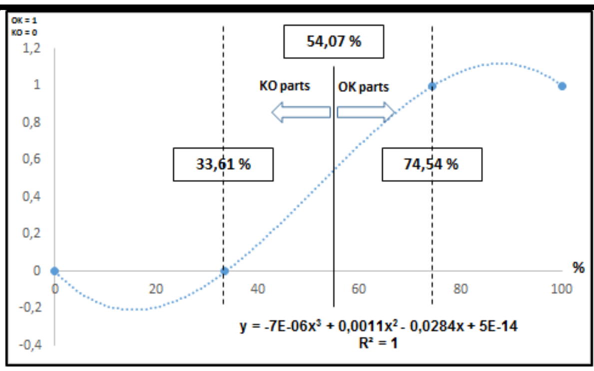

Fig. 8: Mathematical modeling to define the ideal Alpha parameter point

V. CONCLUSION

Using the TP measured in the R profile, in which only the microgeometric errors of the surface roughness are recorded, the macrogeometric errors are eliminated, therefore, the problem could not be perceived.

Using the measured TP in the profile P called in this article as alpha parameter, we were able to observe a smaller fraction of contact, because, in this profile, macrogeometric errors are taken into account during the measurement. With a smaller fraction of contact the synchronizer ring does not brake causing it to affect directly in the synchronization. The large number of harmonics found in circularity measurement are responsible for the low contact area between the gear cone and the synchronizer ring.

With a set parameter for control of the gears, in this case called the alpha with 54,07%, it will allow the production to be able to manufacture gears that do not present synchronization problems.

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