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A COMPARATIVE STUDY REGARDING THE MEASUREMENT OF MACHINED SURFACE ROUGHNESS

BY

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Abstract. The size of roughness surfaces offers the possibility to estimate the evolution of machined workpiece surfaces in exploitation. For this reason, in the literature there are numerous mathematical relationships, both theoretical and empirical for roughness assessment. These relationships were determined taking into account a relatively small number of factors that interfere on the roughness size, making that roughness size calculated theoretical to be different from the real size, which is given by measurement instruments. Therefore the measurement operation of the machined surfaces is a crucial step in determining the quality of the surface in order to ensure the functional proprieties in exploitation of the future part and also to determine accurately the influences exerted by various factors in scientific research.

Key words: surface characterization, roughness meter, optical instrument.

1. Introduction

The importance of machined surface roughness results from the influence that it exercised directly on a large number of characteristics of the feature part. Roughness has a major impact on quality, cost, and also on the

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functional proprieties like: appearance, the imposed tolerances, resistance to fatigue, wear and corrosion of the workpiece.

The surface parameter used to evaluate surface roughness in this experimental study is the roughness average (R_a) the most widely used parameter for surface texture. The roughness average is the area between the roughness profile and its central line, or the integral of the absolute value of the roughness profile height over the sampling length. Determination of R_a is normally computed by the software but can be derived using the following formula:

$$R_a \equiv \frac{1}{l}\int_0^l \left|f(x)\right| dx \qquad (1)$$

where: *f(x)* is the profile deviation from the mean line and *l* − the sampling length.

According to (Durakbasa *et al.*, 2011) the measurement of surface roughness it can be done by using instruments that analyze the value through direct contact with the studied surface (stylus method) or by using instruments that measure roughness without requiring direct contact with the surface track (optical instruments). In the first case a spherical stylus profilometer follows the contour of the surface in order to detect the deviations by the transducer. On the other hand, the optical method is based on the principle that a ray is reflected by reflection, when the surface is smooth or by diffusion when it has a higher roughness. According to the study included in (Pontes & Ferreira, 2010) the most studied factors are the machining parameters: feed rate (*f*) and cutting speed (*v*) and also the rake angle (*k*) or the tool radius (*r*). Regardless of the instrument used in measuring operation, these instruments introduces different kinds of errors, errors due to their operating principle and which are found in the indicated value of the surface roughness. The accuracy of the surface roughness measurement performed depends, under (Myshkin *et al.*, 2003), on the accuracy of the instrument that performs the measurement. This paper aims to outline the advantages and disadvantages resulting from roughness measurements using two different instruments (stylus and electron microscopy), which use different principles regarding the assessment of surface roughness.

2. Comparative Research on Surface Roughness Measurement

In this study a experimental plan was conducted (Table 2) which contains the most influentials factors on roughness in turning on a OL52 workpiece with the characteristics shown in Table 1. The workpiece lenght and diametre is 300 mm and respective 24 mm and it was machined on a SN 320 lathe. Surface roughness is described as the inherent irregularities of workpiece left by various machining processes. The roughness measurements were carried out with Taylor Hobson Surtronic 25 profilograph and on a Scanning Electron Microscope (SEM) and the measuring operating principles are illustrated in Figs. 1 and 2. The roughness data taken from the stylus profilometer were processed in TalySurf Intra software. In the measurements of contact stylus instrument, 60 mm stylus arm length, 5 µm radius conisphere diamond stylus tip size and 1 mN force (speed = 1 mm/s) were selected (Manske *et al*., 2007; Quinsat & Tournier, 2012). For the samples, a standard high-pass Gaussian filter (Mathia *et al*., 2011) with a long-wavelength cutoff of 0.8 mm was used and sampling length as 12.5 mm according to the ISO standards were chosen. Because the value of the machined roughness varies along the workpiece circumference and it is dificult to set the surface in the same position for analise with both instruments I've decided to use the average value (three measurement arranged at 120° one from another) for each stylus measurement which were compared with SEM measurements. To performe the SEM measurement I had to cut the workpiece in slices of 10 mm so it could fit in the SEM's fastening device and the roughness investigation it has been performed with a 100x objectives.

Table 1
Chemical Composition and Mechanical Properties of OL52

Chemical composition				Hardness, HB
0.193%C	0.011%S	1.070%Mn	0.012%P	200.36

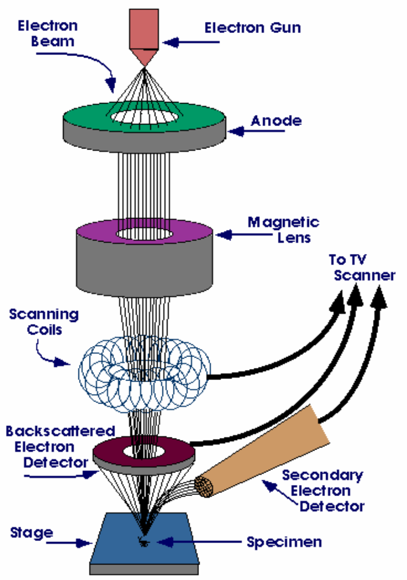


Fig. 1 – Schematic illustration of SEM measurement.

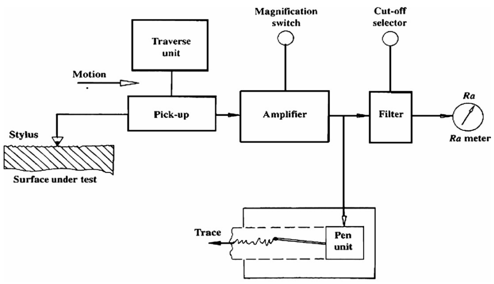


Fig. 2 – Schematic illustration of stylus measurement (Demircioglu & Durakbasa, 2011).

As it could be seen from the Fig. 3 the original profile and the traced profile are different because of the stylus size. In Fig. 4 it can be seen that the measurement of roughness is actually between 0.7÷0.9 of the real size of the studied roughness parameter depending on the stylus size and the also on the texture of the workpiece surface.

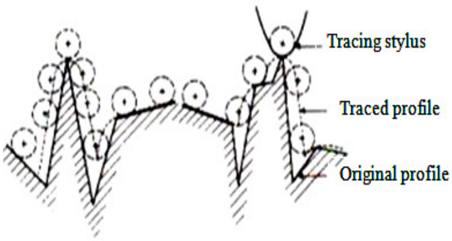


Fig. 3 – Error due to the effect of stylus size (Pontes & Ferreira, 2010).

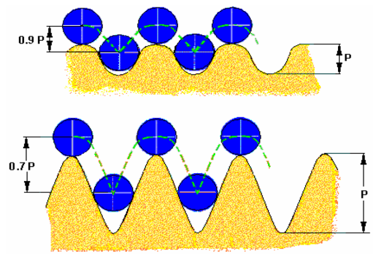


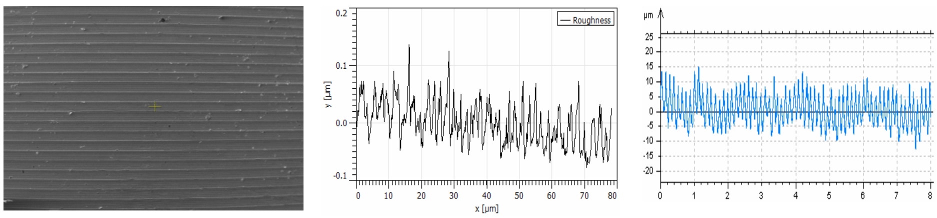
Fig. 4 – Error introduced by stylus size.

The experimental plan was conducted in order to highlight the influences of various parameters that resulted after the analysis of (Pérez, 2002; Vorburger *et al.*, 2007) and concluded that surface roughness is influenced by those. Based on the research undertaken by them we wanted to examine whether these parameters influences also the errors introduced by the measurement instruments used.

Table 2
Experimental Plan on Turning OL52

<table>
<tr><th rowspan="2">Nr.</th><th rowspan="2">s
[mm/rot]</th><th rowspan="2">v
[m/min]</th><th rowspan="2">k
[°]</th><th rowspan="2">r
[mm]</th><th>ERT</th><th>SEM</th><th rowspan="2">SEM
-ERT</th></tr>
<tr><th>R_a</th><th>R_a</th></tr>
<tr><td>1</td><td>0.08</td><td rowspan="3">75</td><td rowspan="6">45</td><td rowspan="9">–</td><td>2.50</td><td>3.64</td><td>1.14</td></tr>
<tr><td>2</td><td>0.12</td><td>3.24</td><td>4.95</td><td>1.71</td></tr>
<tr><td>3</td><td>0.16</td><td>3.43</td><td>4.85</td><td>1.42</td></tr>
<tr><td>4</td><td rowspan="9">0.12</td><td>60</td><td>2.12</td><td>3.13</td><td>1.01</td></tr>
<tr><td>5</td><td>75</td><td>2.26</td><td>3.65</td><td>1.39</td></tr>
<tr><td>6</td><td>120</td><td>2.83</td><td>3.76</td><td>0.93</td></tr>
<tr><td>7</td><td rowspan="6">75</td><td>35</td><td>1.47</td><td>2.46</td><td>0.99</td></tr>
<tr><td>8</td><td>45</td><td>1.48</td><td>2.94</td><td>1.46</td></tr>
<tr><td>9</td><td>60</td><td>2.19</td><td>3.61</td><td>1.42</td></tr>
<tr><td>10</td><td rowspan="3">45</td><td>0.4</td><td>1.08</td><td>2.36</td><td>1.28</td></tr>
<tr><td>11</td><td>0.7</td><td>1.37</td><td>2.91</td><td>1.54</td></tr>
<tr><td>12</td><td>0.9</td><td>2.01</td><td>3.51</td><td>1.50</td></tr>
</table>

For a better understanding of the differences between the surface profile given by both measuring systems, diagrams of roughness profile obtained from the scanning electron microscopy (*a, b*) and from the stylus type system are given in Fig. 5 were the analyzed factor was tool radius. As we can see from the above table and from Fig. 5 there were noticeable differences between the values of the studied surface roughness parameter and as expected the values of stylus profilometer were smaller than the values of the SEM measurements. These differences were caused by the stylus limitation to detect the extreme values given by scratches, cracks due to the geometrical form comparing to the light beam.



a *b* *c*

Fig. 5 − Diferrent texture of test nr. 12: *a* −SEM images, *b* − SEM roughmess mesurement, *c* − contact mesurement.

4. Conclusions

1. The major holdback of stylus measurement system is the need for direct contact with the analysed surface and because of the contact pressure it may damage the assessed surface in case of low hardness materials. The profilometer's transducer and convector are sensitive requiring a free vibration environment.

2. The resulted dates regarding roughness size collected from both measuring systems were compared and there were noticed higher values in optic measurements. These differences are between 0.93 µm and 1.71 µm in optical measurement because the possibility of light beam to penetrate easier the profiles gaps than the stylus which limits the bandwidth of the measurement.

3. The optical measurement can easily detect the smallest roughness variation due to the strenght of light penetration of profiles microirregularities but some time due to the metallic luster this method can insert greater errors than the direct palpation method.

4. Thus roughness measurement method should be chosen according to required machined surface precision to match the functional requirements.

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STUDIU COMPARATIV PRIVIND RUGOZITATEA SUPRAFEŢELOR PRELUCRATE PRIN AŞCHIERE

(Rezumat)

Mărimea rugozităţii suprafeţelor oferă posibilitatea de a estima evoluţia suprafeţelor prelucrate în exploatare. Din acest motiv, în literatura de specialitate, există numeroase relaţii matematice, atât teoretice cât şi empirice, de evaluare a rugozităţii. Aceste relaţii au fost determinate având în considerare un număr relativ mic de factori ce intervin asupra mărimii rugozităţii, ceea ce face ca mărimea rugozităţii calculate teoretic să fie diferită de cea reală. De aceea operaţia de măsurare a rugozităţii suprafeţelor aşchiate este o etapă crucială, atât în determinarea calităţii suprafeţelor prelucrate (în sensul asigurării proprietăţilor funcţionale în exploatare a viitoarei piese), cât şi în determinarea cât mai exactă a influenţelor exercitate de diferiţi factori, în cadrul cercetărilor ştiinţifice.