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CONTACT AND CONTACTLESS INVESTIGATIONS OF MANUFACTURED HIGH-PRECISE SURFACE STRUCTURES

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Abstract − Surface roughness is the measure of the fine irregularities of a surface. Correct function of the manufactured component is critically dependent on its degree of roughness. There are different techniques applicable for surface metrology analysis. This paper presents the analyses of manufactured high-precise surface structures using the results of contact and contactless measurement techniques. The surface structure is primarily a function of the used production processes.

During this experimental work, all measured surface roughness parameters have been analyzed by using SPSS 15 statistically. “Linear Regression” of Ra parameter estimated the coefficients of the linear equation, involving a few independent variables (feed in mm, periodicity, type of material, contrasting, type of production process etc.), that best predicted the value of the dependent variable and the mathematical model giving the values of roughness parameter has been established in terms of feed in mm, the periodicity, contrasting and type of material as a result of the statistical analyses in this experimental study.

Keywords: surface metrology, surface analysis, contact and contactless measurement

1. INTRODUCTION

Most engineers and people such as metalurgists have had interest in surface behaviour and they are acquainted with the view of a manufactured surface, either by eye or through a microscope. These images give comprehensible idea of spacings on the surface as well as the pattern of the lay but not much idea of the “roughness”, which is usually perceived as the heights of the machining marks [1]. But this approach is not true and these methods are insufficient in order to put a numerical value to the surface texture. Inspection and assessment of surface roughness of machined workpieces can be carried out with contact and contactless methods.

2. SURFACE MEASUREMENT TECHNOLOGY

At many practical applications measurement of surface roughness is carried out with the tactile profilometers. A stylus will be driven along a line segment and record the vertical deflection of the stylus as it moves over the surface, thus recording the height of the surface at the sampling points. One disadvantage of such a tactile measurement is that the stylus has to stay in permanent contact with the surface and is therefore easily damaged or soiled. Furthermore, the single profile line covers only a small part of the surface, possibly missing important areas. New developments by the instrumentations have been made in recent years, to establish sophisticated measuring instruments which can acquire a 3D surface structure of the precisely machined surfaces to fulfill the requirements for the application in industrial environment. In this paper, both surface measuring systems will be examined with a lot of practical applications [2].

2.1 Contact (Stylus) Measurement System

The first contact instrument was developed for the assessment of surface texture by G. Schmaltz in 1929. After Schmaltz, Dr. E. Abbot in 1936 and Taylor Hobson in 1939 advanced the surface measurement technology respectively. In recent years the development is towards measuring smaller surface roughness values by using contact measurement instruments [3].

In this experimental study, measurements were performed with a stylus measuring instrument, Form Talysurf Intra 50 which is skidless and can be used for waviness, profile and other parameters such as material ratio with absolute confidence in the measurement results [2].

2.2 Contactless Measurement Systems

Two contactless surface measuring instruments which have been used for the experiments are the optical surface measurement device which is based on the “Focus Variation” technology and the confocal laser scanning microscope [2, 8].

3. MEASUREMENT CONDITIONS

In this study, it was used 60 mm stylus arm length, 2 µm radius conisphere diamond stylus tip size, 1 mN force (speed = 1 mm/s) and Gaussian filter in all measurements [4,5,6]. Also, the evaluation length was determined according to the ISO standards [8]. As a result of this selection, it was decided to choose the evaluation length as 4 mm and thus 0.8 mm cut-off value was taken in return for 4 mm evaluation length. The analyses were then performed for all specimens for several roughness parameters which are Ra and Rz parameters that gave us much of the idea [7]. The measurements were carried out with commercially available instruments. Their results taken from both, contact and non-contact measuring instruments for the surface evaluation under laboratory conditions in this paper.

4. APPLICATIONS WITH CONTACT AND NON-CONTACT METHODS

Fifteen pieces of workpiece with flat surfaces with periodic and random profiles, with different roughness value classes, with shiny and browned surfaces were used in this study. 6 consecutive measurements were made for each measurement condition in the same direction with a 4 mm evaluation length. The same alignment system was applied for all specimens. Their results taken from both, contact and contactless measuring instruments are given in this paper.

4.1 Samples with Periodic Surface Profiles

Three face turning aluminum shiny workpieces, three face turning steel shiny samples and three face turning steel browned samples with periodic profiles were measured with both surface measuring systems. Comparability for periodic surfaces will be verified as a result of the experiments with 9 workpieces. By using the same alignment system, 6 successive measurements were made on 9 samples processed with face turning by means of both instruments. Face turning aluminum shiny sample 1 has periodic surface profiles as shown in Figure 1. The diagrams of roughness profile and roughness values belonging to face turning aluminum shiny sample 1 taken from the contact system were obtained as shown in Figure 2.

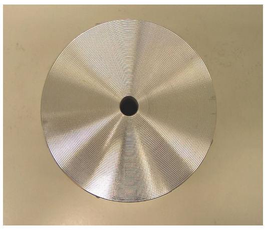
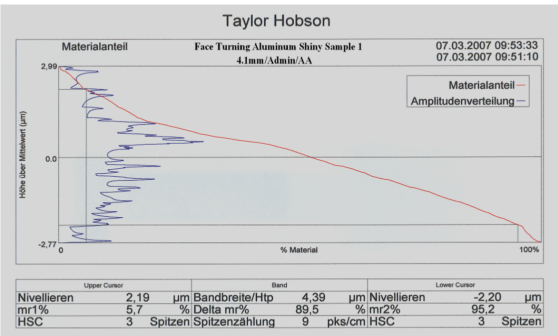


Fig.1 Face Turning Aluminum Shiny Sample 1



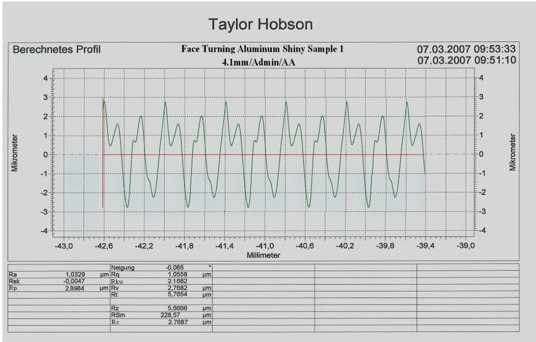


Fig.2 Diagrams of roughness profile and roughness values belonging to face turning aluminum shiny sample 1 respectively obtained them from the contact measuring system whose brand name is Form Talysurf Intra 50 by Taylor Hobson GmbH [8]

Then, the analyses were done by using contactless systems for the same sample and the same alignment system. Its 3D color model captured from contactless systems is given in the following figure. Its diagrams taken from contactless systems are given in Figure 4.

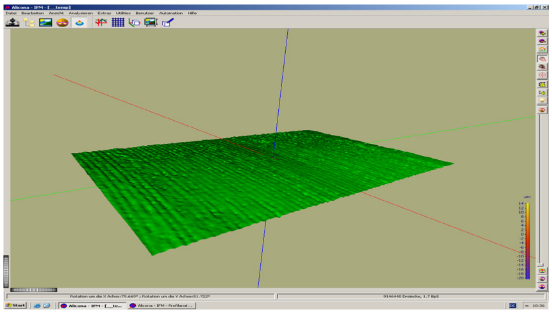


Fig.3 A 3D image of face turning aluminum shiny sample 1 taken from the contactless measuring systems [8]

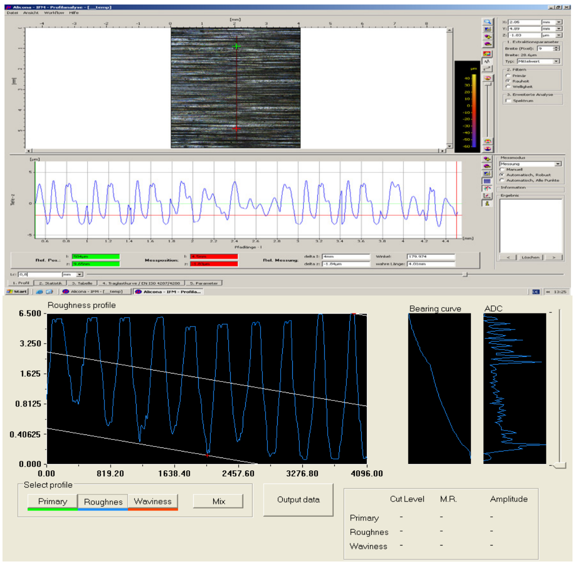


Fig.4 Roughness profiles of face turning aluminium shiny sample 1 taken from the contactless measuring systems [8]

Comparisons of roughness values taken from both systems in terms of parameters Ra, Rz and RSm are given in Figure 5 and 6 where o1 is the abbreviation of optical instrument 1, c is the abbreviation of contact instrument and o2 is the abbreviation of optical surface measurement instrument 2.

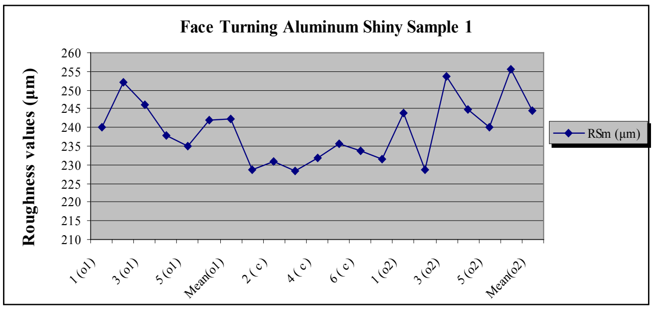


Fig.5 Comparisons of the roughness values taken from the contact and contactless measuring systems in terms of the parameter RSm [8]

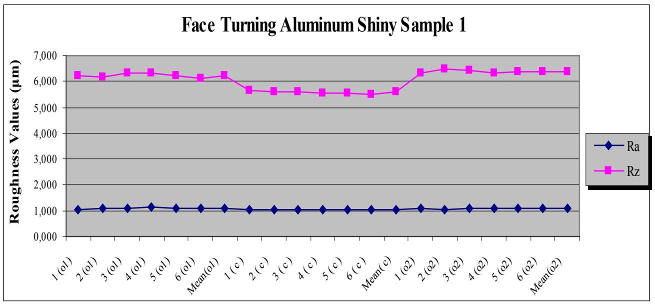


Fig 6 Comparisons of the roughness values taken from the contact and contactless measuring systems in terms of the parameters Ra and Rz [8]

4.2 Samples with Random Surface Profiles

Two surface grinding steel browned samples, two peripheral milling steel browned samples and two front milling steel browned samples with random profiles were used in order to strengthen this study. In this group of profiles there will be couples with roughness class difference of one. Comparability for random surfaces will be verified as a result of the experiments with 6 workpieces. The diagrams of roughness profile and values belonging to surface grinding steel browned sample 1 (Figure 7) taken from both systems were obtained as shown in Figure 8 and 9. Comparisons of roughness values taken from both surface measurement systems in terms of parameters Ra and Rz are given in Figure 10.

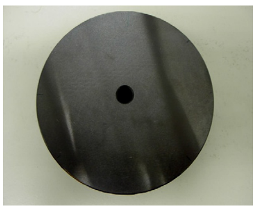


Fig 7 Surface Grinding Steel Browned Sample 1

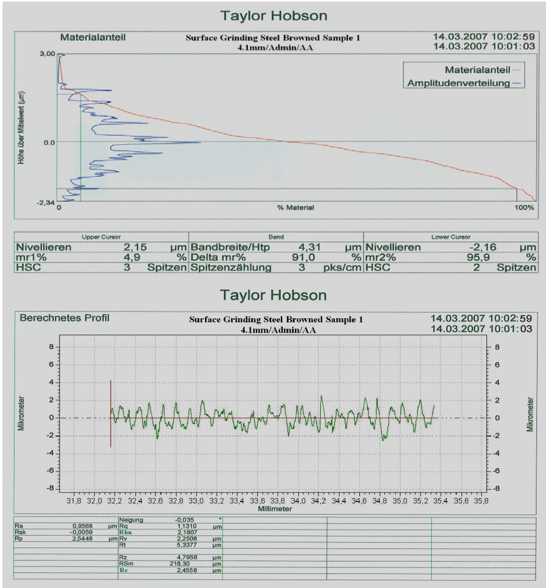


Fig 8 Diagrams of roughness profile and roughness values belonging to surface grinding steel browned sample 1 respectively obtained them from the contact measuring system whose brand name is Form Talysurf Intra 50 by Taylor Hobson GmbH [8]

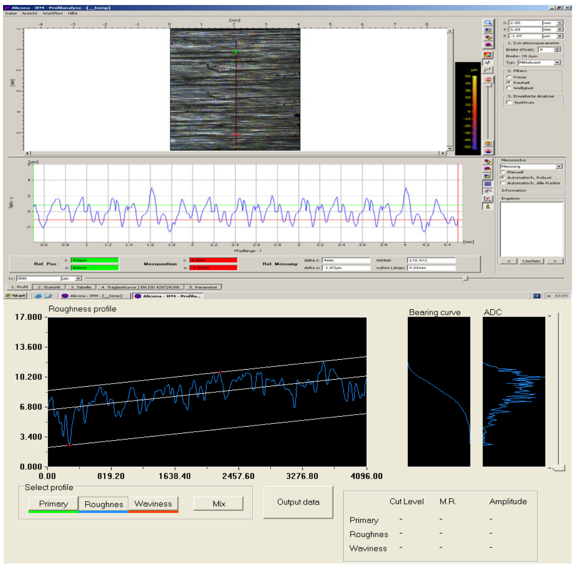


Fig 9 Roughness profiles of surface grinding steel browned sample 1 taken from the contactless measuring systems [8]

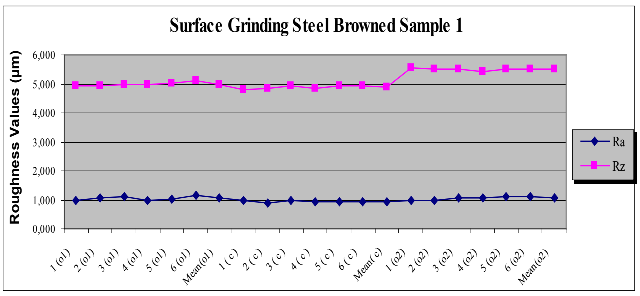


Fig 10 Comparisons of the roughness values taken from the contact and contactless measuring systems in terms of the parameters Ra and Rz [8]

5. EVALUATION OF MEASUREMENT RESULTS

During this experimental work, all measured roughness parameters have been analysed by using SPSS 15 (Statistical Package for Social Science) statistically. Data for each test were statistically analyzed. A one-way analysis of variance (Oneway ANOVA) has been used (α =0.05) to test the significant difference between measurement systems. When the Oneway ANOVA has been applied so as to test the equality of three instruments at one time by using variances, a comparison of them was done employing a Post-Hoc test to identify which groups were significantly different from others assuming a 95 percent of confidence level.

Finally, "Linear Regression" of Ra estimated the coefficients of the linear equation, involving a few independent variables that best predicted the value of the dependent variable. Ra depends on periodicity, the type of material, contrast, the type of production processes, feed and the type of machine as its independent variables but feed, periodicity and contrast predicted the value of the Ra parameter in a best way. The linear equation of Ra is given below.

$$Ra = -1.314 + 9.097 * F + 1.279 * P - 0.188 * C \quad (5.1)$$

whereas F feed, P periodicity and C contrasting [8].

The results for 15 samples were very consistent with each other. This showed the inner accuracy of the both systems. Furthermore, it could be seen that measured values were comparable and the differences between the methods were small. Ra values have been turning out to be extremely well-matched as a result of the measurements because Ra value refers to a mean value. However Rz value refers to the height of a profile, between the minimum and maximum points of the profile. Rz is calculated by measuring the vertical distance from the highest peak to the lowest valley within the sampling lengths, then averaging these distances. Rz averages only the few highest peaks and the deepest valleys, therefore extremes have a greater influence on the initial value. This was the reason why it came out slightly higher than the contact measurement system.

Invariably, the optical system gives a larger value than the stylus system. This is because the stylus system tends to integrate; whereas the optical system differentiates. One disadvantage of a tactile system is that the stylus has to stay in permanent contact with the surface and is therefore easily damaged or soiled. In addition, the single profile line covers only a small part of the surface, possibly missing important areas. The optical system has an advantage over the contact system, that visualization of the profile line with positioning dots enables locations to be selected to measure exact dimensions on the 2D model and "z" height on the 3D model.

6. CONCLUSIONS

In this experimental study, the contact and contactless measurement systems were compared according to their capabilities. It was classified the samples into two groups as periodic and random surface profiles. The reason of having two different groups of profiles was that the profile was an important concern when compared the devices. In addition, samples were allocated as shiny and browned samples. The aim of this application was to understand how the optical systems affected the surfaces having different contrast.

It was observed that three devices were giving comparable results if the surface had a good reflection value, not been very fine machined with a periodic and/or random profile and not a ruined or scratched profile. According to the presumptions, the problem with the fine machined samples having periodic and/or random surface profiles was that contact system could not detect the extreme values of the surface and gave a result due to general fine profile. But optical systems could detect very extreme values of the profile so that the results were getting scattered. In this point, it was experienced the inadequacy of stylus compared to a light beam because of its geometrical form. Of course no man built stylus can reach the thickness of a light beam in the technology of today.

Finally, it should be pointed out that neither of the methods is correct or wrong. This study showed that both systems were compatible with each other [8].

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