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ANOTHER APPROACH OF SURFACE TEXTURE IN TURNING USING MOTIF AND ''Rk'' PARAMETERS

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Abstract

The surface motif combination, ISO 12085:1996, is a method of analyzing surface texture alternatively to the central line system 'M'. It gives a graphical evaluation of surface profile using mainly six parameters without filtering waviness from roughness. Another functional roughness characterization is introduced by the DIN 4776 and ISO 13565-2 standards through the ''Rk'' parameters, which describe the shape of the relevant Abbott curves. This study presents the application of both the aforementioned methods in the analysis of turned textures carrying out turning tests for cutting conditions varied over a representative range. The workpiece material was a 304 stainless steel turned by a P30 cemented carbide tool. Close correlation was detected between many of the parameters considered and primarily feed and cutting speed, a fact that led to the development of regression models. Comparisons made to the variation of popular ''M'' system parameters indicate that motif parameters provide an alternative way for controlling the turning process and determining optimal cutting conditions
.

Key words: *engineering surface, roughness, motif analysis, bearing area (Abbott) curve, ISO 13565 ''Rk'' parameters, turning*

1. INTRODUCTION

Surface roughness measurement is a must for high precision machining performed in industry. The characterization and evaluation of surface topography has constituted a major metrological problem over the years. The establishment of the ''M'' (central line) system has facilitated the communication between laboratory and industrial practice but too many parameters have been proposed; more than one hundred in view of literature! [1]. The ISO-4287:1997 standard comprises thirteen parameters for surface roughness and thirteen relevant surface waviness parameters. This fact is attributed to the usually complicated form of surface textures and the need for obtaining a satisfying description at various levels. As it is expectable, numerous research papers have been focused on better manipulation of these parameters in various manufacturing processes and the impact of process factors on surface characteristics (indicative refs [3,4]).

The surface motif combination is a method of analyzing surface texture alternatively to the 'M' system [5-7] and was introduced in the French automotive industry. Now it is issued as an international standard, ISO 12085:1996 [8]. It provides a graphical evaluation of surface profile using only six parameters without filtering waviness from roughness. This method
filtering waviness from roughness. This method
determines the upper points of the profile, which have functional importance by an envelope based algorithm.

As aforementioned, the motif combination gives emphasis in the significant profile peaks and turned surfaces are as such, possessing regular repetitive peaks. Since their functional performance is evidently controlled by these peaks we are in need of a proper description.

Another function oriented system of surface analysis was developed in Germany (DIN 4776) and now adopted in ISO 13565-2: 1996 [9] to characterize stratified textures like the honed surfaces in internal combustion engine cylinders. It is met many times as the ''Rk'' parameter group (Rk is the first out of five parameters used).

The concept is to describe the shape of the relevant bearing (material ratio or Abbott) curves and to provide information on characteristics at different portions of the surface profiles. An important subject is to investigate into the association of Abbott curve characteristics with cutting factors in machining processes, with turning attracting special attention [10-13].

This study presents the application of both the aforementioned methods in the analysis of turned surfaces and describes the impact of cutting conditions, varied over a representative range, on the relevant parameter values. The workpiece material was a stainless steel turned by a cemented carbide tool.

4. METHODOLOGIES-DEFINITION OF PARAMETERS

The definition of the parameters introduced in the discussed above systems of surface analysis and according to the corresponding ISO standards, is as follows:

a) **MOTIF-method (ISO 12085:1996)**

R: the average of the height values of the adjacent motifs

Rx: the maximum height value

Ar: the mean spacing of the motifs

W: the mean height value of the waviness motifs

Wx: the maximum height value of the waviness motifs

AW: the mean spacing of the waviness motifs

These parameters are calculated with varying sampling length, resolution and measuring sites over the surface.

The recommendations for the roughness motif length is up to 500μm and for the waviness motif less than 2500μm to be separated from error of form. A typical evaluation length is 8mm [7].

An application of this method to a real profile is presented in Fig. 1.

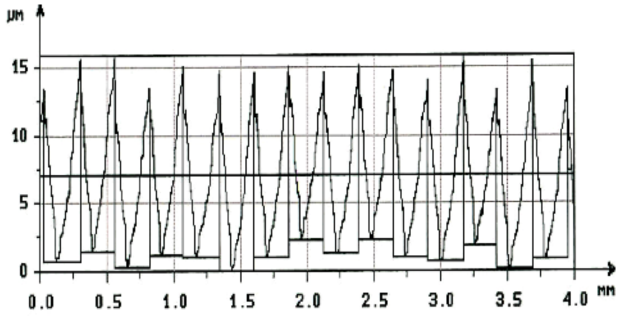

Figure 1: *Surface roughness motifs (R = 12.8 μm, Rx = 15.5 μm, Ar = 245 μm)*

b) **Group of ''Rk'' parameters (ISO 13565-2: 1996)**

A linear approximation of the bearing curve is provided: the depth of profile below 40% bearing area is taken to indicate the steady state wear status of the given surface. A group of five parameters characterizes the following three components of the surface (Fig.2): a) core by R_k, which stands for the depth of the roughness core profile b) peaks by R_{pk} representing the top portion of the surface to be quickly worn away and MR1 that is the upper limit of the core roughness and c) valleys by R_{vk} describing the lowest part of the surface which has the function of retaining the lubricant and MR2, the lowest limit of the core roughness.

The functional behaviour in this way may be predicted and the control of the manufacturing process can be assisted.

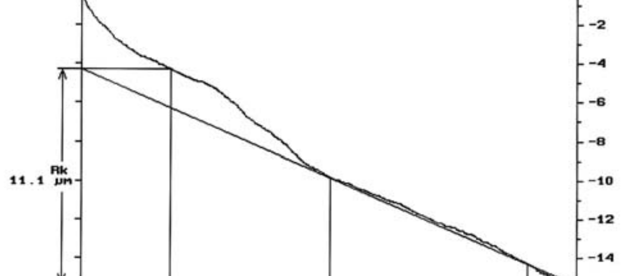

Figure 2: *The family of ''R_k'' parameters (Rk = 10.8 μm, Rpk = 2.68 μm, Rvk = 0.296μm, MR1 = 18.1 %, MR2 = 98 %)*

3. EXPERIMENTAL PROCEDURE

A brief description of the machining set-up and the measurements is given in the following:

Machining process: external longitudinal turning

Workpiece material: 304 stainless steel

Cutting tool: A P30 (DIN 4990) cemented carbide tool with a nose radius of 0.8 mm. The tool was controlled for wear formation during the experiments and practically maintained its sharpness.

Cutting conditions: were selected in order to correspond to a practically applicable range. The feed was set from 0.034 up to 0.60 mm/rev and the cutting speed was varied from 5 to 180 m/min.

Cutting fluid: Turning was performed dry and using emulsion 5%.

Surface texture measurements: The surface texture measurements were carried out on a stylus type profilometer Talysurf 3+ with wavelength cut-off 0.8 mm to 1.2 mm recommended for turned surfaces. In every specimen 5 measurements were undertaken axially, where maximum roughness occurs and the final results appear as averages of 5 measurements. The multi-parameter analysis for motifs and Abbott curves was conducted using the software Talyprof.

4. RESULTS AND DISCUSSION

Feed and cutting speed are considered here as the main cutting factors, which exert the major effect on roughness [3,11].

4.1 Motif parameters variation

The variation of the motif parameters R, Rx, Ar and Wx with respect to feed and for v=180 m/sec is presented in Figs 3-6. An increasing trend is detected in all cases and as the correlation appears high, corresponding single regression models are developed (Table 1). The values of the parameters are lower when using cutting fluid, as its influence on surface roughness is favourable at these cutting speeds. Regarding waviness motifs, the maximum value Rx increases due to intensified vibration and eccentricity in the tool-workpiece system.

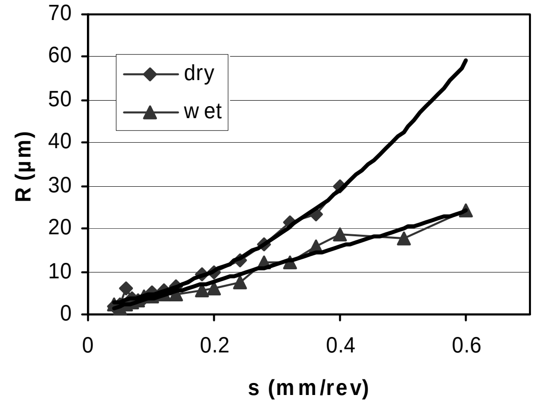

Figure 3: *Variation of R against feed*

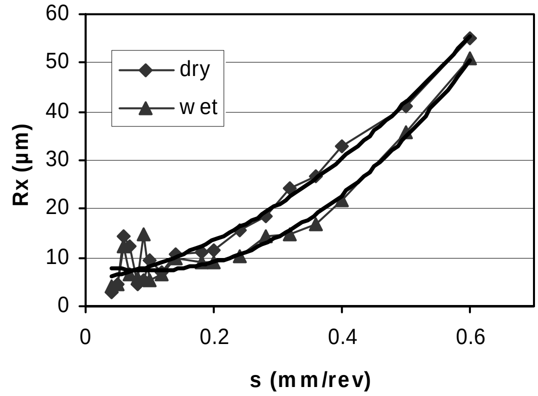

Figure 4: *Variation of Rx against feed*

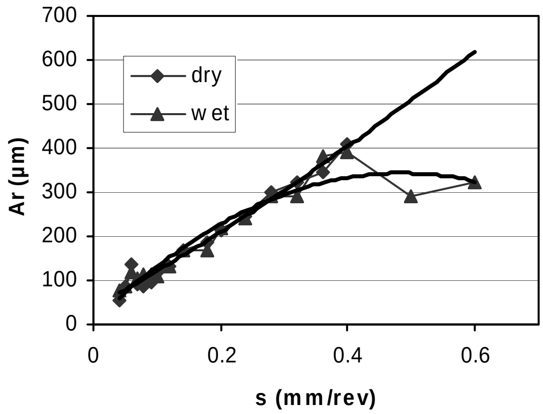

Figure 5: *Variation of Ar against feed*

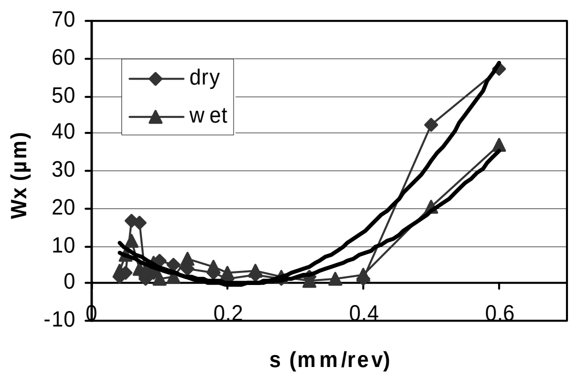

Figure 6: *Variation of Wx against feed*

Table 1: Models for motif parameters with respect to feed

Parameter (turning mode)	Regression models	R^2
R (dry)	$y = 135.51x^2 + 14.003x + 1.9605$	$R^2 = 0.987$
R (wet)	$y = 3.3734x^2 + 38.609x - 0.1397$	$R^2 = 0.96$
Rx (dry)	$y = 105.76x^2 + 20.689x + 5.1613$	$R^2 = 0.95$
Rx (wet)	$y = 172.33x^2 - 34.551x + 9.0952$	$R^2 = 0.949$
AR (dry)	$y = 276.72x^2 + 803.57x + 37.99$	$R^2 = 0.977$
AR (wet	$y = -1427.6x^2 + 1384.3x + 8.0542$	$R^2 = 0.920$
Wx (dry)	$y = 385.42x^2 - 160.82x + 16.526$	$R^2 = 0.850$
Wx (wet)	$y = 246.78x^2 - 110.05x + 12.384$	$R^2 = 0.878$

Note: *y, stands for the relevant parameter; x, for feed; R^2, coefficient of determination*

The behaviour of the parameters appears more complicated in association with the cutting speed, as shown in Figs 7 to 10. The effect of a built-up edge is present in the low values of cutting speed, especially for dry cutting. Statistical models have been also formulated and tabulated in Table 2.

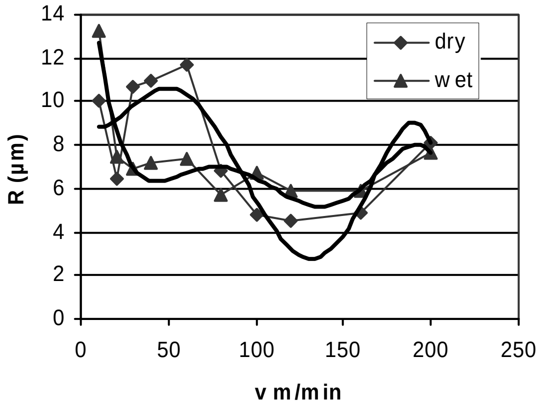

Figure 7: *Variation of R versus cutting speed*

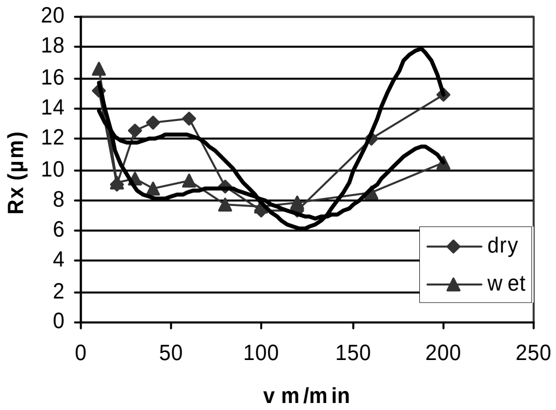

Figure 8: *Variation of Rx versus cutting speed*

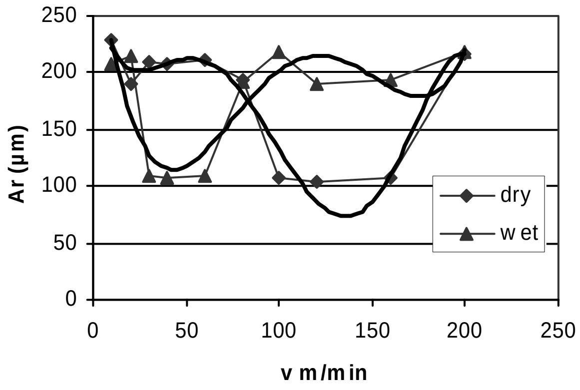

Figure 9: *Variation of Ar versus cutting speed*

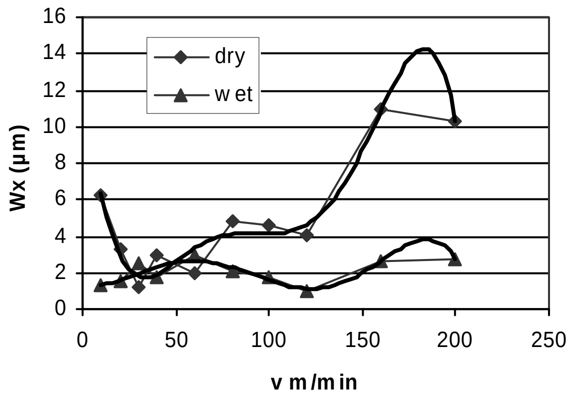

Figure 10: *Variation of Wx versus cutting speed*

Table 2: Models for motif parameters with respect to cutting speed

Parameter (turning mode)	Regression models	R^2
R (dry)	$y = -2E\text{-}09x^5 + 1E\text{-}06x^4 - 0.0002x^3 + 0.0092x^2 - 0.1398x + 9.4379$	$R^2 = 0.763$
R (wet)	$y = -2E\text{-}09x^5 + 1E\text{-}06x^4 - 0.0002x^3 + 0.0214x^2 - 0.886x + 19.61$	$R^2 = 0.881$
Rx (dry)	$y = -3E\text{-}09x^5 + 2E\text{-}06x^4 - 0.0003x^3 + 0.0202x^2 - 0.6039x + 18.124$	$R^2 = 0.919$
Rx (wet)	$y = -3E\text{-}09x^5 + 2E\text{-}06x^4 - 0.0003x^3 + 0.0202x^2 - 0.6039x + 18.124$	$R^2 = 0.919$
AR (dry)	$y = -4E\text{-}08x^5 + 2E\text{-}05x^4 - 0.0038x^3 + 0.2694x^2 - 7.6x + 275.3$	$R^2 = 0.943$
AR (wet)	$y = -1E\text{-}09x^5 + 4E\text{-}06x^4 - 0.0016x^3 + 0.238x^2 - 12.609x + 333.41$	$R^2 = 0.740$
Wx (dry)	$y = -4E\text{-}09x^5 + 2E\text{-}06x^4 - 0.0004x^3 + 0.0287x^2 - 0.9901x + 13.781$	$R^2 = 0.934$
Wx (wet)	$y = -1E\text{-}09x^5 + 5E\text{-}07x^4 - 7E\text{-}05x^3 + 0.0042x^2 - 0.06x + 1.5984$	$R^2 = 0.794$

Note: *y, stands for the relevant parameter; x, for cutting speed; R^2, coefficient of determination*

4.2 Comparison of motif parameters behaviour to ISO 4287 (''M'' system) parameters

A direct comparison of the amplitude parameters R and Rx to the classical parameters Ra and Rt is presented in Figs 11 and 12. Their agreement is evident. The same is valid for the comparison of the spacing parameter AR to the ''M'' system Rsm parameter (Fig 13). Only the data from dry cutting were presented because for both turning modes performed, dry and wet, the results are similar,

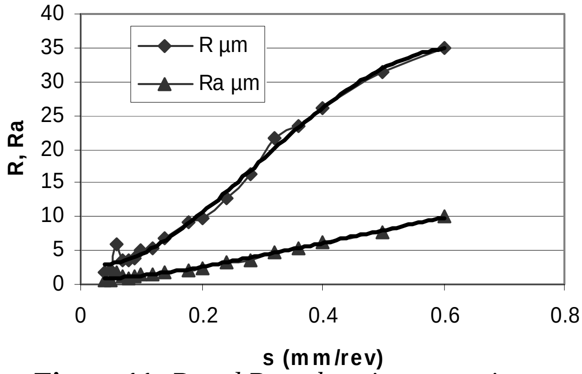

Figure 11: *R and Ra values in comparison*

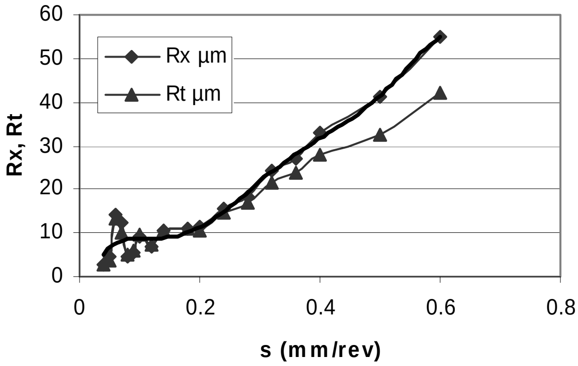

Figure 12: *Rx and Rt values in comparison*

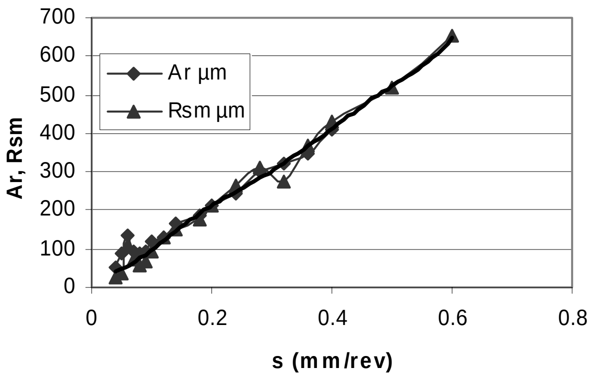

Figure 13: *Ar and Rsm values in comparison*

4.3 ISO 13565 parameters variation

Concerning the variation of ''Rk's'', the R_k and R_{pk} parameters are obviously related to feed and the MR1 and MR2 appear less correlated (Figs 14 to 17). On the other hand, the R_{vk} seems uncorrelated. Rk and Rpk clearly increase with increase in feed, indicating that the core and the upper portions of the surface are strengthened.
The influence of cutting speed is more clarified on Rk and the latter tends to decrease and stabilize, especially when using the cutting fluid. The relevant change in the parameters values and the statistical models developed are given in Fig 18 and Tables 3 and 4, accordingly.
Certainly, ''Rk's'' provide information about the profiles different than single amplitude or spacing parameters and their significance in both functional and morphological features of turned surfaces needs further research [13].

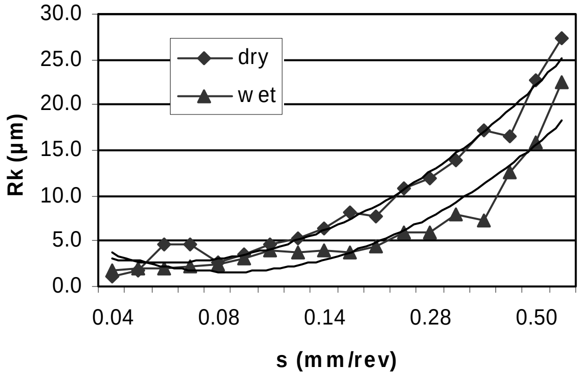

Figure 14 : *Variation of Rk against feed*

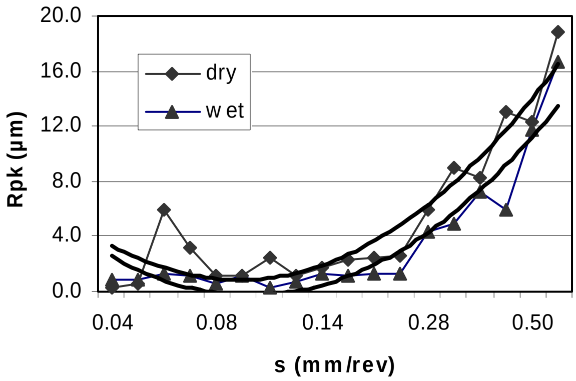

Figure 15: *Variation of Rpk against feed*

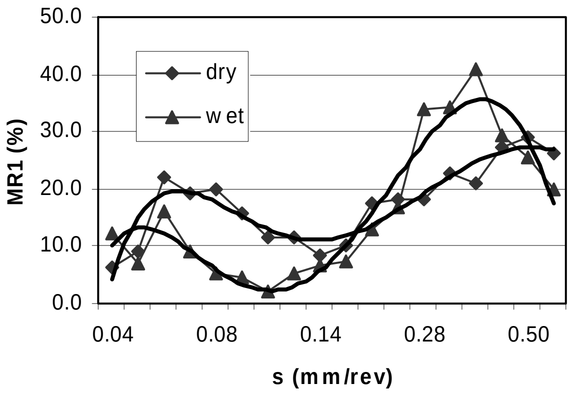

Figure 16 : *Variation of MR1 against feed*

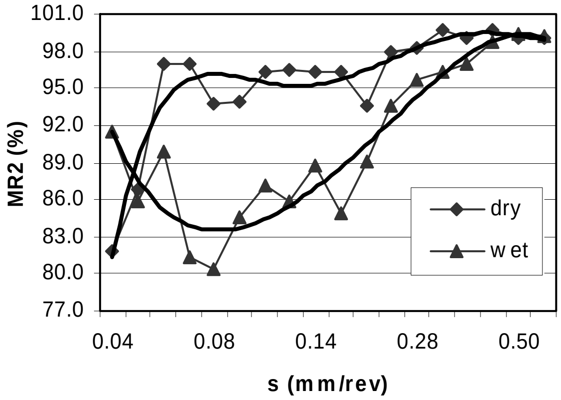

Figure 17: *Variation of MR2 against feed*

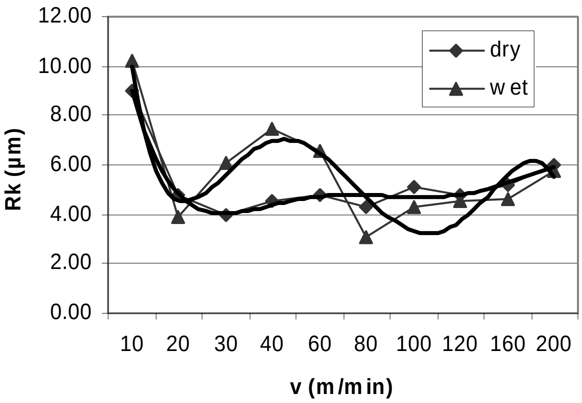

Figure 18 : *Variation of Rk against cutting speed*

Table 3: Models for ''Rk''parameters with respect to feed

Parameter (turning mode)	Regression models	R^2
Rk dry	$y = 0.1009x^2 - 0.6226x + 3.6024$	$R^2 = 0.968$
Rk wet	$y = 0.1047x^2 - 1.1335x + 4.6741$	$R^2 = 0.892$
Rpk dry	$y = 0.1059x^2 - 1.2386x + 4.4862$	$R^2 = 0.877$
Rpk wet	$y = 0.1004x^2 - 1.2636x + 3.7167$	$R^2 = 0.902$
MR1 dry	$y = 0.0004x^5 - 0.0268x^4 + 0.6226x^3 - 6.2146x^2 + 25.269x - 15.56$	$R^2 = 0.872$
MR1 wet	$y = 0.0003x^5 - 0.0227x^4 + 0.541x^3 - 4.6941x^2 + 13.738x + 0.4231$	$R^2 = 0.910$
MR2 dry	$y = 0.0003x^5 - 0.0168x^4 + 0.371x^3 - 3.733x^2 + 17x + 67.705$	$R^2 = 0.884$
MR2 wet	$y = -7E\text{-}05x^5 + 0.0036x^4 - 0.0809x^3 + 1.0945x^2 - 6.5334x + 96.903$	$R^2 = 0.888$

Note: *y, stands for the relevant parameter; x, for feed; R^2, coefficient of determination*

Table 4: Models for ''Rk'' parameters with respect to cutting speed

Parameter (turning mode)	Regression models	R^2
Rk (dry)	$y = -0.0121x^5 + 0.3509x^4 - 3.7532x^3 + 18.07x^2 - 38.249x + 33.589$	$R^2 = 0.836$
Rk (wet)	$y = -0.0025x^5 + 0.0829x^4 - 1.0302x^3 + 5.9983x^2 - 16.083x + 20.024$	$R^2 = 0.971$
Rpk (dry)	$y = -0.0021x^5 + 0.0746x^4 - 0.8652x^3 + 3.9105x^2 - 5.9815x + 4.5357$	$R^2 = 0.890$
Rpk (wet)	$y = 0.002x^5 - 0.0427x^4 + 0.2459x^3 + 0.2747x^2 - 4.9407x + 8.9751$	$R^2 = 0.899$

Note: *y, stands for the relevant parameter; x, for cutting speed; R^2, coefficient of determination*

5. CONCLUSIONS

From the application of the relatively new surface metrology standards, ISO 4287 and ISO 13565 in turned surfaces, the following main conclusions may be drawn:

- Both standards and especially the ''Rk'' group are mainly oriented to functional topographic characterization of engineering surfaces. The present study proved that cutting conditions in turning influence the values of most of these parameters in a definite way, permitting the formulation of statistical regression models showing from good to excellent correlation.
- Comparisons made to the variation of popular ''M'' system parameters indicate that motif parameters provide an alternative way for controlling the turning process and determining optimal cutting conditions
- The application of the ''Rk'' group of parameters to describe other than functional characteristics of turned surfaces needs further clarification.

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