Experimental investigation and modeling of cutting force and surface roughness in hard turning of AISI H11 steel with coated and uncoated ceramic tools using taguchi plan and RMS method: including 2D and 3D surface topography

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Abstract - In this study, the cutting performance of two ceramic cutting tools namely, TiN coated mixed ceramic CC6050 and uncoated mixed ceramic CC650 when machining hardened hot work steel X38CrMoV5-1 [AISI H11] treated at 50 HRC is determined. The cutting performance was evaluated by cutting force and surface roughness. The planning of experiments was based on Taguchi's L36 orthogonal array. The response surface methodology (RSM) and analysis of variance (ANOVA) were used to check the validity of multiple linear regression models and to determine the significant parameter affecting the cutting force and the surface roughness (Rt). From the parametric analysis, it is revealed that, the CC650 insert performs better with reference to cutting force and surface roughness, than the CC6050.

Keywords: ANOVA; MSR; ceramic; hard turning; AISI H11 steel.

Nomenclature

ap	Depth of cut, (mm)	*Ft*	Tangential force, (N)
f	Feed rate, (mm/rev)	α	Clearance angle, (degree)
Vc	Cutting speed, (m/min)	γ	Rake angle, (degree)
r_ε	Cutting radius, (mm)	λ	Inclination angle, (degree)
Rt	Total roughness, (µm)	χ	Major cutting edge angle, (degree)

1. Introduction

In recent years, ceramic tools have attracted the attention of researchers and some works can be highlighted. With the development of ceramic tool materials, they are more and more widely used in the field of metal cutting, because their mechanical properties and cutting performances have been greatly improved. They have been sought in many applications due to their improved properties like good thermal shock resistance, good high-temperature strength, creep resistance, low density, high hardness and wear resistance, electrical resistively, and better chemical resistance [1, 2].

Various studies were conducted to investigate the performance of ceramic tool in the cutting of various hardened materials. D'Errico et al. [3] investigated the cutting performances of different ceramic grades (oxide nitride, mixed and whisker reinforced ceramics) in terms of wear resistance, mechanical toughness and resistance to thermal shock. Experimental results are discussed with application to turning of work material (nickel based alloy, tempered steel and grey cast iron) with diverse machinability. In another study, Fnides et al. [4] conducted experimental study to determine statistical models of surface roughness criteria in turning hardened AISI H11 (X38CrMoV5-1) steel (50 HRC) with mixed ceramic tool. Mathematical models were elaborated based on the software Minitab in order to express the influence degree of each cutting regime on surface roughness. The results indicate that feed rate is the dominant factor affecting surface roughness, followed by cutting speed. As for the depth of cut, its effect is not very important. Jenn-Tsong et al. [5] developed RSM model using CCD in the hard turning using uncoated Al2O3/TiC mixed ceramics tool for flank wear and surface roughness. Flank wear was influenced principally by the cutting speed and the interaction effect of feed rate with nose radius of tool. The cutting speed and the tool corner radius affected surface roughness significantly. Recently, Elbah et al. [6] compared the values of surface roughness obtained with wiper and conventional ceramic inserts during hard turning of AISI 4140 steel. They disclosed that the improved surface quality is achieved with wiper geometry.

The current study investigates the influence of cutting parameters (cutting radius (*r*, mm), cutting speed (*Vc*, m/min), feed rate (*f*, mm/rev) and depth of cut (*ap*, mm)) in relation with the cutting force and the surface roughness (*Ra*) on machinability. The processing conditions are turning of hardened hot work steel (AISI H11) with two different ceramic tools (CC6050 coated with TiN and CC650 conventional) using response surface methodology (RSM) and ANOVA. This last is a computational technique that enables the estimation of relative contributions of each of the control factors to the overall measured response. In this work, the significant parameters will be used to develop mathematical models using response surface methodology (RSM). The RSM is a collection of mathematical and statistical techniques that are useful for the modeling and analysis of problems in which interest response is influenced by several variables and the objective is to optimize the response.

2. Experimental conditions and procedures

3 Material, work piece and tool

Turning experiments were performed in dry conditions using a lathe from TOS TRENCIN company; mode SN 40C with 6.6 KW spindle power. The cutting conditions for finish hard turning under higher parametric condition are shown in Table 1.

The work-piece material used for the experiments is grade AISI H11 steel, hot work steel bars with dimensions of 400 mm length and 75 mm, which is popularly used in hot form pressing. Its resistance to high temperature, its tenacity, its aptitude for polishing and its impact resistance thermal properties enable it to answer to the most severe requests in hot dieing and moulds under pressure [4]. Its chemical composition is given in Table 2. It is hardened to 50 HRC (quenching at 1020°C followed by oil tempering at 250°C). Its hardness was measured by a digital durometer DM2D.

A tool holder and insert geometry, having ISO designation as PSBNR2525K12 and SNGA120408T01020, respectively, were employed with tool geometry as follows: $\chi = 75°$; $\alpha = 6°$; $\gamma = -6°$; $\lambda = -6°$. The cutting forces were recorded using a standard quartz dynamometer (Kistler 9257B) allowing measurements from -5 to 5 kN.

The measurements of surface roughness (Rt) for each cutting condition were obtained from a Surftest 201 Mitutoyo roughness meter. It consists of a diamond point with a 5 μm radius and moves linearly on the working surface. The length examined is 4.0 mm with a basic span of 0.8 mm. The measured value of Ra is within the range 0.05 to 40 μm. Roughness measurements were directly obtained on the same without disassembling the turned part in order to reduce uncertainties due to resumption operations. In addition, two measurements were made using a 3D surface topography with optical platform of metrology modular Altisurf 500. The three-dimensional topographic maps of the machined surfaces were produced using the interferometry technique (Fig. 1). 3D data were also taken along the pitch-surface generator, shape was removed and then parameters were calculated with the Gaussian filter (cut-off was 0.8 mm).

Table 1. *Cutting parameters and their levels for turning.*

Symbol	Control factor	Unit	Symbol of factors	Levels		
				Level 1	Level 2	Level 3
Ap	Depth of cut	Mm	D	0.1	0.3	0.5
F	Feed rate	mm/rev	C	0.08	0.14	0.20
Vc	Cutting speed	m/min	B	100	150	200
R	Cutting radius	Mm	A	0.8	1.2	

Table 2. *Chemical composition of AISI H11 steel.*

Composition	C	Cr	Mo	V	Si	Mn	S	P	Other components	Fe
(Wt %)	0.35	5.26	1.19	0.50	1.01	0.32	0.002	0.016	1.042	90.31

4 Response surface methodology

The response surface methodology (RSM) is the procedure to determine the relationship between the independent process parameters with the desired response and to explore the effect of these parameters on responses, including six steps [7]. These are, in the order, (1) define the independent input variables and the desired responses with the design constants, (2) adopt an experimental design plan, (3) perform regression analysis with the multiple linear model of RSM, (4) calculate the statistical analysis of variance (ANOVA) for the independent input variables in order to find which parameter significantly affects the desired response, then, (5) determine the situation of the multiple linear model of RSM and decide whether the model of RSM needs screening variables or not and finally, (6) optimize and conduct confirmation experiment and verify the predicted performance characteristics.

In the current study, cutting radius (r, mm), cutting speed (Vc, m/min), feed rate (f, mm/rev) and depth of cut (ap, mm) for two different ceramics (CC6050 and CC650) have been chosen as process parameters. The cutting force (Ft) and the surface roughness parameter namely: total roughness (Rt) were been chosen as responses factors. The relationship between the input parameters and the output parameter is given as:

$$Y = \phi(A, B, C, D) \quad (1)$$

Where Y is the desired machinability aspect and ϕ is the response function. The approximation of Y is proposed by using a multiple linear mathematical model, which is suitable for studying the interaction effects of process parameters on machinability characteristics. In the present work, the RMS based multiple linear mathematical model is given by the following:

$$Y = a_0 + \sum_{i=1}^{k} b_i X_i + \sum_{i,j}^{k} b_{ij} X_i X_j \quad (2)$$

where b_0 is the free term of the regression equation, the coefficients $b_1, b_2, \ldots b_K$ and b_{12}, $b_{13}, \ldots b_{k-1}$ are the interacting terms. X_i represent input parameters (r, Vc, f and ap). The output Ft and Rt are also called the response factors. The experimental plan and result of the trials is reported in Table 3. Based on plan of Taguchi $2^1 \times 3^3$ full factorial design, a total of 36 tests were carried out.

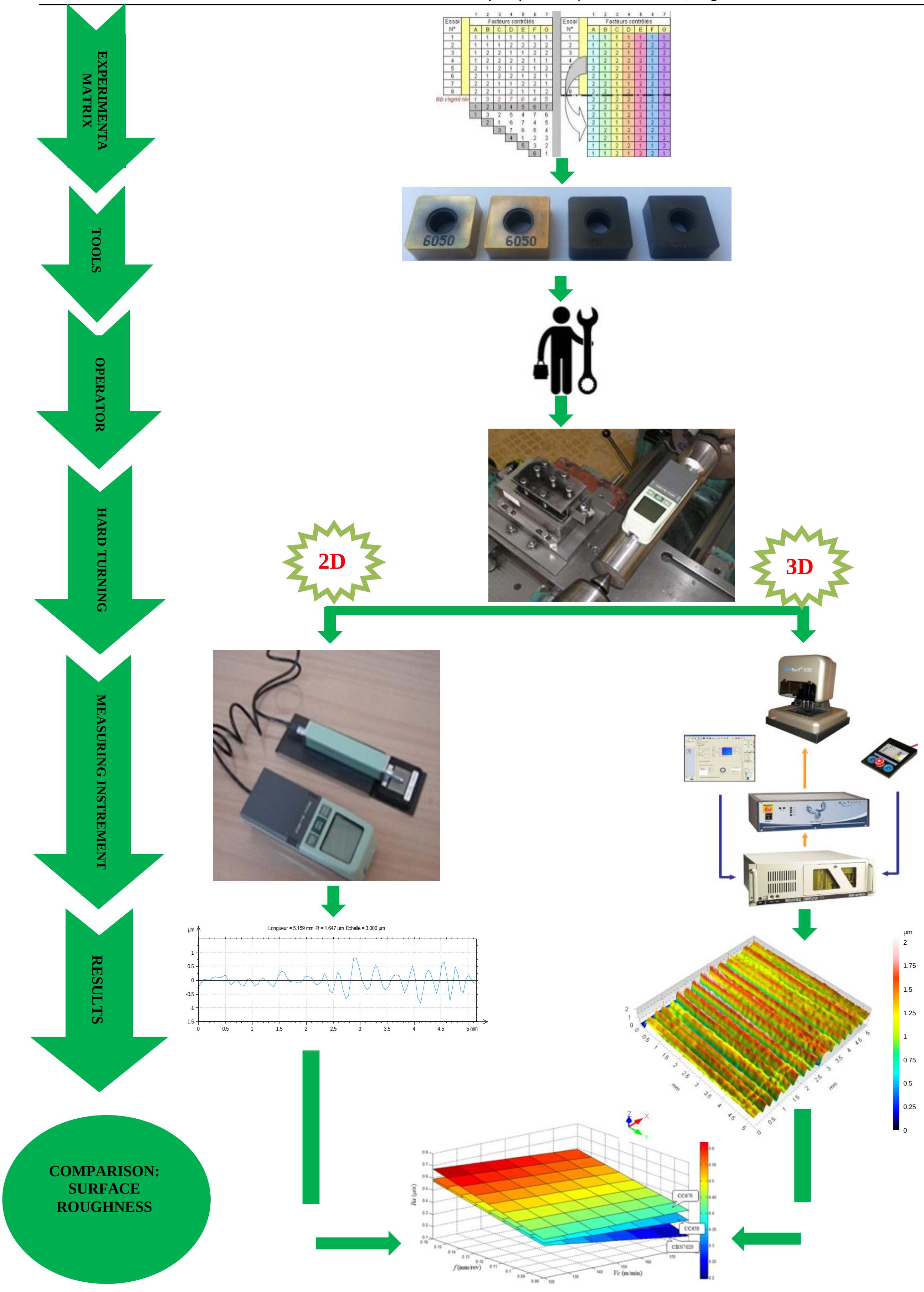


Fig. 1 Illustration of measured surface roughness criteria

***Table 3**. L36 (21×33) orthogonal array, experimental results for cutting force and surface roughness*

Test N°	Machining parameters				Cutting force		Surface roughness	
					CC6050	CC650	CC650	CC6050
	r (mm)	Vc (m/min)	f (mm/rev)	ap (mm)	Ft (N)	Ft (N)	Rt (µm)	Rt (µm)
1	0.8	100	0.08	0.1	164.26	20.41	3.65	2.61
2	0.8	150	0.14	0.3	67.30	78.08	3.23	4.40
3	0.8	200	0.20	0.5	170.16	161.84	5.60	7.40
4	0.8	100	0.08	0.1	72.93	22.71	3.30	2.56
5	0.8	150	0.14	0.3	91.83	87.24	3.96	4.76
6	0.8	200	0.20	0.5	107.03	153.24	6.77	7.01
7	0.8	100	0.08	0.3	175.80	48.98	1.82	2.67
8	0.8	150	0.14	0.5	120.97	131.83	3.27	4.34
9	0.8	200	0.20	0.1	46.54	30.80	6.26	6.38
10	0.8	100	0.08	0.5	31.40	100.70	3.46	2.38
11	0.8	150	0.14	0.1	142.30	33.81	3.59	3.76
12	0.8	200	0.20	0.3	104.85	100.96	5.25	7.96
13	0.8	100	0.14	0.5	167.99	122.15	3.88	4.21
14	0.8	150	0.20	0.1	139.75	31.31	6.31	5.70
15	0.8	200	0.08	0.3	112.13	59.59	2.16	2.46
16	0.8	100	0.14	0.5	41.07	133.28	3.57	3.88
17	0.8	150	0.20	0.1	61.54	48.48	6.70	6.68
18	0.8	200	0.08	0.3	15.35	51.07	2.25	1.65
19	1.2	100	0.14	0.1	55.23	29.93	3.41	3.12
20	1.2	150	0.20	0.3	25.57	105.89	4.36	6.13
21	1.2	200	0.08	0.5	29.63	85.31	1.81	1.77
22	1.2	100	0.14	0.3	114.91	87.19	2.69	3.22
23	1.2	150	0.20	0.5	207.45	163.39	2.88	6.28
24	1.2	200	0.08	0.1	63.19	29.48	1.87	1.33
25	1.2	100	0.20	0.3	88.88	125.40	4.50	5.41
26	1.2	150	0.08	0.5	36.19	90.16	2.45	1.66
27	1.2	200	0.14	0.1	54.71	45.67	2.68	3.38
28	1.2	100	0.20	0.3	105.73	120.7	4.58	5.99
29	1.2	150	0.08	0.5	134.58	96.21	2.19	2.47
30	1.2	200	0.14	0.1	140.62	30.41	2.86	2.93
31	1.2	100	0.20	0.5	48.56	215.75	0.69	6.17
32	1.2	150	0.08	0.1	45.98	14.49	2.03	2.00
33	1.2	200	0.14	0.3	64.73	70.91	3.05	2.63
34	1.2	100	0.20	0.1	123.94	51.11	4.98	6.13
35	1.2	150	0.08	0.3	106.50	43.12	1.48	2.09
36	1.2	200	0.14	0.5	134.34	139.49	2.21	3.48

5 RESULTS AND DISCUSSION

3.1.Statistical analysis

Tables 4-5 show the results of ANOVA, for Ft and Rt for both ceramic cutting tools CC650 and CC6050. This analysis was out for a 5% significance level, i.e., for a 95% confidence level. In addition to freedom degree, mean of squares (MS), sum of squares (SS), F-value and probability (Prob.) associated with each factor level were presented. The last but one column of tables shows the factor contribution (percentage; Cont. %) on the total variation, indicating the degree of influence on the result.

Table 4 shows the results of ANOVA model for surface roughness (*Rt*) of coated ceramic (CC6050) and uncoated ceramic (CC650) tools. From the analysis of Table 4, it is observed that the parameters, feed rate (Cont. = 55.339% and Cont. = 93.084%) and cutting radius (Cont. = 15.660% and Cont. = 3.223%) have great influence on the total roughness (Rt) of CC650 and CC6050 respectively, especially the feed rate. Earlier, Aouici et al. [8] observed that the effect of the feed rate was so notable on surface roughness criteria. Other model terms and interaction can be said to be not significant. The correlation coefficients R^2 of about (0.8624 and 0.9488) are considered as good. They represent the proportion of variation in the response which is explained by the model. The "Pred. R^2" of (0.6860 and 0.8932) is in reasonable agreement with the "Adj. R^2" of (0.8074 and 0.9283) for both cutting ceramic tools respectively.

Table 4. *Analysis of variance for Rt*

Source	SS	DF	MS	F-value	Prob.	Cont. %	Remarks
(a) CC650							
Model	70.90744	10	7.09074415	15.67095	< 0.0001		Significant
A-*r*, mm	8.152613	1	8.15261377	18.01774	0.0003	15.660	Significant
B-*Vc*, m/min	0.058907	1	0.05890714	0.130188	0.7213	0.113	Insignificant
C-*f*, mm/rev	28.80886	1	28.8088632	63.66924	< 0.0001	55.339	Significant
D-*ap*, mm	3.270816	1	3.27081666	7.228693	0.0126	6.283	Significant
AB	0.048931	1	0.04893190	0.108142	0.7450	0.094	Insignificant
AC	1.390497	1	1.39049737	3.073079	0.0919	2.671	Insignificant
AD	1.651184	1	1.65118431	3.649212	0.0676	3.172	Insignificant
BC	0.929685	1	0.92968558	2.054658	0.1641	1.786	Insignificant
BD	3.579892	1	3.57989214	7.911767	0.0094	6.877	Significant
CD	4.167336	1	4.16733631	9.210053	0.0056	8.005	Significant
Residual	11.31192	25	0.45247689				
Lack of Fit	10.11842	16	0.63240139	4.768841	0.0112		Significant
Pure Error	1.193500	9	0.13261111				
Cor Total	82.21936	35					
SD = 0.67					R^2 = 0.8624		
Mean = 3.49					R^2 Adjusted = 0.8074		
Coefficient of variation = 19.26					R^2 Predicted = 0.6860		
Predicted residual error of sum of squares (PRESS) = 25.81					Adequate precision = 13.794		
(b) CC6050							
Model	120.11806	10	12.0118064	46.285163	< 0.0001		Significant
A-*r*, mm	2.4681083	1	2.46810833	9.5103761	0.0049	3.223	Significant
B-*Vc*, m/min	0.0238445	1	0.02384454	0.0918803	0.7643	0.031	Insignificant
C-*f*, mm/rev	71.274847	1	71.2748471	274.64378	< 0.0001	93.084	Significant
D-*ap*, mm	0.8325375	1	0.8325375	3.2080215	0.0854	1.087	Insignificant
AB	0.7523151	1	0.75231516	2.8989003	0.1010	0.983	Insignificant
AC	0.0894116	1	0.08941166	0.3445304	0.5625	0.117	Insignificant
AD	0.0898803	1	0.0898803	0.3463362	0.5615	0.117	Insignificant
BC	0.7154013	1	0.71540132	2.7566600	0.1093	0.934	Insignificant
BD	0.1112695	1	0.1112695	0.4287554	0.5186	0.145	Insignificant
CD	0.2127386	1	0.2127386	0.8197468	0.3739	0.278	Insignificant
Residual	6.4879356	25	0.25951742				
Lack of Fit	4.8856356	16	0.30535223	1.7151407	0.2075		Significant
Pure Error	1.6023	9	0.17803333				
Cor Total	126.606	35				100	
SD = 0.51					R^2 = 0.9488		
Mean = 4.08					R^2 Adjusted = 0.9283		
Coefficient of variation = 12.48					R^2 Predicted = 0.8932		
Predicted residual error of sum of squares (PRESS) = 13.52					Adequate precision = 22.233		

ANOVA table for response surface quadratic model for tangential force (Ft) using two ceramic tools (CC6050 and CC650) is shown in Table 5, the percentage contributions of factors A, B, C and D on the Ft for both ceramic tools CC6050 and CC650 are [(0.23 and 0.10), (0.38 and 0.28), (15.62 and 15.65) and (81.56 and 78.06)] % respectively. In this case, the most effective parameter for the tangential force is factor D; namely, the depth of cut, because increasing depth of cut increases the chip volume removed. The next largest factor influencing Ft is feed rate (C) with (15.62 and 15.65) % for CC650 and CC6050 tools, respectively. The cutting speed and tool nose radius do not present any statistical significance on the tangential force.

Table 5 *ANOVA result for tangential force (Ft).*

Source	SS	DF	MS	F-value	Prob.	Cont. %	Remarks
(a) CC6050							
Model	83350.822	10	8335.0822	51.6559099	< 0.0001		Significant
A-*r*, mm	180.15543	1	180.15543	1.116496795	0.3008	0.23	Insignificant
B-*Vc*, m/min	306.50024	1	306.50024	1.899507211	0.1803	0.38	Insignificant
C-*f*, mm/rev	12496.522	1	12496.522	77.44605472	< 0.0001	15.62	Significant
D-*ap*, mm	65252.167	1	65252.167	404.394337	< 0.0001	81.56	Significant
AB	134.81677	1	134.81677	0.835514632	0.3694	0.17	Insignificant
AC	76.881684	1	76.881684	0.476467203	0.4964	0.10	Insignificant
AD	0.0021559	1	0.0021559	1.33612E-05	0.9971	0.01	Insignificant
BC	317.61405	1	317.61403	1.968383923	0.1729	0.40	Insignificant
BD	1.4316313	1	1.4316313	0.008872405	0.9257	0.01	Insignificant
CD	1243.6552	1	1243.6552	7.707439863	0.0103	1.55	Significant
Residual	4033.9441	25	161.35776				
Lack of Fit	3554.8741	16	222.17963	4.173954728	0.0175		Significant
Pure Error	479.07005	9	53.230005				
Cor Total	87384.767	35				100	
SD = 12.70					R^2 = 0.9538		
Mean = 94.83					R^2 Adjusted = 0.9354		
Coefficient of variation = 13.39					R^2 Predicted = 0.8930		
Predicted residual error of sum of squares (PRESS) = 9346.30					Adequate precision = 24.024		
(b) CC650							
Model	83941.653	10	8394.1653	97.54966654	< 0.0001		Significant
A-*r*, mm	77.543400	1	77.543400	0.90114175	0.3516	0.10	Insignificant
B-*Vc*, m/min	213.64240	1	213.64240	2.482765634	0.1277	0.28	Insignificant
C-*f*, mm/rev	12126.858	1	12126.858	140.9277735	< 0.0001	15.65	Significant
D-*ap*, mm	60474.936	1	60474.936	702.7869527	< 0.0001	78.06	Significant
AB	7.8975154	1	7.8975154	0.091778035	0.7644	0.01	Insignificant
AC	127.14514	1	127.14514	1.477569932	0.2355	0.16	Insignificant
AD	135.67617	1	135.67617	1.576710171	0.2208	0.18	Insignificant
BC	270.39466	1	270.39466	3.142290904	0.0885	0.35	Insignificant
BD	331.22563	1	331.22563	3.849215434	0.0610	0.43	Insignificant
CD	3708.6389	1	3708.6389	43.09856663	< 0.0001	4.79	Significant
Residual	2151.2542	25	86.050169				
Lack of Fit	1678.2582	16	104.89114	1.995831638	0.1472		Insignificant
Pure Error	472.99595	9	52.555105				
Cor Total	86092.907	35				100	
SD = 9.28					R^2 = 0.9750		
Mean = 82.25					R^2 Adjusted = 0.9650		
Coefficient of variation = 11.28					R^2 Predicted = 0.9381		
Predicted residual error of sum of squares (PRESS) = 5332.55					Adequate precision = 34.964		

6 Mathematical modeling

Regression is a technique for investigating functional relationship between output and input decision variables of a process and may be useful for manufacturing process data description, parameter estimation and control [6]. The mathematical models determined by multiple linear regression analysis for predicting the tangential force (Ft) and the surface roughness (Rt) during hard turning of AISI H11 hot work tool steel using different ceramic inserts are given by:

CC650

$$Rt_{CC650} = +1.876 + 1.917r - 0.037Vc + 45.012f + 3.824ap + 5.699\times10^{-3} r\times Vc$$
$$- 25.319 r\times f - 6.918 r\times ap + 0.105 Vc\times f + 0.052 Vc\times ap - 46.512 f\times ap \quad (3)$$

(R^2 = 86.24%)

$$Ft_{CC650} = -13.384 - 33.066r + 0.403Vc + 55.019f + 68.655ap$$
$$- 0.072 r\times Vc + 242.115 r\times f + 62.715 r\times ap$$
$$- 1.802 Vc\times f - 0.497 Vc\times ap + 1387.553 f\times ap \quad (4)$$

(R^2 = 0.9750)

CC6050

$$Rt_{CC6050} = -0.240 + 2.1999r + 5.886\times10^{-3} Vc + 23.324f - 3.522ap - 0.022 r\times Vc$$
$$- 6.420 r\times f + 1.614 r\times ap + 0.093 Vc\times f + 9.120\times10^{-3} Vc\times ap + 10.501 f\times ap \quad (5)$$

(R^2 = 94.88%)

$$Ft_{CC6050} = -34.415 - 5.055r - 0.120Vc + 689.979f + 143.563ap$$
$$+ 0.299 r\times Vc - 188.271 r\times f - 0.250 r\times ap$$
$$- 1.953 Vc\times f + 0.032 Vc\times ap + 803.512 f\times ap \quad (6)$$

(R^2 = 0.9538)

7 Surface topography

The two-factor interaction effects due to feed rate (*f*)–cutting radius (*r*) and depth of cut (*ap*)–cutting speed (*Vc*) on the surface roughness (Rt) during hard turning of AISI H11 (50HRC) hot work tool steel were analyzed for two different ceramic inserts, namely CC650 and CC6050 through surface plots (Figs. 2– 3). The 3D response surface plots were generated considering two machining parameters at a time, while the other parameters were kept at the middle levels.

From interaction plot Fig. 1 it can be observed that, at constant cutting radius, the surface roughness sharply increases with the increase of the feed rate. This is because its increase generates helicoid furrows, the result of tool shape and helicoid movement tool-workpiece. These furrows are deeper and broader as the feed rate increases [6]. On the other hand, surface roughness has a tendency to decrease with an increase in cutting radius at constant feed rate.

Fig. 3 shows the relation of depth of cut (*ap*)–cutting speed (*Vc*) for both ceramic tools CC650 and CC6050. It indicates that for a given depth of cut, the surface roughness decrease with the increase of cutting speed. On the other hand, depth of cut has less effect on surface roughness. In general, the CC650 tool gives lower (better) value results than CC6050 tool.

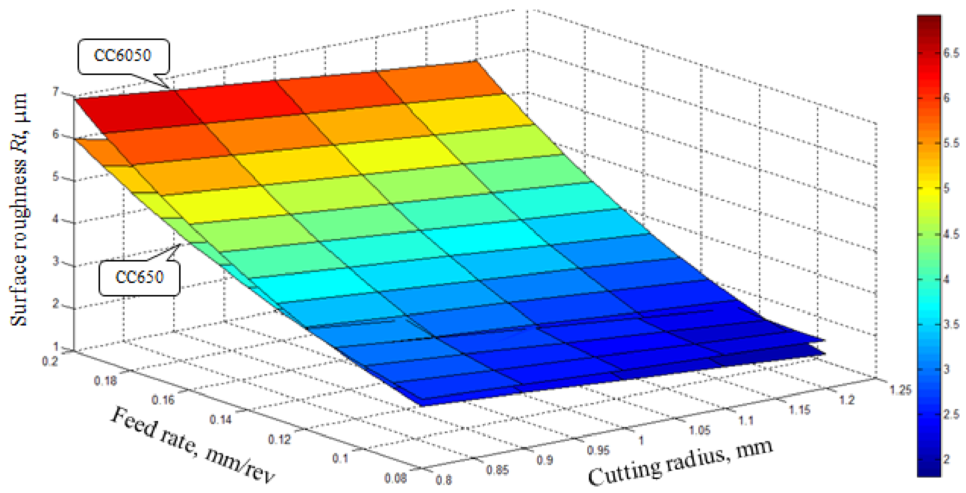


Fig. 2 *3D surface plots for interaction effects of feed rate and cutting radius on total roughness for Rt (CC6050 and CC650)*

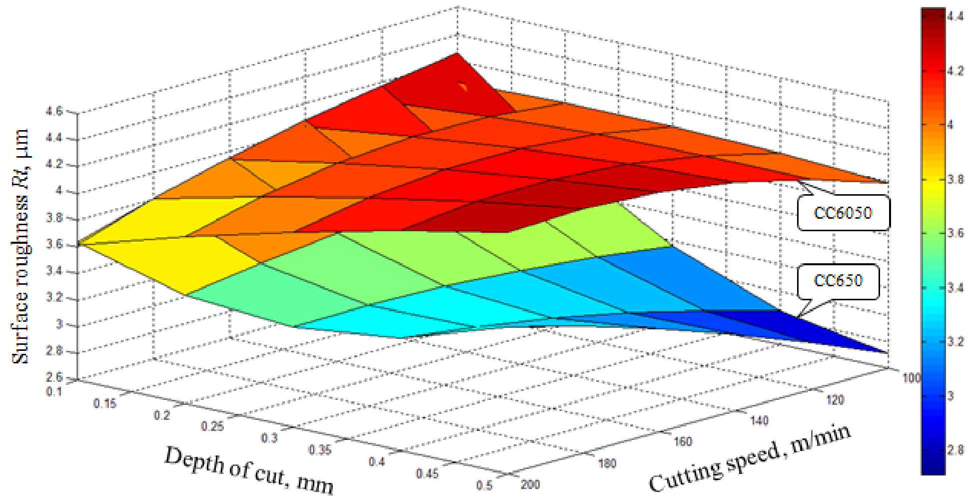
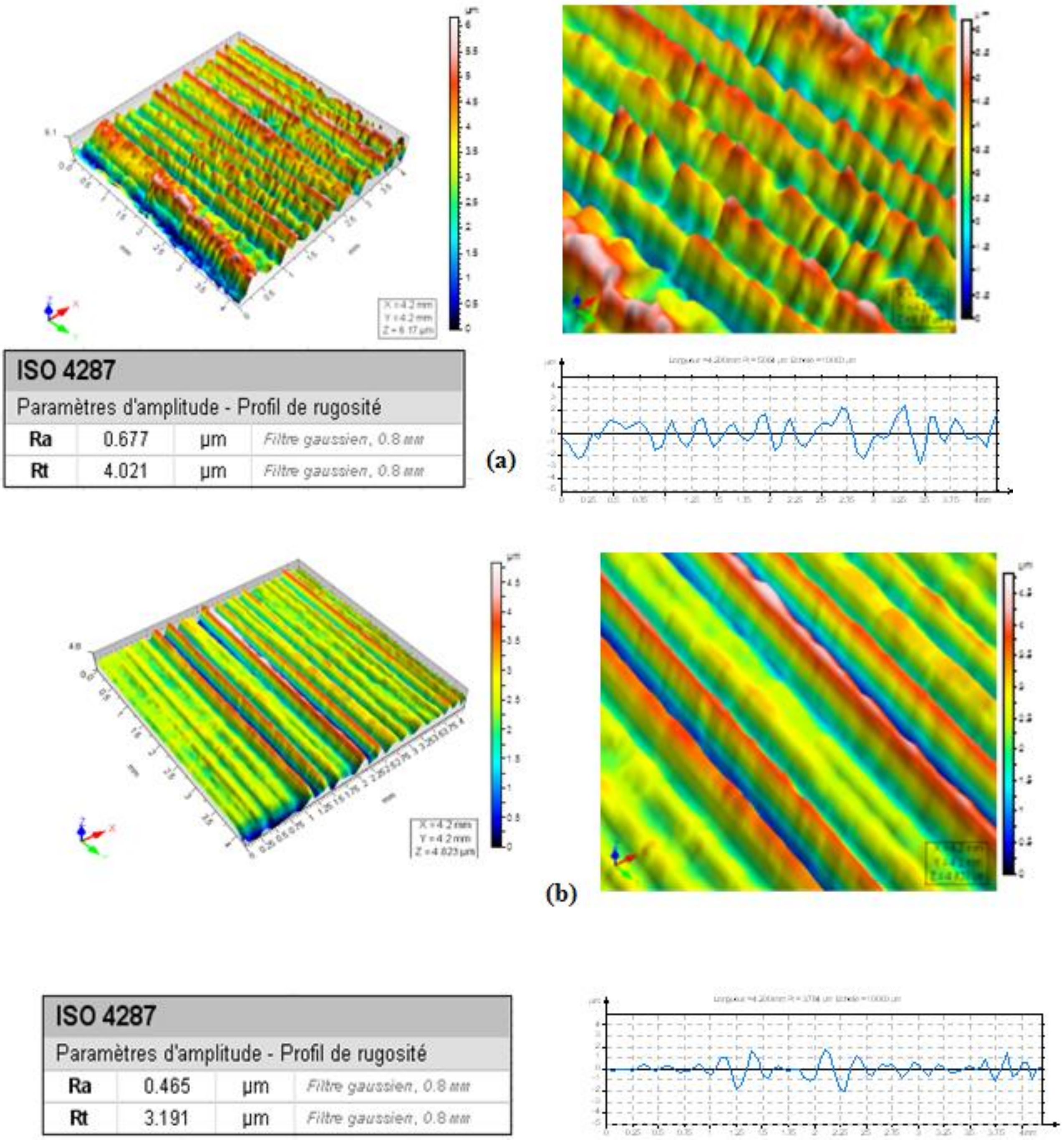


Fig. 3 *3D surface plots for interaction effects of depth of cut and cutting speed on total roughness Rt for (CC6050 and CC650)*

8 3D surface topography

The representative examples of 3D images of hard turned surfaces are visualized by means of four isometric views and contour maps. It must be noted that the both 3D profiles have represented pure roughness values, i.e. the turned surface topography in Figs 6a and 6b shows well-defined peaks and valleys. This is mainly because when the turning operation process uses a single cutting edge generates helicoids furrows the result of tool shape and helicoids movement tool–workpiece. The 2D surface profiles of the hard turned surfaces along the feed direction are shown in Figs. 4a and 4b. It must be noted that all the 2D profiles have represented pure roughness values, i.e. the waviness components have been filtered out.



ISO 4287			
Paramètres d'amplitude - Profil de rugosité			
Ra	0.677	µm	Filtre gaussien, 0.8 mm
Rt	4.021	µm	Filtre gaussien, 0.8 mm

(a)

(b)

ISO 4287			
Paramètres d'amplitude - Profil de rugosité			
Ra	0.465	µm	Filtre gaussien, 0.8 mm
Rt	3.191	µm	Filtre gaussien, 0.8 mm

Fig. 4 *3D topography for turning with; (a) CC6050 and (b) CC650 inserts at r = 0.8 mm.*

11. CONCLUSION

Based on the above results for the hard turning of AISI H11 steel with 50 HRC using coated CC6050 and uncoated CC650 ceramic under conditions similar to those used in this work, the following conclusions are made:

- The analysis of machining parameters using RSM technique allows investigating the influence of each one on the cutting process progress output such as roughness. Additionally, this study shows that the feed rate and cutting radius have significant statistical influences on the surface roughness [(55.339; 93.084) and (15.660; 3.223)] % for CC650 and CC6050 tools, respectively.

- The depth of cut has the highest physical as well statistical influence on the tangential force (Ft) to perform the machining operation followed by feed rate [(81.56; 78.06) and (15.62; 15.65)] % for CC6050 and CC650 tools, respectively. From the parametric analysis, it is revealed that, the CC650 insert performs better with reference to cutting force, while the CC6050.

- In general, uncoated ceramic cutting tool CC650 has the better performance compared with coated ceramic cutting tool CC6050. The ratios mean value for Rt_{CC6050}/Rt_{CC650}, is 0.85.

- 3D visualization confirmed some characteristic features of surfaces produced with both inserts tested.

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