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EVALUATION OF OPTIMAL MACHINING PARAMETERS OF NICROFER C263 ALLOY USING RESPONSE SURFACE METHODOLOGY WHILE TURNING ON CNC LATHE MACHINE

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Abstract The objective of the present work was to investigate the effects of the various machining (turning) process parameters on the machining quality and to obtain the optimal sets of process parameters so that the quality of machined parts can be optimized. The working ranges and levels of the machining process (turning) parameters are found using three factors. Cutting speed (Vc - m/min), feed rate (f – mm/rev) and depth of cut (d - mm). The Design-Expert software has been used to investigate the effects of the Machining process parameters and subsequently to predict sets of optimal parameters for optimum quality characteristics. The response surface methodology (RSM) in conjunction with second order central composite rotatable design has been used to develop the empirical models for response characteristics. Desirability functions have been used for simultaneous optimization of performance measures. Also, the ANOVA technique and utility function have been used for response optimization. Confirmation experiments are further conducted to validate the results.

Keywords: Cutting parameters; turning process; feed force; RSM(Response Surface Methodology); ANOVA; Nicrofer c-263, TiAlN coated carbide tool.

INTRODUCTION:

A manufacturing engineer or machine setup technician is often expected to utilize experience and published shop guidelines for determining the proper machining parameters to achieve a specified level of surface roughness. This must be done in a timely manner to avoid production delays, effectively to avoid defects, and the produced parts monitored for quality. Therefore, in this situation, it is prudent for the engineer or technician to use past experience to select parameters which will likely yield a surface roughness below that of the specified level, and perhaps make some parameter adjustments as time allows or quality control requires. A more methodical, or experimental, approach to setting parameters should be used to ensure that the operation meets the desired level of quality with given ambient conditions and without sacrificing production time. Rather than just setting a very low feed rate to assure a low surface roughness, for example, an experimental method might determine that a faster feed rate, in combination with other parameter settings, would produce the desired surface roughness.

LITERATURE REVIEW

- H.H. Habeeb, K. Kadirgama, M.M. Noor, M.M. Rahman, B. Mohammed, R.A. Bakar and K. A. Abouel Hossein, et al. ,2010, pages 2322-2327, Journal Of Applied Science, Journal " Machining of Nickel Alloy 242 with Cubic Boron Nitride Tools" discusses the development of first and second order of surface roughness prediction model when machining Haynes 242 alloy with Cubic Boron Nitride (CBN). The relationship between the cutting parameters (cutting speed, axial depth and feed rate) with surface roughness are discussed. Response Surface Method (RSM) has been selected to optimize the cutting parameters and reduce the number of experiments. Surface roughness obtained in these experiments ranged from 0.052-0.08 µm, which consider as an extremely fine finish. Increase in cutting speed from 70 to 300 m/min, the roughness getting finer. On the other hand, increase in feedrate (0.1 to 0.3 mm/tooth) and axial depth (0.025 to 0.075 mm) surface roughness become rougher.

- Aman Aggarwal, Hari Singh, Pradeep Kumar, Manmohan Singh, et al., 11 September 2007, pp 373-384, Journal Of Materials Processing Technology, Journal "Optimizing power consumption for CNC turned parts using response surface methodology and Taguchi's technique—A comparative analysis" presents the findings of an experimental investigation into the effects of cutting speed, feed rate, depth of cut, nose radius and cutting environment in CNC turning of AISI P-20 tool steel. Design of experiment techniques, i.e. response surface methodology (RSM) and Taguchi's technique; have been used to accomplish the objective of the experimental study. L27 orthogonal array and face centered central composite design have been used for conducting the experiments. Taguchi's technique as well as 3D surface plots of RSM revealed that cryogenic environment is the most significant factor in minimizing power consumption followed by cutting speed and depth of cut. The effects of feed rate and nose radius were found to be insignificant compared to other factors. Though both the techniques.

EXPERIMENTAL PROCEDURE:

1) First of all preliminary tests are done in order to find out the levels of machining parameters. First feed rate and depth of cut is kept constant and cutting speed is varied. The surface roughness of specimen is measured after each trial and it was found that optimum roughness is lying in between 50 to 100 m/min range of cutting speed. Next Speed is kept constant and feed rate is varied and surface roughness of the specimen is measured after each trial. The feed rate was found to be lying between 0.10 to 0.20 mm/rev for optimum surface roughness. Since according to literature depth of cut does not affect the surface roughness to a greater extent hence depth of cut levels were chosen according to the suitability.

2) After finding levels of parameters, design matrix as shown in table 5 was prepared with the help of Design Expert V 8.0 software.

3) Experiments were done as per the design matrix. The surface roughness was measured after each trial with the help of handysurf and all the data was recorded.

EXPERIMENTAL PLAN PROCEDURE:

Design Matrix with Responses:

RUN OREDER	STANDARD ORDER	SPEED (m/min)	FEED (mm/rev)	DOC (mm)	SURFACE ROUGHNESS (µm)
1	17	50.00	0.15	0.125	0.79
2	16	100.00	0.20	0.150	1.1
3	2	50.00	0.10	0.100	0.72
4	11	100.00	0.10	0.150	0.77
5	18	100	0.15	0.125	0.86
6	28	75	0.15	0.125	0.63
7	4	100	0.10	0.100	0.69
8	25	75	0.15	0.125	0.63
9	1	50	0.10	0.100	0.67
10	21	75	0.15	0.100	0.65
11	24	75	0.15	0.125	0.65
12	3	100	0.10	0.100	0.71
13	5	50	0.20	0.100	0.97
14	19	75	0.10	0.125	0.72
15	7	100	0.20	0.100	0.94
16	26	75	0.15	0.125	0.64
17	8	100	0.20	0.100	0.96
18	13	50	0.20	0.150	0.95
19	10	50	0.10	0.150	0.72
20	12	100	0.10	0.150	0.87
21	9	50	0.10	0.150	0.68
22	6	50	0.20	0.100	0.98
23	15	100	0.20	0.150	0.97
24	22	75	0.15	0.150	0.67
25	27	75	0.15	0.125	0.69
26	23	75	0.15	0.125	0.66
27	14	50	0.20	0.150	0.94
28	20	75	0.20	0.125	0.79

The data tabulated in the table 5.0 is analyzed with Design Expert V8.0 software. The analysis is shown and discussed here.

Table 5.1: Model Summary Statistics

Sequential	Lack of Fit	Adjusted	Predicted		
Source	p-value	p-value	R-Squared	R-Squared	
Linear	0.0011	< 0.0001	0.4185	0.3330	
2FI	0.7368	< 0.0001	0.3736	0.1927	
Quadratic	< 0.0001	0.0631	0.8884	0.7845	Suggested
Cubic					Aliased

Table 5.1 shows that quadratic model has to be applied for the observed sets of reading of surface roughness. It clearly shows that the quadratic model is the best suggested model for surface roughness with larger R2 statistics value.

Table 5.2 - ANOVA for Surface Roughness Quadratic Model

Source	Sum of Squares	df	MEAN SQUARE	F VALUE	p-value Prob > F	
Model	0.48	9	0.053	24.88	< 0.0001	Significant
A-Speed	0.011	1	0.011	5.25	0.0342	
B-Feed	0.23	1	0.23	107.91	< 0.0001	
C-DOC	8.022E-003	1	8.022E-	003 3.74	0.0689	
AB	9.000E-004	1	9.000E-004	0.42	0.5251	
AC	0.013	1	0.013	6.17	0.0230	
BC	1.225E-003	1	1.225E-003	0.57	0.4593	
A2	0.056	1	0.056	25.91	< 0.0001	
B2	0.016	1	0.016	7.48	0.0136	
C2	1.701E-003	1	1.701E-003	0.79	0.3847	
Residual	0.039	18	2.143E-003			
Lack of Fit	0.020	5	3.993E-003	2.79	0.0631	not significant
Pure Error	0.019	13	1.431E-003			
Cor Total	0.52	27				

Table II shows that speed (A), feed rate (B) and two-level interaction effect of speed and depth of cut (BC) and A2, B2 have significant effect on the surface roughness. But the effect of feed rate (B) is the most significant factor associated with surface roughness. This is anticipated as it is well known that for a given tool nose radius, the theoretical surface roughness (Ra= f 2/(32×re)) is mainly a function of the feed rate (Shaw, 1984). The Model F value of 24.88 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B, AC, A2, B2 are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. If there are many insignificant model terms (not counting those required to support hierarchy Model reduction may improve our model. The "Lack of Fit F-value" of 2.79 implies there is a 6.31% chance that a "Lack of Fit F-value" this large could occur due to noise. Lack of fit is bad -- we want the model to fit.

Table 5.3 - Various R2 statistics for Surface Roughness

Std. Dev.	0.046	R-Squared	0.9256
Mean	0.79	Adj R-Squared	0.8884
C.V.%	5.88	Pred R-Squared	0.7845
PRESS	0.11	Adeq Precision	14.782

The "Pred R-Squared" of 0.7845 is in reasonable agreement with the "Adj R-Squared" of 0.8884."Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Ratio of 14.782 indicates an adequate signal.

Final Equation in Terms of Actual Factors:

Ra = 1.70386 - 0.037551 Speed - 5.45880 Feed + 8.27622 DOC – (6.00000E -003) Speed ×Feed + 0.046 Speed×DOC-7.00Feed×DOC + 2.24673E-004Speed2 + 30.16822 Feed2 - 9.32710 DOC2

There are many insignificant terms in the equation and it can also be deduced from ANOVA table. Hence removing the insignificant terms and again analyzing ANOVA table we get,

Table 5.4 - ANOVA for Response Surface Reduced Quadratic Model

Source	Sum of Squares	df	MEAN SQUARE	F VALUE	p-value Prob > F	
Model	0.48	6	0.079	39.30	< 0.0001	Significant
A-Speed	0.011	1	0.011	5.57	0.0280	
B-Feed	0.23	1	0.23	114.53	< 0.0001	
C-DOC	8.022E-003	1	8.022E-003	3.97	0.0594	
AC	0.013	1	0.013	6.55	0.0183	
A2	0.057	1	0.057	28.45	< 0.0001	
B2	0.014	1	0.014	7.16	0.0142	
Residual	0.042	21	2.019E-003			
Lack of Fit	0.024	5	2.974E-003	2.08	0.1159	Not significant
Pure Error	0.019	13	1.431E-003			
Cor Total	0.52	27				

Table 5.5 - Various R2 statistics for Surface Roughness for Reduced Quadratic Model

Std. Dev.	0.045	R-Squared	0.9182
Mean	0.79	Adj R-Squared	0.8949
C.V.%	5.71	Pred R-Squared	0.8305
PRESS	0.088	Adeq Precision	19.227

The various R2 statistics (i.e. R2, adjusted R2 (R2 adj) and predicted R2 (R2 pred)) of the surface roughness are given in Table 5.5. The value of R2 = 0.9182 for surface roughness indicates that 91.82 % of the total variations are explained by the model. The adjusted R2 is a statistic that is adjusted for the “size” of the model; that is, the number of factors (terms). The value of the R2 adj = 0.8949 indicates that 89.49 % of the total variability is explained by the model after considering the significant factors. R2 pred = 0.8305 is in good agreement with the R2 adj and shows that the model would be expected to explain

83.05% of the variability in new data (Montgomery, 2001). ‘C.V.’ stands for the coefficient of variation of the model and it is the error expressed as a percentage of the mean ((S.D./Mean)×100). Lower value of the coefficient of variation (C.V. = 5.71%) indicates improved precision and reliability of the conducted experiments.

Final Equation in Terms of Actual Factors:

Surface Roughness (Ra) = 2.33372 - 0.036045 × Speed - 5.58070×Feed - 2.60556×DOC + 0.046 Speed × DOC+2.08632E-004Speed2 + 26.15789× Feed2

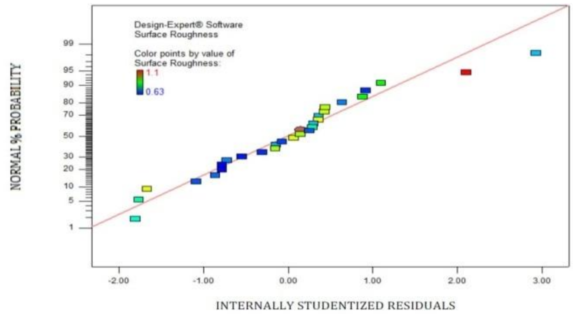

Fig. 5.0 NORMAL PLOT OF RESIDUALS:

Fig. 5.0 the normal probability plot of the residuals (i.e. error = predicted value from model−actual Value) for surface roughness is shown in Fig. 5.0, Fig. 5.0 reveals that the residuals lie Reasonably close to a straight line, giving support that terms mentioned in the model are the only significant (Montgomery, 2001).

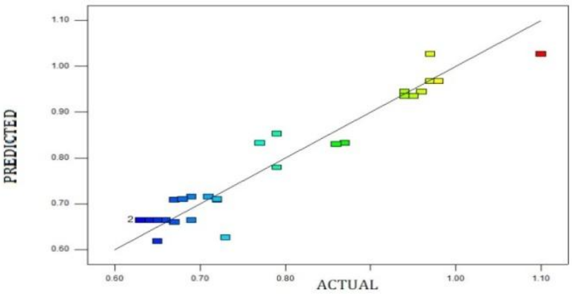

Fig. 5.1 PREDICTED Vs ACTUAL:

Fig. 5.1: Shows the actual values i.e. obtained through experimentation and the predicted valued i.e. values obtained from the model made for the surface roughness.

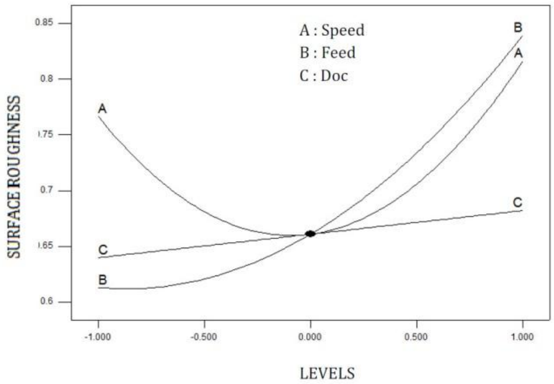

Fig. 5.2 PERTURBATIONS:

Fig 5.2 shows the variation of surface roughness with speed, feed and depth of cut. It can be observed from the fig that increasing depth of cut increases the surface roughness marginally and it can be considered not affecting surface roughness for this range. It can also be seen from the graph that surface roughness decreases with increase in cutting speed upto a certain point then further increase in cutting speed leads to increase in surface roughness. Increasing feed increases the surface roughness, this is anticipated as it is well known that for a given tool nose radius, the theoretical surface roughness (Ra= f 2/(32×re)) is mainly a function of the feed rate (Shaw, 1984).

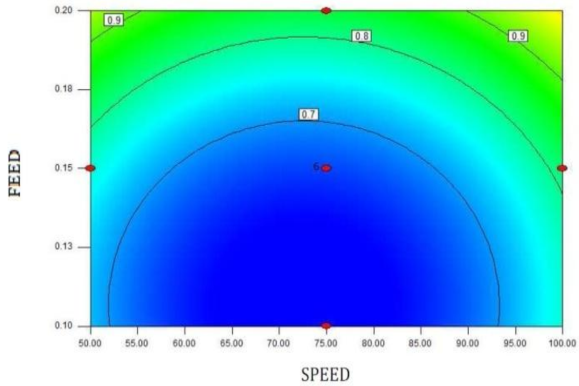

Fig. 5.3 CONTOUR:

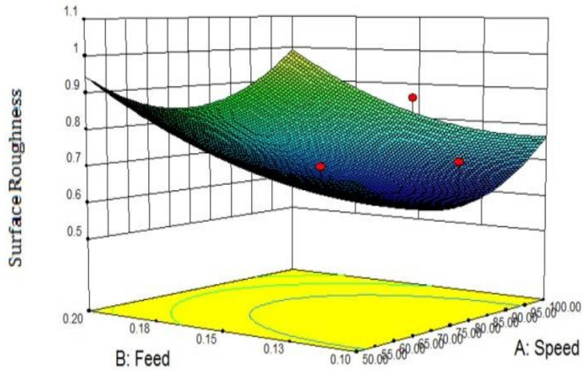

Fig. 5.4 3D SURFACE:

Figure 5.4 - Surface roughness 3D surface in cutting speed and feed rate plane at depth of cut of 0.1mm

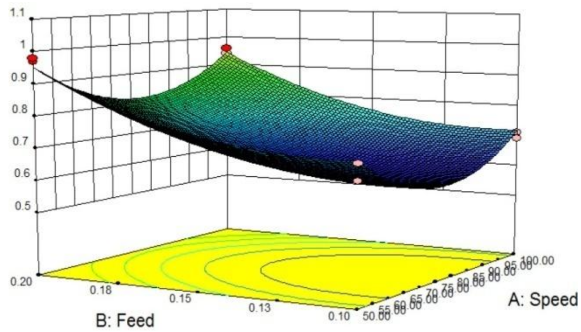

Figure 5.5 - Surface roughness 3D surface in cutting speed and feed rate plane at depth of cut of 0.125mm

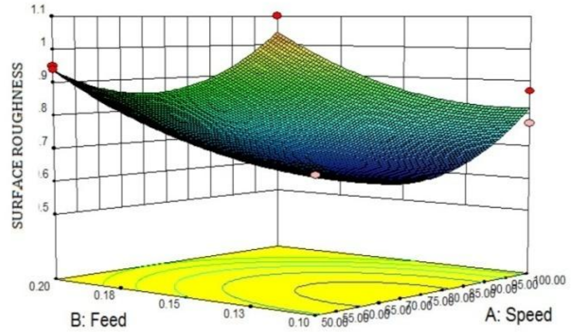

Figure 5.6 - Surface roughness 3D surface in cutting speed and feed rate plane at depth of cut of 0.150mm

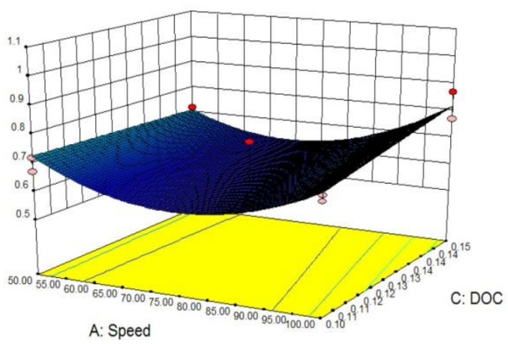

Figure 5.7 - Surface roughness 3D surface in cutting speed and depth of cut plane at feed of 0.01 mm/rev

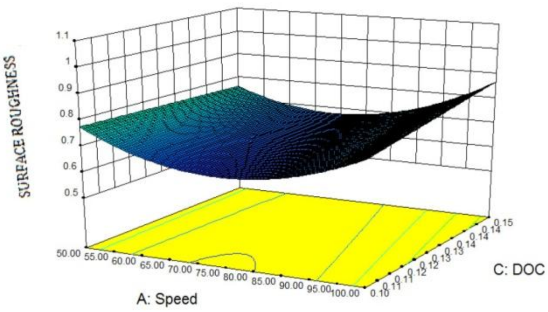

Figure 5.8 - Surface roughness 3D surface in cutting speed and depth of cut plane at feed of 0.015 mm/rev

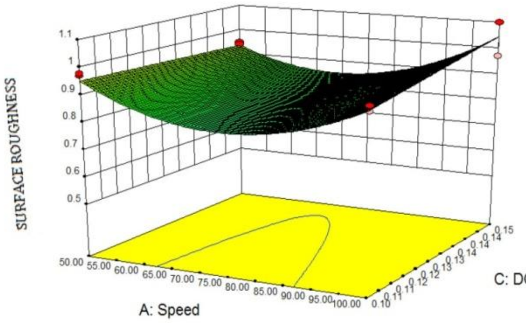

Figure 5.9 - Surface roughness 3D surface in cutting speed and depth of cut plane at feed of 0.02 mm/rev

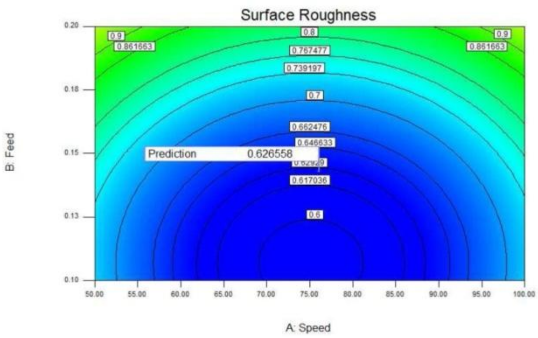

Figure 5.10- Optimation contour highlighting optimized (lowest) value of surface roughness at a Particular setting.

Figure 5.4, 5.5, 5.6 shows the Surface roughness in 3D surface in cutting speed and feed rate plane at three depth of cuts (0.100, 0.125, 0.150 mm) respectively. All have curvilinear profile in accordance to the quadratic model fitted. It can clearly be seen that surface roughness is increasing with increase in the feed rate and it varies with cutting speed, first decreases then increases as discussed before.

Figure 5.7, 5.8, 5.9 - shows the Surface roughness in 3D surface in cutting speed and depth of cut plane at three feed rates (0.10, 0.15, 0.2 mm/rev) respectively. It can clearly be seen that surface roughness does not vary much with the increase in depth of cut.

Figure 5.10 - Shows the optimization contour for surface roughness in feed and cutting speed plane. The figure shows the predicted optimized value (minimum value) of surface roughness which can be obtained in the given sets of feed, speed, depths of cut. The solution obtained through the Design Expert software is shown below. At this set of speed, feed and depth of cut one can get the lowest value of surface Roughness.

Table 5.7- Solution:

Surface Roughness	0.626558 µm
Feed	0.14mm/rev
DOC	0.102 mm
Speed	76.10 m/min

Thus the minimum value of roughness that can be achieved in given ranges of parameter values is 0.626558 μm, which is obtained when feed is approximately at medium level (0.15mm/rev), depth of cut is near to lower level (0.10mm) and speed is also at medium level (75m/min).

SCOPE FOR FUTURE WORK:

- One of the important facts is whether the system contains a maximum or a minimum or a saddle point, which has a wide interest in industry. Therefore, RSM is being increasingly used in the industry. Also, in recent years more emphasis has been placed by the chemical and processing field for finding regions where there is an improvement in response instead of finding the optimum response (Myers, Khuri, and Carter). In result, application and development of RSM will continue to be used in many areas in the future.
- Since C-263 is a High temperature material it is always in use of aircrafts and industrial gas turbines. It can be used in space industry, where temperature goes on high counts. An adjustment in composition is still a very important way to improve the properties.

CONCLUSION:

This project presents the findings of an experimental investigation of the effect of cutting speed, feed rate and depth of cut on the surface roughness in turning of Nicrofer C-263 alloy using PVD TiAlN coated carbide tool and following conclusions are drawn. Quadratic model is fitted for surface roughness. The results show that the surface roughness does not vary much with experimental depth of cut in the range of 0.1 to 0.15 mm. A quadratic model best fits the variation of surface roughness with feed rate, speed and depth of cut. Feed rate is the dominant contributor, accounting for 69.06% of the variation in surface roughness whereas cutting speed accounts for 3.30% and depth of cut 2.41%. Secondary contributions of interaction effect between speed and depth of cut (3.90%), second order (quadratic) effect of cutting speed (17.11%) and feed (4.2 %). Good surface finish can be achieved when depth of cut is set nearer to lower level of the experimental range (0.1mm), feed rate at mid level of the experimental range (0.15mm/rev) and cutting speed also at mid level of experiment range (75 m/min). Contour plots can be used for selecting the cutting parameters for providing the given desired surface roughness. The values of feed, speed, depth of cut has been found for best surface finish (lowest surface roughness). These are 0.14 mm/rev .76.10 m/min and 0.102 mm respectively. The value of surface roughness at these setting is predicted as 0.626558 μm.

REFERENCES:

[1]. Aman Aggarwal, Hari Singh, Pradeep Kumar, Manmohan Singh, et al., 11 September 2007, pp 373–384, Journal Of Materials Processing Technology, Journal "Optimizing power consumption for CNC turned parts using response surface methodology and Taguchi's technique—A comparative analysis".

[2]. A. Karmakar et al., 1970, pp. 123–128, Proceedings of the Fourth All India Machine Tool Design and Research Conference , "Factors influencing surface finish during fine turning".

[3]. C. Courbon, D. Kramar, P. Krajnik, F. Pusavec, J. Rech, J. Kopac, et al., 2009, pp. 1114–1125, International Journal of Machine Tools & Manufacture, Journal "Investigation of machining performance in high-pressure jet assisted turning of Inconel 718: An experimental study".

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