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Optimization Tool Wear on Hard Turning of AISI4140 Steel with Coated Carbide Tool Cutting Conditions

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Abstract: In recent year's traditional grinding process are being replaced by hard turning for the finishing operation of hardened steel. High rate of TW and the cost of CBN inserts associated with hard turning is a cause of concern. In order to minimize the TW, this work proposes the optimal cutting conditions for the hard turning of Hardened AISI 4140 steel (47 HRC) utilizing low affluent CVD coated Ti(C, N) + Al2O3 carbide tool. All the trials are conceded out based on Design of Experiments. Response surface methodology based on BBD is followed for experimentation. The ANOVA is utilized to recognize the most impacting parameters on the TW. Results indicate that both the CS and the DoC influences the TW. Optimization results reveal lower CS results in minimal TW.

Keywords: Hard turning, RSM, coated carbide, ANOVA, TW.

I. INTRODUCTION

Hard turning takes out the arrangement of operations essential for hardened material in machining by conventional processes, subsequently diminishing the process duration and refining the production. Fundamentally a finishing process with materials of choice 45-70 HRC to completed the HT [1]. Despite the fact that it is progressively profitable as far as cost, time, surroundings and production, its use is constrained in industries because of ambiguity in surface integrity, TW and life [5]. Consequently, a thorough assessment in machinability features in HT was directed. Ersan Aslan et al. [2] explored owing to their enhanced hardness and resistance to wear, AISI 4140 with Al_2O_3 + TiCN blended ceramic tools are one of the greatest appropriate cutting tool materials. Influence of CS, Fr and DoC on responses of FW and SR on the orthogonal array and the ANOVA. Sudhansu Ranjan Das et al. [3] explored the agreements with hard turning of AISI 4140 steel utilizing PVD-TiN coated Al_2O_3+TiCN varied ceramic inserts. The joint influence of cutting variables (CS, feed and DoC) on enactment physiognomies such as SR and FW is experimented by FFD and ANOVA. The outcomes demonstrate that feed is the main cutting variable consequence SR, monitored by CS. Though, FW is disturbs by the CS and interaction of feed, DoC, though DoC has no significant effect, but FW is an enhanced function of DoC. Rohit Uppal et al. [4] examined the impacts of shapes of insert through machining of steel. The triangular insert was seen as better than square and round insert for minor SR. Aouici et al. [5], described the HT of steel, examined the impact of speed, feed, workpiece hardness and DoC on CF parts and SR utilizing CBN tools. RSM based regression models were created for the responses. Suresh et al. [6] examined the multilayer CVD coated TiN/TiCN/Al_2O_3 solidified CI execution however machining of hardened steel. It was presumed that the blend of CS, less DoC and less Fr influence minor CF and SR.It is seen that best of the works are restricted to the costly CBN and certainly, there is a requirement for most affordable tool which could be execute HT. In such a setting the offered option is Coated CI which is less expensive than CBN or ceramic tools, only insufficient work is accounted for on the capacity of coated CI through hard turning of alloy steel in the hardness choice (46-48 HRC), for modern applications.In this work, an exhaustive trial examination of cutting parameters was conveyed dependent on RSM. AISI 4140 hardened steel was machined utilizing coated CI. The affecting parameters were discovered utilizing ANOVA. The ideal cutting condition for diminishing wear is likewise investigated.

II. MATERIALS AND METHODS

A. Work piece and Machine tool

Fig. 1.The Machine tool and the work piece

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The material chosen for experimentation is AISI4140 (47 HRC). The machining length is 400mm.The machine tool used is 2.2 *KW* spindle power Kirloskar lathe and the experiments are carried out under dry conditions.

B. Cutting Tool and Tool holder

SECO designated TH1500 (CVD coated Ti(C, N) + Al_2O_3 durotomic carbide tool) is the cutting tool with 0.8*mm* nose radius. Fig 2a shows the cutting tool. The tool holder used for insert (PCLNR2525 M12) have major cutting angle as 95^0, the back rack angle and negative cutting edge inclination angle is -6^0. The tool holder is shown in Fig. 2b.

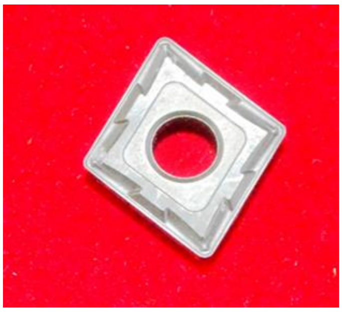

Fig. 2a Cutting tool

Fig. 2b Cutting tool

C. Wear Measurement

A TW microscope (Metz1395) is utilized to extent the flank wear (V_b). The magnification factor is 30X and the transverse distance in both x and y axes are 25mm. The Least count is 0.01mm. The wear values are measured for different cutting conditions after a machining length of 400mm.

Fig. 3 Tool maker microscope

D. Experiments design

The investigations are completed dependent on RSM with BBD, where the numeric factors are changed by three levels signified as - 1; 0; and +1. The relation between input factors and responses is attained deliberately through RSM. The factors chosen and levels allocated are appeared in Table I. The preferred statistical performances are made utilizing the above plan. Additional significant feature is just less number of test runs are executed by17 tests runs are essential for an input of 3 factors.

Table- I: Factors and levels

Level	CS (m/min)	Fr (mm/rev)	DoC (mm)
1	70	0.08	0.3
2	120	0.1	0.45
3	170	0.12	0.6

E. Response surface analysis

To analyse the variation of TW, the RSM take in to account the regression equation and the design of experiment methods. In this present investigation, the association among the input factors (CS, Fr and DoC) and the response (TW) is used for the development of regression model. Regression equation is expressed by the estimate of a nonlinear quadratic polynomial. The R^2 value determines the expectation capability of the model. For the regression model developed, the ANOVA is utilized to find out the statistically important factors on the response. The optimization of input circumstance for the minimization of response is carried out based on the goals prescribed in the Table II.

Table- II: Optimization ranges and goals

Parameters	Goal	Minimum Bound	Maximum Bound
CS	Within	70	170
Fr	Within	0.08	0.12
DoC	Within	0.3	0.6
TW	Minimize	0.12	0.227

III. RESULTS AND DISCUSSION

The trial outcomes for TW are illustrated in Table III. The range obtained for the TW range obtained is 0.12 - 0.227 *mm.*

Table- III: Experimental results

Run No	Input parameters			Response
	CS	Fr (mm/rev)	DoC	TW (mm)
1	120	0.1	0.45	0.16
2	170	0.08	0.45	0.186
3	170	0.12	0.45	0.165
4	120	0.1	0.45	0.16
5	120	0.1	0.45	0.16
6	170	0.1	0.3	0.18
7	70	0.12	0.45	0.14
8	70	0.1	0.6	0.16
9	120	0.08	0.6	0.185
10	120	0.08	0.3	0.135
11	120	0.12	0.3	0.16
12	70	0.08	0.45	0.121
13	120	0.12	0.6	0.2
14	70	0.1	0.3	0.12
15	120	0.1	0.45	0.16
16	120	0.1	0.45	0.16
17	170	0.1	0.6	0.227

A. Regression model and statistical analysis

a. Regression equation for TW

In this work, the response surface model is generated using the Design-Expert software. The regression model for the TW and is formed based on the experimental data. The statistical evaluation of various polynomial models is carried out as in Table IV. A highest polynomial that is not aliased is to be selected form the response surface.

The suggested model that is not aliased is the quadratic model. The difference between predicted R^2 and Adjusted R^2 is less (Table IV).

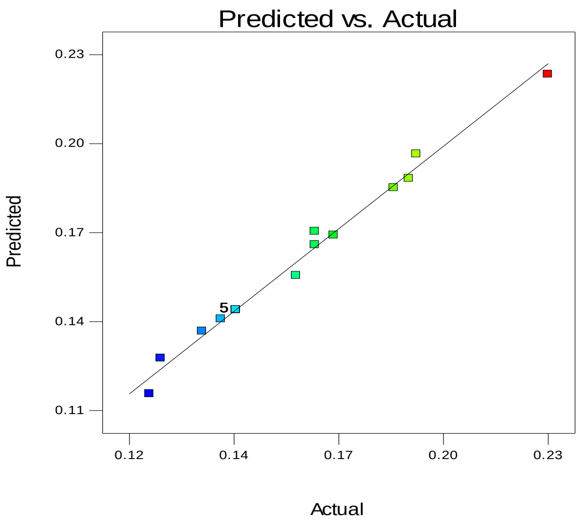

Fig.4 Actual v/s predicted values comparison for 'TW'

The TW values can be predicted from the above mathematical equations. The R^2 value of above model is 82.64% indicating better association among the trial and predicted values. The correlation among the real and the forecasted data is demonstrated in Fig.4.

B. ANOVA for Tool Wear

Table- V: ANOVA for TW

Source	SS	df	MS	F Value	p-value Prob > F	Remarks
Model	0.012	9	$1.35E^{-3}$	70.89	< 0.0001	significant
A	$4.90E^{-3}$	1	$4.90E^{-3}$	256.47	< 0.0001	significant
B	$5.51E^{-5}$	1	$5.51E^{-5}$	2.89	0.1332	insignificant
C	$4.28E^{-3}$	1	$4.28E^{-3}$	223.9	< 0.0001	significant
AB	$4.00E^{-4}$	1	$4.00E^{-4}$	20.93	0.0026	significant
AC	$6.40E^{-5}$	1	$6.40E^{-5}$	3.35	0.1099	insignificant
BC	$1.82E^{-4}$	1	$1.82E^{-4}$	9.54	0.0176	significant
A^2	$1.33E^{-4}$	1	$1.33E^{-4}$	6.97	0.0334	significant
B^2	$4.80E^{-5}$	1	$4.80E^{-5}$	2.51	0.1571	insignificant
C^2	$2.02E^{-3}$	1	$2.02E^{-3}$	105.45	< 0.0001	significant
Residual	$1.34E^{-4}$	7	$1.91E^{-5}$	-	-	-
Lack of Fit	$1.34E^{-4}$	3	$4.46E^{-5}$	-	-	-
Pure Error	0	4	0	-	-	-
Cor Total	0.012	16	-	-	-	-

The ANOVA results for TW are shown in Table V. The parameters used for inference are the F-Value, p-value and lack of Fit. The F-Value for the model is 70.89.5 and p-value < 0.0001 indicates the model is important. The p-value lower than 0.0500 specify that the corresponding model terms are important. It can be seen that the TW is influenced by velocity and DoC. The interaction among velocity and feed is significant. The interaction among DoC and feed is also significant.

C. Response Surfaces on Tool Wear

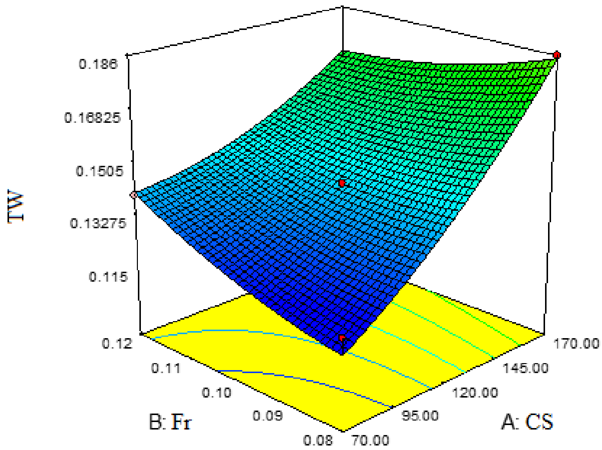

Fig.6 Interaction CS vs Fr on 'TW'

Fig.6 depicts the influence of Fr and CS on the TW. The ANOVA outcomes designate that for TW the interaction of CS and Fr are important. Figure 6 indicates that a lower wear occurs for low CS and Fr. Fig.7 demonstrates the differences of TW with CS and DoC. The ANOVA outcomes specify that for TW the interaction of DoC and CS are not statistically important; it is obvious from fig.7 that a minor TW happens for a less DoC and CS.

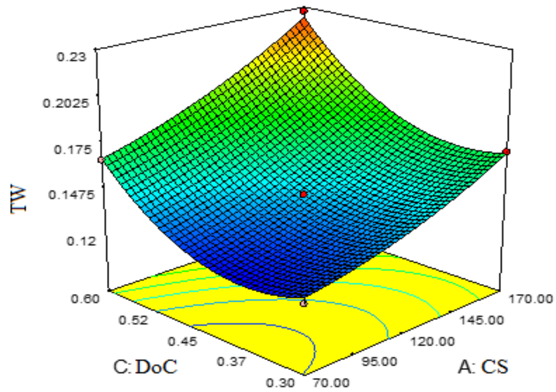

Fig.7 Interaction CS vs DoC on 'TW'

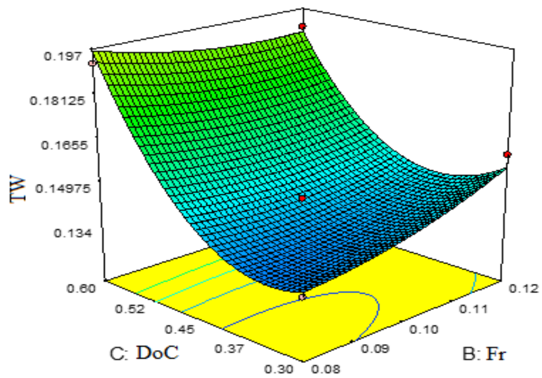

Fig.8 Interaction Fr vs DoC on 'TW'

Fig.8 demonstrates the differences of TW with Fr and DoC. The ANOVA outcomes specify that for TW the interaction of DoC and Fr are not statistically important; it is obvious from fig.8 that a less TW happens for a lesser DoC and Fr.

D. OPTIMIZATION OF CUTTING CONDITIONS

Based on the records obtainable in Table VI, optimal circumstances for minimizing the TW are initiate out. Optimal outcomes attained based on RSM are demonstrated in Table VI. These optimal levels could be deliberated in hard turning of AISI4140steel.

Table- VI: Optimization results for wear and CFs

Number	CS	Fr	DoC	Desirability	Remarks
1	70	0.08	0.45	1	Selected
2	166.67	0.08	0.43	1	
3	76.67	0.12	0.43	1	
4	170	0.12	0.45	1	
5	76.67	0.1	0.32	1	

IV. CONCLUSION

This paper investigates a detailed trial analysis on the influence of machining factors on the TW through hard turning of AISI4140 (47 HRC) steel. Coated carbide tool is utilized as the insert. An RSM with BBD method is utilized for experimentation. Optimal cutting circumstances are consequent for decreasing TW.

- The statistical analysis shows the developed regression model is significant. The Pred- R^2 value of 0.8264 indicates good prediction ability.
- The ANOVA results shows, the CS is the most influencing factor for TW monitored by DoC.
- The influence of process variables interactions on TW are initiate out from the surface exploration plot and the interaction of CS and Fr with TW are significant. The interaction of Fr and DoC with TW are also significant.
- The optimal cutting circumstances for decreasing TW are CS=70m/min, Fr=0.08mm/rev and DoC=0.45mm

Nomenclature	
ANOVA	Analysis of Variance
BBD	Box-Behnken Design
CBN	Cubic Boron Nitride
CF	Cutting Force
CI	Carbide Inserts
CS	Cutting speed
df	Degree of freedom
DoC	Depth of Cut
DoE	Design of Experiments
Fr	Feed rate
HRC	Rockwell Hardness
MS	Mean Square
R^2	Determination coefficient
RSM	Response Surface Methodology
SR	Surface Roughness
SS	Sum of Squares
TW	Tool wear
FW	Flank Wear
FFD	Full Factorial Design
HT	Hard Turning

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