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Experinmental Determination and Optimization of Hard Turned Austempered Ductile Iron (ADI) With AL-TI-N Coated Carbide Insert

Rajesh S[*1] Veerapandian R[2] Madhan Kumar S[3] Hari Krishnan M[4] Vignesh T[3]
[1] *Assistant Professor, Department of Mechanical Engineering, RMK Engineering College, Chennai.*
[2] *Assistant Professor, Department of Mechanical Engineering, SVS College of Engineering, Coimbatore.*
[3] *Assistant Professor, Department of Mechatronics Engineering, Sri Krishna College of Engineering and Technology, Coimbatore.*
[4]*P. G Scholar, Government college of Technology, Coimbatore*

Abstract

In this study, the effects of cutting tool insert on surface roughness, cutting force and interface temperature are investigated at varying cutting speed, depth of cut and feed rate. Hard turning process is carried out for three different cutting speeds (55,85,122 m/min), depth of cut (0.5,1,1.5 mm), and feed (0.1, 0.2 ,0.3 mm/rev). Taguchi method is used to find the optimum cutting parameters in hard turning. The orthogonal array and Signal to noise ratio are employed to study the performance characteristics in turning operation of austempered ductile iron with 32 HRC. Optimal cutting parameters for each performance measure were obtained and the experimental results are provided to illustrate the effectiveness of this approach.

Keywords: Cutting force, surface roughness, austempered ductile iron (ADI), feed rate, depth of cut

INTRODUCTION

Austempered ductile iron (ADI) was studied thoroughly in the late 1970s. ADI offers excellent characteristics of strength, ductility and toughness. It is also providing excellent fatigue strength and wear resistance [1-6]. ADI is better than forged aluminium with respect to weight to strength ratio. Higher strength and hardness of ADI have caused many researchers and engineers to doubt the machinability of this material [8]. Some issues of interest for automated tool breakage detection are: limit learning capability, exibility problems in Computer Numerical Control (CNC) or Numerical Control (NC) controller, including relatively large dynamic errors; instability effects in the controller; the noise problem of the sensor technique; variability effects of different machining processes; and vibration effects of different environments (laboratory and factory). In spite of all these problems, the advantages of automated tool breakage detection systems still outweigh those of a manual approach. With the use of tool breakage detection in machine tools, one is able to increase machine tool life, reach a zero-defect rate, and utilize the unmanned manufacturing environment fully. Without the use of compliance in tool monitoring systems, automation of many machining processes would be simply impossible.

Hard Turning:

The turning of material with hardness greater then 35HRC, has become economically, environmental and technically viable. Hard turning is a competitive finishing process for the manufacturing precision mechanical components, the hard-turning process is similar enough to conventional turning that the introduction of this process into the normal factory environment can happen with relatively small operational changes when the proper elements are addressed. Hard turning is best accomplished with the cutting inserts made from carbide [13].

The Taguchi method has become a powerful tool in the design of experiment methods for engineering optimization of a process. The S/N ratio characteristics can be divided into two categories when the characteristic is continuous:

Smaller the better characteristics:

$$S/N = -10\log\frac{1}{n}(\sum y^2)$$

Larger the better characteristics:

$$S/N = -10\log\frac{1}{n}(\sum {}^{1}/_{y^2})$$

Where y is the average of observed data, n the number of observations.

Experiment Details:

In the present investigation, the experiments were performed on MTAB SIMENS 802C CNC is shown in fig 1

Figure 1. MTAB SIMENS 802C CNC

Work Piece Material

The material employed in this study is Austempered ductile Iron (ADI). Specimens were prepared under different austenizing temperature and austempering temperatures. Specimens were prepared at austenised 920° C for 100 min and then austempered in a salt bath at 400° C for 100 min. The final dimensions of the cylindrical work piece are 150 x 50 mm. Its density is 7.22g cm^3. The chemical composition of Austempered Ductile Iron is shown in the table 1.

Table 1. Chemical composition of Austempered Ductile Iron.

Composition	C	Mn	Si	S	P	Cr	Cu	Mg
%	3.66	0.21	2.76	0.021	0.011	0.05	0.28	0.04

Table 2. Mechanical properties.

S.No	PROPERTIES	RESULT
1.	Tensile Strength	430.02n/mm^2
2.	Yield Strength	390.62n/mm^2
3.	Elongation	4.81%

The Cutting Tool

The turning operation has been carried out using multi-layer Al-Ti-N coated carbide insert using Physical Vapor Deposition – Thermal Evaporation Technique with specification as DNMG with 0.4 mm nose radius. Fig. 2 shows the schematic of multi-layer coated Carbide insert. A Right-hand side tool holder designated by ISO as PCLNR 2020 K12 was used for mounting the insert.

Figure 2. Multi-layer Al-Ti-N coated carbide insert using Thermal Evaporation Technique

The parameters chosen based on a literature survey and preliminary investigations in literatures. In total three parameters were considered, there are cutting speed, depth of cut and feed rate and the response parameters are surface roughness, interface temperature and cutting force.

In the present investigation Taguchi's orthogonal array L9 was selected. The analysis of the experimental data was carried out MINITAB 14 software [7].

Table 3. Values of factors at different levels

PARAMETERS	LEVELS		
	L1	L2	L3
cutting speeds (m/min)	55	85	122
depth of cut (mm)	0.5	1	1.5
Feed (mm/rev)	0.1	0.2	0.315

ANALYSIS OF EXPERIMENTAL RESULTS

Factor effect on surface roughness

Table 4 and 5 shows the orthogonal array and experimental results with its corresponding S/N ratio.

Table 4 L9 Orthogonal Array and experimental data.

Run	Cutting speed (m/min)	Depth of Cut (mm)	Feed (mm/rev)
1	55	0.5	0.1
2	55	1	0.2
3	55	1.5	0.315
4	85	0.5	0.2
5	85	1	0.315
6	85	1.5	0.1
7	122	0.5	0.315
8	122	1	0.1
9	122	1.5	0.2

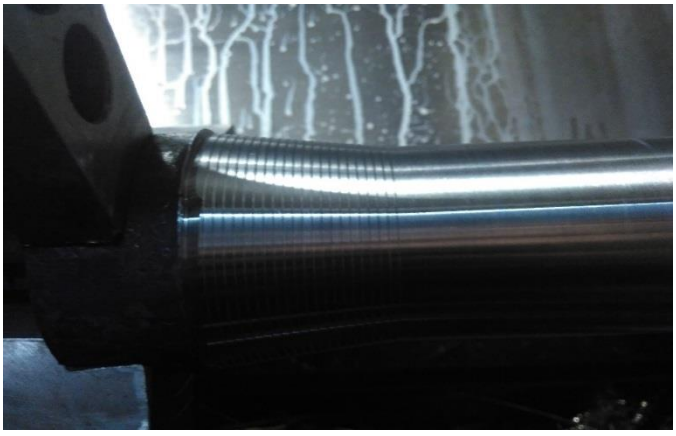

Figure 3. Hard turned ADI

Table 5. Experimental results.

Run	SR	S/N Ratio (dB)	IT	S/N Ratio (dB)	CF	S/N Ratio (dB)
1	2.36	-7.4582	32.16	-30.1463	22.58	27.0745
2	1.27	-2.0761	31.13	-29.8636	20.81	26.3654
3	4.34	-12.7498	56.43	-35.0302	79.25	37.98
4	1.93	-5.7111	34.03	-30.6372	34.69	30.8041
5	2.48	-7.889	41.03	-32.262	61.97	35.8436
6	0.92	0.7242	34.23	-30.6881	37.93	31.5797
7	2.08	-6.3613	30.06	-29.5598	12.601	22.0081
8	1.28	-2.1442	31.23	-29.8914	66.2	36.4172
9	1.27	-2.0761	30.2	-29.6001	63.28	36.0253

Table 6. Response Table for Signal to Noise Ratios Smaller is better

Level	A	B	C
1	-7.428	-6.510	-2.959
2	-4.292	-4.036	-3.288
3	-3.527	-4.701	-9.000
DELTA	3.901	2.474	6.041
RANK	2	3	1

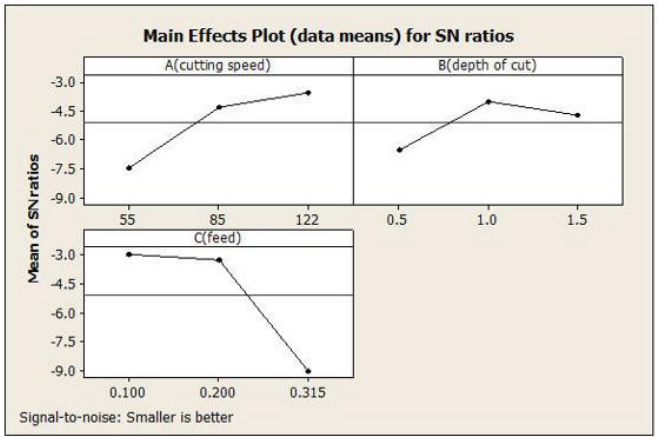

Figure 4. Main effect plots for S/N ratio

Based on the analysis of these experimental results with the help of signal to noise ratio, the optimum condition resulting in surface roughness is shown in the table 6 and figure 4. The figure clearly indicates that the third level of cutting speed, second level of depth of cut and first level of feed rate is optimum for surface roughness [12].

Factor effect on Interface Temperature

Table 7. Response Table for Signal to Noise Ratios Smaller is better

Level	A	B	C
1	-31.68	-30.11	-30.24
2	-31.20	-30.67	-30.03
3	-29.68	-31.77	-32.28
DELTA	2.00	1.66	2.25
RANK	2	3	1

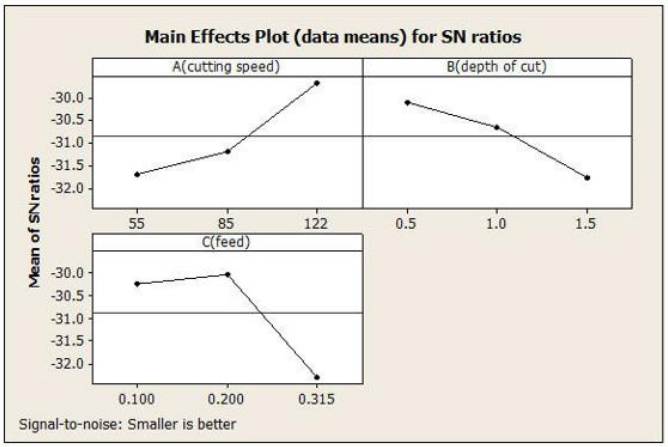

Figure 5. Main effect plots for S/N ratio

Based on the analysis of these experimental results with the help of signal to noise ratio, the optimum condition resulting in interface temperature is shown in the table7 and figure 5. The figure clearly indicates that the third level of cutting speed, first level of depth of cut and second level of feed rate is optimum for interface temperature.

Factor effect on cutting force

Table 8. Response Table for Signal to Noise Ratios Larger is better

Level	A	B	C
1	30.47	26.63	31.69
2	32.74	32.88	31.06
3	31.48	35.19	31.94
DELTA	2.27	8.57	0.88
RANK	2	1	3

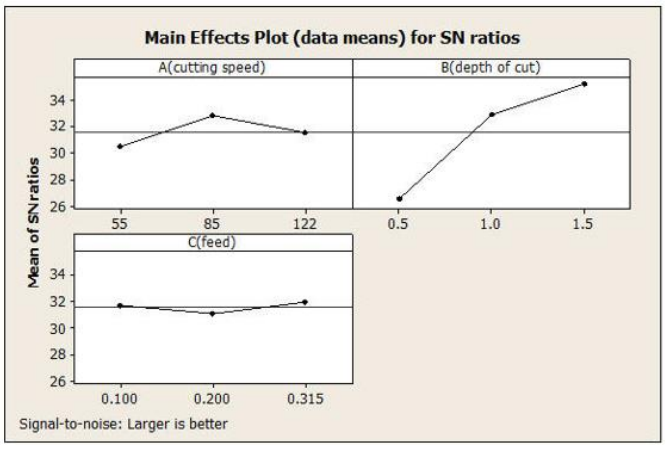

Figure 6. Main effect plots for S/N ratio

Based on the analysis of these experimental results with the help of signal to noise ratio, the optimum condition resulting in cutting force is shown in the table 8 and figure 6. The figure clearly indicates that the second level of cutting speed, third

level of depth of cut and third level of feed rate is optimum for cutting force.

Regression Equation

The following regression equations were found using the least-square method in Minitab-R14 software. In this equation, following units are used to represent the parameters, cutting speeds (55,85,122 m/min), depth of cut (0.5,1,1.5 mm), and feed (0.1, 0.2 ,0.315 mm/rev).

The regression equation is

Surface Roughness = 1.95 - 0.0162 A (cutting speed) + 0.053 B (depth of cut) + 6.88 C (feed)

R-Sq = 95.0% R-Sq(adj) = 93.1%

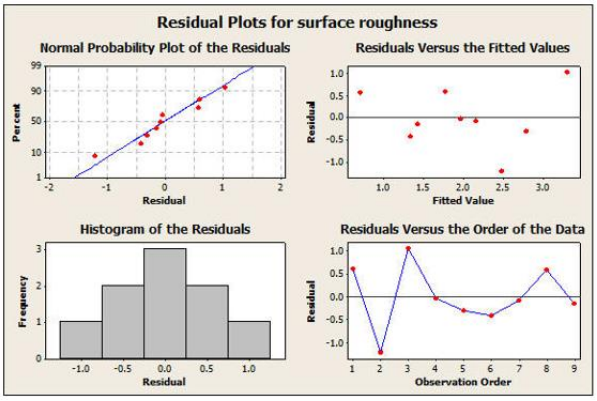

Figure 7. Residual plots for SR

The regression equation is

Interface Temperature = 30.0 - 0.141 A (cutting speed) + 8.20 B (depth of cut) + 47.5 C (feed)

R-Sq = 92.4% R-Sq(adj) = 89.3%

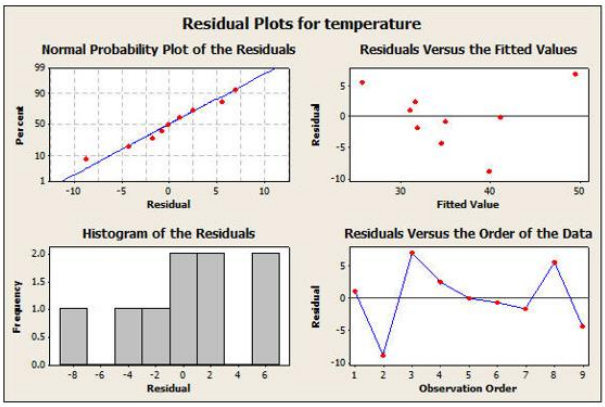

Figure 8. Residual plots for IT

The regression equation is

Cutting Force = - 9.8 + 0.096 A (cutting speed) + 36.9 B (depth of cut) + 43.5 C(feed)

R-Sq = 96.3% R-Sq(adj) = 94.8%

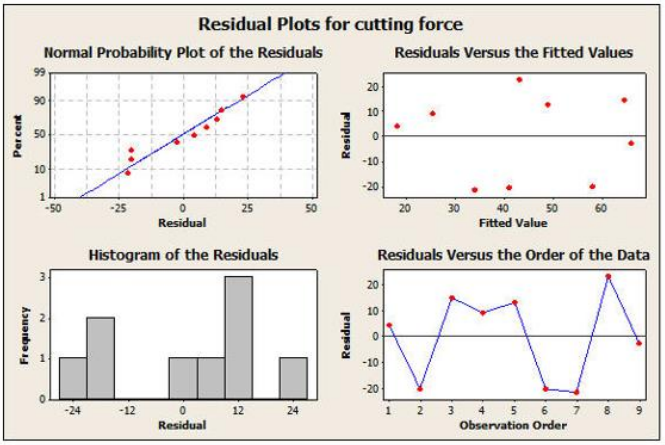

Figure 9. Residual plots for CF

Their R^2 values and adjusted R^2 values confirm the validity of the model as their values are above 90% for all the responses.

Confirmation test:

Confirmation test is the last step in analysis process and the parameter values for three different factors are shown in table 9 and the results of confirmation test are shown in table 10.

Table 9. Confirmation Experiment Parameters

Factors	A	B	C
Value	55	1	0.315

Table 10. Results of Confirmation Experiment

Response	predicted	confirmatory
Surface Roughness	3.27	3.12
Interface Temperature	45.40	44.52
Cutting Force	46.08	46.03

CONCLUSION:

This experiment was conducted to find the influence of the cutting speed, depth of cut and feed on the hard-turning performance characteristics of ADI material with coated insert. It was also tried to formulate a mathematical model for the responses such as SR, IT and CF. The conclusions from the analysis of these experimental results can be specified as follows:

1. Optimum surface roughness, interface temperature and cutting force obtained from the experiment, that the third level of cutting speed, second level of depth of cut and first level of feed rate are the optimum points.
2. The multiple regression equations for surface roughness, interface temperature and cutting force have been obtained.

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