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Design of Experiment Via Taguchi Method For Machining Of AISI D2 Tool Steel In CNC Milling Machine Process

Ravi D. Patel, Nigam V. Oza

[1]Lecturer in Mechanical Engineering Department, K. D. Polytechnic, Patan,
[2]Lecturer in Mechanical Engineering Department, K. D. Polytechnic, Patan,

Abstract - *Hardness greater than 45 HRC, but in general ranges of hardness 53 to 58 HRC, reaching a maximum of 65 HRC, is called "hard machining".By using CNC milling process, a hard machining process provides susceptible benefits in terms of low manufacturing cost with less time compared to traditional machining.Coated tools are generally accepted that coating enhances the oxidation resistance and lubricity of the tool, protects the tool against diffusion wear, and reduces the temperature variation in the tool, rendering it less susceptible to crack. In this paper, TiAlN coated tool is used for machining of AISI D2 tool steel.L-9 orthogonal array is used for experimental work. Taguchi method has been used after experimental work to findout most important affected input parameter.*

Introduction

Milling of hardened steel components provides substantial benefits in terms of reduced manufacturing cost and production time.
Common steels include carburizing steel (~60 HRC), ball bearing steel (~60 HRC) and tool steel (~68 HRC). Hard types of cast irons include white cast iron (~50 HRC) and Construction steel (40–45 HRC).Number of AISI tool steels are also work as hard material which are given below table.

From that, AISI D2 tool steel isAir-hardening, high carbon, high chromium tool steel withextremely high wear resisting properties. High percentage of chromium gives it mild corrosion-resisting properties in the hardened condition.

Table 1. Various Tool Steel Materials

AISI-SAE tool steel grades

Defining property	AISI-SAE grade	Significant characteristics
Water-hardening	W	
Cold-working	O	Oil-hardening
	A	Air-hardening; medium alloy
	D	High carbon; high chromium
Shock resisting	S	
High speed	T	Tungsten base
	M	Molybdenum base
Hot-working	H	H1–H19: chromium base H20–H39: tungsten base H40–H59: molybdenum base
Plastic mold	P	
Special purpose	L	Low alloy
	F	Carbon tungsten

Tool steel (grade D) materials are largely used in the manufacture of cold forming dies owing to excellent wear characteristics and deep hardening. Commonly grade D steels are provided in the annealed condition with maximum hardness of 255 HB[1].

AISI D2 Tool Steel material is dimensionally stable, high-carbon and high-chromium steel with good toughness, and with wide application field. The steel can be used as cutting tools (dies and punches), blanking or punching tools, wood working tools, shear blades, thread rolling tools, tools for deep drawing and cold extrusion, pressing tools, and small moulds for plastic industry[2].

Coating enhances the wear resistance and oxidation resistance. It also reduce temperature produced between tool-workpiece interfaces. So coated tool provide susceptible benefit for hard machining [3].

In milling process, the tool is heated during cutting and cooled when it leaves the cutting zone. Temperature variation can cause periodic expansion and contraction of the tools leading to the formation of thermal cracks which is also known as comb cracks. Thermal cracks are more likely to form at high speeds since the amplitude of the temperature variation increases with increasing speed [4][5]. So dry machining is beneficial for hard machining compare than wet machining.

Experimental Work

For experimental work, Air-hardening, high carbon, high chromium AISI D2 tool steel was used with 150 x 80 x 16 mm dimension. Hardness of AISI D2 tool steel was 58 HRC.

Fig. 1 AISI D2 Tool Steel Workpiece

AISI D2 Steel is examined by spectroscopy to analyse content if AISI D2 tool steel. Test report is given below.

Table 2 Content of AISI D2 Tool Steel

TYPICAL ANALYSIS	**TYPE D2 (UNS T30402)**
Carbon	1.40/1.60
Magnesium	.60 max
Silicon	.60 max
Molybdenum	.70/1.20
Chromium	11.00/13.00
Vanadium (V)	1.10 max
Cobalt (Co)	1.00 max
Nickel (Ni)	.30 max
hardness, Rockwell C	54-61 (Tempered)
TOUGHNESS	Low
WEAR RESISTANCE	High to Very High

CNC milling made by AKIRA SEIKI V 2.5xpwas used for experimental work. Maximum X, Y, Z movement is 30, 17, 20.5 Inch. Maximum spindle speed is 12000 rpm with 22 hp.

Fig 2. CNC milling machine

TiAlN Coated tool was used as a cutting tool for experimental work. L-9 orthogonal array was used for decide number of experiment. This method gives means (average) and variation of experimental results for calculating S/N (Signal to Noise ratio) which describe the test results.
Surface roughness measurements in micrometer were repeated three times on respective cutsusing Stylus probe surface roughness meter and average value was considered for the analysis purpose[7][8].The stylus instrumentation is a widely used technique for analysing technical surfaces. A diamond stylus is traversed across the surface. It' vertical displacement is converted into electric signal representing the profile. Instruments digitize the electrical signal and store for further analyses [9].

From need of specific application, by using these S/N ratio, the range of level can be calculated by design of experiment via Taguchi method. The S/N ratio is considered as smaller is better, larger is better, nominal is best for different output machine response variables. [6] In this study, the value of S/N ratio for surface roughness is considered as smaller is better.
The S/N ratio for the smaller-the-better is

$$S/_N \quad ratio = -10 \log\left(\frac{1}{n}\sum_{i=1}^{n} y_i^2\right)$$

In the equations below, y_i is the mean value and si is the variance. y_i is the observed data at i^{th} trial and n is the number of trials. Where Y_i is the value of surface roughness for the i^{th} test in a run. In our case, n=1. The working ranges of the parameters (shown in table 2) for subsequent design of experiment, based on Taguchi's L9 Orthogonal Array (OA) design have been selected. In the present experimental study, CNC milling machine parameters like speed, feed and depth of cut have been considered as process variables with their units. Following cutting parameters and levels were taken for experimental work.

Table 3 Input parameters for experimental work

Cutting Speed (m/min)	100, 140, 170
Feed (mm/rev)	0.1, 0.2, 0.4
Depth of cut (mm)	4,8, 12

Result and Analysis
Taguchi's orthogonal array method was used for S/N ratio calculation of surface roughness. Following experimental result were observed.

Table 4 S/N ratio value for surface roughness value

Cut Speed (m/min)	Depth of Cut (mm)	Feed Rate (mm/rev)	Surface roughness (µm)	S/N for surface Roughness
100	4	0.1	0.47	6.558
100	8	0.2	0.58	4.731
100	12	0.4	1.67	-4.454
140	4	0.4	0.44	7.131
140	8	0.1	0.46	6.745
140	12	0.2	0.73	2.733
170	4	0.2	0.32	9.897
170	8	0.4	1.18	-1.437
170	12	0.1	0.50	6.021

Now from above calculation[10], first we decide which parameters are most affected on surface roughness. Once these S/N ratio values are calculated for each factors and levels, they are tabulated as shown below table and Range (R) of the S/N for each parameter is calculated and entered into the table(see Table 5).

Table 5 calculation of Range for surface roughness

Input Parameters	**Low**	**Medium**	**High**	**Range**	**Rank**
C.S.	2.27	5.536	4.827	3.266	3
Feed	6.441	5.787	0.413	6.028	2
DOC	7.862	3.346	1.433	6.429	1

So from the above rank, Depth of cut is most significant parameter for surface roughness and Cutting speed is less variation by changing of it.

Conclusion

Hard machining in CNC milling machine, three parameters are mostly important in case of machining like feed rate, cutting speed and depth of cut. These parameters are responsible for good surface finish. Now by experimental analysis on AISI D2 Tool steel,Depth of Cut is most important factor for high surface finish (low surface roughness).

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