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Prediction and optimization of process parameters of CNC machine on carbide inserts

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Abstract

The carbon bearing steel has wide applications and therefore the demand is increasing worldwide. Turning process is used in machining of C56E2 steel which is widely use in automobile industry for making carbide inserts. The present work aims at prediction and optimization of process parameters of CNC machine on carbide inserts. The experiments are performed to evaluate material removal rate and surface roughness at different machining condition. The experiments are conducted using Taguchi design matrix with three level of four controllable parameters and two response parameters. Material removal rate and surface roughness are consider as important response measures which are functions of cutting speed, depth of cut, feed rate, and soaking time. The effect of process parameters on material removal rate and surface roughness are predicted and the optimal conditions are calculated by using a technique called grey relation analysis.

Keywords: Carbide inserts, Taguchi design, Grey relation analysis, etc.

1. Introduction

The CNC turning machines find extensive application in automotive industries. Turning is common operation used for production of parts where cutting speed and thus the material removal rate (MRR) is limited due to high tool wear rate. Use of alternative techniques is increases in order to increase productivity in machining. Tungsten carbide cutting tool is generally used in CNC turning process.Tungsten carbide is having high wear resistance and high hardness. Machining the cutting tools are subjected to high heat and tool wear (Mukkoti et al., 2018). While machining due to high heat generation cutting tool material get softened which leads to tool wear. The tool life is affected by many factors such as cutting speed ,depth of cut ,chip thickness ,tool geometry material or the cutting fluid . Physical and chemical properties of work material influence tool life by affecting from stability and rate of wear of tool .In order to increase productivity , it is necessary to reduce tool wear ,reduce material removal rate and reduce cycle time . In stead of seaking out for new tool or new tool material it is better to develop a working tool in such a way that it will give more productivity and les tool wear.In order to achieve a longer tool life and high tool performance, Cryogenic treatment with ultralow temperature and helium gas is used. Cryogenic treatment is performed to increase wear resistance of carbide tool to reduce friction on cutting zone (Gholsp and Method, 2015. The motivation behind cryogenic treatment is to transform retained austenite phase to martensite phase and raise the hardness of structure. Different methods are used to increase life of cutting tool and to minimize environmental damage of manufacturing process and to reduce cutting tool cost.High machining temperature, excessive tool wear are major two obstacles that increase machining cost. The main objective of this paper is to increase tool life, reduce cycle time for machining. The experiments performed using carbide insert for machining of C56E2 steel. The carbide insert are cryogenically treated for different soaking time to increase hardness of insert, thus to reduce the tool wear and increase productivity. The experiments performed to evaluate material removal rate and surface roughness, cycle time at different machining condition like cutting speed, depth of cut, feed rate, and soaking time (Kaynak and Gharihi, 2018)

Cryogenic treatment is used for treating carbide insert. During deep cryogenic treatment secondary carbide participate in austenite matrix promote the transformation of retained austenite to martensite and consequently enhance hardness and wear resistance. In most hardening treatment ,cooling is stopped at room temperature or above so at end of hardening operation metals or cutting tool may contain some austenite which has not transformed (Yildiz and Nalbant, 2008). This is generally referred to retained austenite property.With increase of heating temperature of high carbon alloy steel, more and more carbon and alloy elements are dissolved in austenite. Higher the carbon and alloy content of austenite, larger is the amount of austenite that untransformed at room temperature austenite at room temperature is ductile and much softer than martensite when the amount of retained austenite increases beyond a level the hardness of steel deceases appreciably.The life of cutting tool are increased by cryogenic treatment in case of steel, the benefits are actually attributed to reduction or elimination of retained austenite because of cryogenic treatment this retained austenite is converted into martensite(Kumar et al., 2015). It improves the cutting tool life. Cryogenic treatment of metal improves the wear resistance.

2. Literature Survey

"Guzel et al. (2014)" presented the work on increasing tool life in machining of difficult to cut materials using non-conventional turning process and they concluded that it is possible to achieve 3-20 times better tool life with turn-milling and rotary turning operation compared to conventional turning. "Vishnu et al. (2018)"observed the Effect of cryogenic treatment of tungsten carbide tool on cutting force and power consumption in CNC milling process .The effect of Deep Cryogenic Treatment (DCT)soaking duration on tungsten carbide end mill cutters. The data collected for the study were based on Box-Behnken design of response surface methodology. The results indicate DCT tools soaked for longer duration is minimizing the cutting forces and power consumption when compared to untreated tool. "Firouzdor et al. (2007)"represented work on effect of deep cryogenic treatment on wear resistant and tool life of M2 HSS drill. The influence of deep cryogenic treatment on wear resistance and tool life of M2 HSS drills in high-speed dry drilling configuration of carbon steels was studied. The experimental results indicated 77% and 126% improvement in cryogenic-treated and cryogenic- and temper-treated drill lives, respectively. The results of wear rate test were in agreement with drill life test. "Celik et al. (2017)" observed effect of cryogenic treatment on the microstructure and wear behaviour of WC-Co end mills for machining of Ti6Al4V titanium alloy. This work compares some of the key machinability aspects acquired during milling of Ti6Al4V titanium alloy with uncoated and coated cryogenically treated end mills. Tool wear, coefficient of friction, cutting force, and chip morphology were the major criteria considered.These improvements were characterized with hardness, fracture toughness, scanning electron microscope (SEM), energy-dispersive spectroscopy (EDS), and X-ray diffraction (XRD) analyses.

"Lee et al. (2015)" worked on tool life improvement in cryogenic cooled milling of the preheated Ti-6Al-4V. Cryogenic-based machining has been drawing attention for machining hard metals and super alloys such as the titanium alloys due to environmental concerns and growing regulations over pollution. "Hong et al."studied, cryogenic-assisted milling of Ti–6Al–4V has been performed with the preheated workpiece methods to avoid the cryogenic hardening by liquid nitrogen (LN2). It was observed that the tool life was increased by 50 to 90 % for Si-coated tools and 50 to 55 % for CrTiAlN-coated tools. "Kursuncu et al. (2018)" represented study of improvement of cutting performance of carbide cutting tools in milling of the incoel 718 super alloy using multilayer nanocomposite hard coating and cryogenic heat treatment .In this study, milling of the Inconel 718 super alloy was performed in dry conditions with the aim of reducing the adverse effects of the coolant on the environment. As a result, the life of the cutting tools has been increased by the thin film coating and cryogenic heat treatment applied to the cutting tools. TiAlN-coated carbide cutting tools increases by 54, 110, 29, and 30%.The EDS analysis applied to the worn tools revealed that the mechanisms causing wear of the cutting tools were abrasion and adhesion. "Manjunath S et al. (2016)" observed that cryogenic framework permit to control vital cycle parameters for example, cooling rate, temperature. "Kumar K et al. (2015)" studied the wear data on various scrapped tools and increase the tool life which results in one of the major form of cost savings in manufacturing industry. After analysing the data collected during the study period the process of standardization of all the important parameters pertaining to a tool can be initiated. "Singh et al. (2012)"represented the results of the experimental investigation of cryogenically treated, coated and uncoated tungsten carbide cutting tool inserts in turning of AISI 1040 steel. Experiments performed to evaluate the cutting forces and tool wear at different machining condition. The results of an experimental investigation that has been carried out on uncoated carbide inserts of type TTR and TTS against C-40 job comparing with the untreated and deep cryogenically treated inserts. Many researcher worked on cryogenic treatment for increasing tool life. For that different types of tools(with different chemical compositions) and different types of operations like turn milling, rotary turning, CNC milling, drilling etc. were used for experimentation. The different parameters such as cutting force, power consumption, wear resistance, environmental concepts, coefficient of friction, chip morphology, microstructure are considered. Most of the researchers has used deep cryogenic treatment with different soaking time and cryogenic treatment by using liquid nitrogen. Till now no one has increased tool life using helium gas with increasing production rate and reducing cost of tool.The present work aims at prediction and optimization of process parameters of CNC machine on carbide inserts.

3. Experimentation

The experiments were conducted on CNC machine. The workpiece rotates in spindle and tool moves in X and Y direction. The workpiece was attached to spindle. The test material were chosen as C56E2 since these materials are commonly used in automobile industry. The composition of workpiece material is given in Table 1. The experiments were repeated under different input parameter like feed rate, depth of cut, cutting speed, soaking time. The inserts used for turning is TNMG-160408DC8035 single point cutting tool with cryogenically treated for different soaking time. The cutting speed, depth of cut, feed rate and soaking time set on machine and experiments were conducted. Material removal rate is calculated and surface roughness are measured using surface roughness tester. The experimental CNC machine setup is shown in Fig 1.

Table 1 Workpiece material composition

Element	W	Fe	Ti	Co	Nb	Ta
Percentage	80.54	0.62	9.33	8.31	0.26	0.85

Fig 1. CNC Machine Setup

The main objective is to study the effect of input process parameters on MRR and surface roughness while machining C56E2 steel material in CNC turning process and also optimization of process parameters. For the experimental study the machining parameter such as feed rate, cutting speed, depth of cut and soaking time are considered. The parameter design was done with three levels of machining parameters. The machining parameter and level used in the experiment can be summarized as follows in Table 2. The experiment was done on CNC turning machine by tungsten carbide insert. The material removal rate and the surface roughness are calculated. The material removal rate was calculated using the formula.

MRR = (IW-FW)/t equation (1)

where, IW=initial weight of the workpiece, FW=final weight of the workpiece, t=time in seconds during turning operation. A Taguchi design of matrix is used for experimentation and surface roughness and material removal rate are measured as given in Table 3.

Table 2.Machining parameter and their level

Machining parameter	Notations	Units	Level 1	Level 2	Level 3
Feed Rate	F	mm/min	0.20	0.25	0.30
Cutting Speed	S	rpm	250	280	310
Depth of Cut	D	mm	0.6	0.8	1.0
Soaking Time	T	hr	14	16	18

Table 3. Taguchi Design Matrix and Response Parameters

Sr. No.	Process Parameters								Response Parameters	
	Coded Value				Uncoded Value					
	F (mm/min)	D (mm)	S (rpm)	T (hr)	F (mm/rev)	D (mm)	S (rpm)	T (hr)	MRR (mm^3/min)	Ra
1	1	1	1	1	0.2	0.6	250	14	0.0017	2.26
2	1	2	2	2	0.2	0.8	280	16	0.0018	2.56
3	1	3	3	3	0.2	1.0	310	18	0.0019	2.86
4	2	1	2	3	0.25	0.6	280	18	0.0017	2.61
5	2	2	3	1	0.25	0.8	310	14	0.0018	2.43
6	2	3	1	2	0.25	1.0	250	16	0.0018	2.20

7	3	1	3	2	0.30	0.6	310	16	0.0018	2.43
8	3	2	1	3	0.30	0.8	250	18	0.0018	2.87
9	3	3	2	1	0.30	1.0	280	14	0.0026	2.43

4. Result and Discussion

4.1 Effect of input process parameters on response parameter

For analysis of effect of input process parameters graphs are drawn as follows:

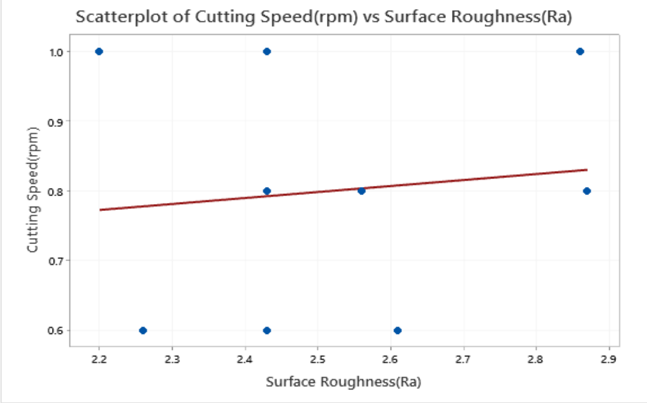

Fig 2. Cutting speed vs Surface Roughness

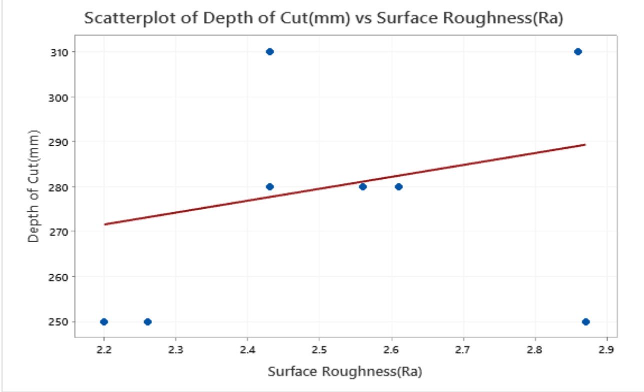

Fig 3. Depth of cut vs Surface Roughness

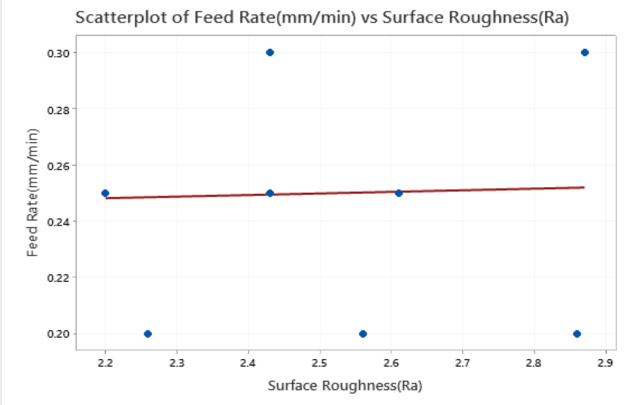

Fig4. Feed rate vs Surface Roughness

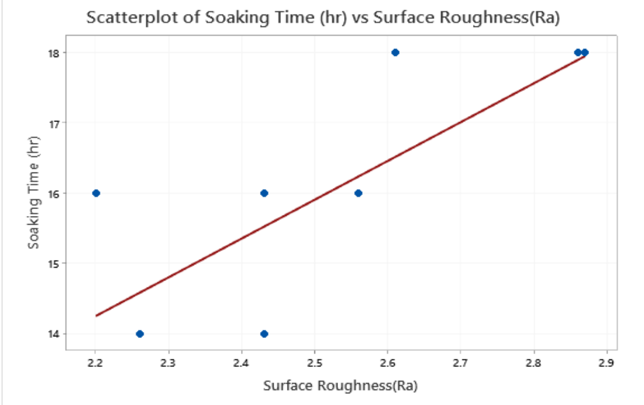

Fig 5. Soaking Time vs Surface Roughness

Fig 2. shows that as cutting speed for machine increases the surface roughness also increases. Fig3. showsthat as depth of cut for machine increases the surface roughness also increases. Fig 4. showsthat as feed rate for machine increases, the surface roughness also increases. Fig 5. showsthat as soaking time for cutting tool increases, the surface roughness also increases.

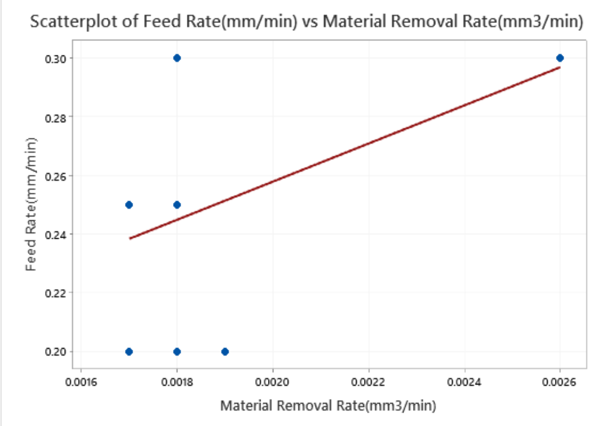

Fig 6. Feed rate vs MRR

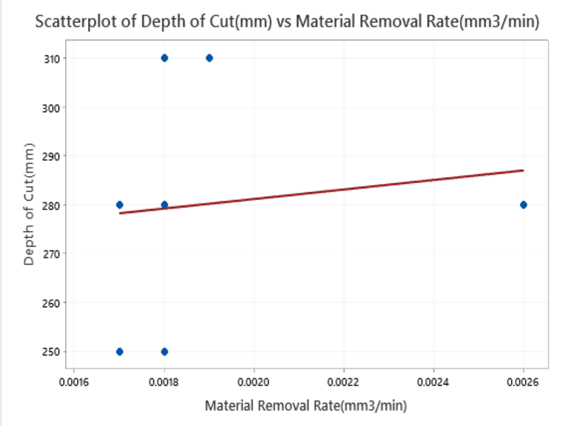

Fig 7. Depth of cut vs MRR

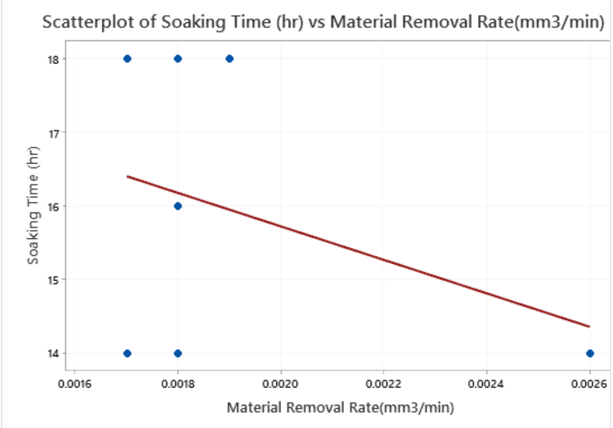

Fig 8. Soaking time vs MRR

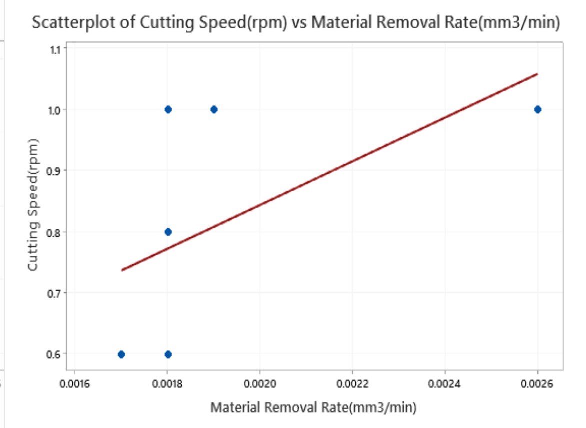

Fig9. Cutting Speed vs MRR

Fig6.showsthat as feed rate for machine increases, the material removal rate also increases. Fig7. shows that as depth of cut for machine increases, the material removal rate also increases. Fig8. shows that as soaking time for cutting tool increase, the material removal rate also increases. Fig9. shows that as cutting speed for machine increases the material removal rate also increases.

4.2 Optimization of input process parameter by Grey Relation Analysis:

After experimentation the surface roughness was calculated using surface roughness tester. Similarly the MRR was calculated using equation (1).The Table 3 shows the L9 orthogonal array designed by Taguchi methodology with experimental results. The left side of table 3 provides the input parameter namely Feed Rate, Speed, Depth of cut. The right side of table 3 provides the performance characteristic namely material removal rate and surface roughness. The parameter of 250 rpm at 0.2mm depth of cut gives better removal rate. The increase in depth of cut rise the MRR. Similarly reduction in speed gives good surface roughness of work piece.

The normalized values for both the material removal rate and surface roughness calculated in grey relation analysis. The surface roughness and material removal rate taken as smaller is better characteristics. The normalized values are given in Table 4. The grey relation coefficient are calculated in Table 4. The material removal rate and surface roughness coefficient are used to find the grey relation grade. The grades are described in Table 4 shows the grey relation grade corresponding to the combination of parameters namely surface roughness and material removal rate. So, the grey relation grade is highest for combination of parameters namely speed=250 m/s, feed rate=0.2 inches/revolution, depth of cut =0.6, soaking time=14 sec.The present optimization results are MRR 0.0017mm^3/min and surface roughness 2.26 N/m.

Table 4 Grey relation analysis

Sr. No.	Process Parameters	Grey relation values	Grey relation Coefficients	
		Response Parameters		

	F (mm/ min)	D (mm)	S (rpm)	T (hr)	MRR (mm^3/min)	Ra	MRR (mm^3/ min)	Ra	Grey Relation Grade	Rank
1	0.2	0.6	250	14	1.000	0.910	1.000	0.848	0.924	1
2	0.2	0.8	280	16	0.889	0.463	0.818	.0482	0.650	6
3	0.2	1.0	310	18	0.778	0.015	0.692	0.337	0.514	8
4	0.25	0.6	280	18	1.000	0.388	1.000	0.450	0.725	3
5	0.25	0.8	310	14	0.889	0.657	0.818	0.593	0.706	4
6	0.25	1.0	250	16	0.889	1.000	0.818	1.000	0.909	2
7	0.30	0.6	310	16	0.889	0.657	0.818	0.593	0.706	4
8	0.30	0.8	250	18	0.889	0.000	0.818	0.333	0.576	7
9	0.30	1.0	280	14	0.000	0.667	0.333	0.593	0.463	9

5. Conclusion

A Taguchi's L9 orthogonal array is used to study the effect of machining parameters such as speed, feed rate, depth of cut and soaking time on response parameters such as surface roughness and material removal rate in machining of C56E2 steel. Also, grey relation analysis method is used to optimize machining parameters. It is found that the best optimal combination of input parameters are speed=250 m/s, feed rate=0.2 inches/revolution, depth of cut =0.6, soaking time=14 seconds for better surface roughness and material removal. Also, it is found that the depth of cut is most important factor affecting both surface roughness and material removal rate.

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