ISSN: 0976-3031

Available Online at http://www.recentscientific.com

International Journal of Recent Scientific Research
Vol. 7, Issue, 7, pp. 12266-12269, July, 2016

International Journal of Recent Scientific Research

Research Article

EXPERIMENTATION OF MULTI-OBJECTIVE OPTIMIZATION OF MACHINING PARAMETERS FOR MILLING PROCESS

Purna Chandra Sekhar B[1]., Sarath Kumar G[2] and Prabhakar Y.V[3]

[1,2]Acharya Nagarjuna College of Engineering and Technology
[3]Aditya College of Engineering and Technology (Ii-Shift Polytechnic)

ARTICLE INFO

Article History:
Received 10th April, 2016
Received in revised form 14th April, 2016
Accepted 08th June, 2016
Published online 28th July, 2016

ABSTRACT

The study of metal removal rate and cutting temperature is most significant among the others like features of tools and work materials. Since these are the determinant factors of the production rate and cost-efficiency of the tools. Milling of hardened tool steels became a highly expensive for the manufacturing industries today as these are being widely used in many applications like automobile, structural, etc. A significant improvement in the efficiency of this process may be obtained with the development of mathematical relations between the set of input and output parameters of a machining process.

In the first part of this investigation, CNC milling experiments are conducted to machine hardened EN 31 tool steel with carbide cutting inserters. Initially, the design of experiments was conducted to plan the experimentation by considering the machining variables of depth of cut, feed and spindle speed. Metal removal rate and cutting temperature were considered as the response variables to measure during the each experimental run. Response surface methodology was used to build the mathematical surface models for the measured values of responses. The ANOVA technique has been used to verify the adequacy of the models at 95% confidence interval.
Since the influence of machining parameters on the metal removal rate and cutting temperature are with conflicting nature, the problem is considered as multi-objective optimization problem.

In the second part, a multi-objective optimization algorithm Gray relational analysis (GRA) was adapted to the measured machining response values to obtain the optimal set of input parameters.

Therefore, the present work enables the industries to perform the CNC milling operations on the hardened EN 31 material within the optimal levels of tool temperatures by maximizing the metal removal rate.

INTRODUCTION

Many approaches have been proposed to minimize the heat generation and enhance tool life and metal removal rate in metal cutting. As the chip formation process in machining is accompanied by heat generation, which influences the mechanical and physical properties of both the work piece and the cutting tool. High temperatures tend to accelerate thermal softening of the tool and subsequent tool wear, which are not desirable because they negatively impact the accuracy of the machined surface and tool life.

Hard milling is a machining process to cut the hardened materials of hardness range over 45 HRC with single point cutting tool. Now a day, hardened steels are being used in a variety of industrial applications like automotive parts such as studs, bearings, gears, cams, etc. However, it is to be noted that the turning of hardened steel with commonly used cutting inserts is influenced by more number of machining parameters and they adversely affects the performance of machining process. In order to minimize this, the conventional cutting inserts are getting replaced by specialized cutting inserts to cut the hardened materials lately. Some of these specialized inserts in existence are cubic boron nitride (CBN) inserts, polycrystalline cubic boron nitride (PCBN) and ceramic inserts. Some experimental investigations have been attempted to predict the performance of hard turning with the mentioned specialized cutting inserts.

The main issue is the progressive wear of the milling tool [1,2] which in combination with low effective cutting speeds [2] results in irreparable surface defects like micro crack formation, surface penetration, rapture and plastic deformation as well as local re-hardening due to formation

---

*Corresponding author: *Purna Chandra Sekhar B*
Acharya Nagarjuna College of Engineering and Technology

of new martensite on the work piece surface. To reduce the milling related impact to the sub-surface area new process technological approaches for high-speed cutting have been developed in the last decades.

LITERATURE SURVEY

Hardened steels are being used in a variety of industrial applications like automotive, aerospace etc. These materials are often classified as difficult-to-machine materials due to high strength and low thermal conductivity. This drives to severe cutting forces and cutting temperatures and hence a shorter the tool life. Tool life is the significant economic factor, particularly for milling and turning of heat resistant alloys [1]. Agawal *et al*. [2] assessed the relative performance of coated and uncoated carbide tools (inserts) in the machining of three cast austenic stainless steels. Uhlmann *et al*. [3] stated that, the harder diamond tools cannot be used to machine the steels due to reactive nature and the secondary harder tools like cubic boron nitride (CBN) and PCBN are efficient in place of former but are highly expensive. Szymon *et al*. [4] Presented a comparison of tool life of sintered carbide and CBN ball end mills. This investigation revealed that the tool life of sintered carbide is higher than the CBN up to a certain range of cutting speed. Also, the cutting speed was observed as an independent dominating factor on abrasive wear of CBN cutter. Pinaki Chakraborty *et al*. [5] developed the a mathematical model for tool wear during end milling of AISI 4340 steel with multilayer physical vapor deposition (PVD) coated carbide inserts under semi-dry and dry cutting conditions. From this research, it is also observed that cutting speed has the most comprehensive effect on tool wear progression. Aslan *et al*. [6] performed a comparative study on cutting tool performance in end milling of AISI D3 tool steel with coated carbide, coated cermet, alumina (Al2O3) based mixed ceramic and cubic boron nitride (CBN) cutting tools.

Implementation of Proposed Methodology

Experimental Details

In this work, depth of cut, feed and cutting speed are considered as the control variables and MRR and cutting temperature as the output responses. In order to reduce the number of experimental runs, experiments were planned based on design of experiments (DoE). Central composite design with 27 experiments was selected. Table 1 lists the machining conditions and Table 2 lists the feasible values of each process variable. Experiments are conducted on a precision CNC milling machine model BFW AGNI 45. Hardened steel EN31 plate of size 150x100x10 mm with ≈ 60 HRC is considered as the work piece material and TaeguTec make M9810048402 carbide milling turning inserts and with SCRM90TP45016R18DTGNL milling cutter with 4 cutting inserts was used in machining. For each experimental run, the metal removal rate is calculated by the weight loss method. Each experiment is run for a fixed length of 75 mm length. During each experiment the cutting temperature was measured by a IR Thermometer by maintaining 1.5 meter distance between the thermometer and cutting tool edge. Each experiment was repeated for three times and the average of the measures values were considered as the final response values. Table 3 represents the matrix of experimental values. The Fig.1 shows the experimental setup. The Figs.2 and 3 show the cutting tools & cutter and the IR Thermometer for temperature measurement used in experimentations. The recorded temperature using IR thermometer during the 10th experiment is shown in The Fig. 4.

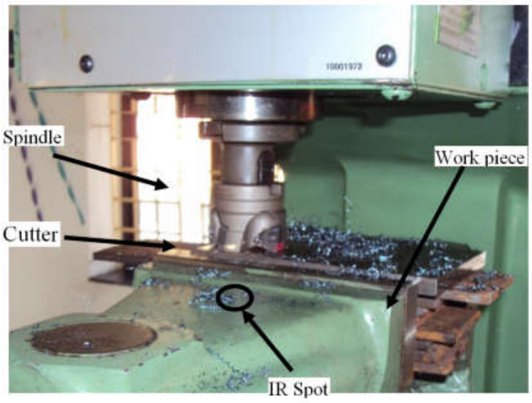
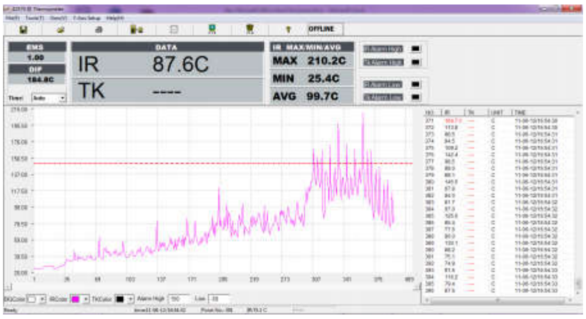


Figure 1 Experimental setup

Figure 2 Cutting inserts and the milling cutter

Figure 3 IR Thermometer



EMS 1.00
DIF 184.8C
IR 87.6C
TK ----
MAX 210.2C
MIN 25.4C
AVG 99.7C

Figure 4 Recorded temperature using IR Thermometer during the 10th experiment. The machining conditions at which the experiments were conducted are listed in Table1

Table 1 Machining conditions

(a)	**Work piece material:**	**EN 31 hardened to about 60HRC**
(b)	Chemical composition:	C-0.43%, Si-0.26%, Mn-0.58%, Cr-1.17%, Ni-1.35%, Mo-0.25%, P-0.028%, S-0.036%
(c)	Work piece dimensions:	150x100x10 mm
(d)	Location of work piece:	Between chuck over the table
(e)	Temperature measurement	IR Thermometer Model: 42570, Make: EXTECH Instruments. Range : up to 2000 deg. C
(f)	Milling Machine	Model : AGNI 45 Make : BFW
(g)	Milling Cutter	Model : SCRM90TP45016R18DTGNL Make : TaeguTec
(h)	Cutting Inserts	Designation : M9810048402 Make : TaeguTec
(i)	Machining Type	Dry Machining

Table 2 Control factors and their levels

S no.	Parameter	Units	Notation	-1	0	+1
1.	Depth of cut	mm	X_1	0.1	0.2	0.3
2.	Feed Rate	mm/tooth	X_2	0.1	0.3	0.5
3.	Cutting speed	m/min	X_3	120	180	240

RESULTS AND DISCUSSION

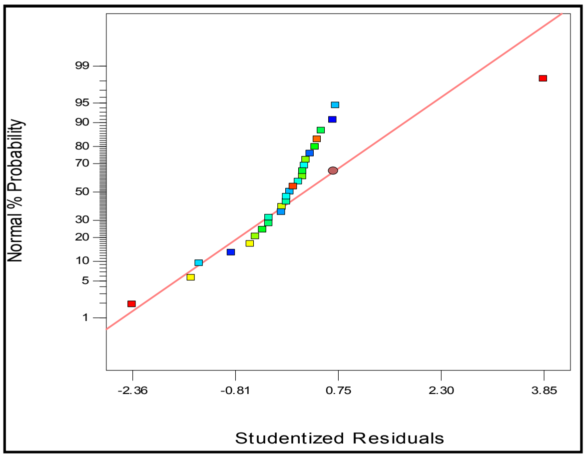


Fig. 5 Normal probability plot of the residuals for T_C

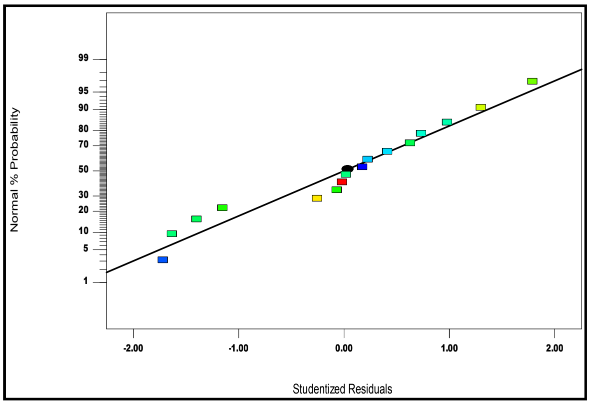


Fig 6 Normal probability plot of the residuals for MRR

Fig 7 shows the effect of cutting temperature with respect to depth of cut. As the depth of cut increases the cutting temperature increased. At a particular feed and speed, the tool wear increases with the increase in depth of cut. As a result of this nose radius of tool increase rigorously. Hence cutting temperature increases with the increase in depth of cut.

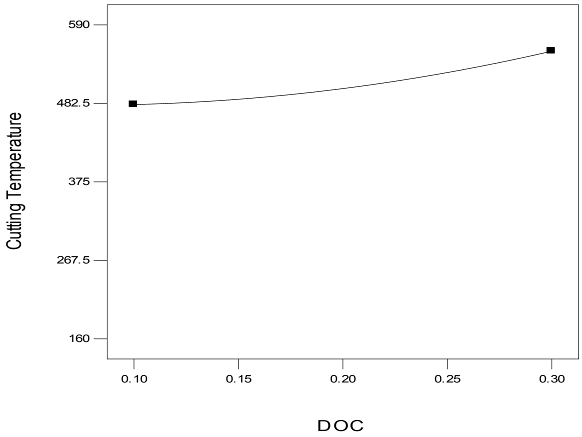


Fig 7 Effect of Depth of Cut on Cutting Temperature

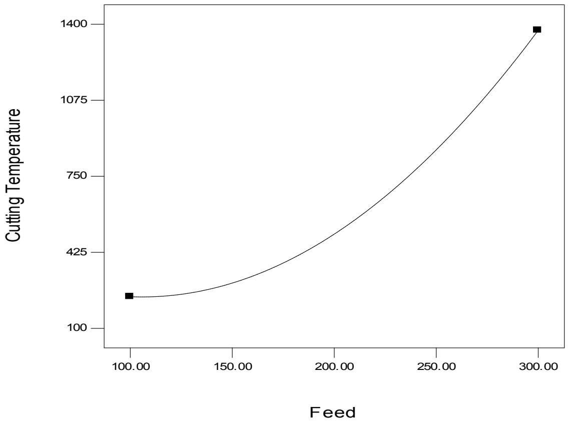


Fig 8 Effect of feed on cutting temperature

Fig 8 shows the effect of feed on cutting temperature. In this figure, the cutting temperature is increased with the increased feed. This is because; during machining more amount metal is fed against the cutting tool with increased feed rate. Due to this, the cutting forces increases. Hence the cutting temperature increased with increased feed rate.

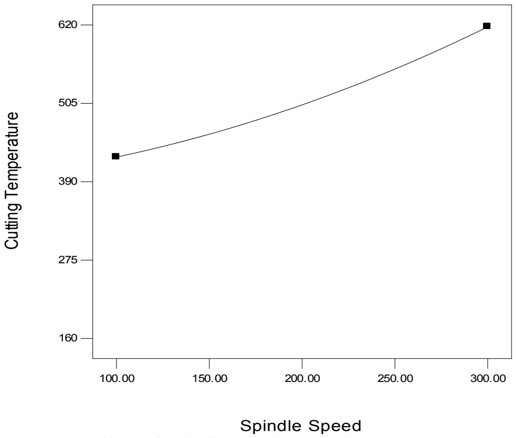


Fig 9 Effect of spindle speed on cutting temperature

Fig 9 shows the effect of spindle speed on cutting temperature. The increased spindle levels of spindle speeds are also increases the cutting temperature. This is because; the rubbing action is more between the cutting tool and work piece and hence the cutting temperature is increased for the increased spindle speed.

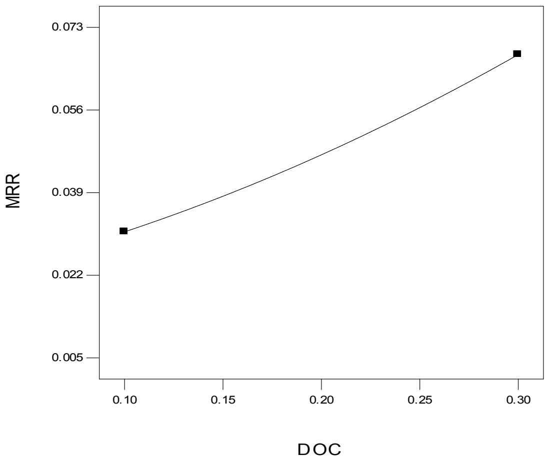


Fig 10 Effect of Depth of Cut on Metal Removal Rate

Fig 10 shows the effect of metal removal rate with respect to depth of cut. The increased nature of metal removal rate can be observed from the figure with the increased depth of cut. At a particular feed and speed, the amount of metal removed per unit time or per unit length of work piece is increased with the increase in depth of cut. Hence metal removal rate is increased for the increase in depth of cut.

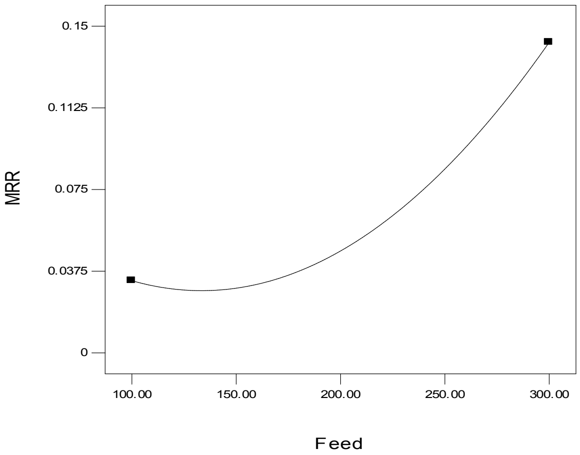


Fig 11 Effect of Feed on Metal Removal Rate

Fig 11 shows the effect of Feed on metal removal rate. As feed increases the metal removal rate is also increased.

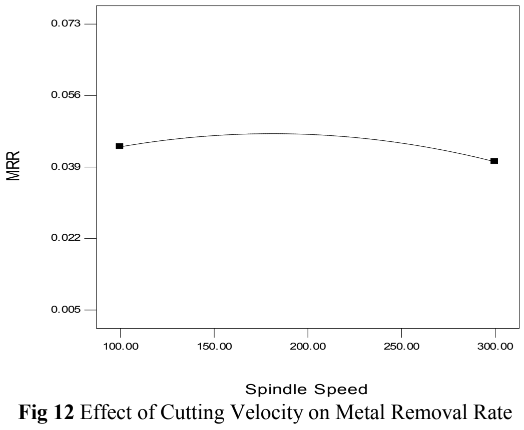


Fig 12 Effect of Cutting Velocity on Metal Removal Rate

This is because; during machining more amount metal is fed against the cutting tool with increased feed rate at particular depth of cut and cutting speed. Hence the metal removal rate was increased with increased feed rate.

Fig 12 shows the effect of cutting velocity on metal removal rate. In this figure, as cutting velocity increases, the metal removal rate is increased up to the middle level of speed and then decreased. This is because; during machining more amount metal is fed against the cutting tool with increased cutting velocity. As the speed increases further, the built-up edge will form on the cutting edges causes to decreased metal removal rate.

CONCLUSIONS

This paper aimed to develop the empirical models and investigate the optimal machinability parameters of milling process during machining EN 31 tool steel. In this consequence, milling experiments were conducted on vertical milling milling centre based on central composite design with 27 experiments. The response surface methodology was adopted to develop the mathematical models for the responses and ANOVA is used to check the adequacy of the developed models and were found that the developed second order models can explain the variation in the temperature up to the extent of 98.06% and 99.07%. Then these experimentally measured values were carried to the optimization. GRA was successfully implemented to the measured experimental runs. The resulted optimal values of the milling process were listed. Hence, an operator can easily find out the optimal marching conditions without compromising at either metal removal rate or the cost of tooling with this investigation.

References

1. Okada, M., Hosokowa, A., Tanaka, R., Ueda, T. Cutting performance of PVD-coated carbide and CBN tools in hard milling, *International Journal of Machine Tools & Manufacture*, 2011, 51, pp. 127–132.
2. E.J.A. Armarego “Fundamental studies of driven and self-propelled rotary tool cutting process”- theoretical investigation, July 1993.
3. Shuting Lei “High speed machining of titanium alloys using driven rotary tool”. *Journal of Manufacturing Tools and Science, January* 2002.
4. P.G. Benardos “Predicting surface roughness in machining: a review”. *International Journal of machine tools and manufacture*, December 2002.
5. Yusuf Sahin “Surface roughness model for machining mild steel”. Materials and design, May 2004.
6. R.K. Katta “Predictive cutting model for forces and power in self-propelled rotary tool turning operations”. January 1997.
7. K. Palanikumar “Modelling and analysis for surface roughness in machining glass fibre reinforced plastics using response surface methodology”. October 2006.

****