Quest Journals
Journal of Research in Mechanical Engineering
Volume 10 ~ Issue 2 (2024) pp: 14-18
ISSN(Online):2321-8185
www.questjournals.org

Research Paper

Anexperimental investigation of cutting mode and cooling conditions on hard milling of AISI D2 steel using carbide inserts

Phan Van Nghi
Department of Manufacturing Engineering, Faculty of Mechanical Engineering, Thai Nguyen University of Technology, Thai Nguyen, 250000, Vietnam
Corresponding author: Phan Van Nghi

Abstract
The presented work aims to study the effects of cutting speed, feed rate and cooling conditions(dry and wet) on surface roughness $R_a$and tool life in hard milling of AISI D2 steel (60 HRC) using carbide inserts. A factorial experimental design was used to evaluate the influence of input parameters. The obtained results indicated that feed rate is still the parameter that has the strongest impact on surface roughness, while cutting speed and cooling modes have thestrong influences on tool life. Also, the technical guides can be provided for further studies on hard milling process.
Keywords: *Hardmachining, hard turning, hard material, cutting parameter; cutting force; surface roughness*

*Received 28 Mar., 2024; Revised 15 Apr., 2024; Accepted 18 Apr., 2024 © The author(s) 2024. Published with open access at **www.questjournals.org***

I. Introduction

In the metal cutting field, milling is one of the popular methods for flat surfaces. Besides, it can process other simple to complex surfaces such as gear teeth, thread, contour, and so on. This is a cutting process using multi-point cutting tools, so it brings out high productivity. In recent years, thanks to advances in more rigid CNC machine tools and cutting tool material technology, direct milling of heat-treated materials has become easier and possible from small workshops to large factories [1]. Indeed, hard milling technology has attracted special attention not only from researchers but also from manufacturers, especially in the field of molds. The hard milling process shows outstanding advantages such as high productivity, dimensional accuracy and high surface quality [1,2]. Therefore, this process has been applied to replace or support the finish grinding process and open up new technological solutions in machining [3]. Studies on the hard milling process initially developed and proved these observations.M.C. Kang et al. [4] investigated the high-speed end milling of AISI D2 tool steel (62HRC) using coated carbide tools. The authors stated that the TiAlSiN coated carbide tools were proven to apply effectively in hard milling. The cooling condition also played a very important role in ensuring the proper wear rate and tool life. Minimum Quantity Lubrication (MQL) exhibited the better lubrication performance compared to dry and wet conditions. An Qinglong et al. [5] experimentally investigated hard milling of high strength steel 30Cr3SiNiMoVA (30Cr3) using PVD-AlTiN coated carbide tool. The results indicated that the increase of cutting speed from 70 to 100 m/min contributed to reduce cutting forces and improve surface finish, while the rises of feed rate and depth of cut negatively influence the surface roughness. The abrasion wear and adhesive wear with oxidation occurrence were the main wear mode in hard milling due to high cutting forces and cutting heat. HalilCalıskan et al. [6] made a study on the effects of three different coating material (nanolayerAlTiN/TiN, commercial TiN/TiAlN and multilayer nanocomposite TiAlSiN/TiSiN/TiAlN) of carbide inserts on the cuttingforces and surface roughness in face milling of AISI D2 cold work tool steel. The experimental results showed that the coating materials had little impact on cutting force and surface roughness. S. Saketi et al. [7] investigated the wear of a high CBN content PCBN cutting tool in hard milling of Uddeholm Vanadis 4 Extra (V4E) and Uddeholm Vancron40 (V40)powder metallurgy cold work tool steels. They concluded that the higher cutting speed led to the micro-chipping along the cutting edge. Besides, the crater, abrasive, and adhesive wear all occurred in hard milling process.

Through the studies mentioned above, it can be seen that cutting speed and feed rate are closely related to cutting forces, cutting heat, machined surface quality and tool life; however, studies on the effects of these parameters on machined surface quality and tool life when hard milling of AISI D2 steel (60 HRC) are still limited. Therefore, the author conducted an experimental study to evaluate the influence of cutting speed, feed rate, and cooling condition on surface roughness R_a and tool life.

II. Methodology

The experiment was conducted on MCV-410 milling machine, Japan (Figure 1). AISI D2 tool steel samples with hardness of 60HRC were used. The surface roughness measurement process was conducted three times after each cut and the average value was taken. Each experiment was conducted in the same mode until the cutting tool reached its end of life. The tool life is evaluated according to the flank wear criteria of up to 0.3mm [1]. The factorial experimental design was used to evaluate the effects of cutting speed, feed rate, and cooling conditions on surface roughness R_a and tool life. The input parameters and their value levels and output parameters are given in Table 1.

Figure 1. Experimental set up

Table 1. Input variables and their levels

Input variables	Low level	High level	Outputs
Cutting speed (m/min)	70	100	Surface roughness R_a (µm) Tool life (min)
Feed rate (mm/tooth)	0.1	0.2	
Cooling condition	Dry	Wet	

III. Results and discussion

The experiments were conducted according to the factorial experimental design.The results in the Pareto chartsexhibit the influence of each parameter and the interactive effects of the input parameters on the output results shown in Figures 2, 3. In Figure 2, it can be seen that feed rate is the parameter that has the greatest influence on surface roughness, followed by cutting speed, but the influence is insignificant because it is located to the left of the reference line. Furthermore, the cooling conditions have little effect on surface roughness.

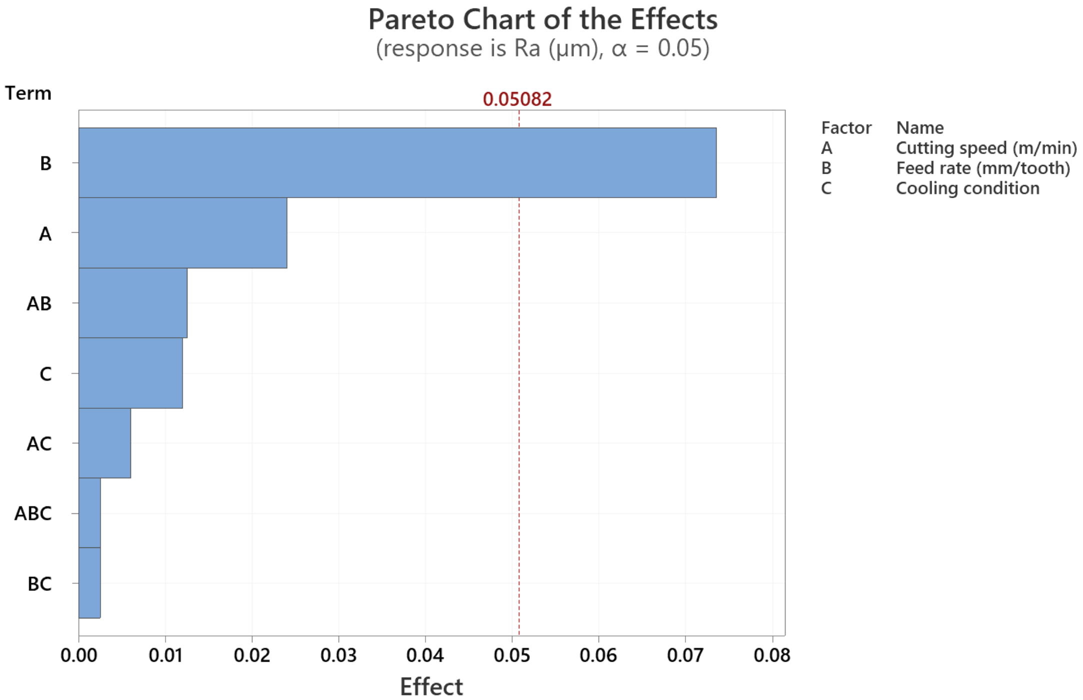

Figure 2. Pareto chart of the effects of input variables on R_a

In Figure 3, it can be seen that cutting speed and cooling conditions have great influences on tool life, in which cutting speed has the greatest impact. This is because increasing the cutting speed from 70 to 100 m/min increases the cutting force and cutting heat [1,5], thereby accelerating the abrasive wear process due to mechanical scratches, which shorten tool life. The use of floodcoolant has contributed to reducecutting heat and cutting forces in the contact zone, thereby helping to prolong tool life when compared to dry hard milling. The investigated feed rate has an insignificant effect on tool life.

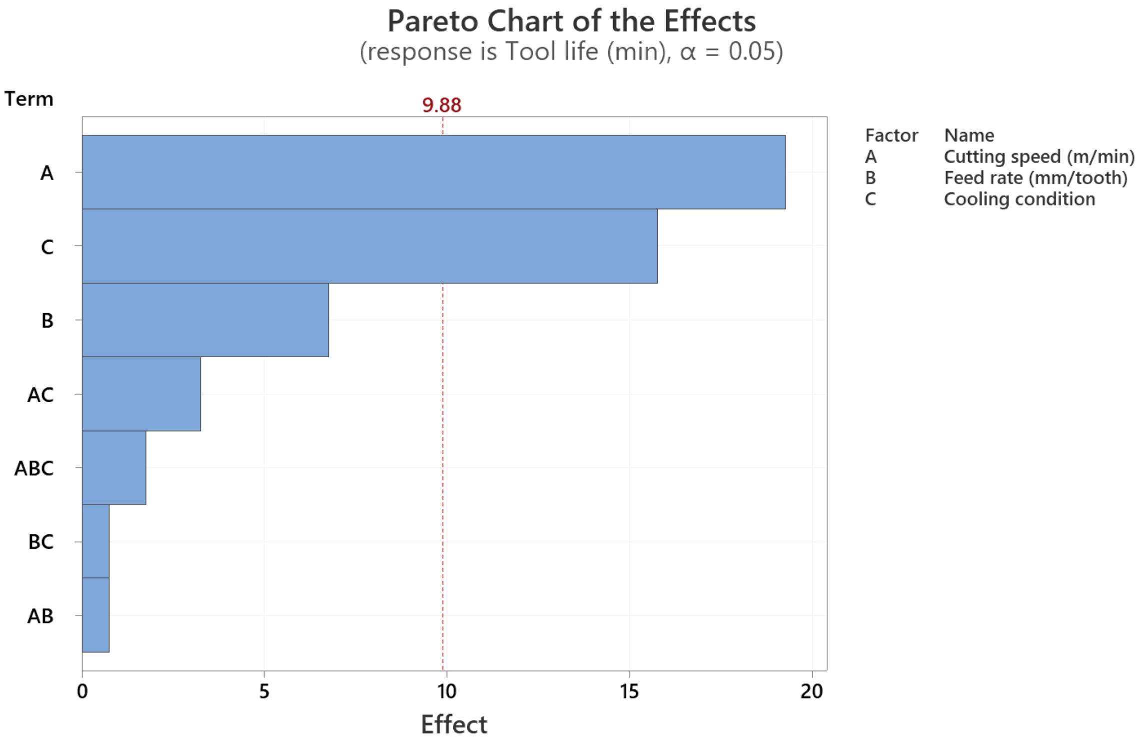

Figure 3. Pareto chart of the effects of input variables on tool life

In Figure 4, the main effects of cutting speed, feed rate and cooling conditions on the surface roughness R_a were illustrated. It can be seen that increasing the cutting speed contributes to reduce the surface roughness R_a, but R_a increases sharply when increasing the feed rate [6]. The use of wetcondition helps to improve the efficiency of lubrication and cooling of the cutting zone, thereby improving the quality of the machined surface.

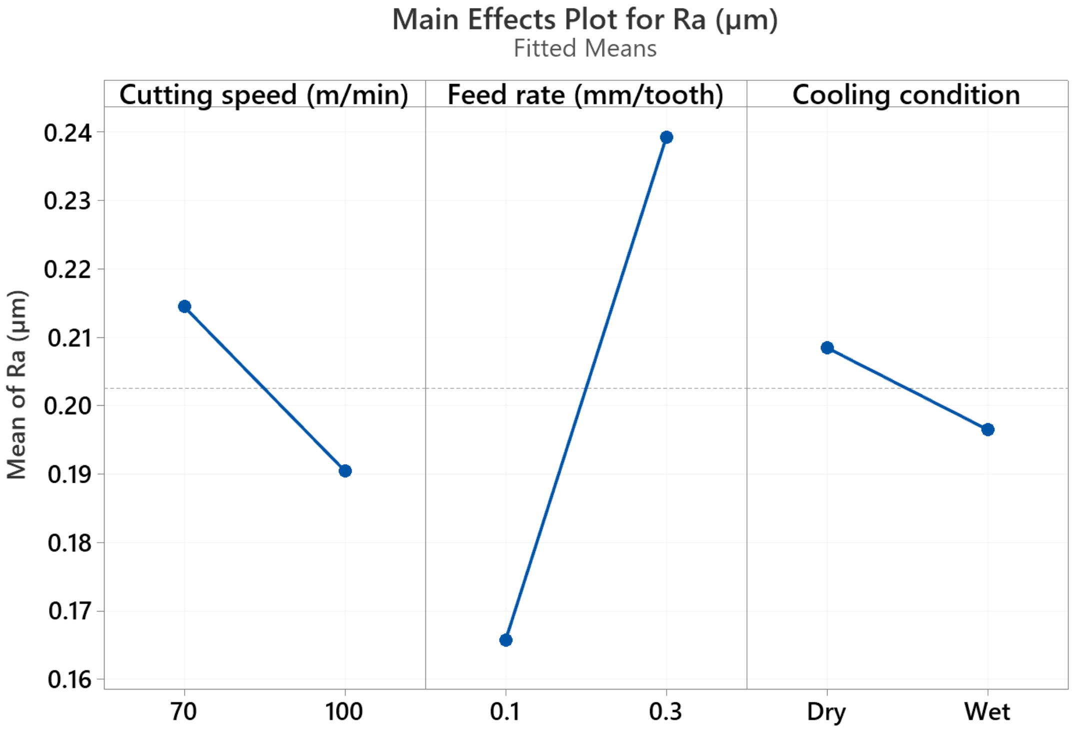

Figure 4. Main effects of input variables on R_a

In Figure 5, the main effects of cutting speed, feed rate and cooling conditions on tool life were shown. It can be seen that when increasing cutting speed and feed rate, tool life decreases due to increased cutting force and cutting temperature. Using flood condition helps to enhance the efficiency of lubrication and cooling of the cutting zone, thereby increasing tool life [2,4].

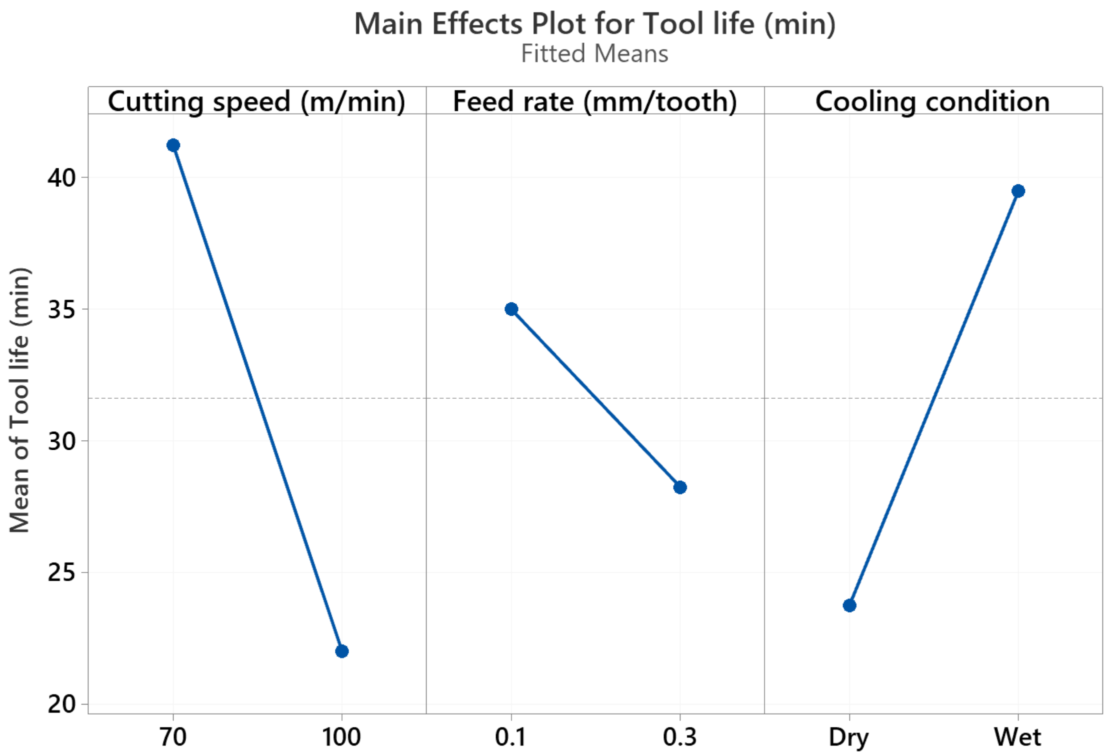

Figure 5. Main effects of input variables on tool life

IV. Conclusion

In the work content, the effects of cutting mode and cooling conditions on surface roughness and tool life in hard milling of AISI D2 steel (60 HRC) using carbide inserts were studied. A factorial experimental design was used to evaluate the influence of parameters including cutting speed, feed rate and cooling conditions, thereby providing influence trends and technological instructions for each specific response. Feed rate is still the parameter that has the greatest influence on surface roughness, while cutting speed and cooling modes have the great influences on tool life.

Acknowledgments

The work presented in this paper is supported by Thai Nguyen University of Technology, Thai Nguyen University, Vietnam.

References

[1]. J. Paulo Davim. Machining of Hard Materials. Springer-Verlag London Limited 2011.
[2]. Tamizharasan T, Selvaraj T, Haq AN. Analysis of tool wear and surface finish in hard turning. The International Journal of Advanced Manufacturing Technology (2006) 28: 671 -679.
[3]. Klocke F, Brinksmeier E, Weinert K. Capability profile of hard cutting and grinding processes. CIRP Annals-Manufacturing Technology (2005) 54:22-45
[4]. M.C. Kang, K.H. Kim, S.H. Shin, S.H. Jang, J.H. Park, C. Kim. Effect of the minimum quantity lubrication in high-speed end-milling of AISI D2 cold-worked die steel (62 HRC) by coated carbide tools. Surface & Coatings Technology 202 (2008) 5621–5624.
[5]. An Qinglong, Wang Chang ying , Xu Jinyang, Liu Pulin, Chen Ming. Experimental investigation on hard milling of high strength steel using PVD-AlTiN coated cemented carbide tool, International Journal of Refractory Metals and Hard Materials (2013), doi : 10.1016/j.ijrmhm.2013.11.007 IRP 37 (1), pp 89-92.
[6]. Halil Calıskan, Cahit Kurbanoglu, Peter Panjan, Miha Cekada, Davorin Kramar. Wear behavior and cutting performance of nanostructured hard coatings on cemented carbide cutting tools in hard milling. Tribology International 62 (2013) 215–222.
[7]. Saketi, S.; Sveen, S.; Gunnarsson, S.; M'Saoubi, R.; Olsson, M. (2015). Wear of a high cBN content PCBN cutting tool during hard milling of powder metallurgy cold work tool steels. Wear, 332-333, 752–761. doi:10.1016/j.wear.2015.01.073