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An investigation on the interaction effects of cutting parameters on the hard turning of AISI H13 tool steel

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Abstract
In this article, the objectives are to study the interaction effects between the two cutting parameters of three input factors on the cutting force component F_z. The experimental matrix was formed by using the factorial design. From the obtained results, the feed rate and depth of cut exhibit the strong impacts on the cutting force F_z while the cutting speed causes little influence. Hence, the selection of low levels of feed rate and cutting depth combined with the high cutting speed would be the suitable strategy for achieving the lower cutting forces. In the meanwhile, the important technical guides are specified for the production practice and further studies in hard turning. Specifically, v=140÷160 m/min, f=0.05÷0.06mm/rev, and a_p=0.3÷0.4mm are proper and should be selected in order to ensure the productivity and technical requirements. Furthermore, the hard turning process under dry condition would contribute to reduce the negative impact of the consumption of cutting fluids and decrease the manufacturing cost.
Keywords: *Metal cutting, hard turning, hardened steel, cutting condition, cutting force*

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I. Introduction

In industry, traditional metal cutting processes still play the key roles and are widely applied in many different fields like automotive, aerospace, construction, and general manufacturing. They are the mechanical operations where material is removed from a workpiece to form chips using tools with sharp cutting edges [1]. They rely on physical contact between the cutting tool and the material to achieve the desired dimensions, shape, and surface finish of a metal part.

Especially, in the finishing stages, there are always the high requirements on surface quality, tolerances, and functional properties of machined parts [2,3]. Grinding is the traditional solution for finishing the hardened steels due to high dimensional accuracy and reliability [4]. Nevertheless, low productivity, low flexibility and negative impacts of the used coolants are the main drawbacks of this process. Hence, hard machining processes have been developed to be an alternative or supplementary method for grinding. They bring out the higher productivity while ensuring the good surface finish and dimensional accuracy. In the hard cutting technology, hard turning is the machining process on materials with high hardness (usually 45HRC or more) using a single cutting tool.

This process was first applied in the automotive industry for finishing the transmission shafts and replacing the grinding. From there, the effectiveness in productivity, flexibility and especially environmental friendliness was achieved due to the elimination of coolants. The complete elimination of coolant means that there is no cooling lubrication media in contact zones, so the cutting forces and cutting temperature are usually high. It makes the choice of cutting tool material and cutting parameters very important [5].

The unsuitable utilization of cutting tool materials can lead to the serious issues such as low tool life and low productivity, leading to increase the tool costs and manufacturing costs. Therefore, coated carbide, ceramic, CBN, and diamond tools are widely used because they possess the high hardness, wear resistance, good heat resistance [6-8]. Moreover, the proper chosen cutting parameters are very important and bring not only the productivity but also technical and economic aspects. However, the studies on their influences on the cutting force components in the hard turning process of AISI H13 steel are limited [9,10]. Therefore, in this article, the main objective is to investigate the impacts of cutting parameters on the cutting force component F_z in the hard turning of AISI H13 tool steel.

II. Methodology

The hard turning process was carried out on the lathe. The AISI H13 tool steel samples were hardened to reach the hardness value of 55 HRC. The chemical composition and mechanical properties are shown in Tables 1, 2. The factorial experimental design with three variables with the help of Minitab 21 software was applied to design the experimental matrix. The input cutting parameters and their levels are given by Table 3.

Table 1 – Chemical composition in % of AISI H13 tool steel according to ASTM A681 standard

ASTM A681	C		Mn		P	S	Si		Cr		V		Mo	
H13	0.32	0.45	0.2	0.6	0.03	0.03	0.8	1.25	4.75	5.5	0.8	1.2	1.1	1.75

Table 2. Mechanical properties of H13 tool steel

Properties	Metric	Imperial
Tensile strength, ultimate (@20°C	1200 - 1590 MPa	174000 - 231000 psi
Tensile strength, yield (@20°C	1000 - 1380 MPa	145000 - 200000 psi
Reduction of area (@20°C)	50.00%	50.00%
Modulus of elasticity (@20°C)	215 GPa	31200 ksi
Poisson's ratio	0.27-0.30	0.27-0.30

Table 3. The input cutting parameters and their levels

Input variables	Symbol and unit	Low	High
Cutting speed	v (m/min)	120	160
Feed rate	f (mm/rev)	0.05	0.15
Depth of cut	a_p (mm)	0.3	0.5

III. Results and discussion

The hard turning trials were implemented by following the experimental matrix obtained from the factorial experiment design. The cutting force F_z was directly measured and reported. The contour plot of effects of cutting speed and feed rate on the cutting force F_z with cutting depth t=0.4mm is shown in Figure 1. Figure 2 presents the interactive effects of cutting speed and depth of cut on the cutting force F_z with feed rate f=0.1mm/rev. Figure 3 illustrates the interactive effects of feed rate and depth of cut on the cutting force F_z with cutting speed V=140 m/min.

In Figure 1, the interaction impacts between the cutting speed and feed rate are clearly shown with the fixed cutting depth a_p=0.4mm. The high level of cutting speed combined with the low level of feed rate would result the smaller values of cutting force F_z (F_z<75N). In detail, the cutting speed v= 130÷160m/min and the feed rate f=0.05÷0.06mm/rev are the appropriate ranges to achieve the smaller cutting force F_z<75N. The similar selection trends were reported for the cutting speed and cutting depth in Figure 2 while the feed rate is kept at 0.1 mm/rev. The high level of cutting speed combined with the low level of cutting depth would bring the smaller values of cutting force F_z (F_z<103N). Looking in detail, the cutting speed v= 157÷160m/min and the depth of cut a_p=0.30÷0.32mm are the suitable ranges to achieve the smaller cutting force F_z<103N. For the cutting speed v=140m/min, the feed rate f=0.05÷0.065mm/rev and cutting depth a_p=0.3÷0.5mm are the proper ranges for the smaller cutting force F_z (F_z<80N).

To ensure the productivity and technical requirements, v=140÷160 m/min, f=0.05÷0.06mm/rev, and a_p=0.3÷0.4mm are suitable and should be chosen.

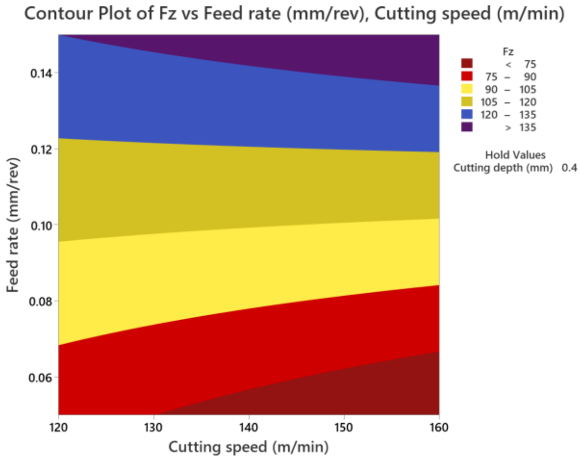

Figure 1. Contour plot of effects of cutting speed and feed rate on the cutting force F_z with depth of cut t=0.4mm

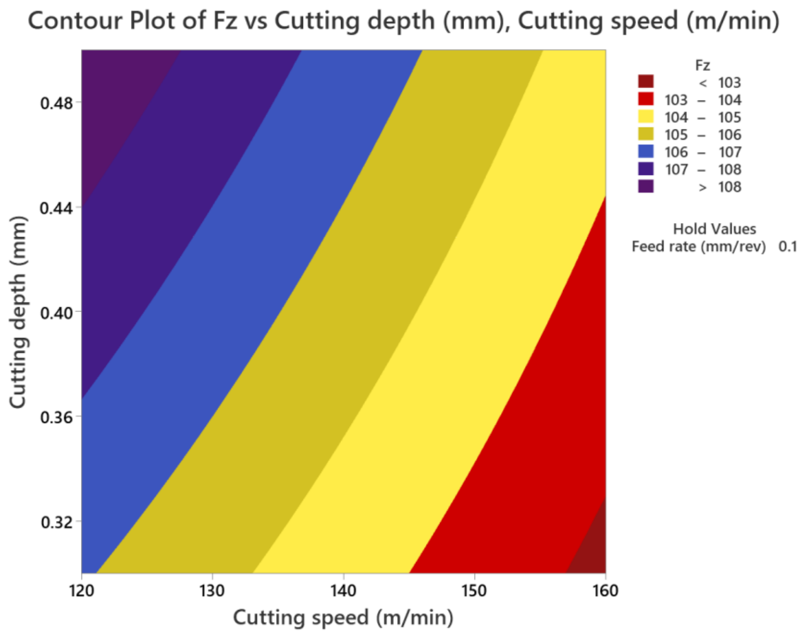

Figure 2. Contour plot of effects of cutting speed and cutting depth on the cutting force F_z with feed rate f=0.1mm/rev

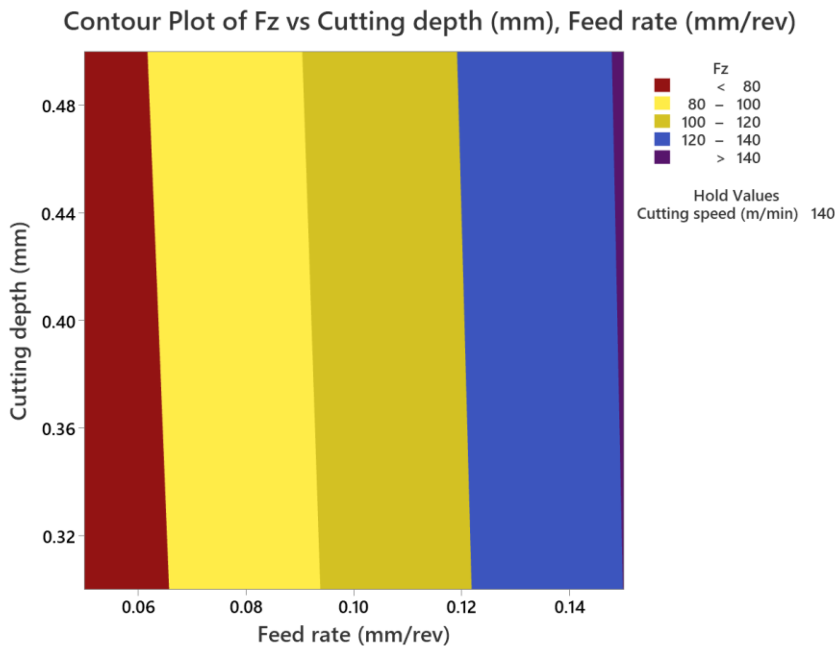

Figure 3. Contour plot of effects of feed rate and depth of cut on the cutting force F_z with cutting speed V=140 m/min

V. Conclusion

In the presented work, the interaction effects between the two cutting parameters on the cutting force component F_z were investigated. The feed rate and cutting depth cause the strong impacts on the cutting force F_z while the cutting speed has little influence. Hence, the use of low levels of feed rate and cutting depth combined with the high cutting speed would be the suitable strategy for achieving the lower cutting forces. At the same time, the important technical guides are provided for production practice and further studies in hard turning. In detail, v=140÷160 m/min, f=0.05÷0.06mm/rev, and a_p=0.3÷0.4mm are suitable and should be selected in order to ensure the productivity and technical requirements. In future work, more investigations will be focused on the optimization of cutting condition.

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References

[1]. D.A Stephenson, J.S Agapiou. Metal Cutting Theory and Practice. CRC Press 2016.
[2]. Mikell P. Groover, Fundamentals of Modern Manufacturing, John Wiley & Sons, Inc. Wiley, 4th Edition, 2010.
[3]. J. Schey,Introduction to Manufacturing Processes, 3rd Edition, 1999
[4]. Sharma, A., Kalsia, M., Uppal, A. S., Babbar, A., & Dhawan, V. (2021). Machining of hard and brittle materials: A comprehensive review. Materials Today: Proceedings. doi:10.1016/j.matpr.2021.07.452.
[5]. Xing, Y.; Deng, J.; Zhao, J.; Zhang, G.; Zhang, K. Cutting performance and wear mechanism of nanoscale and microscale textured Al_2O_3/TiC ceramic tools in dry cutting of hardened steel. Int. J. Refract. Metals Hard Mater. 2014, 43, 46–58. doi:10.1016/j.ijrmhm.2013.10.019.
[6]. Zhang, K.; Deng, J.; Meng, R.; Gao, P.; Yue, H. Effect of nano-scale textures on cutting performance of WC/Co-based Ti55Al45N coated tools in dry cutting. Int. J. Refract. Metals Hard Mater. 2015, 51, 35–49. doi:10.1016/j.ijrmhm.2015.02.011.
[7]. Liu, Y.; Deng, J.; Wang, W.; Duan, R.; Meng, R.; Ge, D.; Li, X. Effect of texture parameters on cutting performance of flank-faced textured carbide tools in dry cutting of green Al_2O_3 ceramics. Ceram. Int. 2018, 44, 13205–13217. doi:10.1016/j.ceramint.2018.04.146.
[8]. Su, Y.; Li, Z.; Li, L.; Wang, J.; Gao, H.; Wang, G. Cutting performance of micro-textured polycrystalline diamond tool in dry cutting. J. Manuf. Process. 2017, 27, 1–7. doi:10.1016/j.jmapro.2017.03.013.
[9]. Sathiya Narayanan, N., Baskar, N., & Ganesan, M. Multi Objective Optimization of machining parameters for Hard Turning OHNS/AISI H13 material, Using Genetic Algorithm. Materials Today: Proceedings 2018, 5(2), 6897–6905. doi:10.1016/j.matpr.2017.11.351.
[10]. J.T.Black, R. A. Kohser, DeGarmo's Materials And Processes In Manufacturing, John Wiley & Sons, Inc, 10th Edition, 2007.