A Study on Effects of Cutting Condition on Hard Turning Performance of AISI H13 Tool Steel

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Abstract
The article content aims to investigate the influences of cutting modes (cutting speed, feed rate and depth of cut) on cutting force components in the hard turning process of AISI H13 steel (55 HRC). The factorial experimental design was used to investigate the effects of input factors including cutting speed, feed rate and depth of cut on cutting force components. The obtain results indicated that the feed rate causes the strongest influence on the cutting forces, while the cutting speed and depth of cut have the less impacts. The growth of feed rate values promotes the cutting forces to increase rapidly. Moreover, the hard turning process under dry environment contributes to the environmental friendly characteristics and reduces the manufacturing cost resulted from the consumption and treatment of cutting fluids.

Keywords: Metal Cutting, Hard Turning, Hardened Steel, Cutting Condition, Cutting Force

1. Introduction

Up to now, metal cutting still has been playing an important role in modern industrial production today, in which the finishing process of hardened steels is crucial to ensure the technical requirements, functional features and the life span [1]. The traditional solution for finishing the heat-treated steels is grinding [2]. However, low flexibility, low productivity and environmental pollution problems from the use of cutting fluid have created new incentives for the development of alternative technological solutions. The research and development of hard machining technology have shown the advantages to overcome the problems caused by grinding. Hard turning is the cutting process on materials with hardness of 45HRC or more using a single cutting tool. Hard turning was first recorded in the automotive industry [2]. The finishing of transmission shafts by hard turning instead of grinding has brought positive effects in productivity, flexibility and especially environmental friendliness due to the elimination of coolant (an environmental pollutant). The complete elimination of coolant makes the choice of cutting tool material and cutting parameters very important [3].

The usage of unsuitable cutting tool materials can lead to problems such as low tool life and low productivity, leading to increase the tool costs and manufacturing costs. The common cutting tool materials used in hard turning include coated carbide, ceramic, CBN, and diamond tools due to high hardness, wear resistance, good heat resistance [3-6]. In addition, the proper selection of cutting parameters determines not only productivity but also technical and economic aspects. However, the studies on the influence of cutting parameters on cutting force components in the hard turning process of AISI H13 steel are limited [7]. Therefore, in this study, the author aims to investigate the impacts of cutting parameters on cutting forces in hard turning of AISI H13 steel. This type of steel is widely used in hot and cold work tooling applications like die, molds, and shafts due to its excellent combination of high toughness and fatigue resistance.

II. Materials and Method

The AISI H13 steel samples were hardened to reach the hardness value of 55 HRC.

The elemental composition and mechanical properties are shown in Tables 1, 2. The factorial design 2^{k-p} with three variables (k = 3) with the help of Minitab 21 software was applied to design the experiments. The input variables and their levels are given by Table 3.

Table 1: Elemental composition in % of AISI H13 tool steel

Element	Content (%)
Chromium, Cr	4.75-5.50
Molybdenum, Mo	1.10-1.75
Silicon, Si	0.80-1.20
Vanadium, V	0.80-1.20
Carbon, C	0.32-0.45
Nickel, Ni	0.3
Copper, Cu	0.25
Manganese, Mn	0.20-0.50
Phosphorus, P	0.03
Sulfur, S	0.03

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

3. Results and Discussion

The ANOVA analysis with 95% confidence level is carried out for cutting force components F_x, F_y, F_z with R^2 equal to 99.99%, 99.99% and 99.98%, respectively, which indicates that the experimental data fit very well with the experimental design model.

The main effects of input variables on the cutting force components are shown in Figures 1÷3. In Figure 1, it can be seen that the feed rate has the greatest influence on the cutting force component F_x, while the cutting speed and cutting depth have little influence. The observations are also reflected through the slope of the graph. When the feed rate increases from 0.05 mm/rev to 0.15 mm/rev, F_x value increases sharply. A similar trend is also observed in the cutting force components F_y, F_z (Figures 2, 3). The increase of cutting layer area is the main reason [8]. In addition, when the cutting depth increases from 0.3mm to 0.5mm, all three cutting force components F_x, F_y, F_z go up slightly. At the same time, when the cutting speed increases from 120 m/min to 160 m/min, the cutting force F_x increases slightly, but F_y and F_z decrease slightly.

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

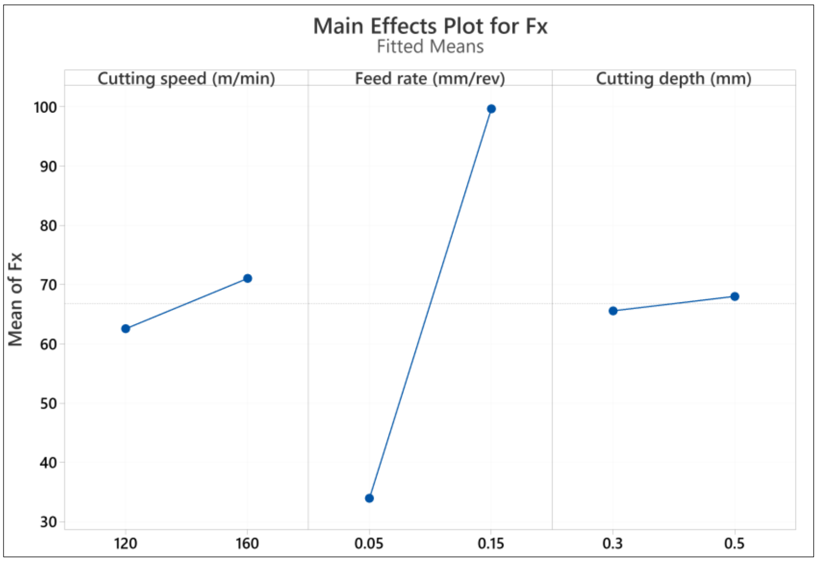

Fig 1: Main effects of input variables on the cutting force F_x

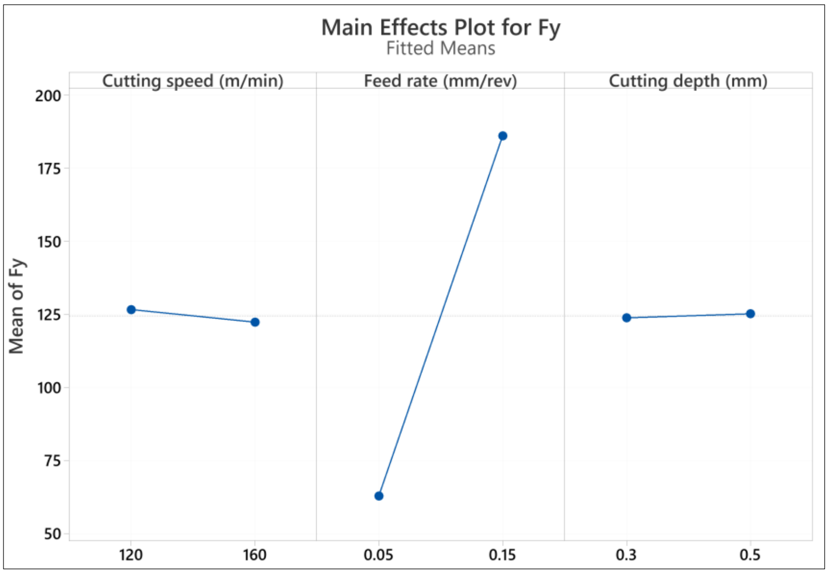

Fig 2: Main effects of input variables on the cutting force F_y

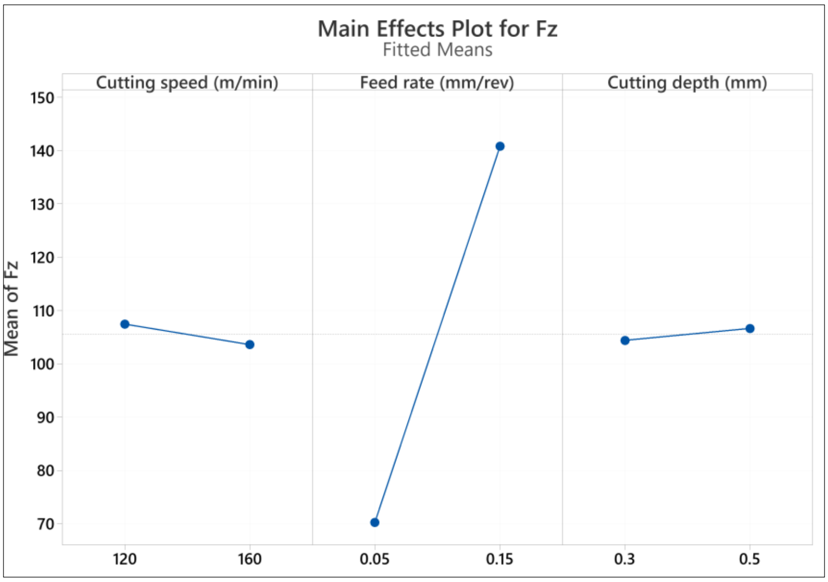

Fig 3: Main effects of input variables on the cutting force F_z

4. Conclusion

In this paper, the effects of cutting modes on the dry hard turning performance were investigated in terms of cutting force components. The factorial experimental design with the help of Minitab 21 software was utilized to study the effect of each input cutting factor on the output responses. From the obtained results, the feed rate caused the most significant effect on the cutting forces. At the same time, the cutting speed and depth of cut have little influence. In addition, the technical guides are provided for production practice and further studies. In detail, v=160 m/min, f=0.05mm/rev, and a_p=0.3mm are suitable and should be recommended for productivity and technical characteristics. In future work, more investigations will be concentrated to find out the optimal set of cutting condition.

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6. References

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