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# A study on effects of cutting parameters on the thrust cutting force in the hard turning process

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***Abstract***
*In hard turning, the thrust force (radial force) plays a critical role in determining machining performance and product quality. The presented work aimsto study the effects of cutting parameters on the thrust force* $F_y$*in the hard turning process. The factorial design was applied to build up the experimental matrix. Based on the experimental results, the influential trend and the interaction effects of the input cutting parameters on* $F_y$ *were investigated, and the appropriate ranges of input variables were specified for each specific cutting condition. In detail,* $v=120\div140$ *m/min,* $f=0.05\div0.1$*mm/rev, and* $a_p=0.3\div0.4$*mm are reasonable and should be used to ensure the productivity as well as the technical requirements.Additionally, the dry conditionused in hard turning would contribute to reduce the negative impact of the consumption of cutting fluids and decrease the disposal expenses.*

***Keywords:*** *Metal cutting, hard turning, hardened steel, cutting condition, thrust cutting force*

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## I. Introduction

Up to now, traditional metal cutting processes have been playing a crucial role in modern industry and are widely applied across various sectors, including automotive, aerospace, construction, and general manufacturing. These processes are fundamental to the production of high-precision components and remain indispensable despite the emergence of advanced manufacturing technologies.Metal cutting processes involve mechanical operations in which material is removed from a workpiece in the form of chips using cutting tools with sharp edges [1]. Common conventional cutting processes consist of turning, milling, drilling, shaping, and grinding, each suited to producing specific geometries and surface characteristics. These processes are typically performed on machine tools such as lathes, milling machines, and drilling machines, which provide the controlled relative motion between the cutting tool and the workpiece.A defining characteristic of traditional metal cutting is the reliance on direct physical contact between the cutting tool and the material. During machining, the tool applies force to the workpiece, causing localized plastic deformation and shearing of the material, which results in chip formation. The mechanics of this interaction significantly influence cutting forces, temperature generation from cutting zone, tool wear, and ultimately the machined surface quality [2]. The cutting parameters, including cutting speed, feed rate, and cutting depth play critical roles in determining machining performance. The suitable selection of these parameters are essential to achieve high dimensional accuracy, good surface finish, and extended tool life while minimizing energy consumption and production costs [3].

In the finishing stages, high requirements are imposed on surface quality, dimensional tolerances, and functional properties of machined parts [4]. Grinding has traditionally been the preferred method for finishing hardened steels due to its high dimensional accuracy and reliability [4, 5]. However, this process suffers from several drawbacks, including low productivity, limited flexibility, and the negative environmental impact of cutting fluids.As a result, hard machining processes have been developed as alternatives or supplements to grinding [6]. These processes offer higher productivity while still ensuring good surface finish and dimensional accuracy. Among them, hard turning is a machining process applied to materials with high hardness (typically 45 HRC or above) using a single-point cutting tool.This process was initially applied in the automotive industry for finishing transmission shafts as a replacement for grinding. Its adoption demonstrated significant advantages in terms of productivity and flexibility, as well as improved environmental performance due to the elimination of cutting fluids [7].However, the complete absence of coolant means that no lubrication or cooling medium is present in the cutting zone. As a result, cutting forces and temperatures are typically high. This makes the selection of cutting tool materials and cutting parameters critically important [8].

The improper choice of tool materials can lead to serious issues such as reduced tool life and decreased productivity, ultimately increasing tooling and manufacturing costs. Therefore, advanced tool materials such as coated carbide, ceramics, cubic boron nitride (CBN), and diamond are widely employed due to their high hardness, excellent wear resistance, and good thermal stability [9,10].In addition, the appropriate selection of cutting parameters plays a vital role not only in enhancing productivity but also in achieving desirable technical and economic performance. The thrust cutting force in hard turning is a critical component of the overall cutting force system, acting perpendicular to the cutting direction. It has a significant influence on machining performance, particularly in terms of tool deflection, vibration, and dimensional accuracy. Nevertheless, studies investigating the influence of cutting parameters on the thrust cutting force in the hard turning process of AISI H13 steel still remain limited [11,12]. Hence, thearticleaims to investigate the impacts of cutting parameters on the thrust cutting force$F_y$inthe hard turning of AISI H13 tool steel.

## II. Material and Method

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

**Table 1** – Chemicalcomposition 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 cutting trials were implemented by followingthe experimental matrix obtained from the factorial experiment design.The thrust cutting force $F_y$ was directlymeasured and documented. The surface plot of effects of cutting speed and feed rate on $F_y$with cutting depth t=0.4mm is shown in Figure 1. Figure 2 presents theinteractive effects of cutting speed and depth of cut on $F_y$with feed rate f=0.1mm/rev. Figure 3 illustrates the interactive effects of feed rate and depth of cut on $F_y$with cutting speed V=140 m/min.

In Figure 1, the use of low levels of cutting speed and feed rate resulted in the low values of thrust force $F_y$. With the cutting depth fixed at 0.4mm, the cutting speed of 120m/min and feed rate of 0.05 mm/rev should be used. In case of the feed rate fixed at 0.1 mm/rev (Figure 2), the combination of high level of cutting speed (160m/min) with the low cutting depth (0.3mm) brings out the smaller thrust force $F_y$. From Figure 3, the low feed rate (0.05mm/rev) combined with the low cutting depth (0.3mm) helps achieve the lower thrust force. To meetthe productivity and technical requirements, $v$=120÷140 m/min, $f$=0.05÷0.1mm/rev, and $a_p$=0.3÷0.4mm are suitable and should be chosen.

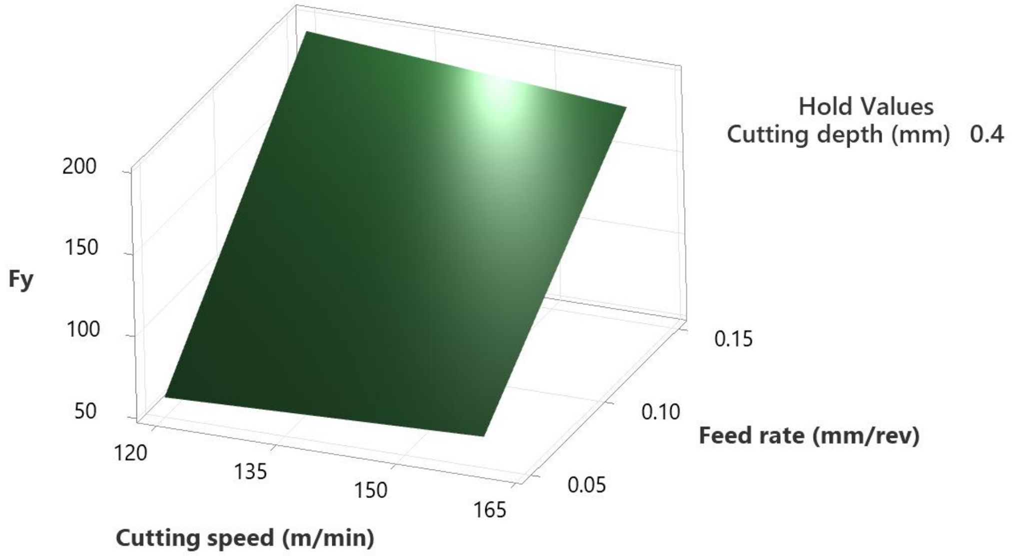

**Figure 1.** Surface plot showing the interaction effects of cutting speed and feed rate on the thrust force $F_y$ with depth of cut t=0.4mm

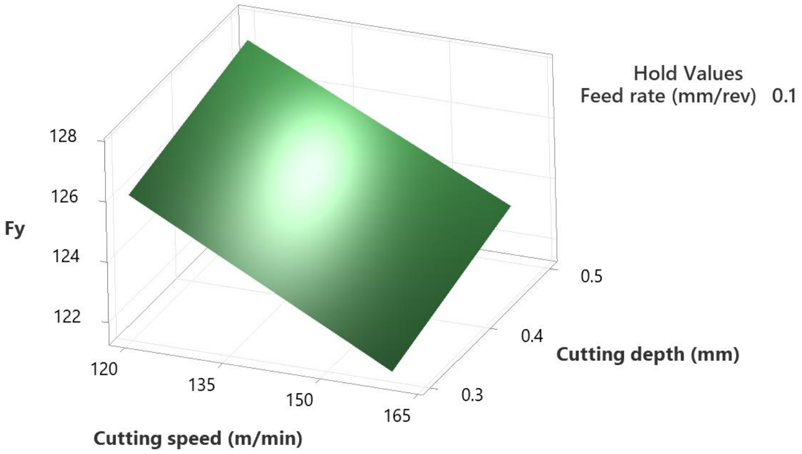

**Figure 2.** Surface plot showing the interaction effects of cutting speed and cutting depth on the thrust force $F_y$ with feed rate f=0.1mm/rev

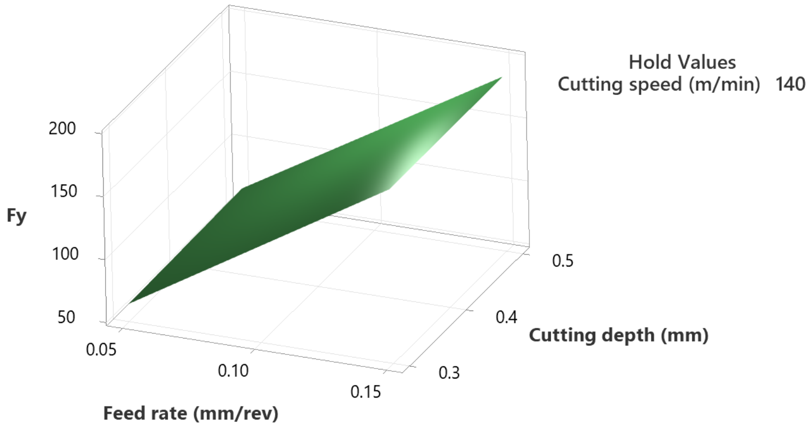

**Figure 3.** Surface plot showing the interaction effects of feed rate and depth of cut on the thrust force $F_y$ with cutting speed $V$=140 m/min

## IV. Conclusion

In this paper, the effects of the cutting parameters including cutting speed, feed rate, and cutting depth on the thrust force component $F_y$in the hard turning process were studied.From the experimental results, the interactive effects of input variables on $F_y$ under each specific cutting condition were also investigated. From this, the reasonable value ranges were determined, providing important technological guidance for achieving the desired output variable and for further studies. Looking in detail, the suitable set of the input parameters $v$=120÷140 m/min, $f$=0.05÷0.1mm/rev, and $a_p$=0.3÷0.4mm was determined and should be usedto achieve the lower thrust force $F_y$.In future work, more attention should be focused on the optimization ofcutting condition.

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