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Effects of cutting parameters on hard turning performance: A review

Nguyen Phu Son

Department of Manufacturing Engineering, Faculty of Mechanical Engineering, Thai Nguyen University of Technology, Thai Nguyen, 250000, Vietnam

***Corresponding author:** Nguyen Phu Son*

Abstract

The work presents a comprehensive review on the effect of cutting parameters on the performance of hard turning. The study has given outstanding results of experimental studies on the effects of cutting speed, feed rate and depth of cut on cutting force components and surface quality in hard turning of different steel grades under dry and flood condition. Moreover, the analysis and discussion have evaluated the parameters that have great influence on the efficiency of the hard turning process as a basis for further studies. The factor domains and research gaps for further studies are pointed out to serve as a basis for research and development of hard turning technology into production practice. Further research directions are also indicated to improve the efficiency of the cutting process while minimizing adverse effects on the environment.

Keywords: *Hard machining, hard turning, cutting parameter, cutting force, surface quality*

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I. Introduction

In the field of machining, dimensional accuracy and machined surface quality are very important parameters not only in terms of the performance of the workpiece, but also as a criterion for evaluating the cutting efficiency [1]. The parameters of the cutting parameters including cutting speed, feed rate and depth of cut are still decisive parameters for the efficiency of the machining process [2]. Therefore, studies on the influence of the cutting condition on the machining process play an important role both economically and technically. From these studies, technological guidelines are developed to apply in production practice. In recent years, the rapid development of the field of materials technology has brought out many new materials, which possess many good properties such as high hardness and toughness [3]. Besides, the development of heat treatment technology has helped many machined parts have higher hardness and durability to better withstand loads, thereby putting the increasing requirements for the processing of these materials. Therefore, hard machining technology is studied and developed to meet this requirement [4].

Hard cutting is essentially using a cutting tool with a geometric-defined cutting edge to directly cut heat-treated steels. In hard machining technology, hard turning was first developed and applied in industrial production to support or partially replace the grinding operation [5]. The study results show that hard turning has a number of advantages such as high productivity and flexibility in production, and is suitable for processing parts with complex profiles while ensuring high dimensional accuracy and surface quality [3-6]. However, in the cutting process, the cutting force and cutting temperature are high, so the selection of the appropriate cutting condition and cutting tool are the crucial factors for the efficiency of the hard turning process. In the content of this paper, the author conducts an overview study on the influence of cutting mode on hard turning. The main research results and discussions will be presented in detail to provide important technological guidelines for further research.

II. Effects of cutting parameters on cutting force

Cutting force is a very important parameter in studying hard machining technology, including hard turning. In machining hard materials, the cutting force is usually higher than when machining materials before heat treatment. In the study of Tönshoff et al. [7], the hardness of the material has a great influence on the cutting force components. When increasing the hardness from 30 to 45HRC, all three components of cutting forces tend to decrease, however, the force value increases sharply when increasing the hardness from 45 to 60HRC. In the study on the effect of cutting speed on cutting forces when turning 30MnVS6 hardening steel, AISI 1045, AISI 5140 with hardness 36 HRC using TiN coated carbide insert [7], the experimental results show that, in case of increasing the cutting speed from 10 to 50 m/min, the cutting force and the thrust force increase sharply, but the values of these two forces decrease with increasing the cutting speed from 50 to 250 m/min. Besides, the cutting force is also closely related to the cutting depth.

In the experimental study of hard turning AISI D2 (60 HRC) steel using ceramic tools [8], the experimental results show that for the increase of cutting depth from 0.2 to 0.6 mm, the cutting force increases rapidly due to the increased cutting area. The main cutting force components F_c and the thrust force F_p are usually the two components with larger values in hard turning process [9]. Excessive cutting forces will be a serious problem because when combined with high cutting temperature, it will accelerate tool wear and causes the breakage, adversely affecting machined surface quality and tool life. In the content of the next section, the author continues to discuss the influence of the cutting mode on the machined surface quality

III. Effects of cutting parameters on surface quality

Surface quality in hard machining is a very important parameter, greatly affecting the performance of the mechanical parts. Due to the enormous cutting heat and cutting force generated from cutting zone, the influence of these parameters on the quality of the machined surface is unavoidable. In many studies, it has been shown that feed rate and tool nose radius are the two parameters that have the greatest influences on the machined surface quality. Abrão et al. [10] investigated the turning performance of 27MNCr5 steel with a surface hardness of 850 HV using polycrystalline cubic boron nitride (PCBN). The surveyed parameters include cutting speed and feed rate, while the cutting depth is fixed at 0.6mm. The obtained results show that the surface roughness is very good (<0.2µm) when the feed rate is at 0.05 mm/rev; however, the microstructure of the machined surface is adversely affected by high cutting heat and the flank wear has a great influence on the surface roughness of the machined surface. Through the research, the authors also proposed a reasonable domain for the feed rate to ensure the best machined surface quality. The study on the effect of cutting condition when turning AISI H13 (52 HRC) and AISIE52100 (62 HRC) steel shows that the CBN inserts possess good efficiency and are suitable for hard machining in the cutting speed range from 70-200 m/min [10].

In the study on hard turning of AISI 4340 (49HRC) [11], the findings indicate that using cutting speeds higher than V = 300 m/min and V = 400 m/min will give smaller surface roughness values. Besides, the author also shows that the use of emulsion oil gives better performance than dry turning due to improved lubrication and cooling in the cutting zone. The authors also pointed out that lubricating and cooling in the cutting zone plays a very important role because the high cutting temperature adversely affects the surface microstructure because of the formation of a white layer. This layer has a close relationship with the cutting mode and is the result of a change in the microstructure of the material, and when viewed under the microscope this layer appears in white color. Also, this layer has a martensite structure without heat treatment, with higher hardness than the transition layer (dark layer) and the base material layer. The mechanism of white layer formation is due to large plastic deformation and/or rapid hot-cold temperature change. The white layer thickness increases with increasing cutting speed and flank wear. As the velocity increases to a critical value, the thickness of the white layer decreases or remains constant. The depth of cut does not affect the thickness of the white layer. The intermediate layer (dark layer) below the white layer is soft and tough, and according to some documents, this layer has a lower hardness than the base layer. In addition, the thickness of the whitening layer and the dark layer increases with increasing tool wear, and the higher cutting speed will increase the white layer thickness, but reduce the thickness of the intermediate layer (dark layer) [12]. The feed rate affects only the whiter layer thickness, and as the feed rate increases, the whiter layer thickness grows.

IV. CONCLUSION

In this paper, a review was conducted on the effect of cutting conditions on hard turning performance. The main studies and outstanding results are presented and briefly summarized to be able to evaluate the influence of cutting speed, feed rate and depth of cut on cutting forces and surface quality. Through the analysis of the experimental results, it is possible to identify the parameters that cause strong/weak influences on the objective functions. Furthermore, research gaps were also identified to serve as the basis for further studies to further develop and complete the technological guidelines for hard turning technology. From the literature review, it can be seen that there are still many issues that are needed to be further investigated to improve the efficiency of hard turning, especially the development of lubricating and cooling technology in the cutting zone.

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