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Experimental Study of Flank Wear in High Speed Turning of Stainless Steel AISI 304

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Abstract

One of the main approaches to reduce the machining time in metal cutting is High Speed Turning (HST). HST increases the material removal rate and then decreases the total machining time. However, in these speeds the flank wear progress will also increase. The aim of this paper is to study experimentally the influence of higher cutting speed on flank wear length when machining AISI 304 as work piece material. This steel is machined by a coated carbide tool. The experiments were planned and implemented using Box Behnken Design (BBD) of Response Surface Methodology (RSM) with three input factors: cutting speed, feeding speed and depth of cut. The experimental results showed that cutting speed is the most effective factor on the flank wear.

Keywords: High Speed Turning, Flank Wear, Stainless Steel 304, Coated Carbide

1. Introduction

The competition among the companies and the demand for shorter times to market are driving innovative approaches in creating faster production process (Layer et al., 2002). One of the main approaches to shorter the machining time in metal cutting is by increasing the cutting speed. The definition of high speed turning is complex and differs from material to material. High speed for one material may still be a low speed for another (for example, the high speed for titanium is a low speed for aluminum). Figure 2 shows the different levels of cutting speed for different types of material (Rahman et al., 2006; Aramcharoen and Mativenga, 2008).

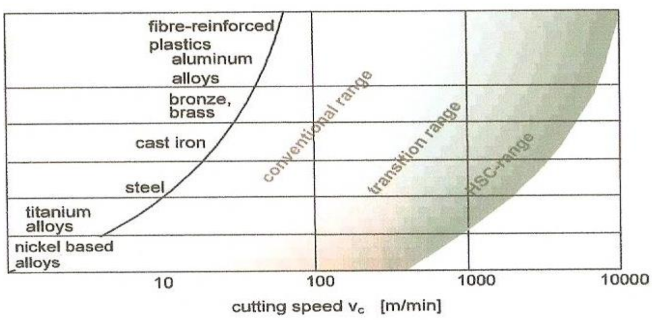

Figure 2: High cutting speeds for different materials (Rahman et al., 2006)

Another sign for the high speed is the chip shape. The chips produced under various cutting speeds have different shapes. At low cutting speeds the chip is a continuous type but when the speed is increased, it is changed to saw-tooth type then to discontinuous chips (Lin et. al., 2008; Sharma, 2001).the different shapes of chips can be concluded as shown in Figure 3.

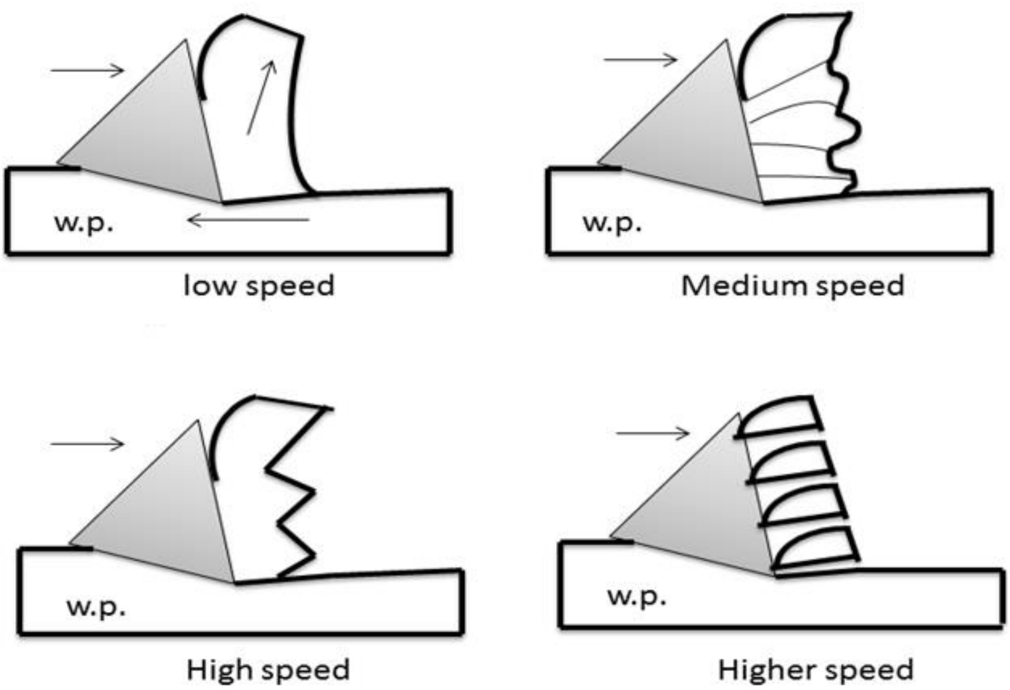

Figure 3: Different types of chips during different cutting speed.

To get a better understanding of high speed turning (HST), it is necessary to look back at temperatures, surface roughness and tool wear types.

1.1 Temperature

It is assumed that almost 98% of the mechanical energy consumed in a machining operation is converted into heat energy (Chiou et al., 2007). This heat is generated in three deformation zones; primary heat zone, secondary heat zone, and tertiary heat zone as shown in Figure 3 (Ghani et al., 2008).

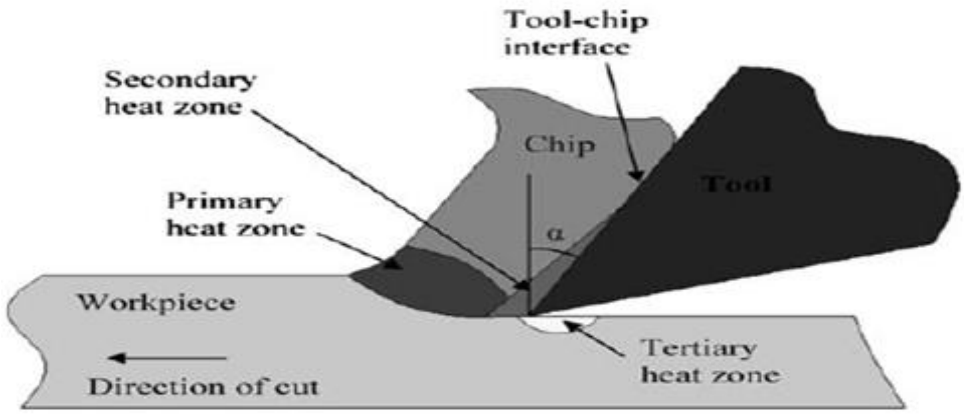

Figure 3: Deformation zones (Ghani et al., 2008)

Firstly, heat is generated in the primary shear deformation zone during the chip formation process. This is the largest source of generated heat as the work piece material undergoes severe plastic deformation in this zone. Secondly, heat is generated in the secondary shear deformation zone as a result of chip deformation and sliding friction between the chip and the tool rake face. Thirdly, heat is generated in the tertiary deformation zone due to the rubbing of the work piece surface against the flank face of the tool. This is the smallest of the three sources of heat generation (Childs et al., 2000; Ghani et al., 2008).

Heat is removed from the primary, secondary and tertiary zones by the chip, the tool and the work piece. The temperature rises in the cutting tool due to the secondary heat source, but the primary heat source also contributes towards the temperature rise of the cutting tool and indirectly affects the temperature distribution on the tool rake face (Abukhshim, Mativenga, and Sheikh, 2005).

In conventional turning below the lower limit of the cutting speed, most of the heat goes into the work piece and tool (Sharma, 2001).

The results for Bosheh and Mativenga, (2006) research on tool steel indicated that the increasing in cutting speed resulted in a decrease in the temperature of the machined surface and increase in the chip temperature. Adesta and Al Hazza, (2011) showed that in the high speed turning the heat is going out with the chip. The machined surface temperature is inversely proportional to the cutting speed while the chip temperature is directly proportional to the cutting speed. Furthermore, they found that increasing the cutting speed is expected to cause a reduction in cutting forces. The reason for that can be attributed to the faster chip removal speed, which results in less contact time and thus less heat being conducted into the work piece and more heat being carried away by the chip.

Sharma (2001) concluded the heat input- output distribution as follows: 80% of heat is generated by the mechanical deformation that creates the chip, 18% is created at the chip/tool interface or secondary shear zone, and 2% is created on the tool tip. The heat which comes in the cut in case of high speed machining, is dissipated as follows: 75% is taken by the chip, 5% by the work piece, and 20% is conducted through the tool.

1.2 Roughness

Surface roughness is classified among the most important technological parameters in the machining process (Fnides et al., 2009). It affects the functional attributes of finished parts. Al Hazza and Adesta (2011) considered the surface roughness as one of the main cost drivers in high speed machining.

Surface roughness is mainly, a result of process parameters such as tool geometry (nose radius, edge geometry, rake angle) and cutting conditions (feed rate, cutting speed, depth of cut). Due to the need for different parameters in a wide variety of machining operations, about 59 developed surface roughness parameters has been developed (Gadelmawla et al., 2002). However the most used parameter is the surface roughness average Ra. The surface roughness average Ra is generally defined as the arithmetical mean of the deviations of the roughness profile from the central line along the measurement (Asiltürk & Cunkas, 2010). This definition is given by the following equation;

$$Ra = 0.032 f^{2} / r_t$$

where, r_t is the nose radius for the cutting tool but in the finish hard turning, tool wear becomes an additional parameter affecting surface quality of finished parts (Ozel and Karpat, 2005).

Thamizhmanii and Hasan (2008) claimed that surface finish in turning is influenced by a number of factors such as cutting speed, depth of cut, tool nose radius, work hardness, feed rate, and cutting edge angles.

Sahin and Riza (2005) found out through an experimental study that the surface finish of machined parts has a considerable effect on some properties such as wear resistance and fatigue strength. Hence, the quality of the surface is of a significant importance when evaluating the productivity of machine tools and mechanical parts. Then, predicting the quality of the surface roughness is important for its economical and mechanical issues (Adesta et al., 2012; Al Hazza et al., 2012).

1.3 Flank Wear

In high speed turning the cutting area is under high temperature, high pressure, and high sliding velocity. The cutting tool under this condition has a complex wear behavior. The wear development during machining can reach unacceptable levels very fast resulting in a poor surface finish (Ozel & Nadgir, 2002). The importance of the wear rate progress, especially on the flank land comes from two main points: tooling cost and surface quality (Al Hazza & Adesta, 2011). The cutting tools can be used only if the surface quality falls in the range of acceptance level (Adesta et al., 2010). Therefore, the cutting tool reaches its life and must be replaced before the cutting edge of the tool cannot give the required roughness.

The failure of the cutting tool happens due to different wear mechanisms. Davim (2008) concluded the general mechanisms that cause tool wear as: abrasion, diffusion, oxidation, fatigue and adhesion. AL Hazza and Adesta, 2013 studied experimentally the influence of feed rate and negative tool rake angle on surface roughness and flank wear length during high speed hard turning and the results show that all factors have a negative effect on the flank wear length

2. Experimental work

2.1 Research methodology

The theoretical and the experimental work have been integrated to analyze and Compare Performance. Figure 4 concluded the research methodology.

2.2 Experiment Design

The experiments were planned and implemented using Box Behnken Design (BBD) of Response Surface Methodology (RSM) with three input factors: cutting speed, feeding speed and depth of cut as shown in table 1. The number of runs of the experiment was 17 runs with different parameters value and range with five center points.

Table 1: Cutting parameters used in the experiment

A	B	C
Cutting speed (m/min)	Feeding Speed (mm/min)	Depth of cut (mm)
700	1000	0.1
600	1500	0.2
500	2000	0.3

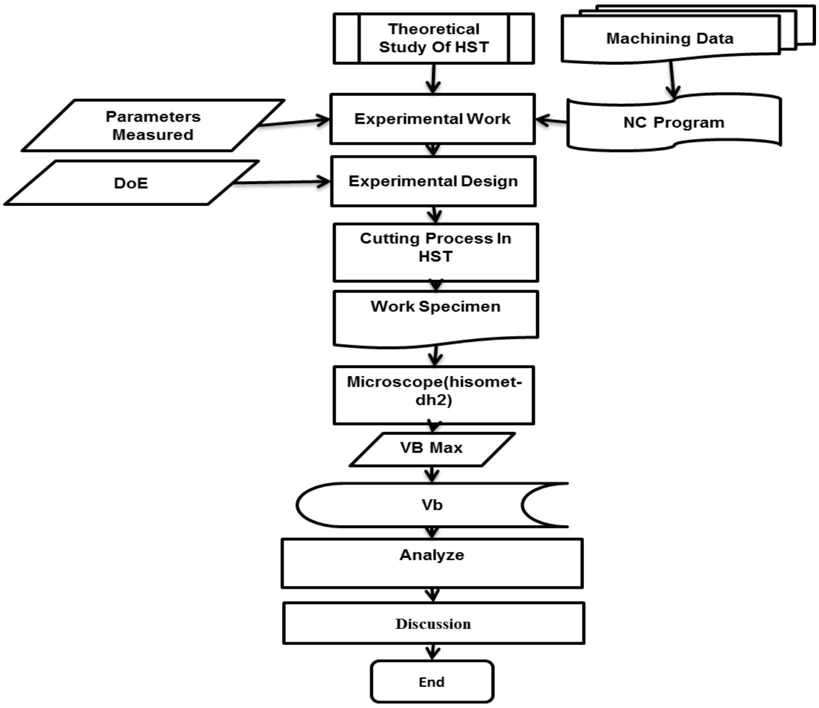

Figure 4: Research Methodology

2.3 Materials

The work piece used in the experiment was stainless steel AISI 304. The tool used for this experiment is GC 2015 (HC) as shown in Figure 5. It is chemical vapor decomposition (CVD) coated cemented carbide. It consist three layer coating on a tough cobalt enriched subtracted as shown in Figure 6. The combination of substrate that can withstand high cutting temperatures and an excellent adhesion of the coating to the substrate make the grade suitable for finishing lighting roughing of stainless steel under fairly good conditions.

This material gives excellent adhesion with high wear, good resistance to diffusion wear and plastic deformation at high temperatures and reduces friction and hence the formation to built-up-edges (Sandvick).

Figure 5: GC 2015 (HC) insert

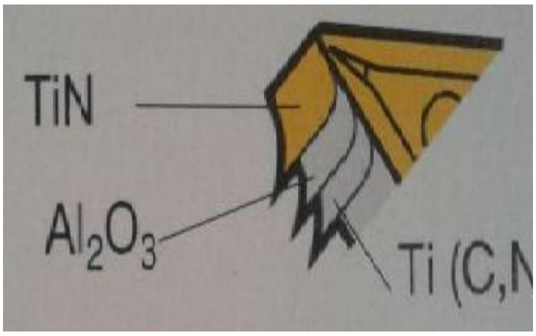

Figure 6: GC2015 (HC) layers(Sandvick)

In order to study about the regression model of flank wear in HST, we used the data and the parameters from the BBD and then proceed with the experiment. From the BBD, it shows 17 runs set of data that equal to the 17 runs for the experiment.

2.4 Instruments

1. CNC turning machine (Romi- Bridgeport 2).
2. Microscope wear rate(Hisomet-DH2)

3. Flank wear measurement

Tool wear was measured using Hisomet II tool maker microscope of model DH II. This microscope is non contact measuring microscope. The flank wear was measured after each three passes (300mm). the results are shown in table 2.

Table 2: Flank wear length during different cutting parametrers

Run	Cutting Speed (m/min)	Feeding Speed (mm/min)	Depth of Cut (mm)	Flank Wear (mm)
1	500	1500	0.1	0.0710
2	500	2000	0.2	0.0460
3	600	1000	0.3	0.0420
4	600	1500	0.2	0.0788
5	700	1500	0.1	0.0470
6	500	1500	0.3	0.2800
7	700	1000	0.2	0.0710
8	600	2000	0.3	0.0580
9	600	1500	0.2	0.0788
10	600	2000	0.1	0.0290
11	600	1500	0.2	0.0788
12	700	2000	0.2	0.0690
13	600	1500	0.2	0.0788
14	600	1000	0.1	0.0680
15	700	1500	0.3	0.0730
16	600	1500	0.2	0.0788
17	500	1000	0.2	0.0590

The perturbation plots are generated by software to recognize the effect of each factor on the measured parameters. Figure 7 shows the perturbation plot of flank wear length.

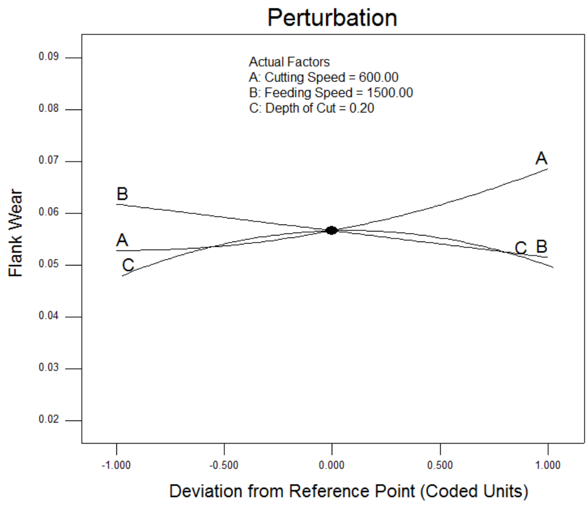

Fig 7: perturbation plot

The figure shows that the cutting speed is the most significant factor on the flank wear length. Increasing the cutting speed will increase the flank wear. Some of the cutting tools were broken from the first run due to the first shock as shown in figure 8 and these tools have been replaced by new tools in the experiments. Figure 9 show the normal wear in the flank land.

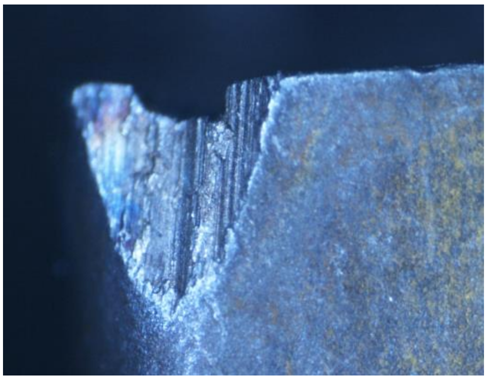

Figure 8: fracture of the cutting tool

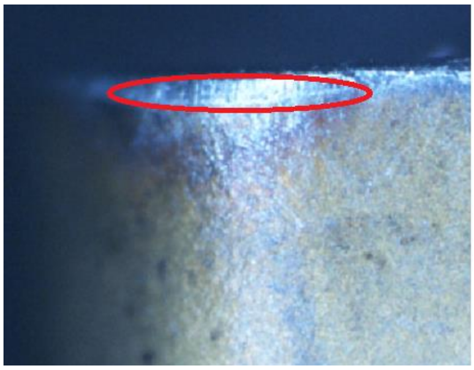

Figure 9: flank wear land

Conclusions

a. Due to high temperature generated in high speed turning and low toughness of coated carbide tools, some of the inserts were broken in early stages.
b. When the cutting speed is low the flank wear decreases
c. The perturbation plot shows that the most effective factor is the cutting speed.
d. The chip shape was continuous and this causes some problems especially when the speed is low

References

Abukhshim, N. A., Mativenga, P. T., and Sheikh, M. A. (2005). Investigation of heat partition in high speed turning of high strength alloy steel. International Journal of Machine Tools & Manufacture (45) pp 1687–1695.

Adesta, E. Y. T., & Al Hazza, Muataz Hazza F. (2011). Tool Life in High Speed Turning with Negative Rake Angle. *Advanced Materials Research*, *264*, 1009-1014.

Adesta, E. Y. T., Al Hazza, Muataz Hazza F.., Suprianto, M. Y., & Riza, M. (2012). Predicting Surface Roughness with Respect to Process Parameters Using Regression Analysis Models in End Milling. *Advanced Materials Research*, *576*, 99-102.

Adesta, E. Y. T., Al Hazza, Muataz Hazza F., Riza, M., & Agusman, D. (2010). Tool life estimation model based on simulated flank wear during high speed hard turning. European Journal of Scientific Research, 39(2), 265-278.

Al Hazza Muataz Hazza F. Muataz. H. F. & Adesta E.Y.T. (2013). Experimental Investigation of the Effect of Feed Rate and Negative Tool Rake Angle in High Speed Hard Turning. Journal of Advanced Science and Engineering Research, 3(1).

AL Hazza, M. H., Adesta, E. Y. T., Riza, M., & Suprianto, M. Y. (2012). Surface Roughness Optimization in End Milling Using the Multi Objective Genetic Algorithm Approach. *Advanced Materials Research*, *576*, 103-106.

AL Hazza, Muataz Hazza F. & Adesta, E. Y. T. (2011). Flank Wear Modeling in High Speed Hard Turning by Using Artificial Neural Network and Regression Analysis. Advanced Materials Research, 264, 1097-1101.

AL Hazza, Muataz Hazza F. & Adesta, E. Y. T. (2011). New Approach in Cost Structuring Of High Speed Hard Turning. *Advanced Materials Research*, *264*, 1003-1008.

Aramcharoen, A., and Mativenga, P. T. (2008). White layer formation and hardening effects in hard turning of H13 tool steel with CrTiAlN and CrTiAlN/MoST-coated carbide tools. International Journal Advanced Manufacturing Technology. (36) pp 650–657.

Asiltürk, İ., & Çunkaş, M. (2011). Modeling and prediction of surface roughness in turning operations using artificial neural network and multiple regression method. *Expert Systems with Applications*, *38*(5), 5826-5832..

Bosheh, S. S., and Mativenga, P.T. (2006). White layer formation in hard turning of H13 tool steel at high cutting speeds using CBN tooling. International Journal of Machine Tools & Manufacture (46) 225–233.

Childs, T., Maekawa, K., Obikawa, T. and Yamane, Y. (2000), Metal Machining Theory and Applications, John Wiley & Sons Inc. New York-Toronto.

Chiou, R., Lu Lin. Y., Chen Jim S. J., and North Mark, T. (2007), Investigation of dry machining with embedded heat pipe cooling by finite element analysis and experiments. International Journal Advanced Manufacturing Technology. 31: 905–914.

Davim, J. Paulo (2008). *Machining: fundamentals and recent advances*.Library of Congress Control Number: 2008931573. Springer-Verlag London Limited British Library Cataloguing in Publication Data. DOI 10.1007/978-1- 84800-213-5

Fnides B., Yallese M. A. Mabrouki T. and Rigal J-F., (2009). Surface roughness model in turning hardened hot work steel using mixed ceramic tool. ISSN 1392 - 1207. MECHANIKA. 2009. Nr.3 (77).

Gadelmawla, E. S., Koura, M. M., Maksoud, T. M. A., Elewa, I. M., & Soliman, H. H. (2002). Roughness parameters. Journal of Materials Processing Technology, 123(1), 133-145.

Ghani, M. U., Abukhshim, N. A. and Sheikh M. A. (2008). An investigation of heat partition and tool wear in hard turning of H13 tool steel with CBN cutting tools. *International Journal Advanced Manufacturing Technology*. 39:874–888.

Lin, H.M., Liao, Y.S., & Wei, C.C. (2008). Wear behavior in turning high hardness alloy steel by CBN tool. *Wear*. (264) 679–684

Ozel, T. and Karpat Yigit (2005). Predictive modeling of surface roughness and tool wear in hard turning using regression and neural networks. *International Journal of Machine Tools & Manufacture* (45)467–479.

Ozel, T. and Nadgir, A. (2002). Predictions of flank wear by using back propagation neural network modeling when cutting hardened H-13 steel with chamfered and honed CBN tools. *International Journal of Machine Tools & Manufacture* (42) 287–297.

Rahman, M., Zhi-Gang, W. and Yoke-San, W. (2006). A Review on High-Speed Machining of Titanium Alloys JSME. International Journal Series. Special Issue on Advanced Manufacturing Technology. Vol. 49 No. 1 (I) pp.11-20.

Sahin and Riza (2005) (Adesta et al., 2012; Al Hazza et al., 2012).

Sharma, I. R. (2001). *Latest Trends in machining*. 209 pages. Http: //www. rishtikona. Com/ books /latest-trends-in-machining/ch-all.pdf (21 OCT 2009).

Thamizhmanii, S. and Hasan S. (2008). Measurement of surface Roughness and flank wear on hard martensitic stainless steel by CBN and PCBN cutting tools. *Journal of Achievements in Materials and Manufacturing Engineering*. Volume 31 Issue 2..