FLANK WEAR OF SURFACE TEXTURED TOOL IN DRY TURNING OF AISI 4140 STEEL

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Abstract: *Surface texturing on a cutting tool is a process which can provide reduction in friction, improved performance of a contact interface and a better tool life. In this paper, influence of surface texturing on tool wear of both textured and non-textured tools were compared. Different textures were applied on coated carbide tools by Femtosecond laser to enchance the wear resistance. Dry cutting experiments on AISI 4140 (32 HRC) were carried out with conventional cutting inserts having parallel and perpendicular textured sufaces to the cutting edge on the flank face. Finally, results showed that surface texturing of cuttting insert was found to be beneficial to the decrease of the flank wear.*

KEY WORDS: SURFACE TEXTURED TOOL, NON-TEXTURED TOOL,FLANK WEAR, DRY TURNING

1. Introduction

Machining industries will change their processes as dry machining in the next years because of environmental protection laws for occupational safety and health regulations. For this reason, the importance of dry machining increasing day by day. The advantages of dry machining includes non-pollution of the nature, no residue on the swarf which will be rejected in reduced disposal and cleaning costs, no danger to health and is allergy free. Moreover, it offers cost reduction in machining. [1] On the other hand, at dry machining tool wear, adhesion between tool and chip, the friction forces and cutting temperature become more important.

Tool wear is the most important phenomenon for dry machining which effects the parts quality, surface roughness and production costs directly. Because of this significant effect, researchers are developing a variety of methods to reduce tool wear. Several authors have studied the surface texturing phenomenon and provided their justification for improving machinability with different techniques for performing surface texturing on the tool. In recent years, several studies have revealed that surface-textured cutting tools can effectively reduce the tool wear, thereby improving tool anti-wear performance, reducing the friction between the tool and chips, and lowering the cutting temperature and forces [2-4]. Most of the textures are accomplished by various authors in the rake face of the cutting tool using femtosecond laser, grinding wheel, Rockwell hardness tester, electric discharge machining etc. Lei et al. [5] have studied the impact of cutting tool which are textured with micro-pits, by comparison against the conventional cutting tool, and found that tool with the micro-pits could effectively reduce cutting forces 10~30%. Liu et al.[6] reported a few surface textured tools with different texture figures. The research results showed that application of the surface textured tools can reduce cutting forces and cutting temperature. Rajbongshi et al.[7] have found that texturing helps in reducing the formation of white layer thickness and micro-hardness as compared to the non-textured tool. Sugihara and Enomoto[8] found that surface texturing on cemented carbide tool at the rake and flank faces in parallel to cutting edge direction caused reduction of crater and flank wear while machining. Wu et al. [9] wrote the surface textured tool could reduce the surface roughness of workpiece, and the tool life of surface textured tool was improved by 15% or so compared with the conventional one. Ze et al. [10] mentioned the benefits of rake or flank face fabricated structures of carbide using molybdenum disulfide in the textured places in the dry cutting of Ti-6Al-4 V alloy. With this texturing the authors were able to get improved machining performances in terms of cutting forces, cutting temperature, chip thickness ratio, and tool wear. Jianxin et al. [11] reported the effect of three microstructures made by lasers created on the rake faces of the cutting tool in machining of AISI 45 steel. The authors wrote that with this kind of texturing, temperature, cutting forces and coefficient of friction could be reduced. Furthermore, as mentioned above, many papers applied this surface texturing process on the rake faces of the tools and very few studies that tried to presents textured surfaces into tool flank face have been carried out, despite the importance of the flank wear resistance of cutting tools.

This study stands on the comparison of non-textured and textured tool wear characteristics. In order to understand the performance of textured tools, a comparative study was carried out using one perpendicular(PPT), one parallel(PT) textured to main cutting edge and non-textured(NT) tool. Femtosecond laser processing technology was used to produce the samples. In addition we have seen that, surface texturing effectted the surface roughness of workpiece and chip formations.

2. Experimental set up

2.1. Workpiece and tool material

The main objective of this experimental work was to investigate the effect of surface textures on flank wear and to observe how texturing was effecting the surface roughness and chip formations in dry turning of AISI 4140 32HRC steel with CVD coated conventional semented carbide tool. An orthogonal turning operation was used with cylindrical AISI 4140 32HRC workpieces with length of 250 mm and diameter of 60 mm. The chemical composition of AISI 4140 is given in Table 1.

Table 1.
Chemical composition of AISI 4140 Steel

C	Mn	P	S	Si	Ni	Cr	Mo
0,38-0,43	0,75-1	0,035	0,04	0,15-0,35	-	0,8-1,10	0,15-0,25

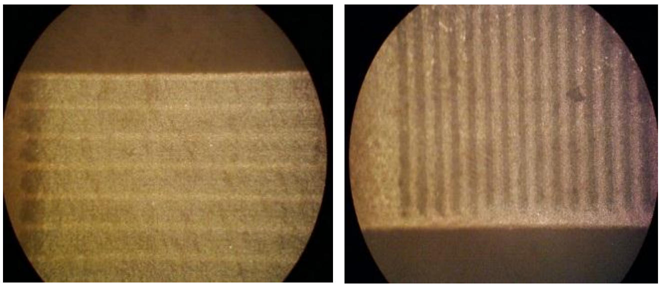
Turning was performed on machining centre Goodway GA-230. Figure 1 showed the experimental set up for dry orthogonal turning. In the experimental study, coated (CVD Ti(C,N)+Al_2O_3+TiN) cemented carbide was used. The type of the tool was Sandvik CNMG 12 04 08 PM 4315 according to the standard ISO 1832 with chip breakers. Tool holder was ACLNL 25 25 M12.

For surface roughness measurement, surface roughness tester Mitutoyo SJ-210 was used. The cut off length (λ_c) was 0,8 mm and sampling length range was 2,5mm. SOIF model optical microscope and having 1.0µm precision OSM model ocular micrometer was used for flank wear measurement.

2.2. Surface texturing on cutting tool

Femtosecond laser was applied to produce textured tools on the flank face. The laser had a marking speed of 1000µm/s, skip speed of 125mm/s and repetation rate of 1000µm/s. The line gap was 100µm, pulse duration was 120fs. Laser had a wawelenght of 800nm and laser power was 50mW. Texture grooves were produced perpendicular (PPT) and parallel (PT) to main cutting edge. In order to specify the effect on flank wear non-textured (NT) tool were used for the comparison. The microscope views of surface textures are shown in Fig. 2.

Fig. 1. Dry orthogonal turning experimental set up



(a) PT tool (b) PPT tool

Fig. 2. Microscope views of surface textures, (a) parallel to maincutting edge, (b) perpendicular to main cutting edge.

2.3. Cutting conditions

Table 2.
Cutting condition parameters used in experiments

Workpiece	AISI 4140 32 HRC
Tool	Cemented carbide, CVD coated tool
	CNMG 12 04 08 PM 4315 (Sandvik Coromant)
Cutting velocity, Vc [m/min]	180
Feed rate, f [mm/rev]	0,2
Cutting depth, ap [mm]	1,5
Cutting fluid	Dry
Corner radius, rℇ [mm]	0,8
Rake angle, ɣ [°]	-7
Clearance angle, α [°]	0
Wedge angle, β [°]	80

The cutting parameters are summarised in Table 2. For the observation of the flank wear, the cutting speed, feed and depth of cut were selected as follows: Vc=180m/min, f=0,2mm/rev ap=1,5mm were selected for proper chip formation.

3. Results and discussion

3.1. Effect of surface texturing types on flank wear and its comparison with a non-textured tool

Flank wear of cutting tools is often selected as a tool life criterion because it determines the dimension accuracy of machining, its stability and reliability.[8] In the study, flank wear of PT, PPT and NT surface of coated carbide tool were measured, thus, the difference between them was revealed. Two types of surface textures have been developed with femtosecond laser which are perpendicular and parallel to main cutting edge.

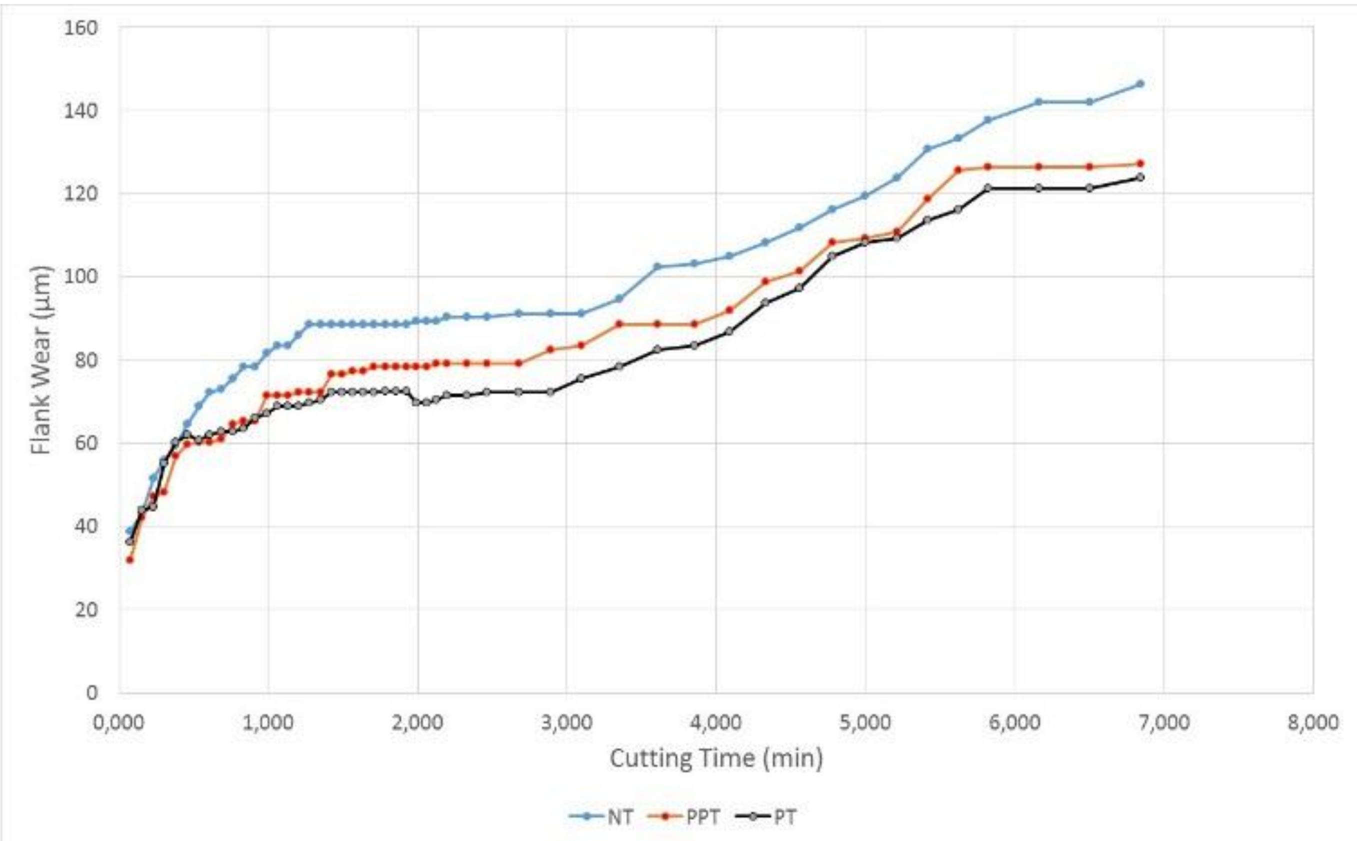
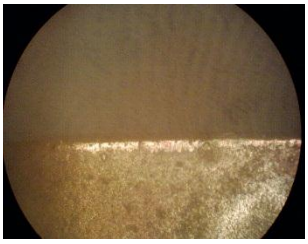
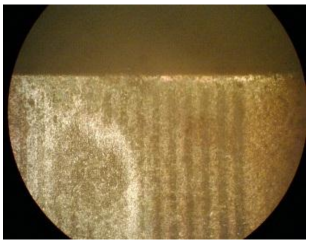


Fig. 3. Variation of tool flank wear with non-textured, perpendicular textured and parallel textured coated carbide tool.

Three samples per each test were used for the responses of flank wear and surface roughness and chip formation. The flank wear comparison of all samples is shown in Fig. 3. The tool wear was measured after every pass and all chips measured for after each of the experiment. Flank wear lenghts on the tools were observed at certain intervals and the wear conditions were compared for the same cutting times. Camera images were taken at certain time intervals of three samples (see Fig. 4.).


(a) NT tool wear: 68,8µm


(b) PPT tool wear: 60,2µm

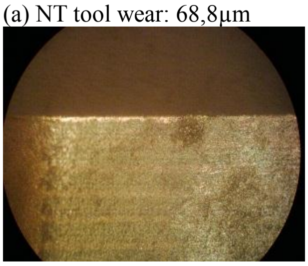
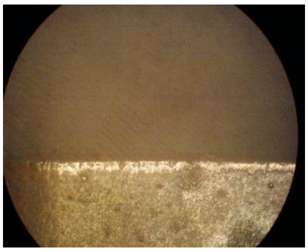
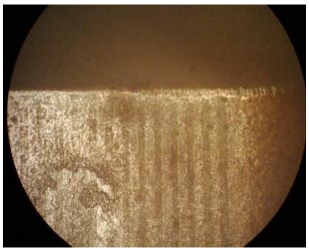

(c) PT tool wear: 60,82µm

Fig. 4.1. Flank wear values at cutting time 32 seconds.


(d) NT tool wear: 88,58µm


(e) PPT tool wear: 77,4µm

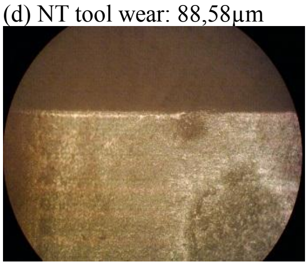
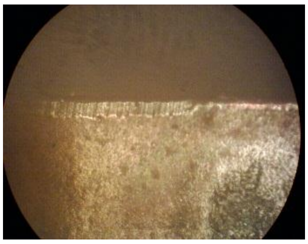
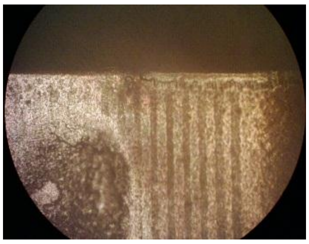

(f) PT tool wear: 72,24µm

Fig. 4.2. Flank wear values at cutting time 98,2 seconds.


(g) NT tool wear: 146,2µm


(h) PPT tool wear: 127,28µm

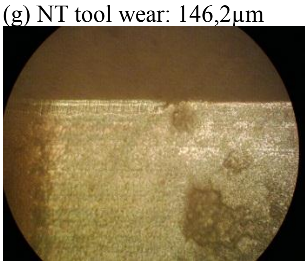

(i) PT tool wear: 123,84µm

Fig. 4.3. Flank wear values at cutting time 410,4 seconds.

As evident from the experimental data, a significant difference of flank wear for the all textured and non-textured tool was observed at same cutting conditions. The flank face textured tools with micro-scale grooves parallel to the main cutting edge (PT) had the most improved flank wear resistance (as shown in Figs. 3., 4.). The aim of the surface texturing is to decrease the contact area between the tool interface and workpiece area. On the occasion of the tool textured, the tool and workpiece friction reduced and consequently the adhesion and abrasion also decreased. Due to the less friction between tool and workpiece, the width of wear land at the flank face decreased. Hence, due to texturing on the flank face, the contact length of the cutting tool and tool wear reduced. As a result, the cutting forces generated during machining become less when it was compared to non-textured tool. In this regard, lower cutting forces, lower friction between tool and workpiece provided reduction in tool flank wear and the tool life improved. [11]

3.2. Effect of surface texturing types on surface roughness and chip formation and its comparision to non-textured tool

Fig. 5. showed the differences of avarage surface roughness on workpieces between textured and non-textured tools. From Fig. 5. It could be seen that PPT and PT tools have respectable effect on Ra. However, there has not been seen significant difference between PPT and PT.

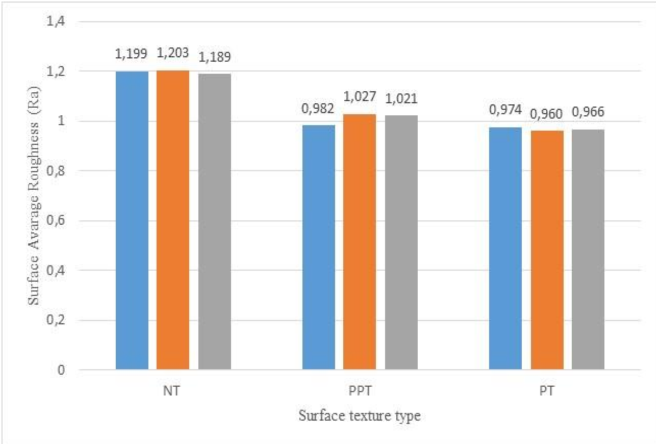


Fig. 5. Surface roughness (Ra) values of NT, PPT and PT tools

These data collected at the same cutting conditions which showed that lower flank wear that induced lower surface roughness values. In the light of all these experiments, the textured tool could reduce the surface roughness of the machined surface in comparison to that of the non-textured tool.


(a) NT tool chip form


(b) PPT tool chip form

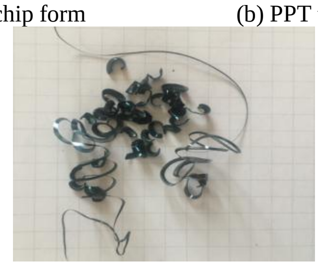

(c) PT tool chip form

Fig. 6. Chip forms of three samples, (a) NT tool chip form, (b) PPT tool chip form, (c) PT tool chip form.

On the other hand, in this paper the chip formation of all three samples were examined. As it is shown in Fig. 6., there has not been observed any visible changes on chip formation but it has seen that during cutting of the workpiece, on entering and exiting of PT tool, different chip formation occurred. Despite the tool has chip breaker, unbroken chip forms were seen on PT tool (Fig. 6.c).

4. Conclusions

In order to decrease tool flank wear and improve tool life in dry orthogonal cutting, two different types of surface texture were adopted. Surface textures were pretreated on flank faces of tools with femtosecond laser. All experiments completed under same cutting conditions with textured and non-textured coated cemented carbide tools in turning of AISI 4140 steel. Experimental results are summarized below:

- It was found that surface texturing on flank face reduced flank wear and tool life was improved. Due to the reduction of tool chip contact, friction forces and the stress on the tool decreased.
- Parallel textured tool hads more significant effect than that of perpendicular textured tool on the flank wear rate.
- It has been seen that, the decrease of flank wear improved the surface quality. But there has not been seen remarkable differences between surface roughnesses of the workpieces cut by PPT and PT tool.
- Additionally, it was observed that there was no visible changes on chip forms but during cutting of the workpiece, on entering and existing of PT tool, different chip formation occurred

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References

[1] Ngoi B.K.A., P.S. Sreejith, Dry machining: machining of the future. Journal of Materials Processing Technology 101 (2000) 287-291.

[2] Enomoto T., T. Sugihara, S. Yukinaga, K. Hirose, U. Satake, Highly wear-resistant cutting tools with textured surfaces in steel cutting. CIRP Annals – Manuf. Technology, 2012, 61(1): 571-574.

[3] Dengn J. X., Z. Wu, Y. S. Lian, T. Qi, J. Cheng, Performance of carbide tools with textured rake-face filled with solid lubricants in dry cutting processes. Int. J. of Refractory Metals and Hard Materials, 2012, 30(1): 164-172.

[4] Qi B.Y., L. Li, N. He, W. Zhao, Z. Wang, Experimental Study on Orthogonal Cutting of Ti6Al4V with Micro-textured Tool. Tribology. 2011, 31(4): 346-351.

[5] Lei S, S. Devarajan, Z. Chang, A study of micropool lubricated cutting tool in machining of mild steel. J. Mater. Process Technol. 2009;209:1612–20.

[6] Liu Y., J. Deng, F. Wu, R. Duan, X. Zhang, Y. Hou, Wear resistance of carbide tools with textured flank face in dry cutting of green alumina ceramics. Wear 372-373 (2017) 91–103.

[7] Rajbongshi S. K., M. A. Singh, D. K. Sarma, A comparative study in machining of AISI D2 steel using textured and nontextured coated carbide tool at the flank face. Journal of Manufacturing Processes 36 (2018) 360–372.

[8] Sugihara T, T. Enomoto, Crater and flank wear resistance of cutting tools having microtextured surfaces. Precision Engineering 37 (2013) 888– 896.

[9] Wu Z., J. Deng, J. Zhao, Study on tool life of surface textured tool in dry cutting of Ti-6Al-4V alloys. Advanced Materials Research Vols. 538-541 (2012) pp 1245-1249.

[10] Ze W., D. Jianxin, C. Yang, X. Youqiang, Z. Jun, Performance of the self-lubricating textured tools in dry cutting of Ti-6Al-4V. Int. J. Adv. Manuf. Technol. (2012) 62:943–951.

[11] Deng J., W. Ze, L. Yunsong, Q. Ting, C. Jie, Performance of carbide tools with textured rake-face filled with solid lubricants in dry cutting processes. Int. Journal of Refractory Metals and Hard Materials 30 (2012) 164–172.