

Tribological Studies of Laser Textured Tool Inserts in Turning Process

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Abstract -Metal forming and machining processes are used for converting the raw materials into the products in the industries. During these processes large amount is energy is consumed in the form of friction energy. In order to conserve this energy and prevent wear of tools, there is a need of green manufacturing. In this project work, an attempt has been made in order to increase the tool life and conserve energy. The comparative study has been done by taking conventional tungsten carbide tool inserts and textured tungsten carbide tool inserts. Turning process has been done on mild steel rod (C-20) with these carbide tool inserts at various parameters like spindle speed, depth of cut and feed rate.

Key words: Laser texture, friction, wears, dry condition and conventional tool insert

1. INTRODUCTION

Manufacturing is a very important component of any engineering realization. It involves providing the different shapes, sizes and cross sections to the components of the products/systems. It is worth noting that high percentage of GDP of many nations comes from the manufacturing sector. In order to achieve a better energy efficiency associated with a manufacturing process, the tribological studies at the tool (or tool insert) and work piece interface are essential for exploring the improvement of tool (or tool insert) life (low wear) and reduction of friction (which is reflected in terms of reduction in temperature rise). It is worth mentioning here that the surface modifications of tool insert by heat treatment, profiling, and texturing, are being used for improving the tribological performances at the insert and work piece interface. Therefore, it is worth exploring the turning process of carbon steels for assessing, improving and comparing the tribological performance behaviors' at the tool insert and work piece interface with conventional and textured tool inserts. It is essential to mention here that the combination of turning operation (manufacturing) and carbon steel work piece is proposed for investigation due to their extensive use in industries. In the past, many attempts have been made by the researchers [1-8] for investigating and improving the tribo-performance behaviours involved in the turning process for extending the tool life and improving the surface quality of machined work piece efficiently. Good surface finish is an essential requirement in a machining process, which is very sensitive to the form accuracy of the tool. It is worth noting here that due to the rapid wear of tool (due to poor lubrication and lack of cooling at the tool and work piece interface); the quality of surface finish deteriorates. Grzesik [1] has tried in his research work to

quantify the surface finish on the turned hardened alloy steel parts in terms of cutting time (leading to tool wear) produced by differently shaped ceramic tool tips. To suppress the adhesion during the milling of aluminium alloy at the cutter face, nano/micro textured surfaces of cutter promoted anti-adhesiveness features as said by Sugihara *et al* [2-3] in his work. For improving the turning process on lathe machine, Enomoto *et al* [6] have used textured WC/Co carbide tools filled with MoS₂ solid lubricants on the rake-face close to the main cutting edge of the tool. Turning operations were performed in dry conditions using the rake-face textured tools and conventional one. It has been reported by the authors that the cutting performance of the rake-face textured tools is significantly improved over that of the conventional one. The studies related to turning of AISI 52100 bearing steel with CBN tool has been reported by Jianxin *et al* [7]. The combined effects of process parameters (cutting speed, feed rate, depth of cut and cutting time) on the performance characteristics (tool wear, surface roughness, cutting forces and metal volume removed) are investigated by the authors [7] using ANOVA analysis. The relationship between process parameters and performance characteristics through the response surface methodology (RSM) are modelled. The results show that the cutting speed exhibits maximum influence on abrasive tool wear. The depth of cut affects strongly the cutting forces; however, it has a negligible influence on surface roughness. The cutting time has a considerable effect on all performance characteristics. The power consumption and roughness characteristics of surface generated in turning operation of EN-31 alloy steel (bearing steel) with TiN+Al₂O₃+TiCN coated tungsten carbide tool under different cutting parameters have been assessed by experimental work of Neves *et al* [8]. The study investigated the influences of the spindle speed, depth of cut and feed rate on surface roughness as well as power consumption. The study presents the results for five different spindle speeds (in the range of 700 -1200 rpm) keeping feed rate between 0.4 mm/s to 1.6 mm/s and depth of cut between 0.12 mm to 0.20 mm.

2. EXPERIMENTAL SETUP

The experimental setup for the conduction of this experiment includes lathe machine, non-contact thermometer, tool holder, tool inserts (Tungsten carbide tool insert), work piece (mild steel rod C-20), weighing machine, confocal microscopy machine, lapping machine and fiber laser machine.

2.1 Equipment's

2.1.1 Lathe Machine

Pioneer-175 lathe machine was identified for turning operation. This machine has speed variation from 54 rpm to 1200 rpm, with least feed rate as 0.2 mm/rev and least depth of cut as 0.04 mm.

2.1.2 Non-Contact Thermometer

The non-contact thermometer of Work Zome (as shown in fig. 1.1) is used for measuring the temperature rise (first measuring the temperature of the tool insert tip before the turning operation and then after the turning operation). The temperature range of this thermometer is from -50°C to 1100°C. The validation of this equipment has been done. The temperature shown by this thermometer is 2°C more than the actual temperature. So the temperature has been noted by taking this error in consideration.



Fig.1.1 Non-Contact thermometer of Work Zome

2.1.3 Tungsten carbide tool insert

The carbide tool inserts which are shown in fig.1.2 are used for the turning operation are triangular in shape. The dimensions of the tool inserts have been noted down along with the weight of each carbide tool insert. The dimensions are measured using Vernier calliper and protector. The length of tool insert is 15.148 mm and width is 6.128 mm. The angle formed by sides of tool insert is 60°. The rake angle is 0° during turning operation

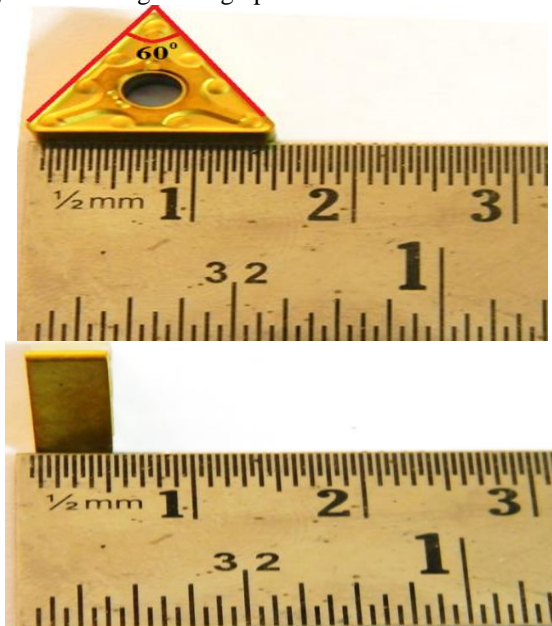


Fig. 1.2 Carbide tool inserts

2.1.4 Tool Holder

Tool holder shown in fig.1.3 is used for holding the tool inserts. This tool holder is mounted on the tool post of the lathe machine. Tool holder is made of cast iron as it has high compressive strength. The length of tool holder which is outside the tool post also contributes in force which acts on the workpiece. Same length of tool holder is outside the tool post so that same force is applied on every workpiece.

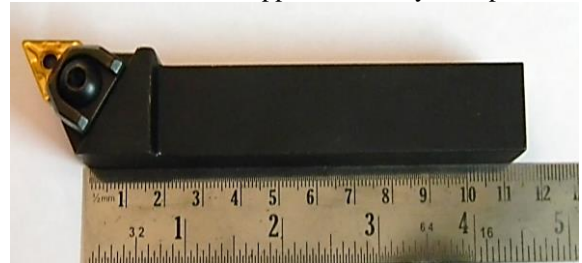


Fig.1.3 Tool holder

2.1.5 Workpiece

Mild steel rod (C-20) is used as workpiece which around 20 cm in length. The turning has been done up to 12.5 cm in the length as shown in fig.1.4.



Fig.1.4 Mild steel rod and turning has been done up to 12.5 cm

2.1.6 Confocal Microscopy Machine

Preliminary trials were performed on fiber laser machine to correlate the laser parameters like frequency of laser pulse, power of laser, scanning speed, and distance between two grooves. Varying these parameters allows optimization of the dimensions and the quality of shape produced. Confocal microscopy machine as shown in fig.1.5 is based on optical imaging technique which is used to increase optical resolution and contrast. It eliminates the out of focus light by using spatial pinhole placed at confocal plane of the lens. It reconstructs the 3-D structures from the obtained images.



Fig.1.5 Confocal microscopy machine

3. RESULTS AND DISCUSSIONS

After conducting the experiments for the conventional tool inserts and textured tool inserts the following results are obtained and is shown in tabulated form. The table includes the condition of tool insert, spindle speed, depth of cut, feed rate, and weight of the tool inserts before and after the experiments, wear and temperature rise at the interface of the tool insert and chip interface.

3.1 Effect of Temperature with various parameters

In this section we will discuss the temperature rise for textured and conventional tool insert for various parameters. In the end this section, we will come to a conclusion that which type of tool insert is best suited of that set of parameters.

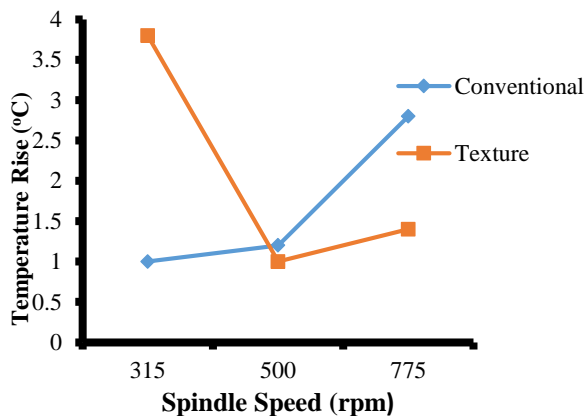


Fig 3.1 Variation of temperature with spindle speeds at 0.12 mm depth of cut and 0.4 mm/rev feed rate

The variation of temperature in relation with various spindle speeds at 0.12 mm depth of cut and 0.4 mm/rev feed rate can be seen in fig.3.1. The temperature rise is more for texture tool insert at 315 rpm. For spindle speed 500 rpm and 775 rpm the temperature rise of textured tool insert is less than the conventional tool insert. This shows that textured tool insert is better at 500 rpm and 775 rpm.

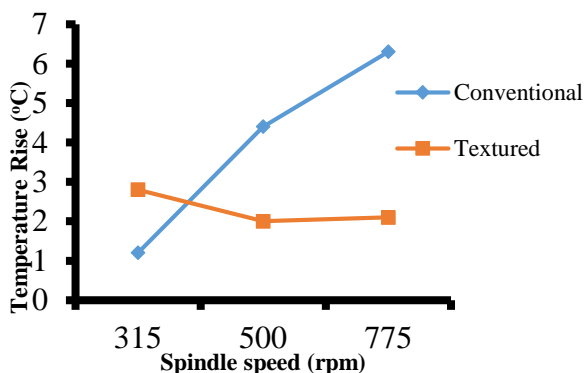


Fig 3.2 Variation of temperature with spindle speeds at 0.12 mm depth of cut and 1.6 mm/rev feed rate

For depth of cut 0.12 mm and feed rate 1.6 mm/rev as shown in fig 3.2, the variation in temperature rise of textured and conventional tool insert for various spindle speed can be observed. The temperature rise of textured tool insert is more

than conventional tool insert at 315 rpm. When the spindle speed has increased from 315 rpm to 500 rpm and 775 rpm then the temperature rise for textured tool insert is less in comparison to conventional tool insert.

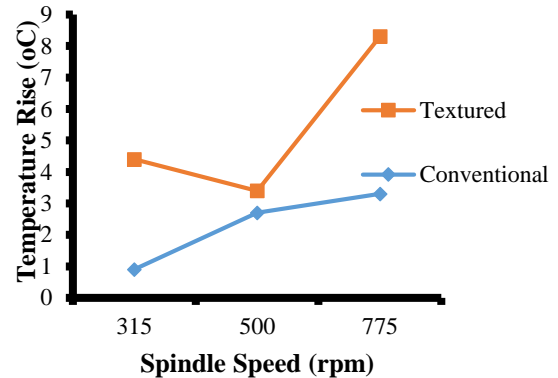


Fig 3.3 Variation of temperature with spindle speed at 0.16 mm depth of cut and 0.4 mm/rev feed rate

The variation of temperature in relation with various spindle speeds at 0.16 mm depth of cut and 0.4 mm/rev feed rate has been shown in fig. 3.3. The temperature rise is more for texture tool insert at all the spindle speeds. Therefore for this parameter conventional tool inserts are better.

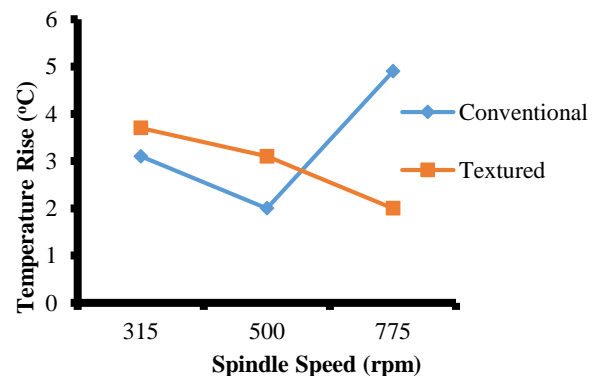


Fig 3.4 Variation of temperature with spindle speed at 0.16 mm depth of cut and 1.6 mm/rev feed rate

The temperature rise for conventional tool insert is less as compared to textured tool insert for 315 rpm and 500 rpm spindle speed, 0.16 mm depth of cut and 1.6 mm/rev feed rate as shown in fig.3.4. When spindle speed increases to 775 rpm, the temperature rise for textured tool insert is less than conventional tool insert.

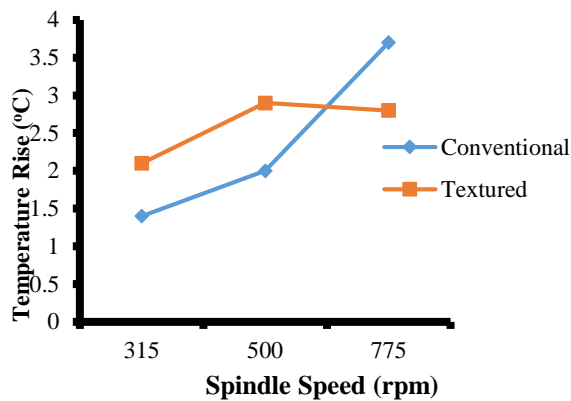


Fig 3.5 Variation of temperature with spindle speed at 0.20 mm depth of cut and 0.4 mm/rev feed rate

The temperature rise for conventional tool insert is less as compared to textured tool insert for 315 rpm and 500 rpm spindle speed, 0.20 mm depth of cut and 0.4 mm/rev feed rate as shown in fig.3.5. When spindle speed increases to 775 rpm, the temperature rise for textured tool insert is less than conventional tool insert.

3.2 Confocal microscopic image of conventional and textured tool inserts

In this section the wear pattern can be observed for both conventional and textured tool inserts. The image of both type of tool inserts are shown together for same set of parameters.

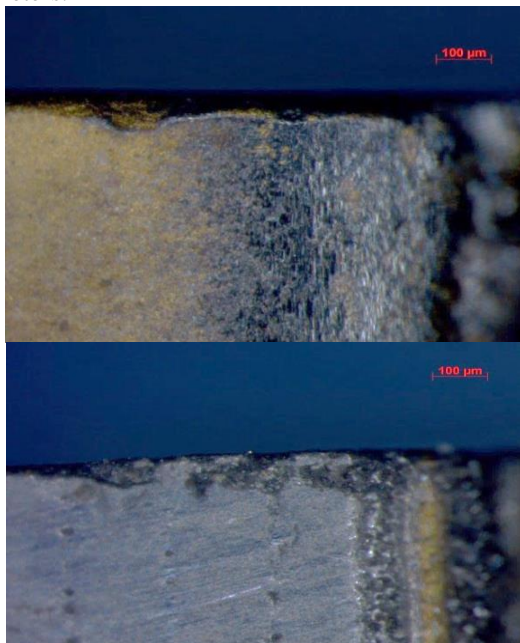


Fig.3.6 Confocal microscopic image of conventional and textured tool inserts after turning operation at 315 rpm, 0.12 mm depth of cut and 0.4 mm/rev feed rate

The wear pattern can be seen in fig. 3.6, the confocal microscopic image of both conventional and insert after turning operation at 315 rpm, 0.12 mm depth of cut and 0.4 mm/rev feed rate. The images are magnified at 120 times magnified.

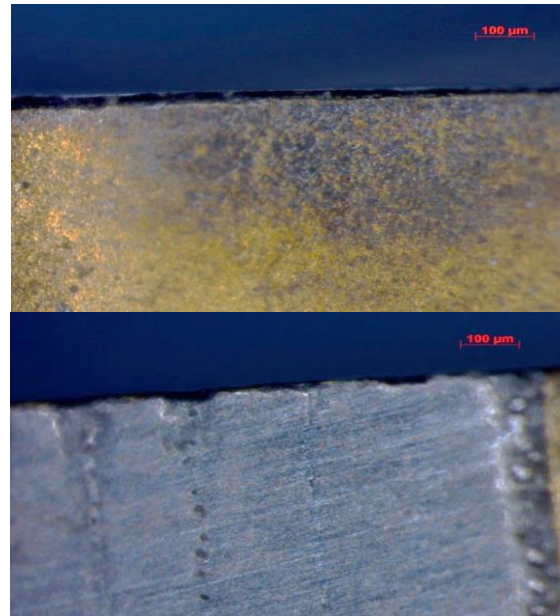


Fig.3.7 Confocal microscopic image of conventional and textured tool inserts after turning operation at 500 rpm, 0.12 mm depth of cut and 0.8 mm/rev feed rate

As shown in fig. 3.7, the wear pattern can be seen in the confocal microscopic image of conventional and textured tool insert after turning operation at 500 rpm, 0.12 mm depth of cut and 0.8 mm/s feed rate. The images are magnified at 120 times magnified.

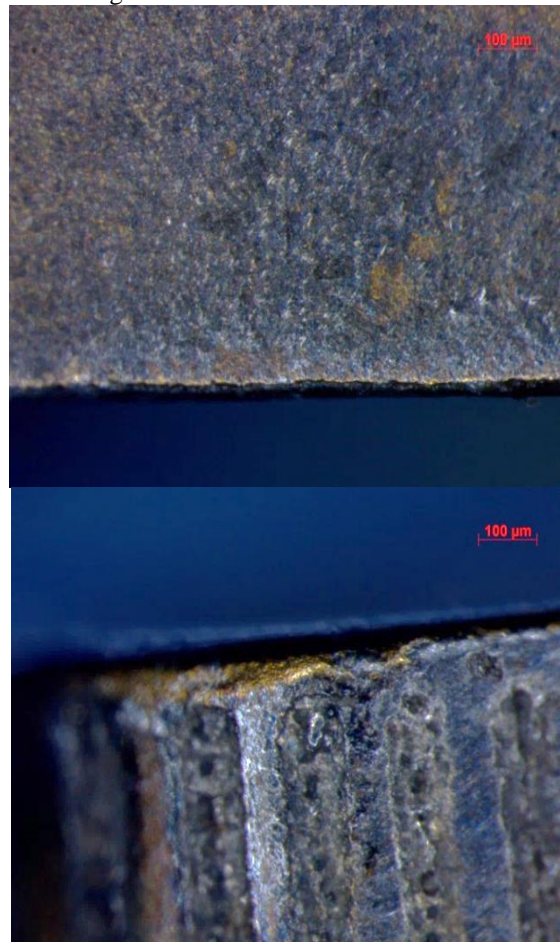


Fig.3.8 Confocal microscopic image of conventional and textured tool inserts after turning operation at 775 rpm, 0.12 mm depth of cut and 1.6 mm/rev feed rate

Confocal microscopic image of conventional and textured tool insert reveals the wear pattern turning operation at 775 rpm, 0.12 mm depth of cut and 1.6 mm/rev feed rate which is shown in fig. 3.8. The images are magnified at 120 times magnified.

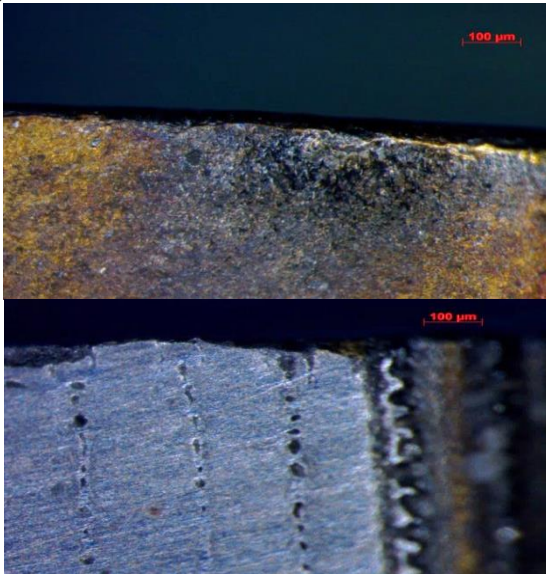


Fig.3.9 Confocal microscopic image of conventional and textured tool inserts after turning operation at 500 rpm, 0.16 mm depth of cut and 0.8 mm/rev feed rate

Confocal microscopic image of conventional and textured tool insert shows the wear pattern after turning operation at 500 rpm, 0.16 mm depth of cut and 0.8 mm/rev feed rate (fig.3.9). The images are magnified at 120 times magnified.

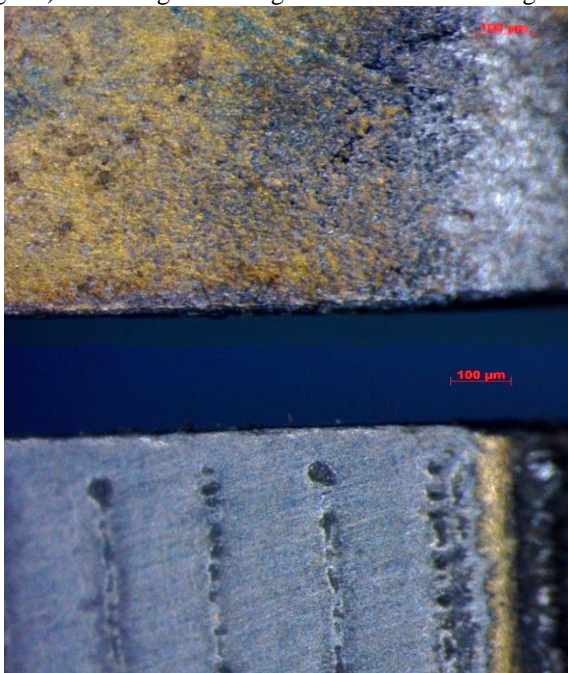


Fig. 3.10 Confocal microscopic image of conventional and textured tool inserts after turning operation at 775 rpm, 0.16 mm depth of cut and 1.6 mm/rev feed rate

Confocal microscopic image of conventional and textured tool insert shows (as shown in fig. 3.10) the wear pattern after turning operation at 775 rpm, 0.16 mm depth of cut and 1.6 mm/rev feed rate. The images are magnified at 120 times magnified.

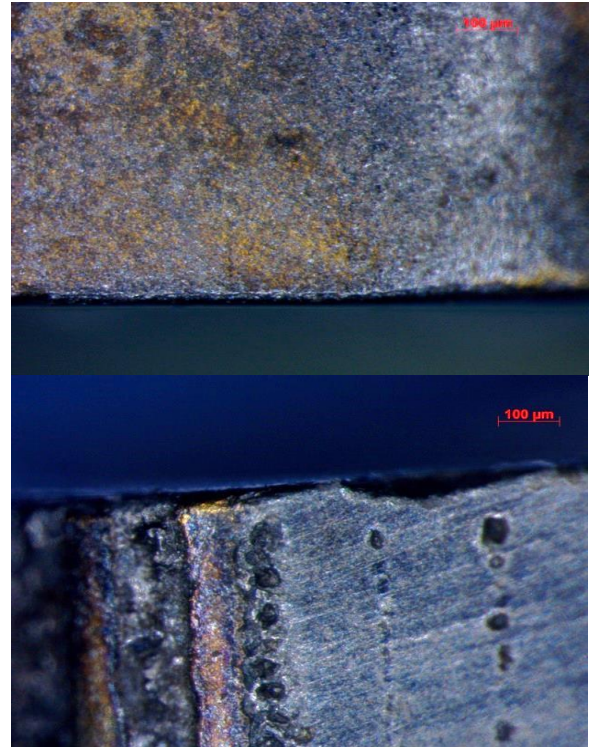


Fig.3.11 Confocal microscopic image of conventional and textured tool inserts after turning operation at 500 rpm, 0.2 mm depth of cut and 0.8 mm/rev feed rate

Confocal microscopic image of conventional and textured tool insert shows the wear pattern after turning operation at 500 rpm, 0.2 mm depth of cut and 0.8 mm/rev feed rate which is shown in fig. 3.11. The images are magnified at 120 times magnified.

4. WEAR BEHAVIOUR OF TOOL INSERTS

In this section, the wear behaviour of conventional and textured tool inserts for various parameters are shown.

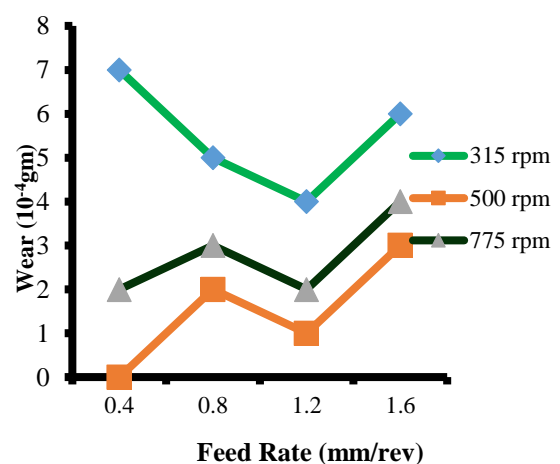


Fig. 4.12 Wear of conventional tool inserts at various rpm, feed rate and at 0.12 mm depth of cut

The graphical representation of wear corresponding to various feed rate for various spindle speed at 0.12 mm depth of cut as shown in fig. 4.12. From the above figure it can be seen that wear of tool insert changes when the feed rate and spindle speed changes. For feed rate 0.4 mm/rev

corresponding spindle speed 315 rpm and 500 rpm, the wear is minimum. Wear increases when feed rate changes to 0.8 mm/rev then again it decreases 1.2 mm/rev feed rate and again increases at 1.6 mm/rev feed rate. The wear behaviour is different for spindle speed 775 rpm.

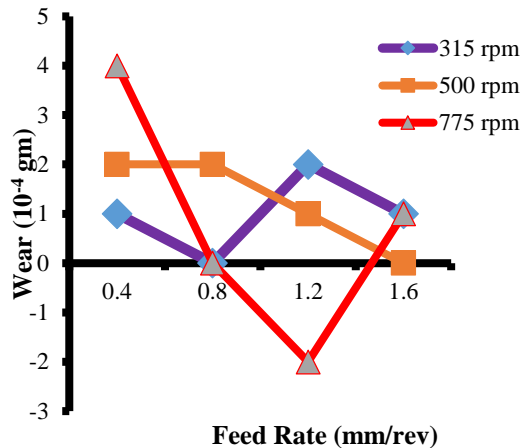


Fig.4.13 Wear of conventional tool inserts at various rpm, feed rate and at 0.16 mm depth of cut

The graphical representation of wear corresponding to various feed rate at various spindle speed at 0.16 mm depth of cut can be seen in fig. 4.13. From the above figure it can be seen that wear of tool insert changes as the feed rate and the spindle speed changes. For feed rate 0.4 mm/rev, wear is maximum for spindle speed 775 rpm and minimum at 315 rpm. For feed rate 0.8 mm/rev, maximum wear is at 500 rpm and is minimum at 315 and 775 rpm. For feed rate 1.2 mm/rev, unexpected wear behaviour is found. There is addition of material due to heating and weight of tool insert increases.

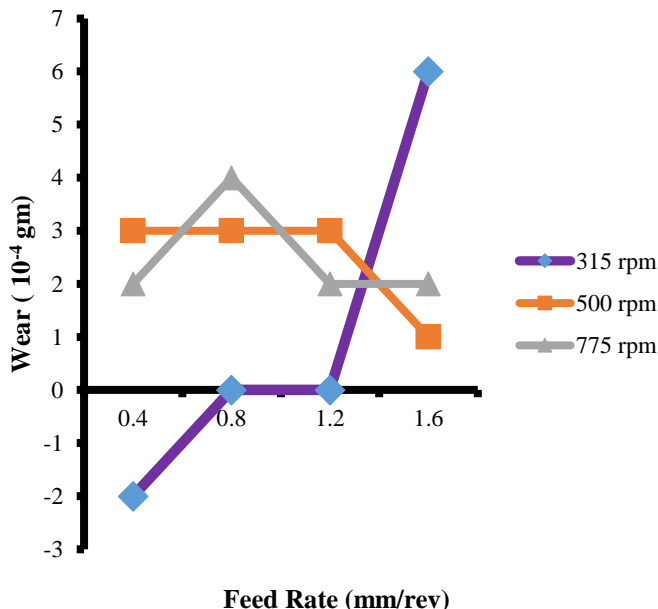


Fig.4.14 Wear of conventional tool inserts at various rpm, feed rate and at 0.20 mm depth of cut

The graphical representation of wear corresponding to various feed rate at various spindle speed (rpm) at constant depth of cut of 0.20 mm is shown in fig. 4.14. Wear behaviour of various tool inserts changes as the feed rate

changes at various spindle speed. For feed rate 0.4 mm/rev, wear changes from minimum at 315 rpm to maximum at 775 rpm. At 315 rpm we can observe that there is addition of material rather than removal and this is due to dirt and impurities getting attached to the tool insert. For feed rate 0.8 mm/rev, maximum wear is at 500 rpm and almost zero wear at 315 rpm. For feed rate 1.2 mm/rev, there is no significant wear of tool insert at 315 rpm and maximum wear is at 500 rpm. For feed rate 1.6 mm/rev, wear of tool insert is maximum at 315 rpm and minimum at 500 rpm.

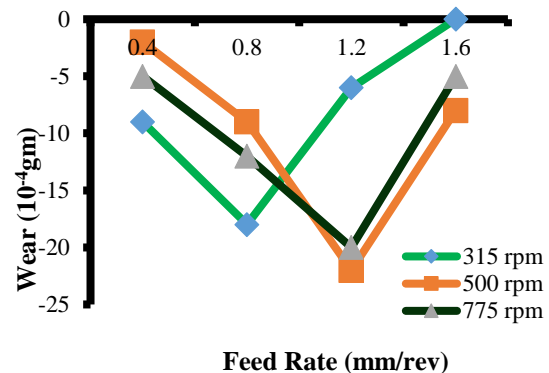


Fig.4.15 Wear of textured tool inserts at various rpm, feed rate and at 0.12 mm depth of cut

The graphical representation of wear corresponding to various feed rate at various spindle speed (rpm) at 0.12 mm depth of cut is shown in fig.4.15. From the above figure it can be seen that no wear of textured tool insert takes place with change in the feed rate at various spindle speed instead there is addition of material. This addition has taken place as the chips of workpiece and particles of tool inserts gets trapped inside the texture.

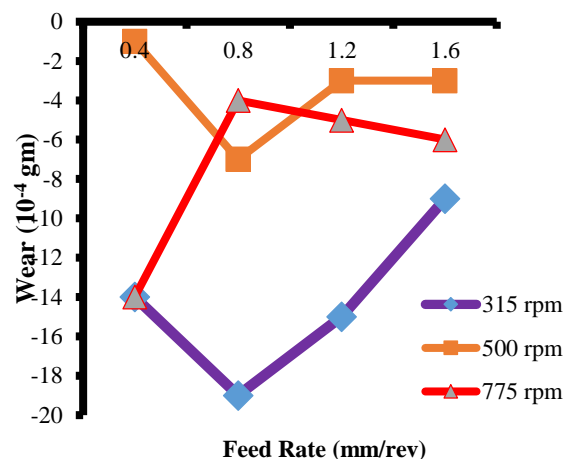


Fig. 4.16 Wear of textured tool inserts at various rpm, feed rate and at 0.16 mm depth of cut

The graphical representation of wear corresponding to various feed rate, spindle speed at 0.16 mm depth of cut can be seen in fig.4.16. From the above figure it can be seen that no wear of textured tool insert takes place with change in the feed rate at various spindle speed instead there is addition of material. This addition has taken place as the chips of workpiece and particles of tool inserts gets trapped inside the

texture. When the spindle speed is 315 rpm the addition of material is more in comparison to 500 rpm and 775 rpm for all the feed rates.

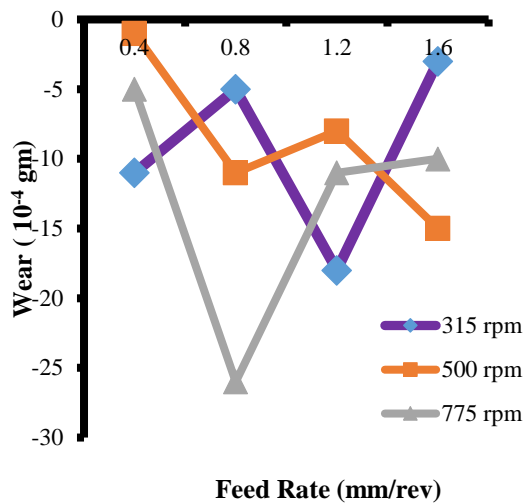


Fig. 4.17 Wear of textured tool inserts at various rpm, feed rate and at 0.20 mm depth of cut

The graphical representation of wear corresponding to various feed rate, spindle speed and at constant depth of cut of 0.20 mm is shown in fig. 4.17. From the above figure it can be seen that no wear of textured tool insert takes place with change in the feed rate at various spindle speed instead there is addition of material. This addition has taken place as the chips of workpiece and particles of tool inserts gets trapped inside the texture. When the spindle speed is 775 rpm the addition of material is more in comparison to 500 rpm and 775 rpm at 0.8 mm/rev feed rate.

CONCLUSIONS

The comparative study has been done successfully by taking conventional tungsten carbide tool inserts and textured tungsten carbide tool inserts. The Turning process has been done on mild steel rod (C-20) with these carbide tool inserts at various parameters like spindle speed, depth of cut and feed rate. Based on detailed study the following conclusions have been drawn:

- Temperature rise is in increasing order when the spindle speed, feed rate and depth of cut is increased for both textured and conventional tool insert. The rise in temperature of textured tool insert is less in comparison to conventional tool insert.
- Weights of conventional tool inserts have decreased after the turning operation. Whereas the weight of textured tool inserts has increased because the chips of workpiece and tool insert articles gets trapped inside the texture.
- Wear of conventional and textured tool inserts changes with change in parameters like spindle speed, feed rate and depth of cut. Wear is more for conventional tool inserts in comparison to textured tool inserts.

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