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COMPARATIVE EVALUATION OF UNTEXTURED AND TEXTURED WC INSERTS UNDER DRY AND NEAR DRY MACHINING OF C45 STEEL

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ABSTRACT

C45 steel is considered under the category of the most difficult to cut materials because of hardness (45-55 HRC). Based on the size effect, the low machine's ability may be improved by surface texturing on the rock faces of the uncoated carbide (WC) inserts, using Femto second laser. Dry and Minimum Quantity Lubrication (MQL) cutting experiments were performed with these plain inserts and textured inserts under condition of cutting speed = 80 m/min and 120 m/min, depth of cut = 0.5 mm and feed rate = 0.16 mm/rev. These experiments were performed on different machining time. The comparative evaluation is in terms of cutting forces, roughness, tool wear (flank) and tool tip temperature. Results obtained reveal that average of output parameters is minimum in textured of inserts with MQL condition, as compared to without textured and dry condition.

KEYWORDS: Hard Turns, MQL, Surface Textured Tool, C-45 Steel

INTRODUCTION

Turning is considered as a machining process, in which a cutting tool, known as a 'non-rotary tool bit' defines a helix tool path, by rotating less or more linearly, when the rotation of work piece takes place [1]. The axes of tool of movement might be a straight line, or might be besides few sets of angles or curves, but they are significantly linear. Numerous scientists have developed numerical models to enhance the slicing parameters to have least surface unpleasantness and instrument wear by turning the process [2]. Turning has developed as a feasible contrasting option to granulating the complete process of machining of solidified steels.

The turning processes are normally performed on a lathe, and taken as the existed machine tools, and may be of four varied types as defined below [3]:

- Straight turning,
- Taper turning,
- Profiling or external grooving.

The mentioned types of turning process generate different material shapes like conical, straight, curved, or grooved work piece. Generally, the turning utilizes accurate single-point cutting tools. Every group of the work piece materials has an optimum set of tool angles which have been executed in the years [4].

Turning Dynamics

Forces

The turning operation has relative forces that are significant in machine tool design [5]. The machine tool with its components should take these forces without any effect of important vibrations and deflections during the operation [6]. Three basic principles are there for the turning process:

- The cutting or tangential force acts downward on the tool tip
- The axial or feed force acts
- The radial or thrust force acts

Speeds and Feeds

These are accepted on the basis of cutter material, setup rigidity, work piece material, machine tool rigidity and spindle power and coolant choice.

Feed

The distance, the tool advances into the material in a single revolution is known as "feed". It is described as mm/revolution (mm/rev).

HARD TURNINGS

Hard turning is performed on materials with hardness in the 45–68 Rockwell Hardness run, utilizing an assortment of tippet or strong cutting supplements [7]. In spite of the fact that, granulating is known to create great surface complete at moderately enhanced sustain rates, hard turning may deliver a great or an enhanced surface complete at essentially higher material evacuation rates [8]. Hard turning can deliver an improved surface complete and less apparatus wear than granulating.

Cutting Tool Materials for Hard Turning

The cutting device material must have a variety of key properties to avoid extreme wear, breakout and cutting high temperatures, with the ensuing properties being the basis for cutting the material to withstand the overwhelming state of the slicing process and providing high caliber and conservative parts [9] [10].

- **Hardness:** On the raised temperatures (purported hot hardness), hardness with the quality of the instrument edge are kept up in high cutting temperatures.
- **Toughness:** Capacity of the material to retain vitality without coming up short. Cutting, if regularly joined by effect compels, particularly if cutting is interfered, and cutting device may flop soon on the off chance, that it is not sufficiently solid.
- **Wear Resistance:** In spite of the fact that there is a solid relationship between's hot hardness and wear resistance, later relies on upon something other than hot hardness. Other imperative qualities incorporate surface complete on the device are, concoction inactivity of the device material as for the work material is concerned and warm conductivity of the instrumental material which influences the most extreme estimation of the cutting temperature, at the apparatus chip interface [11].

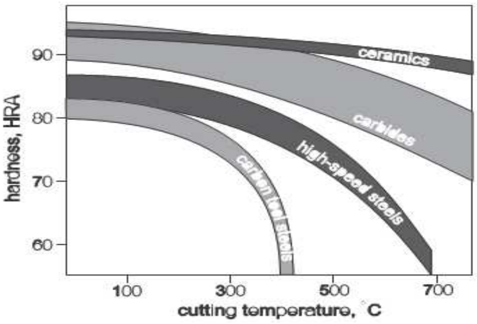


Figure 1: Hot Hardness of Different Tool Materials

Cutting device can be arranged into a few gatherings; fast steels, carbides, clay, cubic boron nitride and precious stone [12]. Each tool has a distinctive feature, which is reasonable for the use of certain materials. It is conceivable that the cutting speed of the carbon steel used in the production of the quick device is three to five times faster than the cutting speed. Due to its high speed capability, the device is called fast steel [13]. The alloy composition of the device is tungsten, molybdenum, chromium and vanadium. These alloy components will enhance the thermal hardness and the resistance of the scrapping area. In the past 650 ℃, the hardness of fast steel decreased rapidly [14]. The rapid steel plant is suitable for invasive cutting, such as machining operations. This is the maximum proportion of the cutting instrument used as part of the processing [15]. The performance of the cemented carbide instrument has a high thermal hardness in terms of various temperatures, high elastic modulus and thermal conductivity. Carbide devices can be divided into two groups: tungsten carbide and titanium carbide [16].

Tool Wears in Hard Turning

The wear on the device is the result of a procedure, which is reflected as the dynamic wear of the particles from the surface of the device [17].

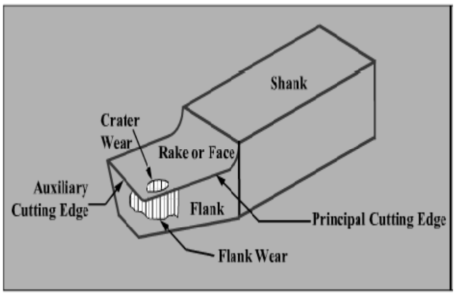


Figure 2: Types of Cutting Tool Wear at the Single Point Cutting

The three wires are largely related to the cutting equipment: side wear, nose wear and pit wear are shown in Figure 2 [18]. Correspondingly, the erosion between the side of the edge of the instrument and the metal being processed causes side wear. A lot of flank wear builds rubbing and makes more power vital for machining [19]. Nose wear happens in the nose of the purpose of the cutting instrument, thus grating between the nose and the metal being machined. Wear on the nose of the cutting instrument influences the nature of the surface completely on the work piece [20]. Hole wear happens a slight separation far from the front line, thus of the chips sliding along the chip-instrument interface, which is an after effect of a developmental edge on the cutting apparatus. In the long run, excessive cavity wear breaks out the bleeding edge [21].

Recent Advancement in Turning

Cutting liquids are utilized in machines to decrease contact, cool the work piece, and to wash away the chips [22]. The utilization of cutting liquid diminishes the device wear and enhances the surface nature of machined surface. The cutting liquid additionally shields the machined surface from erosion [23]. They additionally lessen the cutting powers required in metal cutting, hence sparing the vitality. Above all else, an extensive amount of the cutting liquid is required. Additionally, the transfer of utilizing cutting liquid sullied with cut oxidized chips is likewise a noteworthy test. The transfer of wet chips additionally represents the potential wellbeing and security issues [24]. The transfer of poisonous slicing liquid by assembling units to water channels, waterways (which by and large goes unchecked) may prompt ground water defilement [25]. The utilization of a lot of cutting liquid includes extensive starting expense, accordingly expanding the assembling cost. The utilization of metal working liquids is around 640 million gallons over the globe [26]. The coolants and greases utilized for machining represent nearly16 to 20% of the aggregate assembling costs [27].

Minimum Quantity Lubrication (MQL)

MQL is prepared to imply a small portion of the cutting liquid as an atomized form into the dispersion between the cutting apparatus and the work piece together with the compaction air [28]. The molecular dimensions of the fog are typically below 0.5 [mu] m, sufficiently small to enter portions having curled geometries that cannot be quickly lubricated by cutting the liquid, although for rapid processing [29]. In this way, has taken into account the warmth of the times, cutting equipment and the interface between the chips is limited and improved, respectively, through the use of MQL method. Typically, two types of lubricants are used in MQL technology.

- The first is the synthetic ester of vegetable oil. Due to their high ignition point, high boiling point, low viscosity, good lubricate and high corrosion resistance, they are considered to be good lubricants. Thus, these types of oils are commonly used in processing operations where the friction reduction is more important.
- Other types of lubricants used in MQL technology are fatty alcohols, made from natural materials or mineral oils. It is reported that fatty alcohols are very effective for the processing of the surface and the cutting tool cooling, while its lubrication is not as good as synthetic ester oil. Therefore, it is often used for machining operations that require effective heat dissipation rather than friction reduction. It is known that both types of lubricants are environmentally stable, biodegradable and non-toxic.

Surface Texturing

Techniques like generating textures on the rake face of the inserts to be used for enhancing the performance of cutting inserts during turning operation [31]. Surface Texturing is one such a neoteric green manufacturing practice to alter the surface topography of the cutting tool at the rake face. Different methods (femto second laser, NdYag laser, laser machining, V tip micro grinding, Helicon DC magnetron sputtering and micro EDM) are used to engrave pattern (circular holes or grooves, micro-dimples) on the tool surface [32]. The direction of the texture is elliptical, parallel, linear, inclined, wavy, cross- patterned, square pits and square dots to the main cutting edge of the tool as shown in figure. With the aid of this texturing, the contact of chips with rake face is decreasing, which decreases the effect of friction on the tool–chip interface resulted in the reduction of the value of coefficient of friction and cutting forces and thus prolongs tool life [33].

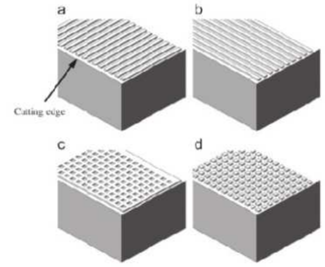


Figure 3: Rake Face with Four Types of Micro Texture
(A) Perpendicular (B) Parallel (C) Square Pits (D) Square Dots

Simulation Model

This research has undertaken a study that helps to explore the potential in turning of hard to machine materials with carbide inserts (Textured) treated under MQL conditions. This study helps in evaluating the optimum combination of vegetable oil based coolant and also helps in evaluating the concentration of coolant/lubricant mixture that minimizes tool wear and has improves surface quality of the machined surface.

Below are the steps used for the evaluation of the proposed work.

- Preparation of specimens for machining.
- Conducting machining of specimens under MQL technique with fabricated textured inserts and recording tool wear, surface roughness of machined specimens for varying input parameters viz. MQL parameters, machining parameters (i.e. cutting speed, feed, depth of cut, etc.)
- Analyzing the influence of various input conditions on different response parameters.
- Analyzing operative wear mode and wear mechanisms in cutting tools under different cutting conditions through SEM-EDAX analysis.
- Optimizing the input conditions to minimize tool wear and surface roughness.
- Mathematical Model will be developed to correlate output variables such as surface finish, tool wear with the input variables, i.e. cutting speed, feed, and depth of cut.

EXPERIMENTAL PROCEDURE

Work Piece

Chemical composition of C45 is shown in the table

Table 1: Chemical Composition of C45 Steel

Material	C%	Si%	Mn%	S%	P%
C45	.43	.235	.676	.0645	.0450

This material was used when we need greater strength and hardness is required. Dimensions of the work piece are listed below:

Length: 300 mm

Diameter: 50 mm

Cutting Tool

The tool used for cutting the work piece is TNMA 160408. It is triangular in shape, having a hole at the centre. Uncoated carbide cutting tool has been used for Hardening the work piece H11 uncoated tungsten carbide. H11 material provides an essential property like high resistance from nature against wear and also used in the components that are subjected to wear high surface loading. Due to its high strength, it finds application in the automobile field.

Figure.4: Work Piece Set Up

Table 1: Conditions for the Cutting Test

Cutting Conditions	Explanation
Work piece	C45 steel
Cutting insert	Uncoated tungsten carbide
Diameter of W/p	50 mm
Length of w/p	300 mm
Hardness	45-50 HRC
Cutting speed	80m/min and 120m/min
Feed	0.16 mm/rev
Depth of cut	0.5 mm
Cutting environment	Dry, MQL

Minimum Quantity Lubrication Setup

To MQL condition, the equipment was applied flow rate at 150ml/hr. The system was connected to the compressed air through a pressure regulator set at 4 bars. It has two independent systems of regulation of the oil/air flow. Once generated, the flows of air and lubricant are supplied to the nozzles of diameter 2 mm by means of two independent coaxial tubes; the mixing and nebulisation of the oil occurs in the terminal part. Colona oil was used in the present work. It is biodegradable, non-toxic and obtained from renewable raw materials

SIMULATION RESULTS

This section explains the results obtained after the simulation of the proposed work:

Simulation Results For Dry Condition for Textured and Untextured Tool with Speed=120m/min

For un-textured or for plain work piece, the average value of surface roughness was 4.79 (µm), the temperature was 77.92 ($℃$), Tool wear435. 76, cutting forces along (x, y, z axis) was62. 044,161.012and738.72N.

Table 2: Parameters Calculated For Untextured in Dry Condition

Speed	Feed	Depth of Cut	Tool			RPM
120 M/Min	0.16 Mm/Rev	0.5 Mm	Untextured			1200
Time	Surface Roughness (Micrometre)	Temperature (° C)	Vb (Tool Wear) In Micrometre	Cutting Forces (N)		
				X	Y	Z
1	3.22	56.8	290	35.54	130.53	98.29
2	4.3	62.4	350.4	50.54	146.96	120.94
4	5.07	73.5	405.1	61.62	158.98	147.15
6	5.56	91.5	498.4	76.96	176.58	152.05
8	5.8	105.4	634.9	85.56	192.01	175.15

Table 3: Parameters Calculated For Textured Tool in Dry Condition

Speed	Feed	Depth of Cut	Tool			RPM
120 M/Min	0.16 Mm/Rev	0.5 Mm	Textured (Parallel)			1200
Time	Surface Roughness (Micrometre)	Temperature (° C)	Vb (Tool Wear) in Micrometre	Cutting Forces (N)		
				X	Y	Z
1	2.81	49.7	270.15	68.7	147.15	61.11
2	3.27	55.8	310.2	78.48	162.36	73.38
4	4.37	64.5	337.2	83.38	174.28	88.92
6	4.85	87.5	435.2	94.27	186.96	101.46
8	6.31	101.5	512.2	107.91	200.36	116.39

The results obtained for texture Parallel when speed of machine is 120 m/min are: average surface roughness was 4.322 (µm), temperature was 71.8 ($℃$), Tool wear 372.99, cutting forces along (x, y, z axis) was 86.54, 174.22 and 328.26 N.

Table 4: Parameters Calculated for Untextured in MQL Condition

Speed	Feed	Depth of Cut	Tool			RPM
120 M/Min	0.16 Mm/Rev	0.5 Mm	Untextured			1200
Time	Surface Roughness (Micrometre)	Temperature (°C)	Vb (Tool Wear) in Micrometre	Cutting Forces (N)		
				X	Y	Z
1	3.31	38.5	285.4	28.87	102.34	52.01
2	4.12	45.8	335.2	38.86	113.76	63.9
4	3.12	49.5	371.2	45.54	124.88	74.55
6	3.97	60.5	450.3	52.26	133.65	87.48
8	4.26	85.4	530.1	65.59	140.89	98.76

These are the results obtained when the speed of the machine is 120 m/min. The average value of all parameters is: The average Surface roughness was 3.756 (µm), the temperature was 55.94 ($℃$), Tool wear 394.44, cutting forces along (x, y, z axis) was 46.244, 123.104 and 315.34 N.

Table 5: Parameters Calculated for Textured in MQL Condition

Speed	Feed	Depth of Cut	Tool			RPM
120 M/Min	0.16 Mm/Rev	0.5 Mm	Textured (Perpendicular)			1200
Time	Surface Roughness (Micron Metre)	Temperature (° C)	Vb (Tool Wear) in Micrometre	Cutting Forces (N)		
				X	Y	Z
1	1.64	34.3	235.4	29.76	103.05	57.44
2	2.78	44.3	256.4	36.75	109.88	70.62
4	2.32	47.2	301.5	44.48	114.61	80.96
6	2.48	59.2	370.4	56.97	127.37	94.38
8	3.98	80.5	390.4	69.23	141.14	107.07

These are the results obtained when the speed of the machine is 120 m/min for texture perpendicular tool wear. The average value of all parameters is: The average Surface roughness was 2.64 (μm), the temperature was 53.1 (℃), Tool wear 310.82, cutting forces along (x, y, z axis) was 54.638, 119.21 and 322.1 N.

Comparison of Tool Wears with Different Condition at 80 M/Min and 120 M/Min

Tool wear parameter is used to study the diminutive failure of cutting tools due to its continuous operation. This term was normally used with tipped tools, tool bits that are used with the machine tool.

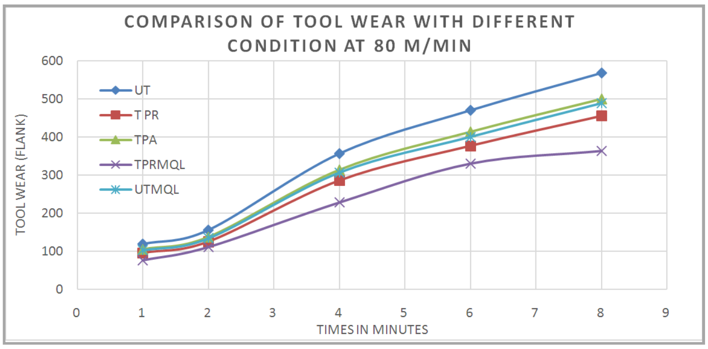


Figure 5: Comparison of Tool Wear with Different Condition at 80 M/Min

In the above figure, UT represents untextured and denoted by a dark blue line, TPR signifies Texture perpendicular, represented by the red line, TPA, signifies texture parallel and represented by light green line, TPRMQL Texture perpendicular with MQL condition and UTMQL untexture with MQL condition are represented by the violet and light blue colour. From the above graph, we concluded that the Tool wear for Texture perpendicular in MQL condition is minimized and for untexture tool wear is maximized.

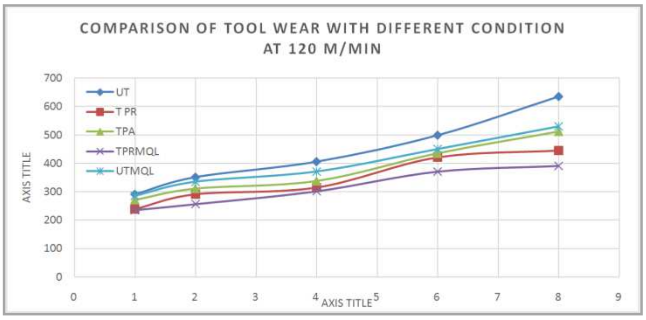
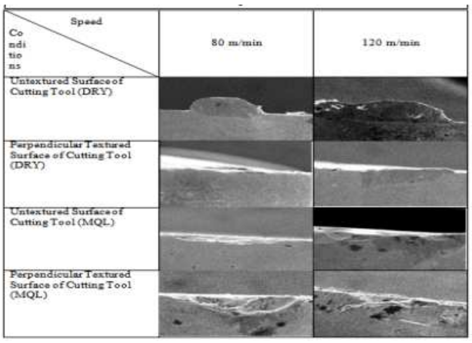


Figure 6: Comparison of Tool Wear with Different Condition at 120 M/Min

Table 6: Scanning Electron Microscope (SEM)

Images of Tool Wear in Different Condition and Speed



When the speed of the machine is 120 m/min, the values obtained for tool wear for different conditions like (UT, TPR, TPA, TPRMQL and UTMQL) has been shown above... From the above graph we concluded that the Tool wear for Texture perpendicular in MQL condition is minimized and for un-textured tool wear is maximized.

Comparison of Surface Roughness with Different Speed at 80m/Min and 120 M/min

Surface roughness often abbreviated to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface of its ideal form.

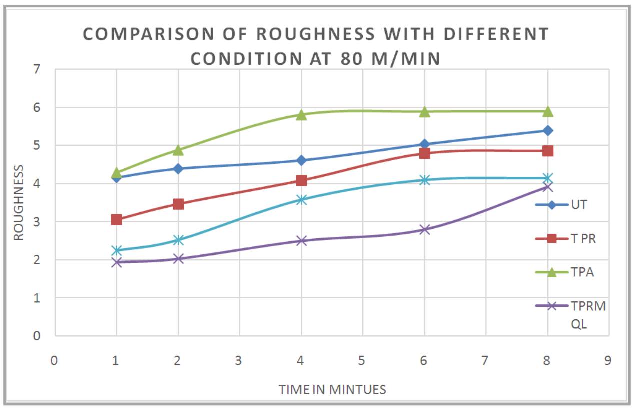


Figure 7: Comparison of Roughness with Different Condition at 80 m/min

If these deviations are large, the surface is rough; if they are small, the surface is smooth. From the above figure, it is concluded that the surface roughness of perpendicular texture with MQL condition is minimized and for parallel texture it is maximized.

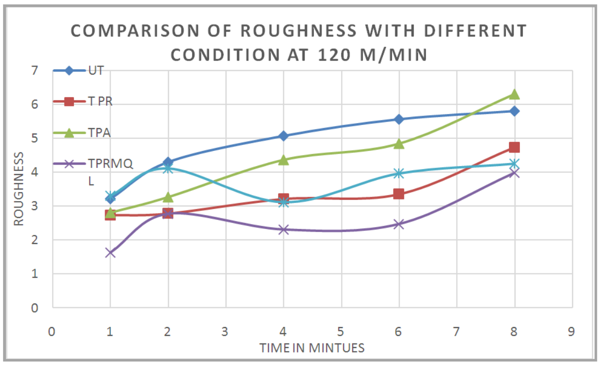


Figure 8: Comparison of Roughness with Different Condition at 120 m/min

From the above graph, it is concluded that the values of roughness for texture perpendicular is minimized and for untexture is maximized. They're average values are represented in tabular as well as in graphical form.

Force X at Speed =80mmin and 120 M/Min

Results obtained for texture and untexture work piece with speed 80 m/min for the dry and MQL condition are shown below. One single tool five experiments have been performed with two different speeds 80m/min and 120 m/min. The force with 80m/min has been measured on the uncoated tungsten carbide.

When the tool is placed vertically on the work piece i.e. when the tool tip was moving from right to left, the values of cutting force obtained for different time intervals have been shown above, and their graphical representation was shown below.

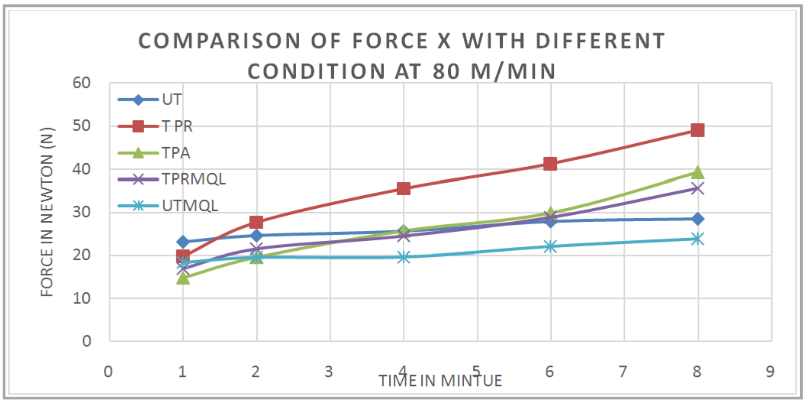


Figure 9: Comparison of Force x with Different Condition at 80 m/min

From the graph, it is concluded that the force along x-axis with speed 80m/min is minimum at untextured MQL and it is maximum at textured perpendicular.

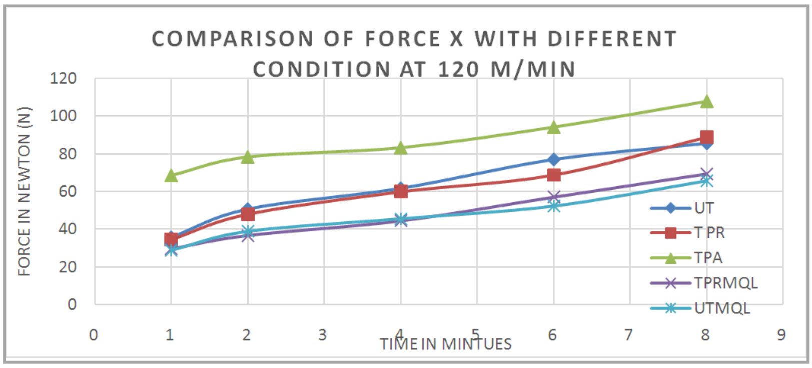


Figure 10: Comparison of Force X with Different Condition at 120 M/Min

When the machine works from different time intervals like for 1 min, 2 mints, 4, 6, 8 minutes and revolution per minute speed is 120 m.min, we will get the above graph. The value of force acting on the work piece is increasing gradually for all the conditions. The value of force acting along x-axis is minimum for un-textured MQL and maximum for textured parallel.

Cutting force along Y-axis with 80 and 120 m/min

The values below are obtained for cutting force when the tool is moving on the work piece from up to down directions.

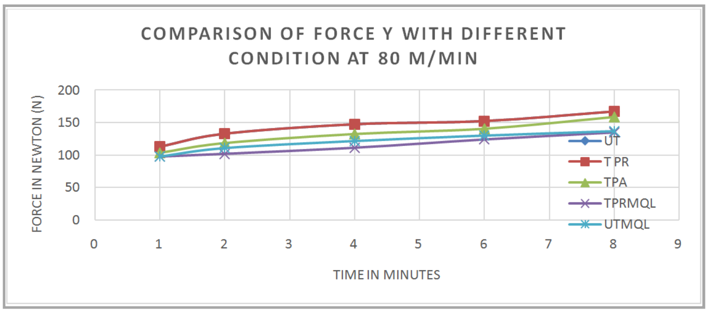


Figure 11: Comparison of Force y with Different Condition at 80 m/min

From the graph, it is concluded that the force along y-axis with speed 80m/min is minimum at untextured MQL, when it is observed for the time period of 1 min, as the time period get increased, force acting on the work piece is also getting increased. It is maximum at textured perpendicular when its force is observed on the work piece for a time period of 8 minutes.

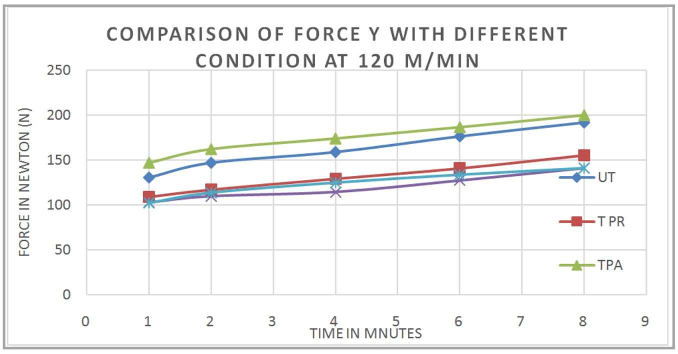


Figure 12: Comparison of Force y with Different Condition at 120 m/min

The value of force acting on the work piece is increasing gradually for all the conditions. The value of force acting along x-axis is minimum for textured perpendicular in MQL condition and maximum for textured parallel.

Cutting force along Z-axis with 80 and 120 m/min

The values below are obtained for cutting force, when the tool is moving on the work piece from front to back direction.

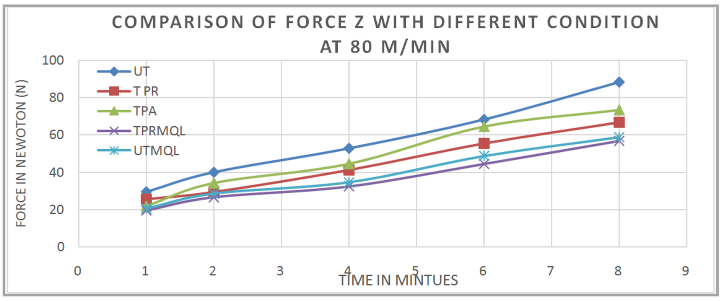


Figure 13: Comparison of Force Z with Different Condition at 80 m/min

For untextured, with dry conditions, the value of force acting on the work piece along Z direction is high, which is maximum at time period t=8 minutes and the value of force is 90 N. The minimum value of force acting on the work piece is 55 N for perpendicular texture during MQL condition.

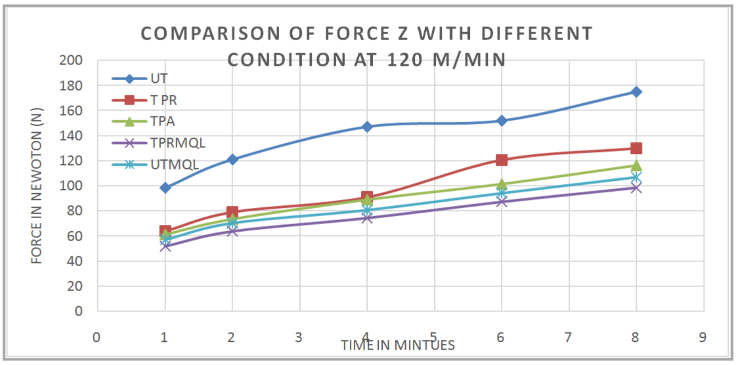


Figure 14: Comparison of Force Z with Different Condition at 120 m/min

For untextured, with dry conditions, the value of force acting on the work piece along Z direction is very high, which is maximum at time period t=8 minutes and the value of force is 170 N. The minimum value of force acting on the work piece is 80 N for perpendicular texture during MQL condition.

Comparison of Temperature with Different Speed at 80m/Min and 120 M/Min

Temperature measurement is considered to be a key enabling technology. The temperature generated during processing will increase the temperature of the cutting area. This temperature is measured by using temperature Gunn. The temperature measured for different conditions like for Dry condition and for the MQL condition of various texture and structure are illustrated in the table below.

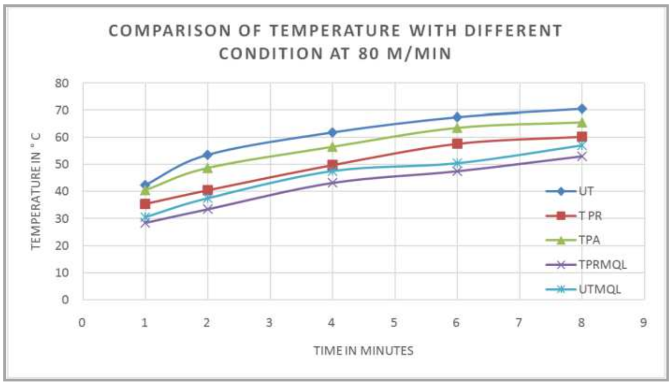


Figure 15: Comparison of Temperature with Different Condition at 80 M/Min

When the machine runs at 80m / min speeds, the temperature values obtained for different time periods are shown graphically as well as listed in tabular form above. The temperature is measured in Celsius. For TPRMQL the measured temperature is low and for UT in Dry condition measure temperature is high. It is clear from the graph that, as the experimentation time for the different texture is increasing the value of temperature also increased.

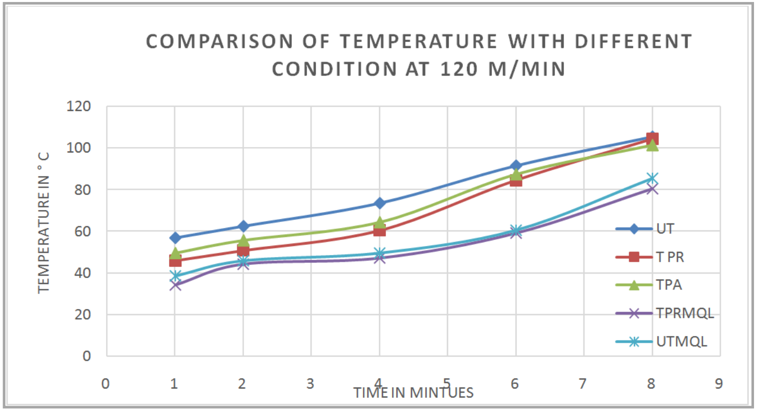


Figure 16: Comparison of Temperature with Different Condition at 120 M/Min

When the machine runs at 120m/min speed, the temperature values obtained for different time periods are shown graphically, as well as listed in tabular form above. The temperature is measured in Celsius. It is concluded that, as the speed of the machine increased the value of temperature measured for different textures also gets increased.

CONCLUSIONS

Based on the different simulation results obtained for work piece made up of material C45 steel, the following conclusions have been drawn depends upon different parameters observed during the experiment. The parameters that have been observed during the experiment are Surface roughness, tool wear, Cutting force and temperature. The experiment has been performed on two conditions named as Dry condition and Minimum quality lubrication (MQL) for different machine speed that is 80m/min and 120 m/min. Here, in the research work we have considered different texture such as perpendicular and parallel texture. The points that have been concluded from the experiment are listed below:

For Dry Condition (Speed=80m/Min)

Untextured

For untextured or for plain work piece, the average value of surface roughness was 4.24 (µm), the temperature was 35.96 (℃), Tool wear 297.3, cutting forces along (x, y, z axis) was 23.54, 137.6 and 64.74 Kg.

Texture Perpendicular

The results obtained for perpendicular texture when the speed of machine is 80m/min are: average surface roughness was 12.57 (µm), temperature was 55.72 (℃), Tool wear 367.358, cutting forces along (x, y, z axis) were 35.32, 155 and 63.76 Kg.

Texture Parallel

The results obtained for parallel texture when the speed of machine is 80m/min are: average surface roughness was 3.148 (µm), temperature was 45.42 (℃), Tool wear 371.888, cutting forces along (x, y, z axis) were 33.36, 208 and 54.92 Kg.

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