COMPARATIVE PERFORMANCE ANALYSIS OF TEXTURED AND UN-TEXTURED TURNING INSERTS IN DRY MACHINE OF AL 7075

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Abstract
Surface texturing is an effective process for improving the tribological characteristics Surface roughness may be beneficial in a number of ways, including decreased friction and tool wear due to the reduced contact area and formation of micro pools of lubricant in textures.
*In machining operations the tool shape material and cutting parameters must all be carefully chosen. These variables can influence both the quality of work piece and the tool wear during machining. Simple and textured (Parallel and perpendicular grooved ,dimple textured) Tungsten Carbide inserts were utilized for machining of Al-7075 in this study. L20 (5*4) Taguchi orthogonal array was used for experimental design. CMM and Surftonic surface meter was used to measure tool wear and surface roughness respectively. The efficiency of this strategy is demonstrated by the Pareto coefficient main effect plot, contour plot, and surface plots. The study found that among the five types of cutting inserts evaluated (untextured, Titanium coated, dimple textured, parallel groove textured, and perpendicular grooved textured), the parallel groove textured insert performed the best exhibiting the lowest surface roughness and tool wear.*

INTRODUCTION

Over the past several years, surface texture has emerged as a highly effective method for enhancing the tribological properties of mechanical components, drawing considerable attention [1]. The application of surface texture proves to be advantageous in multiple aspects, including the reduction of friction and enhancement of durability [2]. It plays a pivotal role in improving the stiffness within the fluid film, minimizing wear, and augmenting the load-carrying capacity[3].
The process of designing texture on a surface is intricately linked to the intended application, underscoring its significance [4]. Notably, the manufacturing technique employed has a profound impact on the quality of the texture, making it imperative to focus on these methods. A comprehensive understanding of the characteristics associated with any manufacturing approach is crucial [5].
The incorporation of created texture significantly enhances cutting performance by increasing the availability of cutting fluid at the sliding point. This is achieved by reducing the tool and chip contact area and effectively capturing worn debris [6]. The advantages of this process include the reduction of cutting forces, cutting temperature, frictional forces, as well as a decrease in flank wear and crater formation.
In this research, an analysis is conducted on the effects of surface texture on the performance of cutting tools. The study explores the utilization of surface texturing in industries and research work to create milli/micro/Nano-textures for tribological components [7]. Surface textures provide a novel approach to investigate cutting force and tool wear

throughout the cutting process, showcasing excellent outcomes in terms of lowering cutting force, delaying tool wear, and enhancing cutting surface quality [8].

Machining stands as an essential component for the manufacturing industry, constituting 23% of total expenses [9]. Friction is prevalent as the formed chip passes through the rake face of the tool. The relative motion generates frictional heat in the cutting tool, resulting in high temperatures between the sliding surfaces of the tool and chip. This high temperature, pressure, and sliding surface speed at the interface lead to the development of crater wear on the rake face of the cutting tool. Cutting oils are employed to mitigate this friction produced at the sliding surface of the chip and tool. Wear is generated on the rake face of the tool due to the elevated temperature, pressure, and high contact area [10].

To counteract the effects of wear, cutting fluids are utilized. Cutting fluids play a fundamental role in lubricating the sliding surface and producing a cooling effect between surfaces to reduce temperature and pressure. However, some cutting fluids may be costly, hazardous, and even corrosive [11]. Each cutting fluid has its own properties and applications, such as cryogenic cooling, flood cooling, minimum lubrication quantity, producing a cooling effect rather than lubricating the surface to reduce the generated heat during the sliding of the chip on the face of the cutting tool.

The surface texture of the cutting tool focuses on the lubrication of the cutting tool and the use of internal micro-pool lubrication [12]. Texturing regular shapes on the cutting tool face, such as grooves, micro-holes, dimples, and other types of regular shapes, can be employed to store lubricant, reduce wear, and minimize friction between the contact area of the tool and chip. Surface roughness also traps debris, which may interfere with surface relative motion and impact the tribological system. This concept represents a novel technique to enhance lubrication by texturing the surface, proving particularly useful in tribological applications [13].

JianzhaoWuetal.[14]fabricatedimplepatterns on bronze specimen surfaces are demonstrated using an indentation process.Inball-on-disc wear experiments, graphite was used as the mating balls. The thin ribbon debris was heaped on the worn surfaces and recessed dimples. Examined microscopically, the impact of wear debris was explained using the morphology and development of wear debris textures within dented dimples. The experimental results show that the edge is responsible for the development of thin ribbon debris. The imprinted dimple hardens. The debris is attracted to the thin ribbon debris and the depressed conical dimple. Accumulation on dimple slopes, which may aid in the production of graphite-rich transfer layers on indented dimples surfaces indented dimple surfaces have lower coefficients of friction and wear than non-textured surfaces. Because of this, the tribological qualities of the indented dimple surface have improved.

Tatsuya Sugihara et al.[15] perform experiments to overcome the use of cutting fluid, dimple shape textures of various dimensions and arrays were developed utilizing a femto second laser on the tool rake face of the cutting tool. Used vertical machining centre(Yamazaki Mazak Corp., AJV-18) to perform experiments, cutting experiments were performed on a specimen of aluminum alloys Al-5052. A laser microscope was used to compute the volume of chip adhesion on the tool rake face to assess the anti-adhesion of cutting tools and also found the forces by using the dynamometer. They conclude that, by facilitating the flaking of the adhesion layer of the tool surface, the dimple patterns dramatically 10% or less reduce aluminum adherence on the tool rake face as in compared to a standard tool with no surface texture, The micro-dimples help to break off adhesion from tool surface that remains during the cutting operation, findings revealed that the micro-dimples have less direction dependency resulting in a broad application range and high adaptability and they outperform the competition in contrast with a grooved texture surface.

Qinghua Li et al.[16] generated micro-textures of various shapes and scales on the rake face of the poly crystalline cubic boron nitride(PCBN)cutting tool and performed turning experiments on hardened steel grade GCr15. The Experiments revealed the impact of micro-textures on tool wear and surface roughness by determining the cutting forces,shear stress, and stress on the tool surface and when compared to non-textured tools, finite element analysis and cutting operations revealed that appropriate micro-hole textures may massively reduce tool wear and enhance machined surface quality. It also determined that the size of textures on the rake face of the cutting tool also has impacts such as cutting forces, tool wear as well as reducing tool surface stress. This research also revealed that the issues of poor machined workpiece roughness and high tool wear of poly crystalline cubic boron nitride tools for cutting harden steel GCr15material have been resolved.

Kairui Zheng et al.[17] investigated the effect of a micro-texture tool on the cutting performance of the titanium alloy Ti6Al4V by developing the line,rhombic,and sinusoidal groove patterns machined out on to the rake face soft the cutting tool of cemented carbide YG8 using laser processing technology (YLPN-1-100-200-R, IPG). They found impacts of cutting depth and cutting speed on feed force and primary cutting force were explored and found all varieties of texturing on the tool rake face were successful in lowering cutting force and tool wear under lubrication conditions. The sinusoidal textured tool had the best cutting performance than the line textured tool and the rhombic textured tool, using textured tools can reduce the main cutting force by up to 30.97 %. Chips made using textured tools have a superior morphology than non-textured tools.Chip breaking is aided by the presence of textures on the tool surface and adhesive wear on the textured tool is less severe. The sinusoidal textured tool has the best anti-adhesion effect. The surface roughness of titanium alloy machined with the sinusoidal textured tool is the lowest, having decreased by 35.8% when compared to the non-textured tool.

Experimental Procedure and Methodology

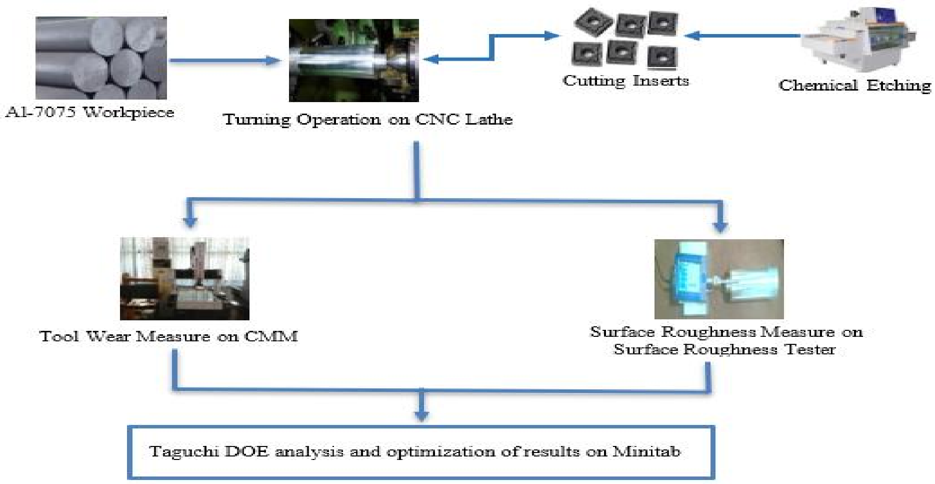

Table1: Experimental Setup

Tool and Workpiece Materials

The effect of several cutting parameters such as cutting speed, feed rate, and depth of cut on turning aluminum alloy Al-7075 was evaluated by examining their effect on surface roughness and tool wear. Statistical methods for design of experiments were used to coordinate the turning tribulations and reduce the size of the experiments, saving time and money. Analysis of Variance was used to determine the elements that influence aperture quality, and a set of cutting parameters for turning aluminum alloy was proposed definitely.

Aluminum Alloy Al-7075 is lightweight and has high toughness properties [18]. This aluminum alloy is the most cost-effective choice for applications involving high-stress conditions such as constant movement and pressure variations [19].

Material properties are the physical, chemical, and mechanical characteristics of a product that determine its usability and manufacturability. This would imply that product material properties would define the product capabilities in all aspects

Table 2 Chemical properties ofAl-7075

Component	Weightage
Aluminum Al	90%
Magnesium Mg	2.29%
Manganese Mn	0.82%
Titanium Ti	0.028%
Copper Cu	1.05%
Silicon Si	0.60%
Zinc Zn	4.89%
Iron Fe	0.55%

Table 3: Physical properties of Al-7075

Property Name	Value
Density [g/cm^3]	2.81
Thermal Conductivity [W/m-K]	130
Melting Point [°C]	477 - 635.0

Table 4:Mechanical properties of Al-7075

PropertyName	Value
UltimateTensileStrength[MPA]	572
Modulus of Elasticity[GPA]	71.7
Elongationatbreak[%]	9
UltimateBearingStrength[MPa]	810
YieldTensileStrength[MPA]	503
PoissonRatio	0.33
ShearModulus [GPA]	26.9

Table5:MatrialHardness Of AI7075

MaterialHardness	Value
Brinellhardness(PA)	120
Knoophardness(PA)	191
Rockwellhardness(PA)	53.5
Vickershardness (PA)	175

Cutting parameters was under consideration when cutting inserts wad selected. To obtain excellent chip control and machining efficiency, consider insert geometry, insert level, insert form (nose point), insert length, nose radius, and entry edge. Select the geometry insert based on the task at hand, such as finishing. For quality and economy, choose the largest possible nose point on the insert. Depending on the depth of the cut, choose an insert size. For maximum insert strength, choose the greatest possible nose radius. Experiments are carried out with tungsten carbide cutting inserts that are uncoated and have a 1.2 mmnoseradius.SNMG120412is the ISO designation for uncoated insert geometry.

For this Experiment ,the MSSNR 2525M12 tool holder is adopted.

Experimental Methodology

Five Cutting tool had been chosen, then three of them taken for chemical Etching than chemically cleaned and degreased to remove any dirt, waxes, or rolling oils that might interfere with the following stage. The sheet is coated with a light sensitive photo resist. For highly reproducible, blemish-free components, good adhesion is critical. Any problem

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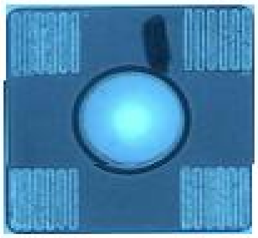
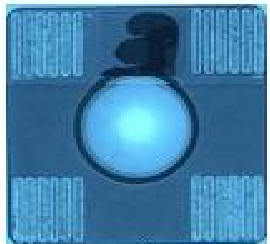
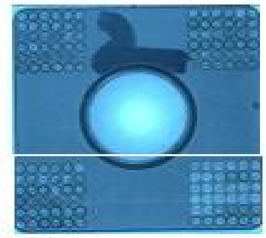
with the laminate bonding to come into touch with the metal shielded portions during etching, jeopardizing the completed components. Then in printing, by exposing the sheet to ultraviolet light using a photo tool mask, the component design is transferred to the photo resist. To uncover the raw material, the unexposed photo resist is removed. During etching, the portion will be protected by the hardened resist. The formed sheet is sprayed with etchant chemical, usually ferric chloride. Skilled experts calculate the etch time by considering factors such as metal type, grade, thickness, and size, all of which have an impact on the ultimate outcome. The sheet is residual photo resist is removed, showing the etched components [20].



Parallel GrooveTextured



Dimple Textured



Perpendicular GrooeTextured

Un Textured

Titanium Textured

This work material was turned on a CNC lathe machine.To ensure consistency of diameter over the length of the bar and limit the risks of mistake, a pre-machining turning operation was undertaken. To decrease vibrations and ensure error-free experimenting, a tail stock and a head stock were also used. Four distinct cutting speeds (300, 400, 500 and 600 m/min), four different feed rates (0.3, 0.4, 0.5, and 0.6 mm/rev), and four different depths of cut were used in the turning experiments (0.02, 0.04, 0.05 and 0.06 mm). Machining was performed 30 minutes for each experiment. After machining, machining workpieces was raped with rapper to avoid from any environment loses. Experiments are carried out using a Taguchi design of experimental. For conducting experiments on CNC Lathe Machine in PCSIR, Lahore facility and then for surface roughness quantification in PCISR ,Department University of Engineering and Technology, Lahore ,four levels of feed four levels of cutting speed ,and four level soft depth of cut were used. For accuracy, surface roughness was measured in two separate locations .In IME, Department University of Engineering &Technology ,Lahore ,implement wear was measured using a CMM. Sixteen experiments were performed using four inserts using different parameters and evaluated surface roughness and tool life as out putparameters .Cutting Inserts were performed on these inserts on designed processing parameters and surface roughness and tool life.

Table 6: Design of Experiment

No. of Exp.	InsertType	Cutting Speed (m/min)	Depth Of Cut (mm)	Feed Rate (mm/rev)
1	1	300	0.02	0.4
2	1	400	0.04	0.5
3	1	500	0.05	0.6
4	1	600	0.06	0.7
5	2	300	0.02	0.4
6	2	400	0.04	0.5
7	2	500	0.05	0.6
8	2	600	0.06	0.7
9	3	300	0.02	0.4
10	3	400	0.04	0.5
11	3	500	0.05	0.6
12	3	600	0.06	0.7
13	4	300	0.02	0.4
14	4	400	0.04	0.5
15	4	500	0.05	0.6
16	4	600	0.06	0.7
17	5	300	0.02	0.4
18	5	400	0.04	0.5
19	5	500	0.05	0.6
20	5	600	0.06	0.7

During experiments, a vernier caliper with no least count is used to measure diameter. Before each run of the instrument, a reading was obtained with the caliper pointing in the same direction. The accurate measurement of the work piece diameter is used to calculate the metal abstraction rate. In experiments, the diameter of the work piece is a critical component in maintaining the required cutting speed. With each implement pass on the shaft during the turning process, the diameter of the shaft is decreased. Cutting speed also lowers when the diameter is reduced [21]

Tool wear is carried out using a coordinate measuring machine which inspects the object in a touch approach. The coordinate measuring equipment can be connected to a computer to provide an accurate and quick output of the object, which aids in design changes on the job site. After machining each length for 30 minutes wear was measured using a 3D coordinate measuring equipment modelno CE-450DV [22].

The workpiece is placed on the work table, and a measuring tool probe is used to contact the object in order to inspect it. Probe movement can be done manually or using computer programs. The data from the probe is gathered to the computer where we can monitor it, and the control unit is utilized to control the machine according to the signal supplied to it by computer program'. We can save time in the inspection process by implementing this sort of monitoring system [23].

Surface Texture Meter portable surface roughness tester with a range of 1000 microns, accuracy of 3%, and resolution of 0.001 microns was used to determine the average surface roughness Ra. The cut off length was set at 0.8 mm, and the celerity was measured at 1 mm/s. At three distinct sites, the surface roughness was quantified to the parallel to machined surface, and the average values of the quantifications were analyzed. The surface roughness measurement is shown in figure 3-12[24].

Surface finish is determined by a set of characteristics. The common place surface roughness (Ra) is selected in this study to identify surface finish in the finish turning process. Which of the following is the most often used surface finish parameter in industry. The microchip determines the parameters and other

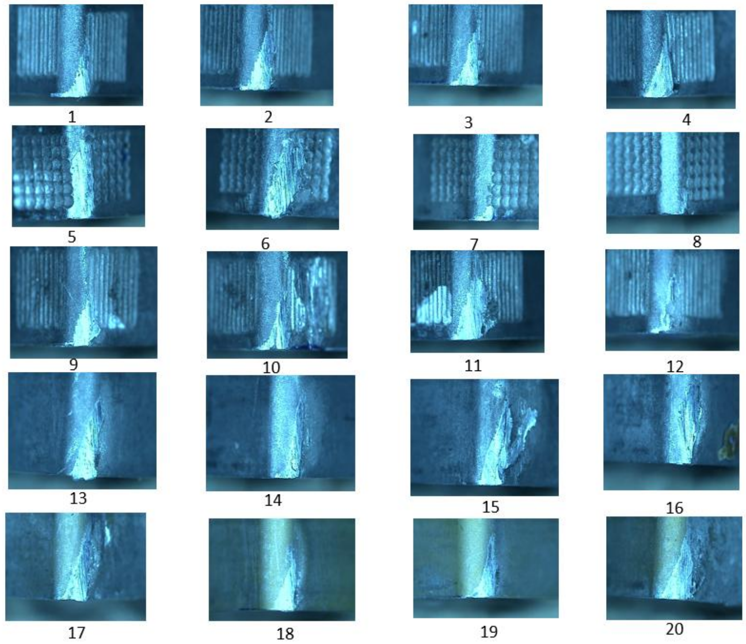
functionalities of the surface finish estimation equipment. The projections are shown on an LCD screen. These properties can be removed from discretionary printers. The hardware is powered by a non-rechargeable battery which is required. [25]
Profile is made up of sampling durations that are far too lengthy to be considered statistically adequate. The culling cut-off wavelength is equal to the sample length for analyzing waviness and roughness. The length of the evaluation in the direction of the X axis used to analyze the profile under consideration. One or more sample lengths may be included in the evaluation length. The assessment length is equivalent to the sample length for the primary profiles.
Surface roughness is traditionally measured using a number of metrics. The average surface roughness (Ra) is selected for characterization of surface finish during turning operations, according to the presented experimental investigation. It is the most commonly utilized surface [26].
The length along the X axis that was used to analyze the profile under consideration. One or more sample lengths may be included in the evaluation length. The assessment length for primary profiles is equal to the sample length.
Surface roughness is often measured using a number of metrics. The average surface roughness (Ra) is selected for characterization of surface finish during turning operations, according to the presented experimental investigation. It is the most often used surface roughness parameter in both research and industry. The cut-off and assessment lengths for measuring surface roughness are 0.7 and 2.7 mm, respectively.

Results and Comparisons
We will discuss about the results and comparisons between the results that have found. The relationship between numerous possible mediators and one or more response variables is investigated using Taguchi design analysis. The primary principle behind Taguchi Design Analysis is to get an optimal result through a series of designed tests. By optimizing operational parameters, statistical methodologies such as Taguchi design analysis may be used to maximize the production of a unique material.

Table7Design of experiments,Tool Wear and surface roughness

No.of Exp.	Insert Type	CuttingSpeed (m/min)	Depth Of Cut (mm)	FeedRate (mm/rev)	SurfaceRoughness (µm)	ToolWear (mm)
1	1	300	0.02	0.4	0.8	0.078
2	1	400	0.04	0.5	0.71	0.066
3	1	500	0.05	0.6	1	0.063
4	1	600	0.06	0.7	1.7	0.068
5	2	300	0.02	0.4	0.98	0.092
6	2	400	0.04	0.5	1.6	0.104
7	2	500	0.05	0.6	1	0.204
8	2	600	0.06	0.7	0.72	0.107
9	3	300	0.02	0.4	1.6	0.141
10	3	400	0.04	0.5	2.7	0.112
11	3	500	0.05	0.6	1.3	0.800
12	3	600	0.06	0.7	1.1	0.150
13	4	300	0.02	0.4	2.4	0.058
14	4	400	0.04	0.5	1.8	0.065
15	4	500	0.05	0.6	1.6	0.134
16	4	600	0.06	0.7	1.3	0.102
17	5	300	0.02	0.4	0.9	0.095
18	5	400	0.04	0.5	1.6	0.101

19	5	500	0.05	0.6	0.73	0.080
20	5	600	0.06	0.7	1.1	0.071



Microscopic Images of edge of cutting inserts

Taguchi Regression for Surface Roughness and Tool Wear on Minitab

Table8: Regression Equations of Ra

Tool Type			
1	Surface Roughness (Ra)	=	2.90.0117 Spindle Speed (rpm)+ 6.12 Feed rate(mm/rev)+7 Depth of cut (mm) + 0.000004 Spindle Speed (rpm) *Spindle Speed (rpm)
2	Surface Roughness (Ra)	=	3.2- 0.0062 Spindle Speed (rpm)- 6.22 Feed rate(mm/rev) + 77 Depth of cut (mm)+ 0.000004 Spindle Speed (rpm) *Spindle Speed (rpm)
3	Surface Roughness (Ra)	=	3.2+ 0.0005 Spindle Speed (rpm)- 15.45 Feed rate(mm/rev) + 113 Depth of cut (mm) 0.000004 Spindle Speed (rpm) *Spindle Speed (rpm)
4	Surface Roughness (Ra)	=	2.2+ 0.0037 Spindle Speed (rpm)- 2.92 Feed rate(mm/rev) - 50 Depth of cut (mm)+ 0.000004 Spindle Speed (rpm) *Spindle Speed (rpm)
5	Surface Roughness (Ra)	=	2.2- 0.0019 Spindle Speed (rpm)- 8.58 Feed rate(mm/rev) + 71 Depth of cut (mm)+ 0.000004 Spindle Speed (rpm) *Spindle Speed (rpm)

Table 9: Coded Coefficient

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	2.9	11.3	0.26	0.809	
SpindleSpeed (rpm)	-0.0117	0.0477	-0.24	0.819	7948.33
Feed rate(mm/rev)	6.12	9.77	0.63	0.565	573.33
Depth of cut (mm)	7	120	0.06	0.958	740.00
Tool Type					
2	0.29	3.13	0.09	0.930	274.67
3	0.27	3.13	0.09	0.935	274.67
4	-0.68	3.13	-0.22	0.838	274.67
5	-0.69	3.13	-0.22	0.837	274.67
SpindleSpeed (rpm)*SpindleSpeed (rpm)	0.000004	0.000021	0.18	0.869	2181.00
SpindleSpeed(rpm) *Tool Type					
2	0.0055	0.0163	0.34	0.754	2874.67
3	0.0122	0.0163	0.74	0.498	2874.67
4	0.0153	0.0163	0.94	0.401	2874.67
5	0.0098	0.0163	0.60	0.581	2874.67
Feedrate(mm/rev) *Tool Type					
2	-12.33	9.77	-1.26	0.275	950.93
3	-21.57	9.77	-2.21	0.092	950.93
4	-9.03	9.77	-0.92	0.407	950.93
5	-14.70	9.77	-1.51	0.207	950.93
Depthofcut(mm) *Tool Type					
2	69.7	84.6	0.82	0.456	534.80
3	106.5	84.6	1.26	0.276	534.80
4	-57.0	84.6	-0.67	0.537	534.80
5	64.0	84.6	0.76	0.491	534.80

Table 10:Analysis of Variance

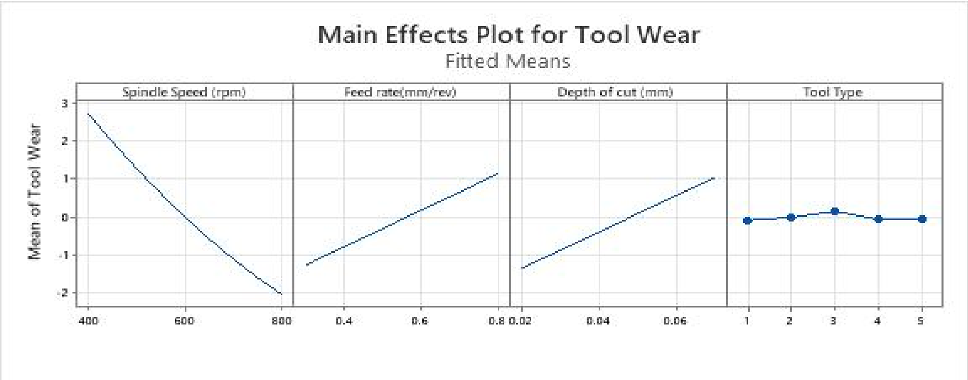
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	20	5.60143	0.280071	1.96	0.272
Spindle Speed (rpm)	1	0.00854	0.008540	0.06	0.819
Feed rate(mm/rev)	1	0.05612	0.056120	0.39	0.565
Depth of cut (mm)	1	0.00046	0.000456	0.00	0.958
Tool Type	4	0.02831	0.007079	0.05	0.994
SpindleSpeed(rpm)*SpindleSpeed (rpm)	1	0.00444	0.004441	0.03	0.869
SpindleSpeed(rpm) *Tool Type	4	0.15339	0.038347	0.27	0.885
Feedrate(mm/rev) *Tool Type	4	0.75181	0.187952	1.31	0.399

Depthofcut(mm) *Tool Type	4	0.67345	0.168362	1.18	0.439
Error	4	0.57235	0.143087		
Total	24	6.17378			

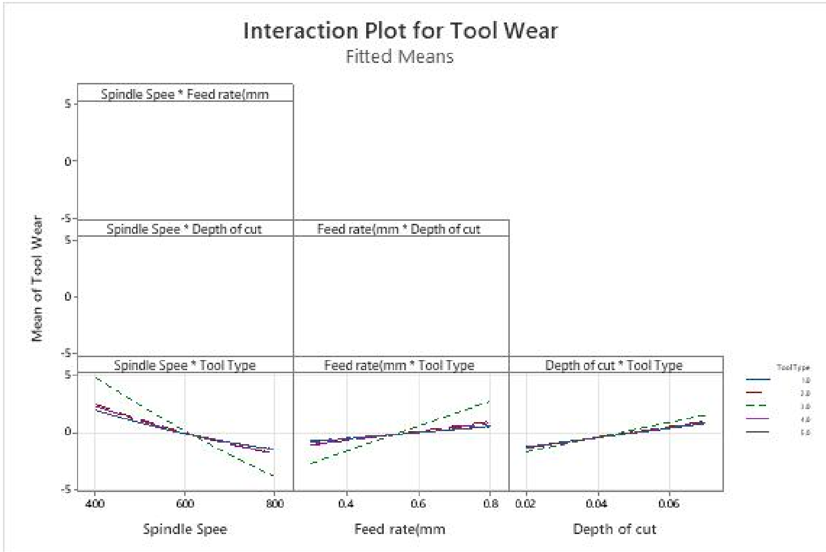
Table 11:Fits and Diagnostics for Unusual Observations

Obs	Surface Roughness (Ra)	Fit	Resid	Std Resid	
1	0.800	0.800	0.000	*	X
2	0.710	0.710	-0.000	*	X
6	0.980	0.980	-0.000	*	X
7	1.600	1.600	0.000	*	X
11	1.600	1.600	0.000	*	X
12	2.700	2.700	0.000	*	X
16	2.400	2.400	-0.000	*	X
17	1.800	1.800	0.000	*	X
21	0.900	0.900	-0.000	*	X
22	1.600	1.600	0.000	*	X

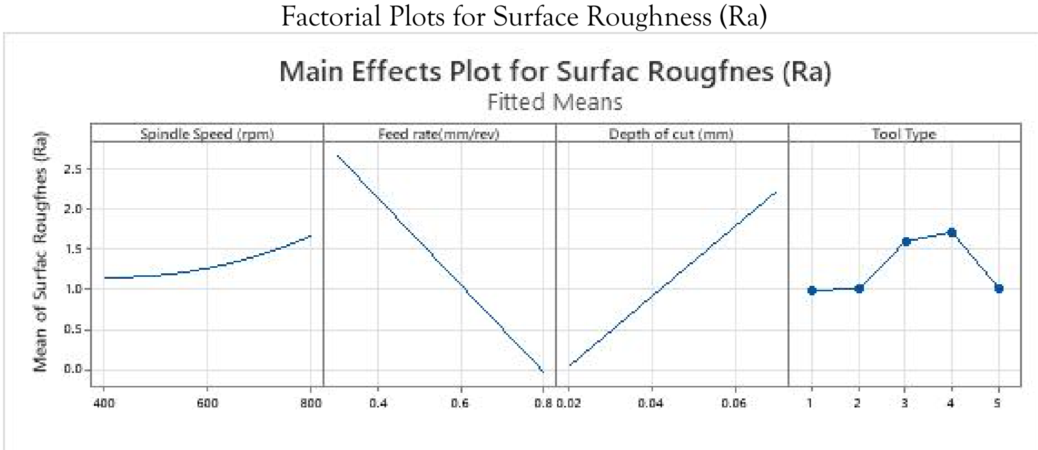
Factorial Plots for Tool Wear

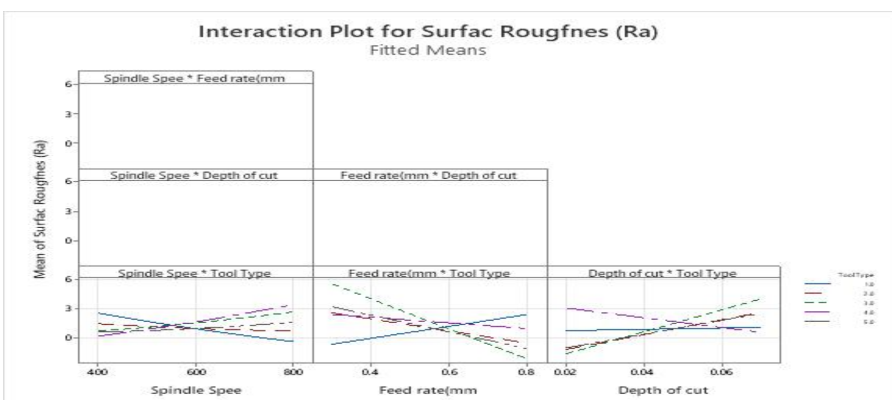


Interaction Plot for Tool Wear



Factorial Plots for Surface Roughness (Ra)





Conclusion

Dry machining of the aluminum alloy Al-7075 carried out with five different cutting inserts (untextured, Titanium coted, dimple textured, parallel groove textured, and perpendicular grooved textured) by four different machining parameters. To optimize the machining parameters for tool wear and workpiece surface roughness, DOE and Taguchi regression analysis were used. The impact of cutting insert mechanical characteristics and adhesion on tool wear and workpiece surface roughness is investigated. In addition, the following findings were reached:

1. Parallel groove textured insert presented lowest surface roughness than the dimple textured, titanium coated, perpendicular groove textured and untextured insert respectively.
2. Parallel groove textured insert has lower tool wear than the untextured ,titanium coated, dimple textured and perpendicular groove textured respectively.
3. Surface roughness of workpiece decreases as cutting speed increase and tool wear increase as cutting speed increase. Surface roughness is increase as depth of cut increase and tool wear increase as depth of cut increase. Surface roughness decreases as feedrate increase and tool wear increase as feedrate increase.
4. optimization results show that the minimum possible surface roughness is 0.71μm for parallel groove textured cutting inserts at the depth of cut of 0.04mm,cutting speed of 400rev/min ,and federate of 0.4m/min .the minimum possible tool wear is0.058mm for Un-textured cutting inserts at the depth of cut of 0.02mm,cutting speed of 300 m/min, and feed rateof0.3rev/min.
5. Cutting speed should be increased and depth of cut should be maintained to a minimum while machining aluminum alloyAl-7075.
6. In evaluating and deciding the performance of cutting tools, the research and industrial groups in machining must consider both mechanical ,strength properties,and cutting parameters.

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