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Study the Effect of Different Jet Conditions on Tribological Properties in the Machining Process

A Thesis Submitted to the Council of the Faculty of the College of Engineering/University of Kerbala in Partial Fulfillment of the Requirements for the Master's Degree in Mechanical Engineering

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

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Dedication

I would want to express my gratitude to the person who instilled in me a deep passion for learning, to the person who has been my pillar of support and my source of strength after God, to my cherished father who instilled in me the belief that there are no boundaries to my desire, and to my cherished mother, who is the source of kindness and the key to successful prayer. My lovely husband, who has been supportive and patient during this suffering, and my cherished children, who have withstood my busy times and the stresses of studying.

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Taking advantage of this occasion, I would want to express my gratitude to **Dr. Hayder Kurji**, who is serving as the head of the Mechanical Engineering Department at the University of Kerbala, as well as to each and every member of the staff that is employed in the department. Throughout the course of my education, Last but not least, I would want to use this opportunity to convey my appreciation to my family for the continuous support and encouragement they have provided during the whole of the research project. Their personal and financial sacrifices were necessary in order to accomplish the scientific work, which would not have been possible without them.

Abstract

This study aims to investigate the effect of lubricant jet speed and angle on tool wear , surface roughness and cutting temperature in the lathe machine by used low carbon steel .The lathe machine played a significant role in the metalworking process, which involves cutting. The operating parameters for the turning process are very important for achieving high performance, which is measured by workability, good surface finishing, lower tool wear, and higher material removal rates. It is necessary to experiment with optimization cutting speeds and feed rates while maintaining a consistent depth of cut. Low-carbon steel. The experimental work contains three different conditions during metal cutting operations, including dry cutting, flood oil cutting, and oil jet lubricant, utilizing (ARO). This study provides information for optimizing oil injection parameters and improving lubrication by examining the characteristics of wear and surface roughness as well as the effects of oil jet lubrication, angle, and speed on lubrication performance. Oil jet lubrication was used throughout the turning process, with two different injection angles (15˚and 40˚) included in the lubrication conditions. Various lubrication pressures, including (6 and 12) bar, were tested to examine how they affected surface roughness, tool wear, cutting temperature, chip expendability at different feed rates, and tribological characteristics over time.

The results showed a significant decrease in roughness, especially for samples that were cutting with oil jet lubricant as the best results in roughness and the best outcomes for cut zone temperature were for samples cut with nozzle jet of angle 15˚ and pressure 6 bar. Through the dry cut, it was demonstrated that the surface roughness reaches (4.853 µm) at (0.03 mm/rev) and cutting speed (28 m/min) in comparison to other conditions, and in flood operation, it reaches (2.53 µm) but uses a significant amount of oil. The problems caused by vibrations and temperature variations were accompanied by an increase in energy usage when the pressure was

raised to 12 bars. The experimental analysis found that lowering pressure and using a small nozzle was the best way to improve tribological properties.

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List of Abbreviations

Abbreviation	**Description**
42CrMo4+QT	Alloy Steel Grade 42 CrMo4
AA	Arithmetic of average
ACBB	Angular Contact Ball Bearing
AISI	American Iron and Steel Institute
$Al2O_3$/TiCN	Aluminum Oxide and Titanium Carbonitride
AlCrN	Aluminum Chromium Nitride
ARO	Al –Rashid oil SAE 15 W 40
BUE	Built-up edge
CFD	Computational Fluid Dynamics
CLA	center line average
Co	Cobalt
CuCrZr	Copper –Chromium –Zirconium Alloy
CuZr	Copper –Zirconium Alloy
CVD	Chemical Vapor Deposition
EDX	Energy Dispersive X-ray
EHL	Elasto-Hydrodynamic Lubricant
EP /AW	extreme pressure and anti-wear
FC	Flood Coolants
HSM	High-Speed Machining
HSS	High-Speed Steel
IC	Internal Coolant
IVR	Iso-Viscous Rigid
LiN	Liquid Nitrogen

M2	Molybdenum High Speed Steel
MJMQCL	Multi jet Minimum Quantity Cooling Lubrication
MQCL	minimum quantity cooling lubrication
MQL	Minimum Quantity Lubrication
MRR	Material Removal Rate
P25	Sintered Carbide
PAWAJM	Pressurized Air-Wet Abrasive Jet Machining
PLS	Pulsing Lubrication
PVD	Physical Vapor Deposition
Ra	Surface Roughness average
RDOC	Radial Depth of Cut
Rq	Root Mean Square
SAE	Society of Automotive
SEM	Scanning Electron Microscope
SRT	Surface Roughness Tester
Ti-6Al-4V	titanium alloy contain 6% aluminum and 4% vanadium
TiAlN	Titanium Aluminum Nitride
VB_3	Flank Wear
VOF	Volume of Fluid
WC	Sintered of tungsten carbide

List of Symbols

ap	cutting depth (mm)
D	work diameter (mm)
Fn	vertical applied force (N)
fr	Feed rate (mm/rev)
Fs	frictional force (N)
g	acceleration (m^2/s)
H	hardness (N/m2)
K	wear coefficient
M	Mass of work piece (g)
N	spindle speed (rpm)
P	pressure (bar)
Q	volume extracted from the surface per unit sliding distance (m^3/m)
Tem.	Temperature (C°)
V	velocity jet speed (m/s)
Vs	cutting speed (m/min)
W	wear volume (cm^3)
µ	coefficient of friction
σ	The Standard Deviation or Variance
ρ	fluid density (g/cm^3)

CHAPTER ONE

Introduction

Chapter One

Introduction

1.1 Preface

The key issues regarding technological equipment are its dependability, wear, and maintenance. Leonardo da Vinci, the first tribologist, established the field of research and proposed the two primary laws of friction between 1452 and 1519 [1]. Both economically and technologically, it is crucial to examine systems' tribological characteristics. Annual energy waste and material wear losses in developed countries amount to billions of dollars. Improvements in design quality and engineering efficiency may be based on a solid understanding of tribological processes. Already, this has had a significant influence on how people will think about energy conservation in the future [2, 3, 4]. Friction is the resistance to relative motion between two contacting surfaces, contingent upon the properties of the interacting surfaces. This phenomenon is measured by the frictional force, which inhibits or postpones the movement of one body about another or against the surface it contacts. Friction occurs even in the absence of relative motion between two bodies, referred to as static friction; conversely, when relative motion is present, it is termed dynamic friction. The frictional force is equal to the product of the coefficient of friction and the resultant normal force, which is determined by the weight of the components and the external forces operating on the system. The coefficient of friction is a dimensionless quantity specific to each pair of contacting materials. Several parameters, including temperature, surface roughness, and relative velocity between the surfaces influence it [5].

Friction science includes wear, friction, and lubrication. Basic knowledge of these consequences is needed to comprehend friction [6, 7]. Reducing wear and friction is essential for machines that need high productivity and a longer lifetime since wear and damage shorten equipment's life. [8]. Connected phenomena to friction include lubrication, adhesion, cohesion, slip-stick behavior, and wear; these phenomena cut across engineering, chemistry, and physics. Our attempts to get beyond simplistic Edisonian formulations and into a more thorough understanding based on molecular and atomic levels have been met with resistance from these most fundamental principles, just as in many other scientific domains [9].

1.2 Lubrication

A lubricant creates a fluid coating that separates contacting surfaces, hence reducing the possibility of metal-to-metal contact. The effectiveness of these lubricants is contingent upon several characteristics, including viscosity index, pour point, flash point, thermal stability, and oxidation resistance [10]. Lubricants reduce the heat, friction, and wear that occurs when moving mechanical parts come into contact with one another. The objective of controlling and minimizing these physical events has always been to create a system that uses as little energy as possible. Lubricants have a fascinating history that starts with natural sources. However, human creativity has created several lubricating oils as technology advances. For which mineral and synthetic forms today constitute the bulk of their sources. Since the raw materials for mineral oils are readily available, they are the most studied oil. These oils are made from petroleum or crude oil that occurs naturally and is widely utilized. Polyalphaolefins, also known as ester oils or hydrocarbon-based polyglycols, are the building blocks of synthetic oils [11].

1.3 Methods of Supplying Lubricant

Several techniques are available to enhance the tribological properties of a type of lubricant flow at different speeds. The three primary methods in use today are dry, flooded oil, and oil jet lubrication. Each of these methods has identifying characteristics that are described in the following sections.

1.3.1 Dry Lubricant

A cutting tool that creates chips is used to remove material from a workpiece during the machining process. The aim of machining is to achieve the required size and shape of the workpiece in accordance with the standards [12]. Extreme metal deformation at the tool-workpiece interface during the machining process generates a significant amount of heat, which can be controlled with the right cooling agents or cutting fluids. The high temperatures, buildup edges, and shorter tool life, which is a major source of waste and has negative environmental effects [13].

The following are some of the main issues or problems that dry machining presents:

1. Heat produced at the cutting zone: Because of increased friction and adhesion forces, there will be a stronger interaction between the tool and the workpiece, resulting in high temperatures at the cutting tool [13].
2. The tool's mechanical strength and resistance to wear are diminished at high temperatures, causing it to deteriorate more quickly and have a shorter lifespan [14].
3. The machined component's surface integrity, dimensional accuracy, and surface roughness all deteriorate as a result of tool wear formation [15].

Furthermore, dry machining without the use of a cutting fluid may result in tiny metal particles that are released into the air and can be harmful [16].

1.3.2 Flooded oil

Heat is produced during metalworking operations as a result of friction between the tool and the work piece. Due to its low rate of heat transfer, ambient air alone is not a very good coolant for metalworking processes. With breaks in between, ambient air cooling is sufficient for minor metalworking operations. However, more heat is generated during intensive metalworking activities, and this heat cannot be eliminated by ambient air alone. When the heat removal can be achieved with a stream of liquid that can keep up with the heat creation, it is not practical to add lengthy idle intervals to the cycle duration to enable the tool to air-cool. Cutting fluid has three main purposes: it cools the cutting tool, workpiece, and remove chips, it lowers friction at the contact surface; and it reduces adhesion between the cutting tool and the workpiece or chips at it. Additionally, the cutting fluid shields the workpiece and tool from excessive heat and removes chips from the cutting zone. Therefore, the usage of cutting fluid is inevitable in machining operations. The desire to investigate a novel cutting fluid type using inexpensive, locally accessible materials is prompted by this constant requirement [17].

1.3.3 Oil jet lubrication

The jet nozzle position, jet elevation angle and jet speed are among the oil jet layout parameters that have been identified. These parameters offer useful theoretical design techniques and technical direction for optimizing oil jet lubrication for a variety of real-world high-speed and heavy-load applications. The primary purpose of jet lubrication is to guarantee enough cooling and appropriate lubrication in high speed operations. In order to choose the best jet lubrication techniques for various engineering applications, the producers mostly rely on expertise. Consequently, it is important to research various oil injection techniques in order to direct the development of the jet lubrication and enhance its cooling impact [18].

1.4 Wear

Wear is typically characterized as the loss of material from solid surfaces due to the movement of one surface over another. Consequently, friction and wear result from the same tribological contact between two moving surfaces. However, their interrelationship remains poorly comprehended. It is frequently observed that low friction correlates with low wear [19].

The following kinds of wear:

• Adhesive wear happens when the atomic bonding forces between the parts are stronger than one of the materials. Even after removal, most of the material is still attached to the other object's surface [20].

• Abrasive wear often occurs when a hard surface moves across a softer surface. Material displacement or removal by cutting happens when material detaches from a surface in the form of chips or debris [20].

• Fatigue wear occurs through pitting, the fatigue failure of the material resulting from the nucleation and development of subsurface fractures (a prevalent wear mechanism in ball bearings), or by spalling, the fatigue failure of the material owing to the nucleation and growth of surface cracks [20].

1.5 Surface Roughness

Surface roughness significantly impacts machined component fatigue strength, wear rate, coefficient of friction, and corrosion resistance. Tool variables, workpiece hardness, and cutting conditions affect surface roughness. Material, nose radius, rake angle, cutting-edge geometry, vibration, and point angle are tool variables. Hard turning surface finish depends on feed rate, cutting speed, tool nose radius, tool geometry, cutting duration, workpiece hardness, and machine tool and workpiece setup stability [21]. The variances in the surface's height about a reference plane are the most typical measure of surface roughness. Measurements may be taken along a single-line profile or a series of parallel lines. The following are some examples of these: Ra, CLA (center-line average), or AA (arithmetic average), the standard deviation (σ), Rq (root mean square) [22].

1.6 Friction

The term "friction" describes the force acting as a brake on the relative motion of two sliding surfaces, whether solid or fluid. The term refers to the resistance of two bodies in contact with relative motion. Adhesion, lubrication, slip-stick behavior, and Aspects such as wear are phenomena connected to friction found in engineering, chemistry, and physics [22]. In cutting, unlike other metal-forming processes, there is considerable friction at the contact interface due to shear, extrusion, and deformation. This friction causes the material to fracture, separating the workpiece and chip [24]. Metal cutting requires about 20% of the total energy to overcome friction at tool-chip and tool-workpiece contact interfaces. Cutting friction behaviors significantly impact the cutting process [25,26].

1.7 Lathe machine

Metal cutting is the process of removing metal chips from a workpiece to produce a product with precise dimensions, form, and surface finish. It is a widely used machining technique in the engineering industry [27]. The turning technique is the most common way to cut metal. The cutting tool removes material by feeding it in a direction parallel to the rotational axis [28].

1.8 Cutting Tool Material

The term "cutting tool" refers to any implement used to shear off material from a workpiece. A cutting tool could have one or many points for making cuts. Turning, shaping, and planning are performed with single-point tools. A multipoint tool is a standard tool for milling and drilling [29]:

1.8.1 High Speed Steel

An alloy comprising iron, molybdenum, chromium, vanadium, and cobalt, high-speed steel (HSS) has a high carbon content. Cast, wrought, and sintered high-strength stainless steel (HSS) forms are commonly available. Sintered comes from the powder metallurgy process. The cost of HSS is low in comparison to other materials used for tools [30].

1.8.2Cemented carbide

Modern cutting tool materials made of mixed, compacted, and sintered tungsten carbide (WC) and cobalt (Co) particles are known as cemented carbide. Co binds the hard WC grains together. Carbide tools are highly conductive electrically and thermally, giving them strong metallic properties [30].

1.8.3Ceramics

Ceramics are inorganic, non-metallic substances that undergo high temperatures during their production or use. They maintain exceptional hardness and rigidity at temperatures above 1000 °C and exhibit little chemical reactivity with most materials at these temperatures [30].

1.9 The Objectives of This Work

The main aim of the present study is to discuss the effect of using a type of lubricant flow at different speeds on enhancing tribological properties:

1. To study the effect of three scenarios (dry, flooded oil, and oil jet lubrication) using (ARO).
2. To study the most important jet nozzle that has angles (15 and 40 degrees) and pressures (6 and 12 bar) with different jet speed.
3. Examine the impact of the three circumstances throughout the machining process using a lathe machine. A comparison of the procedures regarding their effect on surface roughness ,tool wear during operation, and the temperature differential between the work pieces and the cutting tool.
4. A 150-millimeter-long and 15-millimeter-diameter work pieces was prepared from low carbon steel.

CHAPTER TWO

Literature Review

Chapter Two

Literature Review

2.1 Introduction

Various research have examined the effects of cutting speed, feed rate, and depth of cut on surface roughness, tool wear, tool life and cutting temperature under various conditions (dry, flood, MQL, oil jet, MQCL, etc.). This chapter provides a summary of such investigations.

2.2 Literature Review

(Meenu Sahu et al.,2014) [31] Utilized a technique for optimizing the cutting parameters in dry turning of AISI D2 steel in order to meet the following goals: minimal tool wear, low workpiece surface temperature, and maximum material removal rate (MRR): cutting speed, depth of cut, and feed. An analysis of variance (ANOVA) was conducted to determine the impact of the cutting parameters on the response variables, and the experimental layout was developed using Taguchi's Orthogonal array approach. Cutting speed and depth of cut were determined to be the two most critical factors affecting tool wear. Cutting at 150 m/min with a depth of cut of 0.5 mm and feed of 0.25 mm/rev resulted in the least amount of tool wear.

(S.Yuksel et al., 2015) [32] The vortex tube was used to study the effect of cooling on the CNC turning of low alloy chromium molybdenum steel (42CrMo4) specimen turning. Surface roughness, cutting force, and temperature were examined using different cutting parameters (100, 250, and 400 m/min) and cooling temperatures (-4, 8, and 20 °C). Under 0.15 mm/rev feed, 400 m/min cutting speed, -4 °C cutting temperature, and 1.2 mm tool edge radius, the best surface roughness was 0.77 µm Ra. Temperature did not affect cutting forces. Under 0.25 mm feed, 250 m/min cutting speed, -4 °C (with vortex tube) cutting temperature, and 0.8 mm tool edge radius, the lowest cutting temperature was 74.17 °C.

(Yahya Isik et al., 2016) [33] Utilized nickel super alloys such as Waspaloy. This alloy is characterized by high-temperature strength and corrosion resistance. Such alloys enhance cutting temperature and tool damage at low cutting speeds and feed rates. A tool holder with a closed cooling system and cooling fluid circulates inside for metal cutting. The surface quality was 13% better than dry machining, and the tool life was 12% longer. Nickel-based alloy cutting speed affects tool wear and life. Raising the cutting speed from 45 to 95 m/min resulted in a 28% rise in temperature to 641 °C. Testing showed that the IC-Tool reduced temperature and wear, extending tool life.

(A.Damir et al.,2018) [34] Checked the effect of liquid nitrogen (LiN) cryogenic machining on titanium alloy turning compared to traditional flood coolant. Cutting forces, tool wear and surface quality were all areas where cryogenic cooling was performed as a flood coolant during machining. Cutting forces are reduced by 15% at low speeds and feeds and by 44% under heavy cutting conditions when using cryogenic machining instead of flood coolant. With a reduction in surface roughness of up to 19%, a better surface finish was achieved, particularly in harsh cuts. In contrast to flood, which chowed on tools excessively, particularly under high-speed, feed, and radial depth of cut (RDOC) circumstances, cryogenic coolant extended their life by reducing tool wear. Compared to flood, cryogenic technology increased process productivity and improved environmental performance, tool life, and surface quality.

(Sachin M.Agrawal et al.,2018) [35] Tested M2 steel machining using aloe vera oil as a cutting fluid. Different speeds, feeds, and depths were employed for carbide machining. Aloe vera oil reduced surface roughness by 6.7% compared to standard cutting fluid. Aloe vera oil reduces tool wear by 0.14% over standard cutting fluid. Surface roughness is reduced as cutting speed rises because higher cutting temperatures make the material ahead of the tool softer and more plastic. Surface roughness also increases as the cutting feed increases.

(Prianka B.Zaman et al.,2019)[36] Checked the effect of proposes Minimum Quantity Lubrication (MQL) as an alternative to flood cooling and dry machining. It bridges dry and flood cooling. An integrated dual jet nozzle was used to improve MQL nozzle size, angle, air pressure, and oil flow rate are MQL parameters that minimize including cutter the temperature, surface roughness, chip lowering coefficient, and primary force of cutting, according to grey-based Taguchi multi-response optimization. In this case, 1 mm of air the pressure, 19 bar, 15° of secondary nozzles angle, 80 ml/h of the oil flow rate, and 20° of nozzle diameter are all highly suggested based on statistical study. Results from tests using dry processing, alone jet MQL machining, cutting temperatures, roughness of the surface, chip reduction coefficient, main cutting of force, and wear of tools in turning medium shown that the double jet MQL micro nozzle worked admirably. The lowest achievable Ra for the double-jet nozzle is 1.08 μm. When dry machining was replaced with double-jet MQL, the average Ra decrease increased from 10.44% to 25.02%. Twin jets may minimize Ra better.

(Radoslaw W. Maruda et al.,2020) [37] Studied turning-machined surfaces, lubrication, and cooling. Machine testing encompasses a range of procedures, such as dry machining, minimum quantity cooling lubrication with modifications (MQCL+EP/AW), and minimum quantity lubrication (MQL). MQL machining produces the greatest oil retention characteristics in mating components, where as MQCL+EP/AW turning produces the lowest surface roughness. With TiAlN PVD coating and P25 cemented carbide tool material, feed f 0.085–0.28 mm/rev, cutting depth 0.5 mm, and cutting speed 200 m/min were used. Compared to dry machining, MQCL + EP/AW and MQL processes reduced sample wear by 16% and 27%, respectively.

(Sanjeev Kumar et al.,2020) [38] Examined the impact of vortex tube cooling air during difficult turning of AISI 4340 steel. Flanking wear, surface roughness, and cutting force all impacted machining performance. According to experiments, vortex tube cooling air significantly reduces flank tool wear, cutting force, and surface roughness. Compared to dry conditions, tool life increased by 112.25%. Compared to dry machining, cooling air improved surface quality by 58.26% and reduced cutting force by 55.50%. Chip morphology revealed that cooling air produces flat surfaces, whereas other cutting conditions yield serrated surfaces.

(Natalia Szczotkarz1 et al.,2020) [39] Carefully evaluated lubricant oil, MQL-dominated machining methods for 316 stainless steel and used two minimal lubrication-based cooling methods: minimum quantity lubrication (MQL) and minimum quantity cooling lubrication (MQCL) with extreme pressure and anti-wear (EP/AW). A standard lathe, model CU-502, was used for testing. A tool with the CSRNR 2525 holder and the SNUN 120408-PF plate was used in the experiment. Cutting tool wedge material was sintered carbide P25 with a three μm uniform thickness of TiAlN coating applied by physical vapor deposition (PVD). The MQL technique reduced cutting tool wear by 9% compared to MQCL + EP/AW and 21% compared to dry machining. The greatest wear indices were attained during dry machining, and the lowest was during reduced lubrication. The MQL method's oil mist formed a machining liquid layer on the workpiece and tool, reducing cutting friction. The EP/AW additive in the MQCL method also creates a phosphate ester-based tribofilm on the cutting edge of rake faces. This film protects the cutting wedge from wear and tear compared to dry machining.

(Selçuk YAĞMUR et al.,2021) [40] Investigated Inconel 625 cooling settings. The tool's life, wear, surface roughness, cutting forces, and cutting zone temperature were measured. Cooling using dry, minimum quantity lubrication (MQL), and Vortex. Three cutting speeds (60, 80, and 100 m/min) and feed rates (0.08, 0.1, and 0.12 mm/rev) were employed. The tool's wear was measured at 80 m/min and 0.1 mm/rev. The study showed that cooling increases tool life, cutting zone temperature, and surface roughness. MQL was achieved by spraying the least quantity of oil onto the cutting region at high pressure. MQL provides 0.9 ml/min at 3 bars, whereas vortex tubes require 6 bars. Tool wear, life, and cutting power were reduced by MQL conditions and had the lowest average Ra: 0.584 µm, with values of 0.591 µm in vortex circumstances and 0.763 µm in dry conditions.

(Boki Dugo Bedada et al.,2021) [41] Examined the advantages of dry machining compared to wet machining by turning AISI 1020 steel with a cemented carbide tool on a computer numerical control lathe. The infrared thermometer and VOGEL surface roughness tester were used to measure cutting temperature and surface roughness, respectively. Wet machining resulted in an average surface roughness of 2.01 µm and a cutting temperature of 26.540C, which were 17.41% and 44.86% lower than dry machining, respectively. Dry turning's short tool life 41.15 percent less than wet turning is due to the high cutting temperature. When compared to dry turning, the machining cost of wet turning was over 56% higher. The feed rate has the greatest effect on surface roughness and cutting speed has the principal and most powerful influence on tool wear, followed by feed rate and degree of cut. Cutting speed of 119.734 mm/min, feed rate of 0.1 mm/rev, and depth of cut of 0.4 mm were the ideal process parameters.

(Uma Maheshwera Reddy Paturi et al.,2021) [42] Used modelling and optimizing cutting speed, feed, and depth of cut during AISI52100 steel turning to minimize surface roughness and tool wear. The feed rate has the greatest effect on surface roughness, accounting for 85.56% of the total. Cutting speed and depth of cut come in second and third, respectively. With a contribution of 73.15%, cutting speed has the principal and most powerful influence on tool wear. Cutting speed of 119.734 mm/min, feed rate of 0.1 mm/rev, and depth of cut of 0.4 mm were the ideal process parameters. The surface roughness and tool wear measurements are 2.966 lm and 0.052 mm, respectively.

(**Havva Demirpolat et al.,2022) [43]** Examined the cutting parameters and sustainable environmental circumstances that affect AISI 52100 bearing steel turning. Tool flank wear, surface roughness, cutting force, and chip form were examined in minimum quantity lubrication (MQL) and dry sustainable cutting situations. The MQL used to convert AISI 52100 improved performance by preventing excessive cutting temperatures. High temperatures increase tool wear, slow cutting, and degrade surface polish. The tool wear progressions for MQL-assisted turning showed better flank wear than dry cutting. Tooltip temperatures reached 410 °C for high cutting parameters in dry machining, whereas in MQL-assisted machining, 348 °C was observed for maximum cutting parameters. Since lubrication slides chips from the cutting zone, AISI 52100 machined under low cutting parameters in an MQL medium produced longer chips and lesser surface roughness.

(M.S.Kasim et al., 2023) [44] Utilized the pulsing lubrication on the cutting tools. Inconel 718 (nickel-chrome) was employed in severe circumstances, and TIAIN/AICRN coated it with tungsten carbide during milling. Pulsating and flood coolants were used. The PLS outperformed the FC in cutting tool life, built up edge (BUE) formation and flaking area. BLS accelerates cutting fluid in dynamic waves, combining pressure and pulsation to remove BUE more efficiently than FC alone. The coolant is jetted to the cutting zone, but the lack of coolant penetration to the cutting tool area is a problem. The investigation found that pulsation tool life is 11.74 minutes compared to 6.64 minutes for coolant flooding, and cutting force is 39% lower at 133 N compared to FC 198 N.

(Rustem Binali et al.,2023) [45] Examined the utilization of cutting fluid in several applications to increase machinability, sustainability, and manufacturing costs. The study revealed how chip shape, tool wear, roughness, and cutting temperature affect milling machinability. Nimax steel contains aluminum, nickel, vanadium, chromium, manganese, and molybdenum. This alloy is tough, hard, and wear-resistant. The tool uses physical vapor deposition (PVD) coated (TiAl carbide). For dry and minimum quantity lubrication conditions, range of speeds (150 and 200 m/min), rates of feed (0.1 and 0.2 mm/tooth), and cutting depth 0.2 and 0.4 mm, respectively. In several cutting situations, MQL performed better than dry. The investigation found that nose wear on tool edges was the most prevalent. Tool and workpiece abrasions wear noses. The main Nimax steel milling chips are Comma, c, and short curled. Cutting of speed and rate of feed had a significant effect on cutting temperature. Machines with MQL medium have much lower temperatures and higher material removal rate(MRR).

(Gabor Konya et al.,2024) [46] Investigated how cooling and lubrication affect force of cutting, tool wear, and machined surface quality. The nickel-based super alloy has high hot strength, work hardening, and low thermal conductivity. When milling nickel-based super alloy, tool wear, and cutting force were examined with flood oil concentrations of 3%, 6%, 9%, 12%, and 15%. Three-component Kistler dynamometers were used to measure cutting force. At 15% oil concentration, tool load and wear marginally increase, but at 12%, they are the lowest. Increasing oil of concentration reduces heat production and tool-workpiece friction, lowering head load. The cutting power and wear are highest at 6% oil concentration and lowest at(12%) flood cooling of oil concentration. According to the research, concentration flood cooling oil does not affect surface roughness.

(Qianxi He et al.,2024) [47] Studied Cutting speeds beyond 60 m/min are difficult to accomplish with standard titanium alloy cutting tools due to significant tool wear. The study focused on 100-m/min high-speed end milling to improve Ti-6Al-4V alloy machining. AlCrN PVD-coated tools were used to overcome solid carbide end mills. Cutting tools' mechanical parameters significantly impact wear behavior and lifespan. The tool life test, mechanical characteristics analysis, and edge geometry measurement showed that C3-coated tools performed better. Tools with C3-AlCrN coating lasted 1.5 times longer than others.

(Nabil Jouini et al ., 2024) [48] Examined the efficiency of chemical vapor deposition (CVD)-coated carbide inserts in turning hardened AISI 4340 steel at V = 300, 350 m/min in a dry cutting environment. The Taguchi method was used to conduct machinability experiments and evaluate tool life, wear progression, cutting force, and surface roughness. Al_2O_3/TiCN coating results in longer tool life (19.25 min) and lower cutting force (76.8 N) at low settings ($V=300 mmin^{-1}$, $F=0.05 mmrev^{-1}$, depth of cut 0.1mm). The maximum cutting force of 211.94 N and lowest tool life of 9.24 min were obtained at high machining settings (V = 350 m/min^{-1} and F = 0.1 mm rev^{-1}, depth of cut 0.2 mm). Tool flank wear increased cutting force and surface roughness due to coating delamination, substance adhesion, and chipping.

2.3 Summary

The present work investigates the impact of various rates of feed and cutting speeds on roughness of surface and tool wearing under three conditions: cutting dry, cutting with flood oil and oil jet lubrication on tribological properties. The variables studied were cutting speeds (5,10,19,29 m/min), feed rates (0.03,0.043,0.075 mm/rev), depths of cut (1 mm), and injection angles (15° and 40°) and pressures (6 and 12 bar). There is no similar used (ARO) through oil jet lubrication, which was used throughout the lathe machine process, with two different injection angles.

CHAPTER THREE

Theoretical Concepts

Chapter Three
Theoretical Concepts

3.1 Introduction

This chapter present the theoretical background necessary to analyze the tribological behavior of cutting tools under different lubrication conditions. It covers cutting parameters, wear models and lubrication regimes relevant to present study.

3.2 Cutting Parameters

The following simple equation can be used to express the cutting speed may be determined for any lathe machine operation by calculating the rotation speed [49].

$$V = \frac{\pi\, DN}{1000} \qquad (3.1)$$

The value of N is the (rpm) of the shaft, cutting Speed (m/min) is assigned to V, and value for D is the work diameter in (mm).

3.3 Bernoulli’s Equation

To understand Bernoulli's principle, an essential concept in fluid mechanics, the Bernoulli equation provides a theoretical basis for accurately calculating hydraulics in real-world engineering by addressing the force-energy issue that often arises in engineering practice [50].

As a result of the function principle is given by:

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2 \qquad (3.2)$$

The following relationship is universally applicable to any segment of the same flow tube calculated on the formula given by [50]:

$$P + \frac{1}{2}\rho v^2 + \rho g h = Constant \qquad (3.3)$$

Both are referred to as Bernoulli's equations, which delineate the basic principles governing ideal fluid dynamics in stationary flow. When an ideal fluid traverses a horizontal flow tube [50], then the formula given by

$$P + \frac{1}{2}\rho v^2 = Constant \qquad (3.4)$$

Here, p refers to pressure, v for velocity, and h for elevation, g and ρ refer for the fluid density and acceleration.

$$v=\sqrt{2\ p/\rho} \qquad (3.5)$$

3.4 Wear Rate

There are several methods to describe wear. Measurements of material removal are often expressed in terms of volume, weight, or depth (thickness). Also, the wear rate would connect some variable distance, time, or cycles to the quantity of material lost [51].

The relationship between wear rate and normal load may be mathematically described by the Archard wear equation [52]:

$$Q=\frac{K\,N_i}{H} \qquad (3.6)$$

Where Q represents the volume extracted from the surface per unit sliding distance (m^3/m), N_i is the normal load exerted on the surface (N), H signifies the indentation hardness of the worn surface (N/m^2), and K is the wear coefficient.

3.4.1 Wear Factor

Material wear resistance may be estimated from experimental wear factors. An equation connecting the volume of material lost per unit of force and surface velocity yields the wear factor [51].

$$W = K \times F \times V \times T \tag{3.7}$$

Where W = wear volume (cm^3), K = wear factor (cm^3.min/m. N. h), F = load (N), V= velocity (m/min), and T = time (hours).

3.4.2 Wear measurement

Mass loss is often used to quantify wear since it involves material loss. A specimen's mass is measured before and after testing. In addition to measuring mass loss, wear volume may be calculated from the width and length of a worn specimen's wear scar, which a profilometer can measure [53].

3.5 The Factors Affecting on the Cutting Speed

The tool's maximum cutting speed is affected by the following [49]:

- Cutting tool material.
- Change the feed rate and depth of cut.
- Geometry of the tool.
- Tool flank of size.
- Fluid Utilization for Cutting.
- The nature of the machining operation.

3.6 Effect of the Feed and Depth of Cutting

One of the most important factors determining the tool's allowable speed is the depth of cut and rate of feed, both of which effect cutting forces and temperature. Boosting the cutting speed and depth causes the cutting zone to become hotter. The wear mechanism at high temperatures and often speeds up the weakening of the cutting edge, leading to premature tool failure (chipping), which is the breaking of the cutting edge [54].

3.7 Friction

Tool wear, tool life, chip formation, and surface of integrity are all impacted by friction behaviors, which are certain to happen. The tool materials' thermophysical characteristics are altered as a consequence of localized thermo-mechanical gradients created by the severe cutting conditions at the contact interface [55]. Thus, physical processes, chemical reactions, and thermo-mechanical phenomena are the causes of tool wear. Additionally, production expenses rise as a result of shorter tool life. The interface contact mode varies, and the extra thermo-mechanical stresses are increased due to tool wear. The production of chips is directly affected by the secondary shear deformation zone, which is formed by the cutting friction at the tool-chip contact. Surface integrity is greatly impacted by the thermo-mechanical stresses of friction at the tool-workpiece contact. This causes gradient changes in the surface topography, microstructure, and mechanical properties [56,57], as shown in Figure (3.1).

The frictional force, denoted as Fs, is defined by the equation and is only dependent on the vertical applied force, denoted as F_n [49].

$$\mathrm{Fs} = \mu \times F_n \tag{3.8}$$

where μ the coefficient of friction.

The coefficient of friction is a variable dependent upon the specific materials of the block and plate.

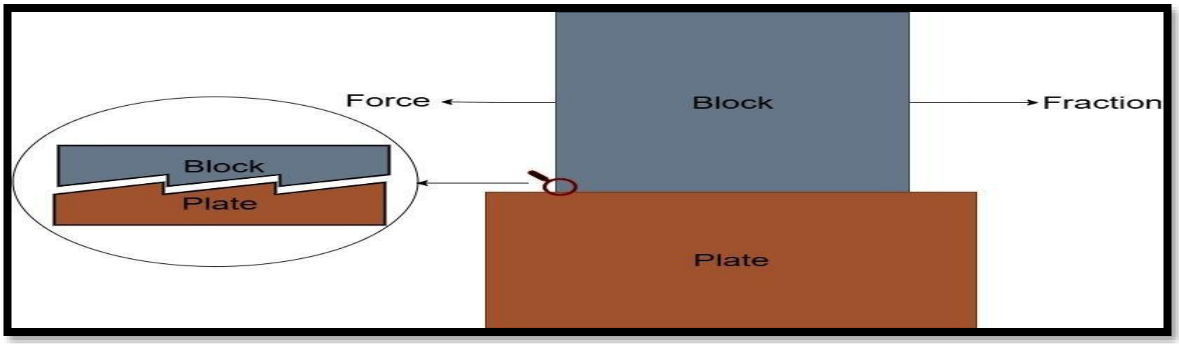


Figure 3.1: Illustration of the relationship between the block and plate.

3.8 Lubrication

Lubrication is a typical method for lowering friction. As seen in Figure 3.2 shown lubricant film separating two surfaces. Inserting an incompressible solid or liquid lubricant between the two surfaces that will be touching causes it to fill the spaces between the sharp edges [58] .

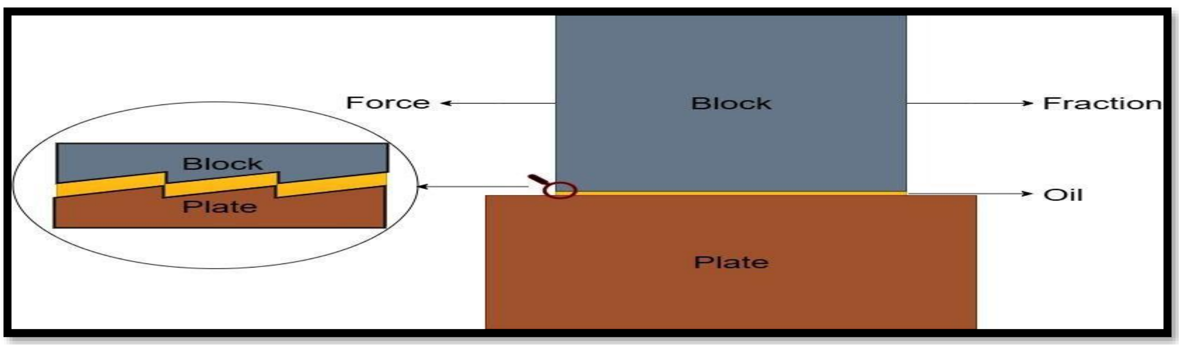


Figure 3.2: Illustration of lubricant between block and plate.

3.9 Lubrication Regimes

Stribeck's study of the fluid film lubricated journal bearing system [59,60] revealed four frequent lubrication regimes: boundary, mixed, elastohydrodynamic, and hydrodynamic lubrication, as illustrated in Figure 3.3. The graph illustrates how the lubrication regime affects the coefficient of friction's dependency on Hersey's number. Full contact at the contacting surfaces' asperity points results in the maximum coefficient of friction values under dry contact. The coefficient of friction decreases as relative velocity and viscosity rise. The hydrodynamic regime of complete separation of the metal surfaces by the lubricant layer starts as the coefficient decreases to a minimum as the viscosity and velocity increase. With a rather thick layer (>0.25 µm) at the contact, this regime is also known as full-film lubrication. Since there is no metal-to-metal contact and the coefficient of friction is solely reliant on the lubricant's viscosity, the primary cause of frictional resistance is the requirement to overcome the entrained lubricating film's shear strength. Elastohydrodynamic lubrication falls under the hydrodynamic lubrication subcategory, in which the hydrodynamic pressure of a very thin fluid film (0.025–5 µm) elastically deforms the asperities [61].

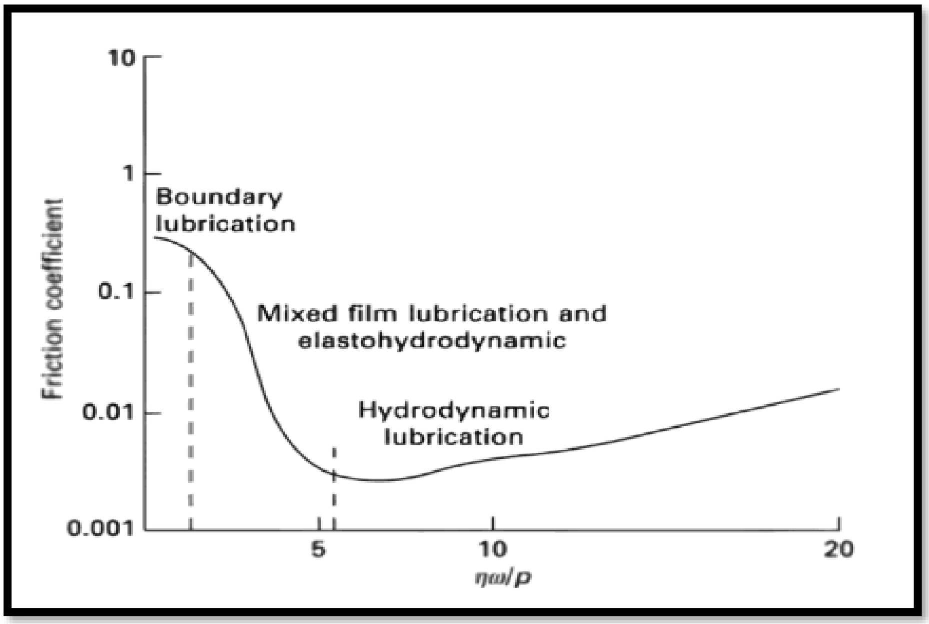


Figure 3.3: Stribeck Curve [61].

3.9.1 Boundary Lubrication

In the case of extremely harsh conditions or insufficient lubrication, the contact between the solids (or corresponding boundary lubricant films) dictates the amount of friction generated in the contact; in cases when the parameter viscosity η is relatively modest, the solid-to-solid connections sustain the full load. In the solid-to-solid contact, the friction generated is usually very high in comparison to the friction caused by the viscous shear of the lubricating layers. Known as the boundary lubrication (BL) regime as shown in (Figure 3.4) [61].

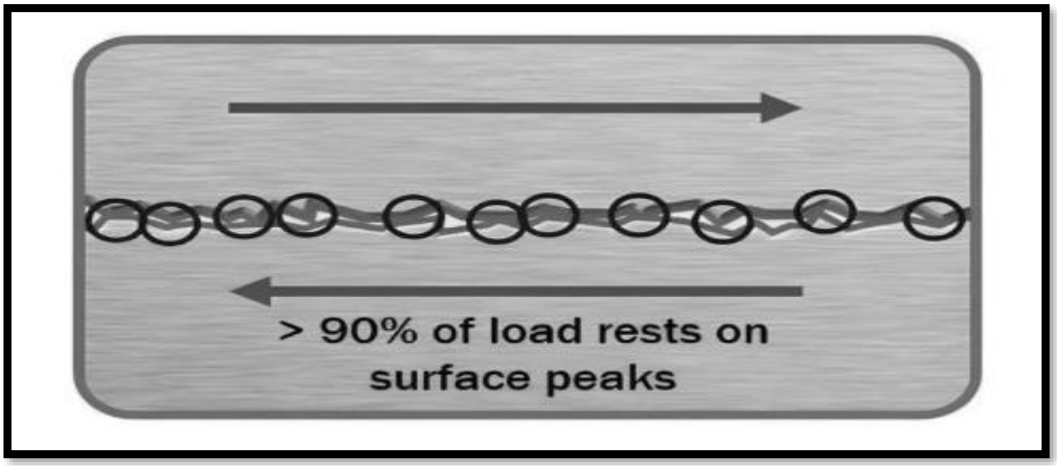


Figure 3.4 : Boundary Lubrication Regime[61].

3.9.2 Mixed Lubrication

This regime is identified when the operating circumstances become less harsh and the lubricating layer thickness increases. When the lubricant's thickness starts to separate the surfaces and bear some of the load, only a portion of the particles make direct contact with it. Both the friction of the solid-to-solid contact friction and the friction of the lubricant layers contribute to the overall friction in this case, as shown in Figure 3.5. Between the BL and hydrodynamic/elastohydrodynamic regimes, this is the gray area. As the oil film thickness continues to increase, the system now enters total film lubrication, which can be either hydrodynamic or elastohydrodynamic. Because lubricant layer friction is typically lower than solid-to-solid contact friction, overall friction decreases [61].

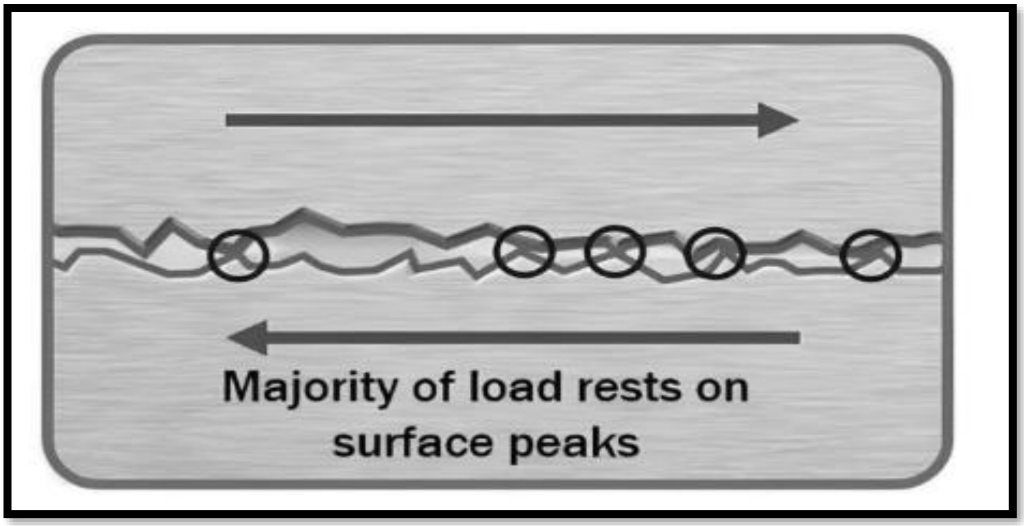


Figure 3.5: Mixed Lubrication Regime [61].

3.9.3 Elastohydrodynamic lubrication

Lubrication based on elastohydrodynamics When lubricated contacts have non-conformal contacting surfaces and a high external load per unit area relative to the material stiffness, EHL applies. Elastic deformation of the surfaces is inevitable given the high load and small contact area. The lubricant will be pulled into the contact's converging gap by shear pressures imposed by the surfaces if they roll, slide, or spin in relation to each other. Naturally, this calls for a viscous lubricant, and shear stresses in the intake area are proportional to viscosity. The very low loading time for a contact point—usually a few hundred microseconds—is another characteristic of an EHL contact. This necessitates characterizing the lubricant and the contacting entities' materials in a manner that accounts for potential temporal effects. We may classify EHL into two categories: hard and soft. Materials with a high elastic module are associated with hard EHL. Materials with a low elastic modulus are considered soft EHL [62].

3.9.4 Hydrodynamic Lubrication

When a machine begins to rotate and the loads and speeds are such that an oil wedge forms between the shaft and the bearing surfaces, this lubrication regime condition occurs. This oil wedge raises the shaft off the bearing surface, reducing the possibility of asperity contact. This is the optimal condition to reduce wear and friction. Film thickness rises as working conditions improve. When full-film (FF) lubricating conditions are reached, solid-to-solid contact eventually stops. Here, friction is produced by the viscous shear of the lubricant layers. Even when the solid-to-solid contact vanishes, Figure 3.6 shows how friction rises over the whole film lubrication regime [61].

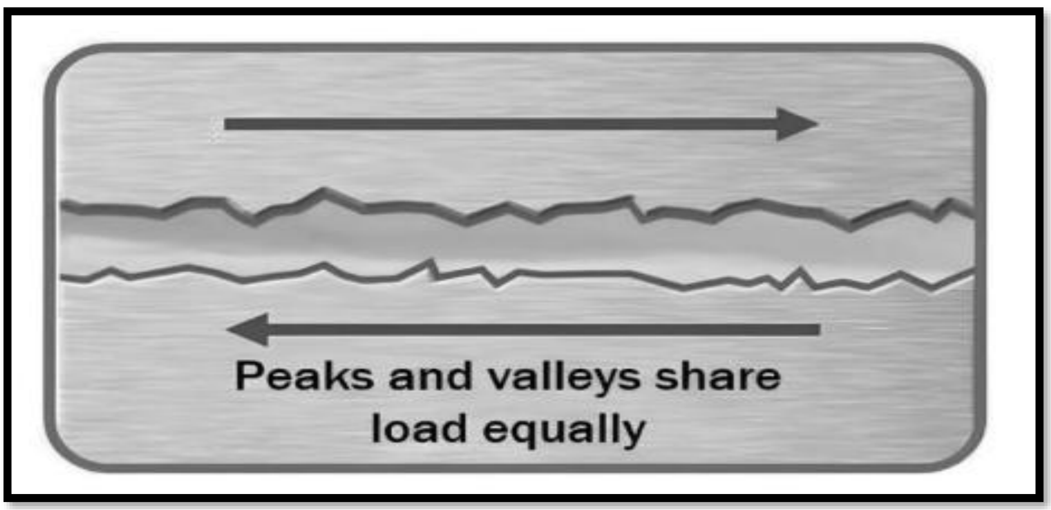


Figure 3.6: Hydrodynamic Lubrication [61].

3.9.5 Lambda Ratio

The lambda ratio is a widely recognized statistic in the domains of lubrication and tribology that is employed to distinguish between lubrication regimes [63,64]. The lambda ratio is defined as the ratio

$$\lambda = \frac{h}{\sigma} \quad (3.9)$$

where λ lambda ratio ,h the surface heights and σ standard deviation.

3.10 Chipping

Machining chips are small particles that separate from the workpiece material, facilitating the creation of new surfaces. Flowy, wavy, serrated, and segmented are some geometric features that categorize chips produced during milling. The machining process is reflected in the chip form. The form of chips is greatly affected by lubricating circumstances and the degree of cutting procedures. Irregular heat production, chip breakability, and tangles around the tool and workpiece are three important indicators that may be used to categorize chips [65].

3.11 Material Removal Rate (MRR)

As a quality indicator, this study considers the material removal rate (MRR) value to explore the influence of chip removal speed under varied lubricating circumstances. Equation (3.11) provides the formula for calculating the MRR, where Vs is the cutting speed, ap is the cutting depth, and fr is the feed rate [66].

$$MRR = Vs \times ap \times fr \tag{3.11}$$

3.12 The parameter influenced the cutting process:

- Speed of Cutting

It is the rate at which the cutting tool contacts the workpiece's surface; this rate varies with the cutting tool and the workpiece's substance.

- Rate of Feed

It is the amount of material that the cutting tool removes from the operating surface in one cycle of operation.

- Cutting Depth

This is the thickness of the material that is taken off in just one cut, measured in unit.

3.13 Summary

This chapter presented the theoretical foundations and main equations related to friction, wear, and speed, in addition to the various lubrication regimen through the Stribeck curve. The specific equation was used to calculate cutting speed (3.1) and to calculate jet speed through the equation (3.5).

CHAPTER FOUR

Experimental Work

Chapter Four
Experimental Work

4.1 Introduction:

This chapter describe the experimental methodology adopted to investigate the effects of dry cutting, flood cutting, and oil jet lubrication on surface roughness, tool wear and cutting temperature. Utilizing (ARO) in the second and third techniques. The graphic depicts the experimental procedure succinctly in Figure (4.1).

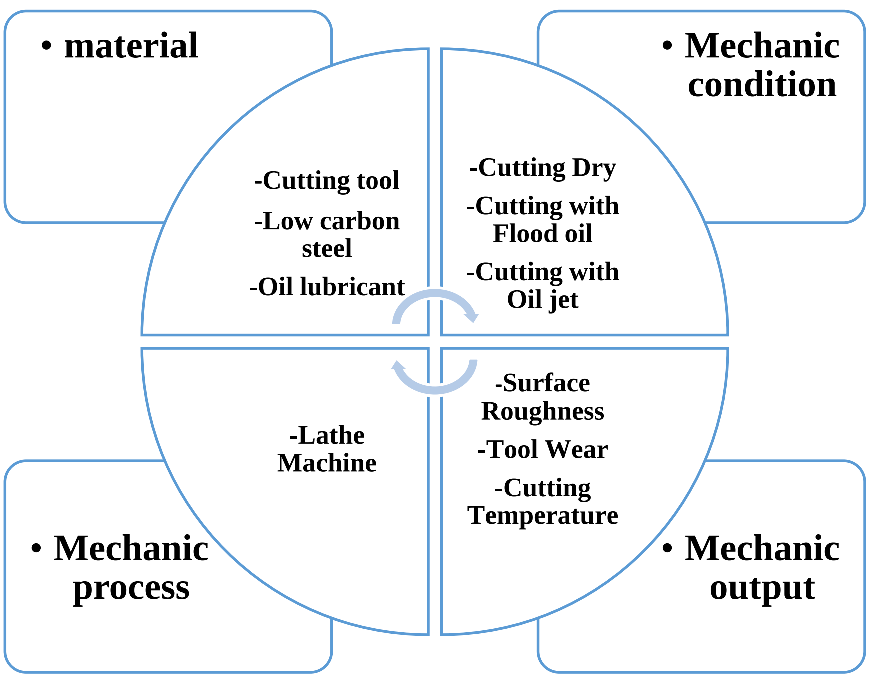


Figure 4.1: The graphic depicts the experimental procedure succinctly.

4.2. Materials and parameters:

Table 4.1: The parameters of machining process.

Cutting speed Vs(m/min)	**Feed rate F_r(mm/rev)**	**Cutting depth a_p(mm)**	**Angles of jet**	**Pressure (bar)**	**Lubrication Conditions**
5	0.03	1	15˚	6	Dry cutting
10	0.043		40˚	12	Flood oil cutting
19	0.075				Oil jet lubrication
28					

4.2.1. Cutting Tool

The cutting tool is made of high speed steel (HSS), coated with a layer of TiNLa and has a sharp edge. It is used to remove layers from the workpiece by cutting it as it is being operated in order to obtain the required form, size, and precision. As shown in the Figure 4.2.

Figure 4.2: Cutting tool.

where fixed on the tool post, shows in the Figure (4.3). This part is located in the cross slide of the cross carriage. Its main function is to securely hold the cutting tool in place for the turning operation. It should be properly adjusted to decrease vibrations and extend the lifespan of cutting tool.

Figure 4.3: The Tool Post.

Used the scanning electron microscope SEM analysis of workpiece and tool cutting, as well as energy dispersive x-ray EDX to show the element composition. taken at the University of Karbala's College of Veterinary Medicine, as shown in Figure (4.4).

Figure 4.4: Scanning Electron Microscope (SEM).

These were acquired chemical composition for cutting tool and work piece indicated in Figures (4.5,6) and Table (4.2,3). The EDX profile shows only the chemical composition of the coating layer, because the penetration for EDX is no deeper than 3 µm

Table 4.2: Chemical Composition for cutting tool.

El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
Ti	22	K-series	97.39	47.56	46.43	3.74
La	57	L-series	82.87	40.47	13.62	3.58
N	7	K-series	24.52	11.97	39.96	6.57
		Total:	204.77	100.00	100.00	

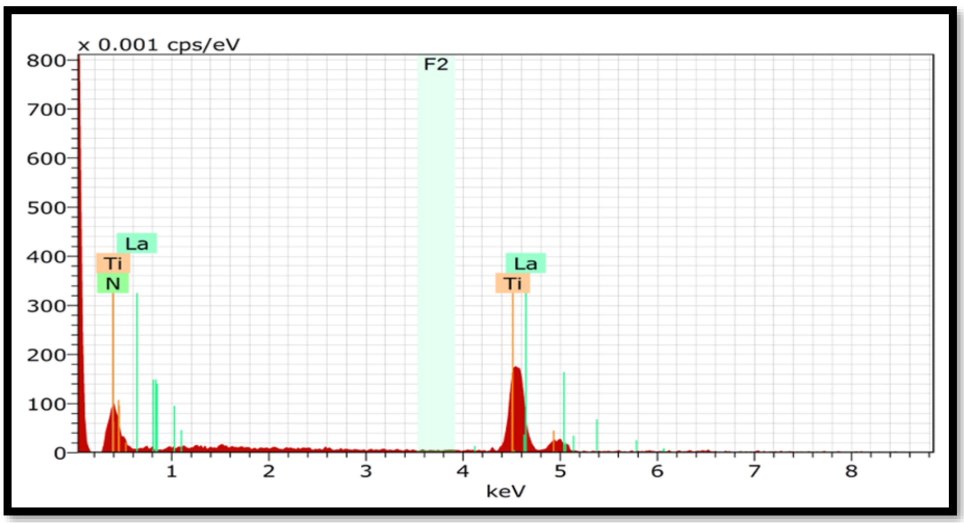
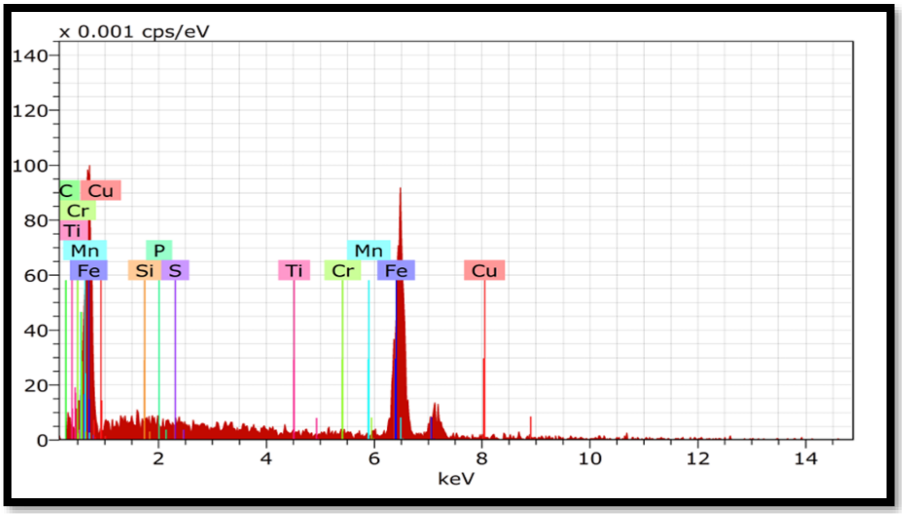


Figure 4.5: Chemical composition for cutting tool.

Table 4.3: Chemical composition for work piece.

El	AN	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error (1 Sigma) [wt.%]
Fe	26	K-series	70.86	95.14	95.06	3.12
Mn	25	K-series	3.62	4.86	4.94	0.44
		Total:	74.49	100.00	100.00	



Figure(4.6) Chemical composition for work piece.

4.2.2. Low Carbon Steel

In this study, low carbon steel was used with an initial diameter (15 mm) and length (150mm), as shows in the Figure (4.7) . Its most important features are good strength and flexibility, cheap cost, and simplicity of manufacture.

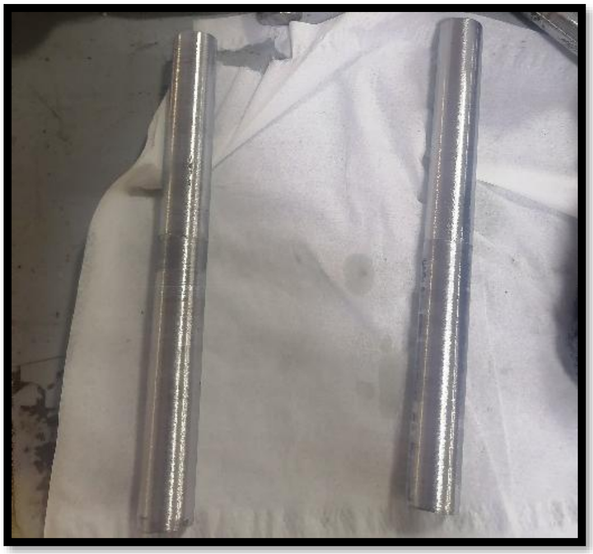


Figure 4.7: The work piece.

The roughness of surface for workpiece was measured with surface roughness tester (SRT-6210). Testing device contains a sensor placed on the workpiece's surface at distance (0.8 mm). The sensor can assess the surface roughness using a built- sharp probe. Displayed in Figure (4.8).

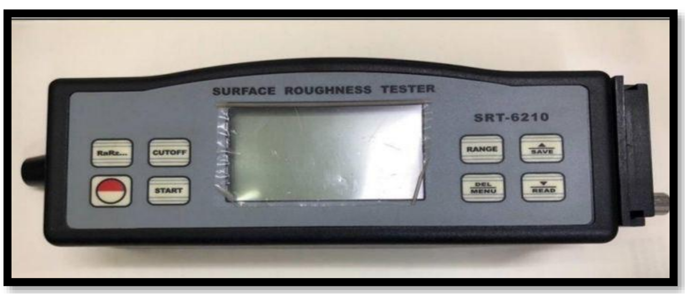


Figure4.8Surface Roughness Tester.

4.2.3. Oil Lubricant

In this study, the base oil lubricant was used (ARO) as shown in Figure (4.9), manufactured by the Midland Refineries Company_Daura Refinery. The properties oil as shown in Table (4.4).

Figure 4.9: AL-Rashid Oil(SAE 15W_40).

Table 4.4: The properties oil.

Base Oil	**Physical properties**	**Value**
SAE 15 W-40	Density	0.900 g/cm^3
	Viscosity @100 ċ	14.5 w/m.k
	Viscosity Index	130
	Pour point	-24 ċ
	Flash point	220 ċ

4.3. Lathe machine

The experimental work was conducted using lathe machine (turning), indicates in the Figure (4.10). The workpiece were rotating at fixed axis and using cutting tool . The process can be controlled by cutting of speed, rate of feed and depth of cutting. The rotating speed (110,210,400,600) rpm and feed of rate (0.03,0.043,0.075) mm/min.

Figure 4.10: lathe Machine .

4.4 Experimental Method

4.4.1 Preparation of measurement

The work piece's weight was measured using a (High precision balance) before and after the operation, shown in Figure 4.11, the cutting of tool weight by (Denver instrument) are measured, as shown at Figure 4.12. Additionally, the surface of roughness was checked before and after the operation by using (Surface Roughness Tester).

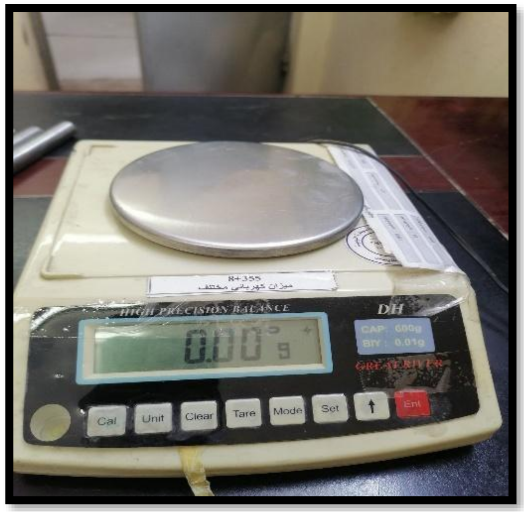


Figure 4.11: High-Precision Scale.

Figure 4.12: Denver Instrument.

The infrared thermometer, shown in Figure (4.13), was placed (200 mm) away from the work area when the temperature was taken. This device is used to measure temperature from a certain distance without touching the body. It uses a laser to target the area to be measured and contains a sensor that captures infrared rays and converts them into an electrical signal, which is then translated into a number displayed on the digital display.

Figure 4.13: Infrared Thermometer.

4.4.2 Mechanic condition

4.4.2.1 Dry cutting, Flood oil cutting and oil jet lubrication cutting

As a first step in dry of cutting procedure, the sample was clamped into the working machine's stator and cut at distance of (50 mm) from the sample's free of end, indicated in figure (4.14). The speed of cutting and rate of feed were adjusted to (5,10,19,29) m/min and (0.03,0.043,0.075) mm/rev respectively with cutting depth (1) mm.

Figure 4.14: Dry Condition .

The second method is flood oil cutting, which involves a cooling system that includes an oil tank (10 liters), a gear pump, a return valve, a pressure gauge (0-10) bar, flexible pipes, a flowmeter and a jet nozzle (diameter 3 mm) ,as shown Figure (4.15).

Figure 4.15: System of Flood Oil.

Samples were cutting by applying oil through Jet nozzle at distance of (20 mm) from sample, and with changing the feeding rates and cutting speeds ,indicated in figure (4.16).

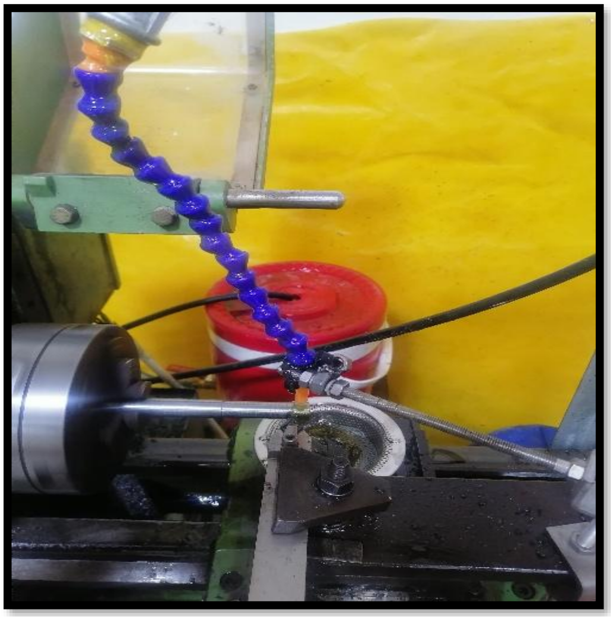


Figure 4.16: The Jet Nozzle at Distance of (20 mm).

Third method is oil jet lubrication cutting, which requires a hydraulic pump with (3 hp and 20 bar), a (60-liter) oil tank, a control valve, flexible pipes, flowmeter and a (1) mm jet nozzle, indicated at Figure 4.17, a, b ,c.

(a) **(b)** **(c)**

Figure 4.17: The system oil jet lubrication.

The cutting was done at an angles of (15, 40) degrees, as shown in Figure (4.18, a, b) and a pressure of (6,12)bar. These angles were used to ensure a more accurate oil flow and reduce the ripples or roughness resulting from the speed or pressure of the oil by controlling the angle.

A: The jet nozzle of 15˚. **B:The jet nozzle of 40˚.**

Figure 4.18: The Jet Nozzle Angles.

A sample together with dimensions that include 150 (mm) in length and (15 mm) in diameter was taken, and the work piece's weight was measured using a (High precision balance) before and after the operation. Additionally, the surface roughness was checked before and after the operation by using (Surface Roughness Tester). The cutting area's temperature is at a distance of (200 mm). The speed of cutting and feed rate were adjusted to (5,10,19,28 m/min) and (0.03,0.043,0.075 mm/rev) respectively. A jet nozzle was employed at angle 15˚ with pressures of 6 and 12 as shown in figure (4.19), after that a jet nozzle was employed at angle 40˚ with pressures of 6 and 12 as shown at Figure (4.20) and schematic of oil jet lubrication as shown in figure (4.21).

Figure 4.19: The Oil jet lubrication with angle 15˚.

Figure 4.20: The oil jet lubrication with angle 40˚.

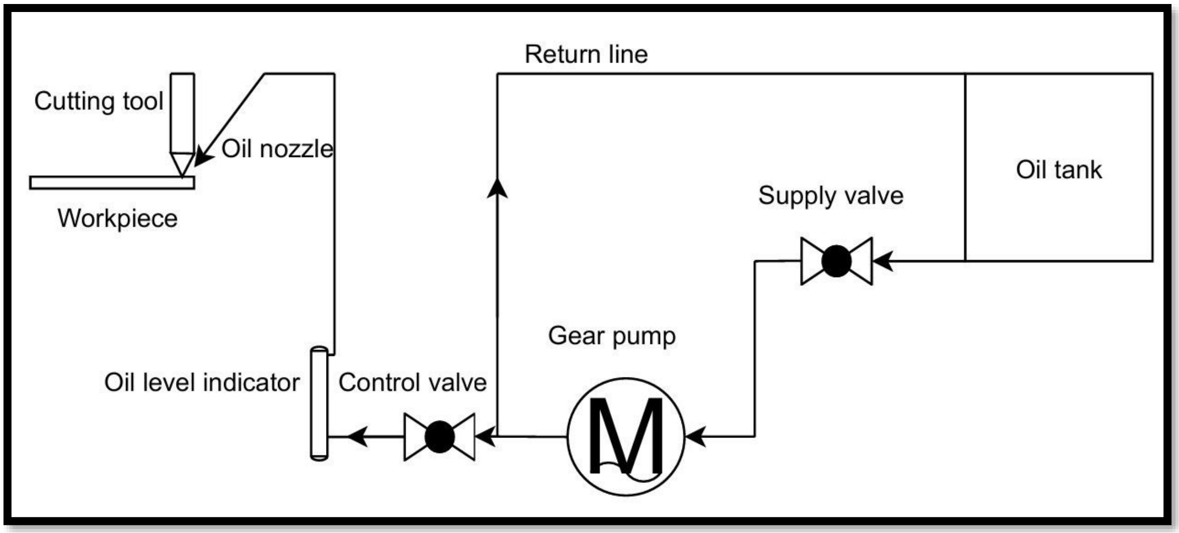


Figure 4.21: Schematic Oil Jet Lubrication.

4.4.3 Assessment of surface of Roughness

This study used the roughness of surface tester (SRT-6210) at the University of Kerbala. The workpiece surface roughness was tested before the turning and after. Where the (SRT-6210), sensor is set up on the surface at (0.8 mm) and then using the tester's internal mechanism, it evenly glides over the surface. As shown in Figure (4.22). In dry condition , the surface roughness were not quality compared with other conditions. Where the Ra at low cutting speed 5 m/min, Ra reach about (4.229µm) for dry cutting.

Figure 4.22: The Sensor of Surface Roughness Tester.

4.4.4 The wear measurement

Wear was measured by loss of mass, as it represents material loss. To determine the amount of mass loss, the mass of each tool was measured both before and after the test. The findings showed that the wear rate was greater when cutting in dry circumstances compared to other cutting conditions.

4.4.5 Evaluation of Cutting Zone Temperature

A laser thermometer was used during the sample-cutting operation. The temperature was recorded while the process was underway with the thermometer set at distance (200 mm) according to the work item. The temperature was first recorded (T1) after a certain amount of time had passed and then again just before the cutting operation came to an end (T2). Due to the absence of any lubricant, temperatures increased during dry cutting. In flood oil and jet cutting, the cooling process decreases heat instead of cutting when lubricant is applied. Removing the chip from the work area reduces heat because Cutting with the sample becomes much easier with the oil's reduced friction.

Note: Where T% using in all tables $=\frac{T_2-T_1}{T_1}\times 100\%$

4.4.6 Flow Rate Measurement

The flow meter is one of the essential devices for measuring the flow of fluid during operational processes. It is used to accurately measure fluid (oil) movement entering the region of the blade. During flood oil cuts the pressure was maintained at (1 bar) and the rate of flow (0.428 l/min). To make sure the right quantity of oil got to the jet nozzle, a return valve was used. A flowmeter was used to monitor the flow at different angles (15°and 40°) and pressures (6 and 12 bar) at the oil jet lubrication was cutting. The jet tube is linked to the flow meter, which is mounted on the pump's discharge line. During the jet nozzle (15˚) and (6) bar, the rate of flow (1.92 l/min)and the jet speed by used equation (3.5) was (37.81 m/s). At the jet nozzle (15˚) and (12) bar, the rate of flow (2.054 l/min) and the jet speed was 53.46 m/s. While the jet nozzle (40˚) and (6) bar, the rate of flow (2.264 l/min) and jet speed was (47.68 m/s). At the jet nozzle (40˚) and (12) bar, the rate of flow was (2.429 l/min) and the jet speed was (67.41 m/s).

CHAPTER FIVE

Results and Discussion

Chapter Five

Results and Discussion

5.1 Introduction

This chapter present the experimental results of surface roughness, tool wear and cutting temperature under dry, flood oil and oil jet lubrication conditions. The findings are analyzed to identify optimal lubrication parameters and compare tribological performance across the three cutting conditions.

5.2. Result of Dry Condition

During a study was carried out with intent to discuss the outcomes of achieving dry-cutting precision. Figure (5.1) with Table (5.1) Shows the impact of various rate of feed on surface roughness as a function the speed of cutting. The surface roughness at (5 m/min) was (4.229 µm) in (0.03mm/rev) feed rate, (5.919 µm) in (0.043 mm/rev) rate of feed, (5.374 µm) in 0.075 rate of feed. The surface roughness rose slightly with each successive feed rate increase. This apparent increase in wear and surface deformations is likely caused by the difference in the amount of time the workpiece and cutting tool remain in contact. Increasing cutting speeds to exceed (19 m/min) can lead to increased surface roughness if other factors things like tool damage and built-up edges go unchecked when coolant isn't used.

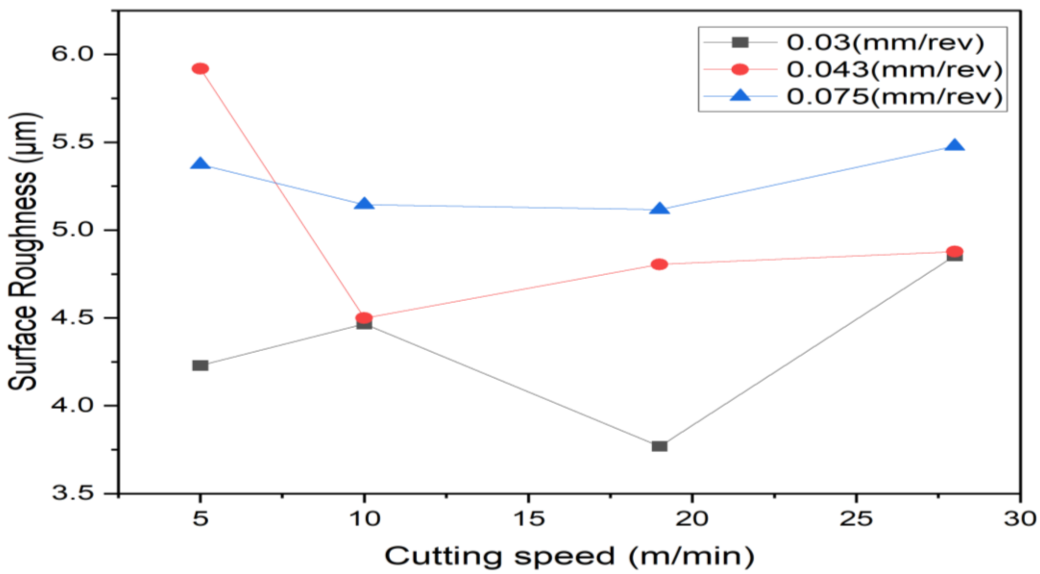


Figure 5.1: Relationship between cutting speed and surface roughness at feed rate (0.03,0.043,0.075) mm/rev under dry cutting.

Table 5.1: Result of dry condition.

Ra(µm)	Vs (m/min)	Fr (mm/rev)	ap (mm)	Tem. %	Time (min)
4.229	5	0.03	1	48%	14
4.466	10	0.03	1	21%	7.22
3.769	19	0.03	1	57%	4
4.853	28	0.03	1	16%	2.28
5.919	5	0.043	1	9%	12.27
4.499	10	0.043	1	18%	5.39
4.805	19	0.043	1	30%	2.34
4.877	28	0.043	1	33%	1.56
5.374	5	0.075	1	99%	5.58
5.144	10	0.075	1	21%	3.3
5.117	19	0.075	1	25%	1.39
5.477	28	0.075	1	64%	1

5.3. Result of flood oil condition:

Figure (5.2) and table (5.2) shows surfaces' roughness values at different cutting speeds at feed rates. The system contains an oil pump, control valve, oil tank, and jet (20 mm) from the workpiece, using engine (ARO). In

Fig. 5.2, with a velocity of (5 m/min) and rate of feed of (0.03 mm/rev), surfaces' roughness measured (3.62 µm), whereas the maximum surface roughness reached (4.37 µm) in feed rate (0.043mm/rev). An improvement in the cutting tool's efficiency might explain the variation in roughness of the surface advancement each cycle beside the reduction in contact duration in between the cutting edge and the substance being sliced. It is noted the better surface finish (lower roughness of the surface) with the use flood oil indicated little signs of tool damage while operating at a low rate of feed and fast cutting speeds.

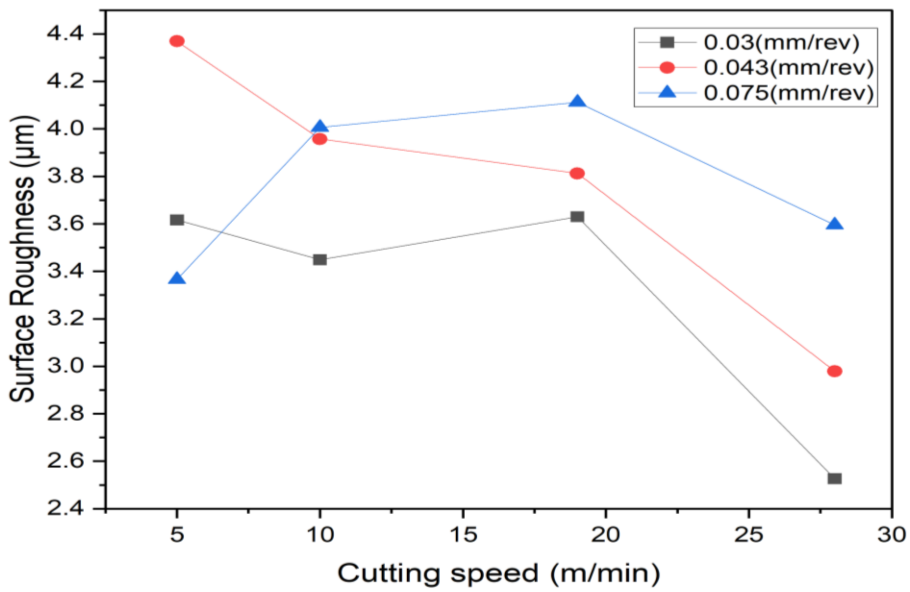


Figure 5.2: Relationship between cutting speed and surface roughness at feed rate (0.03,0.043,0.075) mm/rev under flood cutting.

Table 5.2: Result of flood oil condition.

Ra(μm)	Vs (m/min)	Fr (mm/rev)	ap (mm)	T %	Time (min)
3.62	5	0.03	1	24%	14.32
3.45	10	0.03	1	17%	7.52
3.63	19	0.03	1	17%	4.6
2.53	28	0.03	1	25%	2.42
4.37	5	0.043	1	47%	10.3
3.96	10	0.043	1	7%	5.3
3.81	19	0.043	1	36%	2.48
2.98	28	0.043	1	15%	1.5
3.37	5	0.075	1	13%	6.2
4.01	10	0.075	1	30%	3.21
4.11	19	0.075	1	33%	1.4
3.6	28	0.075	1	29%	1.09

5.4 Result of Oil Jet Lubricant Cutting Condition:

5.4.1 Effect of angle (15˚) and pressure (6 ,12) bar

Cutting speed as a function of roughness of the surface at varying pressure and angles of 15˚ is shown in Figures (5.3, 4) and Table (5.3,4). The jet angle is formed by the oil jet's direction with respect to the sample's surface. According to the experimental data, the surface roughness peaked at (1.43 μm) at speed of cutting (10 m/min) and rate of feed (0.075 mm/rev) when pressure was 6 bar, according to Figure (5.3).

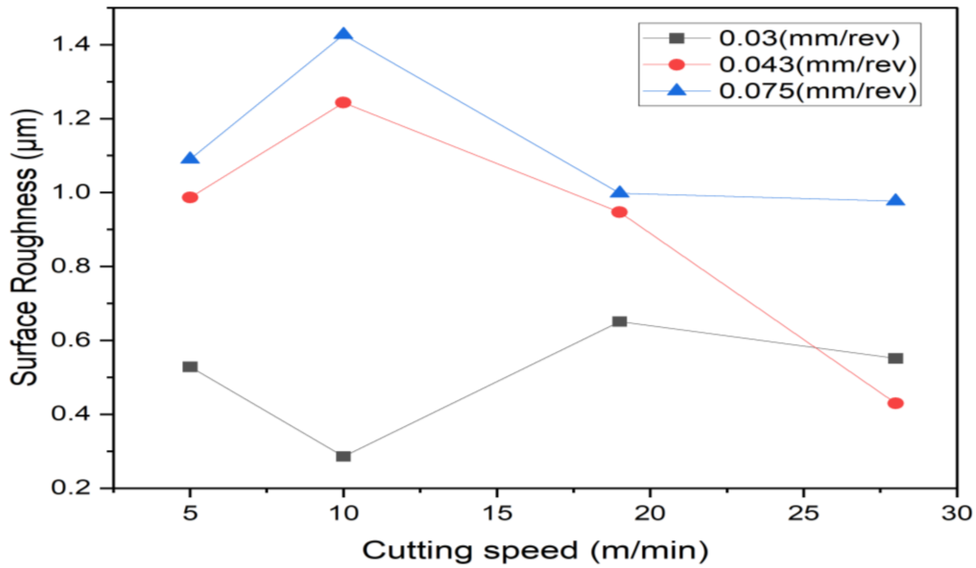


Figure 5.3: The correlation between cutting speed and roughness of the surface at feed rate (0.03,0.043,0.075mm/rev) at pressure 6 bar.

The roughness increased at the lowest speed of cutting and with there is a rise in rate of feed as the pressure was raised to 12 bar, as shown in figure (5.4). This happened because there was more time for the cutting component to come into contact with the cutting tool.

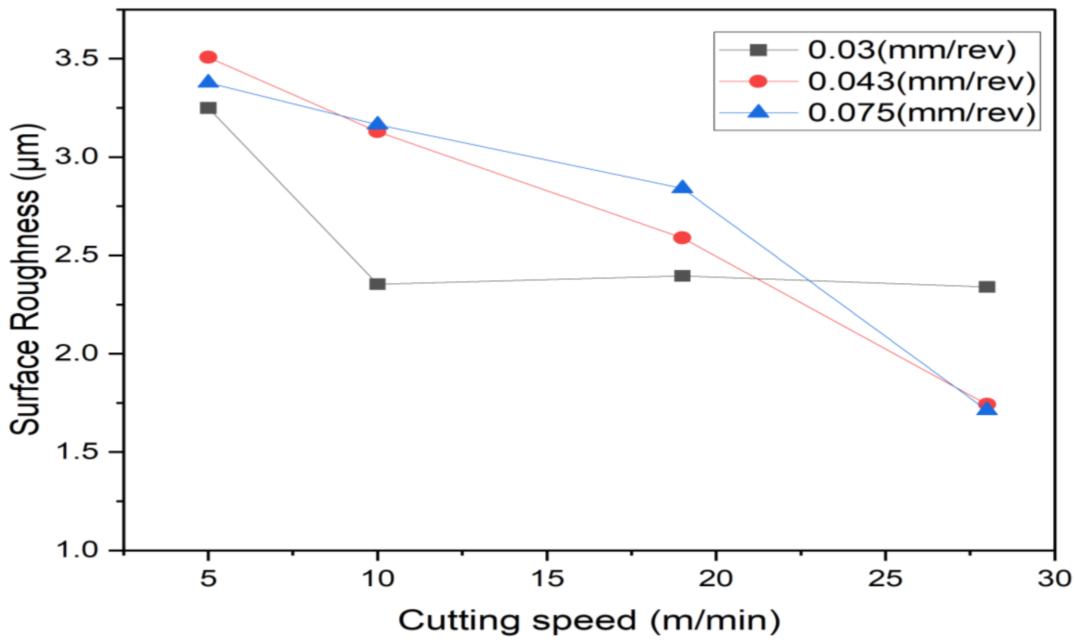


Figure 5.4: The correlation between speed of cutting and roughness of the surface at feed rates (0.03,0.043,0.075 mm/rev) at pressure 12 bar.

When the pressure changed at the same angle, surface roughness was highest at a pressure of 12 bar for all speeds and feed rates (Figure 5.5,6,7). Indicating that oil jet lubrication requires a much lower pressure source to operate, which advantage over spray lubrication setups in applications where high-value pressure is not available, since most of the spray nozzles in prior studies request the pressure value to meet certain thresholds for atomization to happen, the high pressure causes tiny cracks on the surface, which raises the roughness value.

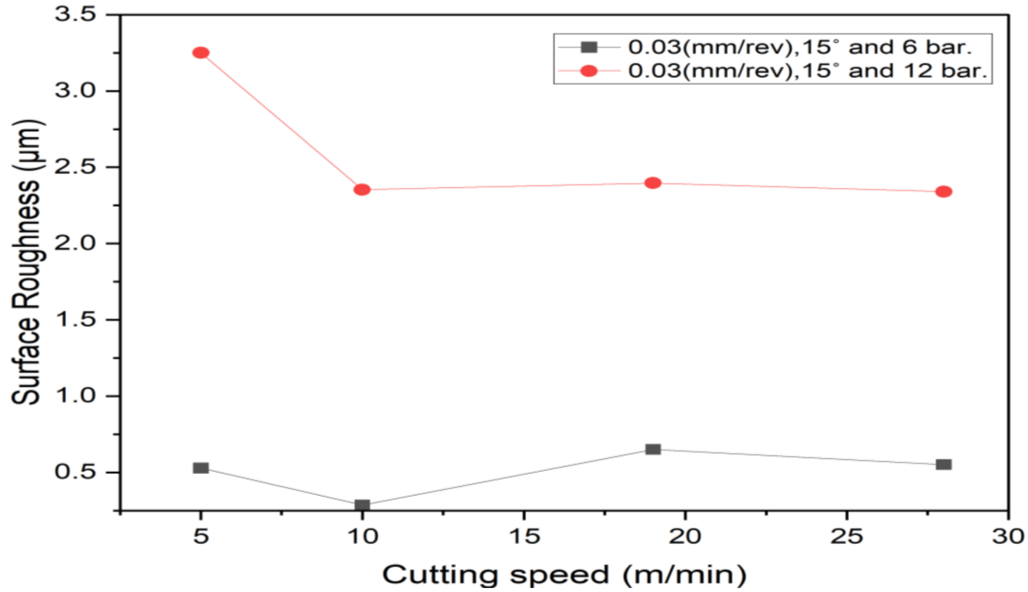


Figure 5.5: The correlation between speed of cutting and roughness of the surface at feed rate (0.03 mm/rev) at angle 15˚ and pressure (6, 12) bar.

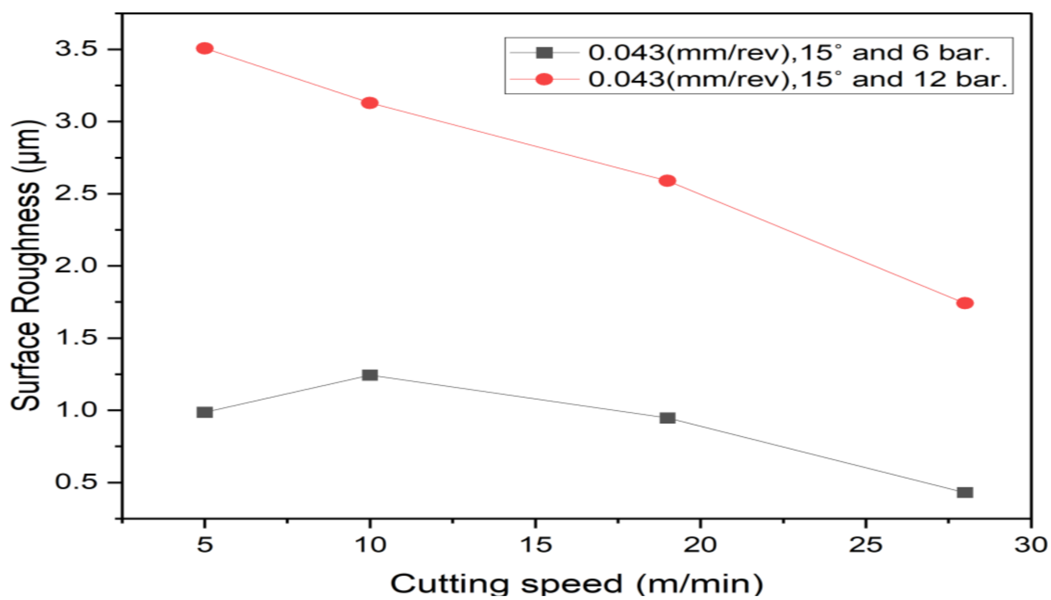


Figure 5.6:The correlation between speed of cutting and roughness of the surface at feed rate (0.043 mm/rev) at angle 15˚ and pressure (6, 12) bar.

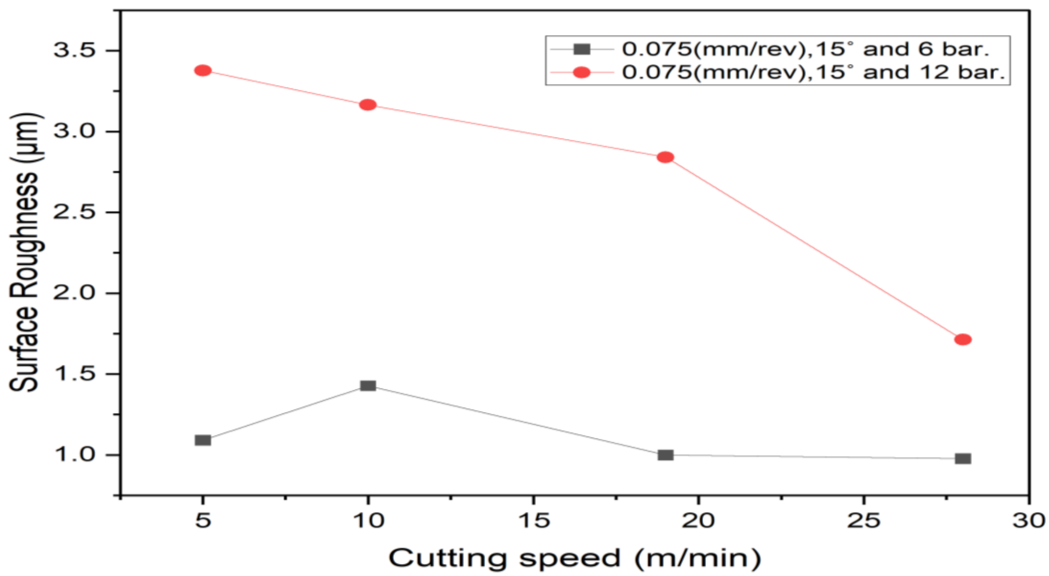


Figure 5.7: The correlation between speed of cutting and roughness of the surface at feed rate (0.075 mm/rev) at angle 15° and pressure (6, 12) bar.

Table 5.3: Result of angle 15° , pressure 6 bar.

Ra(μm)	Vs (m/min)	Fr (mm/rev)	ap (mm)	Tem. %	Time (min)
0.53	5	0.03	1	12%	14.1
0.29	10	0.03	1	10%	7.2
0.65	19	0.03	1	9%	3.5
0.55	28	0.03	1	6%	2.5
0.99	5	0.043	1	18%	7.2
1.24	10	0.043	1	12%	6.2
0.95	19	0.043	1	12%	2.52
0.43	28	0.043	1	17%	2.1
1.09	5	0.075	1	10%	5.46
1.43	10	0.075	1	18%	3.31
1	19	0.075	1	9%	1.5
0.98	28	0.075	1	8%	1.1

Table 5.4: Result of angle 15°,pressure 12 bar.

Ra(μm)	Vs (m/min)	Fr (mm/rev)	ap (mm)	Tem. %	Time (min)
3.25	5	0.03	1	22%	14.58
2.35	10	0.03	1	4%	7.53
2.4	19	0.03	1	8%	3.54
2.34	28	0.03	1	16%	2.1
3.51	5	0.043	1	3%	8.5
3.13	10	0.043	1	12%	5.2
2.59	19	0.043	1	3%	2.4
1.74	28	0.043	1	3%	1.5
3.38	5	0.075	1	15%	5.5
3.16	10	0.075	1	1%	35
2.84	19	0.075	1	14%	1.5
1.71	28	0.075	1	4%	1.02

5.4.2 Effect of angle 40°, pressure (6 ,12)bar

The result shows oil jet lubrication with of 40° For pressure (6 bar ,12 bar). Figure (5.8,9) with Table (5.5,6) Illustrates the value of roughness about different cutting speed at feeds rate. At rate of cutting is (5 m/min) a (40°), pressure (12) bar and (0.075 mm/rev) rate of feeding natural setting, the lack of smoothness is (3.54 μm), and the Ra drop at (10 m/min). Since the speed of cutting (19 m/min) to (29 m/min), the Ra raises and then drops. Ra drops at (40°), (6) bar at the same input pace at which (0.075 mm/rev) regardless the velocity of cutting. The Ra is (1.53 μm) at a velocity of cutting of (5 m/min), decreasing as the speed of cutting increases (10 m/min). With same feed rate and circumstances, the Ra increases to (1.66 μm) at a speed of cutting (19 m/min) and decreases (1.46 μm) at a cutting speed of (28 m/min).

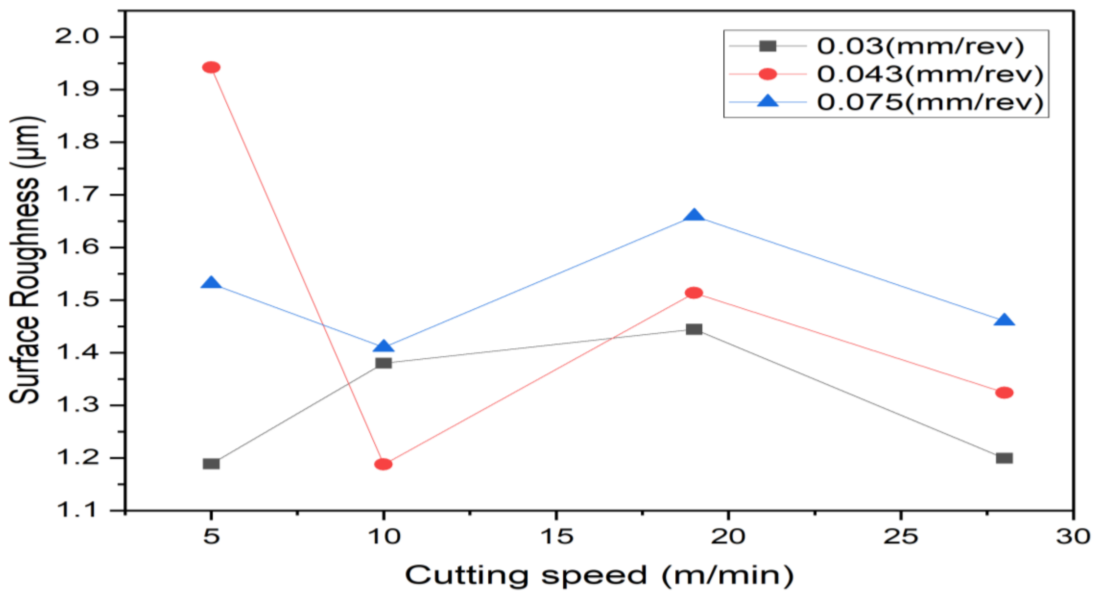


Figure 5.8: The relationship between cutting speed and surface roughness at feed rate (0.03,0.043,0.075mm/rev) at pressure 6 bar

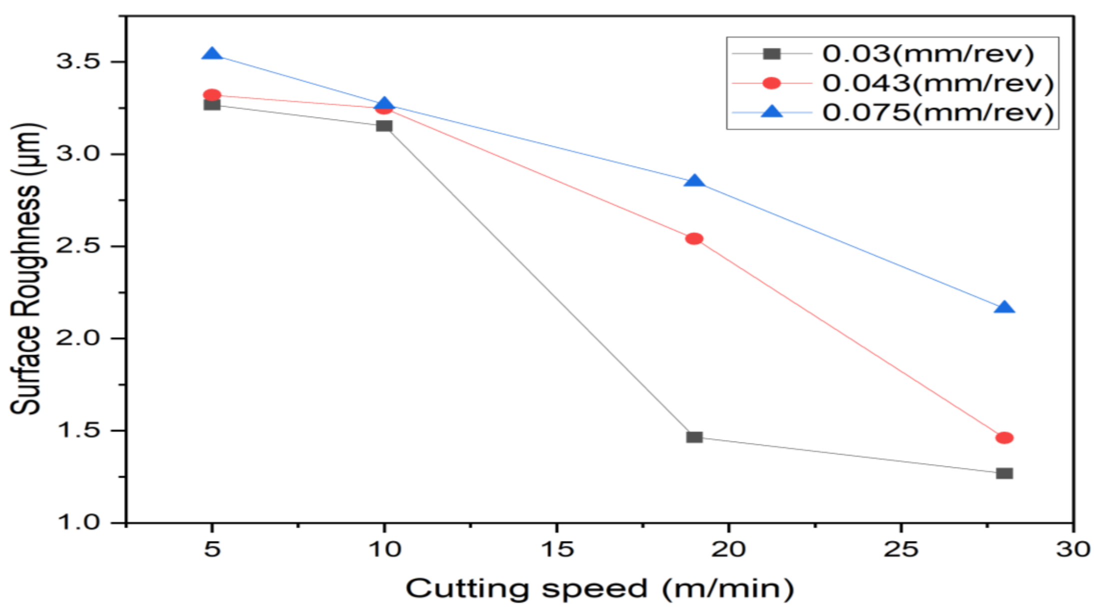


Figure 5.9: The relationship between cutting speed and surface roughness at feed rate (0.03,0.043,0.075mm/rev) at pressure 12 bar.

Figures (5.10,11,12) indicates that the pressure changed at the same angle (40˚), surface roughness was highest at a pressure of 12 bar for all speeds (5,10,19,28 m/min) and rate of feed (0.03,0.043,0.075 mm/rev). This explains that when pressure increases, very fine vibrations or ripples occur, causing the roughness of the sample and resulting in a strong flow of oil.

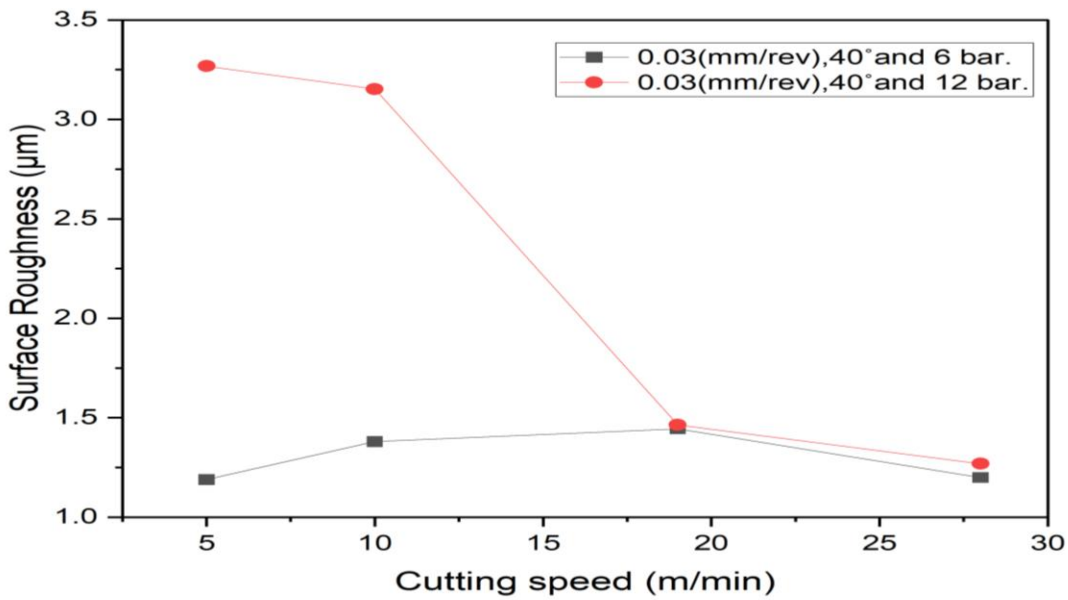


Figure 5.10: The relationship between cutting speed and surface roughness at feed rate (0.03mm/rev) at pressure 6, 12 bar.

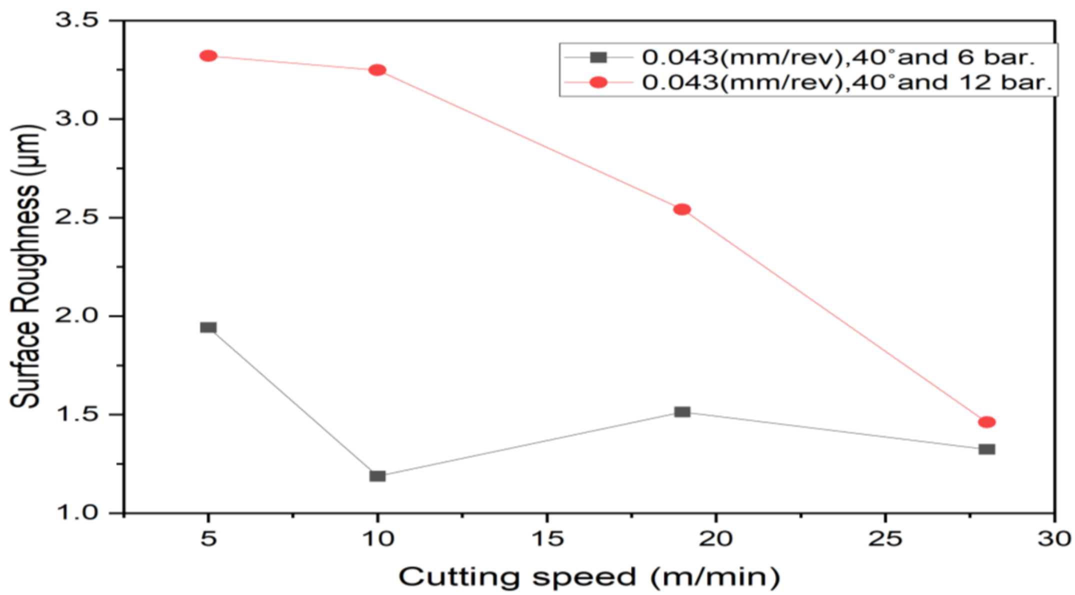


Figure 5.11: The relationship between cutting speed and surface roughness at feed rate (0.043 mm/rev) at pressure 6, 12 bar.

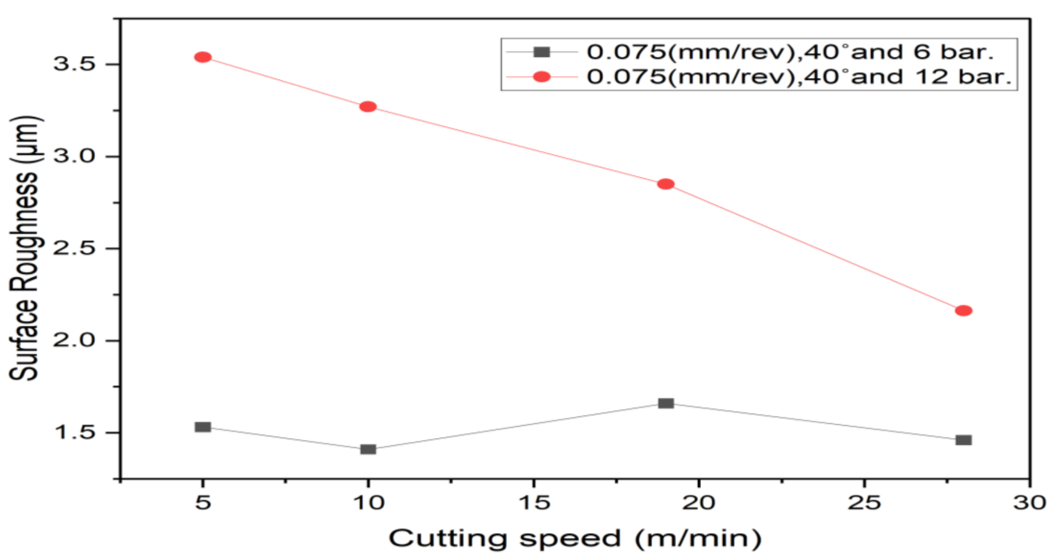


Figure 5.12: The relationship between cutting speed and surface roughness at feed rate (0.075) mm/rev at pressure 6, 12 bar.

Table 5.5: Result of angle 40˚ ,pressure 6 bar.

Ra(µm)	Vs (m/min)	Fr (mm/rev)	ap (mm)	Tem. %	Time (min)
1.19	5	0.03	1	10%	15.5
1.38	10	0.03	1	8%	7.3
1.44	19	0.03	1	11%	4.4
1.2	28	0.03	1	11%	2.1
1.94	5	0.043	1	34%	14.17
1.19	10	0.043	1	30%	7.2
1.51	19	0.043	1	5%	4
1.32	28	0.043	1	17%	2.33
1.53	5	0.075	1	8%	5.43
1.41	10	0.075	1	6%	3.4
1.66	19	0.075	1	9%	1.36
1.46	28	0.075	1	10%	1.17

Table 5.6: Result of angle 40˚, pressure 12 bar.

Ra(µm)	Vs (m/min)	Fr (mm/rev)	ap (mm)	Tem. %	Time (min)
3.27	5	0.03	1	11%	14.7
3.15	10	0.03	1	15%	9.01
1.46	19	0.03	1	3%	4.1
1.27	28	0.03	1	6%	2.1
3.32	5	0.043	1	14%	9.4
3.25	10	0.043	1	5%	5.5
2.54	19	0.043	1	3%	2.4
1.46	28	0.043	1	5%	1.51
3.54	5	0.075	1	11%	5.55
3.27	10	0.075	1	5%	2.5
2.85	19	0.075	1	4%	1.44
2.16	28	0.075	1	2%	1.1

5.5 The Result From all Conditions about Surface Roughness

Different conditions were studied during the cutting process using a lathe machine (dry cutting, flood oil cutting, and oil jet lubrication cutting). Based on the outcomes of the experiments, the optimal approach in all conditions is the use of oil jet lubrication with a nozzle of 15° and a 6 bar pressure, as mentioned in the Figure 5.13. In terms of the factors that influenced the sample's surface roughness, temperature decrease, and cutting tool contact duration resulted in the lowest reported surface roughness value of (0.29 μm) and the temperature reached 10% with a significant reduction in cutting time to 7 seconds at cutting speed (10 m/min) compared to other speeds. Based on these results using the jet with a 15° angle and a 6 bar pressure was the most effective and its use is recommended in applications similar to this process.

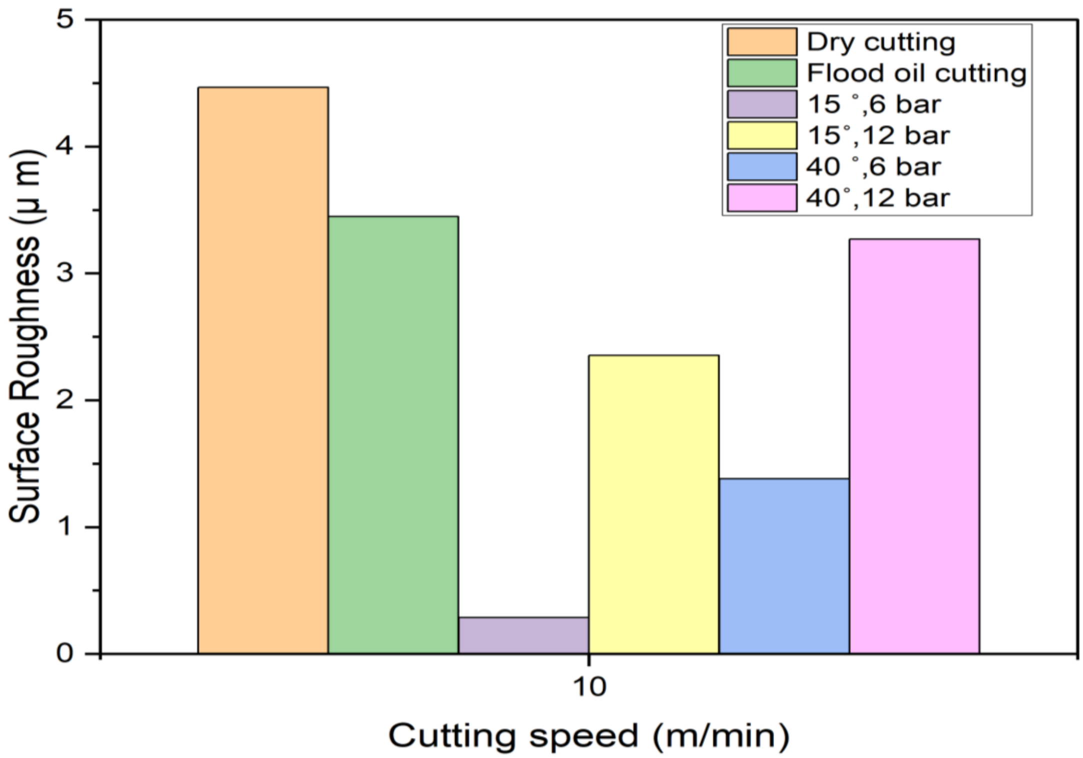
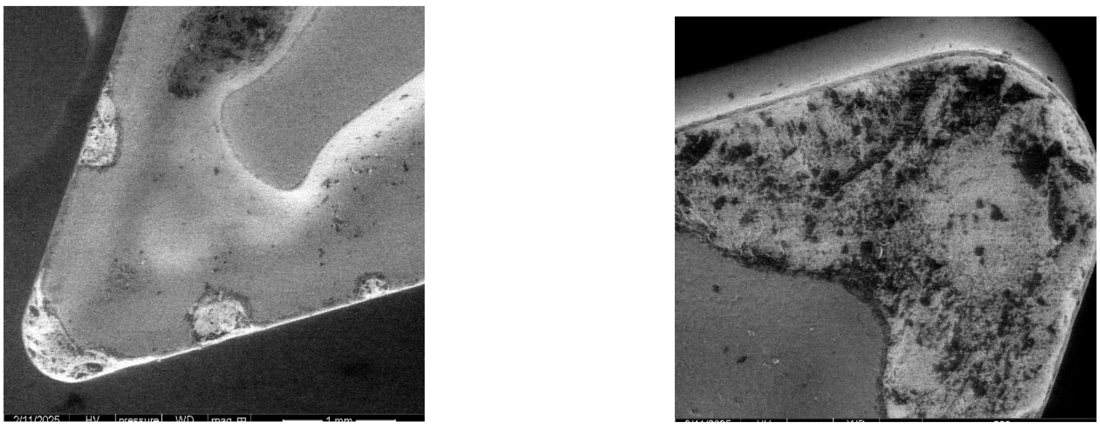


Figure 5.13:Cutting Speed Vs. Surface Roughness about (15°) and (6) bar at (10 m/min) cutting speed and 0.03 mm/rev feed rate.

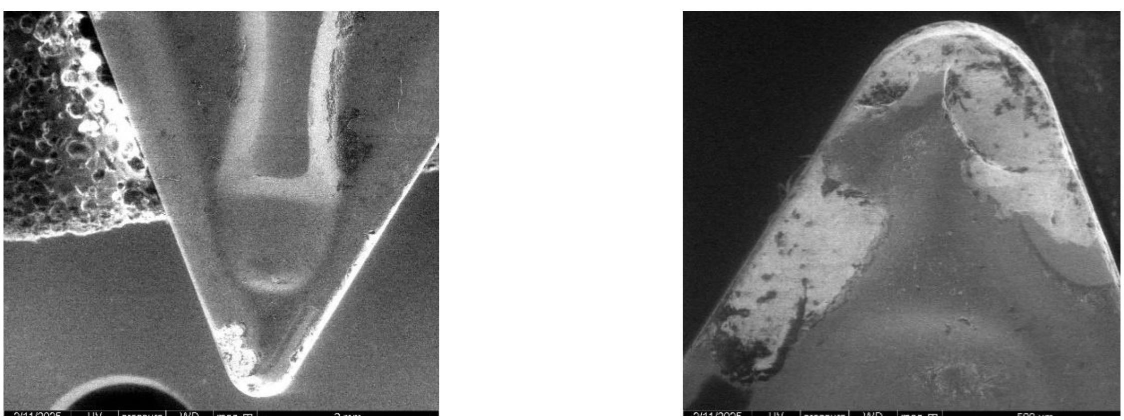
5.6 Effect Machining Operation on Cutting Tools

Figures 5.14, 15.16 and 5.17 display SEM images of cutting tools in action as they experience different cutting processes. Experiments findings demonstrate that on the cutting velocity of 5 meters per minute and a feeding rate of 0.043 millimeters per revolution., as shown at Figure 5.14 a,b, which displays the cutting of tool during dry of cutting where indicates amount damage along the edge of the cutting tool. Initial measurements of a tool for cutting weight were (14.4972 g) and subsequent measurements were (14.4922 g), taken before and after the machining process. Under flood cutting settings, a picture of the cutting tool edge captured by SEM is displayed in the figure 5.15a, b. In rate of feed (0.043 mm/rev) with velocity of (5 m/min). Using a scale (Denver instrument), the cutting tool's weight was measured before and after the cutting operation sequentially (15.7244, 15.7214) g. SEM image under circumstances of oil jet lubricant is shown in Figure (15.16 a,b). With a velocity of (5 m/min) and rate of feed (0.043 mm/rev), the cutting tool's weight was noted before and after the procedure (15.7214 and 15.7190) g respectively.

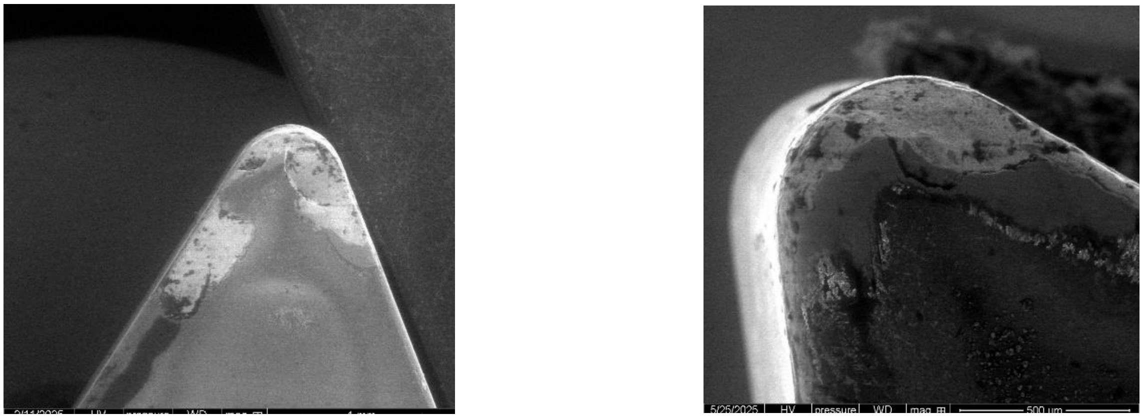


A: Before cutting operation **B: After cutting operation**

Figure 5.14: The SEM for cutting tool at dry condition.



A: Before cutting operation **B: After cutting operation Figure 5.15:The SEM for cutting tool at flood oil condition.**



A: Before cutting operation **B: After cutting operation Figure 5.16:The SEM for cutting tool at oil jet lubricant condition.**

CHAPTER SIX

Conclusion and Recommendation

Chapter Six
Conclusion and Recommendations

6.1 Conclusions

This study demonstrated that oil jet lubrication significantly improve machining performance compared to dry and flood oil conditions by reducing surface roughness, cutting temperature and tool wear.

1. This study has found that, generally, a better surface finish (lower surface roughness) achieved with the use of oil jet lubricant resulted in minimal tool wear compared with flood oil and dry conditions.

2. Tool wear increased with increased cutting speeds, particularly at higher feed rates.

3. The roughness of surface increases with increases the feed rate. At higher rate of cutting (over 19 m/min), Raising the cutting speed results in a surface that is more rough. However, increasing the speed of cutting to more than (20 m/min) for lower rate of feed makes little difference on surface roughness.

4. It has been demonstrated that oil jet lubrication application yields the most favourable outcomes for reducing cutting zone temperature.

5. The minimum average surface roughness value recorded with oil jet lubrication by applied 15˚ and 6 bar was (0.55 µm) with cutting speed 28 m/min and feed rate (0.03 mm/rev), flood oil was (2.53 µm) with cutting of velocity (28 m/min) and rates of feeding (0.03 mm/rev), whereas, when circumstances are dry, it (4.853 µm) in the same speed of cutting and rate of feed (0.03 mm/rev).

6. It was observed that the temperature increases in circumstances of dry cutting, in addition to this gathering of the reich causes high temperature where the sample and the cutting of tool make contact, but in flood cutting conditions, the temperature decreases, the friction decreases, and the chance of collecting the reich in the cutting area is less.

7. This study has shown that the cutting speed significantly impacts the tools' and workpiece's surface of roughness and wearing. As the workpiece's experiences more plastic deformation to a greater degree of speed of cutting, there is a noticeable rise in temperature because a larger quantity of mechanical energy is converted into heat energy. According to experimental trials, oil jet lubrication allowed temperature and wear mechanism control at angle (15˚) and (6) bars.

8. That is one of the study's most noteworthy discoveries at 40˚ and 6 bar of pressure, the cutting speed is from (5 to 28 m/min), with the highest temperature of 34% and with 15˚ and 6 bar the highest temperature of 18%. The oil jet lubrication with low angle and pressure may effectively lower the cutting temperature.

The present experimental investigation leads to the following findings have shown that oil jet lubrication at varying angles and pressures allows for precise regulation of temperature and wear mechanisms. Results showed that, compared to other conditions, using the jet with a 15˚ angle and 6-bar pressure was the most effective where the cutting tool's weight was noted before and after the procedure (15.7214 and 15.7190) g. The practical findings presented here may serve as a foundation for developing a cooling system that a lathe machine can use during the cutting process. This technology can reduce temperature increases, minimize friction and wear, and also impact surface roughness. As a result, this study has the potential to advancing scientific expertise in this field with investigates potential methods for enhancing it through the use of systems during operational procedures.

6.2 Recommendation for future work

Towards the improvement and expansion of the current experimental investigation it can be recommended for the following points are recommended for additional study in this field.

1. Test additional nozzle angles and different distance about work piece.
2. Compare mineral oils with eco-friendly or nano-lubrication.
3. Apply computational fluid dynamic (CFD) modeling to optimize oil jet design.
4. Study the tool’s geometry’s effect on the tribological behavior.

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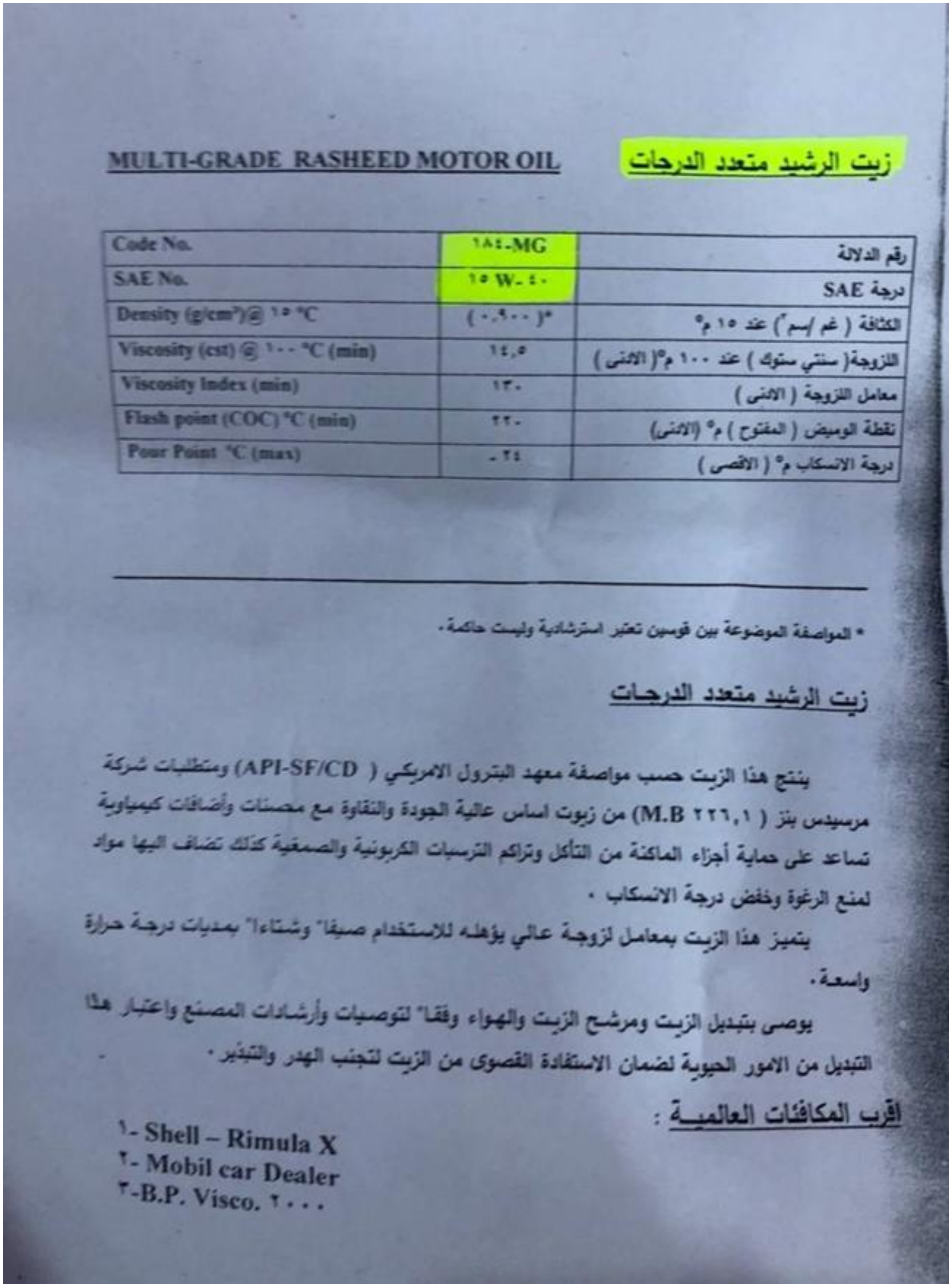
Appendix A



MULTI-GRADE RASHEED MOTOR OIL

زيت الرشيد متعدد الدرجات

Code No.	١٨٤-MG	رقم الدلالة
SAE No.	١٥ W-٤٠	درجة SAE
Density (g/cm³)@ ١٥ °C	(٠,٩٠٠)*	الكثافة (غم /سم٣) عند ١٥ م°
Viscosity (cst) @ ١٠٠ °C (min)	١٤,٥	اللزوجة(سنتي ستوك) عند ١٠٠ م°(الادنى)
Viscosity Index (min)	١٣٠	معامل اللزوجة (الادنى)
Flash point (COC) °C (min)	٢٢٠	نقطة الوميض (المفتوح) م° (الادنى)
Pour Point °C (max)	-٢٤	درجة الانسكاب م° (الاقصى)

* المواصفة الموضوعة بين قوسين تعتبر استرشادية وليست حاكمة.

زيت الرشيد متعدد الدرجات

ينتج هذا الزيت حسب مواصفة معهد البترول الامريكي (API-SF/CD) ومتطلبات شركة مرسيدس بنز (M.B ٢٢٦,١) من زيوت اساس عالية الجودة والنقاوة مع محسنات وأضافات كيمياوية تساعد على حماية أجزاء الماكنة من التأكل وتراكم الترسبات الكربونية والصمغية كذلك تضاف اليها مواد لمنع الرغوة وخفض درجة الانسكاب .

يتميز هذا الزيت بمعامل لزوجة عالي يؤهله للاستخدام صيفا" وشتاءا" بمديات درجة حرارة واسعة.

يوصى بتبديل الزيت ومرشح الزيت والهواء وفقا" لتوصيات وأرشادات المصنع واعتبار هذا التبديل من الامور الحيوية لضمان الاستفادة القصوى من الزيت لتجنب الهدر والتبذير .

اقرب المكافئات العالميــة :

١- Shell – Rimula X
٢- Mobil car Dealer
٣-B.P. Visco. ٢٠٠٠

Figure 1: Al –Rashid Oil SAE 15 W 40 .

الخلاصة

تهدف هذه الدراسة إلى دراسة تأثير سرعة وزاوية نفث مادة الزيت على البلى لأداة القطع وخشونة السطح ودرجة حرارة القطع في آلة الخراطة باستخدام الفولاذ منخفض الكربون. لعبت آلة الخراطة دورًا مهمًا في عملية تشغيل المعادن، والتي تتضمن القطع. تُعد معاملات التشغيل لعملية الخراطة مهمة جدًا لتحقيق أداء عالٍ، والذي يُقاس بقابلية التشغيل، والتشطيب الجيد للسطح، وانخفاض البلى الأداة، وارتفاع معدلات إزالة المواد. من الضروري تجربة تحسين سرعات القطع ومعدلات التغذية مع الحفاظ على عمق ثابت للقطع. تم استخدام الفولاذ منخفض الكربون. يحتوي العمل التجريبي على ثلاثة ظروف مختلفة أثناء عمليات قطع المعادن، بما في ذلك القطع الجاف، وقطع بالغمر، و نفث الزيت، باستخدام توفر الدراسة معلومات لتحسين معلمات حقن الزيت وتحسين التزييت من خلال فحص البلى وخشونة السطح، بالإضافة إلى تأثيرات تزييت نفث وزاويته وسرعته على أداء التزييت. تم استخدام نفث الزيت طوال عملية الخراطة، مع تضمين زاويتي حقن مختلفتين (15 و40 درجة) في ظروف التزييت. تم اختبار ضغوط تزييت مختلفة، بما في ذلك (6 و12) بار، لفحص كيفية تأثيرها على خشونة السطح، وبلى الأداة، ودرجة حرارة القطع، وقابلية استهلاك الرقاقة بمعدلات تغذية مختلفة، وخصائص الاحتكاك بمرور الوقت. أظهرت النتائج انخفاضًا كبيرًا في الخشونة، خاصة بالنسبة للعينات التي تم قطعها باستخدام نفث الزيت، حيث كانت أفضل النتائج في الخشونة وأفضل النتائج لدرجة حرارة منطقة القطع للعينات المقطوعة باستخدام فوهة نفث بزاوية 15 درجة وضغط 6 بار. من خلال القطع الجاف، تبين أن خشونة السطح تصل إلى (4.853 ميكرومتر) عند (0.03 مم/لفة) وسرعة القطع (28 مترًا/دقيقة) مقارنةً بالظروف الأخرى، وفي عملية الغمر، تصل إلى (2.53 ميكرومتر) ولكنها تستهلك كمية كبيرة من الزيت. وقد صاحبت المشاكل الناتجة عن الاهتزازات وتغيرات درجات الحرارة زيادة في استخدام الطاقة عند رفع الضغط إلى 12 بار. ووجد التحليل التجريبي أن خفض الضغط واستخدام فوهة صغيرة كان أفضل طريقة لتحسين خصائص الاحتكاك

جمهورية العراق
وزارة التعليم العالي و البحث العلمي
جامعة كربلاء
كلية الهندسة
قسم الهندسة الميكانيكية

دراسة تأثير ظروف نفث مختلفة على الخواص الترايبولوجيه في عمليات التشغيل

رسالة مقدمة الى مجلس كلية الهندسة / جامعة كربلاء وهي جزء من متطلبات نيل درجة الماجستير في علوم الهندسة الميكانيكية

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