Experimental Investigation of Alsi 6082 Steel in Dry and Wet Using Double Turning Tool and Optimization of Cutting Parameters

Yosef Hailu Fantaye

A Thesis Submitted to the Department of Mechanical Engineering
School of Mechanical, Chemical, and Materials Engineering

Presented in Partial Fulfilment of the Requirement for the Degree of Master's in Manufacturing Engineering

Office of Graduate Studies
Adama Science and Technology University

October 2022
Adama, Ethiopia

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Advisor: Dr. Moera Gutu Jiru (Assistance Professor)

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Approval Sheet

I/we, the advisors of the thesis entitled "**Experimental Investigation of Alsi6082 Steel in Dry and Wet Using Double Turning Tool and Optimization of Cutting Parameters**" and developed by Yosef Hailu hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Yosef Hailu have read and evaluated the thesis entitled "**Experimental Investigation of Alsi 6082 Steel in Dry and Wet Using Double Turning Tool and Optimization of Cutting Parameters**" and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Mechanical Engineering

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I hereby declare that this Master Thesis entitled "**Experimental Investigation of Alsi 6082 Steel in Dry and Wet Using Double Turning Tool and Optimization of Cutting Parameters**" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation

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I/we, the advisor(s) of this thesis, hereby certify that I/we have read the revised version of the thesis entitled "**Experimental Investigation of Alsi 6082 Steel in Dry and Wet Using Double Turning Tool and Optimization of Cutting Parameters**" prepared under my/our guidance by Yosef Hailu submitted in partial fulfillment of the requirements for the degree of Master's of Science in Mechanical Engineering. Therefore, I/we recommend the submission of a revised version of the thesis to the department following the applicable procedures.

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______________________	________________	____________
Co-advisor	Signature	Date

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List of Acronyms and Abbreviations

AA	Arithmetic Average
AISI	American Iron and Aluminum Institute
AlSi	Aluminum silicon
ANOVA	Analysis of variance
CBN	Cubic boron nitride
Cc	Coolant Cost
Ce	Energy Consumptions Cost
C_l	Lighting Cost
C_m	Machine Depreciation Cost
C_o	Overhead Cost
C_{op}	Operator Cost
C_t	Tool Cost
C_T	Total Cost
C_{LA}	Central Line Average
CNC	Computer Numerical Control
DOE	Design of experiment
DoF	Degree of freedom
f	Feed Rate
HRC	Rockwell Hardness
MQL	Minimum Quantity Lubrication
MRR	Material removal rate
N	Spindle Speed
OA	Orthogonal Array
S/N	Signal to Noise ratio
t_m	Machining Time
v_c	Cutting Speed
Ra	Surface Roughness

Abstract

Aluminum alloys 6082 are frequently used in the automotive, aerospace, and marine industries due to their excellent corrosion resistance and machinability. Turning considerations can affect how well the surface is finished, which could lead to unwanted surface roughness. The quality of machined parts may therefore be improved by setting of turning parameters. The aim of this thesis was to optimize double turning machining parameters to get good surface finish. Data was analyzed using Taguchi method to get optimum parameters. This experimental work investigated how different cutting parameters affected surface roughness and tool wear. The aim of this thesis work was investigating advantage of dry turning over wet turning and optimization of cutting parametrs. Double tool turning was used to increase machining productivity.To examine the effects and contributions of depth of cut, feed rate, and cutting speed on the response variable, an orthogonal array, signal to noise (S/N) ratio, and analysis of variance (ANOVA) were used. Using an HSS tool and a traditional turning procedure, analyses were conducted on round aluminum 6082 bars.. On completion of turning 6082 aluminum alloy, the tool's material, tool shape, cutting speed, feed rate, and depth of cut were determined. The effect of feed rate was discovered to be the main component contributing 32.6% to the workpiece's surface roughness. On the other hand, cutting speed (45.4%) and depth of cut (22.0%) were the main determinants of surface roughness. High levels of cutting speed, medium levels of cut depth, and low levels of feed rate from the chosen levels were the best optimized cutting conditions for the desired surface roughness and tool wear reduction. In order to identify the cutting parameter levels that result in the least amount of surface roughness, the link between cutting parameters and surface roughness was also examined. The findings of this study demonstrated that the most important variable influencing surface roughness is feed rate. Higher feed rates result in rougher surfaces.

Keywords: Aluminum 6082, double turning, machine parameters, Taguchi method, optimization

CHAPTER-1

INTRODUCTION

1.1. Background of the sduy

Machining is the most commonly used method of all manufacturing technologies. It involves the cutting of metals to obtain the desired geometry with accurate dimensional tolerances and proper surface finish. Turning is the machining operation in which a cutting tool fed linearly parallel to the axis of rotation of the spindle to remove material from the surface of a rotating cylindrical workpiece. Turning is carried out on a lathe machine that provides the power to turn the workpiece at a given rotational speed and to feed the cutting tool at a specified rate and depth of cut. Therefore, three cutting parameters, i.e. spindle speed, feed rate, and depth of cut are the most effective cutting parameters in turning operations.(Wegener et al., 2016)

1.1 Machining of Aluminum Alloy

Aluminum alloy is widely used for demanding multiple industrial applications due to its good combination of formability, lightweight, strength, recyclability, durability, ductility, conductivity, and mechanical properties.(Wegener et al., 2016) The use of various aluminum alloy materials in industries is expanding significantly as a result of these exceptional combinations of characteristics that are unique to them. Aluminum alloys have to be machined to get the correct form, size, and dimension for optimal functioning because they are often produced utilizing near-net manufacturing techniques. The manufactured product is anticipated to be significantly impacted by machining factors such as depth of cut, spindle speed, feed, cutting fluid application, created vibration during machining. The improvement of aluminum alloy surfaces is a significant field of research.(Isa et al., 2021)

The work material for this investigation was aluminum alloy 6082, which has the maximum strength of the 6000 series alloys and is a medium-strength alloy with outstanding corrosion resistance. As a relatively recent alloy, alloy 6082 is recognized as a structural alloy. Due to its superior strength, alloy 6082 has replaced alloy 6061 in numerous applications(König & Erinski, 1983); (Yan et al., 2016). (Yan et al., 2016). The purpose of the machining operation is to use the cutting tool as efficiently as possible during its lifetime to achieve the specified surface quality and geometry for the workpiece. The performance of a cutting operation can be impacted by the geometry of the cutting tool, material properties, machine and cutting parameters, vibrations during operation, and cutting forces.(Yan et al., 2016)

One of the most popular lightweight metallic materials with excellent mechanical and thermal properties is aluminum alloys. In contrast to other metals, this substance is quite simple to machine. Machinability measures the effectiveness of the machining process, which can be determined by a number of factors, including tool life, surface quality, material removal rate, and power consumption.

The mechanical qualities of pure aluminum are relatively poor, but they can be increased by alloying it with other metals including copper, manganese, silicon, magnesium, silicon, and zinc. The Al-Mg-Si series, whose mechanical properties can be enhanced by heat treatment, includes the AA6082-T6. This series is widely utilized in the manufacture of machines, the chemical sector, and several automobiles.(Wegener et al., 2016)

1.1.1 Turning Operation

Turning operation requires lathe machine and selection of cutting parameters. It is the process of removing metal from a revolving cylindrical workpiece's outer diameter. Turning is used to achieve a smooth finish on the metal and reduce the diameter of the workpiece, usually to a specific specification.

1.1.1.1. Double Cutting Tool Turning Operation

Double cutting tool turning is the practice of using two single point cutting tools to turn a single shaft as opposed to one. The additional tool post, which is mounted with the second tool and is powered by the same lead screw as the first, is coupled to the same carriage. The schematic illustration of two single cutting tools operating simultaneously on a single work piece is shown in Figure 1. A double point cutting tool is made up of two cutting tools that are able to cut or shear at the same time in one pass. In contrast, a multi-point cutting tool has more than one cutting edge for performing machining operation than a single point cutting tool, which has just one main cutting edge.(Kalidasan et al., 2016)

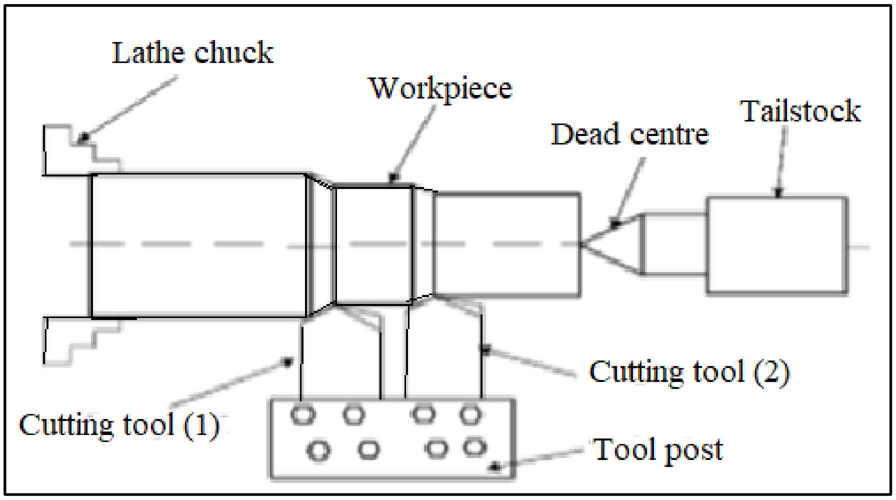


Figure 1. 1 Double cutting tools on the same tool post(Vaibhav, 2016)

1.1.1.2. Turning Parameters

Speed, feed, and depth of cut are the three main variables in any basic turning operation. Spindle and work piece are always mentioned while discussing speed. It indicates the rotational speed when it is expressed in revolutions per minute (RPM). It represents the spindle's complete rotation in one minute. However, the crucial element for a certain turning operation is the surface speed, also known as the cutting speed, which is the rate at which the material of the work piece rotates quickly against the stationary cutting tool. It is just the result of multiplying the spinning speed by the work piece's radius. Even if the rotating speed is constant, each diameter on a work piece will rotate at a different speed.

The term "feed" is always used to describe the cutting tool and describes how quickly it travels along its cutting path. The feed rate is typically given in millimeters per minute (mm/min) on power-fed lathes and is inversely proportional to spindle speed. The other important cutting parameter is depth of cut. It is the thickness of the layer being removed (in a single pass) from the work piece or the measurement in millimeters between the work's uncut and cut surfaces. However, because this layer is being removed from both sides of the work, it is crucial to keep in mind that the diameter of the work piece is reduced by twice the depth of cut.

1.1.1.3. Lathe for turning

A turning machine is any form of lathe. Engine, turret, automated, numerical control, etc. are different types of manufacturing lathes. All tool movements are driven, and they are sturdy machine tools. Although swings up to 50 inches and centers up to 12 feet are not unheard of, they commonly have swings between 12 and 24 inches and centers between 24 and 48 inches. Most engine lathe equipment has features like chip pans and coolant circulation systems.

1.1.2. Aluminum-Silicon 6082

Aluminum and its alloy are exceedingly difficult to machine because a built-up edge (BUE) forms on the tool's surface. By choosing the appropriate cutting speed, feed, and cutting tool material, this can be reduced to a minimum. The work piece's service and performance are greatly impacted by surface integrity and tool life during machining. Modern day applications of aluminum and its alloy can be found in the automotive and aerospace industries (Pattnaik et al., 2017). A medium strength alloy with outstanding corrosion resistance is aluminum alloy 6082. The 6000 series alloy with the maximum strength is this one. Alloy 6082 is known as a structural alloy. In bar form, Aluminum alloy 6082 is the most commonly used for machining. As a relatively new alloy, the higher strength of Aluminum alloy 6082 has seen it replace 6061 in many applications. The addition of a large amount of manganese controls the grain structure which in turn results in a stronger alloy (Machado et al., 2020).

1.1.2.1 Dry Machining and Machining with Cutting Fluid

In machining operations, cutting fluids are used to improve the tribological processes that take place when two surfaces, such as the tool and the workpiece, come into contact. The process as a whole benefits from the cutting fluid's are increased tool life and workpiece surface roughness. Additionally, it aids in removing the heat and scraps created during machining. Cutting fluids, on the other hand, have a lot of negative consequences. The friction between the tool and the workpiece during machining causes high temperatures, which affect the dimensional accuracy and surface quality of the workpiece.(Lee et al., 2002)

In order to reduce friction at the interface of the tool with the workpiece and the tool with the chip, proper lubrication is frequently used to regulate machining temperatures. The traditional choice for both lubricants and coolants is cutting fluids. However, their use has a number of detrimental side effects, including water pollution, oil contamination during disposal, dermatitis in the operators, and environmental degradation(Lee et al., 2002)(Buongiorno, 2006) The cost of the cutting fluids contributes significantly to the overall cost of manufacturing. Investigations on the use of biodegradable coolants or coolant-free machining were sparked by these factors. Therefore, as an alternative to cutting fluids, researchers experimented with dry machining, coated tools, cryogenic cooling, minimum quantity lubrication (MQL), and solid lubricants. With the development of cutter materials, dry machining has reportedly been able to do away with cutting fluids(Ogedengbe et al., 2018).

When cutting under specific conditions, dry machining uses less power and creates a smoother surface than wet machining (Pradeepkumar et al., 2015). Since both characteristics have a significant impact on the wear resistance of coated tools, toughness and hardness are equally relevant in tribological applications of hard protective coatings (Weinert et al., 2004). (Itakura et al.2004). Coated cemented carbide tools to conduct dry double turning condition experiments to determine the mechanisms of tool wear when milling Inconel 718, and they came to the conclusion that in continuous cutting, essentially no rake wear but only flank wear emerged. This study compared these two techniques for removing material and looked at how surface roughness, cutting temperature, tool life, and analysis of machining cost were affected by the primary cutting parameters of spindle speed, feed rate, and depth of cut.

1.1.3 Statement of the Problem

The biggest issues facing machining industry are related to improving the quality of machined components. Due to its relationship to surface quality, surface roughness continues to be the primary indicator of the quality of machined components. Given the growing significance of turning operations in industry, improvements are being made to the material's surface roughness. Higher cutting parameter values in turning provided chances to increase productivity, but they also carried a larger risk of surface quality degradation and shorter tool life if the wrong process parameters were utilized. Rough surface roughness leads to unacceptable product with poor dimensional accuracy. Machining aluminum is difficult due to the chips formed are ductile and curling. Due to this surface finish of machined Al alloys (ALSI 6082) is very poor. Controlling cutting parameters requires experimental research and optimization techniques. Heat treatment, machine configuration choice, surface finish, cutting conditions, chattering, and other issues are affecting surface quality.

1.1.3.1 Research Questions

To analyze optimization of machine parameters during double turning tool of ALSI 6082 and the quality of surface roughness. The research questions focused in this study are:

- Why surface irregularity occurs?
- How does cutting parameters affect surface quality?
- How to optimize cutting parameters of double turning to get good surface finish?

- Does cutting speed affect surface quality?

1.1.4 General Objective

The general objective of this thesis is optimize of machining parameters during aluminum turning to get high surface quality.

1.1.4.1 Specific Objectives

To achieve the main objectives, the following specific objectives are accomplished.

1. Investigation on factors that affects surface finish (cutting speed, feed, depth of cut).
2. Optimizing cutting parameters to get high surface finish using Taguchi experimentation Design.
3. Investigation of temperature during dry machining on tool life.

1.1.5 Significance of the Study

To make high-quality products and to achieve longer tool life, it is crucial to investigate the cutting parameters that have the greatest impact on surface finish, cutting temperature, and tool life while dry double turning condition ALSI 6082 aluminum. The general product characteristics and tool life are significantly impacted by the presence or absence of cutting fluid. This study will also be important to obtain optimum cutting parameters that produce high surface finish in dry double turning condition. Generally, the significances of the study are the following:

- To obtain better surface finish.
- To increase precision of product.
- To obtain longer tool life.
- To enable customer satisfaction.

1.1.6 Scope and limitations of the Study

This study is focusing on the double turning of ALSI 6082 aluminum and to analyze the effect of cutting parameters (spindle speed, feed rate and depth of cut) on surface roughness, cutting temperature, tool life and identifying most significant cutting parameter that affect surface roughness, cutting temperature and tool life in dry and wet double turning condition condition. But in this study the effect of cutting force and machine vibration on the surface roughness was not included because of difficulties to measure cutting force without dynamometer and difficulties to measure vibration frequencies.

1.1.7 Structure of the Thesis

This thesis entitled as Experimental Investigation of Alsi 6082 Steel in Dry and Wet Using Double Turning Tool and Optimization of Cutting Parameters five Chapters one presents background of the study. Chapter two presents related literature works optimization of machine parameters during double turning tool of (ALSI 6082) machining of different materials, surface roughness and effect of cutting parameters on surface roughness, tool life, cutting temperature, machining cost, problem of the statement, Research gap, objectives, significance of the study, scopes and limitations of the study. Chapter 3 discussed about materials and methods including experimental procedures, equipment used and explains different methods. Chapter 4 presents result and discussion of major findings of this experimental work. Chapter 5 summarizes findings of the study, draws conclusions from the overall study, and recommendations certain directions for further research.

1.1.8 Research Motivation

Surface quality and cost of the machined product are crucial factors in every manufacturing industry to raise customer demand and manufacturer competition. Without good surface quality, it is difficult to discuss high production rates, a product's long lifespan free of defects, the occurrence of cracks, and corrosion resistance. In addition to surface quality, movable parts applications for assembly components depend heavily on it. Therefore, the aforementioned factors play a major role in motivating this effort.

CHAPTER-2

LITERATURE REVIEW

2.1 Introduction

Aluminium alloy 6082 is a medium strength alloy with excellent corrosion resistance. It has the highest strength of the 6000 series alloys. Alloy 6082 is known as a structural alloy. In bar form, Aluminium alloy 6082 is the most commonly used for machining. As a relatively new alloy, the higher strength of Aluminium alloy 6082 has seen it replace 6061 in many applications. The addition of a large amount of manganese controls the grain structure which in turn results in a stronger alloy.(Ndaruhadi et al., 2014)

2.2 Surface Roughness and Effect of cutting Parameters

Surface roughness has a significant role in determining how well-machined a product's surface is. It is influenced by a number of factors, including cutting condition, vibration of the machine tool, cutting tool, and work holding mechanisms. The surface roughness of the completed component is significantly influenced by the cutting speed, feed, and depth of cut. The surface quality of the machined component has been the subject of extensive research. The efficiency of the machine parts that are interfaced is significantly influenced by the surface quality of the contacted surface. These characteristic is typically described as surface roughness (Suker et al., 2016). They conducted an experimental investigation on the effects of cutting parameters such as feed rate, depth of cut, and cutting speed and reported that cutting speed is the most significant factor followed by the depth of cut and feed rate (Yusuf et al., 2010). Surface roughness is affected by factors such as spindle speed, feed rate, depth of cut, work piece hardness, stability of the machine tool, and the work piece set up examined the impact.(Suker et al., 2016).

(Debnath et al., 2016) investigated the effects of cutting fluid properties and cutting parameters (cutting speed, feed rate, and depth of cut) on tool wear and surface roughness when turning mild aluminum bar using a TiCN + Al2O3 + TiN coated carbide tool insert. The results show that feed rate has the most impact (34.3%) on surface roughness, but cutting speed had the greatest impact (43.1%) on tool wear. Along with cutting fluid, tool wear and surface roughness both demonstrated a substantial contribution of 33.1%. (13.7 percent). They came to the conclusion that typical machining of aluminums, aluminum alloys, and cast irons, with the exception of aluminum alloys, can be done using dry machining. However, the substantial friction between the tool and workpiece was higher. (Rodrigues et al., 2012)

According to some researches, cutting force and surface roughness are significantly influenced by feed rate and depth of cut (Deva et al. 2016) used Taguchi's Signal-to-Noise ratio (S/N ratio) and Analysis of Variance (ANOVA) techniques to investigate the experimental investigation of machining parameters, such as cutting speed, feed rate, and depth of cut influence over surface roughness parameters during turning ALSI 4340 aluminum. It was determined that the feed rate, which accounts for 70.50 percent of the total contribution, is more important than cutting speed (9.15 percent) and depth of cut (18.54 percent). Similar research was conducted by (Muamar et al,2021) using carbide cutting tools with a constant tool nose radius to machine low carbon aluminum workpieces under dry and wet double turning condition conditions. They looked at the cutting parameters (spindle speed, feed rate, and depth of cut) and their impact on the surface roughness of the workpieces. Results showed that chilling conditions and cutting settings have a significant impact on surface roughness. Johari (Yang & Tarng, 1998) investigated the impact of the cutting parameters—cutting speed, feed rate, and depth of cut—during dry double turning condition of using a standard lathe machine, concluding that the spindle speed—the most important factor—contributed 63.90 percent, the depth of cut—the second-most important factor—contributed only 11.32 percent, and the feed rate contribution—the least important factor—contributed 8.33 percent for Ra.

In dry double turning condition aluminum on a lathe, feed and RPM contributed 60.91 percent and 29.83 percent, respectively, whereas the contribution from depth of cut was just 7.82 percent. This led to the conclusion that while feed rate for surface roughness showed an increasing tendency, speed and depth of cut had minimal effect. (Senthil et al,2010) experimental work on turning and facing Inconel 718 with an uncoated carbide insert took into account responses such surface roughness and flank wear as well as cutting parameters including cutting speed, feed, and depth of cut. It is anticipated that cutting speed and depth of cut will be dominating elements for turning, while feed will be dominant for facing cutting speed. (Isik, 2010) has performed an experimental investigation employing a CVD coated carbide Tic+Al2O3 +TiN insert to convert ALSI 1050 aluminum (ISO P25). The cutting parameters of cutting speed, feed, and depth of cut are the subject of this work, as well as the reactions of flank wear, tool life, tool wear, and surface roughness. Both dry and wet cooling conditions were used for the experiment, and the tool.

An experimental investigation on converting mild aluminum using a carbide cutting tool has been looked into by (Harsimran et al,2012). Cutting speed, feed rate, cut depth, and surface roughness are the variables taken into consideration in this work. The Taguchi DOE is used in the experiment's design. According to this research, the best value of the surface will be determined by the turning cutting speed, depth of cut, and feed rate. In an experimental investigation, (Suleiman et al,2011) turned ALSI 1045 aluminum using a molybdenum high-speed aluminum turning tool. Surface roughness is the response in this work, with depth of cut, feed rate, and spindle speed being the turning parameters. The Box Benhenken experimental design was used to create the experiment. High cutting and spindle speeds may have a beneficial impact on surface roughness in relation to feed rate. An experimental examination on turning EN-8 using a carbide cutting tool has been done by (Hardeep et al,2011).

Surface roughness and material removal rate are the work's main reaction variables, while depth of cut and feed rate are its main cutting factors. Taguchi methodology has been applied to optimize cutting settings for surface roughness analysis. The level of importance of the input components was examined using analysis of variance (ANOVA) on the nine experimental data. According to the findings, the spindle speed, followed by the depth of cut and feed rate, has the biggest influence on surface roughness. In their experimental study(Yadav, 2012). Turning medium carbon, aluminum,are used a STALLION-100 HS CNC lathe (ALSI 1045). The turning characteristics of this are taken into account for the cut speed and feed. According to (Kagade et al,2011), a CNMG 09 03 08-PF carbide insert tool was used in an experimental investigation on turning high carbon, high chromium aluminum (HCS). Cutting parameters taken into account in this work include cutting speed, depth of cut, and feed rate. Results taken into account also include surface roughness and spindle load. This research has led to the conclusion that cutting depth has the least impact on surface roughness and speed has the greatest impact. On the lathe, the impact of dry double turning condition and wet double turning condition on the surface characteristics of mild aluminum was examined by the outcome demonstrates that mild aluminum turned in damp conditions had a better surface property. (Butola et al., 2017).

2.3 Dry and Wet Machining

Dry machining is seen as essential for industrial businesses and is environmentally beneficial. Dry machining is a need for the enforcement of environmental protection legislation for occupational safety and health requirements in the metal fabrication industry(Galanis et al., 2008). The benefits of dry machining include the absence of air or water pollution, the absence of residue on the chip, which will result in lower disposal and cleaning costs, and the absence of any health risks. It also lowers the cost of machining. However, in dry cutting operations, there is a tendency for more friction and adhesion between the chip and the tool, which raises temperatures, increases wear rates, and shortens tool life as a result. On the other hand, employing cutting fluids during machining results in greater part quality and less tool wear. During cutting, cutting fluids have been used.(Liew et al., 2017)

Generally, the use of cutting fluids increases the tool life, contributes to a more economical cutting speed, and generally improves the efficiency of the production systems (Galanis et al., 2008). A tour of most factories where demonstrate that some cutting operations are carried out dry. However, in many other cases, a flood of liquid is directed over the tool, to act as a coolant and/ or a lubricant. These cutting fluids perform a very important role and many operations cannot be efficiently carried out without the correct fluid (Liew et al., 2017). They are used to prevent the tool, workpiece, and machine from overheating and distorting, increase tool life, improve surface finish and clean the chips from the cutting area.

2.3.1. Dry Machining

Dry machining is viewed as essential for industrial businesses and is environmentally beneficial. Metal fabrication industries are forced to take into account dry machining to enforce environmental protection legislation for occupational safety and health standards. The benefits of dry machining include no contamination of the air (or water), no residue on the chip, which will result in lower disposal and cleaning expenses, and no health risks (Science, 2021).

2.3.2 Wet Machining

Wet machining is a type of machining where a cooling jet is directed at the active zone to cool, lubricate, and remove chips generated during machining. Due to the water content of the coolant, which is included in the employed emulsion, it is ideal for the grinding and turning process where high temperatures or sparks may arise can be avoided (Anton et al., 2015a). One benefit of cutting fluids in machining operations, according to Adler et al examination of the cutting fluid(Adler et al., 2006),is their capacity to transmit heat. In situations where the size of the machined surface imperfections of a surface is generated in an optimal manner, heat transfer can be very beneficial in the reduction of error surface. (Adler et al., 2006)

2.4 Cutting Fluids

According to Arsoy (2015), Review (2012), and Zhao et al. (2019), cutting fluids are used in machining solely for the purposes of lubricating and cooling to reduce friction and wear that occurs on the surface between the tool point and the machined object, remove heat from the work piece and the cutting zone, carry away chips from the cutting area, and prevent erosion. Although those functions can be used to define cutting fluids, lubricating and cooling are generally considered to be a cutting fluid's primary purposes (Sidik et al., 2017)(Adler et al., 2006). They compared the rate of tool wear during machining with and without coolant and found that utilizing coolant resulted in greater surface quality and a 30 percent increase in tool life. In order to convert carbon aluminum with the best surface reliability, (Onuoha et al., 2016). Employed a cutting fluid made of groundnut oil. When (Shetty et al., 2061). Examined surface roughness during turning of Ti-6Al-4V under near dry machining conditions, they came to the conclusion that lubrication had the highest physical impact on surface roughness, with a 95.1 percent significance when utilizing PCBN tools. In a comparison of dry and MQL conditions, (Okonkwo et al., 2015). Utilized a 10 percent boric acid and SAE 40 base oil MQL mixture, which they found to be effective in reducing surface roughness by 20 percent. By using coolant throughout the cutting process, the materials are less likely to wear down, corrode, or creep(Das et al., 2012)(Orisanmi et al., 2017).

2.4.1 Function of Cutting Fluid

The primary purpose of employing cutting fluids in machining processes, as previously mentioned, is to lower the cutting temperature and friction wear by lubrication or cooling through heat conduction (Palanisamy et al., 2009). Despite the increasing public health concerns about conventional cutting fluids around the world, (Aggarwal et al., 2008), have highlighted the following cutting fluid limitations:

- Environmental pollution because of chemical breakup of cutting fluid at high shear.
- Biological (dermatological) problems to the operators like skin problems and respiratory problems

- Contamination of water and soil during disposal.
- The cost of disposal of cutting fluids becomes higher as environmental regulations become harder. Efficient cooling strategies within the metal cutting industry are important for profitable production (Anton et al., 2015b).

The needs for the using lubricants are:

- Cooling of machines, work materials, equipment, and cutting tools
- Breaks of chips and transport chips
- Reduction of friction
- Reduction of the built-up edge formation.

During machining, heat is generated close to the cutting zone to prevent corrosion on the machine and the workpiece. Even if part of the heat is passed to the tool and then the workpiece, the majority of the heat generated remains inside the chip (Stephenson et al., 1995). In line with (O'Sullivan & Cotterell, 2001), higher cutting temperatures have a negative impact on tool life because even a small decrease in temperature can increase tool life shows the regions where heat is generated while spinning. According to (Boswell et al., 2017), the thermal conductivity of the tools, tool design, and cooling methods all affect how much heat is dissipated from the cutting zone. However, in dry machining, the heat generated in the cutting zone is not dissipated by a cutting fluid.

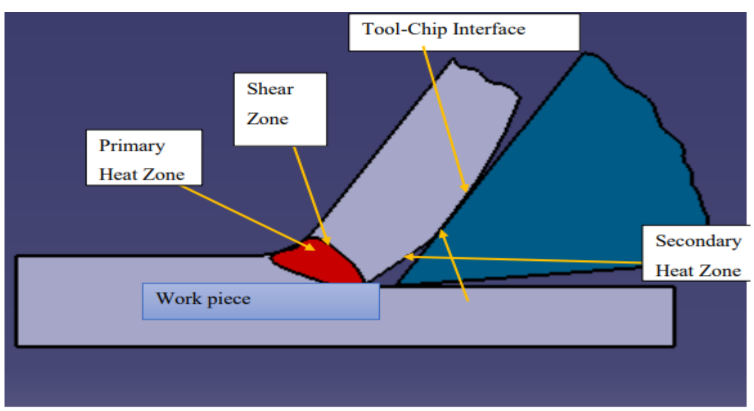


Figure 2. 1 Regions of heat generation in turning (Debnath et al., 2016)

2.4.2 Types of Cutting Fluid

Conventional cutting fluids can be divided into four primary types based on their thermophysical characteristics, mode of use, and techniques of treatment(Adler et al., 2006),(Çakīr et al., 2007).

i) Straight oils

Straight oil is used largely for lubrication-related operations and is manufactured wholly of mineral oil (neat cutting oil) or vegetable oils (biodegradable). Straight oils are good lubricants, but they have very poor heat transfer capacities. Highly flammable mineral oil has low efficiency at high cutting speed and relatively high cost. (Khan et al., 2009), reported that vegetable oils are non-toxic and environmentally friendly in terms of resource renewability, biodegradability, and performance efficiency in many applications. This is proved by(Elmunafi et al., 2015),were, in their research, they found that the use of vegetable oil has shown some positive results. Straight oil is used largely for lubrication-related operations and is manufactured wholly of mineral oil (neat cutting oil) or vegetable oils (biodegradable). Straight oils are good lubricants, but they have very poor heat transfer capacities. Mineral oil is highly flammable, has poor performance at high cutting speeds, and is relatively expensive. Vegetable oils are non-toxic and environmentally benign in terms of resource renewability, biodegradability, and performance effectiveness in a variety of applications, according to (Khan et al., 2009). This is proved by (Elmunafi et al., 2015), were, in their research, they found that the use of vegetable oil has shown some positive results.

ii) Soluble oils

When oil and water are combined, soluble oil is created, which has a greater cooling capacity than pure oil and offers rust and corrosion prevention. Because new cutting tool materials like strong metals and fast cutting speeds are being used, this type of water-based cutting fluid is appropriate for turning, milling, and grinding operations. Additionally, water-based cutting fluids are reported to lessen the impact of generated heat on cutting tool wear (Adler et al., 2006). A Ti-48Al-2Cr-2Nb alloy's machinability was studied by (Priarone et al., 2015). Low cutting fluid (water and emulsion) volumes were applied to the cutting region in the form of a finely metered mist. They discovered that emulsion mist has a longer tool life than vegetable oil.

iii) Semi-synthetics

Semi-synthetic oil performs similarly to soluble oil or not significantly differently. Its composition is different, though, as inorganic material or other water-soluble chemicals make about 30% or less of the overall concentration. When emulsified oil is added to synthetic cutting fluid, semi-synthetic fluids are created that have a combination of qualities. It is also easier to maintain than soluble oil, although it tarnishes quickly when in contact with other machine fluids and poses a risk of dermatitis for employees (Adler et al., 2006).

iv) Synthetics

A chemical liquid classified as synthetic contains inorganic or other compounds that are highly soluble in water and provide exceptional cooling performance. The use of biodegradable lubricant is crucial for green production. Synthetic lubricants have been steadily and gradually being replaced with biodegradable lubricants. The least amount of environmental pollution is achieved using biodegradable cutting fluids, which can offer great reliability and favorable economic conditions. Additionally, because bio-based cutting fluid manufacturing is much cleaner and contributes less to air pollution, there is a lower risk of occupational illness. Although the bio-based cutting fluids are imperfect in certain ways, they are less harmful to the environment than other cutting fluids (Debnath et al., 2016).

2.5 Cutting Temperature

In machining procedures, high temperatures that occur in the cutting zone are still a problem. At the cutting point during machining, heat is produced primarily from three sources. These sources include the primary shear zone, where the majority of the energy is transformed into heat, the secondary deformation zone, where additional heat is produced owing to rubbing or shear at the chip-tool interface, and the flanks due to rubbing between the tool and the finished surfaces. The consequences of the high cutting temperature mostly harm the tool and the task. The chip materials remove a large percentage of the heat. But it does not matter since the chips are thrown out.(Yip & To, 2018)(Gupta & Laubscher, 2017)

Rapid tool wear, plastic deformation of cutting edges due to insufficiently hard and robust tool materials, thermal flaking and fracture of cutting edges as a result of thermal shocks, and built-up edge development are all potential negative effects of high cutting temperatures on cutting edges. The dimensional inaccuracy of the job due to thermal distortion and expansion contraction during and after machining, surface damage by oxidation, corrosion, burning, and induction of tensile residual stresses and microcracks at the surface and sub-surfaces are just a few of the potentially harmful effects of cutting temperature on the machined workpiece. However, by softening or lessening the shear strain, high cutting temperature aids in somewhat reducing the size of the cutting force and cutting power consumption.

2.6 Tool Life

Tool life is the length of time that a cutting tool performs as desired and to the user's satisfaction during machining. It is the amount of time between changes of the cutting tool that a tool will cut successfully. Since a lot of time is lost every time a tool needs to be changed and reset, tool life is crucial in the machining process. A longer tool life increases productivity and lowers machining costs. Surface roughness and work piece accuracy both increase as a result of cutting tool wear and failure. The material of the machined component, the material and shape of the cutting tool, as well as the cutting circumstances, are the key determinants of tool life in machining.(Narasimha et al., 2013)

2.6.1 Taylor's Tool Life Equation

Tool wear is always used as a lifespan criterion since it is straightforward to quantify. Because it affects the precision and roughness of the workpiece's surface, flank wear land is typically utilized as the criterion. The following is the Taylor tool life formula;

$$C = VT^{n} \quad (2.1)$$

Where n is an exponent that relies on the cutting parameters, V is the cutting speed (in m/min), T is the tool life (in min), and C is a constant. The values of "n" and "C" are mostly influenced by the materials used for the tools and the cutting environment (cutting fluid application). Cutting speed is the only factor that influences the life of the cutting tool, according to the original Taylor tool life formula. This is due to the fact that this formula was created utilizing tool aluminum made of high-carbon and high-speed aluminum. It was discovered that the cutting feed and the depth of the cut are also important with the further development of carbides and many other tool materials. As a result, the following adjustments were made to Taylor's tool life calculation to account for these changes:

$$\mathrm{C}= VT\ nf\ a\ t\ b \quad (2.2)$$

where f is the feed (mm/rev) and t is the cut depth (mm). For each of the cutting conditions, the exponents n, a, and b need to be found experimentally.

2.7. Research Gap

Due to difficulties in machining in terms of surface quality of machined item, cutting temperature, tool life, Studying comparison of effective cutting parameters during dry double turning condition of ALSI 6082 aluminum is crucial. Turning factors on lathe machines including cutting speed, depth of cut, feed rate, and cutting environment that affect the desired output like surface quality, cutting temperature, and tool life for various types of aluminum were researched. To compare the effects of cutting parameters on surface finish, cutting temperature, tool life, and machining cost during dry double turning condition of ALSI 6082 aluminum, however, there have been few experimental studies conducted. More research is still needed to fully understand the effects of cutting parameters on surface finish, cutting temperature, and tool life. Therefore, it is crucial to compare the effective cutting parameters used during dry and wet double turning condition of ALSI 6082 aluminum in order to determine the cutting parameters that produce a high level of surface finish.

CHAPTER-3

MATERIALS AND METHODS

Introduction

This study was performed to compare the effect of cutting parameters on surface roughness, cutting temperature, and tool life during dry and wet turning of AISI 6082 steel through experimental work. The aim of this chapter is to present the details of the experimental procedures and material used for the study. All machines and instruments were discussed with supporting photographs and schematic diagrams.

3.1 Materials

This study was performed to compare the effect of cutting parameters on surface roughness, cutting temperature, and tool life during dry and wet double turning condition of ALSI 6082 aluminum through experimental work. The aim of this chapter is to present the details of the experimental procedures and material used for the study.

3.1.1 Materials and Compositions

Aluminum of the ALSI 6082 grade was chosen for the study's materials. This aluminum alloy is known for its excellent machineability. A wide range of engineering applications, including automotive parts, general engineering and machinery parts and components, shafts and camshafts, pins and spindles, spare parts, gears, pinions, bolt and nuts, high speed screw machine parts, etc., highly benefit from the use of ALSI 6082 material. Table 3.1, in weight percentages, displays the material's chemical compositions.Table

Table 3. 1 Chemical composition of 6082 alloy aluminum (Wt. %)(AZO Materials, 2005)

Si	Fe	Cu	Mn	Mg	Zn	Ti	Cr	Al
0.7-1.3	0.0-0.5	0.0-0.1	0.4-1.0	0.6-1.2	0.0-0.2	0.0-0.1	0.0-0.25	Balance

One of the most crucial decisions in the production process is the selection of materials for the machining operation, which is the main component of a product. On the other side, poorly chosen materials may cause the intended product's pieces or components to fail, incurring additional costs and wasting resources like time and energy. The Federal Democratic Republic of Ethiopia's Technical and Vocational Training Institute hosted the experimental work. The aluminum alloy of ALSI 6082, which is widely used in industry, is the sample material for the thesis. The ALSI 6082 round bar was double turned on a traditional lathe machine using parameters such an HSS cutting tool, cutting fluid coolant, and input selection process parameters (cutting speed, depth of cut, feed, and bake rake angle).

Table 3. 2 Physical properties of ALSI 6082 Aluminum(AZO Materials, 2005)

No	**Physical Properties**	**Value**
1	Density	2500 kg/m^3
2	Melting Point	555°C
3	Modulus of Elasticity	70 GPa
4	Electrical Resistivity	0.38 x 10^{-6} Ω.m
5	Thermal Conductivity	250 W/m.K
6	Thermal Expansion	24 x 10^{-6}/K

Understanding the machining characteristics including mechanical and physical properties of a material are very important conditions Table 3.2. In addition, selecting the correct cutting tool with the recommended angle during machining of ALSI 6082 is explored in this experimental study Table 3.3

Table 3. 3 Mechanical properties of 6082 alloy aluminium(AZO Materials, 2005)

No	**Properties**	**Metric**
1	Yield strength	255 MPa
2	Ultimate tensile strength	295 MPa
5	Shear modulus	85 MPa
6	Poisson’s ratio	0.31-0.34
7	Elongation	8%
9	Hardness Rockwell B	35 HB

3.1.2 Specimen Preparation

The workpiece materials for this investigation were aluminum of the ALSI 6082 grade, which is widely utilized as an alloying element in a wide range of technical applications, such as automobile parts, different components, shafts and camshafts, pins and spindles, spare parts for spacecraft, etc. The preparation of two ALSI 6082 aluminum specimens measuring 180 mm in length and 52 mm in diameter. Nine trials were then conducted with a cut length of 20 mm and a depth of 0.75, 0.5, and 0.25 mm. For this experimental study, a range of turning parameters were used, and they were chosen using an orthogonal array as shown in Figure 3.1

To enable a direct comparison of the related outcomes, cutting parameters for both dry and wet machining were equal.

Figure 3. 1 Specimen preparation

3.1.3 Cutting tool preparation

The design of the cutting tool must include forces acting on the tool, feed rate, speed, chip disposal, needed accuracy, etc. Since the shape and function of all other types of cutting tools' cutting tips different, the process for creating single point cutting tools is consider physical and mechanical properties of the material being cut. The HSS tool was selected for this study due to its good characteristic such as fracture toughness, high hot hardness, high melting point, good chemical inertness, high temperature chemical stability, thermal shock, and economical advantages. The 1900 HSS has strong wear resistance due to high speed development high stability, formation of high resistance to mechanical stress, dimensional stability at elevated cutting temperatures, and wide wear resistance.

Two methods are used to execute the design. First, a fixed angle is used (side relief angle (8^o), side back rake angle (9^o), end relief angle (7^o), and nose radius (0.5^o), as shown in figure 3.2 , and then a variable back rake angle (3^o, 5^o, and 7^o) is used.

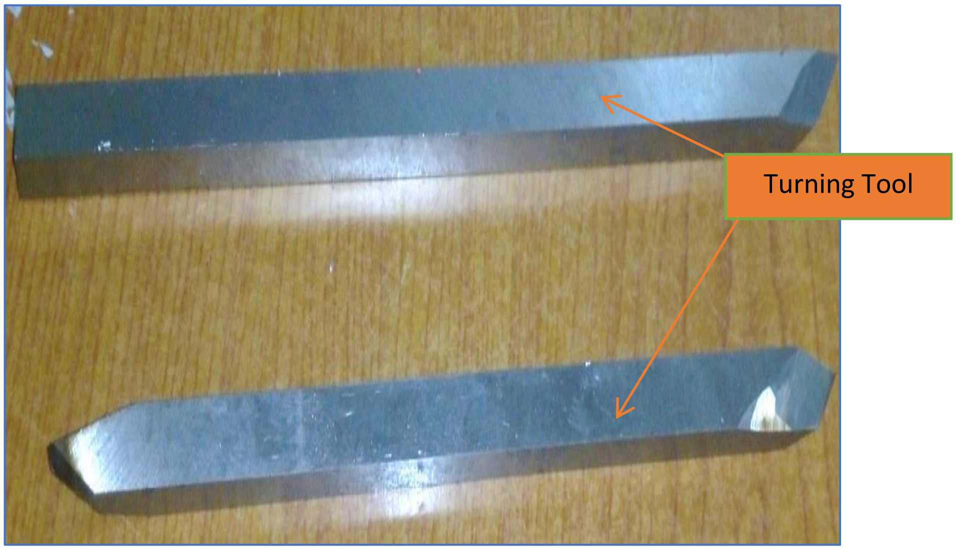


Figure 3. 2 Cutting tool before grind

3.1.4 Cutting Tool Selection

The tool is chosen in accordance with the machining characteristics of the work material. The work material, ALSI 6082 steel. In this experimental work, HSS tool containing compositions with tungsten, molybdenum, together with percentages of chromium, vanadium and cobalt was employed in accordance with the cutting circumstances and the tool manufacturer's recommendations.(Ji et al., 2018)

3.1.5 Selection of Process Parameter

The crucial step in the turning process is choosing the cutting settings that will result in excellent cutting performance. According to information available in the literature, tool manufacturer guidelines, manufacturer's handbooks recommended for the tested material, current industry practice, and experience, cutting parameters for ALSI 6082 aluminum were chosen for experimentation purposes (Debnath et al., 2016),(Isik, 2010),(Bedada et al., 2021). The cutting parameters that were chosen were displayed in Table 3.4.

Table 3. 4 List of Parameters and their Levels

Cutting Parameters	Designations	Levels		
		1	2	3
Depth of Cut (mm)	t	0.25	0.5	0.75
Feed Rate (mm/min)	f	60	80	100
Spindle Speed (rpm)	N	355	500	710

3.1.6 Tools and Equipment

Tools and machines type selection are very crucial in the machining operation to generate good surface finish. In this study, double single point cutters which are made from HSS and lathe machine (CM6241X1000YANCHENG C&J MACHINERY CO, LTD and China country)

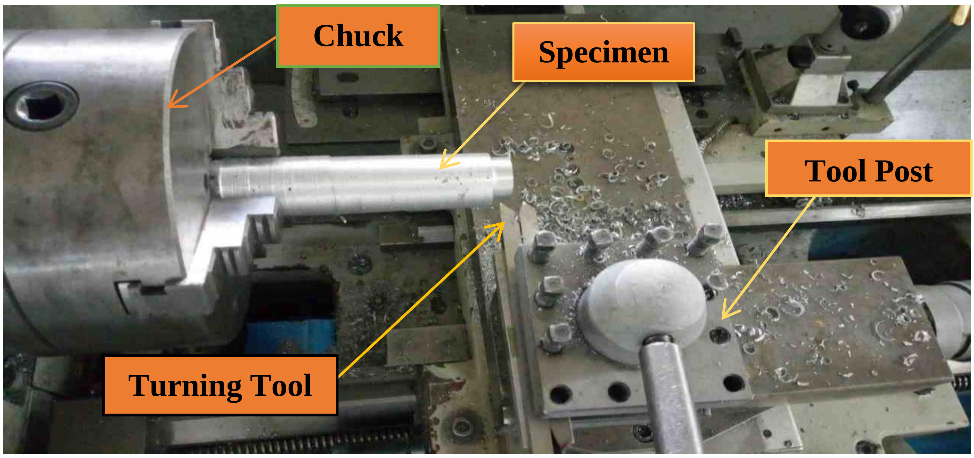


Figure 3. 3 Machine set up for the experiment

3.1.6.1 Turning Machine

There are many different shapes and sizes of turning machines, sometimes known as lathes. Although vertical turning machines are occasionally employed, the majority of lathes are horizontal turning machines, usually for large diameter work pieces. The type of control that is provided can also be used to classify turning machines. When using a conventional lathe, the turning process requires the operator to manage the cutting tool's motion. On the other hand, turning machines can also be controlled by computers; in this instance, they are known to as CNC lathes (computer numerical control) lathes.

Figure 3. 4 Conventional lathe machine

3.1.7 Surface Roughness Measurement

The most important factor in the machining process is surface roughness because it is thought to be the foundation of product quality. It gauges how inadequately refined the surfaces are. Because a smooth surface (better finished components) reduces the likelihood of surface damage caused by wear, corrosion, improves fatigue strength, reduces creep failure, and increases productivity & economics of the industry, the quality of the surface produced using conventional and non-conventional machining is important. The effectiveness of the surface for preventing wear and corrosion can also be influenced by the quality of a part produced by a turning operation. Depending on its uses, such as Ra, Rq, Rz, and Rt, surface roughness can be defined in a variety of ways. The average surface roughness, however Ra, also known as the arithmetic average (AA) or the center line average (CLA), is a measure of surface roughness that is frequently used in industry for mechanical components. For this reason, Ra was employed in this study to indicate surface roughness.

The German-made VOGEL Surface Roughness Tester which is depicted in Figure 3.5, was used to measure surface roughness. The micrometer (m) value of surface roughness is displayed on this tester. The VOGEL Surface Roughness Tester 65711 measures between 0.02 and 50 micro meters. The surface imperfections of the workpiece will be traced using a stylus attached to the tester's detecting unit. The instrument's liquid crystal display digitally displays the vertical stylus movement that occurred during the trace after being processed.

Figure 3. 5 Surface-roughness testing equipment

3.1.8 Temperature Measurements

An infrared thermometer was employed to measure and analyze the cutting temperature. When machining, each set of parameters under each turning situation, the cutting zone's temperature was recorded in dry and wet conditions.The fundamental operation of an infrared thermometer is to measure an object's surface temperature at the interface betweeb the contact of cutter and work piece. The energy that the unit optics transmit, reflect, and sense is pooled and concentrated onto a detector. The information is converted into a temperature reading by the unit electronics and displayed there. Point the meter at the surface you want to measure while holding it by the handle grip. To turn the meter on and start the test, pull and hold the trigger. The laser pointer is focused onto the cutting zone while you keep pulling the trigger. When you let go of the trigger, an LCD display will show that the reading is being retained. The temperature units ^{0}C and ^{0}F are available. Figure 9 below depicts the infrared thermometer that was used to measure the temperature of tool and surface cotact.

Figure 3. 6 Infrared thermometer for measure temperature

3.1.9 Spectrometers

Numerous metals and alloys' elemental compositions can be easily detrmined by spectrosmetry analysis. The chemical makeup of ALSI 6082 aluminum material was tested using Txc02 type spark spectroscopy equipment.

Figure 3. 7 Spectrometer for Composition Analysis

3.2 Research Methodology

By using the selected material the following method the experimental work was done. Under research methodology the way of specimen preparation, design of experiment procedure, selection of orthogonal array and analysis of variance would be explained.

3.2.1 Experimental Procedures

The experimental approaches were the most effective ways to machine the double-turning aluminum alloy. Figure 3.8 displays all of the specific actions taken during the experiment based on the conceptual frame work.

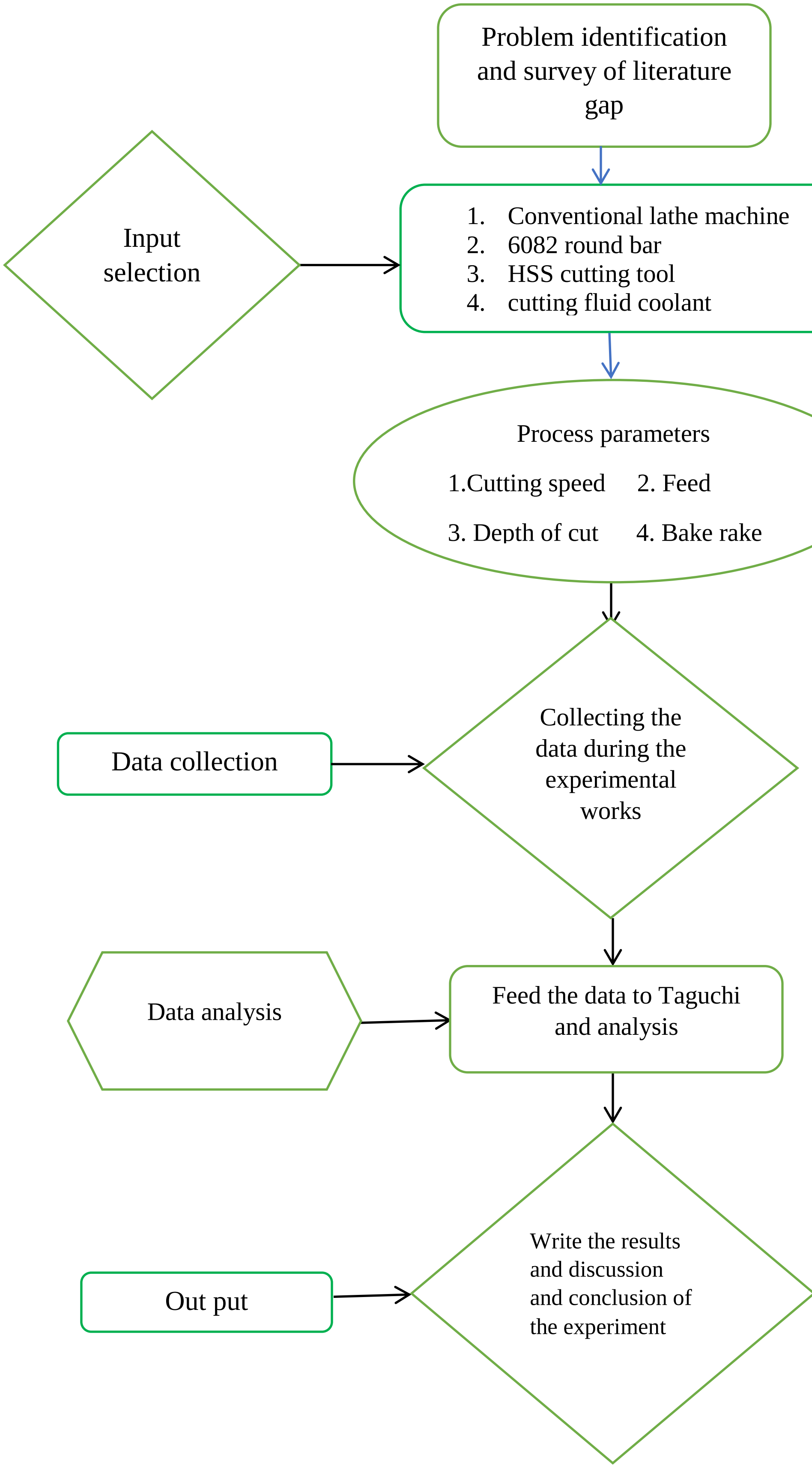


Figure 3. 8 Study flow chart

3.2.2 Process Plan for a Turning Experiment

The process route was designed for an experiment utilizing 6082 alloy aluminum on a standard lathe machine. The type of surface finish produced depends on the cutting parameters (cutting speed, depth of cut, feed rate, and back rake angle), the condition of the cutting tool bit, the stiffness of the machine, the types of workpieces, and other factors. For both dry and wet experimental trials, the same workpiece material and cutting parameters, such as cutting speed, depth of cut, feed rate, and back rake angle, are utilized.

The material that uses for the experiment was prepared as shown in figure 3.1. the process was listed below:

- The 250mm aluminum blank was cut into six pieces, three for dry double turning condition and the remaining three for wet double turning condition.
- The major diameter of spaceman is 52mm and minor diameter is 20mm.
- Using the HSS cutting tools, face each specimen on the right side of the conventional lathe machine CL6136A model.
- Using a 5 mm center drill, create the center at the right end of the specimen..
- Tighten the 250mm long specimen between centers, then spin it in accordance with the 20mm setup criteria by creating a step turning by 20mm gap using the parting tool. 9 experiments overall, 3 experiments for each type of dry and wet conditions.
- Finally, a vernier caliper was used to verify the machined surface diameter before sending it to be tested for surface roughness.

3.2.3. Design of Experiment

The cutting parameters, which were divided into several level values and varied throughout the experiment, included spindle speed, feed rate, and depth of cut. Because it is a tool for problem-solving that can enhance product performance, process design, shorten experimental times, lower costs, and identify significant factors more quickly, the Taguchi approach is frequently used in the design of experiments to optimize machining parameters (Yadav, 2012),(Onuoha et al., 2016). Each cutting parameter at three levels was taken into account in the case of this study to identify the most significant cutting parameters in the dry and wet double turning condition of ALSI 6082 aluminum process. These control factor level settings were chosen in accordance with suggestions made by a tool manufacturer and knowledge available in the literature. Then, these levels were aligned using the Taguchi L9 orthogonal array (OA), which is depicted in Table 3.6. The Taguchi-based orthogonal array has the advantage of minimizing the number of experiments while maintaining a significant level of accuracy (Onuoha et al., 2016). To carry out the Taguchi-based experiments, the following actions were taken

- State the problem
- Determine the objective
- Determine the response parameters and its measurement
- Identify factors influencing the performance characteristic
- Separate the factors into control and noise factors
- Determine the number of levels and their values for all factor
- Identify control factors that may interact
- Select the Orthogonal Array
- Assign factors and interactions to the columns of OA
- Conduct the experiment
- Analyze the data
- Interpret the results
- Select the optimal levels of the significant factors
- Predict the expected results
- Run a confirmation experiment

Three types of quality characteristics are provided by the Taguchi technique to examine the best quality characteristics, and the S/N ratio is used to measure the quality characteristics deviating from the ideal value.(Kemal Temam Ebrahim, Moera Gutu Jiru, 2020)

i) Nominal is the best characteristics,

$$S/N = 10\log y / S^2{}_y \tag{3.1}$$

ii) Smaller are the better characteristics,

$$S/N = -10\log 1/n \left(\sum S^2\right), \ =1 \tag{3.2}$$

iii) Larger is the better characteristics,

$$S/N = 10\log 1/n \left(\sum \frac{1}{y^2}\right), ni=1\ ) \tag{3.3}$$

Here Y = observation n = total number of observation, $\bar{Y}$ = the average of observed data, S 2 = the variation of Y and Yi = ith response.

- Larger is preferable for determining profit, material removal rate, production rate, etc.
- Surface roughness, cutting temperature, unit cost, and other factors all benefit from smaller being better.
- Nominal is the better is applicable for current.

To determine the impact of each parameter on the reaction under dry and wet double turning condition conditions, the S/N ratio was determined for surface roughness in each of the nine trial situations. In order to conduct additional experiments, as shown in Table 3.7, Minitab 18 has provided the L9 orthogonal array, which specifies nine experiments. The steps to go through are as follows:

- Selection of factors to be evaluated
- Selection of number of levels
- Selection of appropriate orthogonal array
- Conduct the experiment and analyse the results

3.2.3.1. Selection of Orthogonal Array and Column Assignment

Utilizing HSS tools for dry and wet double turning condition of an ALSI 6082 aluminum workpiece with chosen cutting parameters within three levels shown in Table 5 in accordance with suggested cutting parameters, the turning tests were performed on a typical lathe machine. The number of levels of different factors was used to determine which orthogonal array to use. Three factors, each at three levels, were chosen in this case to conduct the studies. The orthogonal array's (OA) total DOF should, however, be larger than or equal to the experiment's total DOF requirements. This setup allows the testing of all three variables without having to run 27 for both dry and wet double turning condition. Nine different samples were manufactured with different parameters and at different levels both for dry and wet double turning condition. Thus, the Degree of Freedom (DOF) can be calculated by the formula as given below. For OA;

$$DOF = a - 1 \qquad (3.4)$$

$$= 9\text{-}1 = 8$$

For an experiment;

$$DOF = P * (L - 1) \qquad (3.5)$$

Where, DOF is degree of freedom, P is number of factors and L is number of levels

DOF = 3*(3-1) = 6.

Therefore, 8>6; i.e. DOF of OA is greater than DOF of the experiments.

The cutting parametrs were selected from others resaerch work were the ranges were selected for this work (Kemal Temam Ebrahim, Moera Gutu Jiru, 2020).

Table 3. 5 Experimental Layout Using an L9 Orthogonal Array(Kemal Temam Ebrahim, Moera Gutu Jiru, 2020).

Exp. No	1	2	3	4	5	6	7	8	9
Depth of Cut (mm)	0.75	0.75	0.75	0.5	0.5	0.5	0.25	0.25	0.25
Feed rate (mm/min)	60	80	100	60	80	100	60	80	100
Spindle Speed (rev/min)	710	500	355	710	500	355	710	500	355

3.2.4 Analysis of Variance (ANOVA)

Finding the factors that significantly affect the quality feature was the goal of the analysis of variance (ANOVA). The statistical method used to determine the impact of each control parameter is called an ANOVA. The percentage contributions of each control factor were employed in the analysis of variance to calculate the associated effects on the performance attributes. In this analysis, the significance level of 5%, or for a 95% level of confidence, was taken into account. The outcomes of an ANOVA show whether or not there is a statistically significant difference in the output qualities. When results are less than 0.05, an ANOVA analysis is significant, and when they are greater than 0.05, it is not. Percent contribution gauges each model term's percentage contribution to the entire sum of squares. The percentage contribution is frequently a basic but reliable indicator of the relative weight assigned to each model parameter. The following formula was used to calculate each influential parameter's percentage contribution from the variance analysis:

$$P = SS/\ SST * 100 \tag{3.6}$$

Where, P: Percentage contribution of individual factor, SS: Sum of squares or treatment sum of squares, and SST: Total sum of squares.

CHAPTER-4

RESULTS AND DISCUSSION

4.1 Introduction

Dry double turning machining was carried out on conventional machining using aluminum alloys. However, in dry cutting conditions, excessive friction between the tool and workpiece causes the temperature to rise dramatically, which in turn causes a higher amount of abrasion, diffusion, and oxidation. The workpiece also experiences much heat, which makes it difficult to attain precise tolerances and causes metallurgical damage to its outermost layer. The experiment focused on the turning experiments with varying cutting speed, feed, and tool nose radius, with and without the use of cutting fluid, to determine the ideal conditions for dry cutting.

In this work, cutting parameter adjustment, together with the impact of cutting fluid quantity and flow rate, were examined in an effort to achieve the desired surface roughness and extend tool life. To conduct the fewest possible experiments, a Taguchi orthogonal L9 array was used. The experimental variables were the operating parameters, such as the depth of cut, feed rate, and lubrication state. A conventional turning machine was used to conduct the experiment on aluminum alloy bars. The chips at various turning experimental levels were gathered for further investigation.

For dry and wet double turning condition of ALSI 6082 grade aluminum, experimental research was done to examine the effects of cutting parameters, such as spindle speed, feed rate, and depth of cut, on the surface roughness, to compare the surface roughness, to investigate cutting temperature. In this chapter, both dry and wet double turning condition of ALSI 6082 aluminum, the Taguchi design of the experiment was utilized to examine the effect of cutting parameters on surface roughness and to find the most significant cutting parameters on surface finishing. Figure 4.1 presents the results of all nine experiments using ALSI 6082 aluminum with varying cutting conditions and the same length of cut (20 mm).

In Experiments 1, 2, and 3, the depth of cut was 0.75 mm, but the feed rates were 60, 80, and 100 mm/min and the spindle speeds were 710, 500, and 355 rpm, respectively, for both dry and wet double turning condition. Similar to experiment number 4,5 and 6, 0.5mm depth of cut was used but various feed rates (60, 80, and 100 mm/min, respectively) and spindle speeds (710, 500, and 355 rpm, respectively). Last but not least, trials 7, 8, and 9 used depth of cut of 0.25 mm but different feed rates of 60, 80, and 100 mm/min with spindle speeds of 710, 500, and 355 rpm, respectively. The experiment's finding regarding surface roughness.

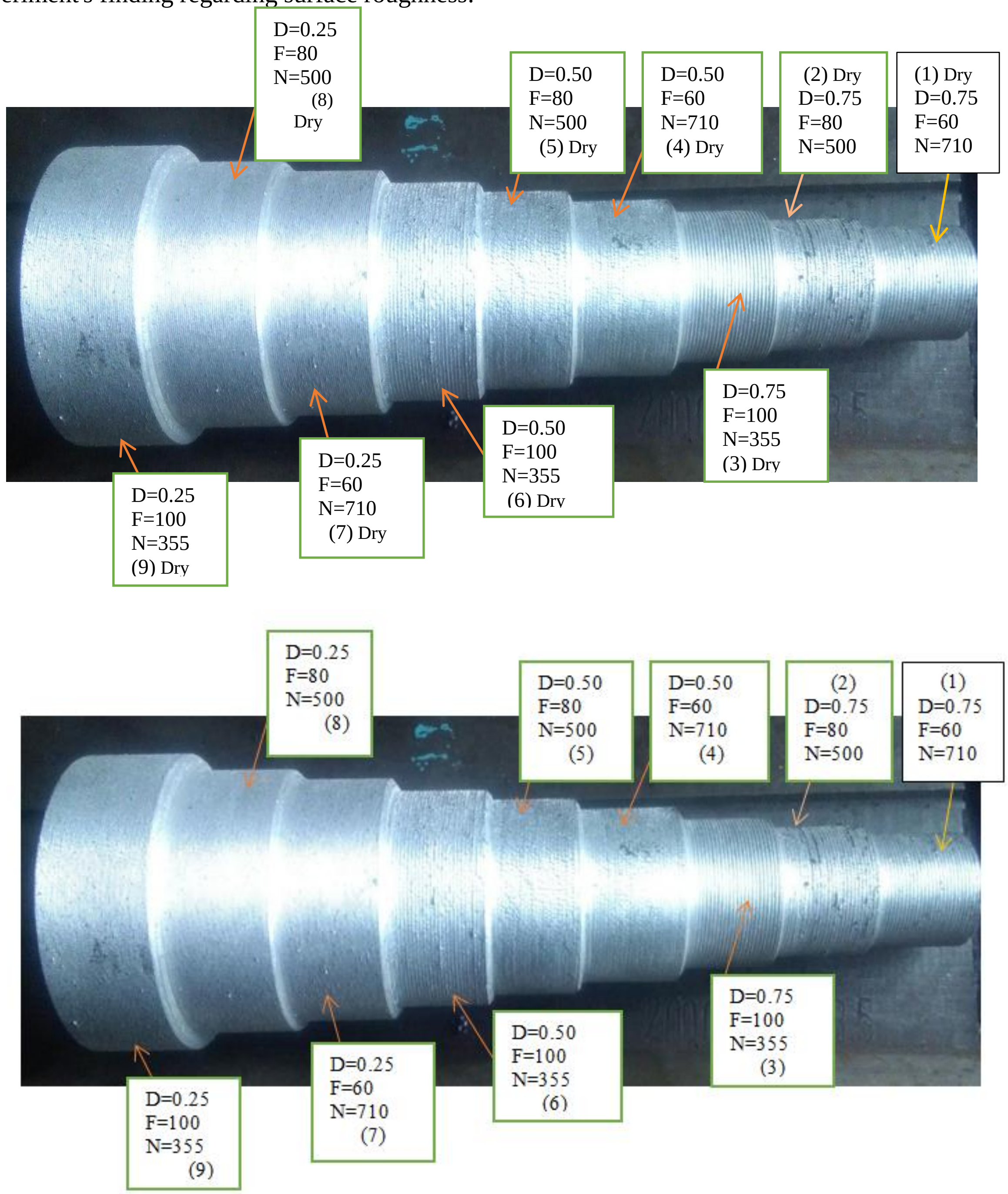


Figure 4. 1 The dry and wet double turning condition

Figure 4. 1 displays three machined specimens, each with a 20mm length of cut and three different depths of cut for dry and wet double turning condition. Wet turned specimens with a first level depth of cut of 0.75mm were used in the first work piece (WP), those with WP1, WP2, and WP3, those with a second level depth of cut of 0.5mm were used in the second piece, and those with WP4, WP5, and WP6 were used in the third piece, those with a third level depth of cut of 0.25mm were used. Each piece had a different spindle speed and feed rate. Similar to the first piece with WP1, WP2, and WP3, which consists of three dry turned

specimens with first level depth of cut (0.75mm), the second piece with WP4, WP5, and WP6 was created using the same techniques.

4.2 Comparison of Surface Roughness for Dry and Wet double turning condition

The experimental results of surface roughness (Ra) values for each object when turned dry and wet are shown in Tables 4. 1 and 4.2 Each surface roughness (Ra) trial value used in this study is the average of three trial readings.

Table 4. 1 Experimental Results of Surface Roughness Ra for Dry double turning condition

Exp't	Cutting Parameters			Surface Roughness (Ra) micro				
				Dry double turning condition				
	t (mm)	f (mm/min)	N (RPM)	I	II	III	Average	S/N
1	0.75	100	710	2.19	2.25	2.22	2.2	-6.6485
2	0.75	80	500	1.89	1.85	1.87	1.87	-5.2368
3	0.75	60	355	2.1	2.15	2.14	2.13	-6.3676
4	0.5	80	710	1.97	1.92	1.97	1.95	-5.6007
5	0.5	60	500	1.76	1.85	1.7	1.77	-4.7595
6	0.5	100	355	4.06	3.91	4.0	3.99	-12.0195
7	0.25	60	710	1.68	1.82	1.78	1.76	-4.9103
8	0.25	80	500	3.19	3.24	3.32	3.25	-10.2377
9	0.25	100	355	3.08	2.88	2.95	2.97	-9.4551

Table 4. 2 Experimental Result of Surface Roughness Ra for Wet double turning condition

Exp't no	Cutting Parameters			Surface Roughness (Ra)				
				Wet double turning condition				
	t (mm)	f (mm/min)	N (RPM)	I	II	III	Average	S/N
1	0.75	100	710	1.75	1.78	1.74	1.75	-5.1333
2	0.75	80	500	1.09	1.12	1.16	1.14	-3.0938
3	0.75	60	355	1.65	1.58	1.61	1.61	-5.0893
4	0.5	80	710	1.30	1.32	1.26	1.29	-4.0005
5	0.5	60	500	1.16	1.12	1.30	1.19	-2.8603
6	0.5	100	355	3.48	3.44	2.98	3.30	-10.2910
7	0.25	60	710	1.22	1.19	1.21	1.20	-2.2118
8	0.25	80	500	2.69	2.72	2.75	2.72	-8.6914
9	0.25	100	355	2.19	2.42	2.35	2.32	-7.3098

Figure 4.2 depicts surface roughness under various dry and wet machining settings. When comparing the right and left panes dry and wet in the graph, it was evident that wet double turning condition produces less surface roughness than dry double turning condition. The surface roughness attained with wet machining is 17.41% lower than dry machining when all roughness measurements measured under dry and wet double turning condition are averaged. The previous study by (Kaynak et al., 2014). Wet machining reduces tool wear when compared to dry machining, it aids in maintaining tool geometry for an extended period of time by minimizing or eliminating the possibility of built-upedge (BUE) formation, and it improves surface finish. The effect of cutting tool with workpiece interface temperature during dry cutting allows for the quick removal of chips that are loosely adhered to the surface, which helps to reduce surface roughness. The temperature is lowered and friction between the contacting parts is reduced when coolant permeates the cutting zone. Similar findings from other researchers suggested that cooling the cutting zone with cutting fluid was necessary to reduce friction by lubricating the contacting surfaces during machining(Yildirim et al., 2020),(Bagherzadeh & Budak, 2018). From an experimental run, it is displayed.

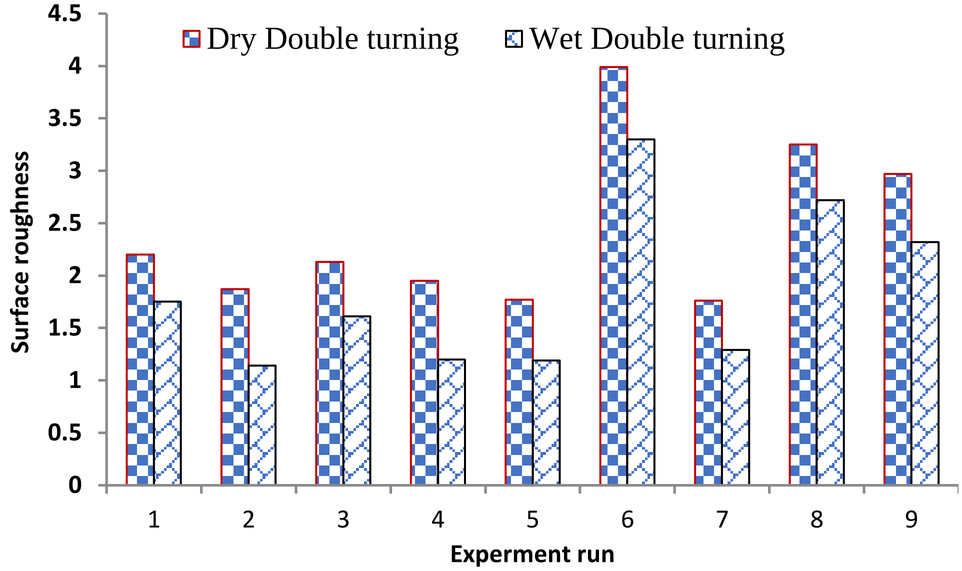


Figure 4. 2 Surface roughnesses for each experimental run

The surface roughness of dry double turning condition was higher than the surface roughness of wet double turning condition, as illustrated in Figure 4.2. above. Nine experimental runs of wet double turning condition and dry double turning condition had average surface roughness of 2.01 µm and 2.43 µm, respectively. According to the findings, dry double turning condition's average surface roughness was 17.41% higher than wet double turning condition's average surface roughness.

4.3 Effect of Cutting Parameters on Surface Roughness

Cutting conditions, chip breaking characteristics, tool wear, machine tool precision, built-up edge, cutting edge shape, and these factors all affect surface roughness. These also vary depending on whether wet or dry conditions are used during machining process.

4.3.1 The effect of feed rate on surface roughness

At spindle speeds of 355 rpm, 500 rpm, and 710 rpm, respectively, the impact of feed rate on surface roughness (Ra) is depicted in Figures 4.4.

4.3.2 Effect of Spindle Speed on Surface Roughness

The findings in Figures 4.3 demonstrate how the spindle speed affects the evolution of surface roughness while maintaining a constant feed rate.

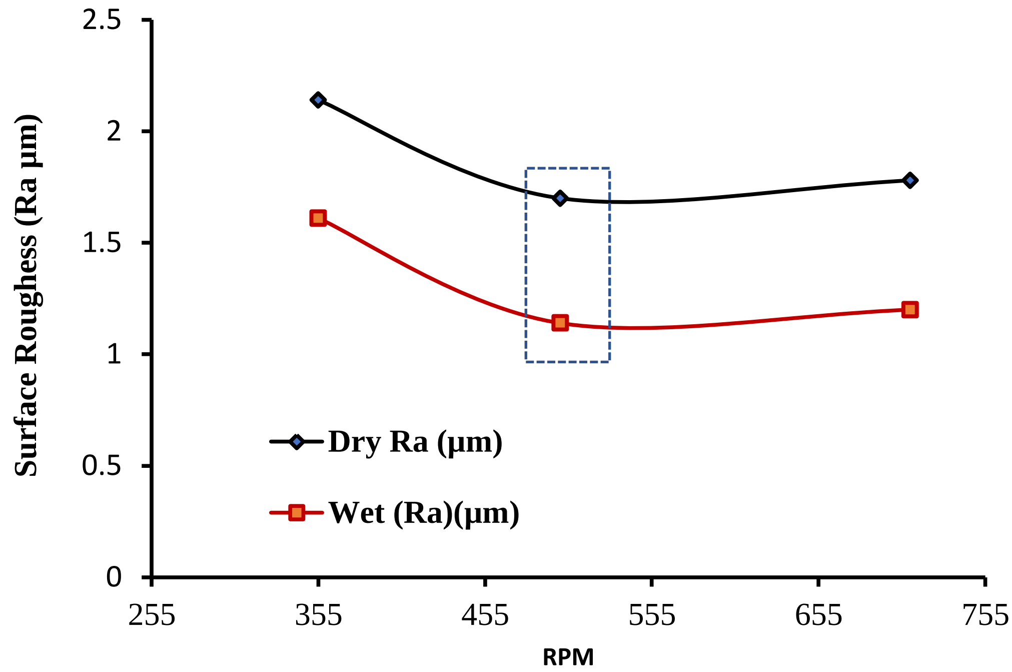


Figure 4. 3 The effect of cutting speed on surface roughness

It is clear that as spindle speed increased, the roughness of the turned surface decreased. Low spindle speeds cause chips to fracture easily and develop a greater built-up edge, which produces a rough surface. The BUE disappears as spindle speed rises, minimizing chip fracture and producing a superior finish (Davis et al., 2012). The other possible explanation for this is that at faster spindle speeds, the temperature rises as a result of the more violent material removal, which results in the phenomena of softening, which enhances cutting and reduces surface roughness. Additionally, when turning is carried out at a low spindle speed, a subsurface material fracture takes place, which adds to an increase in surface roughness; this effect is eliminated by ALSI the cutting speed.

The minimum surface roughness for dry double turning condition was 1.76 µm and for wet double turning condition it was 1.20 µm m at 710 rpm spindle speed and 60 mm/min feed rate. For dry double turning condition, it was raised to 2.2 µm, and for wet double turning condition, to 1.75µm. As a result, increasing spindle speed caused an increase in surface roughness whereas increasing feed rate had the reverse effect. The results match with the works of (Sarikaya & Güllü, 2014). In both the dry and wet double turning condition experiments, the maximum and minimum values of surface roughness were recorded. This is due to the lowest feed rate and highest spindle speed at run number 7, and the highest feed rate and highest spindle speed at run number 1.

Figures 4.2. demonstrated that wet double turning condition produced the best surface finish. According to the findings, utilizing coolant liquid lessens surface roughness. This brings us back to the idea that coolant liquid is crucial for cooling the cutting tool, lowering friction between the tool and the workpiece, and extending the life of the tool. Additionally, employing cooling liquid might help push chips away from the workpiece's surface, helping to prevent the built-up edge (BUE) of the cutting tool, which results in rough surfaces finishing(D. K. Suker et al., 2016),(Debnath et al., 2016),(Isik, 2010).

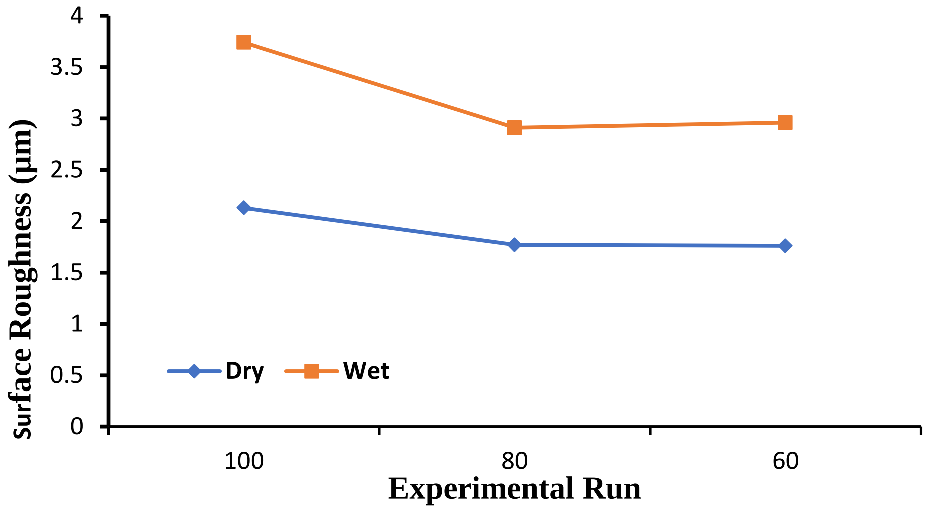


Figure 4. 4 Effect of feed rate on surface roughness

Figures 4.3, and 4.4 illustrate how surface roughness increases for both dry and wet turned specimens as feed rate increases while spindle speed remains constant. Higher feed rates mean that there is more material in contact with the cutting tool, which results in a higher development of the cutting force, which manifests as vibration and produces high surface roughness. Additionally, higher feed rates raise the cutting temperature, which brings on tool wear and, as a result, unwanted surface roughness (Rodrigues et al., 2012). Surface roughness reduces at increasing spindle speeds. The maximum surface roughness was 2.20 mm (for dry double turning condition) and 1.76mm (for wet double turning condition) at 100 mm/min feed rate and 710 RPM spindle speed, respectively (for wet double turning condition). When the spindle speed was increased to 355 RPM, it was reduced to 2.13mm (for dry double turning condition) and 1.61mm (for wet double turning condition). The effect of RPM on surface roughness as increased from 355 to 555 sourface roughness was reduced how ever the optimum RPM was 455 surface roughness optimum. Wet double turning condition, in contrast to dry machining, was shown to reduce surface roughness due to its superior property of reducing the cutting temperature and friction at the tool-work interface, which is similar to the outcome discovered by Muamar et al.(Isa et al., 2021)

4.3.2 Effect of Depth of cut on Surface Roughness

Figures 4.5 show the impact of cutting depth on surface roughness when ALSI 6082 aluminum is turned dry or wet at depth of cut of 0.25, 0.5, and 0.75 RPM, respectively.

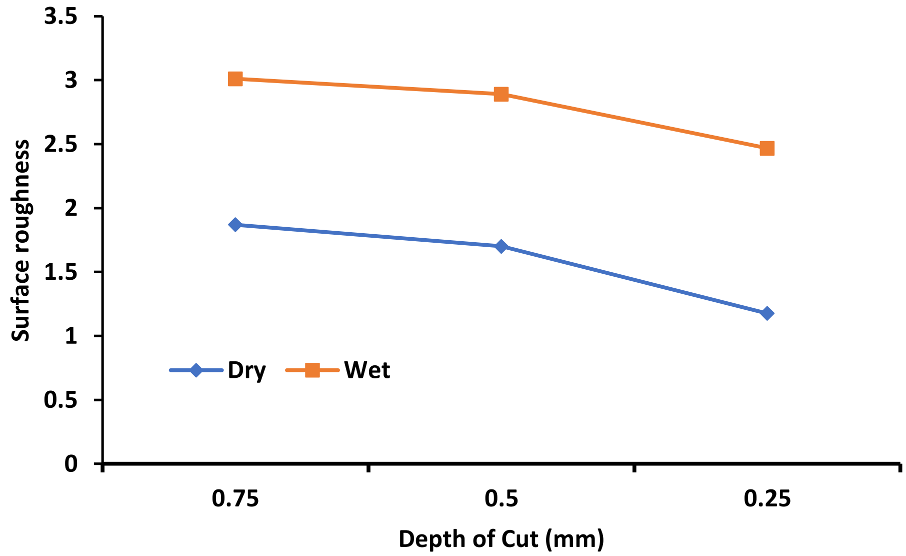


Figure 4. 5 Effect of depth of cut on surface roughness

The procedure for determining feed rate The influence of depth of cut on surface roughness for dry and wet double turning condition of ALSI 6082 aluminum is shown in Figures 4.5 With constant spindle speed values for both dry and wet double turning condition, the figure shows the correlation between the depth of cut and the surface roughness. Surface roughness increased as depth of cut at constant spindle speed increased. Higher cutting forces are needed to remove a greater volume of material with deeper cuts, for this reason. As cutting forces increase, machine tool vibration becomes apparent and negatively impacts surface roughness(Isa et al., 2021)(Yadav, 2012).

The highest surface roughness was 3.30 mm and 3.99 mm (for wet and dry double turning condition) at 0.50 mm depth and 355 rpm spindle speed, respectively, as spindle speed rose (for wet double turning condition). When the spindle speed was increased to 710 rpm, it was reduced to 1.76 mm (for dry double turning condition) and 1.20 mm (for wet double turning condition).

4.4 Analysis of Variance (ANOVA) for Surface Roughness

Analysis of variance (ANOVA) is used to identify the most significant factors which affects the surface roughness of the machined part. It was calculated and reported in Table 4.3 for dry double turning condition and in Table 4.4 for wet double turning condition. Percent contribution for each factor was calculated. Where DoF = degree of freedom, SS= Sum of squares, MSS = Mean Sum of squares, and F = F- Ratio generated by using Minitab 17 software.

Table 4. 3 Analysis of variance for dry double turning condition

source	DoF	SS	MSS	F-Value	P-Value	Percent contribution	Significance α = 0.05
t	2	0.613	0.307	7.9	0.112	12.35%	Less Significant
f	2	1.768	0.884	22.78	0.042	35.58%	Significant
N	2	2.509	1.255	32.33	0.03	50.51%	Highly Significant
Error	2	0.078	0.039			1.56%	
Total	8	4.969				100%	

$F_{0.05, 2, 8} = 4.26$

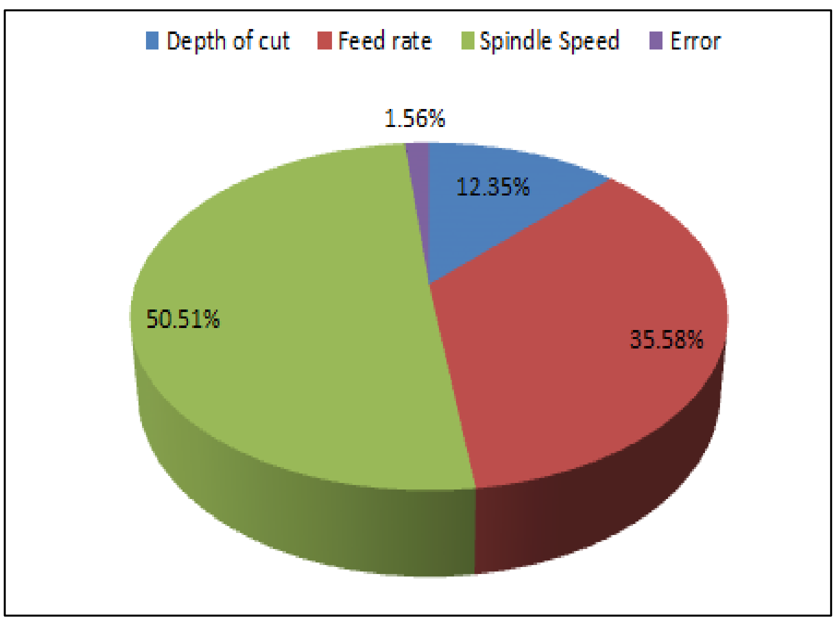


Figure 4. 6 Percentage contribution of cutting parameters to Ra for dry double turning condition

Table 4.3. presents surface roughness percentage contribution variation of factors t, f and N; where factors represents depth of cut, feed rate and spindle speed respectively during dry

double turning condition. It is observed that spindle speed has statistical significances on the surface roughness value during dry double turning condition of ALSI 6082 aluminum at 95% confidence level. From the Table4.3. and Figure 4.6. it is clearly observed that the depth of cut weight percentage (12.35 %), feed rate (35.58%) and spindle speed (50.51%) have significant influence on the surface roughness of dry turned aluminum 6082 specimens.

Table 4. 4 Analysis of variance for Wet double turning condition

source	**DoF**	**SS**	**MSS**	**F-Value**	**P-Value**	**Percent contribution**	**Significance α = 0.05**
t	2	0.15002	0.07501	2.34	0.299	4.31%	Less Significant
f	2	1.27182	0.63591	19.87	0.048	36.51%	Significant
N	2	1.99762	0.99881	31.2	0.031	57.34%	Highly Significant
Error	2	0.06402	0.03201			1.84%	
Total	8	3.48349				100%	

F0.05, 2, 8 = 4.26

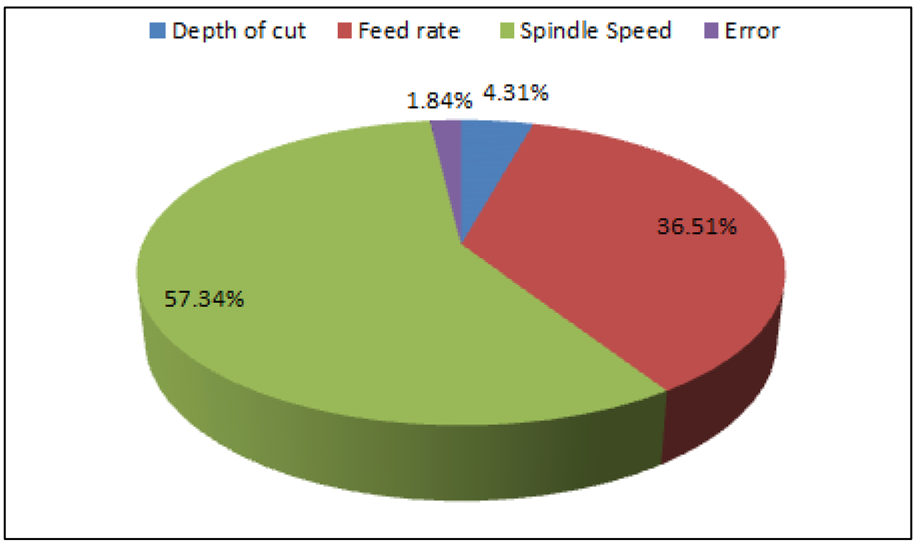


Figure 4. 7 Percentage contribution of cutting parameters to Ra for wet double turning condition

Surface roughness percentage contribution variation of each factor for wet double turning condition is shown in Table 4.4. and Figure 4. 7. The surface roughness was shown to be significantly influenced by the depth of cut weight percentage (4.31%), feed rate (36.51%), and spindle speed (57.34%). This analysis was conducted with a degree of confidence of 95% and a level of significance of 5%. The F-values and P-values are also included in the ANOVA table. Understanding the relevance of the factors requires comparing the F-values with the tabulated ones. If a parameter's obtained F value is higher than its calculated value, then that particular parameter significantly affects the response variable. Tables 4.3 and 4.4 show that, at a 95 percent confidence level, spindle speed has the greatest impact on surface roughness, followed by feed rate. In both dry and wet double turning condition conditions, the analysis of variance (ANOVA) reveals that spindle speed (N) and feed rate (f) are significant factors impacting the surface roughness (P 0.05), although depth of cut (t) has essentially little importance (P>0.05). Additionally, spindle speed significantly affects surface roughness while turning ALSI 6082 aluminum in both dry and wet conditions. In order to achieve good surface roughness, it is therefore important to manage the spindle speed when turning ALSI 1020 aluminum in both dry and wet conditions.

4.5 Optimization of Cutting Parameters for Dry double turning condition

Taguchi's orthogonal arrays are extremely fractional designs with a strong emphasis on the major effects. Using only a few experimental runs, these designs are employed to estimate the main impacts.(Mia et al., 2018) Optimal results can be predicted by using Taguchi Signal-to-Noise ratios (S/N), which are log functions of the desired output and act as objective functions for optimization. The signal-to-noise (S/N) ratio is used in the Taguchi method to analyze response variance.

4.5.1 Analysis of Mean for Surface Roughness for Dry double turning condition

Using a design of experiments, the average mean value of surface roughness for each factor—depth of cut (t), feed rate (f), and spindle speed (N)—for both dry and wet double turning condition was determined. The surface roughness (Ra) values obtained through experimentation for each specimen under dry and wet double turning condition circumstances are shown in Tables 4.5 and 4.6. Using the Minitab 17 design and analysis of experiments program, the mean value of surface roughness for each factor, namely depth of cut (t), feed rate (f), and spindle speed (N), at each level during dry double turning condition, was determined. The result is shown in response Table 4.5.

Table 4. 5 Mean Ra of cutting parameters for dry double turning condition

Level	Depth of cut	Feed rate	Spindle speed
	Symbol		
	t	f	N
1	2.570	1.97	1.887
2	2.363	2.297	2.263
3	2.63	3.03	3.147
Delta	0.207	1.06	1.260
Rank	3	2	1

Spindle speed (Delta = 1.260, Rank = 1) has a significant impact on the mean in Table 4.5 (Rank = 1). Depth of cut (Delta = 0.207 , Rank = 3) is the factor that has the least impact on the mean. t1d1N3 will be considered as a potential parameter combination for better values if any parameter levels during dry double turning condition of specimens have better surface finish values. Spindle speed, feedrate, and depth of cut are important variables that affect surface roughness in an orderly fashion, as illustrated in Table 4.5. Figure 4.8. depicts the major effect plot for the means of surface roughness value variations during dry double turning condition. The outcome derived from the data in Table 4. 5 above indicates that for surface roughness value, smaller is preferable.

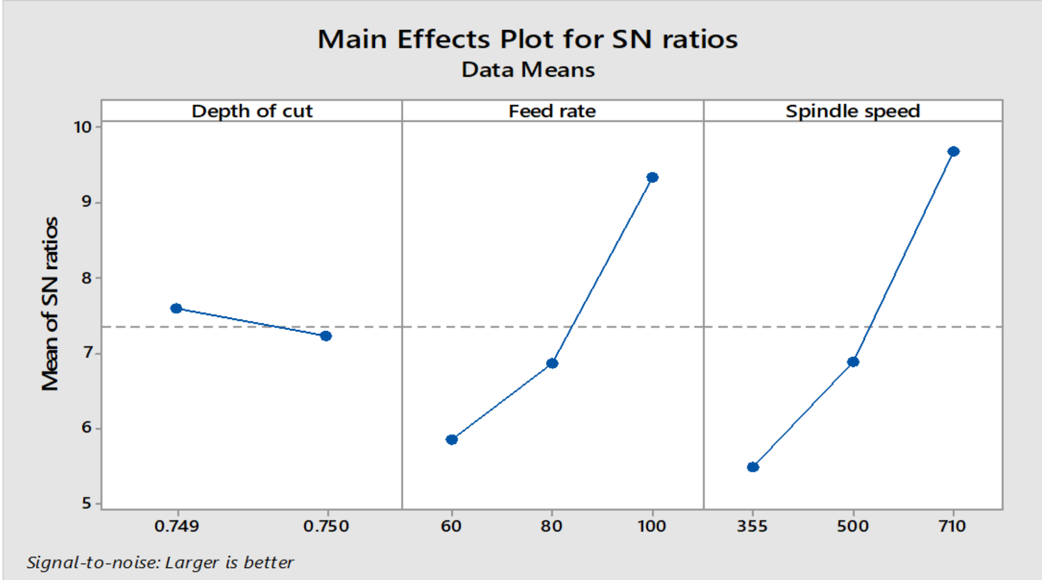


Figure 4. 8 Main effect plot of mean surface roughness for dry double turning condition

Figure 4.8 shows that, for the purposes of this study, the ideal circumstances for achieving a superior surface roughness are at the minimum point on the graph for each turning parameter. While the minimum point on this graph for feed rate and depth of cut was at level one, it was at level three for spindle speed. Because of this, the optimum turning parameter, t1f1N3, was found to be at low feed, low depth of cut, and high spindle speed. Three parameters are chosen by the tiny mean value in order to forecast the best response. The ideal level of parameters for surface roughness for dry double turning condition is t1f1N3. The following linear regression equation is used to determine the predicted value of the responses (surface roughness value) (Kemal Temam Ebrahim, Moera Gutu Jiru, 2020).

$$Yopt = m + (t1 - m) + (f1 - m) + (N3 - m) \quad (4.1)$$

$$= t1 + f1 + N3 - 2\,m$$

where, m is average performance mean value for surface roughness, t1 is optimum level value for parameter t, f1 is optimum level value for parameter f, N3 is optimum level value for parameter N.

$Yopt$ = 2.570 + 1.970 + 3.147− (2 ∗ 2.432)

$Yopt$ = 2.823 (Predicted mean value for surface roughness value for dry double turning condition)

4.5.2 Analysis of S/N Ratio for Surface Roughness for Dry double turning condition

The S/N ratio is used by the Taguchi method to calculate the variances in response values in experimental designs. The properties of the reported response variables serve as the basis for the equations used to calculate the signal to noise ratios. The lower the response variables in this experiment, the better. The results of the surface roughness calculations for turning utilizing the design of trials are shown in Table 4.6 and Figure 4.9 shows the surface roughness signal to noise ratios, with smaller being preferable for dry double turning condition.

Table 4. 6 Signal to noise ratios of Ra for smaller is better for dry double turning condition

Level	Depth of cut	Feed rate	Spindle speed
	Symbol		
	t	f	N
1	-6.284	-5.853	-9.702
2	-7.593	-6.878	-6.898
3	-8.201	-9.347	-5.479
Delta	1.917	3.494	4.223
Rank	3	2	1

$$Delta = Maximum\ S/\ N\ ratio - Minimum\ S\ /N\ ratio \qquad (4.2)$$

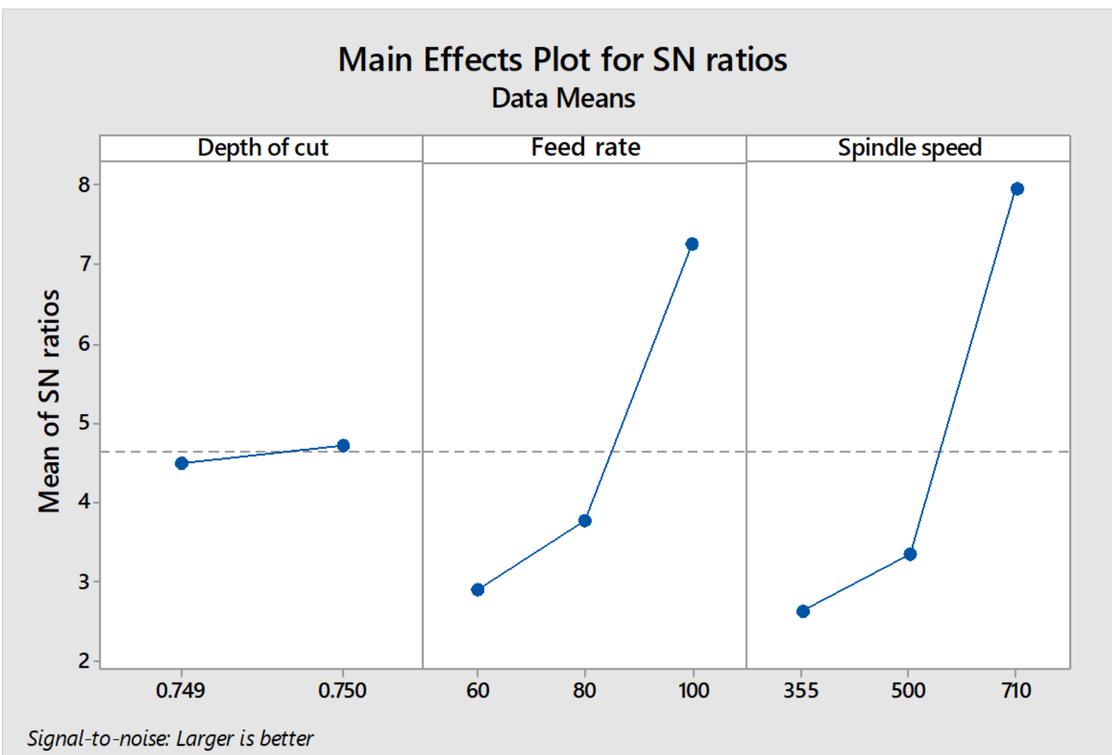


Figure 4. 9 Main effects plot of s/n ratio of Ra for dry double turning condition

The spindle speed weight percentage has the biggest impact, as demonstrated in Table 4.7 and the major effect plot for the signal to noise (S/N) ratios of the dry double turning condition surface roughness response (Delta = 4.223, Rank = 1). The depth of cut (Delta = 1.917, Rank = 3) was the factor that had the least impact on the (S/N) ratio. The superior surface quality character on smaller objects, as shown in Table 10, is t1f1N3. This parameter combination may be used to improve the surface quality of dry turned specimens. Figure 4.9 displays the major effect plot of the control factor for the surface roughness S/N ratio.

Each graph's maximum point's numerical value displays the best value for that particular parameter at that level. In the range of the experimental settings, they also point out the ideal conditions (Krishnaiah & Shahabudeen,2012.). When compared to other cutting parameters, the spindle speed weight percentage has the greatest potential to increase surface roughness, while depth has the least potential to do so, which is consistent with the findings of mean analysis. Since a smaller S/N ratio is preferable, the smallest S/N ratio possible was chosen for this investigation, as seen in the graph of Figure 4. 9. That is why level 1 (t1f1N3) spindle speed, feed rate, and depth of cut were chosen.

4.5.3. Determining the Optimum Condition for Dry double turning condition

Table 4.8 presents the optimum parameters setting selected for surface roughness obtained from the design of experiment and experimental results for dry double turning condition. The selected optimum parameters in this study were at higher cutting speed, at lower feed and at maximum depth of cut, which is at t1f1N3.

Table 4. 7 Optimum parameter level and their value for dry double turning condition

Factors	Level Selected	Value of the Level	Rank of affecting the Response
Depth of Cut (mm)	1	0.75	3
Feed Rate (mm/min)	1	60	2
Spindle Speed (RPM)	3	710	1

4.6 Optimization of Cutting Parameters During Wet double turning condition

In the current work, the turning operations on aluminum alloy have had the cutting parameters (depth of cut, feed rate, and spindle speed) optimized. As a consequence, the combination of the optimal values of the factors was obtained to get the minimum surface roughness

4.6.1 Analysis of Mean for Surface Roughness for Wet double turning condition

Similar to dry double turning condition, Minitab 18 was used to determine the mean value of surface roughness for each factor, including depth of cut (t), feed rate (f), and spindle speed (N), at each level. The results are shown in Table 4.8.

Table 4. 8 Mean Ra of cutting parameters for wet double turning condition

Level	Depth of cut (t)	Feed rate (f)	Spindle speed (N)
1	1.897	1.413	1.363
2	1.805	1.683	1.553
3	1.500	2.410	2.590
Delta	0.092	0.997	1.227
Rank	3	2	1

Spindle speed (Delta = 1.227, Rank = 1) is the factor that has the biggest impact on mean surface roughness during wet double turning condition (Table 4.8). A depth of cut has the least impact on the mean (Delta = 0.092, Rank = 3). Similar to dry double turning condition, the lowest surface roughness value produced during wet double turning condition of specimens at t1d1N3 was determined by the level of cutting parameters. As shown in Table 4.8, the key factors that have an increasing impact on surface roughness are spindle speed, feed rate, and depth of cut. Figure 4.10 depicts the primary effect plot of the mean surface roughness value for wet double turning condition.

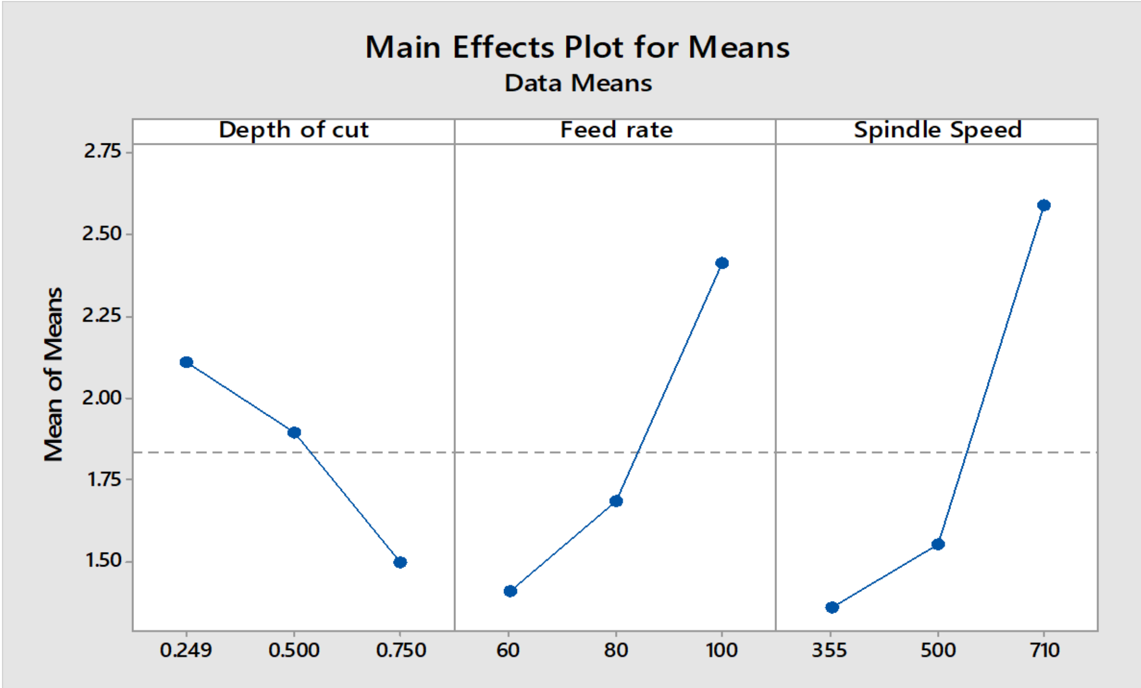


Figure 4. 10 Main effect plot of mean surface roughness for wet double turning condition

Figure 4.10 demonstrates that the ideal circumstances in which a better surface roughness is obtained are at the minimum point in the graph for each turning parameter. While the minimum point on this graph for feed rate and depth of cut was at level one, it was at level three for spindle speed. Because of this, the optimum turning parameter, t1f1N3, was found to be at low feed, low depth of cut, and high spindle speed. Three parameters are chosen by the tiny mean value in order to forecast the best response. The ideal level of parameters for surface roughness for wet double turning condition is t1f1N3. Using the following linear regression equation (4.1), the projected value of the responses (surface roughness value) is determined.

$Yopt = 1.897 + 1.413 + 2.590 - (2 * 2.109)$ -- 4.1

$Yopt = 1.682$(Predicted mean value for surface roughness of wet double turning condition)

4.6.2 Analysis of S/N Ratio for Surface Roughness for Wet double turning condition

Table 4.10 shows the response table for a surface roughness signal to noise ratio, with smaller being better for wet double turning condition.

Table 4. 9 Signal to noise ratios for smaller is better Ra for wet double turning condition

Level	Depth of cut	Feed rate	Spindle speed
	Symbol		
	t	f	N
1	-5.172	-4.094	-8.305
2	-5.763	-5.082	-5.047
3	-6.071	-7.830	-3.654
Delta	0.899	3.736	4.651
Rank	3	2	1

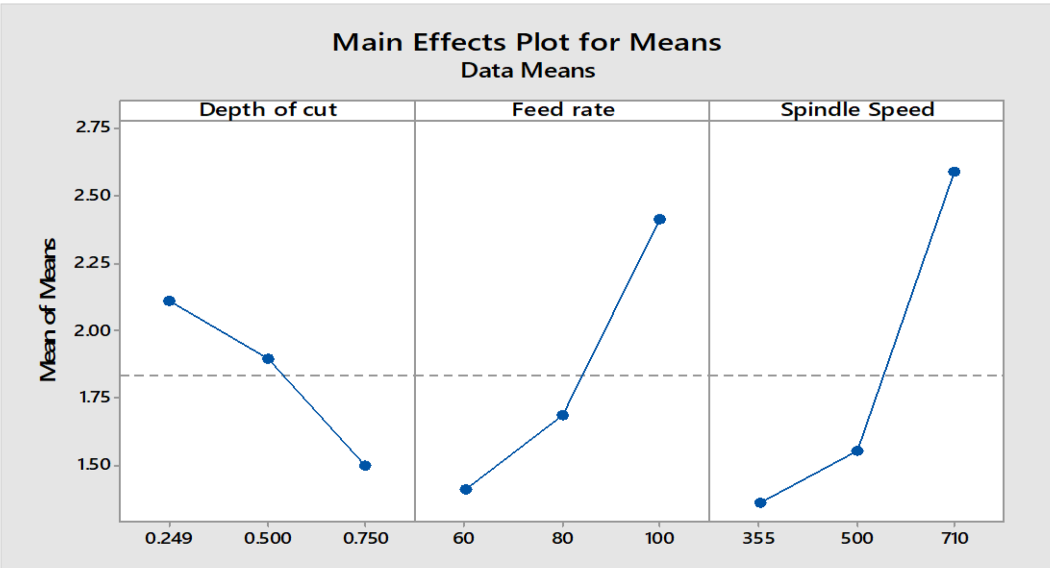


Figure 4. 11 Main effects plot of s/n ratio of Ra for wet double turning condition

Similar to dry double turning condition, the spindle speed weight percentage has the largest effect and the depth of cut has the smallest effect (Delta = 4.651, Rank = 1) on the surface roughness, as shown in Table 4. 10 and the main effect plot for the signal to noise (S/N) ratios of the wet turned surface roughness response. Delta is 0.889, and rank is 3.

The parameter combination for smaller is the better surface quality character is t1f1N3, and it's a potential parameter combination that gives the wet turned specimen with the least amount of surface roughness.

4.6.3 Determining the Optimum Condition for Wet double turning condition

The optimal parameter settings for surface roughness for wet double turning condition are shown in Table 4.10 based on the design of the experiment and experimental findings. In this investigation, the greater cutting speed, lower feed, and maximum depth of cut, which is at t1f1N3, were the chosen optimum settings.

Table 4. 10 Optimum parameters levels and their values in wet double turning condition

Factors	Level Selected	Value of the Level	Rank of affecting the Response
Depth of Cut (mm)	1	0.75	3
Feed Rate (mm/min)	1	60	2
Spindle Speed (RPM)	3	710	1

4.7 Validation of the Optimum Results for Dry and Wet double turning condition

The purpose of the confirmation experiment in this study were to validate the optimum cutting conditions. As per the DOE analysis and the improvement steps of Taguchi approach, validation experiment were performed to check the predictability of the result. By considering this, the optimum parameter are used to perform the confirmation test. The predicted surface roughness at optimum machining conditions resulted by Taguchi analysis. Also based on these machining conditions, experimental values for surface roughness were measured. Validation experiments were conducted using the optimum cutting parameters obtained from Taguchi analysis both for dry and wet double turning condition. The result of surface roughness at optimum level of cutting parameter (i.e. t1f1N3) were in Table 4. 11 below.

Table 4. 11 Comparison of the actual surface roughness with the predicted

Turning Condition	Surface Roughness Ra(µm)			
	Trial 1	Trial 2	Trial 3	Mean
Dry double turning condition	1.17	1.08	1.14	1.13
Wet double turning condition	0.85	0.8	0.78	0.81

The comparison of the actual and predicted surface roughnesses using the optimal cutting parameters is shown in Table 4.12.

Table 4. 12 Comparison between Predicted and Experimental Value

Turning Condition	Predicted Value of Ra (µm)	Experimental Value of Ra (µm)	Error %
Dry double turning condition	1.08	1.13	4.42
Wet double turning condition	0.78	0.81	3.70

Table 4.12 shows that there is very little variation between experimental and projected outcomes for both dry and wet double turning condition. The values predicted by the Taguchi technique are fairly close to the ones that were achieved experimentally. This demonstrates the remarkable correlation between the anticipated and experimental surface roughness data. The percentage error is computed by dividing the experimental value by the projected value after subtracting the experimental value. The corresponding percentage error for dry and wet double turning condition was 4.42 percent and 3.70 percent, respectively.

4.8 Analysis of Cutting Temperatures for Dry and Wet double turning condition

The experimental combinations created using the Taguchi approach are displayed in Table 4.13 For each experiment run, the temperature of the workpiece's surface was measured using an infrared thermometer. Additionally, Figure 3.6 displays the workpiece's greatest surface temperature at the cutting zone for each run of the experiment. It is clear that run number 7 with a cut depth of 0.25mm and a spindle speed of 710 rpm, both during dry and wet double turning condition circumstances, recorded the workpiece's highest surface temperature.

Observations of all the experimental runs show that the feed rate has a very minor impact on the cutting temperature, whereas the depth of cut and cutting speed have a larger impact. This might be explained by the cutting inserts' failure to keep their precise cutting geometry at higher spindle speeds and cut depths. The experiments clearly showed that the inserts maintained the least cutting temperatures at the lowest cut depth and spindle speed levels. Furthermore, there is a good likelihood that the built-up edge (BUE) was created at a faster spindle speed, which led to the tool having more dull cutting edges and, as a result, greater cutting temperatures(Reis et al., 2007).

Table 4. 13 Experimental result of cutting temperature for dry and wet double turning condition

Exp't No	Depth of Cut (mm)	Feed Rate (mm/min)	Spindle Speed (rpm)	Temperature (^{0}C)	
				Dry	Wet
1	0.75	60	355	38.2	24.2
2	0.75	80	500	43.4	25.8
3	0.75	100	710	53.8	28.3
4	0.5	60	710	45.0	26.4
5	0.5	80	500	58.3	27.0
6	0.5	100	355	41.8	25.6
7	0.25	60	710	59.2	28.1
8	0.25	80	500	44.1	26.4
9	0.25	100	355	35.60	27.2

The cutting temperature values for each specimen were recorded during both dry and wet double turning condition, as can be shown in Table 4.13. With a high spindle speed of 710rpm and a depth of cut of 0.25 mm for dry double turning condition, the maximum cutting temperature (59.20C) was established. For wet double turning condition, the maximum cutting temperature (28.30C) was attained with a spindle speed of 355 rpm and feed rate of 100 mm/min. For dry double turning condition, a spindle speed of 355 rpm, a cut depth of 0.25mm, and a feed rate of 60mm/min were used to achieve the minimum cutting temperature of (35.60C). Similar to dry double turning condition, the minimal cutting temperature (24.20C) was attained at 355 rpm spindle speed, 0.75mm cut depth, and 60mm/min feed rate. As a result, the resultant cutting temperature rises as spindle speed increases. However, applying coolant while rotating significantly lowers the cutting temperature.

4.8.1 Comparison of Cutting Temperature for Dry and Wet double turning condition

Figure 4.12 depicts the contrast cutting temperature for dry and wet double turning condition. The bar graph demonstrates that wet double turning condition had a lower cutting temperature than dry double turning condition. The results of computing the average of all temperature results saved during dry and wet double turning condition were 48.14 ^{0}C and 26.54 ^{0}C, respectively. According to the findings, wet double turning condition has an average cutting temperature that is 44.86 percent lower than dry double turning condition. To remove the heat created during machining, the cutting fluid enters the cutting zone. The workpiece and tool surface cool as a result. Additionally, the results imply that lubricating the contacting surfaces with cutting fluids in the cutting zone reduces friction, which tends to lower cutting temperature.

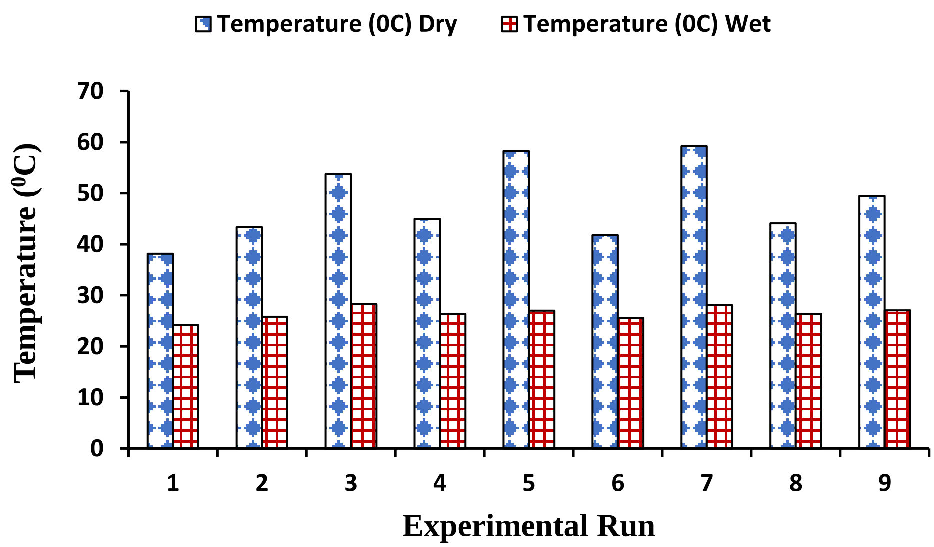


Figure 4. 12 Cutting temperature value for each experimental run

4.8.2 Analysis of Effect Cutting Parameters on Cutting Temperature

Table 14.displays the average cutting temperature for each cutting parameter (depth of cut, feed rate, and spindle speed) for dry double turning condition. Figure 4.12 displays the main effect plot for mean cutting temperature.

Table 4. 14 Mean cutting temperature for dry double turning condition

Level	Depth of Cut	Feed Rate	Spindle Speed
	Symbol		
	t	f	N
1	43.13	45.47	39.37
2	46.37	46.60	43.97
3	**48.93**	**46.37**	**55.10**
Delta	5.80	1.13	15.73
Rank	2	3	1

Depth of cut increased to 0.25 mm, and then increased to 50.93 ^{0}C as the depth of cut increased to 1.00 mm. However, it was decreasing as the feed rate increased from the first level to the second level and increasing as feed rate increased to the third level. The mean cutting temperature climbed from 47.47 ^{0}C to 48.60 ^{0}C as feed rate increased from 60 mm/min to 80 mm/min, and subsequently reduced to 48.37 ^{0}C as feed rate increased to 100 mm/min. The mean cutting temperature climbed from 41.370C to 45.97 ^{0}C as spindle speed went from 355rpm to 500rpm, and then to 57.10 ^{0}C as spindle speed increased to 710 rpm.

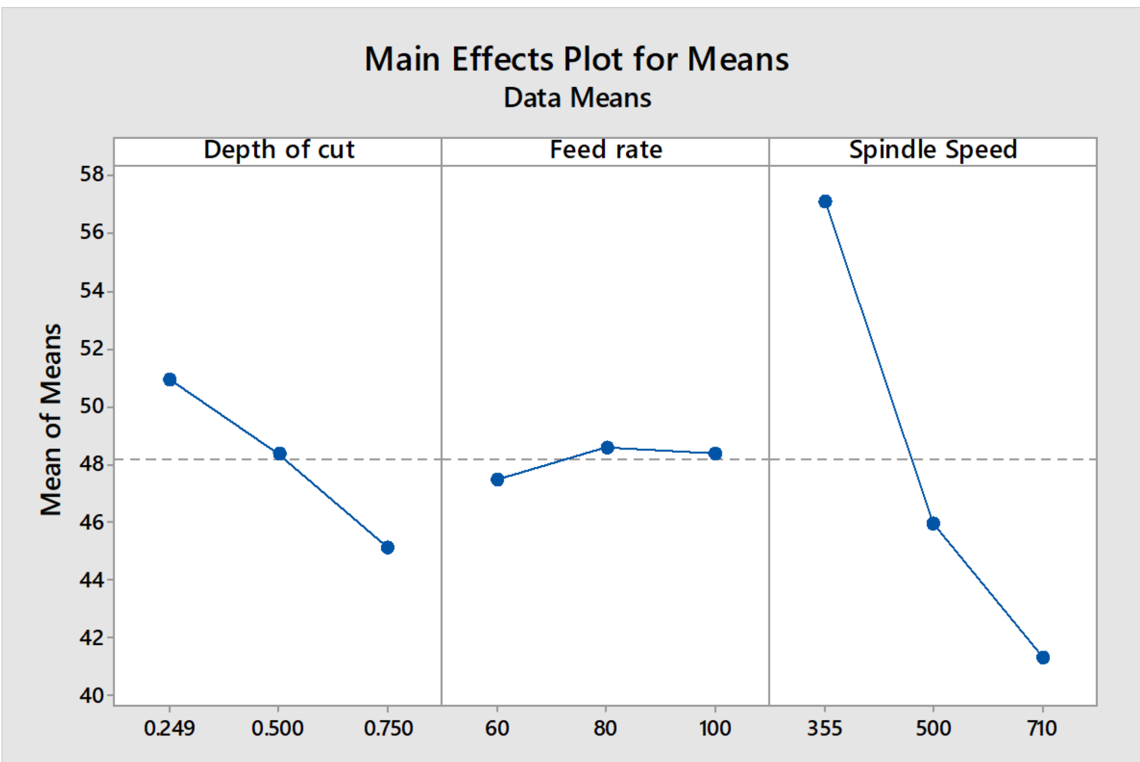


Figure 4. 13 Main effects plot of cutting temperature for dry double turning condition

Spindle speed, depth of cut, and feed rate had larger slopes on the main influence plot for mean temperature for dry double turning condition than did feed rate. This suggests that spindle speed and depth of cut had a greater impact on cutting temperature than feed rate. The graph also shows that the most important factor affecting the cutting temperature was spindle speed. The same thing was shown in Table 4.16, where the value of delta spindle speed showed that feed rate and depth of cut came in second and third, respectively. The average impact of each cutting parameter on cutting temperature for wet double turning condition is shown in Table 4.15

Table 4. 15 Mean cutting temperature for wet double turning condition

Level	Depth of Cut	Feed Rate	Spindle Speed
	Symbol		
	t	f	N
1	24.10	24.23	23.40
2	24.33	24.40	24.43
3	25.20	25.00	25.80
Delta	1.10	0.77	2.40
Rank	2	3	1

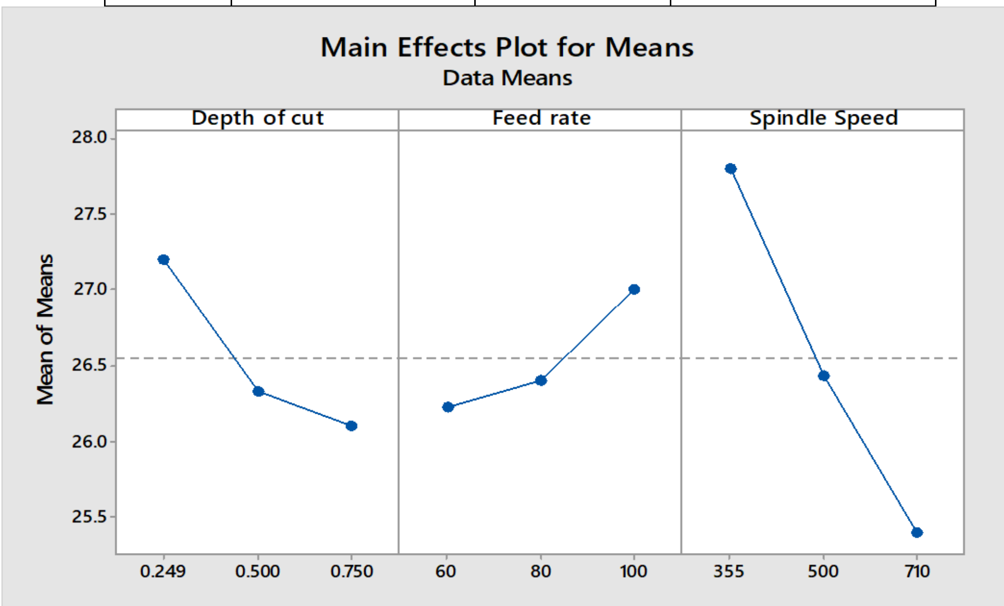
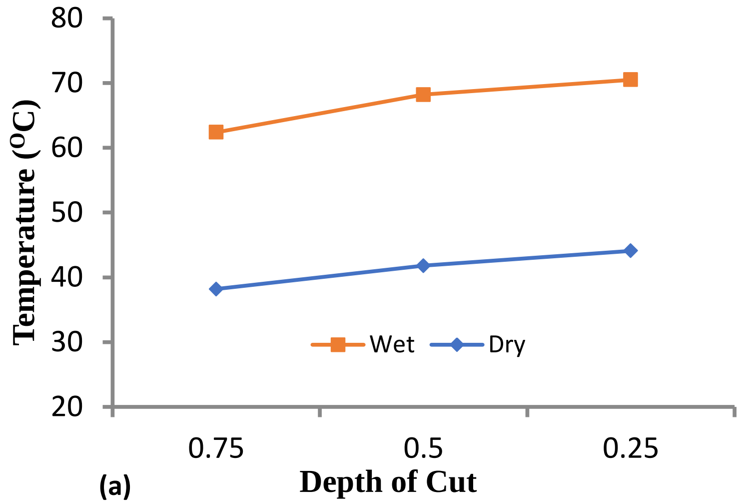
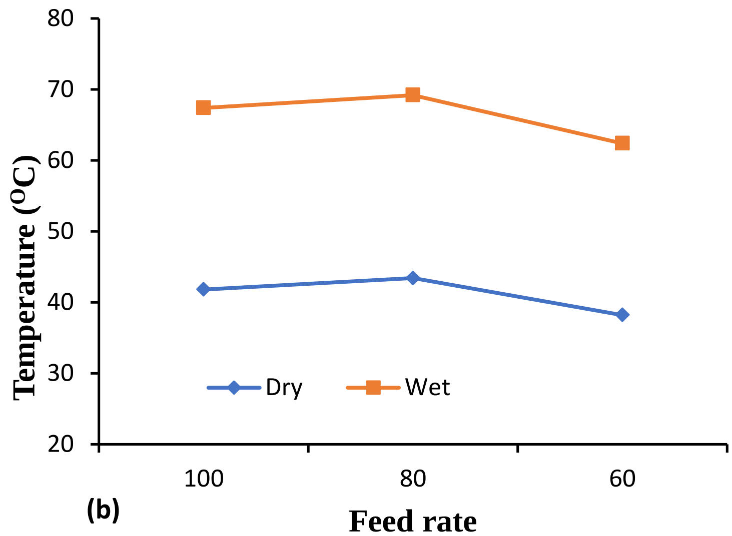


Figure 4. 14 Main effects plot of mean cutting temperature for wet double turning condition

Similar to dry double turning condition, the influence of cutting settings on the mean cutting temperature for wet double turning condition is shown in Table 4.15 and Figure 4.14. The graph demonstrates that the mean cutting temperature increased as the cutting parameters increased, i.e., as the depth of cut grew from 0.25mm to 0.5mm, the mean cutting temperature climbed from 26.10 ^{0}C to 26.33 ^{0}C and then to 27.20 ^{0}C as the depth of cut increased to 0.75mm.





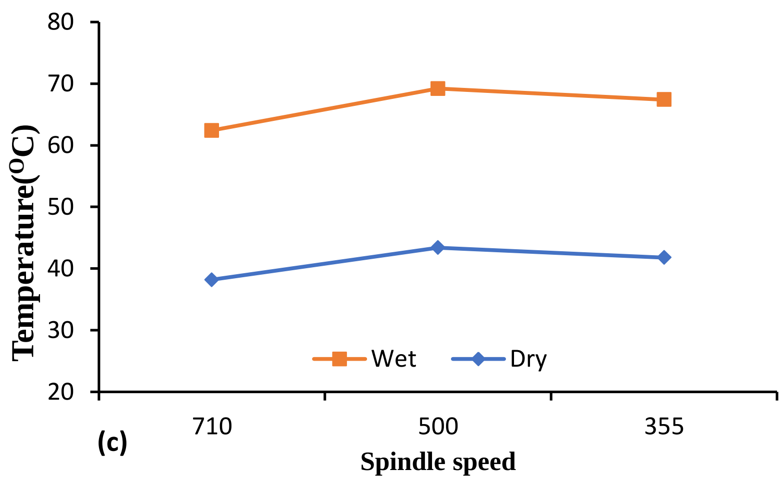


Figure 4. 15 Mean effect of (a). Depth of Cut, (b) Feed Rate (C) Spindle speed

The mean cutting temperature rose from 26.23 ^{0}C to 26.40 ^{0}C as feed rate climbed from 60mm/min to 80mm/min, and subsequently rose to 27.0 ^{0}C when feed rate increased to 100mm/min. The mean cutting temperature climbed from 25.40 ^{0}C to 26.46 ^{0}C and then to 27.80 ^{0}C when spindle speed increased to 710 rpm. This increase occurred as spindle speed went from 355 rpm to 500 rpm. The mean cutting temperature was strongly influenced by spindle speed, followed by depth of cut and spindle speed, according to the slope of the main effect plot in Figure 4.15. and the value of the delta in Table 4.15. Figure 4.15 (a), (b), and (c) compare the average effects of the various cutting parameters depth of cut, feed rate, and spindle speed on cutting temperature for dry and wet double turning condition operations. Mean cutting temperature increasing with increasing all cutting parameters s shown in Figure Figure 4.15 The cutting temperature was highly reduced for wet double turning condition, due to cooling effect of cutting fluid, which absorb heat from the cutting zone.

4.8.3 Analysis of Variance for Cutting Temperature

Analysis of Variance was done to identify the significant factors which affects the cutting temperature of the dry and wet turned specimens. It was calculated and reported in Table 4.15 and 4.16 for dry and wet double turning condition respectively. Percent contribution for each factor were calculated by Equation (3.4)

Table 4. 16 Analysis of variance of cutting temperature for dry double turning condition

Source	DoF	SS	MSS	F-Value	P-Value	Percentage Contribution
Depth of Cut (mm)	2	50.682	25.341	31.63	0.031	11.34%
Feed Rate (mm/min)	2	2.149	1.074	1.34	0.427	0.48%
Spindle Speed (RPM)	2	392.649	196.324	245.07	0.004	87.82%
Error	2	1.602	0.801			0.36%
Total	8	447.082				100%

Cutting temperature % contributions from each factor during dry double turning condition of ALSI 1020 specimens are shown in Table 4.16 and Figure 4.16. It is noted that the feed rate (0.48%), spindle speed (87.82%), and depth of cut weight percentage (11.34%) all have a substantial impact.

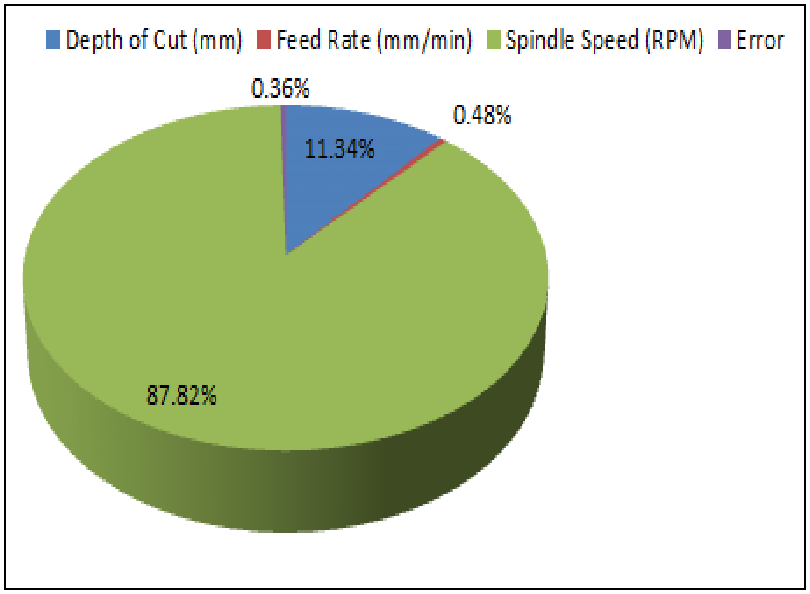


Figure 4. 16 Percentage contribution of cutting parameters to cutting temperature for dry double turning condition

The F-value result demonstrates that at a 95% confidence level, spindle speed has the greatest impact on cutting temperature, followed by depth of cut. However, in dry double turning condition conditions, the effect of feed on the cutting temperature is essentially nonexistent.

Table 4. 17 Analysis of variance of cutting temperature for wet double turning condition

Source	DoF	SS	MSS	F-Value	P-Value	Percentage Contribution
Depth of Cut (mm)	2	2.0156	1.0078	1.53	0.395	15.50%
Feed Rate (mm/min)	2	0.9756	0.4878	0.74	0.574	7.50%
Spindle Speed (RPM)	2	8.6956	4.3478	6.61	0.131	66.88%
Error	2	1.3156	0.6578			10.12%
Total	8	13.0022				100%

$F_{0.05, 2, 8} = 4.26$

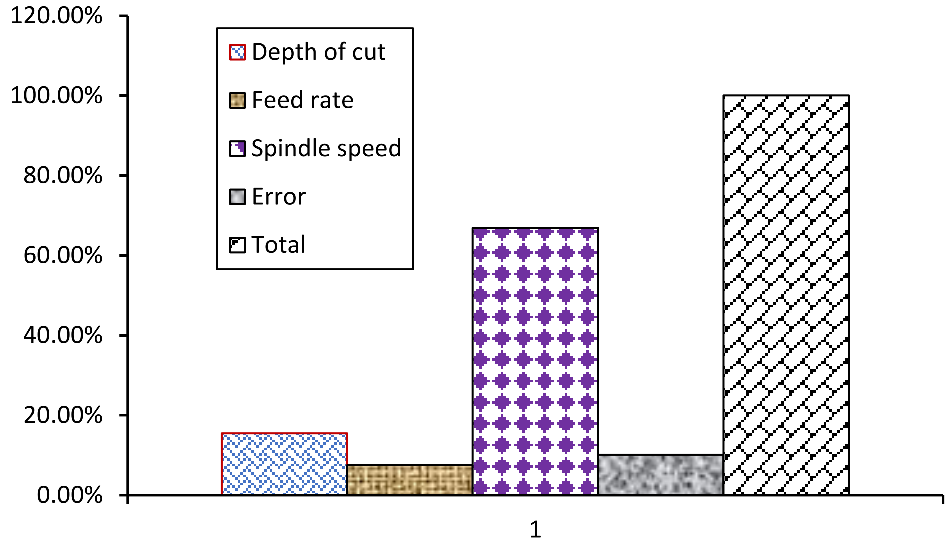


Figure 4. 17 Percentage contribution of cutting parameters to cutting temperature for dry double turning condition

In Table 4. 17 and Figure 4. 17 for cutting temperature, the percentage contributions of each factor during the wet double turning condition of ALSI 6082 are displayed. It is demonstrated that the depth of cut weight percentage (15.50%), feed rate (7.50%), and spindle speed have a substantial impact on cutting temperature (66.88 percent). Along with the percent contribution, Table 4.18 also included the F-value and P-value. The data shown in the table indicate that spindle speed, followed by depth of cut, had the greatest influence on cutting temperature at a 95% level of confidence within the limits of the particular test range. However, feed has almost no effect on the cutting temperature, even under damp turning conditions. Comparing spindle speed to dry double turning condition and wet double turning condition, the latter exhibited a higher percentage contribution from spindle speed.

4.9 Analysis of Tool Life

In general, tool life refers to how long a cutting edge or new tool will function satisfactorily before being deemed inoperable. The amount of time the instrument can be utilized to cut is what this term refers to. One method of defining tool life is operating the tool until eventual catastrophic failure. However, in a production setting it is frequently counterproductive to continue using the tool until this failure happens due to challenges with re-sharpening the tool and poor work surface quality. Alternately, the tool can be replaced when the degree of wear specified as a criterion of tool life is reached. A convenient tool life criterion is a certain flank wear value of 0.5 mm. Tool life is always assessed or expressed by span of machining time (T) in minutes.

The tool life for each experimental run was determined for both dry double turning condition and wet double turning condition using the Taylor tool life equation, VTnfatb = C. Where C is constant and n, a, and b are the exponents of Taylor's tool life. The materials used to produce the tools have a major impact on the values of "n" and "C," whereas "a" and "b" are affected by both the cutting environment and the materials used to make the tools (cutting fluid application). The typical values for cemented carbide tools used in practice to machine aluminum (low carbon aluminum) as the work piece are shown in Table 4. 18 (Caggiano et al., 2018)(Al-dulaimi et al., 2016).

Table 4. 18 Taylor tool life equation constant values

Cutting Conditions	Taylor tool life equation constants			
	C	n	a	B
Dry double	500	0.25	0.30	0.15
Wet double	500	0.25	0.45	0.2

For each run of the experiment, the tool life for dry and wet double turning condition was computed as shown in Table 4.18. According to the table, in both dry and wet double turning condition conditions, the longer tool life was obtained when all cutting parameters were at their lowest levels. When all parameters are set to their lowest levels during the first trial run (0.25mm of cut depth, 60 mm/min of feed rate, and 500 RPM of spindle speed), the maximum tool life of 14.22 minutes for dry double turning condition and 43.60 minutes for wet double turning condition is reached.

4.9.1 Comparison of Tool Life for Dry and Wet double turning condition

Figure 4.18 depicts a comparison of the tool life for dry and wet double turning condition. The bar charts demonstrated that longer tool lives were attained during wet double turning condition due to the coolant's role in cooling the cutting region, which contributes to longer tool lives. This supports (Al-dulaimi et al., 2016),'s finding that cutting tool life is exceptionally long when using low cutting parameters for machining. It also supports the finding of (Isik, 2010), who found that decreasing tool wear increases tool life, which in turn lowers cutting zone temperature and improves chip tool interaction. For both dry and wet double turning condition, the maximum tool life was attained at the lowest spindle speed (500 rpm). As previously mentioned, an increase in spindle speed tends to raise the cutting temperature, which shortens the life of the tool. As demonstrated in Figure 17, cutting temperatures were lower in trial runs 1, 6, and 8. On the other hand, tool life values were higher at this time. Similar results were obtained for experiment runs 3, 5, and 7 at the minimal tool life, as shown in Figure 4.17. The findings demonstrate that greater spindle speeds tend to raise cutting temperatures, which shorten tool life.

Table 4. 19 Tool life result for dry double turning condition

S/n	Cutting Parameters			Tool Life (min)	
	Depth of Cut (mm)	Feed Rate (mm/min)	Spindle Speed (rpm)	Dry double turning	Wet double turning
1	0.25	60	355	14.22	43.60
2	0.25	80	500	8.09	12.33
3	0.25	100	710	6.44	7.30
4	0.5	60	500	7.95	10.95
5	0.5	80	710	6.31	6.73
6	0.5	100	355	9.68	17.01
7	0.75	60	710	6.40	6.76
8	0.75	80	355	9.76	16.35
9	0.75	100	500	6.68	7.33

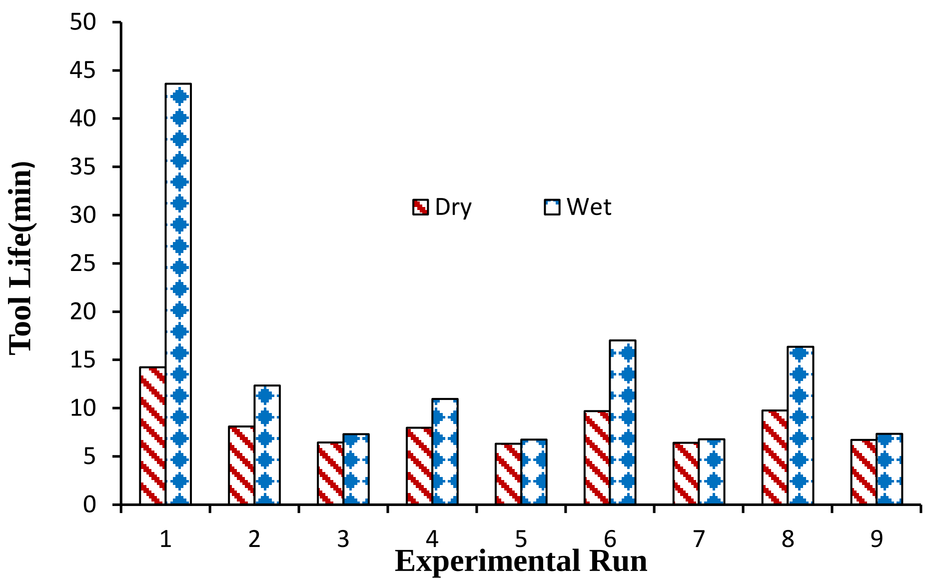


Figure 4. 18 Tool life for each experimental run

4.9.2 Analysis of Effect of Cutting Parameters on Tool Life

The average tool life for dry double turning condition is shown in Table 4.20. The life of the cemented carbide tool during dry double turning condition of ALSI 6082 is shown to be reduced when all cutting parameters depth of cut, feed rate, and spindle speed increase. The value of delta shows that spindle speed was the main element influencing tool life.

Table 4. 20 Means of tool life for dry double turning condition

Level	Cutting Parameters		
	Depth of Cut	Feed Rate	Spindle Speed
1	9.383	9.322	11.021
2	7.780	7.953	7.373
3	7.413	7.402	6.182
Delta	1.970	1.920	4.839
Rank	2	3	1

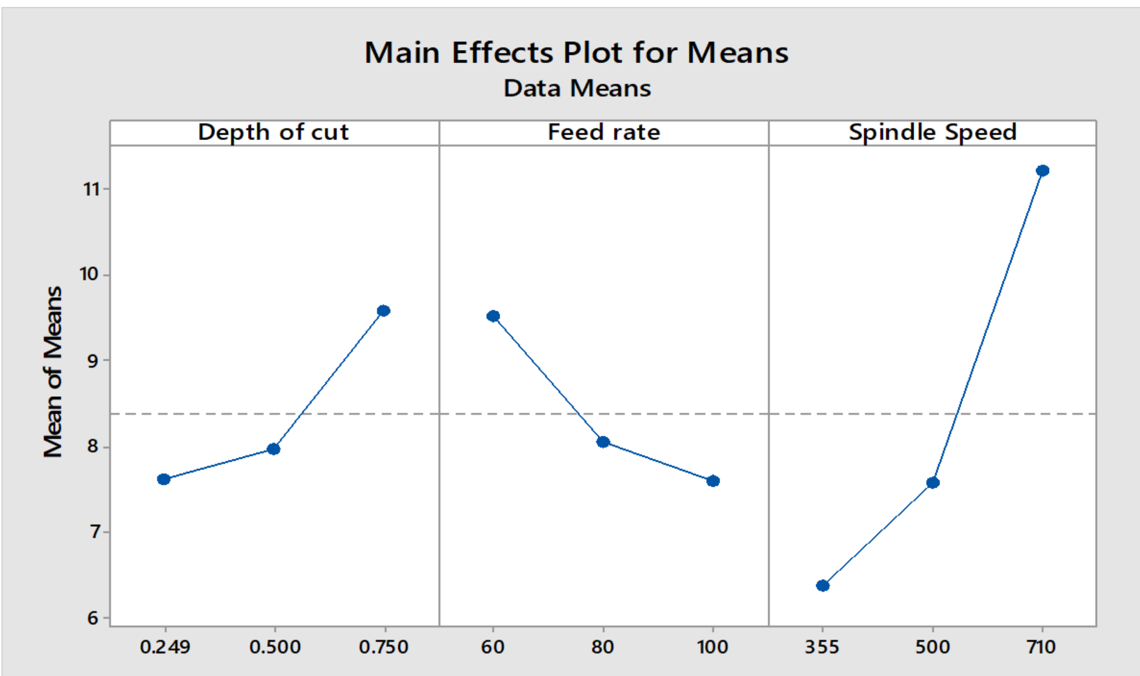


Figure 4. 19 Main effects plot for means of tool life for dry double turning condition

The key influence plot for tool life during dry double turning condition is depicted in Figure 4.19 when can be seen from the graph, all of the graph's slopes are negative, which means that as the value of each cutting parameter was increased, the tool's lifespan decreased. Table 4.21 for wet double turning condition provides the mean effect response of each parameter at each level. The delta value shows that, similar to dry double turning condition, spindle speed has the greatest influence on tool life, followed by feed rate and depth of cut. The outcome demonstrates that tool life decreased as each cutting parameter's level increased.

Table 4. 21 Means of tool life for wet double turning condition

Level	Cutting Parameters		
	Depth of Cut	Feed Rate	Spindle Speed
1	20.778	20.238	25.455
2	11.361	11.603	10.002
3	9.947	9.747	6.729
Delta	10.931	9.891	18.726
Rank	2	3	1

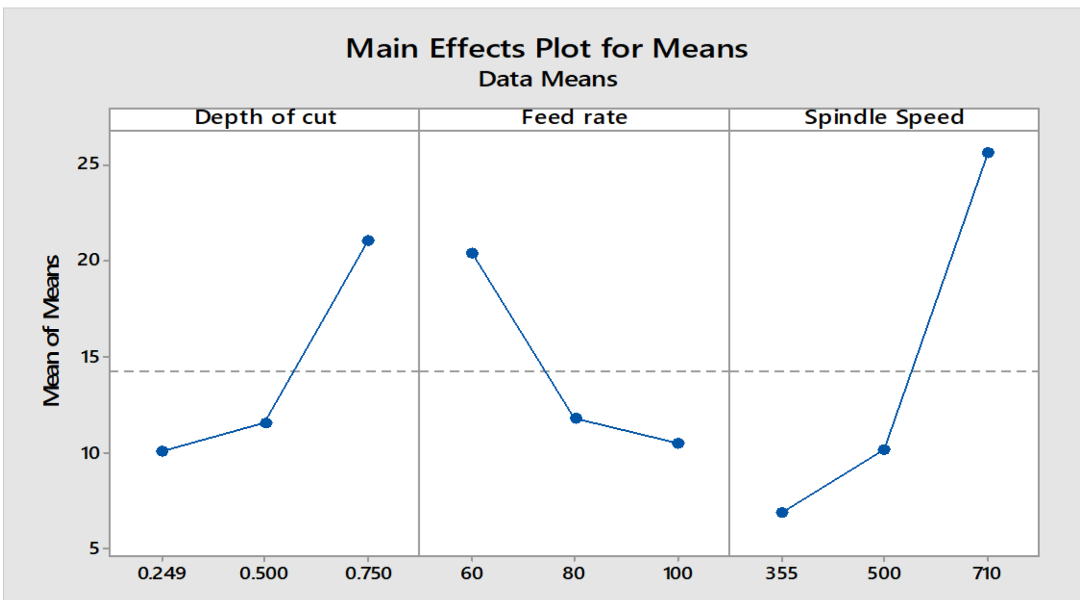


Figure 4. 20 Main effects plot for means of tool life for wet double turning condition

The primary influence plot for tool life for wet double turning condition is shown in Figure 4.20 The plot shows that as all the cutting parameters were increased, the tool's life began to shorten. The plot illustrates that while the lowest tool life is acquired at the maximum level of all cutting parameters, the longest tool life is obtained at the least level of all cutting parameters.

5. Conclusions and Recommendations

5.1. Conclusions

In this experimental study, to reduce surface roughness, cutting parameters have been optimized. In order to achieve the best surface finish possible when double turning AlSi 6082 under dry and wet conditions, an experimental investigation is presented in the current thesis. Due to the variation in cutting parameter values required to optimize cutting parameters during the machining process, a comparison was made to emphasize the significance of choosing the response variable to be evaluated accurately. According to the study, surface roughness increases for the range under investigation as feed rate and depth of cut rise, whereas it reduces as cutting speed rises.

The current study compared the most efficient cutting parameters for turning aluminum alloy 6082 from the American Iron and Steel Institute (AlSI) standard material for dry and wet on a traditional lathe machine. In this investigation, feed rate, depth of cut, and spindle speed were the three key cutting factors. L9 Taguchi orthogonal array design was used to examine the impact of these cutting parameters on surface roughness, cutting temperature, tool life, and machining cost. Based on information from the literature, suggestions from the tool manufacturer, current industrial practice, and experience, cutting settings were chosen. The analysis of variance (ANOVA) for each response revealed the contribution of each element. Surface roughness decreases at higher spindle speeds, and it increases by the increase of the feed rate and depth of cut both for dry and wet turning conditions. The following conclusions and findings were drawn:

- ✓ The minimum surface roughness, which was 1.13 µm in dry turning but improved to 0.81 µm in wet turning and a 28.32 percent improvement, was achieved at a depth of cut of 0.25 mm, feed rate of 60 mm/min, and spindle speed of 1100 RPM.
- ✓ According to an analysis of variance (ANOVA), spindle speed had the greatest impact on surface roughness, followed by feed rate and depth of cut, which had respective effects of 50.51 percent, 35.58 percent, and 12.35 percent for dry turning and 57.34 percent, 36.51 percent, and 4.31 percent for wet turning.
- ✓ In dry double turning, increasing the cutting parameters including the depth of cut, feed rate, and spindle speed reduced tool life and raised the temperature at which the

cutting occurs. However, the use of coolant greatly lowers the cutting temperature and lengthens the life of the tool

- ✓ Following depth of cut, spindle speed had the greatest impact on cutting temperature and tool life. For dry and wet turning, respectively, it contributed 88.82 percent and 66.88 percent of the cutting temperature. It provided 54.70 percent to wet turning and 72.19 percent to dry turning in terms of tool life.
- ✓ Dry turning had a lower overall machining cost than wet turning because coolant was more expensive. whereas in wet turning, the cost of the coolant accounted for 70% of the whole machining expense. Wet turning was more expensive than dry turning overall, as measured by the average of all expenditures for all experimental runs, by around 56%. Spindle speed for dry turning and feed rate for wet turning had a significant impact on the overall cost of the operation.

5.2. Recommendations

The researcher offers the following suggestions based on the findings and conclusions of this study;

- The optimized turning parameters for dry and wet turning of AISI 6082 aluminum alloy can be used by the metal fabrication, automotive, and spare part manufacturing industries to produce products with the least amount of surface roughness.
- Double tool turning can be used to increase production and further the study.
- AISI 6082 aluminum has been used in this study. This can be expanded to explore the impact of cutting parameters on surface roughness, cutting temperature, tool life, and machining costs for the same level of cutting parameters under dry and wet turning.

5.3. References

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