UGC & Govt. Approved
Sonargaon University (SU)
সোনারগাঁও ইউনিভার্সিটি (এসইউ)

AN INVESTIGATION OF THE EFFECTS OF TOOL GEOMETRY ON CHIP FORMATION AND HEAT GENERATION DURING METAL CUTTING PROCESS

A Thesis
By

Md. Jahidul Islam	BME-2001020627
Md Suruj Alam	BME1902018214
Md. Elias Hossen.	BME2001020546
Amirul Islam	BME2001020628
Md.Nasimul Islam	BME1803016049

Supervisor
A M M Shamsul Alam
Associate Professor

Department of Mechanical Engineering
Sonargaon University (SU)
Dhaka-1215, Bangladesh

September 2023

AN INVESTIGATION OF THE EFFECTS OF TOOL GEOMETRY ON CHIP FORMATION AND HEAT GENERATION DURING METAL CUTTING PROCESS

Submitted by

Md. Jahidul Islam	BME-2001020627
Md Suruj Alam	BME1902018214
Md. Elias Hossen.	BME2001020546
Amirul Islam	BME2001020628
Md.Nasimul Islam	BME1803016049

Submitted to the:

A M M Shamsul Alam
Associate Professor

Department of Mechanical Engineering

Sonargaon University (SU)

In partial fulfillment of the requirement for the award of the degree of Bachelor of Science in Mechanical Engineering

September 2023

LETTER OF TRANSMITTAL

September 2023

To

A M M Shamsul Alam

Associate Professor

Department of Mechanical Engineering.

Sonargaon University, Dhaka-1215

Subject: Submission of Thesis Report**.**

Dear Sir,

We are pleased to submit the project report on **“An Investigation of the Effects of Tool Geometry on Chip Formation and Heat Generation during Metal Cutting Process ".** It was a great pleasure to work on such an important topic. This project has been done per the instruction of your supervision and according to the requirements of Sonargaon University.

We expect that the concerned authority will accept the project. We are happy to explain anything further as you may feel necessary.

Thank You

Sincerely yours,

Md. Jahidul Islam	BME-2001020627
Md Suruj Alam	BME1902018214
Md. Elias Hossen.	BME2001020546
Amirul Islam	BME2001020628
Md.Nasimul Islam	BME1803016049

STUDENT'S DECLARATION

We do hereby solemnly declare that, the work presented here in this project report has been carried out by us and has not been previously submitted to any University/ Organization for the award of any degree or certificate.

We hereby ensure that the works that have been prevented here do not breach any existing copyright.

We further undertake to indemnify the university against any loss or damage arising from a breach of the foregoing obligation.

Md. Jahidul Islam BME-2001020627	Amirul Islam BME-2001020628
Md Suruj Alam BME-1902018214	Md.Nasimul Islam BME-1803016049
Md. Elias Hossen BME-2001020546	

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project. In my opinion, this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Science in Mechanical Engineering.

A M M Shamsul Alam
Associate Professor
Department of Mechanical Engineering
Sonargaon University (SU)

ACKNOWLEDGEMENT

First, we started in the name of Almighty Allah. This thesis is accomplished under the supervision of A M M Shamsul Alam, Associate Professor, Department of Mechanical Engineering, Sonargaon University. It is a great pleasure to acknowledge our profound gratitude and respect to our supervisor for this consistent guidance, encouragement, helpful suggestion, constructive criticism, and endless patience through the progress of this work. The successful completion of this thesis would not have been possible without his persistent motivation and continuous guidance.

The authors are also grateful to Professor Md. Mostofa Hossain, Head of the Department of Mechanical Engineering, and all respectful teachers of the Mechanical Engineering Department for their cooperation and significant help in completing this project work successfully.

ABSTRACT

In any machine shop, power plant, car repair and manufacturing plant we use various types of cutting tools including Right hand turning tool, Radius turning form tool, Threading or parting tool etc. to prepare different types of equipment's. These tools got multi types of angles. In this book we tried to find out the differences when the angles is increased or decreased. Due to paucity of time we limit our study within two angles of cutting tools and tried to investigate their effects on heat generation and chip formation.

TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 Background

Turning is a form of machining, a material removal process, which is used to create rotational parts by cutting away unwanted material. In this process cutting tool, typically a non-rotary tool bit, describes a helix tool path by moving more or less linearly while the work piece rotates. The tool's axes of movement may be literally a straight line, or they may be along some set of curves or angles, but they are essentially linear. Usually the term "turning" is reserved for the generation of external surfaces by this cutting action, whereas this same essential cutting action when applied to internal surfaces (that is, holes, of one kind or another) is called "boring". Thus the phrase "turning and boring" categorizes the larger family of (essentially similar) processes known as lathing.

The cutting of faces on the work piece (that is, surfaces perpendicular to its rotating axis), whether with a turning or boring tool, is called "facing", and may be lumped into either category as a subsetTurning can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using an automated lathe which does not. Today the most common type of such automation is computer numerical control, better known as CNC. (CNC is also commonly used with many other types of machining besides turning.). When turning, a piece of relatively rigid material (such as wood, metal, plastic, or stone) is rotated and a cutting tool is traversed along 1, 2, or 3 axes of motion to produce precise diameters and depths. Turning can be either on the outside of the cylinder or on the inside (also known as boring) to produce tubular components to various geometries.

Although now quite rare, early lathes could even be used to produce complex geometric figures, even the platonic solid; although since the advent of CNC it has become unusual to use non-computerized tool path control for this purpose, The turning process requires a turning machine or lathe, work piece, fixture, and cutting tool. The work piece is a piece of per-shaped material that is secured to the fixture,which itself is attached to the turning machine, and allowed to rotate at high speeds. The cutter is typically a single-point cutting tool that is also secured in the machine, although some operations make use of multi-point tools. The cutting tool feeds into the rotating work piece and cuts away material in the form of small chips to create the desired shape.The use of metal working fluids (MWF) is an important approach to reduce tool wear and increase productivity in machining processes. The positive effect of MWF is known for a long time, and thus, MWF is commonly used especially for hard-to-cut materials. Current investigations mostly focus on the use of high-pressure cooling strategies. An increased tool-life due to high-pressure machining strategies could be shown for machining of titanium [1, 2], Inconel 718 [3, 4], and steel [5]. The main functions of MWF are cooling and lubrication. Temperature reductions in wet machining processes compared to dry processes were presented by various authors and can be attributed to several effects, e.g., reduced friction and heat absorption of the MWF [2, 6].

The influence of MWF on friction is often investigated on tribometers. Claudin et al. used an open pin-cylinder tribometer, in which the pin (cemented carbide with TiN coating) moves helical along the circumferential side of the cylinder (AISI4140) [7]. The investigations showed a reduction of the friction coefficient from $\mu = 0.5$ to $\mu = 0.15$ when using oil for low sliding velocities $vs = 10$ m/min. For high sliding velocities $vs = 300$ m/min, low friction coefficients of $\mu = 0.1–0.2$ were measured in dry and wet experiments. These results were later validated for different oil types [8] and were also confirmed in [9] with an uncoated pin. Lakner and Hardt used a defined contact between the flank face of a TiCN-coated cemented carbide tool and an AISI4140 shaft to identify the friction coefficient [10]. They determined friction coefficients $\mu = 0.2–0.3$ for dry and wet processes and sliding velocities vs = 40–120 m/min.

All tribometer tests have in common that the local varying boundary conditions (normal loads, process temperatures, sliding velocities) differ from the real cutting process. Thus, deviations compared to the friction in actual cutting processes can occur.
Although a large number of publications deal with the advantages of MWF, investigations on the influence of MWF on local loads and chip formation are very limited due to the limited visibility of the cutting process when using MWF. Many researchers found improved chip breakage and an increased chip curl, which also indicates reduced contact lengths [5, 11]. In regard to reduced tangential stresses on the rake face due to the lubrication of MWF, Childs [12] and Williams and Tabor [13] stated that the penetration depth of the MWF in contact area between chip and rake face is very low. However, the

penetration depth might be increased by increasing the roughness of the rake face [12]. In summary, there is a lack of investigations concerning the influence of the MWF on chip formation, e.g., contact lengths and plowing forces resulting from the minimum chip thickness hmin. A detailed analysis of the chip formation process and process forces, however, could enable quantitative and qualitative statements about mechanical stresses on the cutting wedge [14].

Thereby, more detailed knowledge about the influence of MWF on friction phenomena in cutting processes could be generated. In this paper, a novel test setup is introduced, which allows high-speed recordings of the chip formation process on a planing test rig during wet machining. The MWF is brought to the tool rake face with high-pressure by a self-developed accumulator system. Using a high-speed camera and a three-component dynamometer, statements can be made about the chip formation process and mechanical loads during chip formation.

1.2 Objectives

The main objectives of this project are pointed out below:

- To gather knowledge through study materials on metal cutting processes, chip formation, and losses involved in metal cutting, etc. for our investigations.
- To investigate of the effects of tool geometry (tool angles) on chip formation**.**
- To investigate of the effects of tool geometry (tool angles) on heat generation.

1.3 Motivation

The main motivations for an Experimental analysis of using different types of angle for different types of cutting tools can be summarized as follows: Enhance manufacturing efficiency by optimizing cutting processes and reducing tool wear. Minimize tool replacement costs and improve material utilization. Ensure a safer workplace environment by controlling chip formation and reducing hazards. Improve surface finish and precision of machined parts. Reduce energy consumption and material waste in machining. Gain a competitive edge in industries where precision machining is crucial.Contribute to scientific knowledge in materials science and engineering. These motivations highlight the practical, economic, safety, and academic reasons for conducting this research project.

1.4 Structure of the Project

This Project is organized as follows:

Chapter 1 Introduction**:** The first chapter contains the statement of the introduction, our background study for the project, problem statement, objectives of the study and the project outline.

Chapter 2 Literature Review**:** The chapter two contains our introduction, literature review part.

Chapter 3 Metal cutting process**:** Chapter three describes elaborately about our experimental analysis as well as pros and cons. Features working procedure and description of our all equipment's.

Chapter 4 Methodology**:** Chapter four describes the theoretical model. Here we mainly discuss about proposed system, sample selection, experimental setup & procedure etc.

Chapter 5 Findings **:** Chapter five deals with the finding from our investigation.

Chapter 6 Conclusion**:** Chapter six all about discussion and discuss about our project advantage and applications.

Chapter 7 Conclusion: This chapter is all about conclusion and future scope.

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter is arranged on Literature Review. Here's a look at some of last year's literature, like our project. By reading them, we can overcome the mistakes of the previous project and make a more effective project.

2.2 Related Research/ Works

2.1 The Review of Major Research on Chip Formation It has become the elementary knowledge of chip control investigators that there exists a very close relationship between chip flow, chip curling and chip breakage. These components are the basic elements of chip formation. In the past, all the elements were respectively studied in certain machining conditions and their internal relation was investigated in some of the research. The process of chip formation has been investigated by several notable researchers since the beginning of the century.

The early work by F.W. Taylor in 190 in which he introduced an empirical approach to metal cutting, is still regarded as significant in metal cutting research and applications (Taylor, 1907). Since then a number of researchers have developed cutting models and presented theories on chip formation. The chips produced in metal cutting belong to the following model-based classes of chip formation: (1) quasi-static 2-D chip formation models for continuous chips; (2) dynamic 2-D chip formation models for segmented chips and elemental chips; (3) 3-D chip formation models for continuous chips.

The basic aim of the theoretical research in metal machining is to provide a comprehensive system of ideas and procedures upon which the future technology of metal cutting is expected to operate. Some of the research effort is also of immediate applicability thus providing a rational basis for many rules sanctioned hitherto by experience. It is well known that the central problem of the chip formation mechanism is that it involves a complicated process of plastic deformation. Almost all of the major metal cutting theories known to the world today are based on the orthogonal cutting process producing a continuous chip. While it is fully acknowledged that these theories have in the past laid a strong foundation in our understanding of the process of metal cutting, it is also to be recognized that recent advances in automated machining systems n o w inevitably require the modelling, predicting, and monitoring of the process of chip breaking for which the traditional theories on chip formation need to be extended in three ways: (1) to include the dynamics of the chip formation process; (2) to develop three-dimensional chip formation models; and (3) to include chip breaking (van Luttervelt, 1977).

To accomplish these major objectives it is essential to understand the mechanisms and mechanics of chip flow, chip curling and chip breakage. Chip formation is part of the process of cutting materials by mechanical means, using tools such as saws, lathes and milling cutters. An understanding of the theory and engineering of this formation is an important part of the development of such machines and their cutting tools. The formal study of chip formation was encouraged around World War II and shortly afterwards, with increases in the use of faster and more powerful cutting machines, particularly for metal cutting with the new high speed steel cutters. Pioneering work in this field was carried out by Kivima (1952) and Franz (1958).[1][2].

Chip formation is usually described according to a three-way model developed by Franz. This model is best known within the field of machine tool design, although it is also used when an application area, such as woodworking, requires a vocabulary to describe chip formation in more detail than is usually attempted.[3][4] Many surveys have been done considering different rake angles. Researchers have long investigated its effect on cutting forces, temperature and tool life etc. The works of various authors from various fields have been referred from 2000 onwards. In this paper, previous research and important findings in the orthogonal machining process is critically reviewed.

Peng Lo 2000[5] worked on the elastic plastic finite element method so as to investigate the effect of tool rake angle on the chip formed and the machined work piece in precision cutting process. The results indicates that with increase in rake angle cutting force, maximum equilent strain on the section decreases and top of the chip contour become smoother. McClain et al. 2002 [6] focused on the shear and normal stress distribution in orthogonal metal cutting by the help of FEM (Finite Element Model) Fang and Jawahir 2002 [7] predicted three important machining parameters, i.e. the cutting force ratio, chip thickness, and chip back-flow angle, on the basis of: the universal slip-line mode. Again Fang 2002 [8] discussed and analyzed the forces, chip thickness, and natural tool–chip contact length in machining with a double-rake-angled tool and demonstrated that double-rake-angled tool increases the thrust forces in comparison with single rake angled tool. It is found that tool–chip friction on the tool secondary rake face plays an important role in machining than the tool–chip friction on the tool primary rake face.

Tool chip length is one of the important parameter in orthogonal cutting. Toropov and Lim Ko 2003[9] they proposed a new formula for tool chip contact length as a result there is same correspondence between theoretical and experimental results. This research could also be helpful for the analysis of, temperature phenomena, tool strength and wear problems. Fang 2002 [10] proposed a slipline model in favor of the tool–chip contact on the tool secondary rake face. Chip curl in

2.3 Summary

The above has been discussed in detail in the past few literature's which has given us a lot of motivation to do this project.

CHAPTER 3
METAL CUTTING PROCESS

3.1 Introduction

In this section, we will discuss elaborately about our experimental analysis of using different angles and the consequent as well as pros and cons. Also description, features, working procedure and description of our all equipment.

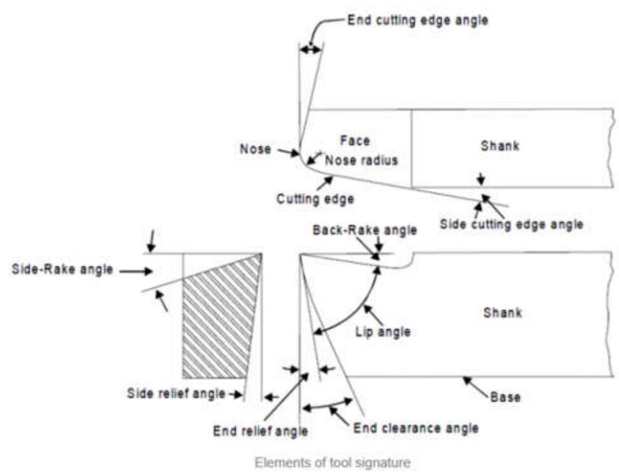


Figure 3.1: Nomenclature and Tool Signature [B.L.; Seth, Nitin and Sekhon, "Fundamentals of Metal Cutting and Machine Tools, mechanics of machining process",2nd Edition,2003]

3.2 Different Types of Rake Angle

(i) Back rake angle:

Back rake angle is the angle between the face of the single point cutting tool and a line parallel with base of the tool measured in a perpendicular plane through the side cutting edge. If the slope face is downward toward the nose, it is negative back rake angle and if it is upward toward nose, it is positive back rake angle. Back rake angle helps in removing the chips away from the work piece.

(ii) Side rake angle:

Side rake angle is the angle by which the face of tool is inclined side ways. Side rake angle is the angle between the surface the flank immediately below the point and the line down from the point perpendicular to the base. Side rake angle of cutting tool determines the thickness of the tool behind the cutting edge. It is provided on tool to provide clearance between work piece and tool so as to prevent the rubbing of work piece with end flake of tool.

(iii) End relief angle:

end relief angle is defined as the angle between the portion of the end flank immediately below the cutting edge and a line perpendicular to the base of the tool, measured at right angles to the flank. End relief angle allows the tool to cut without rubbing on the workpiece.

(iv) Side relief angle:

Side rake angle is the angle between the portion of the side flank immediately below the side edge and a line perpendicular to the base of the tool measured at right angles to the side. Side relief angle is the angle that prevents the interference as the tool enters the material. It is incorporated on the tool to provide relief between its flank and the work piece surface.

(v) Side cutting edge angle:

Side cutting edge angle is the angle between straight cutting edge on the side of tool and the side of the shank. It is responsible for turning the chip away from the finished surface

The seven elements that comprise the signature of a single point cutting tool are always stated in the following order:

- Back rake angle (0°)
- Side rake angle (7°)
- End relief angle (6°)
- Side relief angle (8°)
- End cutting edge angle (15°)
- Side cutting edge angle (16°) and
- Nose radius (0.8 mm)

- It is usual to omit the symbols for degrees and mm, simply listing the numerical value of each component in single point cutting tool (15)

3.3 Advantage of Positive rake angles

1. Reduced Cutting Forces: Positive rake angles, where the cutting edge is inclined upward, can reduce cutting forces, making machining more efficient and reducing tool wear. This is often discussed in machining textbooks under sections on cutting forces and tool geometry.

2. Improved Chip Control: A larger positive rake angle promotes chip curling and breaking, leading to better chip control and management. This is an important topic covered in machining textbooks in the context of chip formation.

3. Enhanced Tool Life: Positive rake angles can reduce tool wear and extend tool life, especially when machining materials that are prone to adhesion or built-up edge formation. Tool wear mechanisms and tool life are discussed in machining and materials science text (16)

3.4 Disadvantage of Positive rake angles

1. Increased Cutting Forces: Negative rake angles, where the cutting edge is inclined downward, typically result in higher cutting forces. This can put additional stress on the machine and tool, leading to wear and potentially affecting machining accuracy. You can find discussions on cutting forces and tool geometry in machining textbooks.

2. Poor Chip Control: Negative rake angles can lead to poor chip control, causing long, stringy chips that are difficult to manage and dispose of properly. This can impact machining efficiency and safety. Chip formation and control are often covered in machining textbooks.

3. Surface Finish Issues: In some cases, negative rake angles can lead to a rougher surface finish on the work piece due to increased friction between the tool and the work piece. This can affect the quality of the machined surface. Surface finish considerations are discussed in machining textbooks.

4. Tool Chipping and Breakage: Negative rake angles can make cutting tools more susceptible to chipping or breakage, especially when machining materials that are difficult to cut.(17)

3.5 Advantages of Increasing & Decreasing Rake Angle

1. Reduced Cutting Forces: Increasing the positive rake angle (making it more inclined) can reduce cutting forces, making the machining process more efficient. You can explore this topic in machining textbooks under sections discussing cutting forces.

2. Improved Chip Control: A larger positive rake angle promotes chip curling and breaking, leading to better chip control and management. Chip formation is often covered in machining textbooks.

3. Enhanced Tool Life: With the right material and application, increasing the rake angle can reduce tool wear and extend tool life. Tool wear mechanisms are discussed in machining and materials science textbooks.

3.6 Decreasing Rake Angle

1. Improved Tool Strength: Reducing the rake angle (negative rake) can increase the tool's strength and resistance to chipping, which is beneficial for machining tougher materials. Tool geometry and tool wear are topics covered in machining textbooks.

2. Enhanced Surface Finish: In some cases, decreasing the rake angle can result in a better surface finish on the work piece due to reduced friction between the tool and the work piece. Surface finish considerations are discussed in machining textbooks.

3. Stability in Interrupted Cuts: Negative rake angles can provide more stability and reduce the risk of tool failure when machining interrupted cuts or difficult-to-machine materials. This can be explored in machining textbooks.(18)

3.7 Advantage of Negative rake angles

1. Enhanced Chip Control in Certain Materials: Negative rake angles can be advantageous when machining materials that tend to form continuous chips with built-up edges (BUEs). The downward inclination helps break these chips more effectively.

2. Stability in Interrupted Cuts: Negative rake angles provide more stability when machining interrupted cuts, such as when working with cast iron or other materials with irregularities, reducing the risk of tool failure.

3. Reduced Cutting Temperatures in Certain Applications: In some cases, negative rake angles can help dissipate heat away from the cutting zone, which can be beneficial when machining heat-sensitive materials.

3.8 Disadvantage of Negative rake angles

1. Increased Cutting Forces: Negative rake angles typically result in higher cutting forces compared to positive rake angles. This can put additional stress on the machine, tool, and work piece, potentially affecting machining accuracy and tool life.

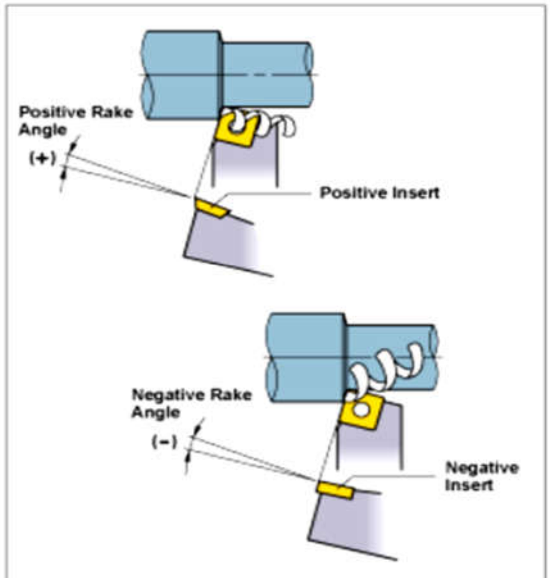
2. Poor Chip Control: Negative rake angles can lead to poor chip control, causing long, continuous chips that are difficult to manage and dispose of properly. This can impact machining efficiency and safety.

3. Reduced Heat Dissipation: Negative rake angles may hinder the effective dissipation of heat from the cutting zone. This can lead to elevated cutting temperatures, potentially affecting

3.9 FUNCTION OF TOOL FEATURES FOR TURNING

■ **RAKE ANGLE**

Rake angle is a cutting edge angle that has large



Chip Disposal and Rake Angle

Figure 3.2: Rake Angle [V. P. Astakhov,"Geometry of Single-point Turning Tools and Drills – Fundamentals and Practical Applications"]

■ Effects of Rake Angle

1. Increasing rake angle in the positive (+) direction improves sharpness.
2. Increasing rake angle by 1° in the positive (+) direction decreases cutting power by about 1%.
3. Increasing rake angle in the positive (+) direction lowers cutting edge strength and in the negative (-) direction increases cutting resistance.

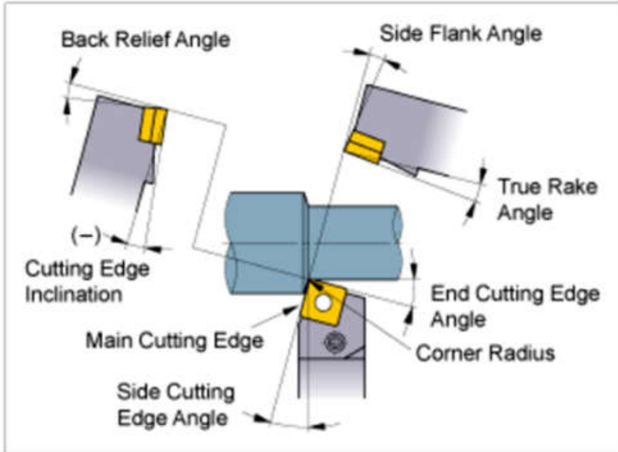


Figure 3.3: Effects of rake angle[V. P. Astakhov,"Geometry of Single-point Turning Tools and Drills – Fundamentals and Practical Applications"]

3.10 Chip Formation

Chip formation is part of the process of cutting materials by mechanical means, using tools such as saws, lathes, and milling cutters. An understanding of the theory and engineering of this formation is an important part of the development of such machines and their cutting tools. The formal study of chip formation was encouraged around World War II and shortly afterward, with increases in the use of faster and more powerful cutting machines, particularly for metal cutting with the new high-speed steel cutters. Chip formation is usually described according to a three-way model developed by Franz. This model is best known within the field of machine tool design, although it is also used when an application area, such as woodworking, requires a vocabulary to describe chip formation in more detail than is usually attempted.

3.11 Three Types of Chips Formation

(i) Continuous Chips

(ii) Continuous Chips with built-up edge, and

(iii) Discontinuous Chips

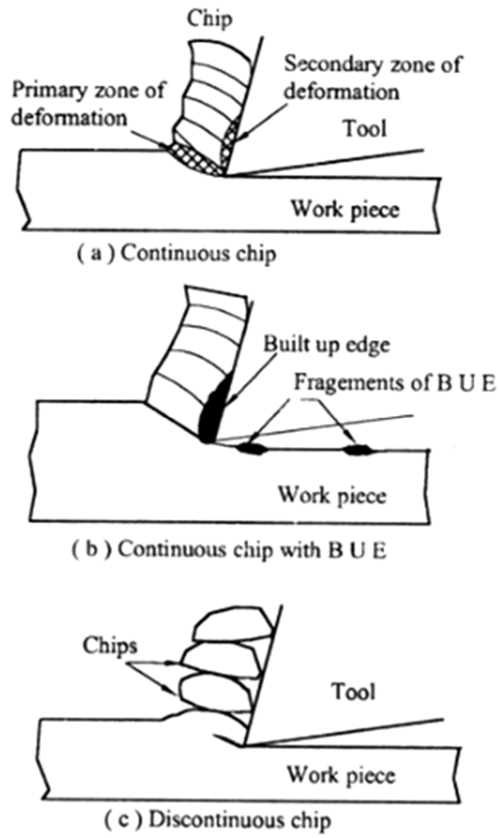


Figure 3.4: Types of Chip [M.C. Shaw, "Metal Cutting Principles"]

1. Continuous Chips

During the cutting of ductile materials like low carbon steel, copper, brass and aluminium alloys, etc., a continuous ribbon type chip is produced. The pressure of the tool makes the material ahead of the cutting edge deform plastically. It generally suffers compression and shear. The material then slides over the tool rake face for some distance and then leaves the tool. In the machining process, continuous chips are formed during the machining of ductile material with high speed and minimum friction between the tool and material. Due to continuous plastic deformation by applying the tool, this type of chip is produced. Mild steel and copper is ductile material. The thickness of the chip is equal to entire the length. It commonly provides a good surface finish. The main drawback of this type of chip is difficult to handle and dispose of. The conditions which are responsible for the formation of continuous types of chips are

- Ductile material like mild steel is used.
- The bigger rake angle of the tool.
- High cutting speed.
- Minimum friction between the chip and tool interface.
- Small depth of cut.

The extent of primary zone of deformation depends on

(i) Rake angle of tool
(ii) Cutting speed
(iii) Work Material Characteristics,
(iv) Friction on rake face.

Continuous chips: According to its name, continuous chips have a continuous segment. This chip is form during cutting of ductile material like aluminum, mild steal, cooper etc. with a high cutting speed. The friction between tool and material is minimum during this process. Continuous chips usually occur during the machining of malleable metals such as steel, copper, or aluminium at high cutting speeds. During the machining, the temperature between the tool tip and ductile work piece gets high.Continuous chip obtained when cutting of ductile material like aluminium and low carbon steel.

The chips come out without fracture in the form of either long string or bend into a tight roll. If this chip hit finished parts of the work, it spoils the finished surface.Continuous chips adversely affect surface quality, tool wear, coolant supply to the cutting point, and even operator safety, resulting in reduced machining efficiency [1]. The solution to this problem is the use of tools with chip breakers and/or the supply of a high-pressure coolant [2–4]. Continuous chips form when machining ductile materials, including mild steel, copper and aluminum. The plastic deformation of ductile material produces long, continuous chips, desirable from the perspective of cutting action because it produces good surface roughness with low power consumption and longer tool life.

2. Discontinuous Chips

In the machining process, the chips formed in a small segment or with breakage during cutting are known as discontinuous or segmented chips. Discontinuous chips are formed by using brittle or hard material in machining. Brass, bronze, and cast iron are brittle materials. Due to slow cutting speed and small rack angle, this type of chip is produced. These chips are made when the friction between the tool and the work piece is high. Discontinuous chips in ductile materials provide a poor surface finish. The discontinuous chips are easily handled and disposed of.

Here is how do discontinuous chips form during machining

1. Due to the low feed rate in the machining process.
2. The cutting speed of the machining is low.
3. High friction between chip and tool face.
4. Due to the large depth of cut.
5. The rake angle of the tool is small.

In the machining process, the chips formed in a small segment or with breakage during cutting are known as discontinuous or segmented chips. Discontinuous chips are formed by using brittle or hard material in machining. Brass, bronze, and cast iron are brittle materials. It means chips become broken pieces before it departs from the cutter.It is often happened in high brittle materials, such as cast iron or bronze.Because the chip forms then broken off promptly,which won't have pressure for the tool surface, the remainder of the irregular surface, it's easy to be cut, so it can get a more flat surface. And lower the pressure of the tool surface, less wear happened,so the tool life is longer.Such as discontinuous chip caused by higher friction coefficient or higher soft ductile materials, it means poor cutting conditions.

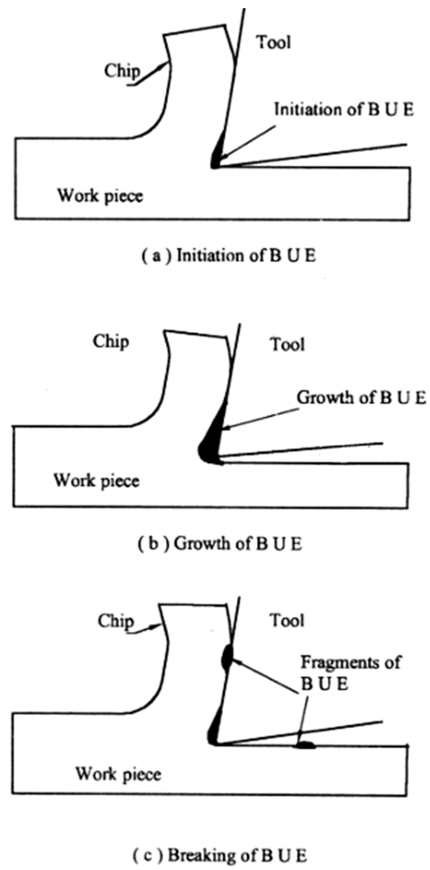


Figure 3.5: periodic variation of BUE Size and Its Fragmentation [M.C. Shaw, "Metal Cutting Principles"]

3. Continuous Chips With Built-Up Edges

In the machining process of ductile material, continuous chips are made with built-up edges when the temperature and pressure in the cutting and friction of the chip and tool face are high. It is almost similar to the continuous chips but it is rough due to the built-up edge. This function may cause the material to stick or weld to the edge of the tool.

You may wonder how it produces!

It is created, when the chip flows upward and friction between the interface of the chip and tool is high. The heat generated at the nose of the tool is very high, due to the high friction between the chip and the tool.

Hence, compressed metal fit to the tool nose is welded therefore it is known as built-up edges. If the chip flows through this built-up edge, it breaks and is sent away from the chip and is termed a built-up edge chip. The rest of the built-up edge adheres to the surface of the work piece and does it thicker.

Continuous Chips with BUE occurs:-

1. By using the ductile material while machining.
2. Due to the smaller rake angle of the tool.
1. The cutting speed of the tool is slow.
2. Lack of coolant may cause increases in friction between chip-tool faces.
3. The thickness of the chip is high.
4. Due to the high temperature between the workpiece and tool.
5. High rate of feed of the tool.

BUE, referred to the material of high soft ductile and friction coefficient during cutting process, due to the high pressure between the friction coefficient and the chip, resulting in a number of particles bonded in the surface of the tool, when cutting process goes on, there is more bonding material accumulation, at last the chips drained away when it accumulates into the appropriate height, or it embedded itself in a part of the work surface. Since this effect is recurrent in period, so the shine and smooth of the machined surface much lower than continuous chip surface. In general, this phenomenon can be reduced by reducing the chip thickness and increasing the inclination.

- Reasons for cause of continuous chip formation in the crumbs of blade:
- The cutting speed is too low when cutting ductile materials.
- The ductility of work material is more adhesive.

The most significant feature of the milling cutter cutting is interrupted cutting, the chip length of vortex-like and spiral chip is usually the cutting width, the equivalent the cutting edge to be cut into the work piece to leave the length of work material, which cutting chip belong to a continuous form and cut the shape; As for crack-shaped chips, like the cutting of cast iron, it will be broken into a broken flake chip during halfway. As for steel cutting, if you use the cutter with chip breaker gap or welding scar wear occurs, it can also produce the same chip.

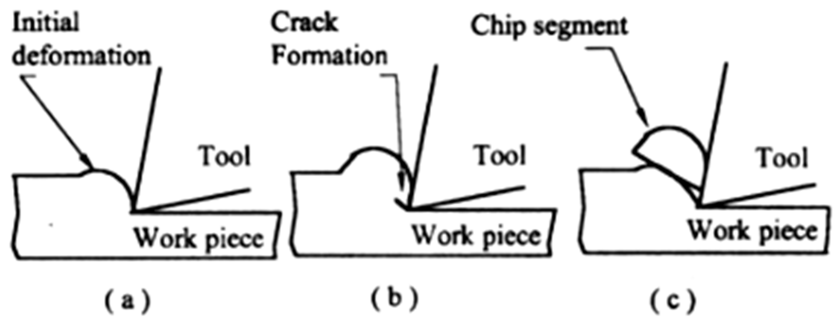


Figure 3.6: Formation Discontinuous Chips [M.C. Shaw, "Metal Cutting Principles"]

3.12Advantages of Continuous Chips:

1. Smooth surface finish: Continuous chips produce a smooth surface finish on the work piece, which is especially important in industries such as automotive and aerospace where high precision and quality is required

2. Reduced heat generation: Continuous chips provide better chip control and management, resulting in reduced heat generation during machining. This helps in preventing thermal damage to the work piece and prolongs the tool life.

3.Improved chip evacuation: Continuous chips are easier to evacuate from the cutting zone compared to segmented or non-segmented chips. This improves the efficiency of the cutting process and reduces the chances of chip re-cutting, which can lead to poor surface finish and tool wear

4.Enhanced process stability: Continuous chips offer better process stability by ensuring consistent chip formation and flow. This results in improved machining accuracy, reduced vibrations, and increased productivity

5.Longer tool life: Continuous chips have a lower tendency to cause tool wear compared to segmented. chips, which reduces the frequency of tool changes. This leads to longer tool life and reduced tooling costs

3.13 Advantages of Discontinuous or Segmented Chips

1. Cost-effectiveness: Discontinuous or segmented chips require less material and fewer manufacturing steps compared to continuous chips. This can result in lower production costs, making them a more cost-effective option for chip manufacturers.

2,Flexibility: Discontinuous chips offer greater flexibility in terms of design and functionality. They can be easily customized to meet specific requirements, allowing for the creation of innovative and unique chip designs.

3.Enhanced performance: Segmenting chips into smaller units can improve their performance in certain applications. For example, segmented chips can provide improved heat dissipation, reduced power consumption, and better signal integrity, leading to enhanced overall performance.

4.Yield improvement: Discontinuous chips can increase manufacturing yields by reducing the number of defects and improving the overall success rate of production. If a defect is identified in a segmented chip, it only affects a specific segment, minimizing the impact on the entire chip and allowing for easier identification and rectification of the issue

5.Scalability: Segmenting chips into smaller units can facilitate scalability in terms of chip production. (3)

3.14Advantages of Continuous Chips with built-up edges

1.Improved tool life: Continuous chips with built-up edges can help extend the life of cutting tools. The built-up edge serves as a protective layer on the tool, reducing wear and prolonging tool life. (4)

2.Enhanced productivity: Continuous chips with built-up edges help in achieving higher cutting speeds, leading to increased productivity. The reduced friction and improved chip control enable faster machining processes (5)

3. Better surface finish: Continuous chips with built-up edges can provide improved surface quality of machined parts. The built-up edge acts as a cushion between the tool and workpiece, minimizing tool marks and surface imperfections (6)

4.Reduced machine downtime: With continuous chips and built-up edges, there is less risk of chip breakage or entanglement in the machining process. This reduces machine downtime and the need for frequent interruptions to clear chips and restart machining operations

5.Cost savings: By optimizing tool life and increasing productivity, continuous chips with built-up edges can result in cost savings. Longer-lasting tools and improved machining efficiency translate into reduced tooling costs and higher throughput (7)

3.15Disadvantages of Continuous Chips

1.Tool wear and breakage: Continuous chips can lead to increased tool wear and breakage. As the chip continuously wraps around the cutting tool, it can cause friction and heat build-up, leading to accelerated tool wear. This can reduce the tool life and increase the frequency of tool replacement, resulting in higher machining costs

2.Poor surface finish: Continuous chips can negatively impact the surface finish of the machined part. As the chip slides along the machined surface, it can cause scratching and gouging, reducing the smoothness and precision of the finished product. To achieve a better surface finish, continuous chips may need to be managed or controlled.

3.Chip disposal challenges: While continuous chips are generally easier to handle and dispose of compared to other chip types, they can still pose challenges in certain situations. Continuous chips can be long and tangled, making it difficult to collect and transport them for recycling or disposal. This can require additional effort and resources for chip management.

4.Limited chip control options: Continuous chips offer limited options for chip control compared to segmented or discontinuous chips. This limitation can make it challenging to optimize machining processes for improved chip evacuation, cooling, and lubrication. (8)

3.16Disadvantages of Discontinuous or Segmented Chips

1. Poor Surface Finish: Segmented chips can result in an inferior surface finish on the machined part due to interruptions in the cutting process.

2. Tool Wear: Discontinuous chips can lead to increased tool wear and breakage as the cutting forces vary during the machining operation.

3. Heat Generation: The start-and-stop nature of segmented chips can result in localized heat buildup, potentially affecting the workpiece material and the cutting tool's performance

4. Inefficient Material Removal: Discontinuous chips may reduce the efficiency of material removal, leading to longer machining times and increased energy consumption.

5. Chip Disposal: Managing and disposing of segmented chips can be more challenging compared to continuous chips, potentially adding to production costs and environmental concerns. (9)

3.17 Disadvantages of Continuous Chips with built-up edges

1. Tool Wear Irregularities: Continuous BUEs can lead to uneven tool wear, impacting tool life. You may find discussions on this in machining textbooks.

2. Dimensional Inaccuracy: BUEs can result in variations in the dimensions of machined parts, affecting precision and accuracy. Look for references in machining and manufacturing textbooks.

3. Elevated Cutting Temperatures: BUEs can contribute to higher cutting temperatures, which may have detrimental effects on tool longevity and work piece properties. This topic is often covered in machining and heat transfer textbooks

4. Chip Disposal Challenges: Managing and removing continuous chips with BUEs can be more challenging, potentially leading to chip entanglement and tool damage. You can find information on chip management in machining resources.(10)

Single point cutting tool:

Single point cutting tool consists of only one main cutting edge that can perform material removal action at a time in a single pass. It is to be noted that in insert based cutting tools, multiple cutting edges may present in a single tool; however, only one cutting edge can engage in material removal action at a time (11)

Examples of single point cutting tool

Turning tool, also known as Single Point Turning Tool (SPTT), is the perfect example of a single point cutter. SPTT has only one main cutting edge (called Principal Cutting Edge) arises from the intersection of rake surface and principal flank surface. Auxiliary cutting edge does not usually participate in cutting action, unless the feed rate and depth of cut are high. Apart from turning tool, few other cutters are also single point tool as enlisted below.

- Shaping tool
- Planing tool

- Slotting tool
- Boring tool (12)

Advantages of single point cutting tool

- Design and fabrication of single point cutter is quite simple and less time consuming.
- Such tools are comparatively cheaper (13)

Disadvantages of single point cutting tool

- A single cutting edge continuously remains in physical contact with the work material during machining. So the tool wear rate is also high and as a result tool life is low.
- Due to continuous contact, rate of rise in tool temperature is high. This, in one hand accelerates tool wear and in other hand causes thermal damage of the finished/machined surface.
- High temperature rise may plastically deform the tool tip that can lead to poor accuracy in machining. (14)

Single Point Cutting Tool: Nomenclature and Tool Signature

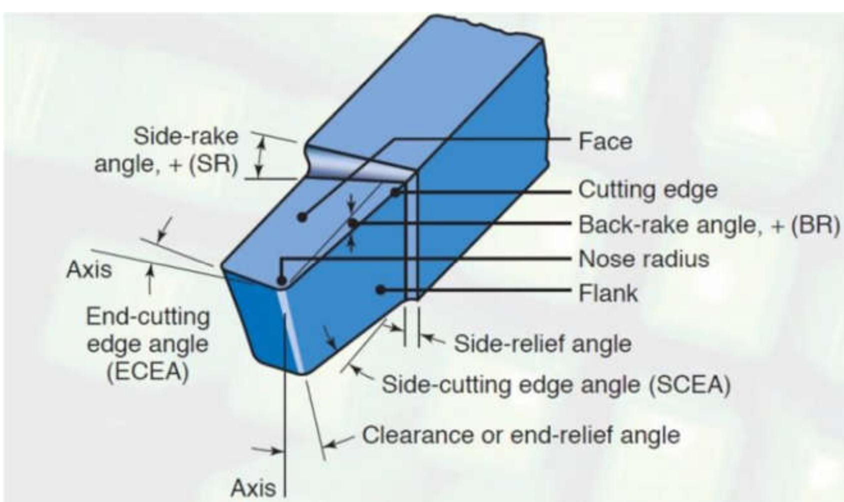


Figure: 3.7 Nomenclature of Single point Cutting tool. [V. P. Astakhov,"Geometry of Single-point Turning Tools and Drills – Fundamentals and Practical Applications"]

CHAPTER 4
METHODOLOGY

4.1. **Research Design**

This study employed an experimental research design to investigate the effects of different cutting tool angles on machining performance. The research has been conducted in different local workshops which have variety of environment as well as our university mechanical laboratory to ensure accuracy and reliability in the experimental results.

4.2. **Sample Selection**

The selection of cutting tools for experimentation involved a variety of types and materials commonly used in machining processes. A diverse range of cutting tool angles was also considered. The sample size was determined based on the widw use of different constructional projects to ensure the needful of the findings.

4.3. **Experimental Setup**

4.3.1 **Cutting Tools Preparation**:

Different types of cutting tools (e.g., Right hand cutting tools, threading or parting tools etc.) were selected.
Cutting tools were carefully inspected for any defects or irregularities before use.
Tools were sharpened and maintained to their optimal condition.

4.3.2 **Machining Parameters**:

Cutting speed, feed rate, and depth of cut were standardized.

Experiments were conducted under controlled environmental conditions to minimize external variables.

4.3.3 **Measurement Instruments**:

Machining performance should assessed using instruments such as surface roughness testers, tool wear analyzers, and cutting force sensors. We find it difficult to arrange measuring instruments. We use multi types gauge to measure angles and manufacturing chart to find the cutting speed and depth of cut.

4.4. **Experimental Procedure**

4.4.1 **Grouping and Randomization**:

Cutting tools were grouped based on their type.
Within each group, different angles were randomly assigned to minimize bias.

4.4.2 **Testing and Data Collection**:

Each cutting tool angle underwent a series of machining tests.
Data on cutting forces, surface finish, and tool wear were recorded for each test.

Different types of cutting tools.

Different size diamond cutting tools.

Cut off or parting tool, used for thread cutting, Neutral rake angle

Left & Right diamond cut tool. Diamond cutting tool used to Cut hard materials.

Figure 4.1 Differetnt types of cutting tools.

Measuring side flank angle using Multi-functional Weld gauge.

Measuring End cutting edge angle using weld gauge.

Turning operation for 42 mm dia Reinforcement to prepare Pinion

Preparing bevel using Neutral Rake angle Right hand cutting tool

Figure 4.2 Measuring Different Angles of cutting tools & Turning operation.

Measuring temperature during turning operation using Negative rake angle right hand cutting tool.

Measuring temperature Using laser type temperature gun.

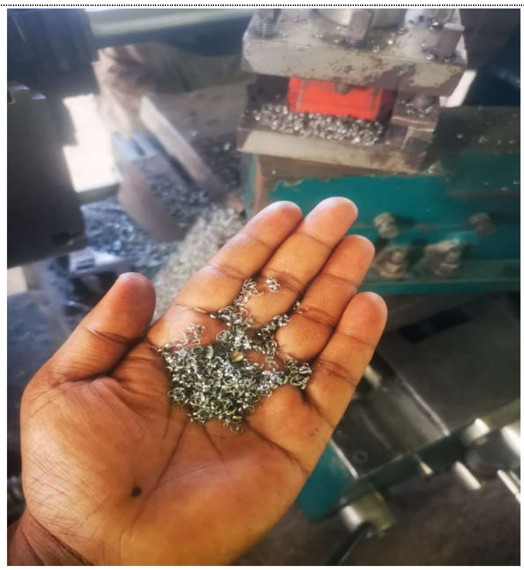
Observing Turning operation, Cut off as well as preparing bevel single bevel.

Prepare lathe machine chuck pinion for Mechanical four jaw lathe machine

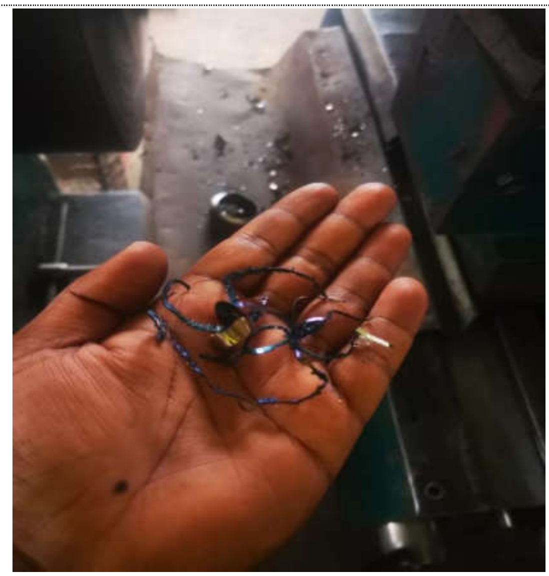
Figure 4.3 Observing temperature & Measuring Final Product.

Continuous chips during turning operation

Tool setup for turning



Discontinuous chips found using negative rake angle as well as high power cut.



Discontinuous chips during making bevel.

Figure 4.4 Different Types of Chips.

Figure 4.5 Discontinuous chips.

CHAPTER 5

FINDINGS

5.1 Positive Rake Angles:

5.1.1 **Small Positive rake angle – 15 degrees**

Chip Formation: Small positive rake angles create thick and continuous chips. These chips are easier to manage and evacuate from the cutting zone.

Tool Life: Tool life is relatively longer due to reduced friction and heat generation. The tool experiences less wear and maintains sharpness.

5.1.2 **Moderate Positive Rake Angle-30 degrees**

Chip Formation: Moderate positive rake angles produce chips that are thinner and more curled. This can improve chip control and reduce the likelihood of chip jamming.

Tool Life: Tool life is still good, but the balance between chip control and tool life is optimized at this angle.

5.1.3 **Large Positive Rake Angle- 60 degrees**

Chip Formation: Large positive rake angles generate very thin and fragmented chips when the cutting depth is very low. It produces continuous chip removal when the depth of cut is moderate or high which is difficult to manage.

Tool Life: Tool life may be slightly reduced due to increased cutting forces and heat generation, but it can still be acceptable for many applications.

The choice of the positive rake angle depends on various factors, including the workpiece material, cutting speed, and desired surface finish. Smaller rake angles are suitable for tougher materials, while larger angles may be preferred for softer materials. It's essential to consider these factors when selecting the appropriate rake angle for a specific metal cutting operation.

Rake angle (degrees)	Cutting speed (m/s)	Cutting performance	Surface finish	Chip formation
15	3.5	Excellent	Smooth	Small, Manageable chips.
30	4.5	Good	Moderate	Moderate Sized Chips.
60	5	Fair	Slightly rough	Continuous Chips, Difficult to manage.

Table : 5.1

5.2 Negative Rake Angles:

5.2.1 **Higher Rake Angle (Less Negative)**:

5.2.1.1 **Chip Formation**: Smoother chip formation and better surface finish. Reduced cutting forces, which can lead to less tool wear.

5.2.1.2 **Tool Life**: Reduced tool life compared to more negative rake angles.

5.2.2 **Moderate Rake Angle (Intermediate Negative)**:

5.2.2.1 **Chip Formation**: Tool wear and chip control may not be as optimal as with a more negative rake angle.

5.2.2.2 **Tool Life**: A compromise between tool life and surface finish.Suitable for a wider range of materials and cutting conditions compared to extreme rake angles.

5.2.3 **Lower Rake Angle (More Negative):**

5.2.3.1 **Chip formation**: Effective chip control, especially in tougher materials. May produce a rougher surface finish compared to less negative rake angles.

5.2.3.2 **Tool life**: Extended tool life due to increased tool strength.Higher cutting forces, which can impact machine and toolholder stability.

5.3 **Temperature variations**

5.3.1 Positive Rake Angle:

With a positive rake angle, the cutting edge is inclined in the direction of the tool's motion. This reduces the cutting resistance and lead to lower cutting temperatures. Lower temperatures are generally beneficial because they reduce tool wear and extend tool life. Some cases we found where excessive positive rake angles cause chip thinning, which leading to higher temperatures due to increased friction between the chip and tool.

5.3.2 Negative Rake Angle:

This configuration increases cutting resistance and results in higher cutting temperatures. The increased friction and deformation during cutting generates more heat at the tool-chip interface. Higher temperatures is detrimental as they may shorten tool life and reduce machining precision.

Rake Angle	Cutting speed (m/min)	Feed Rate (mm/rev)	Temperature [ºC]
+15	50	.5	280
+30	50	.5	230
+60	50	.5	195
-10	50	.5	330
-30	50	.5	350
-45	50	.5	385

Table: 5.2

CHAPTER 6

DISCUSSION

6.1 Discussion

While working on our project, we did face some difficulties as it is a very complex system but the end results, we came up with were quite satisfactory. We have put the whole system through several tasks to validate our work and also have taken necessary notes for future improvements. Some future recommendations that we have involves improvement in system design and adding features for more efficient.

6.2 Advantages

There are certainly many advantages of our project and some of the major ones have been given below:

- Improved Machining Efficiency.
- Enhanced Product Quality.
- Optimized Tool Selection.
- Increase tool durability.
- Enhanced Safety.
- Education and Training.
- Contribution to Scientific Knowledge.

6.3 Application

This project has applications in many fields due its necessity. We have selected a few of them and they are given below:

- It can be used in Manufacturing Process Optimization.
- Aerospace and Automotive Industries.
- Metalworking and Machining Companies
- Tool and Equipment Manufacturers.

CHAPTER 7

CONCLUSION

7.1 Conclusion

In conclusion, an experimental analysis of Using Different Types of Angle for Different Types of Cutting Tools is a valuable and multifaceted project with wide-ranging benefits for both the scientific community and industrial applications. While cutting some materials the force initially increases and then decreases This can be attributed to the fact that material surface is usually hard as it is cold rolled and the force values are observed to be higher initially which then decreases as the rake angle value. For higher depth of cut the Max force will be higher because of higher contact area and the tool is likely to break due to shear load and wear out quickly due to higher friction between the tool and chip and tool and work piece. This type of research project involves a systematic study of how metal chips are generated during machining operations and how they can be effectively controlled. Here are the key takeaways: Such projects contribute to the advancement of scientific knowledge in the field of metal cutting, providing a deeper understanding of the complex processes involved in chip formation and control. The project's findings can lead to significant improvements in manufacturing processes, including increased efficiency, enhanced product quality, and reduced production costs. By optimizing cutting parameters and chip control strategies, the project can extend the lifespan of cutting tools, reducing the frequency of tool changes and associated downtime. Better understanding of chip formation can lead to safer machining environments and improved operator safety by mitigating the risk of accidents related to chip ejection and tool breakage. The project promotes sustainable manufacturing practices by reducing material waste, energy consumption, and the environmental impact of machining processes. In summary, an experimental analysis of chip formation and chip-breaking processes in metal cutting is a valuable research endeavor with broad applications, offering solutions to industry challenges, contributing to scientific knowledge, and driving advancements in manufacturing technology. Its impact extends to sectors ranging from aerospace and automotive to medical devices and beyond, making it a pivotal area of study in the field of manufacturing engineering.

7.2 Future Scope

Can apply the principles to adjust its parameters autonomously during the machining process to determine optimum parameters and have maximum output or higher material removal rate with less tool wear. With the increasing demand for high-speed machining, future research can focus on understanding chip formation and tool behavior at elevated cutting speeds, which can lead to improved productivity and quality.

REFERENCE

[1] B.L.; Seth, Nitin and Sekhon, "Fundamentals of Metal Cutting and Machine Tools, mechanics of machining process",2nd Edition,2003,

[2] Groover, M.P. Fundamentals of Modern Manufacturing: Materials, Processes, and Systems. Wiley.4th Edition,2016

[3] Rao Tummala,"Advances in Microelectronics Packaging",2nd Edition,2018

[4] John R. Walker,"Machining Fundamentals"10th Edition

[5] M.C. Shaw, "Metal Cutting Principles"

[6] Thomas, H. C, "Metal Machining: Theory and Applications"

[7] Gorazd Knob and Mitjan Kalin, "Introduction to Machining Science"

[8] Latyshev et al,"Cutting Data for Turning of Steel"

[9] Milton C. Shaw."Metal Cutting Principles"

[10] John R. Walker,"Machining Fundamentals"

[11] A. Bhattacharya,"Metal Cutting: Theory And Practice"

[12] S. Kalpakjain and S. Schmid,"Manufacturing Process for Engineering Materials"

[13] V. P. Astakhov,"Geometry of Single-point Turning Tools and Drills – Fundamentals and Practical Applications"

[14] A. B. Chattopadhyay,"Machining and Machine Tools"

[15] Sachin Thorat,"Single Point Cutting Tool – Diagram, Geometry, Nomenclature"

[16] John R. Walker,"Machining Fundamentals"

[17] Milton C. Shaw,"Metal Cutting Principles"

[18] A. Bhattacharya,"Metal Cutting: Theory And Practice"\

[19] V. P. Astakhov,"Geometry of Single-point Turning Tools and Drills – Fundamentals and Practical Applications"

[20] Winston A. Knight, Geoffrey Boothroyd,"Fundamentals of Metal Machining and Machine Tools", function of tool for turning,2019

[21]Mustafa Sekmena, Mustafa Gunaya,Ibrahim Ciftcib, Ihsan Korkuta, Ulvi SEKER,The Influence Of Cutting Tool Rake AngleOn Cutting Forces When MachiningAluminium Alloys, International Conferenceon Leading Edge Manufacturing in 21stCentury Oct. 19-22, 2005.

[22]C.J.Raoa, D.Sreeamulua Arun TomMathewb, Analysis of Tool Life duringTurning Operation by Determining OptimalProcess Parameters, 12th Global Congress onManufacturing and Management, GCMM2014.