Tool life performances, wear mechanisms and surface roughness characteristics when turning austenite and quenched AISI EN19

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DR. SUDHIR CHANDRA SUR DEGREE ENGINEERING COLLEGE

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DISSERTATION APPROVAL FOR B.TECH

This dissertation entitled **Tool life performances, wear mechanisms and surface roughness characteristics when turning austenite and quenched AISI EN19** is approved for the degree of **BACHELORS OF TECHNOLOGY.**

Examiners

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Supervisor (s) **Supervisor (s)**

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DECLARATION

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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CERTIFICATE

This is to certify that the thesis entitled ***"Tool life performances, wear mechanisms and surface roughness characteristics when turning austenite and quenched AISI EN19"*** being submitted for the degree of **BACHELORS OF TECHNOLOGY** (in Mechanical Department) of **Dr. Sudhir Chandra Sur Degree Engineering College** by **Pallab Saha,Nabarun Roy , Subon Mallick , Rajib Bhowmick**, under our supervision. The results incorporated in this thesis are original in nature. Neither the thesis nor a part of it has been submitted for the award of any other degree.

It may further be mentioned that **Pallab Saha,Nabarun Roy , Subon Mallick , Rajib Bhowmick** has fulfilled other requirements as per rules of **Dr. Sudhir Chandra Sur Degree Engineering College & Mechanical Department** regarding the award of B.TECH. degree.

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ABSTRACT

The characteristics and the constituents of tool matters in the its use and the hurdles it can take. It is necessary to know the proper endurance of the tool for proper functioning and the proper demographic arrangements for the supply.

Material parameter therefore plays a crucial role for signifying the machining characteristics of Lathe operation. Our work will deal with the machining parameters and related aspects like surface roughness, metal removal rate (MRR), chip analysis and surface morphology during wet turning on austenitic stainless steel EN19 by Coated Carbide Insert Tool.

We will take deep observation on results varying with cutting conditions at different levels of speed, feed, and depth-of-cut. The best parametric combination that satisfied all performances at high level will evaluated by Teaching-Learning-Based Optimization (TLBO).

The study shows that, surface roughness directly influenced by Spindle speed, Feed and Depth of Cut. Surface roughness increases with increasing feed rate, highest in lowest spindle speed condition and have less effect for depth-of-cut for Turning Operation.

Also MRR influenced by input parameters. MRR directly proportional with FEED and Depth-of cut (DOC), highest in top FEED and DOC input values; also speed has moderate effect on MRR. In polishing study, we will observe that higher grit sized polish paper gave better surface finish with minimal scratches and we got better shiny surface by using higher grit polish paper in dry condition than wet condition.

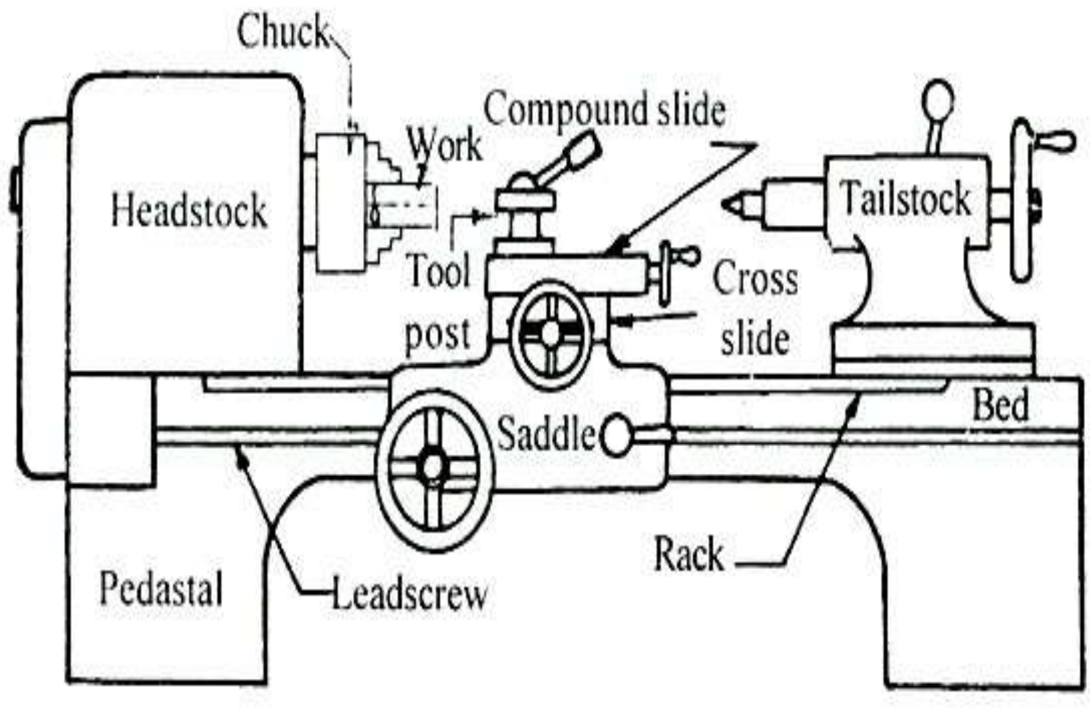
CONTENTS

Introduction

Machining is a manufacturing term encompassing a broad range of technologies and techniques. It can be roughly defined as the process of removing material from a workpiece using power-driven machine tools to shape it into an intended design. Most metal components and parts require some form of machining during the manufacturing process. Other materials, such as plastics, rubbers, and paper goods, are also commonly fabricated through machining processes.

Lathe Machine

The main function of a lathe is to remove metal from a piece of work to give it the required shape and size. This is accomplished by holding the work securely and rigidly on the machine and then turning it against a cutting tool which will remove metal from the work in the form of chips.



A geared-head lathe

Types of Lathes

1. Speed lathe
2. Tool room lathe
3. Engine lathe

4. Special purpose lathe
5. Bench lathe
6. NC and CNC lathe
7. Production lathe (Automatic lathe, capstan and turret lathe)

Speed lathe

A speed lathe derives its name from the fact that very high spindle speeds are used in this machine. This is the simplest of all lathes. It consists of a bed supported on legs, a head stock, a tail stock and an adjustable slide for supporting the tool. There is no feed box, carriage or lead screw. The workplace is held between centres or attached to the face plate. It may be driven from a variable speed motor. The tool is fed and controlled by hand while being supported on the tool slide. The speed lathe is used principally for turning of wood for small cabinet work.

Engine lathe

Engine lathe is the most important member of the lathe family and the most commonly used. This lathe differs from a speed lathe in that a much larger number of speed steps are available on this machine.

The power to the engine lathe spindle may be given with the help of a belt drive from an overhead line shaft but most modern machines have a captive motor with either a cone pulley drive or an all geared head stock arrangement. The work piece may be supported between centers. The tools are held generally in the tool post on the carriage but sometimes in the tail stock.

Bench lathe

It is a small lathe that is mounted on a work bench. It is used for small work pieces having a maximum swing of 250 mm at the face plate. Lathes of this type are used for precision work on small parts for instrument making.

Production lathe

Production lathes are machines designed to produce large number of duplicate parts faster and with less skill and labour. They employ faster work holding devices and may have two or more tools operating simultaneously. The supervision is simplified and much less skill is needed except for setting the machine. These machines may also be made partially or fully automatic with the operator being needed only for loading the bar stock and removing the finished workpieces. Depending upon the complexity, production lathes may be divided into automatic lathes, capstan and turret lathes.

Lathe Construction

The machine essentially consists of the following major units:

1. Bed
2. Head stock
3. Tall stock
4. Carriage assembly

Bed

The bed of the lathe forms the base of the machine. It is supported on two legs at a convenient height. It carries the head stock and the tail stock for supporting the work and provides a base for the movement of the carriage assembly which carries the tool. To ensure accurate machining work it is necessary that the bed has enough rigidly and torsional stiffness to withstand the action of cutting forces. The bed of the lathe is sometimes made with a small gap in front of the head stock to accommodate short jobs which need a swing larger than that available on the rest of the bed.

Head stock

The head stock houses the spindle and the means for supporting and rotating the spindle. It is rigidly fixed on the bed. The spindle which is made of steel is made hollow so that long bars which are being machined at the end may pass through it. The right-hand end of the spindle which projects out of the head stock body has a threaded outside and a tapered bore. For turning between centres a carrier plate may be mounted on the threaded end. In larger lathes instead of the threaded end, a flange is provided over which the dog plate, chuck or face plate as the case may be, are located and bolted. The tapered end and the hollow spindle also permit mounting of a draw-in collect chuck when designed.

Tail stock

The tail stock is for the purpose of primarily giving an outer bearing, support for work being turned on centres. It can be adjusted for alignment or non-alignment with respect to the spindle centre and carries a centre called dead centre for supporting one end of the work. Both live and dead centres have 60 conical points to fit centre holes in the work, the other end tapering to allow for good fitting into the spindles. Now-a-days, the dead centre is mounted in ball bearing so that it rotates with the job avoiding friction of the job with dead centre. This is especially necessary with heavy jobs.

Carriage Assembly

The carriage assembly of the lathe comprises of a number of components which support, move and control the tool. The carriage assembly consists of a saddle, cross slide, compound rest, top slide, tool post and apron. Movement of the entire carriage assembly along the bed provides feed for the tool parallel to the lathe axis: movement of the cross slide along its guides on the saddle provides feed of the tool across the lathe axis and the movement of the top slide along its guide over the compound rest provides motion to the tool along a direction set by the compound rest. The movement of the carriage and cross slide may be by hand or by power but the movement of top slide is only by hand.

CNC Types and Applications

Lathes are available in large variety of types and sizes. It is difficult to classify them into categories. There is a fairly large variation in their design, construction and use. However, according to their construction and design we can classify the lathes as follows:

1. Bench Lathe:

It is a very small lathe and is mounted on a separately prepared bench or cabinet. It is used for small and precision work since it is very accurate. It is usually provided with all the attachments, which a larger lathe carries, and is capable of performing almost all the operations which a larger lathe can do.

2. Speed Lathes:

These lathes may be of bench type or they may have the supporting legs cast and fitted to the bed. These lathes have most of the attachments which the other types of lathe carry but have no provision for power feed. They have no gear box, carriage and the lead screw. With the result, the tool is fed and actuated by hand. Usually the tool is either mounted on a tool post or supported on a T-shaped support. Such lathes are usually employed for wood turning, polishing, centring and metal spinning, etc. Thus, they can be considered as merely of a theoretical value so far as the modern machine shops are concerned. They are named so because of the very high speed at which the spindle rotates.

3. Engine Lathe:

It is probably the most widely used type of lathe. The name Engine Lathe is a little confusing in modern practice as all these lathes are now made to have an individual motor drive. However, it carries a great historical significance that in the very early days of its development it was driven by a steam engine. From this, it derived the name which is popular even today.

Although it practically resembles a speed lathe in most of its features, but its construction is relatively more robust. Its headstock is bigger in size and more robust, incorporating suitable mechanism for providing multiple speeds to the lathe spindle. The headstock spindle may receive power, from a lathe shaft or an individual motor, through belts. In that case, it will have a cone pulley with back gears in the headstock to provide different speeds to the spindle. It carries a combination of gears, instead of the cone pulley and back gears combination, the lathe is known as geared head lathe and the headstock as all geared head stock.

4. Tool Room Lathe:

It is nothing but the same engine lathe but equipped with some extra attachments to make it suitable for a relatively more accurate angle of speeds and feeds. The usual attachments provided on a tool room lathe are taper turning attachment, follower rest, collets, chucks, etc. This lathe is made to have a comparatively smaller bed length than the usual engine lathe. The most commonly used lengths are 135 to 180 cm.

5. Capstan and Turret Lathe:

These lathes form as very important and useful group and are vastly used in mass production. These machines are actually of semi-automatic type and a very wide range of operations can be performed on them. In operating these machines, a very wide range of operations can be performed on them. In operating these machines, a very little skill is required of the operator. Whatever skill is needed of the operator is only in the setting of tools in the turret or capstan head, and once this setting has been successfully accomplished further operation of these machines is more or less automatic. They carry special mechanisms for indexing of their tool heads.

6. Automatic Lathe:

These lathes help a long way in enhancing the quality as well as the quantity of production. They are so designed that all the working and job handling movements of the complete manufacturing process for a job are done automatically. No participation of the operator is required during the operation. Another variety of this type of lathes includes the semi-automatic lathes, in which the mounting and removal of work is done by operator whereas all the operations are performed by the machine automatically. Automatic lathes are available having single or multi spindles. They fall in the category of heavy duty, high speed lathes mainly employed in mass production.

7. Special Purpose Lathes:

A large number of lathes are designed to suit a definite class of work and to perform certain specified operations only. They prove to be more efficient and effective as compared to the common engine lathe so far as this specified class of work is concerned. A brief description of these machines will be given in the following table.

Name of Machine	**Special Description**	**Application**
Precision Lathe	Capable of giving a dimensional accuracy of 0.002 mm.	Precision turning of previously rough-turned workpiece. In many cases, replace a high-class grinding machine because of its fine dimensional accuracy.
Facing Lathe	In this, the carriage is driven by a separate motor, independent of the main spindle. It carries no tailstock	Used to machine the end faces of bulky cylindrical jobs.
Frontal Lathe	In this, two carriages are provided, one on each end. Also, two tool heads are provided. This enables machining of two jobs simultaneously	Its specific use is in machining short jobs
Vertical Lathe	It carries a vertical column, on which are fitted the cross slide and vertical slide. A heavy base at the bottom carries a face plate to hold the jobs.	It is used for turning and boring very large and heavy rotating parts which cannot be otherwise supported on other types of lathes. These machines are specifically employed for jobs like heavy flywheels and large gear blanks etc.
Crankshaft Lathe	It carries all the attachments, like taper turning and threading, etc. In addition, a number of rests (supports) for the shafts.	It is used for turning very long parts such as turbine and engine shafts and crankshafts.
Production Lathe	It distinguishes itself by its bed which is made inclined towards the rear for ensuring an efficient chip removal.	Its special design makes it suitable for mass production of cylindrical parts. Its use increases the rate of production of such items. It is

		not very suitable for repair work.
Duplicating Lathe	It carries a special tracer attachment connected to the carriage, which moves along a template and guides the carriage.	It is used for mass production of identical parts where either a previously machined part works as a template or a separate template is prepared and used for this purpose.
Screw Cutting Lathe (automatic)	It is operated through cams and cam plates.	It is used for mass production of screwed parts. Especially suitable for precision screw work.

Working Principle

The lathe is a machine tool which holds the workpiece between two rigid and strong supports called centers or in a chuck or face plate which revolves. The cutting tool is rigidly held and supported in a tool post which is fed against the revolving work. Lathe machine is one of the most important machine tools which is used in the metalworking industry. It operates on the principle of a rotating work piece and a fixed cutting tool. The cutting tool is feed into the work piece which rotates about its own axis causing the workpiece to form the desired shape.

CUTTING SPEED

Cutting speed for lathe work may be defined as the rate in meters per minute at which the surface of the job moves past the cutting tool. Machining at a correct cutting speed is highly important for good tool life and efficient cutting.

MATHEMATICAL FORM

The rotational speed in turning is related to the desired cutting speed at the surface of the cylindrical workpiece by the equation.

$$N=v/\pi d$$

Where N = rotational speed, rev/min; v = cutting speed, m/min (ft./min); and Do= original diameter of the part, m (ft.). The turning operation reduces the diameter of the work from its original diameter Due to a final diameter Do as determined by the depth of cut d.

$$D_f = D_o - 2d$$

The feed in turning is generally expressed in mm/rev (in/rev). This feed can be converted to a linear travel rate in mm/min (in/min) by the formula.

$$F_r = N f$$

Where f r = feed rate, mm/min (in/min); and f = feed, mm/rev (in/rev). The time to machine from one end of a cylindrical work-part to the other is given by

$$T_m = L/f_r$$

Where Tm =machining time, min; and L = length of the cylindrical work-part, mm (in). Cutting Conditions in Turning.

A more direct computation of the machining time is provided by the following equation.

$$T_m = \pi D_o L/f v$$

Where Do = work diameter, mm (in); L=work-part length, mm (in); f=feed, mm/rev (in/rev); and v = cutting speed, mm/min (in/min). As a practical matter, a small distance is usually. Added to the work-part length at the beginning and end of the piece to allow for approach and over-travel of the tool. The volumetric rate of material removal can be most conveniently determined by the following equation.

The cutting speed is calculated from rotating speed for any turning operation as the following.

UNITS

C.S = πDN/1000

Where,

C.S	Cutting Speed
D	Día of work piece (mm)
N	Speed in RPM (c/min)
Π	Constant

FACTOR EFFECTING CUTTING SPEED

- Material of work piece
- Material of tool
- Depth of Cut
- Rigidity of work piece and cutting tool
- Shape of cutting tool
- Size of tool flank
- Cutting fluid used
- Maximum permissible amount of tool wear
- Type of machining being performed

- Kind of material being cut
- Cutting tool material
- Shape of cutting tool
- Rigidity of machine tool and the job piece

Types

1. High speed
2. Slow speed

EFFECT OF SLOW CUTTING SPEED

Too slow cutting speeds reduce productivity and increase manufacturing costs:

- Decrease production rate
- Increase production cost
- Waste of time
- Increase wastage of work material

EFFECT OF HIGH CUTTING SPEED

- Decrease tool life greatly
- Damage work piece accuracy
- Non accuracy
- Cutting tool shape
- Heat generation

CHIP'S FORMATION

Machining is a semi-finishing or finishing process essentially done to impart required or stipulated dimensional and form accuracy and surface finish to enable the product.

- fulfill its basic functional requirements
- provide better or improved performance
- Render long service life.

Machining is a process of gradual removal of excess material from the preformed blanks in the form of chips. The form of the chips is an important index of machining because it directly or indirectly indicates:

- Nature and behavior of the work material under machining condition
- Specific energy requirement (amount of energy required to remove unit volume of work material) in machining work
- Nature and degree of interaction at the chip-tool interfaces

TYPES OF CHIPS

Chips type	Material	Rake angle	Cutting speed	Cutting feed
Continuous chips	Ductile	Positive	High	Low
Continuous chips with blue	Ductile but hard	Medium	medium	Medium
Discontinuous chips	Brittle	Negative	Low	High

Different types of chips of various shape, size and color are produced by machining.
The basic major types of chips are given below:

- Discontinuous chips
- Continuous chips
- Continuous chips with Blue
- Jointed type chips

Formation of chips depends upon a following factors as under;

- Work material
- Cutting tool geometry
- Cutting speed
- Type of cut

COMPARISON TABLE OF CHIPS

Advantages & Disadvantages

<u>Advantage</u>

1. **Accuracy advantage**
   Universal lathe by gear and ordinary screw nut drive. Due to the existence of gaps between each part when movement, coupled with the manual operation is not accurate, so the repeat accuracy is lower. Need to manually stop the measurement of universal lathe measurement, measurement error larger. CNC lathe driven by ball screw drive with motor. the ball screw has interference after pre-tension installation, no gap transmission, the accuracy of the machine itself and the program guarantees. In processing, it can do position measurement by encoder, can compensate for tool wear and other causes of error. So processing quality, accuracy and stability.

2. Mass production efficiency advantages
The universal lathe needs a skilled operator. Due to the use of manual three-jaw

chuck, and measurement must be manually measured after parking, processing inefficiency.
In mass production, the use of hydraulic chuck or collet clamping the workpiece, an unskilled worker can operate at least two CNC lathes at the same time. Production efficiency is more than 4 times the universal lathe.

3. Pass rate advantage
Universal lathe as a manual operation, human influence is very large, once the operator's physical condition or lack of concentration, product rejection rate will rise sharply.
CNC lathe basically rely on equipment to ensure machining accuracy, the operator basically only played the role of loading and unloading work pieces and switches, human impact is very small, so the product pass rate is relatively high.

4. Procurement costs higher
The same specifications of CNC lathe price is 1.5 times more than universal lathe. However, with the decline of the price of CNC system, the disadvantages of CNC lathe cost will be getting smaller and smaller.

5. One-piece processing costs are higher now
The current CNC lathe single-piece processing cost is higher than universal lathe. However, if improved, CNC lathes will also outperform conventional lathes in the cost and efficiency of a single piece of production.

<u>Disadvantage</u>

Limitations of Centre lathe

1. Setting time for holding job is very high
2. Only one tool can be used generally at a time
3. Idle time in between the operation is high
4. Preciseness of the job depends highly on the skills of operator

For overcoming limitations of Centre lathe, Capstan, Turret and Automatic lathes are invented. They have basically achieved improvements in the following areas.

1. Work holding methods
2. Multiple tool availability
3. Automatic feeding of tool
4. Automatic stopping of tool at precise locations
5. Automatic control of proper sequence of operations

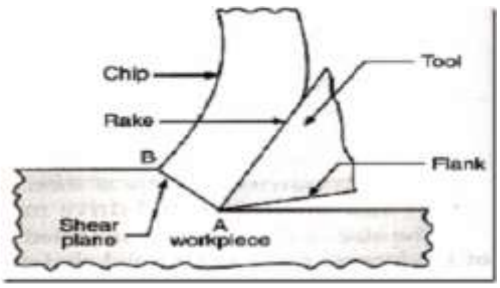
<u>METAL CUTTING</u>

Introduction

Metal cutting is the process of producing a job by removing a layer of unwanted material from a given workpiece. Fig. shows the schematics of a typical metal cutting process in which a wedge shaped, sharp edged tool is set to a certain depth of cut and moves relative to the workpiece.

Under the action of force, pressure is exerted on the workpiece metal causing its compression near the tip of the tool. The metal undergoes shear type deformation and a piece or layer of metal gets repeated in the form of a chip.

If the tool is continued to move relative to workpiece, there is continuous shearing of the metal ahead of the tool. The shear occurs along a plane called the shear plane.

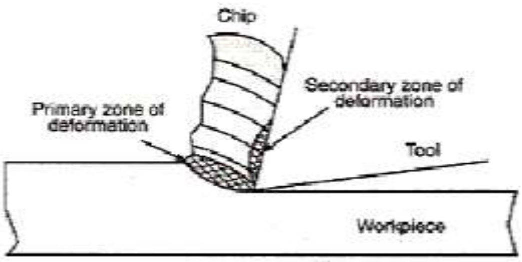


Metal Cutting

All machining processes involve the formation of chips; this occurs by deforming the work material on the surface of job with the help of a cutting tool. Depending upon the tool geometry, cutting conditions and work material, chips are produced in different shapes and sizes. The type of chip formed provides information about the deformation suffered by the work material and the surface quality produced during cutting.

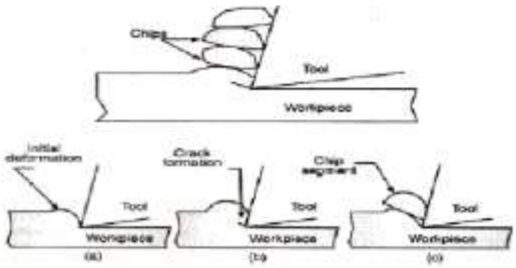
Types of Chips:

1. Continuous chips: While machining ductile materials, large plastic deformation of the work material occurs ahead of the cutting edge of the tool. The metal of the workpiece is compressed and slides over the tool face in the form of a long continuous chip.

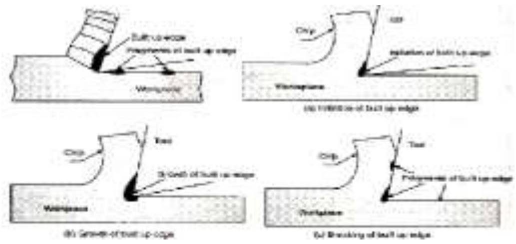


2. **Discontinuous (segmented) chips:** A discontinuous chip is a segmented chip produced in the form of small pieces. The discontinuous chips are produced when cutting brittle materials like cast iron, bronze and brass.

The working on ductile materials under poor cutting condition may also sometimes lead to the formation of discontinuous chips.



3. **Continuous chips with built-up-edge:** The term built-up-edge refers to the small metal particles that stick to the cutting tool and the machined surfaces as result of high temperature, high pressure and high frictional resistance during machining. The building up and breaking down of the built-up-edge is periodic; its size first increases, then decreases and again increases-the cycle gets repeated rapidly.



1.3.2 Types of Cutting Processes

Machining is not just one process; it is a group of processes. There are many kinds of machining operations. Each of which is specialized to generate a certain part geometry and surface finish quality.

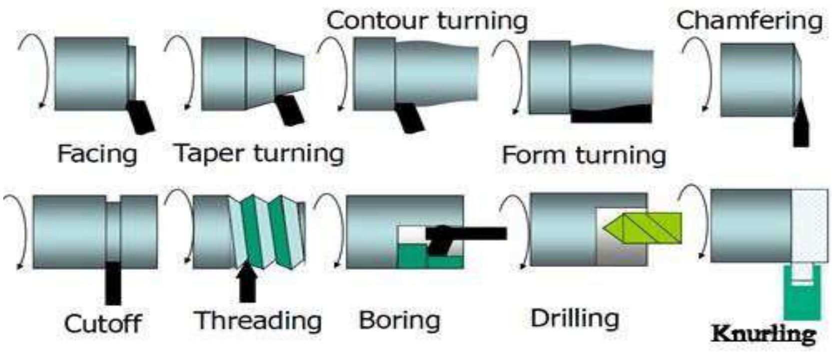
I. **Turning**: Turning is used to generate a cylindrical shape. In this process, the work piece is rotated and cutting tool removes the unwanted material in the form of chips. The cutting tool has single cutting edge. The speed motion is provided by the rotating work piece, and the feed motion is achieved by the cutting tool moving slowly in a direction parallel to the axis of rotation of the work piece.

II. **Drilling**: Drilling is used to create a round hole. In this process, the cutting tool is rotated and feed against the work piece fixed in a holding device. The cutting tool typically has two or more cutting edges. The tool is fed in a direction parallel to its axis of rotation into the work piece to form the round hole.

III. **Boring**: Boring is used to enlarge an already drilled hole. It is a fine finishing operation used in the final stage of product manufacture.

IV. **Milling**: Milling is used to remove a layer of material from the work surface. It is also used to produce a cavity in the work surface. In the first case it is known as slab-milling and in second case it is known as end-milling. Basically, the milling process is used to produce a plane or straight surface. The cutting tool used has multiple cutting edges. The speed motion is provided by the rotating milling cutter. The direction of the feed motion is perpendicular to the tool's axis of rotation.

V. **Cutting-Off**: Cutting-off is used to cut the metal into two parts. In this operation, the work piece is rotated and cutting tool moves radially inward to separates the components.



Factors & Variables Influencing Metal Cutting Process

A. **Factors**

I. Cutting parameters.
II. Cutting fluid.
III. Tool geometry.
IV. Tool wear.
V. Temperature rise.
VI. Machinability.
VII. Continuous chips.
VIII. Built-up edge chips.
IX. Discontinuous chips.

Variables

Dependent and Independent variables

Independent variables	Dependent variables
1. Cutting velocity	1. Chip reduction coefficient (CRC)
2. Feed	2. Shear angle
3. Depth of cut	3. Shear strain
4. Workpiece material	4. Material removal rate (MRR)
5. Cutting tool material	5. Chip form and color
6. Tool geometry	6. Burr form and dimension
7. Cutting environment	7. Cutting forces
	8. Cutting power
	9. Surface integrity
	10. Cutting temperature
	11. Tool life
	12. Machining time and productivity

Methods of Metal Cutting

Laser cutting

With laser cutting, a highly concentrated beam of light reaches an extremely high temperature. This hot beam can cut metal precisely and efficiently. When used in conjunction with the latest computer programs, the laser can be controlled with a high level of accuracy, giving a neat finish and enabling intricate designs to be followed.

Flame cutting

In a similar way to laser, a hot gas flame (reaching approximately 3,500 degrees centigrade) can be used to cut metal. This kind of cutter is known as an oxy acetylene cutter or just oxy cutter.

Water jet cutting

Water jets work by shooting a stream of highly pressurized water at the metal in order to cut it, effectively eroding away the unnecessary metal.

Plasma cutting

Another method which utilizes heat, plasma cutting involves a plasma torch pumping out oxygen or an inert gas at a high speed, while sending electricity through the gas at the same time. This creates a hot plasma stream that can melt metal and blow molten metal away fast, resulting in a clean cut. The latest plasma cutting technology is not as accurate as laser cutting. The best plasma's are only accurate to ±2mm whereas lasers are accurate to ± 0.2mm.

Metal Turning

With this method of metal cutting, the metal is turned quickly on a device such as a lathe while a sharp cutting tool is applied to the surface.

Drilling

When force and rotation are combined with a drill bit to form a hole or other shape in the metal's surface, it's simply known as drilling.

Metal cutting from Shape CUT

For all your metal cutting needs, contact Shape CUT in Brisbane today. As a profile cutting company with over 20 years' experience, you can trust us to offer shape cutting with the latest technology and best service, whether you require an intricate one-off design or a bulk order.

Principle of Metal Cutting

A typical metal cutting process by single point cutting tool is shown in Fig. In this process, a wedge shaped tool moves relative to the work piece at an angle a. As the tool makes contact with the metal, it exerts pressure on it. Due to the pressure exerted by the tool tip, metal will shear in the form of chips on the shear plane AB. A chip is produced ahead of the cutting tool by deforming and shearing the material continuously, along the shear plane AB. The shear plane is actually a narrow zone and extends from the cutting edge of the tool to the surface of the work piece. The cutting edge of the tool is formed by two intersecting surfaces.

A detailed about various terminologies is given below:

I. **Rack Surface**: It is the surface between chip and top surface of the cutting tool. It is the surface along which the chip moves upwards.

II. **Flank Surface**: It is the surface between work piece and bottom of the cutting tool. This surface is provided to avoid rubbing with the machined surface.

III. **Rack Angle (α)**: It is the angle between the rack surface and the normal to work piece. Rack angle may be positive or negative.

IV. **Flank Angle/Clearance Angle/Relief angle (γ)**: It is the angle between the flank surface and the horizontal machined surface. It is provided for some clearance between flank surface and machined surface of work piece to avoid rubbing action of cutting tool to the finished surface.

VI. **Primary Deformation Zone**: It is the zone between tool tip and shear plane AB.

VI. **Secondary Deformation Zone**: It is the zone between rack surface of the tool and chip.

VII. **Tertiary Deformation Zone**: It is the zone between flank surface of the tool and machined surface of work piece.

Almost all the cutting processes involve the same shear-deformation theory. The cutting tool used in cutting process may be single-point or multi-point cutting tool. Turning, threading, and shaping, boring, chamfering, and facing are some cutting operations done by single point cutting tool. Milling, drilling, grinding, reaming and broaching are some cutting operations done by multi-point cutting tool.

CUTTING TOOL

A machine tool is no more efficient than its cutting tool. There is nothing in shop work that should be given more thoughtful consideration than cutting tools. Time is always wasted if an improperly shaped tool is used. The cutting action of the tool depends on its shape and its adjustment in the holding device. Lathe cutter bits may be considered as wedges which are forced into the material to cause compression, with a resulting rupture or plastic flow of the material. The rupture or plastic flow is called cutting. To machine metal efficiently and accurately, it is necessary that the cutter bits have keen, well-supported cutting edges, and that they be ground for the particular metal being machined and the type of cut desired. Cutter bits are made from several types of steel, the most common of which are described in the following subparagraphs.

Types of Cutting Tools

1. Turning tool.
2. Chamfering tool.
3. Thread cutting tool.
4. Internal thread cutting tool.
5. Facing tool.
6. Grooving tool.
7. Forming tool.
8. Boring tool.
9. Parting-off tool.
10. Counterboring tool
11. Undercutting tool
12. According to the method of applying feed
    1. Right-hand tool
    2. Left-hand tool
    3. Round Nose

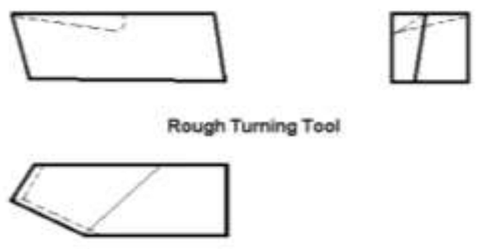
Classification of Cutting Tool

1. Turning Tool

There are mainly two classes of turning tool:

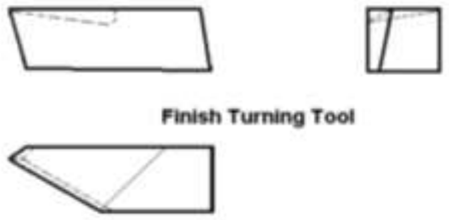
1. Rough turning tool.
2. Finish turning tool.

1.1 Rough Turning Tool



The main function of a rough turning tool is to remove the maximum amount of metal in minimum time that the tool, work, and the machine will permit. The cutting angle is so ground that it can withstand maximum cutting pressure.

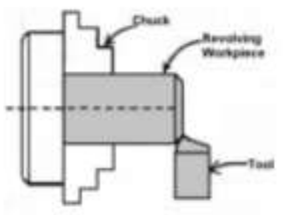
1.2 Finish Turning Tool



Finish Turning Tool

Turning tool is used to remove the very small amount of metal. A tool angle is so ground that it can produce a very smooth and accurate surface.

3. **Chamfering Tool**

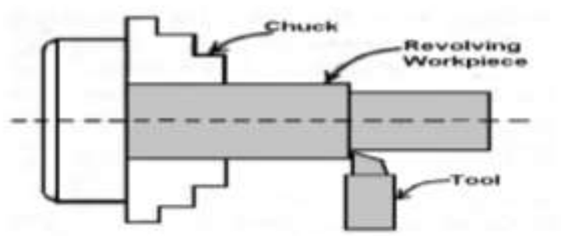


Chamfering

Straight turning tools are also used as a chamfering tool when the cutting edges are set at an angle of the chamfer.

Where a large number of chamfer works are to be performed a special chamfering tool with its side cutting edge angle ground to the angle of the chamfer is used.

3. Shoulder Turning Tool



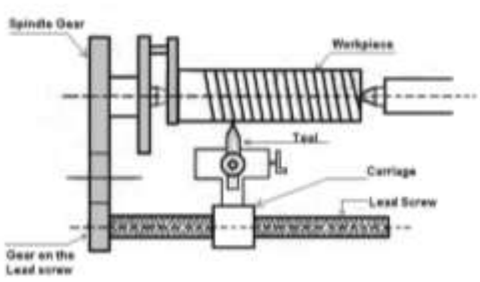
Shoulder Turning

A square shoulder is turned by a knife-edge turning tool or facing tool. A bevelled shoulder may be turned by a straight turning tool having a side cutting edge angle and zero nose radius. A filleted shoulder is turned by a straight turning tool with a nose radius corresponding to the fillet radius of the work.

4. Thread Cutting Tool

1 External Thread Cutting Tool

Metric, B.S.W or American "V" thread are formed by a single point thread cutting tool. Its cutting edges sharpened to the shape and size of the thread to be cut.

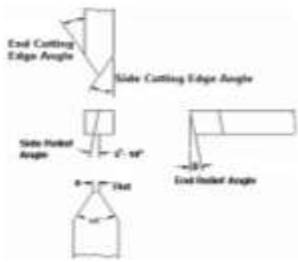


Thread Cutting

The shape of the tool is determined by the included angle at the nose of the tool which should correspond to the angle of the thread. It may be 60° for metric threads or 55° for B.S.W threads.

he included angle at the nose of the tool which should correspond to the angle of the thread. It may be 60° for metric threads or 55° for B.S.W threads.

The size or cross-section of the cutting edges of the tool depends upon the pitch of the thread. Below figure illustrates an H.S.S. thread cutting tool.



So for machining different screw threads having different pitches separates tools are used to produce accurate threads. The nose of the tool is pointed, flat or rounded according to the shape of the root of the thread.

A thread tool gauge is used to check the shape and size of the tool after it has been ground.

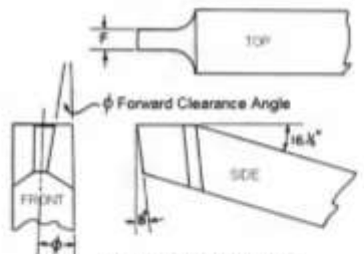
Tool for cutting square threads

The side clearance of the tool for cutting square thread is of prime importance in order to prevent the tool from interfering or rubbing against the vertical flank of the thread.

$$\angle\emptyset = 5^{\circ}\left(tan^{-1}\frac{lead}{\pi\times Core\ Dia.}\right)$$

$$\angle\theta = \left(tane^{-1}\frac{lead}{\pi\times Outside\ Dia.}\right) - 5^{\circ}$$

As a rule, the forward side clearance angle is determined by adding 5° to the helix angle of the thread and trailing side clearance is obtained by subtracting 5° from the helix angle, if ø be the forward side clearance angle and θ be the trailing side clearance angle, then from the formula:The width of the cutting edge should be equal to half the pitch of the thread.



Square Thread Cutting Tool

Small clearance angle of 1° to 2° are provided at the side of the tool to prevent the surface from ribbing with the work.

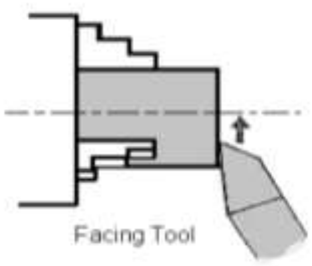
2 Internal Thread Cutting Tool

The cutting edge of the tool is exactly similar to an external thread cutting tool but the front clearance angle is sufficiently increased as in a boring tool.

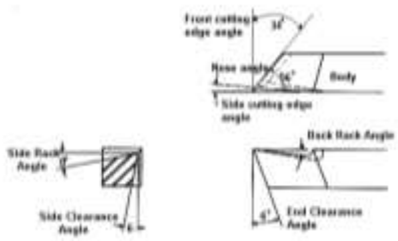
The tool is a forged type orbit type and held on a boring bar. The point of the tool must be set square with the work.

Read also: 22 Different Types of Operations used in Lathe Machine

5. Facing Tool



A facing tool removes metal by its side cutting edges. So no top rake in necessary in a facing tool. The figure shows H.S.S. facing tool intended for finishing operation.

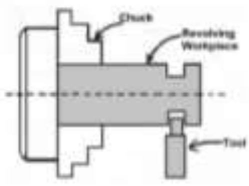


The tool has 2° side cutting edge angle and 34° end cutting edge angle can be accommodated in the space between the end of the work and 60° dead centre leaving a clearance of 2° on both sides.

The standard shank section is 20X20, 25X25, 32X32, 40X40, and 50X55 all expressed in mm. The length of the tool is 125, 140,170, 200 and 240 mm and the nose radius varies from 0.5 to 1.6 mm.

6. Grooving Tool

Grooving tool is similar to a parting-off tool illustrated in the figure. The cutting edges are made square, rounded or “V” shape according to the shape of the groove to be cut.



Grooving

7. Forming Tool

Turning curved profiles may be affected by using

1. Ordinary lathe tools,
2. Flat forming tools,
3. Circular forming tools.

An ordinary lathe turning tool may sever the purpose where a copying attachment is used to reproduce the form of a template. Flat forming tools are made of two types:

1. Simple forming tools
2. Flat dovetail forming tools.

Simple forming tools

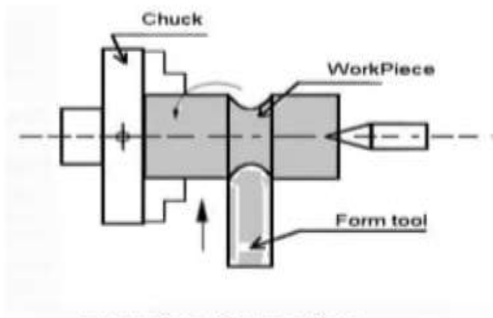
These tools have their cutting edges ground to the shape of the groove, undercut, or thread to be cut.

Flat dovetail forming tools have a wider cutting edge corresponding to the shape desired. Dovetail end of the tool is fitted in a special tool holder. No front rake is provided but sufficient front clearance angle is given and it ranges from 10° to 15°.

Regrinding is always done on the top face of the tool which does not alter the form of the tool.

Circular Form Tools

These tools are preferred in production work as a very long cutting surface can be used resulting in longer tool life.



Forming Operation

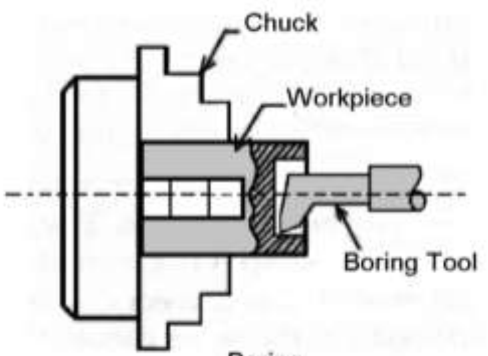
The centre of the tool is set slightly above the centre line of the work to provide an effective front clearance angle on the tool. The tool will rub against the work if the centres are of the same height.

The tool centre is usually higher than the centre line of the lathe by 1/20 to 1/10 of the tool diameter. This height is termed 'offset'. Regrinding is done by grinding the flat only.

8. Boring Tool

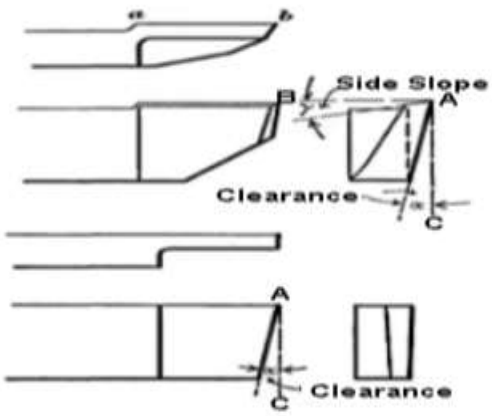
A boring tool is similar to a left-hand external turning tool so far its cutting edge is concerned.

The tool may be a bit type inserted in a boring bar or holder, or forged type having a tool shank. The figure shows an H.S.S. tool bit inserted in a boring bar.



Boring

A boring bar is made of mild steel with slots or holes cut into it to accommodate the tool bit which is locked by an Allen screw. The amount of projection of the cutting edge of the tool from the centre of the bar determines the finished hole diameter of the work.



BORING TOOL

The bit is generally inserted at right angles to the centre line of the bar for boring a continuous hole passing from one end to the other end.

8.1 Different Design of The Boring Tool

The bit is set at a single to the axis projecting beyond the end of the bar for boring a blind hole.

- A tool bit having two cutting edges at it two ends is used for quick machining.
- A wide double-bladed cutter is inserted in the boring bar to finish the boring operation.
- Two or more bits may be inserted in a boring bar for different diameters in one setting.

8.2 Boring Bars:

- Boring bars are held in the tailstock for boring small holes ranging from 12 to 100 mm.
- For boring larger hole diameters, boring bars are gripped by two clamp blocks and held in the tool post.
- For precision boring or boring in odd size work that is supported on cross-slide, the bar is supported on centres and is made to revolve.

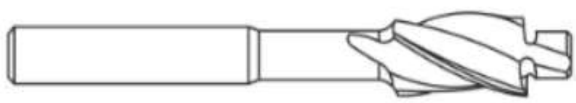
8.3 Clearance for Boring Tool

- In a boring tool, the tool cutting edge most have sufficient front clearance to clear the work.
- To strengthen the tool point double clearance, primary and secondary, is provided.

- The smaller be the hole diameter the larger should be the front clearance.
- Larger clearance angle necessitates the reduction in rake angle in a boring tool.
- The nose of the tool is straight or round according to the type of finish desired.

9. Counterboring Tool

The counterboring operation can be performed by an ordinary boring tool. The tool cutting edge is so ground that it can leave a shoulder after turning. A counterbore having multiple cutting edges is commonly used.



COUNTERBORING TOOL

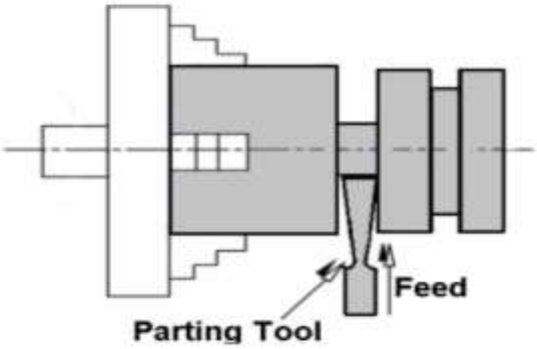
10. Undercutting Tool

Undercutting or grooving tool has a point and form of the cutting edge exactly similar to the form of the required groove.

Clearance angle is given at all the sides of the tool. For the recessing groove cutting edge, the longitudinal feed is employed. The front clearance angle depends upon the bore of the work.

4. Parting Off Tool

A parting off tool is normally forged and used as bits for cemented carbide tipped tools. Parting off tool is made as narrow as possible to remove the minimum of metal.



The width of the cutting edge range from 3 to 12 mm only. The length of the cutting tool which inserts into the work should be slightly longer than the radius of the bar stock being machined.

As the tool penetrates deep into the work, clearance is provided all around the tool cutting edge to prevent it from rubbing against the work surface.

As the tool is purely ended cutting it has no side rake slight back rake is provided on the tool to promote an easy flow of the ships.

Materials of Tools

I. **Carbon Steel -** Carbon steel, or tool steel is high in carbon content, hardens to a high degree of hardness when properly heated and quenched. The carbon-steel tool will give good results as long as constant care is taken to avoid overheating or "bluing," since the steel will lose its temper or hardness at a relatively low heat becoming ineffective as a cutting tool. For low-speed turning, high carbon steels give satisfactory results and are more economical than other materials.

II. **High-Speed Steel -** High-speed steel is alloyed with tungsten and sometimes with chromium, vanadium, or molybdenum. Although not as hard as properly tempered carbon steel, the majority of lathe cutting tools are made of high-speed steel because it retains its hardness at extremely high temperatures. Cutter hits made of this material can be used without damage at speeds and feeds which heat the cutting edges to a dull red.

III. **Stellite -** These cutter bits will withstand higher cutting speeds than high-speed steel cutter bits. Stellite is a nonmagnetic alloy which is harder than common high-speed steel. The tool will not lose its temper, even though heated red hot from the friction that is generated by taking a cut. Stellite is more brittle than high-speed steel. To prevent breaking or chipping, it requires just enough clearance to permit the tool to cut freely. Stellite is also used for machining hardened steel, cast iron, bronze, etc.

IV. **Tungsten Carbide -** Tungsten carbide is used to tip cutter bits when maximum speed and efficiency is required for materials which are difficult to machine. Although expensive, these cutter bits are highly efficient for machining cast iron, alloyed cast iron, copper, brass, bronze, aluminium, Babbitt metal, and such abrasive on metallic materials as fiber, hard rubber, and bakelite. Cutter bits of this type require very rigid support and are usually held in open-side tool posts. They require special grinding wheels for sharpening, since tungsten carbide is too hard to beredressed on ordinary grinding abrasive wheels.

V. **Tantalum Carbide and Titanium Carbide -** These cutting tools are similar to tungsten carbide tools but are used mostly for machining steel where extreme heavy cuts are taken and heat and pressure tend to deform the cutting edge of the other types of cutting tools.

Cutting Tool Angles

The face and the flank are pain surfaces, the cutting edge can be assumed to be a line. These surfaces and the edges are inclined with respect to some reference plan or line. The inclinations are called tool angles. These angles are defined by various names. They are provided for various purposes. Consider the case of the face abgf, as shown in Figure 1.4.5.A. It is a plane surface no doubt, but can have some inclinations. This surface may be parallel to the base or say to horizontal surface, or it can be inclined upward or downward with respect to the horizontal plane. Again it may have inclination sideward also. So in general the face can have two inclinations simultaneously, backward and sideward. Similarly the flank (Principal flank abed or auxiliary flank adef) can have two inclinations.

For efficient machining operation, the cutting tool must be provided with necessary tool angles. A tool with proper geometry (cutting edge and tool angles) cuts the metal effectively. Therefore reducing the chattering, breaking of the tool with less heat generation. Figure 1.4.5.B & Figure 1.4.5.C shows a single point cutting tool with various cutting edges and tool angles.

A. **The Geometry of Cutting Tool Angles Are**

I. Rake Angle (α):

Black rake angle.

Side rake angle.

II. Clearance or Relief Angle (γ):

End clearance relief angle.

Side clearance relief angle.

III. Cutting Edge Angle:
End cutting edge angle.
Side cutting edge angle.

1) **Back Rake Angle**: It is the angle between the face of the tool and plane parallel to its base. It is also known as front rake angle or top rake angle.

2) **Side Rake Angle**: It is the angle between the face of the tool and the shank of the tool.

3) **End Clearance (Relief) Angle**: It is the angle between the front surface of the tool and a line normal to the base of the tool. It is also known as front clearance angle.

4) **Side Clearance (Relief) Angle**: It is the angle between the side surface of the tool and a line normal to the base of the tool.

5) **End Cutting Edge Angle**: It is the angle between the end cutting edge of the tool and a line perpendicular to its shank.

6) **Side Cutting Edge Angle**: It is the angle between the side cutting edge of the tool and shank of the tool.

7) **Nose Radius**: Nose radius is one which connects the side and end cutting edge. Now, we will discuss the functions and effects of cutting tool angles on cutting process.

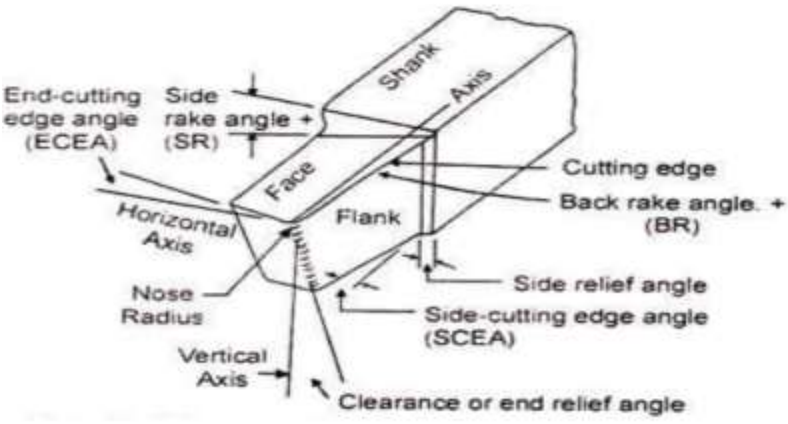


Figure 1.7 - Angles of Single Point cutting Tool

B. **Function of Angles**

I. **Functions of Back Rake Angle:**

a) It helps to control the chip flow in a convenient direction.

b) It reduces the cutting force required to shear the metal and consequently helps to reduces power requirements and increase tool life.

c) It also helps counteract the pressure against the cutting tool from the work by pulling the tool into the work.

d) It provides keenness to the cutting edge and improves the surface finish.

II. **Functions of Side Rake angle:**

a) It performs similar functions as performed by back rake angle.

b) Side rake angle along with back rake angle controls the chip flow direction.

c) It partly counteracts the resistance of the work to the movement of the cutter.

d) For example, brass requires a back and side rake angle of almost 0°, while aluminium uses a back rake of 35° and a side rake of 15°.

III. **Functions of End Clearance (relief) Angle:**

a) It allows the tool to cut freely without rubbing against the work surface.

b) This angle varies from 0° to 15°, and usually 8°.

c) Excessive relief angle reduces strength of the tool.

IV. **Functions of Side Clearance (relief) Angle:**

a) It avoids the rubbing of flank against the work piece when the tool is fed longitudinally.

b) This angle is 6° to 10° for steel, 8° for aluminium.

c) It maintains that no part of the tool besides the actual cutting edge can touch the work.

V. **Functions of End Cutting Edge Angle:**

a) It avoids rubbing between the edge of the tool and workspace.

b) It influences the direction of chip flow.

VI. **Functions of Side Cutting Edge Angle:**

a) Increase in side cutting edge angle tends to widen and thin the chip.

b) An excessive side cutting edge angle redirects feed forces in radial direction which may cause chatter.

VII. **Functions of Nose Radius:**

a) A sharp point at the end of tool is undesirable, because it is highly stressed, short lived and leaves groove in the path of cut.

b) Therefore Nose Radius is favorable for long tool life and good surface quality.

c) It affects the tool life, radial force, and surface quality of work piece.

d) If nose radius is too large chatter will occur.

e) There is an optimum value of the nose radius at which the tool life is maximum.

f) If the nose radius exceeds optimum value, the tool life decreases.

g) Larger nose radius means larger area of contact between tool and work piece. Resulting more frictional heat is generated. Also, cutting force increases due to which the work part may start vibrating and chattering, if work part holding is not very tight.

h) The recommendations for use of more nose radius are.

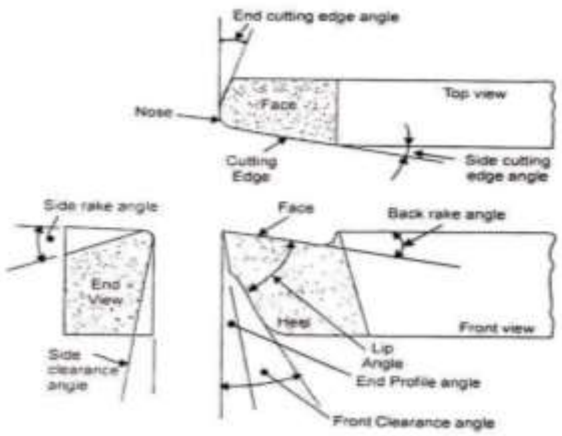
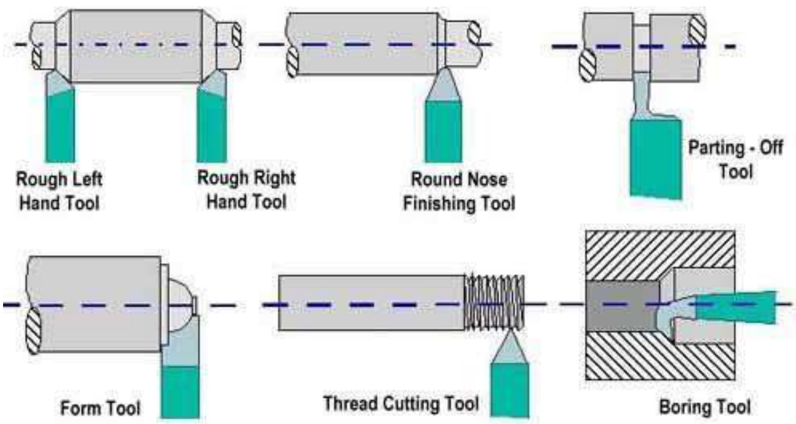


Figure 1.8 - Tool Geometry of Single Point Cutting Tool



Various Types of Cutting Tool

Tool Life

Meaning of Tool Life:

Every device or tool has its functional life. At the expiry of which it may function, but not efficiently. So it is also true with a cutting tool. During use, the tool losses its material, i.e., it gets worn out. As the wear increases, the tool losses its efficiency. So its life has to be defined and on expiry of its life, it should be reground for fresh use.

The tool life can be defined in following different ways:

(i) The time elapsed between two successive grindings.

(ii) The period during which a tool cuts satisfactory.

(iii) The total time accumulated before tool failure occurs.

Tool life is expressed in minutes.

The relation between cutting speed and tool life is given by the Taylor's tool life equation:

$VT^n = C$

Methods for Tool Life Measurements:

The most commonly used methods for tool life measurements are following:

(i) Machining Time:

Elapsed time of operation of machine tool.

(ii) Actual Cutting Time:

The time during which the tool actually cuts.

(iii) A fixed size of Wear Land on Flank Surface:

On carbide and ceramic tools where crater wear is almost absent. Tool life is taken as corresponding to 0.038 or 0.076 mm of wear land on the flank surface for finishing respectively.

(iv) Volume of metal removed.

(v) Number of pieces machined.

The tool life between re-conditioning and replacement can be defined in a number of ways, such as:

(a) Actual cutting time taken to failure.

(b) Volume of metal removed to failure.

(c) Number of parts produced to failure.

(d) Cutting speed for a given time to failure.

(e) Length of work machined to failure.

Tool Life Expectancy (Taylor's Tool Life Equation):

In 1907, F. W. Taylor developed relation between tool life and cutting speed, temperature, by keeping feed as constant. The Taylor's Equation for Tool Life Expectancy provides a good approximation.

$V_C T^n = C$

A more general form of the equation considering depth of cut and feed rate is

$V_c T^n D^x F^y = C$

Where,

K_C = Cutting speed (m/min)

T = Tool life (min)

D = Depth of cut (mm)

F = Feed rate (mm/rev)

x, y = Exponents, that are determined experimentally for each cutting conditions.

n = Exponent, that depends on tool materials.

Value of n = 0.1 to 0.2; for H.S.S. tools

0.2 to 0.4; for Carbide tools

0.4 to 0.6; for Ceramic tools

C = Machining constant, found by experimentation or published data-book. It depends on properties of tool material, workpiece and feed rate.

Observations from the Tool Life Equation:

i. Tool life decreases with increase in cutting speed.

ii. Tool life also depends to a great extent on the depth of cut (D) and feed rate (F).

iii. Decrease of tool life with increased speed is twice as great (exponentially) as the decrease of life with increased feed.

iv. The greatest variation of tools life is with the cutting speed and tool temperature which is closely related to cutting speed.

Tool Life Plots (Curves):

Tool life curves are plotted between tool life and various process parameters (such as cutting speed, feed, depth of cut, tool material, tool geometry, workpiece hardness, and cutting fluids, etc.). To draw these curves, experimental data obtained by conducting cutting tests on various materials under different conditions and with varying process parameters.

Tool life curves are generally plotted on log-log graph paper. These curves are used to determine the value of exponent ‘n’. The exponent ‘n’ can indeed become negative at low cutting speeds. Fig. 9.22 (a) shows the tool life plot between tool life and cutting speed for various workpiece materials having different hardness. It shows that, as the cutting speed increases, the tool life decreases rapidly. If cutting speed Versus tool life, curves are plotted on a log-log graph paper, straight lines are obtained as shown in Fig. 9.22. (b).

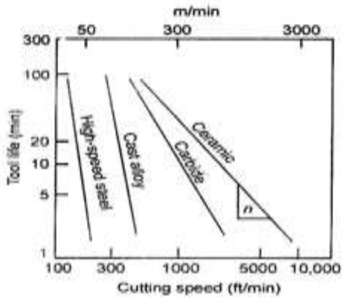
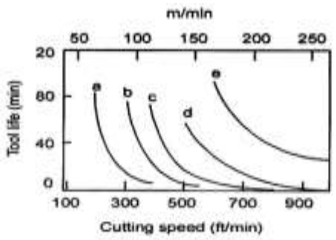


Fig. 9.22. (a) Tool Life Curves for a Variety of Cutting Tool Material.



	Hardness (HB)	Ferrite	Pearlite
a. As cast	265	20%	80%
b. As cast	215	40	60
c. As cast	205	60	40
d. Annealed	185	97	3
e. Annealed	170	100	–

Fig 9.22. (b) Tool Life Curves for Various Workpiece Material having different Hardness.

Impurities and hard constituents in the workpiece material (such as rust, slag, scale, etc.) are also cause of abrasive action which reduces tool life.

Tool Life Criteria (Criteria for Judging Tool Failure):

Due to wear on the tool, the cutting force increases and surface finish deteriorates. Therefore, when should we say that a tool has failed and it should be reground. In other words, certain criterion is required for judging the tool failure.

A tool fails when it no longer performs its function properly. This may have different meaning under different circumstances. In a roughing operation, where, surface finish and dimensional accuracy are of little importance, a tool failure can mean an excessive rise in cutting forces and power requirements.

In a finishing operation, where, surface finish and dimensional accuracy are prime important, a tool failure will mean that the specified conditions of surface finish and dimensional accuracy can no longer be achieved. All of these failures are basically related to the wear on the clearance face of the tool.

The following are some criterion for judging tool life/failure:

(i) Complete failure.

(ii) Flank or crater failure.

(iii) Finish failure.

(iv) Size failure.

(v) Cutting force failure.

(i) Complete Failure:

According to this criterion, the cutting with the tool is continued till it is able to cut. So when the tool fails to cut, then only it should be reground. This criterion is not used in practice because of its obvious disadvantages.

(ii) Flank or Crater Failure:

According to this criterion, when the wear on the flank reaches a certain height the cutting with the tool is discontinued and grinding is done. Say when the flank wear height h equals to 0.3 mm, for example, the tool is said to have failed. Some common recommended values of wear land are given in Table 9.11. (a, b).

Due to wear on the flank, the actual depth of cut decreases from AC to BC as shown in Fig. 9.23. The workpiece becomes taper if cutting continued. This is the most usual criterion followed in practice. The flank wear is measured with a tool maker's microscope.

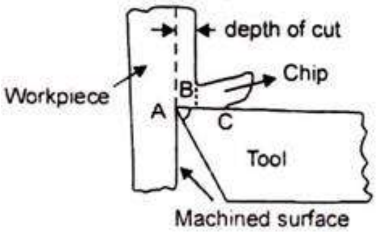


Fig. 9.23. Flank Failure.

Also, it is important to note that, the flank wear is not uniform along the active cutting edge, therefore, it is necessary to specify the locations and the degree of wear, when deciding tool life criterion, before regrinding.

(iii) Finish Failure:

According to this criterion, when the surface roughness reaches a specified high value, the cutting with the tool is stopped and grinding is done. Say at a particular cutting condition the surface roughness, comes to be 0.7 microns. As in process of cutting the flank wear develops so the cutting edge becomes rough and irregular so the surface roughness gradually increases, as shown in Fig. 9.24. Say 1.3 microns, for example, are kept as a criterion.

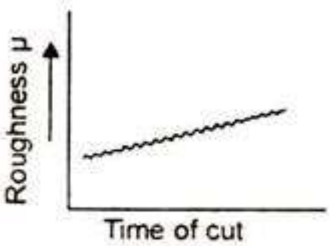


Fig. 9.24. Finish Failure.

The roughness of the surface is measured continuously along its length. When the roughness reaches the specified value, the cutting is discontinued. For example, this maximum specified value of surface roughness may be occurs on the 10^{th} workpiece, so the 11^{th} and next workpieces won't be machined with the same tool, without regrinding.

This criterion becomes specially important when close fitting objects are machined. Due to rough and uneven surfaces, the proper fitting may not be done.

(iv) Size Failure:

According to this criterion, a tool will be considered to have failed if there is a deviation in the size of a produced finished component from its specified value.

(v) Cutting Force Failure:

According to this criterion, a tool will be considered to have failed, if the amount of cutting force increases by certain specified amount. This is due to flank wear. Flank wear increases the area of contact between the workpiece and the tool, resulting into increase in the cutting force. Fig. 9.25. shows that an increase in cutting force with development to flank wear.

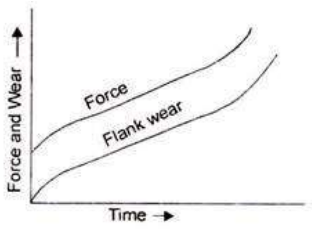


Fig. 9.25. Cutting Force Failure.

Factors Affecting Tool Life:

The following factors play an important role in tool life:

(i) Cutting speed.

(ii) Feed rate and Depth of cut.

(iii) Hardness of workpiece.

(iv) Microstructure of workpiece.

(v) Tool material.

(vi) Tool geometry.

(vii) Type of cutting fluid and its method of application.

(viii) Nature of cutting.

(ix) Grain size of workpiece.

(x) Rigidity of workpiece machine-tool system.

(i) Cutting Speed:

F.W. Taylor has conducted numerous experiments in the field of metal cutting. In 1907, he gave the following relationship between tool life and cutting speed, which is known as Taylor's Tool Life Equation.

$V_C T^n = C$

where, V= Cutting speed (m/min)

T= Tool life (min) C = Constant or machining constant

n = Tool life index. It depends on tool and work material combination and cutting conditions.

If T = 1 min

then $C = V_c$

So, the constant C can be interpreted physically as the cutting speed for which the tool life is equal to one min. The tool life equation can be represented on log-log paper; it becomes straight line as shown in Fig. 9.26.

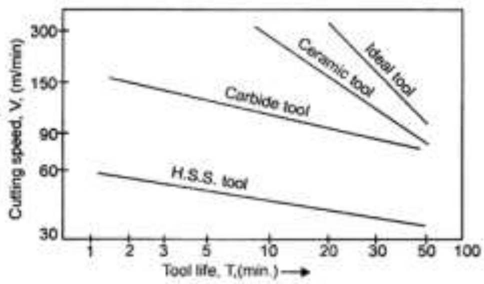


Fig. 9.26. Tool Life Plots for Various Tool Materials.

It is clear that the cutting speed has the highest effect on tool life followed by feed and depth of cut, respectively. As cutting speed increases, the cutting temperature increases, and tool life decreases.

(ii) Feed Rate and Depth of Cut:

According to the Taylor's tool life equation, tool life decreases when feed rate increases. Also, the same case for depth of cut.

The following relation justifies the above statement:

$$V T^{n} F^{x} D^{y} = C$$

$$V.T^{0.20} F^{0.35} D^{0.08} = C \quad \text{(For cemented carbide tool and low carbon steel)}$$

or

$$\boxed{T^{n} = \frac{C}{V F^{x} D^{y}}}$$

where,

V = Cutting speed (m/min)
T = Tool life (min.)
F = Feed (mm/min)
D = Depth of cut (mm)
C = Machining constant

(iii) Hardness of Workpiece:

As the hardness increases, the permissible velocity decreases for a given tool life. For example, the tool life is 50 minutes for cutting less hard material, now if say harder material is to be cut then to maintain the tool life as 50 minutes, the cutting velocity should be reduced proportionate.

The above statement is justified by the following equation given by Yanitsky:

$$\boxed{V = \frac{C}{H_b^{1.7}\ \Psi}}$$

where,

H_b = Brinel hardness number of work material

Ψ = Percentage reduction

V = Permissible cutting speed for a given tool life

(iv) Microstructure of Workpiece:

As the structure becoming more and more perlites, the tool life decreases at any increase in cutting speed, as shown in Fig. 9.27.

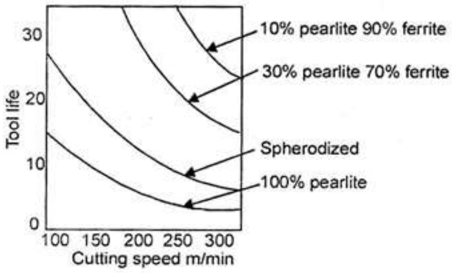


Fig. 9.27. Effect of Microstructure of Work Material on Tool Life.

(v) Tool Material:

The major requirements of cutting tool materials are: Hot hardness, impact toughness, and wear resistance. For better tool life, the material must have the above properties. Fig. 9.26 shows tool life variation against cutting speeds for different tool materials. It is very clear from the figure; at any cutting speed the tool life is maximum for ceramic tool and lowest for the high speed steel tool. So using ceramic tool maximum volume of material could be removed at any cutting speed for a specific tool life.

An ideal tool material will have n = 1 (Taylor's tool life index). It means ideal material tool at all cutting speeds, removes maximum volume of work material.

Some tool materials with their properties are following:

i. Carbon Sleets:

Very sensitive to temperature. They rapidly loose their hardness at low temperatures. Only suitable for cutting at slow speed and with machining of soft non-ferrous metals.

ii. H.S.S.:

They are affected only above 600°C, and starts loosing their hardness.

H.S.S. has good performance below 600°C.

Above 600°C tendency to form B.U.E.

iii. Cemented Carbide:

Good performance till 1200°C.

Can be used at much higher cutting speeds than H.S.S.

iv. Sintered Oxides or Ceramics:

Can be used at cutting speeds of 2 and 3 times more than with carbides.

(vi) Tool Geometry:

The tool geometry greatly affects the tool life. We will discuss the effect of all the tool parameters on tool life in following pages:

(a) Back Rake Angle.

(b) Principal Cutting Edge.

(c) Clearance Angle.

(d) Nose Radius.

(a) Back Rake Angle:

Larger the rake angle smaller will be the cutting angle and larger will be shear angle, this reduces the cutting force and power, and hence less heat generated during cutting, means reduced cutting temperature, results in longer tool life.

But on the other hand, increasing the rake angle results in mechanically weak cutting edge the positive rake tool experiences shear stress and the tip is likely to be sheared-off.

Negative rake increases cutting force and power, hence more heat and temperature generated results in smaller tool life.

Therefore, there lies an optimum value of the back rake which depends upon tool material and work material. It ranges from -5° to +15°. An optimum value of rake angle is about 14° which gives maximum tool life.

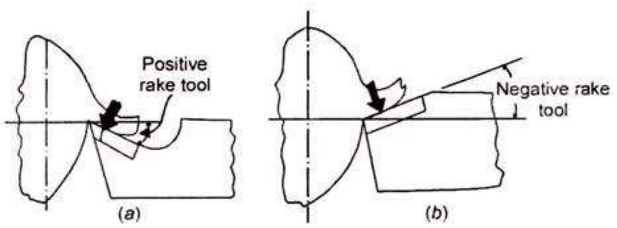


Fig. 9.28. Cutting Process Using Positive and Negative Rake Tools.

Fig. 9.28 shows cutting process using positive and negative rake tools. The positive rake tool experiences shear stress and the tip is likely to be sheared off. Whereas tool with negative rake experiences compressive stress. The carbide and ceramic tools are generally given negative rake because they are weak in shear and good in compression.

(b) Principal Cutting Edge:

Fig. 9.29 shows two different arrangements of principal cutting edge angles. Fig. 9.29 (a), the contact is gradually starting from a point quite away from the tip. Therefore, the tool experiences the cutting force gradually and over a larger area. Hence the tool is safer and tool life is more as compared to the Fig. 9.29 (b) in which the principal cutting edge angle is 90°.

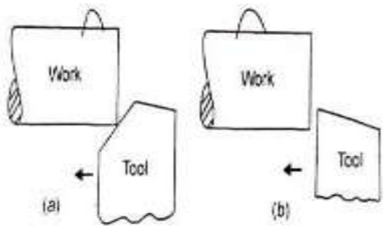


Fig. 9.29. Principal Cutting Edge.

(c) Clearance Angle:

An increase in clearance angle results in significant reduced flank wear, so increased tool life. But the cutting edge will become weaker as the clearance angle is increased. Therefore an optimum value is required. The best compromise is 5° (with carbide tools) to 8° (with H.S.S. tools) for common work materials.

(d) Nose Radius:

The nose radius improves tool life and surface finish.

A relationship between cutting speed, tool life and nose radius is given below:

$VT^{0.09} = 300R^{0.25}$

Where, R = Nose radius (for H.S.S. tool cutting SAE-2346 steel)

T= Tool life (min)

V = Cutting speed (m/min)

i. There is an optimum value of nose radius at which the tool life is maximum.

ii. If the radius exceeds optimum value, the tool life decreases.

iii. Larger radius means larger area of contact between the tool and workpiece. Due to which more frictional heat is generated, results in increased cutting force. Due to which the workpiece may starts, vibrating, hence if rigidity is not very high, brittle tools (carbides and ceramics) will fail due to chipping of cutting edge.

(vii) Type of Cutting Fluid and its Method of Application:

Application of suitable cutting fluid obviously increases tool life or in other words, for the same tool life, allowable cutting speed increases. Fig. 9.30 shows the effect of cutting fluid on tool life for different tool materials. The tool life even increases by 150 per cent at some speeds. All types of cutting fluids do not have equal effect, some of them more, some are less.

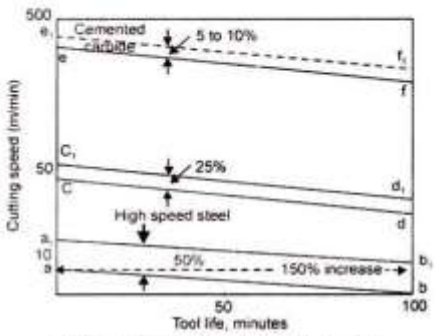


Fig. 9.30. Effect of Cutting Fluid on Tool Life.

(viii) Nature of Cutting:

If the cutting is intermittent, the tool bears impact loading, results in chance of its quick failure. In continuous and steady cutting, the tool life is more.

(ix) Grain Size of Workpiece:

Tool life increases if grain size increases. As if grain size increases, then mean number of grains per square area decreases, and hence hardness decreases, these results in increased tool life.

(x) Rigidity of Workpiece-Machine Tool System:

Higher is the rigidity of system higher will be the tool life. Lower the rigidity of the system, higher is the chance of tool failure, by vibrations of tool or workpiece. Rigidity is the prime requirement in case of intermittent cutting specially when brittle tools are used.

1.5 CHIP FORMATION

1.5.1 Introduction

Chip formation is part of the process of cutting materials by mechanical means, using tools suchas 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.

1.5.2 Types of Chips

1. CONTINUOUS CHIP

During cutting of ductile materials, a continuous chip is produced due to the presence of tool cutting edge in compression and shear. These types of chip are in the form of long coil and have the same thickness throughout the length.

This type of chip is required, since it gives a good surface finish, improving the tool life and less power consumption. However, chip disposal is not easy and the surface finish of the finished work gets affected.

The following condition favours the formation of continuous chips.

1. Smaller depth of cut.

2. High cutting speed.

3. Large rake angle.

4. Proper cutting fluid.

5. Low friction between tool face and the chips.

2. DISCONTINUOUS CHIP OR SEGMENTAL CHIP

Discontinuous chip are as shown in the figure, which are produced while machining brittle materials such as grey cast iron, bronze, high carbon steel at low cutting speed without fluids when friction exists between the tool and chip.

During machining, the brittle materials lack its density which is necessary for plastic chip formation. But, it should be less. This will result in formation of discontinuous chip. In continuous chip formation the shearing occurs at head of cutting tool continuously without fracture whereas in discontinuous chip formation, intermittently rupture occur which will produce segment of chips.

Handling of these chips is easier and it can be easily disposed off, since they are having small length. Also , it will not spoil the finished work piece surface as they do not interfere.

The following condition favours the formation of discontinuous chips.

1. Machining of brittle materials.

2. Small rake angle.

3. Higher depth of cut.

4. Low cutting speed.

5. Excess cutting fluid.

6. Cutting ductile material at very low feeds with small rake angle of the tool.

3. CONTINUOUS CHIP WITH BUILT-UP EDGE

During cutting process, the interface temperature and pressure are quite high and between tool-chip interface the friction is also high. It causes the chip material to weld itself to tool face near the nose as shown in the figure. This is called “built-up edges”.

Formation of built-up edges in continuous chip is a transient and not steady phenomenon. The collected built-up of chip material will then break away, part adhering to the undesired of the chip and part to the work piece. Thus, the process will result in a poor surface finish on the machined surface and accelerated wear on the tool face.

However, this type of chip having some advantage, the one important favour of it is that, from the wears the rake face of the tool is protected due to moving chip and the action of heat. It may result in the increasing of tool life.

The following condition favours the formation of continuous chip with built-up edges.

1. Low cutting speed.

2. Small rake angle.

3. Coarse feed.

4. Large uncut thickness.

5. Insufficient cutting fluid.

1.5.3 Built Up Edge

When the chip is flows in upward direction and high friction is exist in between the interface of the chip and tool. Due to the high friction between the chip and tool a very intense heat is generated at the nose of the tool. The compressed metal adjacent to the tool nose gets welded to it. This compressed metal welded to the nose is called built up edge. When the chip flows through this built up edge, it gets broken and carried away by the chip and called as built up edge chips, the rest of the built up edge is adhere to the surface of the workpiece and makes it rough.

Due to formation of the built up edge the rake angle of the tool gets changed and so is the cutting force.

A. **The Responsible Factors For Promoting The Formation Of The BUE Chips**

a. Excessive feed rate.
b. Small rake angle of the tool.
c. Low cutting speed.
d. Lack of coolant and this increase the friction between the chip tool interfaces.

B. **Advantages**

The making of the BUE has one advantage i.e. it protects the tool from getting damaged from high friction and temperature generated during machining process and hence the tool life increases.

C. **Disadvantages**
The formation of these types of chips results in rough surface finish, change in the
rake angle and cutting forces.

1.6 TURNING OPERATION

1.6.1 Introduction

Turning is one of the most common of metal cutting operations. In turning, a work piece is rotated about its axis as single-point cutting tools are fed into it, shearing away unwanted material and creating the desired part. Turning can occur on both external and internal surfaces to produce an axially-symmetrical contoured part. Parts ranging from pocket watch components to large diameter marine propeller shafts can be turned on a lathe. The capacity of a lathe is expressed in two dimensions. The maximum part diameter, or "swing," and the maximum part length, or "distance between centers." The general-purpose engine lathe is the most basic turning machine tool. As with all lathes, the two basic requirements for turning are a means of holding the work while it rotates and a means of holding cutting tools and moving them to the work. The work may be held on one or by both its ends. Holding the work by one end involves gripping the work in one of several types of chucks or collets. Chucks are mounted on the spindle nose of the lathe, while collets usually seat in the spindle. The spindle is mounted in the lathe's "headstock," which contains the motor and gear train that makes rotation possible. Directly across from the headstock on the lathe is the "tailstock." The tailstock can hold the work by either alive or dead center. Work that is held at both ends is said to be "between canters." Additionally, longer work pieces may have a "steady rest" mounted between the headstock and tailstock to support the work. Typically work pieces are cylindrical, but square and odd shaped stock can also be turned using special chucks or
fixtures. Lathe cutting tools brought to the work may move in one or more directions. Tool movement on the engine lathe is accomplished using a combination of the lathe's "carriage", "cross slide", and "compound rest". The carriage travels along the machine’s bed ways, parallel to the work piece axis. This axis is known as the "Z" axis. Motion perpendicular to the work is called the "X" axis. On an engine lathe this motion is provided by the cross slide mounted on the carriage. The compound rest also holds the "tool post," where tools are mounted. Tools may also be mounted in the tailstock for end-working operations. External turning can be broken down into a number of basic operations. "Straight turning" reduces the work to a specified diameter equally along the work’s axis. "Taper turning" produces a taper along the axis of the work piece. Tapers are

produced by either offsetting the tailstock from centre line or by using a "taper attachment." Some short, steep tapers can be obtained by using the compound rest alone. "Contour turning" or "profiling" uses a single-point cutting tool to reproduce a surface contour from a template. This operation has been almost entirely replaced by numerically controlled or "NC" programming. "Forming" uses a cutting tool ground with the form or geometry of the desired shape. This forming tool is advanced
perpendicular to the axis of the work to reproduce its shape on the work piece. Other external lathe operations include "chamfering" to remove sharp edges, "grooving" to produce recesses and shoulders, "facing" to finish the ends of a work piece, "parting" to cut off finished pieces from the stock, and "thread chasing" with tools to produce the desired thread form. The most common method of internal turning on the lathe is to present the rotating end of a work piece to the point of a non-rotating drill bit mounted in the tailstock. Roughly drilled holes are finished to exact size by using a reamer which also mounts in the tailstock. Large diameter holes are made by boring. A boring bar with a cutting tool attached is moved along the work’s axis as in surface cutting, but inside a previously drilled hole. Internal threads are obtained by using tapping tools mounted in the tailstock. Turning can produce long chips that may interfere with the work in progress. The right cutting tools and proper lubrication are used to control chip formation. Many types of lathes are used for production turning. A cousin of the low volume engine lathe is the electronic engine lathe. This lathe is able to operate semi automatically and fully automatically through electronic controls. The major production lathe today is the numerically controlled or "NC" lathe. These lathes can perform both linear and rotary cuts simultaneously with great precision to produce large numbers of identical parts. Any motion which can be expressed mathematically can be programmed into the lathe’s computer control. Basic NC lathes include the two axis, single turret models and two turret, four axis models. Milling operations can also be added to a lathe’s capabilities by using rotating tools or "live tools" on work pieces. Additionally, some NC lathes incorporate a secondary or sub-spindle to expand the lathe’s production capacity. Long lengths can be fed through the head stock, short lengths or "slugs" can be manually or automatically chucked. Gantry systems are used to handle large, heavy pieces of stock. Production lathes bring tools and arrangements of tools to the work by the use of turrets on larger machines and slide mounted "gang tooling" on smaller, more compact lathes. Regardless of the type of lathe, three key parameters determine productivity and part quality. These parameters are: • the cutting speed • the feed rate • the depth of cut the cutting speed is the speed of the work as it rotates past the cutting tool. The feed rate is the rate at which the tool advances into the work. The depth of cut is the amount of material removed as the work revolves on its axis. Other factors include the machinability of the

stock, the type and the geometry of the cutting tool, the angle of the tool to the work, and the overall condition and power of the lathe itself.

1.6.2 Turning Operations

This operation is one of the most basic machining processes. That is, the part is rotated while a single point cutting tool is moved parallel to the axis of rotation. Turning can be done on the external surface of the part as well as internally (boring). The starting material is generally a work piece generated by other processes such as casting, forging, extrusion or drawing.

A. TAPERED TURNING
I. From the compound slide.
II. From tapper turning attachment.
III. Using a hydraulic copy attachment.
IV. Using a lathe.
V. Using a form tool.
VI. By the offsetting of the tailstock-this method more suited for shallow tappers.
B. SPHERICAL GENERATION
The proper expression for making or turning a shape is to generate as in to generate a
form around a fixed axis of revolution.
I. Using hydraulic copy attachment.
II. Lathe.
III. Using a form tool.
IV. Using bed jiz.
C. HARD TURNING
Hard Turning is a turning done on material with Rockwell C hardness greater than 45. It is typically performed after the work piece is heat treated. The process is intended to replace or limit traditional grinding operations. Hard turning, when applied for purely stock removal purposes, completes favorably with rough grinding. However, when it is applied for finishing where form and dimension are critical, grinding is superior. Grinding produces higher dimensional accuracy of roundness and cylindricity. In addition, polished surface finishes of RZ-0.3-0.8Z cannot be achieved with hard turning alone. Hard turning is appropriate for parts requiring roundness accuracy of 0.5 to 12 micro meters, and surface roughness of RZ0.8-7.0 micro meters. It is used for gears, injection pump components, and hydraulic components and among other applications.

D. FACING
Facing in the context of turning work involves moving the cutting tool at right angle to the axis of rotation of the rotating work piece. This can be performed by

the operation of the cross-slide, if one is fitted, as distinct from the longitudinal field (turning). It is frequently the first operation performed in the production of work piece, and often the last-hence the phrase “ending up”.

1.6.3 Dynamics of Turning

A. **FORCES**

The relative forces in a turning operation are important in the designing of machine tools. The machine tools and its component must be able to withstand these forces without causing significant deflections, vibrations, chatter during the operation. There are three principle forces during a turning process:

I. The cutting or tangential force acts downward on the tool tip allowing deflection of the work piece upward.

II. The axial or feed force act in the longitudinal direction. It is also called the feed force because it is in the feed direction of the tool. This force tends to push the tool away from the chuck.

III. The radial or thrust force acts in the radial direction and tends to push the tool away from the work piece.

B. **CUTTING SPEED**

Speeds and feeds for turning are chosen based in cutter material, work piece material, set up rigidly, machine tool rigidly and spindle power, coolant choice, and other factors.

C. **FEED**

The distance the tool advances into the material in one revolution is called “feed”. It is specified as mm per revolution (mm/rev).

1.7 POLISHING EFFECT

1.7.1 Introduction

Polishing is the process of creating a smooth and shiny surface by rubbing it or using a chemical action, leaving a surface with a significant specular reflection (still limited by the index of refraction of the material according to the Fresnel equations.) In some materials (such as metals, glasses, black or transparent stones) polishing is also able to reduce diffuse reflection to minimal values. When an unpolished surface is magnified thousands of times, it usually looks like mountains and valleys. By repeated abrasion, those "mountains" are worn down until they are flat or just small "hills." The process of polishing with abrasives starts with coarse ones and graduates to fine ones.

I. A process to generate a reflective surface

II. Normally, the polish is generated by using a fine-micron or sub-micron abrasive particle in combination with a liquid. Polishing is a “wet” process.

III. Often the polishing process utilizes a pad to contain the abrasive, so polishing may not be a “loose abrasive process.” The pad is softer than the part.

IV. Very little material is removed during the polishing process, normally measured in Microns.

V. The surface finish of the work-piece to be polished must be of a high quality prior to the polishing process taking place, so the pre-polishing process is often a “lapped” surface.

1.7.2 Polished Surface Functions

A. Enables sealing of high pressure gases and liquids.
B. Cosmetic purposes.
C. Enables the use of optical flatness measurement instruments.
D. Reduces the amount of surface and sub-surface damage.
E. Provides better uniformity of surfaces requiring epitaxial processes or deposited materials.
F. Generates sharper edges on cutting tools.

1.7.3 Types of Polishing

- disc finishing machines
- centerless finishing machines
- buffers
- cylindrical polishers
- honing machines
- lapping machines
- orbital devices
- polishing lathes
- super-finishing equipment
- vibratory or oscillatory machines
- specialty devices

1.7.4 The Polishing Process

A. **Rough Polish**: Fine machining, EDM, grinding, etc. can be polished with a rotating surface polisher with a rotational speed of 35 000 to 40 000 r/min. Then there is a manual oil stone grinding, strip of oil stone plus kerosene as a lubricant or coolant. The order of use is 180#→240#→320#→400#→600#→800#→1 000#.

B. **Semi-Fine Polish**: Semi-finishing mainly uses sandpaper and kerosene. The number of sandpaper is in order: 400#→600#→800#→1000#→1200#→1500#. In fact, #1500 sandpaper only uses mold steel suitable for hardening (above 52HRC), and is not suitable for pre-hardened steel, because it may cause damage to the surface of prehardened steel and cannot achieve the desired polishing effect.

C. **Fine Polish**: Fine polishing mainly uses diamond abrasive paste. If grinding with a polishing cloth wheel to mix diamond abrasive powder or abrasive paste, the usual 33 grinding order is 9 µm (1 800 #) → 6 µm (3 000 #) → 3 µm (8 000 #). The 9 µm diamond paste and polishing cloth wheel can be used to remove the hair marks from the 1 200# and 1 50 0# sandpaper. The polishing is then carried out with a felt and a diamond paste in the order of 1 µm (14 000 #) → 1/2 µm (60 000 #) → 1/4 µm (100000 #).

1.7.5 Working Environment

The polishing process should be carried out separately at two working locations, that is, the rough grinding processing location and the fine polishing processing location are separated, and care should be taken to clean the sand particles remaining on the surface of the workpiece in the previous process.

Generally, after rough polishing with oil stone to 1200# sandpaper, the workpiece needs to be polished to clean without dust, ensuring that no dust particles in the air adhere to the mold surface. Accuracy requirements above 1 µm (including 1 µm) can be performed in a clean polishing chamber. For more precise polishing, it must be in an absolutely clean space, as dust, smoke, dandruff and water droplets can scrap high-precision polished surfaces.

After the polishing process is completed, the surface of the workpiece should be protected from dust. When the polishing process is stopped, all abrasives and lubricants should be carefully removed to ensure that the surface of the workpiece is clean, and then a layer of mold anti-rust coating should be sprayed on the surface of the workpiece.

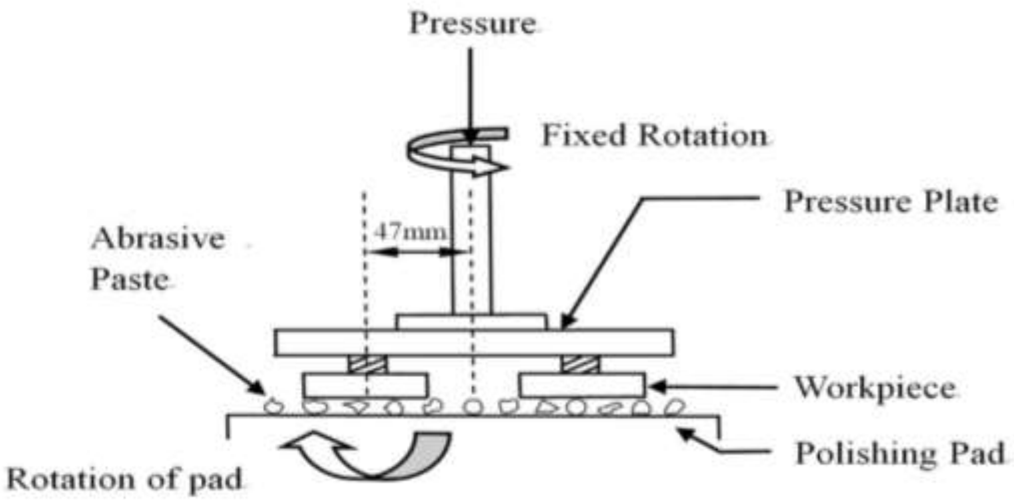


Figure 1.12. Working Principle of Polishing

1.8 SURFACE ROUGHNESS

1.8.1 Introduction

A surface is a boundary that separates an object from another object or substance. In order to make understand the measurement of surface finish, surfaces can then further be divided into two more types as following:

I. **Real Surface:** It is the actual boundary of an object. It is produced as a result of the process that created the surface.

II. **Measured Surface:** A measured surface is a representation of the real surface obtained with some measuring instrument. This distinction is made, because no measurement will give the exact real surface.

III. **Surface is made of** − Roughness, Waviness and Lay.

1.8.2 Surface Finish Imperfections

The subject of surface finish imperfections consists of mainly following two imperfections: Form Error and Texture. The Form Error is for longer wavelength deviations of a surface from the corresponding nominal surface. Form errors result from large scale problems in the manufacturing process such as errors in a machine tool ways, guides or spindles, inaccurate alignment of work-piece. Form error is on the dividing line in size scale between geometric errors and finish errors. We shall be discussing more on the surface Texture imperfection, as it is indicated in the drawing as surface roughness symbol.

I. **Surface Texture --** Surface texture is the combination of fairly short wavelength deviations of a surface from the nominal surface. Texture includes roughness, waviness and a lay, that is, all of the deviations that are shorter in wavelength than form error deviations.

II. **Roughness --** Roughness includes the finest (shortest wavelength) irregularities of a surface. Roughness generally results from a particular production process or material condition.

III. **Waviness --** Waviness includes the more widely spaced (longer wavelength) deviations of a surface from its nominal shape. Waviness errors are intermediate in wavelength between roughness and form error. Note, the distraction between waviness and form error is not always made in practice and it is not always clear how to make it.

IV. **Lay --** Lay refers to the predominant direction of the surface texture. Ordinarily, lay is determined by the particular production method and geometry used. Both the words – "Surface Texture" and "Surface Roughness" are used to explain common meaning of surface roughness symbols. Surface roughness heights are generally measured in micro inches or micrometers. A micrometer, abbreviated μ, is one millionth of a meter.

1.8.3 Interpretation of Surface Traces

To be of any use to humans, surface traces are magnified moderately in the horizontal direction and significantly in the vertical direction in order to be presented on a computer screen or a piece of paper. As a typical example, a 4 mm trace with a 10 μ height from the highest peak to lowest valley might be expanded to fit on a 160 mm wide by 100 mm high plot. This is a 40X magnification horizontally and a 10,000X magnification vertically. This differences leads to a very sharply undulating trace that easily deceives the uninitiated as to the actual shape of the surface.

Parameter Details –

i. **Ra** Roughness Average (Ra)
ii. **Rq** Root Mean Square (RMS) Roughness
iii. **Rt** Maximum Height of the Profile
iv. **Rv**, **Rm** Maximum Profile Valley Depth
v. **Rp** Maximum Profile Peak Height
vi. **Rpm** Average Maximum Profile Peak Height

vii. **Rz** Average Maximum Height of the Profile
viii. **Rmax** Maximum Roughness Depth
ix. **Rc** Mean Height of Profile Irregularities
x. **Rz**(ISO) Roughness Height
xi. **Ry** Maximum Height of the Profile
xii. **Wt, W** Waviness Height
xiii. **S** Mean Spacing of Local Peaks of the Profile
xiv. **Sm, RSm** Mean Spacing of Profile Irregularities
xv. **D** Profile Pieak Density
xvi. **Pc** Peak Count (Peak Density)
xvii. **HSC** Keight Spot Count
xviii. **la** Average Wavelength of the Profile
xix. **lq** Root Mean Square (RMS) Wavelength of the Profile
xx. **Da** Average Absolute Slope
xxi. **Dq** Root Mean Square (RMS) Slope
xxii. **Lo** Developed Profile Length
xxiii. **Lr** Profile Length Ratio
xxiv. **Rsk,Sk** Skewness

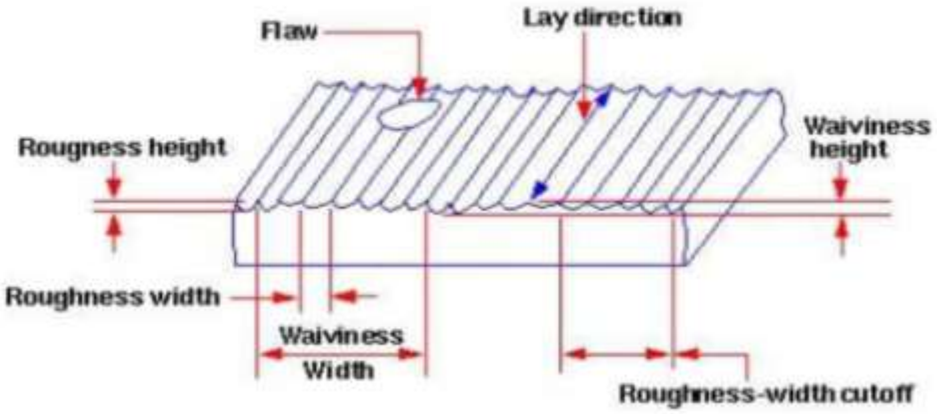


Figure 1.13 - Details of Roughness Parameters

1.8.4 Parameters

A. **Arithmetical Mean Heigh t (Ra, Pa, Wa)**: Arithmetical mean height indicates the average of the absolute value along the sampling length. When dealing with the roughness profile, Ra is referred to as the arithmetic mean roughness, while Wa is referred to as the arithmetic mean waviness for the waviness profile.

B. **Maximum Height of Profile (Rz, Pz, Wz)**: The maximum height of the profile indicates the absolute vertical distance between the maximum profile peak height and the maximum profile valley depth along the sampling length. When dealing with roughness profile, Rz is referred to as the maximum roughness, while Wz is referred to as the maximum waviness when dealing with waviness profile.

C. **Maximum Profile Peak Height (Rp, Pp, Wp)**: Maximum profile peak height indicates the point along the sampling length at which the curve is highest.

D. **Maximum Profile Valley Depth (Rv, Pv, Wv)**: Maximum profile valley depth indicates the point along the sampling length at which the profile curve is lowest.

E. **Mean Height of Profile Elements (Rc, Pc, Wc)**: Mean height of profile elements indicates the average value of the height of the curve element along the sampling length.

Profile elements consist of a peak and a neighboring valley. The peaks (or valleys) that constitutes as an element have minimum height and length standards such that they will be treated as noise and considered a part of the preceding valley (or peak) if the height (or depth) is less than 10% of the maximum height or the length is less than 1% of the segment length.

F. **Total Height of Profile (Rt, Pt, Wt)**: Total height of profile is the vertical distance between the maximum profile peak height and the maximum profile valley depth along the evaluation length.

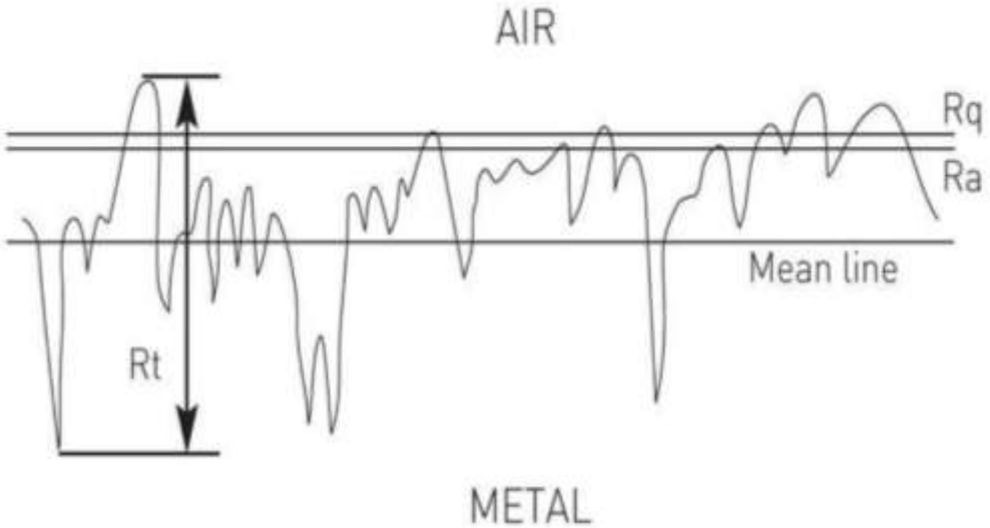


Figure 1.14 - Surface Roughness Graph

Figure 1.15 - Portable Surface Roughness Tester

1.9 TOOL WEAR

1.9.1 Introduction

Cutting tools are subjected to an extremely severe rubbing process. They are in metal-tometal contact between the chip and work piece, under high stress and temperature. The situation becomes severe due to the existence of extreme stress and temperature gradients near the surface of the tool.

Tool wear is generally a gradual process due to regular operation. Tool wear can be compare with the wear of the tip of an ordinary pencil. According to Australian standard, the tool wear can be defined as "The change of shape of the tool from its original shape, during cutting, resulting from the gradual loss of tool material".

1.9.2 Dependent Parameters

I. Tool and work piece material.
II. Tool shape.
III. Cutting Speed.
IV. Feed.
V. Depth of cut.
VI. Cutting fluid used.
VII. Machine Tool characteristics etc..

1.9.3 Tool Wear Affecting Items

I. Increased cutting forces.
II. Increased cutting temperature.

III. Decreased accuracy of produced parts.
IV. Decreased tool life.
V. Poor surface finish.
VI. Economics of cutting operations.

1.9.4 TYPES OF TOOL WEAR

I. Tool rake face and chips.
II. Tool flank face and machined surface.

These results in a variety of wear patterns observed at the rake face and the flank face. This is
called gradual wear of the tool. The gradual wear is unavoidable but controllable. It is the wear which cannot be prevented. It has to occur after certain machining time. The gradual
wear can be controlled by remedial action. The gradual wear can be divided into two basic
types of wear, corresponding to two regions in the cutting tool.
These are following:

A. **FLANK WEAR**

Wear on the flank face (relief or clearance face) of the tool is called flank wear. The
flank wear is shown in Figure 1.17

a) The characteristics of flank wear are following:

i. It is the most important wear that appears on the flank surface parallel to the cutting edge. It is most commonly results from abrasive/adhesive wear of the cutting edge against the machined surface.
ii. It is generally results from high temperatures, which affect tool and work material properties.
iii. It results in the formation of wear land. Wear land formation is not always uniform along the major and minor cutting edge of the tool.
iv. It can be measured by using the average wear land size (V3) and maximum wear land size (VBmax).
v. It can be described using the Tool Life Expectancy Equation.

VcTn = C

b) Reasons of Flank Wear:

i. Increased cutting speed causes flank to wear grow rapidly.
ii. Increase in feed and depth of cut can also result in larger flank wear.
iii. Abrasion by hard panicles in the work piece.
iv. Shearing of micro welds between tool and work-material.
v. Abrasion by fragments of built-up edge, which strike against the clearance face (Flank face) of the tool.

B. **CRATER WEAR**

Wear on the rake face of the tool is called crater wear. As the name suggests, the shape

of wear is that of a crater or a bowl. The crater wear is shown in Figure 1.9.4.B.
a) The characteristics of crater wear are following:
i. In crater wear chips erodes the rake face of tool.
ii. The chips flows across the rake face develop severe friction between the chip and rake face. This produces a scar on the rake face which is usually parallel to the major cutting edge.
iii. It is somewhat normal for tool wear and does not seriously degrade the use of a tool until it becomes serious enough to cause a cutting edge failure.
iv. The crater wear can increase the working rake angle and reduce the cutting force, but it will also weaken the strength of the cutting edge.
v. It is more common in ductile materials like steel which produce long continuous chips. It is also more common in H.S.S. (High Speed Steel) tools than the ceramic or carbide tools which have much higher hot hardness.
vi. The parameters used to measure the crater wear can be seen in the Fig. 1.17. The crater depth KT is the most commonly used parameter in evaluating the rake face wear.
vii. It occurs approximately at a height equal to the cutting depth of the material, i.e., Crater wear depth ≃ cutting depth.
viii. At high temperature zones (nearly 700°C) create wear occurs.
b) Reasons of Crater Wear:
i. Severe abrasion between the chip-tool interfaces, specially on rake face.
ii. High temperature in the tool-chip interface.
iii. Increase in feed results in increased force acting on tool interface, this leads to
rise in temperature of tool-chip interface.
iv. Increase in cutting speed results in increased chip velocity at rake face, this leads to rise in temperature at chip-tool interface and so increase in crater wear.

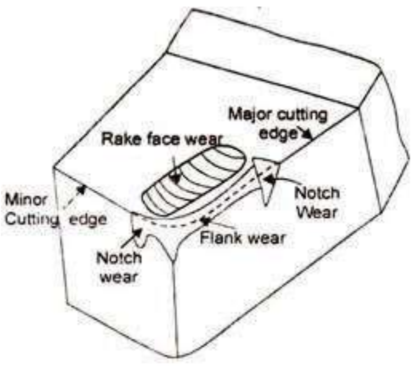


Figure 1.16 - Tool Wear Phenomena Figure

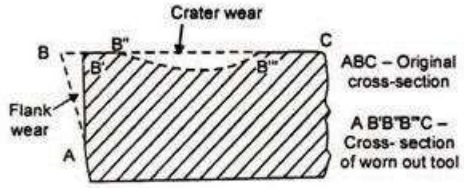


Figure 1.17 - Crater Wear & Flank Wear

1.9.5 CAUSES OF TOOL WEAR

There are large numbers of causes for tool wear. Some important points are.

A. **Abrasive Wear (Hard Particle Wear):**

Abrasive wear is basically caused by the impurities within the work piece material,
such as carbon nitride and oxide compounds, as well as the built-up edge fragments. It
is a mechanical type of wear. It is the main cause of the tool wear at low cutting speeds.

B. **Adhesive Wear:**

Due to high pressure and temperature at tool-chip interface, there is a tendency of hot
chips to weld on to the tool rake face. This concept leads to subsequently formation and
destruction of welded junctions. When the weld intermittently breaks away picking
particles of cutting tool. This leads to a crater wear.

C. **Diffusion Wear:**

Diffusion wear is usually caused by atomic transfer between contacting materials under
high pressure and temperature conditions. This phenomena start at chip-tool interface.
At such elevated temperatures, some particles of tool materials diffuse into the chip
material. It can also happen that some particles of work material also diffuse into the
tool materials.

There are several ways of diffusions like:

i. Gross Softening of the Tool
ii. Diffusion of Major Tool Constituents into the Work
iii. Diffusion of a Work Material Component into the Tool

D. **Chemical Wear:**

The chemical wear is caused due to chemical attack of a surface.
For example: Corrosive wear.

E. **Facture Wear:**

The facture wear usually caused by breaking of edge at end or length. The bulk

breakage is the most harmful and undesirable type of wear, and it should be avoided as
far as possible.

1.9.6 FORMS OF TOOL WEAR

Flank and crater wear are very common type of wears. Some other forms of tool wear are:

A. **Thermo-Electric Wear**:

It can be observed in high temperature region. The high temperature results in the formation of thermal-couple between the work piece and the tool.

Due to this effect voltage established between the work piece and tool. It may cause an
electric current flow between the two. However, this type of wear has not been clearly
developed.

B. **Thermal Cracking and Tool Fracture**:

It is common in case of milling operation. In milling, tools are subjected to cyclic thermal and mechanical loads. Teeth may fail by a mechanism not observed in continuous cutting. Thermal cracking can be reduced by reducing the cutting speed or
by using a tool material grade with a higher thermal shock resistance.

C. **Cyclic Thermal and Mechanical Load Wear**:

The cyclic variation in temperature in milling process induce cyclic thermal stress at the
surface layer of the tool expands and contracts. It may leads to the formation of thermal
fatigue cracks near the cutting edge.

Mostly, such cracks are perpendicular to the cutting edge and begin formation at the
outer corner of the tool, spreading inward as cutting progresses. The growth of these
cracks eventually leads to edge chipping or tool breakage. An insufficient coolant can
promote crack formation.

D. **Edge Chipping**:

Edge chipping is commonly observed in milling operation. It may occur when the tool
first contacts the part (Entry Failure) or, more commonly, when it exits the part (Exit
Failure).

E. **Entry or Exit Failures**:

Entry failure most commonly occurs when the outer corner of the insert strikes the part first. This is more likely to occur when the cutter rake angles are positive. Entry failure is therefore most easily prevented by switching from positive to negative rake angle cutters.

1.9.7 EFFECTS OF TOOL WEAR

The effects of the tool wear on technological performance are following:

A. **Increase in Cutting Forces**:

The cutting forces are normally increased by wear of the tool. Crater wear, flank wear (or wear land formation) and chipping of cutting edge affect performance of the cutting tool in various ways. Crater wear may, however under certain circumstances, reduce forces by effectively increasing the rake angle of the tool. Clearance face (Flank or

wear-land) wear and chipping almost invariably increase the cutting forces due to increased rubbing forces.

B. **Increase in Surface Roughness**:

As the tool wear increases, the surface roughness of machined component also increases. This is particularly true for a tool worn by chipping .Although, there are circumstances, in which a wear land may burnish (polish) the work piece and produce a good finish.

C. **Increase in Vibration or Chatter**:

Vibration or chatter is another important aspect of the cutting process which may be influenced by tool wear.

A wear land increases the tendency of a tool to dynamic instability or vibrations. When the tool is sharp, the cutting operation is quite free of vibrations. On the other hand, when the tool wears, the cutting operation is subjected to an unacceptable vibration and chatter mode.

D. **Decreases in Dimensional Accuracy**:

Due to flank wear, the plan geometry of a tool may disturb. This may affect the dimensions of the component produced. It may influence the shape of the component.

For example: If tool wear is rapid, cylindrical turning could result in a tapered work piece.

1.10 MATERIAL REMOVAL RATE

1.10.1 INTRODUCTION

Material Removal Rate (MRR), otherwise known as Metal Removal Rate, is the measurement for how much material is removed from a part in a given period of time. Every shop aims to create more parts in a shorter period of time, or to maximize money made while also minimizing money spent. One of the first places these machinists turn is to MRR, which encompasses Radial Depth of Cut (RDOC), Axial Depth of Cut (ADOC), and Inches Per Minute (IPM). If you’re aiming to boost your shop’s efficiency, increasing your MRR even minimally can result in big gains.

With higher MRR’s, chip evacuation becomes vitally important as more chips are evacuated in a shorter period of time. Utilizing a tool best suited for the operation – in terms of quality and flute count – will help to alleviate the additional workload. Additionally, a tool coating optimized for your workpiece material can significantly help with chip packing.

Further, compressed air or coolant can help to properly remove chips from the tool and workpiece.

1.10.2 CALCULATING MRR

The calculation for Material Removal Rate is RDOC x ADOC x Feed Rate. As an example, if Radial Depth of Cut (RDOC) is 0.500″, Axial Depth of Cut (ADOC) is 0.100″ and Feed Rate is 41.5 inches/minute, calculation of MRR the following way:

MRR = .500″ x .100″ x 41.5 in/min = 2.08 cubic inches per minute.

Another process is (Volume Removed / Time)

Volume Removed = Lwto

Time to move a distance L = L/V

Therefore, MRR = Lwto/(L/V) = Vwto

MRR = Cutting Velocity x Width of Cut x Depth of Cut

1.10.3 OPTIMIZING EFFICIENCY

A machinists’ depth of cut strategy is directly related to the Material Removal Rate. Using
the proper RDOC and ADOC combination can boost MRR rates, shaving minutes off of
cycle times and opening the door for greater production. Utilizing the right approach for your
tool can also result in prolonged tool life, minimizing the rate of normal tool wear.
Combining the ideal feed rate with your ADOC and RDOC to run at your tool’s “sweet spot”
can pay immediate and long term dividends for machine shops.

Optimizing workplace efficiency is vital to sustained success and continued growth in
every business. This is especially true in machine shops, as even a very minor adjustment in
operating processes can result in a massive boost in company revenue. Proper machining
methods will boost MRR, minimize cycle times, prolong tool life, and maximize shop output.

1.11 MICROSTRUCTURE

1.11.1 INTRODUCTION

Metals are crystalline when in the solid form. The crystal structure of a solid metal refers to
the internal structure or arrangement of the atoms in an ordered, repeating, three dimensional
pattern. Normal metallic objects are polycrystalline, which means they consist of an
aggregate of many very small crystals. These crystals are called grains. Some metallic
objects, such as castings, have very large grains that can be resolved with the naked eye and these structures are referred to as macrostructures. Typically, the grains of a metal object are
very small, and can’t be viewed with the naked eye. The structural features of the small
grains are observed using an optical microscope or metallograph, or an electron microscope,
at magnifications greater than 100 times. Structures requiring this range of magnification for
their examination are called microstructures.

Microstructures are material structures seen at the micro level. Specifically, they are

structures of an object, organism, or material as revealed by a microscope at magnifications
greater than 25 times.

When typically mentioned, the microstructures are defects, impurities, grains, and grain boundary. Simply put, anything that is not regular from a given crystalline structure is a
microstructure. Useful definitions below:

Defects in general are simply errors or interruptions in the uniform crystalline lattice.

Impurities are atoms (like dirt) that don't belong in the regular crystalline structure.

Grains are pure crystals or uniform sections of crystal growth.

Grain boundaries are boundaries around the separated grains.

1.11.2 MICROSTRUCTURE FORMATION

Microstructures form through a variety of different processes. Microstructures are almost always generated when a material undergoes a phase transformation brought about by changing temperature and/or pressure (e.g. a melt crystallising to a solid on cooling). Microstructures can be created through deformation or processing of the material (e.g. rolling, pressing, and welding). Finally, microstructures can be created artificially by combining different materials to form a composite material

A. **Solidification:** Solidification of a crystal from a melt occurs through a process of nucleation and growth. Below the freezing temperature, small clusters of atoms in the melt come together through random chance to form a small crystalline particle (a nucleus). The nucleus forms a template onto which other atoms can attach. Each nucleus grows into an individual grain of the crystal. When adjacent grains impinge
they form grain boundaries. Since individual nuclei form in different orientations, there
is no orientation relationship between adjacent grains.

B. **Phase separation** (exsolution, precipitation)**:** A multi-component material can exist as
a single phase if the components are intimately mixed (i.e. miscible) at the atomic scale (Forming a solid solution). In many materials, miscibility is restricted to a limited range
of compositions. The range of miscibility is a strong function of temperature: a material
that is happy to form a single phase at high temperature might be forced to unmix into
two phases at lower temperature (i.e. the components become immiscible). This process

is known as phase separation, exsolution or precipitation. We have already seen a
classic example of this phenomenon in the case of the Fe-Ni meteorite in Part 1.2.

IMPOTENCY OF MICROSTRUCTURE

The most important aspect of any engineering material is its structure. The structure of a
material is related to its composition, properties, processing history and performance. And
therefore, studying the microstructure of a material provides information linking its
composition and processing to its properties and performance. Interpretation of
microstructures requires an understanding of the processes by which various structures are
formed. Physical Metallurgy is the science which provides meaningful explanations of the
microstructures, through understanding what is happening is inside a metal during the various
processing steps. Metallography is the science of preparing specimens, examining the
structures with a microscope and interpreting the microstructures.

MICROSTRUCTURAL ANALYSIS

Macrostructural and microstructural examination techniques are employed in areas such as routine quality control, failure analysis and research studies. In quality control, microstructural analysis is used to determine if the structural parameters are within certain specifications. It is used as a criterion for acceptance or rejection. The amount or size of these features can be measured and quantified, and compared to the acceptance criterion. Various techniques for quantifying microstructural features, such as grain size, particle or pore size, volume fraction of a constituent, and inclusion rating, are available for comparative analysis. Microstructural analysis is used in failure analysis to determine the cause of failure. Failures can occur due to improper material selection and poor quality control. Microstructural examination of a failed component is used to identify the material and the condition of the material of the component. Through microstructural examination one can determine if the component was made from specified material and if the material received the proper processing treatments. Failure analysis, examining the fracture surface of the failed component, provides information about the cause of failure. Failure surfaces have been well documented over the years and certain features are associated with certain types of failures. Using failure analysis, it is possible to determine the type of stress that caused the component to fail and often times determine the origin of the fracture. property testing. Through these research programs the processing - structure – property. Microstructural analysis is used in research studies to determine the microstructural changes that occur as a result of varying parameters such as composition, heat treatment or processing steps. Typical research studies include microstructural analysis and materials relationships are developed.

METALLOGRAPHY

Metallography is the study of the structure of metals. It includes the techniques used to prepare specimens for examination, examining the specimen and interpreting the structures. Specimen preparation is an important part of metallography. A specimen must be appropriately prepared to ensure correct observation and interpretation of the microstructure. Specimen preparation consists of sample selection, sectioning, grinding, polishing, and etching. Adequate sample selection provides a statistically reliable description of the material quality. The number, location and orientation of the samples examined are important parameters in sample selection. Sectioning, grinding and polishing are used to prepare a flat specimen with a mirror like finish. The as polished condition is useful for examining the microstructures of materials whose constituents exhibit large differences in light reflectivity after polishing. Porosity and inclusions are examples of features that are easily observed in the as polished condition. But most materials are etched to reveal the microstructure. Etching is a controlled corrosion process resulting from electrolytic action between surface areas of different potential. Etching reveals the microstructure of a material by selective dissolution of the structure. Specimens are then examined using optical and electron microscopes. There are also many other techniques used to characterize the structure of metals, but this article will concentrate on microstructural characterization.

RESIDUAL STRESS

INTRODUCTION

Residual stresses or locked-in stresses can be defined as those stresses existing within a body in the absence of external loading or thermal gradients. In other words residual stresses in a structural material or component are those stresses which exist in the object without the application of any service or other external loads. Residual stresses are locked-in stresses within a metal object, even though the object is free of external forces. These stresses are the result of one region of the metal being constrained by adjacent regions from expanding, contracting, or releasing elastic strains. Residual stresses can be tensile or compressive. In fact, tensile and compressive residual stresses co-exist within a component.

CAUSES OF RESIDUAL STRESS

Residual stresses arise whenever a component is stressed beyond its elastic limit and plastic deformation occurs. Plastic deformation occurs when the stress exceeds a metal’s yield strength. This can be as a result of:

- Non-uniform plastic deformation during mechanical processing, such as that during rolling, forming operations (bending or drawing), machining, and mechanical surface treatments (shot peening and roller burnishing).
- Phase transformations during cooling from elevated temperatures
- Non-uniform plastic deformation during heating or cooling
- Heterogeneity of a chemical or crystallographic order (nitriding or case hardening)
- Various surface treatments (enamelling, electroplating PVD and CVD coating)

1.12.3 EFFECTS OF RESIDUAL STRESS

Residual stresses can be beneficial or detrimental, depending on whether the stress is tensile or compressive. Tensile residual stresses can be large enough to cause component distortion or cracking. Also, fatigue and stress corrosion cracking require the presence of tensile stresses. Because residual stresses are algebraically summed with applied stresses, surface residual tensile stresses combined with an applied tensile stress can reduce the reliability of components. In fact, a residual tensile stress is sometime sufficient to cause stress corrosion cracking. Surface residual compressive stresses are generally helpful because they reduce the effects of applied tensile stresses. In most cases, surface compressive stresses contribute to the improvement of fatigue strength and resistance to stress-corrosion cracking.

RESIDUAL STRESS MEASURING METHODS

- X-Ray Diffraction
- Ultrasonic Methods
- Magnetic Methods
- Electronic Speckle Pattern Interferometer
- Hole Drilling And Strain Gage Technique
- Core Hole Drilling And Strain Gage Technique

TYPE OF RESIDUAL STRESS

I. **Macro-residual stresses** are developed in several grains. Any change in the equilibrium of Type-1 residual stress will result in a change in macroscopic dimensions. Any treatment or process which causes inhomogeneous distribution of strains produces Type-1 residual stresses.

II. **Micro-residual stresses** are developed in one grain. They can be in different sizes in different grains. Especially martensitic transformation produces Type-2 residual stress. During the transformation, incomplete transformation of austenite is observed. The volume of martensite is larger than that of austenite and this difference forms residual stresses.

III. **Sub-micro residual stresses** are developed within several atomic distances of the grain. Formation is caused by crystalline defects such as vacancies, dislocations, etc. In real life, components have all the residual stress types.

Chapter – 2: Literature Review

J. A. GOLLER AND G. BARROW states :

A model for the prediction of surface finish in turning is presented. This model is based on an extensive series of experiments using various tool and workpiece combinations over a wide range of cutting conditions. In common with previous work it was found that for all the conditions tested there is a velocity dependent region and a velocity independent region with respect to the Ra value of surface finish. Contrary to theoretical predictions it was found that the Ra value is not inversely proportional to tool nose radius r and that it increases at low value of feed rate such that, in general, there is an optimum feed/rev for minimum Ra.

S. Veerendra Prasad, B. V. R. Ravi Kumar and V. V. Subba Rao states

Finding surface roughness of a turned product involves taking the product from the machine and measuring the surface roughness separately, which involves downtime during the machining process. This paper covers a new method of predicting the surface roughness, which involves recording the sound generated during machining and analyzing the sound level versus frequency graph for patterns specific to a particular condition, i.e., if the surface roughness produced during machining is high, it produces distinctive graph when compared to graph generated during machining of the product which got less surface roughness values. If a correlation is done for specific patterns in the graphs generated and surface roughness values, the process can be automated such that the sound generated during the machining is analyzed and checked for predetermined correlated conditions and surface roughness can be estimated during the machining process itself without removing the workpiece. EN19 (AISI 4140) steel round stock is taken and is turned at different speeds, feeds and depths of cut parameters combination. The surface roughness values of the turned workpieces were measured separately. Sound generated during the machining processes is recorded by using a sound recorder. The recorded sound is processed in audio-editing software to remove any ambient noises and to eliminate the sound generated due to chips from the machining sound. Frequencies versus sound level graphs are generated and peak amplitude values are noted. Prediction conditions were framed by analyzing graphs generated between experiment number—peak amplitude and experiment number—surface roughness. Confirmation experiments were performed and the sound recorded was analyzed and surface roughness was predicted within a close range and the surface roughness was later measured by a profilometer showed the predicted surface roughness values were true.

Rupesh Chalisgaonkar states

In this research investigation, input parameters—cutting speed (CS), feed rate (f) and depth of cut (doc)—were selected for process capability evaluation in milling process using CNC VMC. The process capability index of surface finish was calculated using two types of tools (titanium nitride coated carbide tool and solid carbide tool) during CNC milling operation of EN 19 alloy steel. The optimal process parametric setting was evaluated using single response optimization through Taguchi's robust design. The single response optimization was done for process capability index so that manufactured component could not fall beyond the criteria set for surface finish by customer in case of using both tools. Confirmatory experiments were conducted finally to validate the results.

D. Kumaravel and K. Arunkumar states

This project deals with improving the wear property of En19 steel by boronizing process. En19 steel is used in industrial applications such as gear and shaft manufacturing. It is often selected for high-strength application. Due to its less wear resistance property, En19 steel is not preferred for certain applications. In this project, boronizing by paste method was selected to increase the wear property of En19 steel. Boronizing is a surface modification technique used to enhance the hardness of a metal. Wear studies of the coated specimen were conducted as per the standards. The pin-on-disc tribometer with its combined computer control and Tribo-X software was used to rank the wear property of material.

Anis Fatima, Asim Zaheer & Muhammad Fahad states

Surface structuring has been long existed to improve the tribological application. Recently, it has been applied to the cutting tools and has shown the promising results. However, no study has been yet conducted that identified the suitable shape of structures that can be meritoriously applied to the cutting tool. In this study, laser-radiated micro-structures in shape of holes and slots were created on the rake face of cutting tools. Their machining performance was observed over the range of cutting speed and compared to unstructured cutting tool. Machining factors such as cutting force, compression ratio, contact length and tool wear were selected as a criterion of performance. Wide range of orthogonal cutting experiments was performed to identify shapes of microstructures that can bring elevated results in mechanical machining. Sticking and sliding contact characterization were executed. For the greater advantage, the assessment of machinability rating has also been taken under consideration. It was found that the end goal (better performance or reduced energy consumption) of mechanical machining process is associated with structure shape.

N. R. Abhaya Simha, M. P. Sushanth, V. Bagali Sachin, Maruti, T. S. Prasanna Kumar & V. Krishna states

A hardness model employing the end quench Jominy method is developed for steels C25, EN8, EN19, EN31 and EN24. The time-temperature data are obtained from four thermocouples mounted at critical places of a specimen. The heat flux during the quenching is determined from the cooling curve obtained with the help of the thermocouple closest to the end of the specimen (quenching place). The two-dimensional axisymmetric equation of heat conduction is solved and used jointly with the models of decomposition of austenite to obtain the distribution of microstructure at the places used to plot the cooling curves. The computed distribution of microstructure and the chemical compositions of the steels are used to estimate the hardness. The computed hardness values agree well with those determined experimentally over the length of the specimen.

Future Work

The work piece details are collected for EN19 and after that the physical properties, mechanical properties, chemical properties will be done.
This if followed by experiments which are done to find MRR and take a note of feed and depth of cut.

- Detailed study with large variety of input parameters for Turning operation
- Detailed surface morphology study Turning operation
- Detailed residual stress study Turning operation
- Tool wear and character study after and before all Turning operation
- Detail study for polishing effects on Steel, especially on SSEN19.
- Detailed studies will be done with the parameters to find enough variations in Jaya
- Details studies will be done with Tlbo software to input parameters and observe the output.

REFERENCES

1. K. Venkatesan, Arun Tom Mathew, S. Devendiran, Nouby M Ghazaly, S.Sanjith, R. Raghul, Machinability study and multi-response optimization of cutting force, Surface roughness and tool wear on CNC turned Inconel 617 superalloy using Al2O3 Nanofluids in Coconut oil, Procedia Manufacturing 30 (2019) 396–403

2. E. García Plaza, P.J. Núñez López, Analysis of cutting force signals by wavelet packet transform for surface roughness monitoring in CNC turning, Mechanical Systems and Signal Processing 98 (2018) 634–651

3. E. García Plaza , P.J. Núñez López, Application of the wavelet packet transform to vibration signals for surface roughness monitoring in CNC turning operations, Mechanical Systems and Signal Processing 98 (2018) 902–919

4. Rogério Pontes Araújo, Tiago L Rolim, Carlos A Oliveira, Alex E Moura, José Carlos A Silva, Analysis of the surface roughness and cutting tool wear using a vapour compression assisted cooling system to cool the cutting fluid in turning Operation, Journal of Manufacturing Processes 44 (2019) 38–46

5. N. Satheesh Kumar, Ajay Shetty, Ashay Shetty, Ananth K, Harsha Shetty, Effect of spindle speed and feed rate on surface roughness of Carbon Steels in CNC turning, Procedia Engineering 38 (2012) 691 – 697

6. Majid Abdoos, Kenji Yamamoto, Bipasha Bose, German Fox-Rabinovich, Stephen Veldhuis, Effect of coating thickness on the tool wear performance of low stress TiAlN PVD coating during turning of compacted graphite iron (CGI), Wear 422–423 (2019) 128–136

7. S. Capasso1, J. M. Paiva2, E. Locks Junior3, L. Settineri4, K. Yamamoto5, F.L. Amorim6, R.D. Torres7 D. Covelli8, G.Fox-Rabinovich9 and S. Veldhuis10, A novel method of assessing and predicting coated cutting tool wear during Inconel DA 718 turning, S0043-1648(19)30552-6\

8. C. Chungchoo, D. Saini, On-line tool wear estimation in CNC turning operations using fuzzy neural network model, International Journal of Machine Tools & Manufacture 42 (2002) 29–40