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Department of Mechanical & Chemical Engineering (MCE)

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

Organisation of Islamic Cooperation

EFFECT OF ULTRASONIC SOUND WAVE ON MACHINABILITY PARAMETERS DURING TURNING OPERATION OF MILD STEEL

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Department of Mechanical & Chemical Engineering (MCE)

ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

October, 2013

DECLARATION

It is hereby declare that the undergraduate project work reported in this thesis has been performed by me and this work has not been submitted elsewhere for any purpose (except for publication).

Signature of the candidate

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Dedicated

To

My Beloved Parents

ACKNOWLEDGEMENT

All praises belongs to the almighty Allah for giving me the strength and courage to successfully complete my B.Sc thesis

It could never be possible for the authors to complete this thesis without the help of some people throughout these two semesters of final year. At first I want to give thanks and express my sincere gratitude to **Dr. Md. Anayet Ullah Patwari,** Professor, Department of Mechanical and Chemical Engineering, IUT. I am deeply indebted to him for giving us moral support throughout the whole year. His patient guidance and constant supervision made me work in definite direction towards the completion of the project. His care and concern for all the students are appreciated and provided continuous encouragement for me.

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Although I have given my best effort to complete this thesis paper, I seek excuses if there is any mistake found in this report.

ABSTRACT

This project aims to investigate the effects of ultrasonic sound signal on the machinability control of mild steel during turning operation. The machinability responses include tool wear, surface roughness, temperature, chip morphology. A control experiment was also done where no ultrasonic sound is applied at all.

Turning is a form of machining which is used to create rotational parts by removing unwanted material.

In turning process sometimes tool life, machined surface quality is damaged because of formation of chatter. Chatter causes unwanted excessive vibratory motion in between the tool and the work-piece causing adverse effects on the product quality and machine-tool and tool life. In addition to the damage of the work-piece surface due to chatter marks, the occurrence of severe chatter results in many adverse effects, which include poor dimensional accuracy of the work-piece, reduction of tool life, and damage to the machine.

The main purpose of this research is to send sound signal in the cutting processes and to investigate the effect of ultrasonic sound waves signal during turning operation on the machinability responses such as tool wear, surface roughness, and chip behavior. The ultrasonic sound wave that has been used is 40 KHZ. There are two ultrasound modules from where that sound wave has formed. The results show clear improvement in the machinability responses during the turning process which include significant reduction in the tool wear, improvement in surface quality, and decrease in the serration behavior of chips.

The quality of the finished product along with the productivity play a significant role in today's manufacturing market. From customers' viewpoint quality is very important because the extent of quality of the produced item influences the degree of satisfaction of the consumers during usage of the product. Every manufacturing industry aims at producing a large number of products within relatively lesser time. But it is felt that reduction in manufacturing time may cause severe quality loss. However application of ultrasonic sound can result in the surface quality of the product conditioned by the cutting parameter. The surface quality during ultrasound cutting is significantly improved than that obtained from normal cutting. The

frequency change of ultrasonic sound also has some impact on the surface quality which is mainly because of the chip adhering to the tool during cutting operation.

Behavior of chips indicate the vibration nature of the machine and the tool. Chips produced during cutting operation have some teeth in its cross section which have been viewed with microscope to find out the effect of these ultrasonic sounds on the serration behavior. Here also it is clearly shown that the teeth produced during ultrasound cutting are smaller in size whereas they are much bigger for normal cutting. This phenomenon indicates that application of external ultrasonic sound reduces the vibration of the machine tool.

The increase of the force increases the temperature of the work piece and the tool insert. Having difficulties in measuring the temperature of the work piece, I have measured the temperature of the insert near the cutting junction with the aid of a thermocouple.

The project is successful in establishing an improvement in tool life with the application of ultrasonic sound on the tool insert during turning operation.

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CHAPTER 1

INTRODUCTION

Objective:

- To design and fabricate ultrasonic sound wave set up for turning operation.
- Investigation of machining parameters in terms of tool wear,surface roughness,chip morphology and cutting temperature.
- To compare the machining reponses by ultrasonic sound waves with normal machining.
- To find out the effect of ultrasonic sound wave on these machinabilities by changing the frequency of ultrasonic sound wave.

Background:

The quality of machined components is evaluated in respect of how closely they adhere to set product specifications for length, width, diameter, surface finish, and reflective properties. Dimensional accuracy, toolwear and quality of surface finish are three factors that manufacturers must be able to control at the machining operations to ensure better performance and service life of engineering component. In the leading edge of manufacturing, manufacturers are facing the challenges of higher productivity, quality and overall economy in the field of manufacturing by machining. To meet the above challenges in a global environment, there is an increasing demand for high material removal rate (MRR) and also longer life and stability of the cutting tool .Tool wear and surface roughness prediction plays an important role in machining industry for gaining higher productivity, product quality, manufacturing process planning and also in computer aided process planning. The useful life of cutting tool is limited by the progressive and frequently rapid deterioration of its active edges, a phenomenon commonly called "tool wear". Tool wear affects productivity, dimensional accuracy and thereby product quality in most machining processes. This results in poor surface quality. The length of effective tool life is a matter of great concern in establishing the economic performance of machining processes, for which means are constantly searched for its enhancement by minimizing the wear susceptibility of the tool insert. To reduce the tool wear the effect of external ultrasonic sound wave is studied by many contemporary researchers most of which involve the study of the tool life improvement at a particular cutting condition and changing the frequency of ultrasonic sound wave. This is why in this experiment the study has been extended further to a wide range of cutting conditions. The surface roughness of the finished product has been measured using digital image processing technique. Thus this study analyzes the extent to which improvement in all these machinability factors is obtained and the interrelation among them by the application of ultrasound wave with different frequency of ultrasonic sound wave.

1.1 OVERVIEW OF TURNING PROCESS:

Machining is the term used to describe a variety of material removal processes in which a cutting tool removes unwanted material from a work piece to produce the desired geometric shape and surface finish. The work piece is typically cut from a larger piece of stock, which is available in a variety of standard shapes, such as flat sheets, solid bars, hollow tubes, and shaped beams. Machining can also be performed on an existing part, such as a casting or forging. Out of these machining processes, turning still remains most important operation used to shape metal, because in turning the condition of operation are most varied. Turning is a form of machining, a material removal process, which is used create rotational parts by cutting away unwanted material. The turning process requires a turning machine or lathe, work piece, fixture, and cutting tool. The work piece is a pre-shaped material that is secured to the fixture, which itself is attached to the turning machine, and allowed to rotate at high speeds. The cutter is typically a single-point cutting tool that is also secured in the machine, although some operations make use of multi-point tools. The cutting tool feeds into the rotating work piece and cuts away material in the form of small chips create the desired shape. Turning is used to produce rotational, typically axi-symmetric, parts that have many features, such as holes, grooves, threads, tapers, various diameter steps, and even contoured surfaces. Parts that are fabricated completely through turning often include components that are used in limited quantities, perhaps for prototypes, such as custom designed shafts and fasteners. Turning is also commonly used as a secondary process to add or refine features on parts that were manufactured using a different process. Due to the high tolerances and surface finishes that turning can offer, it is ideal for adding precision rotational features to a part whose basic shape has already been formed.

The cutting characteristics of most turning applications are similar. For a given surface only one cutting tool is used. This tool must overhang its holder to some extent to enable the holder to clear the rotating work piece. Once the cut starts, the tool and the work piece is usually in contact until the surface is completely generated. During this time the cutting speed and cut dimensions will be constant when a cylindrical surface is being turned. In the case of facing operations the cutting speed is proportional to the work piece diameter, the speed decreasing as the center of the piece is approached. Sometimes a spindle speed changing mechanism is provided to increase the rotating speed of the work piece as the tool moves to the center of the part.

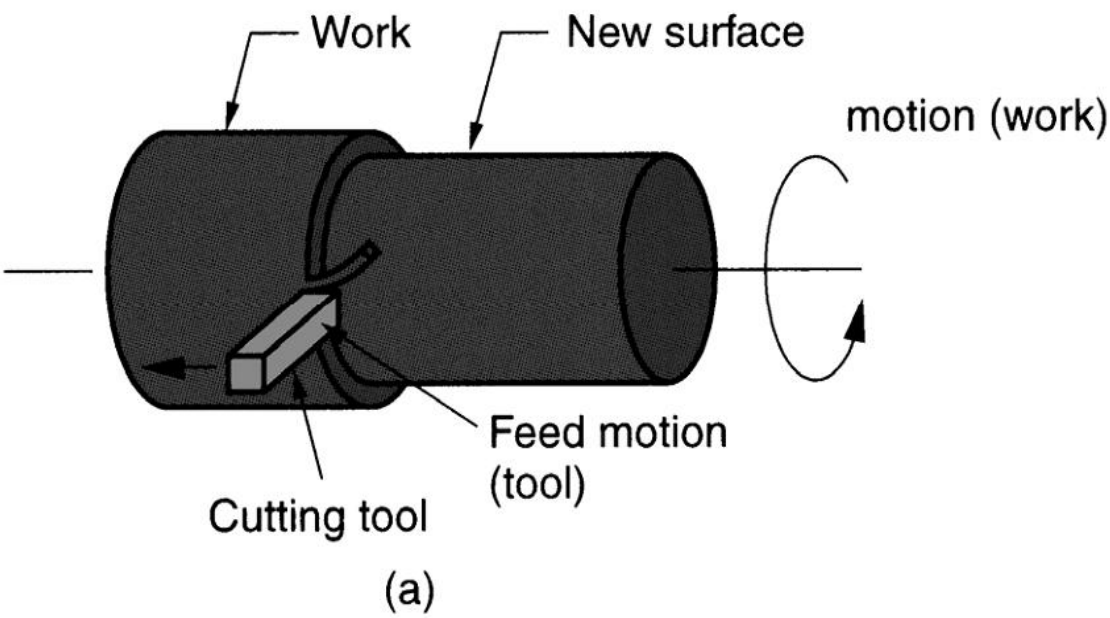


Fig 1.1 : Adjustable parameters in turning operation

1.1.1: ADJUSTABLE CUTTING PARAMETERS

The three primary factors in any basic turning operation are speed, feed, and depth of cut. Other factors such as kind of material and type of tool have a large influence, but these are the ones the operator can change by adjusting the controls, right at the machine.

<u>SPEED</u>:

Speed always refers to the spindle and the work piece. When it is stated in revolutions per minute (rpm) it tells their rotating speed. But the important feature for a particular turning operation is the surface speed, or the speed at which the work piece material is moving past the cutting tool. It is simply the product of the rotating speed times the circumference of the work piece before the cut is started. It is expressed in meter per minute (m/min), and it refers only to the work piece. Every different diameter on a work piece will have a different cutting speed, even though the rotating speed remains the same.

$$v = \frac{\pi \mathrm{DN}}{1000} \ \mathrm{m/min} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(1.1)}$$

Here v is the cutting speed in turning, D is the initial diameter of the work piece in mm, and N is the spindle speed in rpm.

<u>FEED:</u>

Feed always refers to the cutting tool, and it is the rate at which the tool advances along its cutting path. On most power-fed lathes, the feed rate is directly related to the spindle speed and is expressed in mm of tool advance per revolution of the spindle or mm/rev.

Feed of the tool, F_m = f. N mm/min; where *f* is the feed in mm/rev and N is the spindle speed in rpm.

<u>DEPTH OF CUT:</u>

Depth of cut is practically self explanatory. It is the thickness of the layer being removed in a single pass from the work piece or the distance from the uncut surface of the work to the cut surface, expressed in mm. It is important to note that the diameter of the work piece is reduced by two times the depth of cut because this layer is being removed from both sides of the work piece.

$$d_{cut} = \frac{D-d}{2} \text{ mm} ; \qquad \textbf{(1.2)}$$

Here *D* and *d* represent initial and final diameter (mm) of the job respectively.

1.1.2 : DIFFERENT TURNING OPERATION

Chamfering: The tool is used to cut an angle on the comer of a cylinder.

Parting: The tool is fed radially into rotating work at a specific location along its length to cut off the end of a part.

Threading: Feeding a pointed tool linearly across the outside or inside surface of rotating parts to produce external or internal threads.

Boring: Enlarging a hole made by a previous process. A single-pint tool is fed linearly and parallel to the axis of rotation.

Drilling: Producing a hole by feeding the drill into the rotating work piece along its axis. Drilling can be followed by reaming or boring to improve accuracy and surface finish.

Knurling: Metal formation operation used to produce a regular cross-hatched pattern in work surfaces.

1.1.3 : TURNING MACHINE

The turning machines are every kind of lathes. Lathes used in manufacturing can be classified as engine, turret, automatics, and numerical control etc. They are heavy duty machine tools and have power drive for all tool movements. They commonly range in size from 12 to 24 inches swing and from 24 to 48 inches center distance, but swings up to 50 inches and center distances up to 12 feet are not uncommon. Many engine lathes equipped with chip pans and built-in coolant circulating system.

Turret Lathe:

In a turret lathe, longitudinally feedable, hexagon turret replaces the tailstock. The turret, on which six tools can be mounted, can be rotated about a vertical axis to bring each tool into operating position, and the entire unit can be moved longitudinally, either annually or by power, ot provide feed for the tools. When the turret assembly is backed away from spindle by means of a capstan wheel; the turret indexes automatically at the end of its movement, thus, bring each of the six tools into operating position. The square turret on the cross slide can be rotated manually about a vertical axis to bring each of the four tools into operating position.

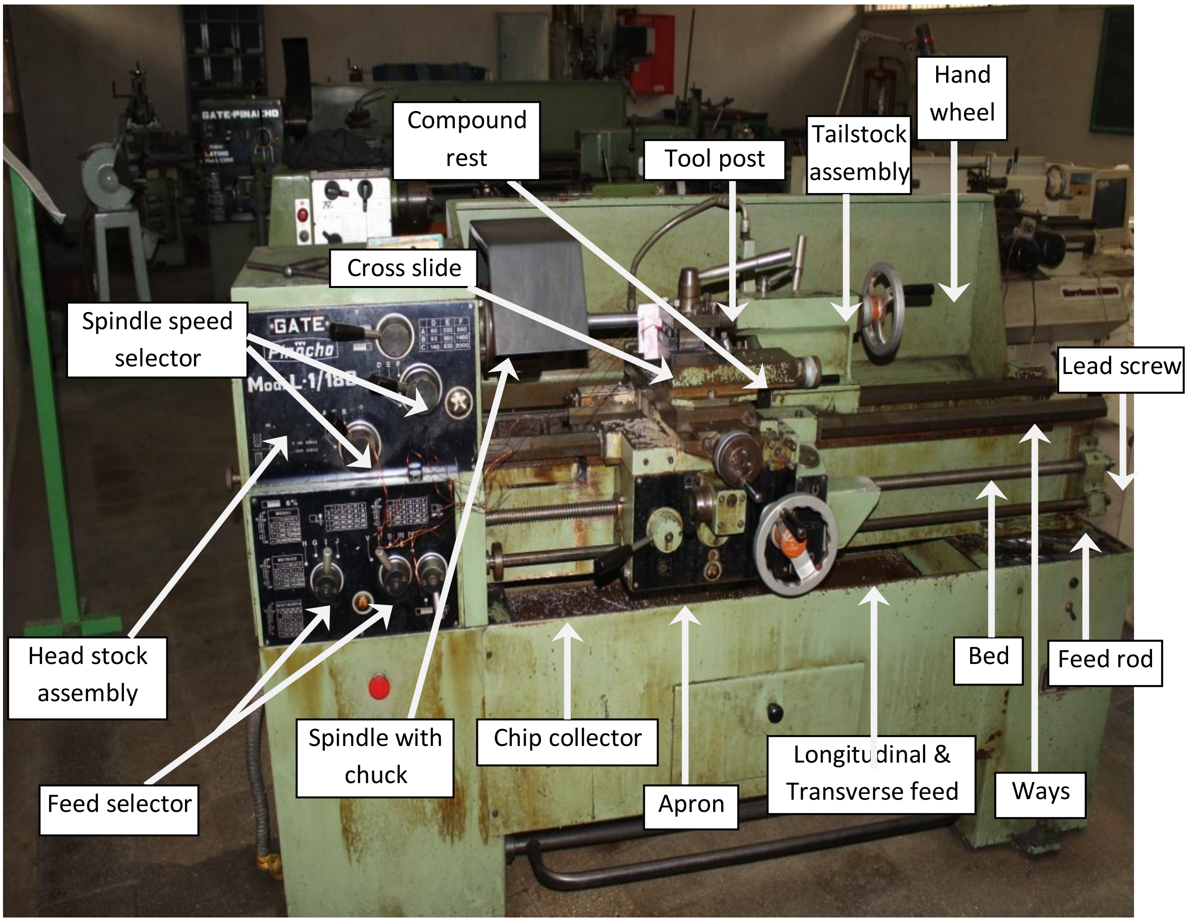


Fig 1.2: Centre lathe used for turning

On most machines, the turret can be moved transversely, either manually or by power, by means of the cross slide, and longitudinally through power or manual operation of the carriage. In most cased, a fixed tool holder also is added to the back end of the cross slide; this often carries a parting tool. Through these basic features of a turret lathe, a number of tools can be set on the machine and then quickly be brought successively into working position so that a complete part can be machined without the necessity for further adjusting, changing tools, or making measurements.

Single-Spindle Automatic Screw Machine:

There are two common types of single-spindle screw machines, one, an American development and common called the turret type (Brown & Sharp), is shown in the following figure. The other is of Swiss origin a and is referred to as the Swiss type. The Brown & Sharp screw machine is essentially a small automatic turret, cross slide, spindle, chuck and stock-feed mechanism are controlled by cams. The turret cam is essentially a program that defines the movement of the turret during a cycle. These machines usually are equipped with an automatic rod feeding magazine that feeds a new length of bar stock into the collect as soon as one rod is completely used.

CNC Machine:

Now-a-days more and more Computer Numerically Controlled (CNC) machines are being used in every kind of manufacturing processes. In a CNC machine, functions like program storage, tool offset and tool compensation, program-editing capability, various degree of computation, and the ability to send and receive data from a variety of sources, including remote locations can be easily realized through on board computer. The computer can store multiple-part programs, recalling them as needed for different parts.

1.1.4 : COMPONENTS OF A LATHE MACHINE

Bed:

The bed of the lathe provides the foundation for the whole machine and holds the headstock, tailstock and carriage in alignment. The surfaces of the bed that are finely machined – and upon which the carriage and tailstock slide – are known as “ways”.

Some beds have a gap near the headstock to allow extra-large diameters to be turned. Sometimes the gap is formed by the machined ways stopping short of the headstock, sometimes by a piece of bed that can be unbolted, removed – and lost.

Some very large lathes have a “sliding bed” where the upper part, on which the carriage and tailstock sit, can be slid along a separate lower part – and so make the gap correspondingly larger or smaller.

Saddle:

The casting that fits onto the top of the bed and slides along it is known, almost universally, as the "Saddle" – a self-explanatory and very suitable term.

Apron:

The vertical, often flat and rectangular "plate" fastened to the front of the "Saddle" is known as the "Apron" and carries a selection of gears and controls that allow the carriage to be driven (by hand or power) up and down the bed. The mechanism inside can also engage the screw cutting feed and various powered tool feeds, should they be fitted. The lead screw, and sometimes a power shaft as well, are often arranged to pass through the apron and provide it with a drive for the various functions. The sophistication of the apron-mounted controls, and their ease of use is a reliable indicator of the quality of a lathe. Virtually all screw-cutting lathes have what is commonly called a "half-nut" lever that closes down one and sometimes two halves of a split nut to grasp the lead screw and provide a drive for screw cutting.

Apron design can be roughly divided into " single-wall" and "double-wall" types. The "single-wall" apron has just one thickness of metal and, protruding from it (and unsupported on their outer ends) are studs that carry gears. The "double-wall" apron is a much more robust structure, rather like a narrow, open-topped box with the gear-carrying studs fitted between the two walls- and hence rigidly supported at both ends. This type of construction produces a very stiff structure – and one that is far less likely of deflect under heavy-duty work; another advantage is that the closed base of the "box" can be used to house an oil reservoir the lubricant ion which is either splashed around or, preferably, pumped to supply the spindles, gears and even, on some lathes, the sliding surfaces of the bed and cross slide as well.

Compound Slide Rest consisting of the Cross Slide and Top Slide:

Sitting on top of the "Saddle" is the "Cross Slide" – that, as its name implies, moves across the bed – and on top of that there is often a "Top Slide" or "Tool Slide" that is invariably arranged so that it can be swiveled and locked into a new position.

Very early lathes had a simple T-shaped piece of metal against which the turner "rested" its tool (all turning being done by hand) but when it became possible to move this “Rest” across the bed by a screw feed it became known, appropriately enough, as a “Slide-rest”.

When two slides are provided, the complete assembly is known as the “Compound” or “Compound Slide” or even “Compound Slide-rest”.

Carriage:

The whole assembly of Saddle, Apron, Top and Cross Slide is known as the “Carriage”.

Headstock:

The lathe headstock used, at one time, to be called the “Fixed Headstock” or “Fixed Head” , and the rotating within it the “Spindle”. The head stock is normally mounted rigidly to the bed (exceptions exist in some production, CNC, automatic and “Swiss-auto” types) and holds all the mechanisms, including various kinds and combinations of gears, so that the spindle can be made turn at different speed.

Headstock Spindle:

The end of the headstock spindle is usually machined so that it can carry a faceplate, chuck, drive-plate, internal or external collets – or even special attachments designed for particular jobs. In turn, these attachments hole the work piece that is going t o be machined.

The “fitting” formed on the end of the spindle is normally one of the five types:

(i) A simple flange through which threaded studs on a faceplate or chuck (for example) can pass and be tightened into place with nuts. This is secure method, and allows high-speed reverse, but is very inconvenient on a general purpose lathe.\

(ii) A threaded nose onto which fittings screw. This is perfectly acceptable for smaller lathes, but unsatisfactory on larger industrial machines where, for reasons of production economy, the spindle may need to be reversed at high speed.

(iii) A “D-1 taper Cam lock” fitting a long used, standard system that employs three or more “ studs” that are turned to lock into the back of the chucks and faceplates, etc.

(iv) A taper- either of the simple Harding type or, for bigger lathes, the “taper-nose, long-key drive” –an older but excellent American design where a large screwed ring was held captive on the end of the spindle and used to draw the chuck, or other fitting, onto a long, keyed taper formed on the spindle end.

(v) Various fittings that became increasingly complex and apparently invented for the sake of being able to claim a National Standard. All these succeeded in doing was to raise manufacturing costs by preventing the interchange of spindle-nose tooling between machines and requiring firms to keep larger inventories of spares and numbers of duplicated firings.

Back gear:

As its name implies, “back gear” is a gear mounted at the back of the headstock that allows the chuck to rotate slowly with greatly increase torque. Back geared lathes are sometimes referred to a “Background for slow speeds” or “Background and screw cutting”. A large diameter casting, fastened to the faceplate and run at 200 rpm (about the slowest speed normally available on a lathe without back gear) would have a linear speed at its outer edge beyond the turning capacity of a small lathe. By engaging back gear, and so reducing the speed but increasing the torque, even the largest faceplate-mounted jobs can be turned successfully. Screw cutting also requires slow speeds, typically between 25 and 50 rpm – especially if the operator is a beginner, or the job tricky.

Lead Screw:

Originally termed a “master thread”, or described as the leading screw”, but now always referred to as the “lead screw”, this is a long threaded rod normally found running along the front of the bed or, on some early examples running between the bed ways down the bed’s center line. By using a train of gears to connect the lathe spindle to the lead crew- and the lead screw to the lathe carriage- the latter, together with its cutting tool, could be forced to move a set distance for every revolution of the spindle.

Tailstock:

The tailstock is arranged to slide along the bed and can be locked to it at any convenient point; the upper portion of the unit it fitted with what is variously called a “barrel”, “spindle”, “ram” or shoot that can be moved in and out of the main casting by hand, lever or screw feed and carries a “Dead Center” that supports the other end of the work piece held in the headstock.

Countershaft:

It is used to reduce the speed of the motor and provide to the lathe’s spindle. In a typical arrangement, the motor is fastened to an upright, hinged, cast-iron plate and fitted with a small pulley on its spindle. On the same shaft as the very large pulley is a set of three smaller pulleys, arranged in the “reverse” order from those on the lathe. If the middle pulley on the countershaft is made to drive the identically-sized pulley on the lathe spindle that too, of course, will turn at 300 rpm. The pulleys each side of are normally arranged to halve and double that speed – hence the creation of a speed set covering a useful 150 rpm, 300 rpm and 600 rpm.

Change wheels and Tumble Reverse:

These are the gears that take the drive from the headstock spindle down to the lead screw. They are normally contained within a cover at the extreme left-hand side of the lathe. They are called "change wheels" because of the necessity to change them every time a different thread, or rate of tool feed, was required. The *gear train* is usually carried on a *quadrant arm* able to be adjusted by being swung on its mounting to allow the mesh of the topmost gear with the output gear on the spindle (or tumble reverse mechanism) to be set.

1.1.5 : THE SPECIFICATION OF THE LATHE MACHINE USED IN THIS STUDY

CAPACITY	SP/200	
	mm	inches
center height	200	7 7/8``
center distance	750-1000	30''-40''
swing over bed	400	15 3/8''
swing over gap	560	22''
swing over carriage	375	14 3/4''
swing over cross slide	245	9 5/8''
bed width	250	10``
gap length in front of face plate	120	4 3/4''
HEAD STOCK		
main spindle bore	42	1 5/8''
main spindle nose	DIN 55027-5	cam lock no 5
main spindle morse taper	4	4
9 speed range	60-2000	60-2000
THREAD AND FEED BOX		
44 longitudinal feeds	0,05-0.75	0.0018-0,026''
44 cross feeds	0,025-0,375	0,0005-0,0076''
44 metric threads	0,5-7,5	0,5-0,7
44 withworth thread in T.P.1	60-4	60-4
44 modular threads	0,25-3,75	0,25-3,75
44 pitch diametral thread	120-8	120-8
thread oflead screw	6	4h/1h''
SLIDE AND CARRIAGE		
cross slide travel	245	9 5/8''
tool post slide travel	120	4 3/4''
maximum tool dimensions	20*20	3/4''-3/4''
TAILSTOCK		
tailstock barrel diameter	58	2 9/32"
tailstock barrel travel	200	7 7/8''
tailstock taper	4	4
MOTORS		
main motor power in kW	4	4
pump motor power in kW	0,06	0,06
STEALDIES		
max~min capacity of fixed steady	10-130	3/8''-5''
max~min capacityof traveling steady	Oct-80	3/8''-3'' 3/16''

The lathe used in our experiment is GATE INC. (UK); Model: L-1/180.

The specification of the lathe machine used in this experiment is shown in the above figure.

1.1.6 : BRIEF DESCRIPTION OF THE CUTTING TOOL GEOMETRY

For cutting tools, geometry depends mainly on the properties of the tool material and the work material. The standard terminology is shown in the following figure. For single point tools, the most important angles are the rake angles and the end and side relief angles.

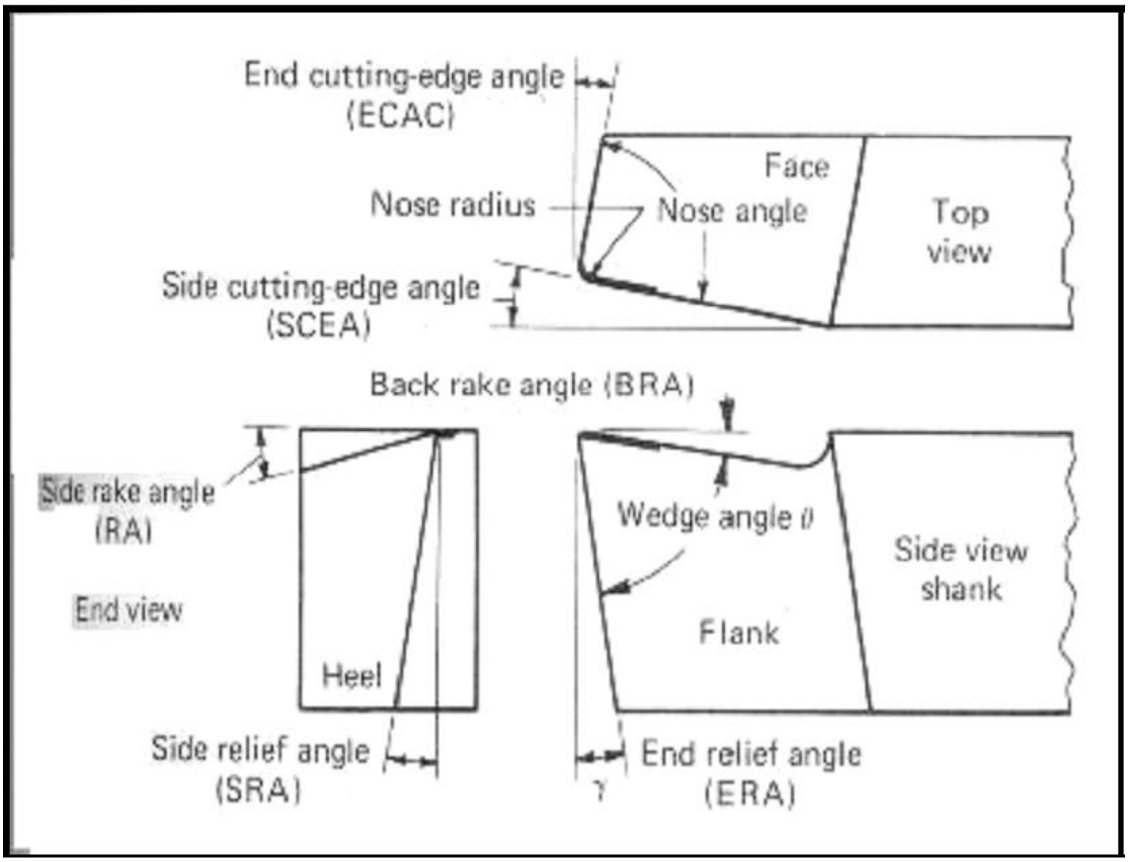


Fig 1.3 : Geometry of a single point turning tool

Flank:

A flat surface of a single-point tool that is adjacent to the face of the tool. During turning, the side flank faces the direction that the tool is fed into the work piece, and the end flank passes over the newly machined surface.

Face:

The flat surface of a single point tool through which, the work piece rotates during turning operation. On a typical turning setup, the face of the tool is positioned upwards.

Shank:

It is the main body of tool. The shank is used to attach with tool holder.

Back rake angle:

If viewed from the side facing the end of the work piece, it is the angle formed by the face of the tool and a line parallel to the floor. A positive back rake angle tilts the tool face back, and a negative angle tilts it forward and up.

Side rake angle:

If viewed behind the tool down the length of the tool holder, it is the angle formed by the face of the tool and the centerline of the work piece. A positive side rake angle tilts the tool face down toward the floor, and a negative angle tilts the face up and toward the work piece.

Side cutting edge angle:

If viewed from above looking down on the cutting tool, it is the angle formed by the side flank of the tool and a line perpendicular to the work piece centerline. A positive side cutting edge angle moves the side flank into the cut, and a negative angle moves the side flank out of the cut.

End cutting edge angle:

If viewed from above looking down on the cutting tool, it is the angle formed by the end flank of the tool and a line parallel to the work piece centerline. Increasing the end cutting edge angle tilts the far end of the cutting edge away from the work piece.

Side relief angle:

If viewed behind the tool down the length of the tool holder, it is the angle formed by the side flank of the tool and a vertical line down to the floor. Increasing the side relief angle tilts the side flank away from the work piece.

End relief angle:

If viewed from the side facing the end of the work piece, it is the angle formed by the end flank of the tool and a vertical line down to the floor. Increasing the end relief angle tilts the end flank away from the work piece.

Nose radius:

It is the rounded tip on the cutting edge of a single point tool. A zero degree nose radius creates a sharp point of the cutting tool.

Lead angle:

It is the common name for the side cutting edge angle. If a tool holder is built with dimensions that shift the angle of an insert, the lead angle takes this change into consideration. The back rake angle affects the ability of the tool to shear the work material and form the chip. It can be positive or negative. Positive rake angles reduce the cutting forces resulting in smaller deflections of the work piece, tool holder, and machine. If the back rake angle is too large, the strength of the tool is reduced as well as its capacity to conduct heat. In machining hard work materials, the back rake angle must be small, even negative for carbide and diamond tools. The higher the hardness, the smaller will be the back rake angle. For high-speed steels, back rake angle is normally chosen in the positive range.

1.1.7 CUTTING TOOL MATERIALS:

The classes of cutting tool materials currently in use for machining operation are high-speed tool steel, cobalt-base alloys, cemented carbides, ceramic, polycrystalline cubic boron nitride and polycrystalline diamond. Different machining applications require different cutting tool materials. The Ideal cutting tool material should have all of the following characteristics:

- Harder than the work it is cutting
- High temperature stability
- Resists wear and thermal shock
- Impact resistant

- Chemically inert to the work material and cutting fluid

To effectively select tools for machining, a machinist or engineer must have specific information about:

- The starting and finished part shape
- The work piece hardness
- The material's tensile strength
- The material's abrasiveness
- The type of chip generated
- The work holding setup
- The power and speed capacity of the machine tool

Some common cutting tool materials are described below:

Carbon steels:

Carbon steels have been used since the 1880s for cutting tools. However carbon steels start to soften at a temperature of about 180 ^{O}C. This limitation means that such tools are rarely used for metal cutting operations. Plain carbon steel tools, containing about 0.9% carbon and about 1% manganese, hardened to about 62 Rc, are widely used for woodworking and they can be used in a router to machine aluminium sheet up to about 3mm thick.

High speed steels (HSS):

HSS tools are so named because they were developed to cut at higher speeds. Developed around 1900 HSS are the most highly alloyed tool steels. The tungsten (T series) was developed first and typically contains 12 - 18% tungsten, plus about 4% chromium and 1 - 5% vanadium. Most grades contain about 0.5% molybdenum and most grades contain 4 - 12% cobalt. It was soon discovered that molybdenum (smaller proportions) could be substituted for most of the tungsten resulting in a more economical formulation which had better abrasion resistance than the T series and undergoes less distortion during heat treatment. Consequently about 95% of all HSS tools are made from M series grades. These contain 5 - 10% molybdenum, 1.5 - 10% tungsten, 1 - 4% vanadium, 4% Chromium and many grades contain 5 - 10% cobalt. HSS tools are tough and suitable for interrupted cutting and are used to manufacture tools of complex shape such as drills, reamers, taps, dies and gear cutters. Tools may also be coated to improve wear resistance. HSS accounts for the largest tonnage of tool materials currently used. Typical cutting speeds: 10 - 60 m/min.

Cast Cobalt alloys:

Introduced in early 1900s these alloys have compositions of about 40 - 55% cobalt, 30% chromium and 10 - 20% tungsten and are not heat treatable. Maximum hardness values of 55 - 64 Rc. They have good wear resistance but are not as tough as HSS but can be used at somewhat higher speeds than HSS. Now only in limited use.

Carbides:

Also known as cemented carbides or sintered carbides were introduced in the 1930s and have high hardness over a wide range of temperatures, high thermal conductivity, high Young's modulus making them effective tool and die materials for a range of applications. The two groups used for machining are tungsten carbide and titanium carbide; both types may be coated or uncoated. Tungsten carbide particles (1 to 5 micrometer) are bonded together in a cobalt matrix using powder metallurgy. The powder is pressed and sintered to the required insert shape. Titanium and niobium carbides may also be included to impart special properties. A wide range of grades are available for different applications. Sintered carbide tips are the dominant type of material used in metal cutting. The proportion of cobalt (the usual matrix material) present has a significant effect on the properties of carbide tools. 3 - 6% matrix of cobalt gives greater hardness while 6 - 15% matrix of cobalt gives a greater toughness while decreasing the hardness, wear resistance and strength. Tungsten carbide tools are commonly used for machining steels, cast irons and abrasive non-ferrous materials. Titanium carbide has a higher wear resistance than tungsten but is not as tough. With a nickel-molybdenum alloy as the matrix, TiC is suitable for machining at higher speeds than those which can be used for tungsten carbide. Typical cutting speeds are: 30 - 150 m/min or 100 - 250 when coated.

Coatings:

Coatings are frequently applied to carbide tool tips to improve tool life or to enable higher cutting speeds. Coated tips typically have lives 10 times greater than uncoated tips. Common coating materials include titanium nitride, titanium carbide and aluminium oxide, usually 2 - 15 micro-m thick. Often several different layers may be applied, one on top of another, depending upon the intended application of the tip. The techniques used for applying coatings include chemical vapor deposition (CVD) plasma assisted CVD and physical vapor deposition (PVD). Diamond coatings are also in use and being further developed.

Cermets:

Developed in the 1960s, these typically contain 70% aluminium oxide and 30% titanium carbide. Some formulation contains molybdenum carbide, niobium carbide and tantalum carbide. Their performance is between those of carbides and ceramics and coatings seem to offer few benefits. Typical cutting speeds: 150 - 350 m/min.

Ceramics:

Alumina introduced in the early 1950s, two classes are used for cutting tools: fine grained high purity aluminium oxide (Al_2O_3) and silicon nitride (Si_3N_4) are pressed into insert tip shapes and sintered at high temperatures. Additions of titanium carbide and zirconium oxide (ZrO_2) may be made to improve properties. But while ZrO_2 improves the fracture toughness, it reduces the hardness and thermal conductivity. Silicon carbide (SiC) whiskers may be added to give better toughness and improved thermal shock resistance. The tips have high abrasion resistance and hot hardness and their superior chemical stability compared to HSS and carbides means they are less likely to adhere to the metals during cutting and consequently have a lower tendency to form a built up edge. Their main weakness is low toughness and negative rake angles are often used to avoid chipping due to their low tensile strengths. Stiff machine tools and work set ups should be used when machining with ceramic tips as otherwise vibration is likely to lead to premature failure of the tip. Typical cutting speeds: 150-650 m/min.

Silicon Nitride:

In the 1970s a tool material based on silicon nitride was developed, these may also contain aluminium oxide, yttrium oxide and titanium carbide. SiN has an affinity for iron and is not suitable for machining steels. A specific type is 'Sialon', containing the elements: silicon, aluminium, oxygen and nitrogen. This has higher thermal shock resistance than silicon nitride and is recommended for machining cast irons and nickel based super alloys at intermediate cutting speeds.

Cubic Boron Nitride (CBN):

Introduced in the early 1960s, this is the second hardest material available after diamond. CBN tools may be used either in the form of small solid tips or as a 0.5 to 1 mm thick layer of polycrystalline boron nitride sintered onto a carbide substrate under pressure. In the latter case the carbide provides shock resistance and the CBN layer provides very high wear resistance and cutting edge strength. Cubic boron nitride is the standard choice for machining alloy and tool steels with a hardness of 50 RC or higher. Typical cutting speeds: 30 - 310 m/min.

Diamond:

The hardest known substance is diamond. Although single crystal diamond has been used as a tool, they are brittle and need to be mounted at the correct crystal orientation to obtain optimal tool life. Single crystal diamond tools have been mainly replaced by polycrystalline diamond (PCD). This consists of very small synthetic crystals fused by a high temperature high pressure process to a thickness of between 0.5 and 1mm and bonded to a carbide substrate. The result is similar to CBN tools. The random orientation of the diamond crystals prevents the propagation of cracks, improving toughness. Because of its reactivity, PCD is not suitable for machining plain carbon steels or nickel, titanium and cobalt based alloys. PCD is most suited to light uninterrupted finishing cuts at almost any speed and is mainly used for very high speed machining of aluminium - silicon alloys, composites and other non - metallic materials. Typical cutting speeds: 200 - 2000 m/min.

To improve the toughness of tools, developments are being carried out with whisker reinforcement, such as silicon nitride reinforced with silicon carbide whiskers. As rates of metal removal have increased, so has the need for heat resistant cutting tools.

The result has been a progression from high-speed steels to carbide, and on to ceramics and other super hard materials. High-speed steels cut four times faster than the carbon steels they replaced. There are over 30 grades of high-speed steel, in three main categories: tungsten, molybdenum, and molybdenum-cobalt based grades. In industry today, carbide tools have replaced high-speed steels in most applications. These carbide and coated carbide tools cut about 3 to 5 times faster than high-speed steels. Cemented carbide is a powder metal product consisting of fine carbide particles cemented together with a binder of cobalt. The major categories of hard carbide include tungsten carbide, titanium carbide, tantalum carbide, and niobium carbide. Ceramic cutting tools are harder and more heat-resistant than carbides, but more brittle. They are well suited for machining cast iron, hard steels, and the super alloys. Two types of ceramic cutting tools are available: the alumina-based and the silicon nitride-based ceramics. The alumina-based ceramics are used for high speed semi- and final-finishing of ferrous and some non-ferrous materials. The silicon nitride-based ceramics are generally used for rougher and heavier machining of cast iron and the super alloys.

1.1.8 INSERTS:

A tipped tool generally refers to any cutting tool where the cutting edge consists of a separate piece of material, either brazed, welded or clamped on to a separate body. Common materials for tips include tungsten carbide, polycrystalline diamond, and cubic boron nitride. The advantage of tipped tools is only a small insert of the cutting material is needed to provide the cutting ability. The small size makes manufacturing of the insert easier than making a solid tool of the same material. This also reduces cost because the tool holder can be made of a less-expensive and tougher material. In some situations a tipped tool is better than its solid counterpart because it combines the toughness of the tool holder with the hardness of the insert. Inserts are removable cutting tips, which mean they are not brazed or welded to the tool body. They are usually indexable, meaning that they can be rotated or flipped without disturbing the overall geometry of the tool (effective diameter, tool length offset, etc.). This saves time in manufacturing by allowing fresh cutting edges to be presented periodically without the need for tool grinding and setup changes.

Indexable turning inserts are manufactured in a variety of shapes, sizes and thicknesses, with straight holes, with countersunk holes, without holes, with chip breakers on one side, with chip breakers on two sides or without chip breakers. The selection of the appropriate turning tool holder geometry, accompanied by the correct insert shape and chip breaker geometry, will ultimately have a significant impact on the productivity and tool life of a specific turning operation.

Insert strength is one important factor in selecting the correct geometry for a work piece material or hardness range. Triangle inserts are the most popular shaped inserts primarily because of their wide application range. A triangular insert can be utilized in any of the seven basic turning holders mentioned earlier. Diamond-shaped inserts are used for profile turning operations while squares are often used on lead angle tools. The general rule for rating an insert's strength based on its shape is: The larger the included angle on the insert corner, the greater the insert strength.

Fig 1.4: Carbide tool inserts

1.1.9 : MATERIAL REMOVAL RATE

The material removal rate (MRR) in turning operations is the volume of material/metal that is removed per unit time in mm^3/min. For each revolution of the work piece, a ring-shaped layer of material is removed. MRR = ($v. f. d$ *1000) in mm^3/min

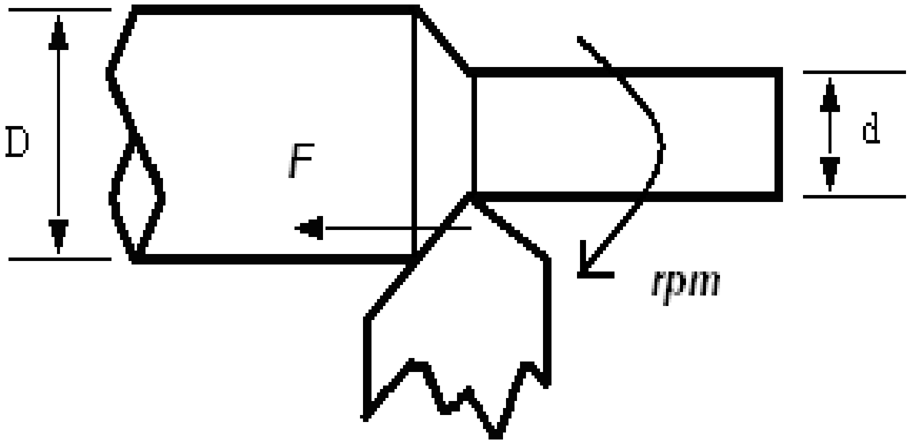


Fig 1.5: MRR in turning

$$mrr = \left(\frac{\pi D^2}{4} - \frac{\pi d^2}{4}\right) \times F \times rpm \qquad \textbf{(1.3)}$$

Where

D = diameter of the work piece before cutting

d = diameter of the work piece after cutting

1.1.10: WORK HOLDING METHODS

In lathe work the three most common work holding methods are:

- Held in a chuck.
- Held between centers.
- Held in a collet.

Held in a Chuck:

The most common method of work holding, the chuck, has either three or four jaws and is mounted on the end of the main spindle. A three-jaw chuck is used for gripping cylindrical work pieces when the operations to be performed are such that the machined surface is concentric with the work surfaces.

With the four-jaw chuck, each jaw can be adjusted independently by rotation of the radially mounted threaded screws. Although accurate mounting of a work piece can be time consuming, a four jaw chuck is often necessary for non-cylindrical work pieces.

Held between Centers:

For accurate turning operations or in cases where the work surface is not truly cylindrical, the work piece can be turned between centers. Initially, the work piece has a conical center hole drilled at each end to provide location for the lathe centers. Before supporting the work piece between the centers (one in the headstock and one in the tailstock) a clamping device called a dog is secured to the work piece. The dog is arranged so that the tip is inserted into a slot in the drive plate mounted on the main spindle, ensuring that the work piece will rotate with the spindle.

Lathe centers support the work piece between the headstock and the tailstock. The center used in the headstock spindle is called the live center. It rotates with the headstock spindle. The dead center is located in the tailstock spindle. This center usually does not rotate and must be hardened and lubricated to withstand the wear of the revolving work.

The hole in the spindle into which the center fits is usually of a Morse standard taper. It is important that the hole in the spindle be kept free of dirt and also that the taper of the center be clean and free of chips or burrs. If the taper of the live center has particles of dirt or a burr on it, it will not run true. The centers play a very important part in lathe operation. Since they give support to the work piece, they must be property ground and in perfect alignment with each other. The work piece must have perfectly drilled and countersunk holes to receive the centers. The center must have a 60-degree point.

Held in a Collet:

Collets are used when smooth bar stock, or work pieces that have been machined to a given diameter, must be held more accurately than normally can be achieved in a regular three or four jaw chuck. Collets are relatively thin tubular steel bushings that are split into three longitudinal segments over about two thirds of their length. The smooth internal surface of the split end is shaped to fit the piece of stock that is to be held. The external surface at the split end is a taper that fits within an internal taper of a collet sleeve placed in the spindle hole. When the collet is pulled inward into the spindle, by means of the draw bar that engages threads on the inner end of the collet, the action of the two mating tapers squeezes the collet segments together, causing them to grip the work piece.

1.2 : TOOL WEAR

Tool wear in machining is defined as the amount of volume loss of tool material on the contact surface due to the interactions between the tool and work piece. Specifically, tool wear is described by wear rate (volume loss per unit area per unit time) and is strongly determined by temperature, stresses, and relative sliding velocity generated at the contact interface. Metal cutting tools are subjected to extremely arduous conditions, high surface loads, and high surface temperatures arise because the chip slides at high speed along the tool rake face while exerting very high normal pressures (and friction force) on this face. The forces may be fluctuating due to the presence of hard particles in the component micro-structure, or more extremely, when interrupted cutting is being carried out. Hence cutting tools need:

- Strength at elevated temperatures
- High toughness
- High wear resistance
- High hardness

During the past 100 years there has been extensive research and development which has provided continuous improvement in the capability of cutting tool. A key factor in the wear rate of virtually all tool materials is the temperature reached during operation; unfortunately it is difficult to establish the values of the parameters needed for such calculations. However, experimental measurements have provided the basis for empirical approaches. It is common to assume that all the energy used in cutting is converted to heat (a reasonable assumption) and that 80% of this is carried away in the chip (this will vary and depend upon several factors - particularly the cutting speed). This leaves about 20% of the heat generated going into the cutting tool. Even when cutting mild steel tool temperatures can exceed 550^{o}C, the maximum temperature high speed steel (HSS) can withstand without losing some hardness. Cutting hard steels with cubic boron nitride tools will result in tool and chip temperatures in excess of 1000 ^{O}C. During operation, one or more of the following wear modes may occur:

- Flank
- Notch
- Crater
- Edge rounding
- Edge chipping
- Edge cracking
- Catastrophic failure

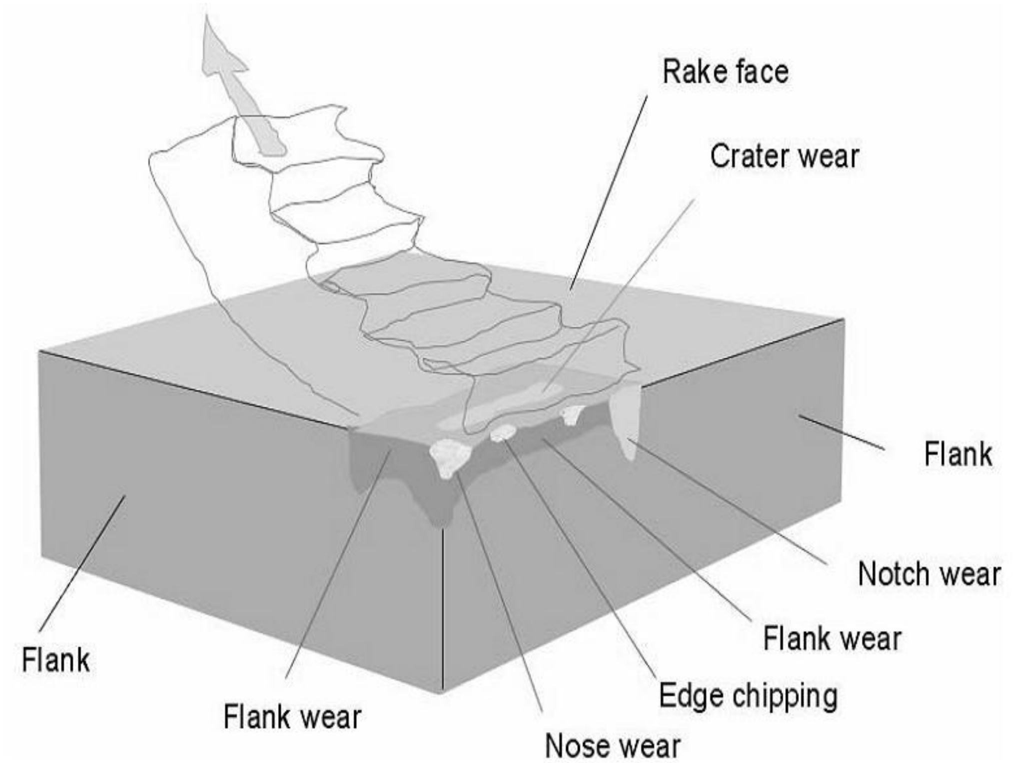


Fig. 1.6: Different Modes of Wear

Cutting tools are subjected to an extremely severe rubbing process. They are in metal-to-metal contact between the chip and work piece, under conditions of very high stress at high temperature. The situation is further aggravated (worsened) due to the existence of extreme stress and temperature gradients near the surface of the tool. During machining, cutting tools remove material from the component to achieve the required shape, dimension and surface roughness (finish). However, wear occurs during the cutting action, and it will ultimately result in the failure of the cutting tool. When the tool wear reaches a certain extent, the tool or active edge has to be replaced to guarantee the desired cutting action.

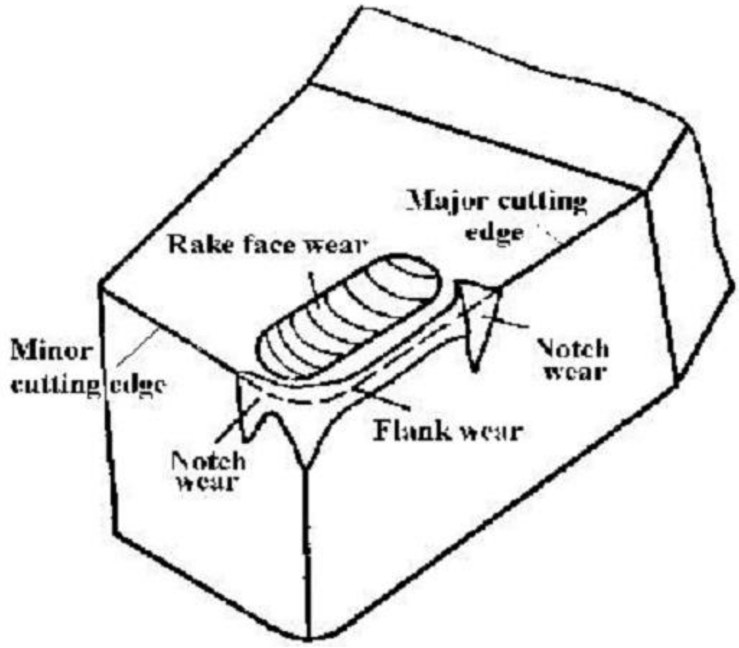


Fig 1.7: Tool wear phenomenon

1.2.1: TYPES OF TOOL WEAR

CRATER WEARS:

The chip flows across the rake face, resulting in severe friction between the chip and rake face, and leaves a scar on the rake face which usually parallels to the major cutting edge. 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. The parameters used to measure the crater wear can be seen in the diagram. The crater depth KT is the most commonly used parameter in evaluating the rake face wear.

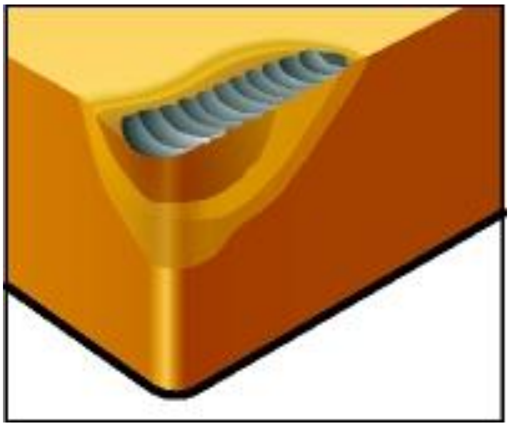


Fig 1.8: Crater Wear

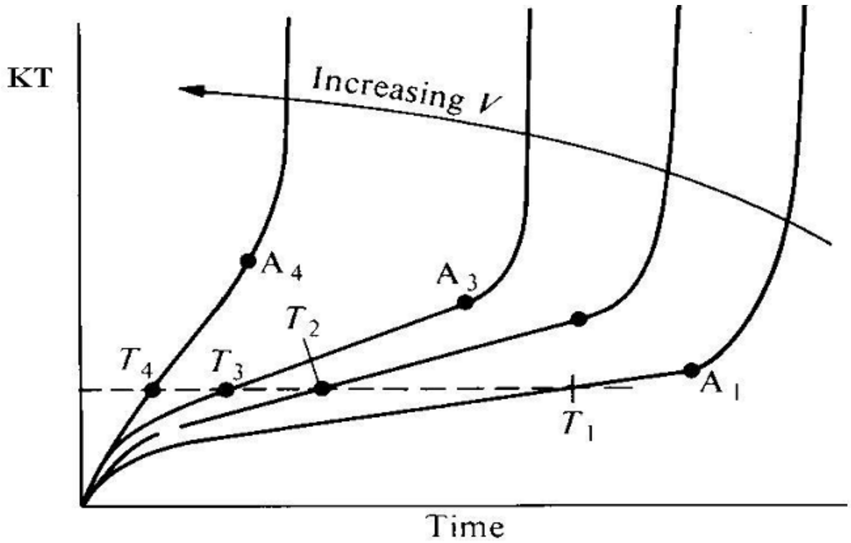


Fig. 1.9: Effects of cutting speed V and cutting time T on crater wear depth KT

FLANK WEAR (Clearance Surface):

Wear on the flank (relief) face is called Flank wear and results in the formation of a wear land. Wear land formation is not always uniform along the major and minor cutting edges of the tool. Flank wear most commonly results from abrasive wear of the cutting edge against the machined surface. Flank wear can be monitored in production by examining the tool or by tracking the change in size of the tool or machined part. Flank wear can be measured by using the average and maximum wear land size VB and $V_{B\ max}$.

Due to micro-cracking, surface oxidation and carbon loss layer, as well as micro-roughness at the cutting tool tip in tool grinding (manufacturing). For the new cutting edge, the small contact area and high contact pressure will result in high wear rate. The initial wear size is VB=0.05-0.1mm normally. After the initial (or preliminary) wear (cutting edge rounding), the micro-roughness is improved, in this region the wear size is proportional to the cutting time. The wear rate is relatively constant.

When the wear size increases to a critical value, the surface roughness of the machined surface decreases, cutting force and temperature increase rapidly, and the wear rate increases. Then the tool loses its cutting ability. In practice, this region of wear should be avoided. Flank wear and chipping will increase the friction, so that the total cutting force will increase. The component surface roughness will be increased, especially when chipping occurs. Flank wear will also affect the component dimensional accuracy. When form tools are used, flank wear will also change the shape of the component produced.

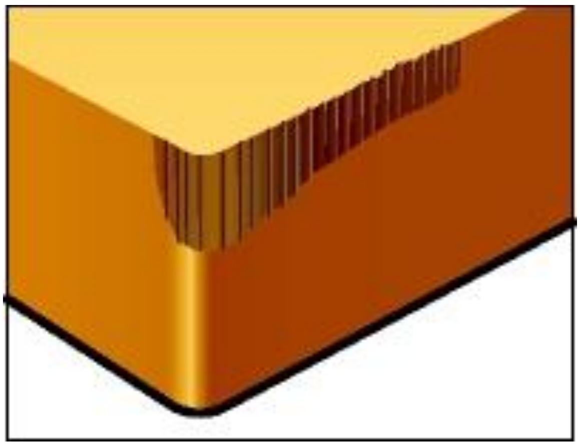


Fig. 1.10 : Flank Wear

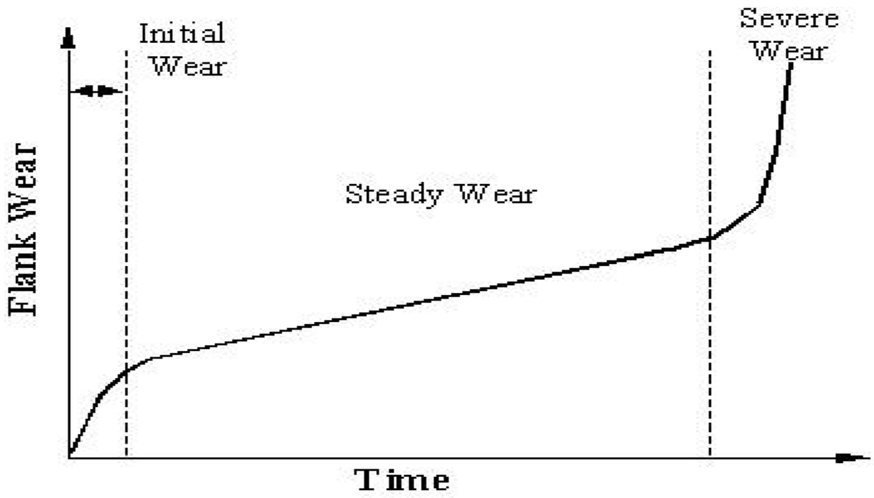


Fig. 1.11: Different regions of wear

NOTCH WEAR:

Wear on the flank (relief) face is called Flank wear and results in the formation of a wear land. Wear land formation is not always uniform along the major and minor. This is a special type of combined flank and rake face wear which occurs adjacent to the point where the major cutting edge intersects the work surface. The gashing (or grooving, gouging) at the outer edge of the wear land is an indication of a hard or abrasive skin on the work material. Such a skin may develop during the first machine pass over a forging, casting or hot-rolled work piece. It is also common in machining of materials with high work-hardening characteristics, including many stainless steels and heat-resistant nickel or chromium alloys. In this case, the previous machining operation leaves a thin work-hardened skin.

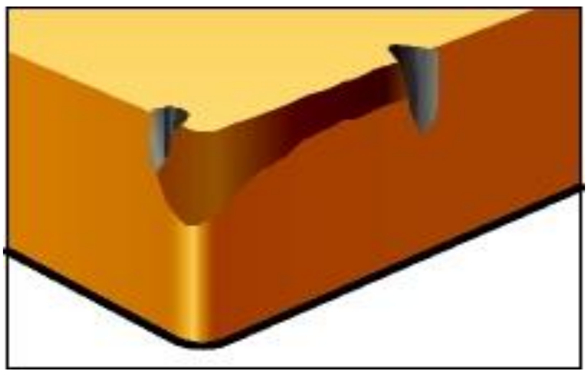


Fig. 1.12 : Notch Wear

CHIPPING:

Chipping of the tool, as the name implies, involves removal of relatively large discrete particles of tool material. Tools subjected to discontinuous cutting conditions are particularly prone to chipping. Chipping of the cutting edge is more like micro-breakages rather than conventional wear. Built-up edge formation also has a tendency to promote tool chipping. A built-up edge is never completely stable, but it periodically breaks off. Each time some of the built-up material is removed it may take with it a lump (piece) of tool edge

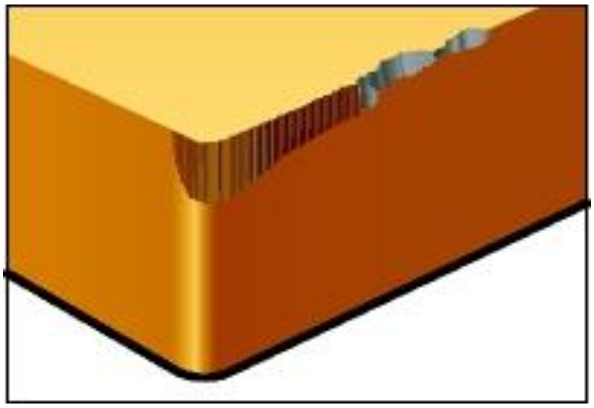


Fig. 1.13: Chipping Wear

ATTRITION WEAR:

Sometimes called Adhesion wear, this pattern is found on very slow surface feed operations. It is characterized by a very rough surface on the land and face of the tool. Usually, a built up edge (BUE) is observed. Chips will be thick and not curl.

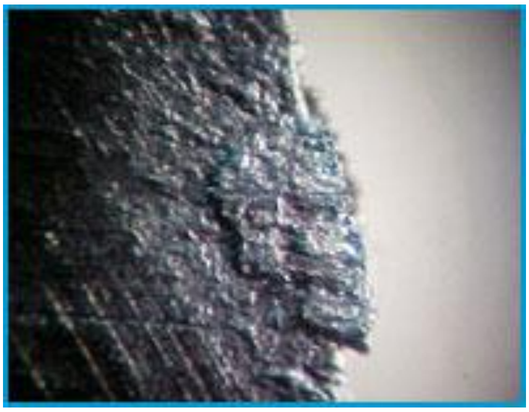


Fig. 1.14: Attrition Wear

ABRASIVE WEAR:

Deep, multiple scratches or scores are observed on the land (flank) of the tool. The scoring may appear predominantly on front rows of cutting teeth or it may appear randomly anywhere on the broach tool. The scoring will not appear uniform in length and will be at different positions across the land of the tool.

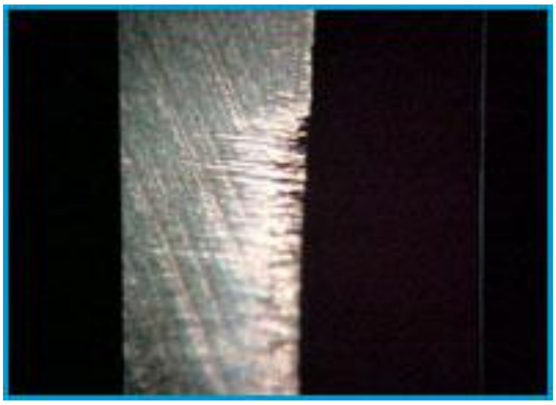


Fig. 1.15: Abrasive Wear

FRACTURE:

Often the evidence is lost when the insert is shattered. It may be the result of over use or severe overload. If it occurs very late in the life of the tool, other wear patterns probably existed such as Chipping, Crater, Deformation or Flaking and the tool was overrun.

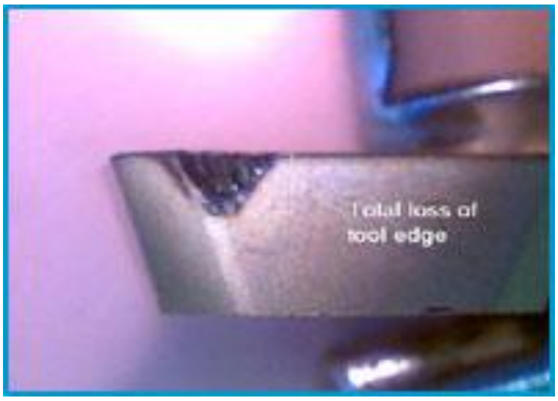


Fig. 1.16: Fracture

SPALLING:

This wear pattern is difficult to observe as it occurs relatively early in the life of the tool. If left in place, the tool will eventually demonstrate failure modes such as Crater, Flaking, Flank or Fracture wear. If Spalling and Thermal Cracking are both observed, condition should be treated as thermal shock first. Since spalling occurs early, other wear patterns develop that mask and may mislead the observer.

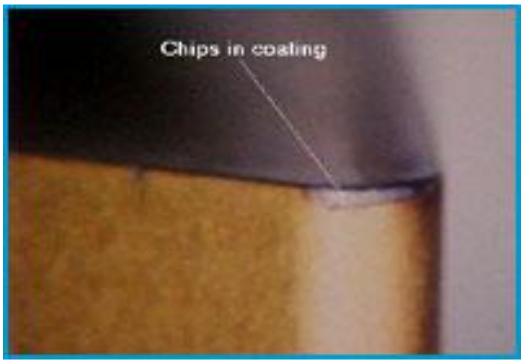


Fig. 1.17: Spalling

BUILT UP EDGE:

This common problem is identified by work piece material sticking to the face of the tool. The BUE often leads to chipping of the tool cutting edges. Often it will be an irregular wear pattern and will generate poor surface micro-finish on the part. Remnants of a built up edge may show on the finished part as a streak left behind when the tool is extracted from the work piece.

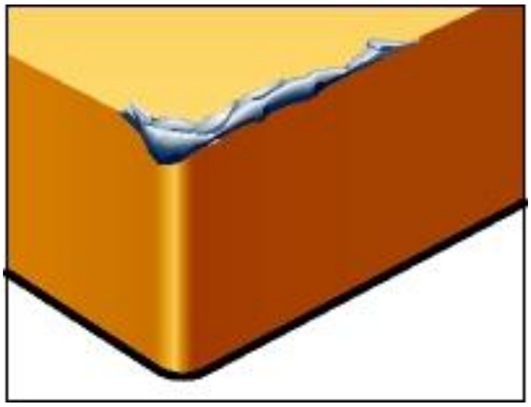


Fig. 1.18: Built up edge

THERMAL CRACKING:

This wear pattern is unique as shows up as hairline cracks that are perpendicular to the cutting edge. Many times the parallel cracks are uniformly distributed long the cutting edge. These edge chips will appear to be very uniform in depth and are in line with the direction of tool travel.

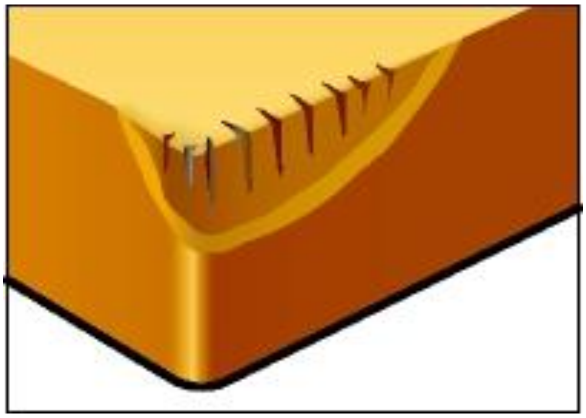


Fig. 1.19: Thermal Cracking

PLASTIC DEFORMATION:

This is caused by the plastic deformation of edge, depression or flank impression, leading to poor chip control, poor surface finish and insert breakage. Another factor contributing on plastic deformation is the cutting temperature and high pressure. It can be avoided by selecting a more wear resistant or harder grade of tool, reducing cutting speed or reducing the feed.

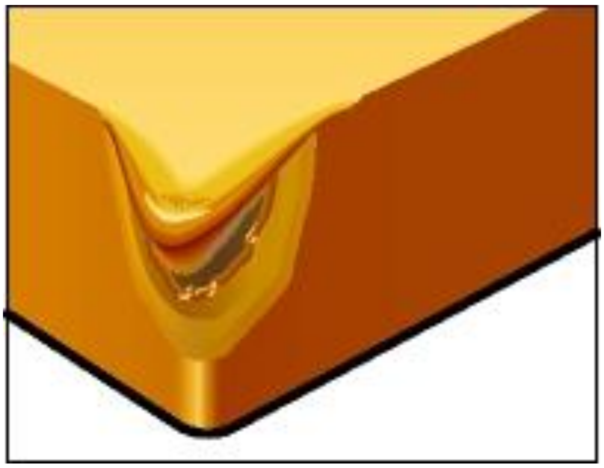


Fig. 1.20: Plastic Deformation

ULTIMATE FAILURE:

The final result of tool wear is the complete removal of the cutting point - ultimate failure of the tool. This may come about by temperature rise, which virtually causes the tool tip to soften until it flows plastically at very low shear stress. This melting process seems to start right at the cutting edge and because material flow blunts the edge, the melting process continues back into the tool; within a few seconds a piece of tool almost as large as the engaged depth of cut is removed. An alternative mechanism of ultimate failure is the mechanical failure (usually a brittle fracture) of a relatively large portion of the cutting tip. This often results from a weakening of the tool by crater formation. Ultimate failure by melting and plastic flow is most common in carbon and high-speed-steel tools, while fracture failures are most common in sintered carbide or ceramic tools.

1.2.2 : TOOL WEAR EVOLUTION

Tool wear curves illustrate the relationship between the amount of flank (rake) wear and the cutting time, τ_m, or the overall length of the cutting path, L. Figure 1.21(a) shows the evolution of flank wear $V_{B\,max}$, as measured after a certain length of cutting path. Normally, there are three distinctive regions that can be observed in such curves. The first region (region I in Figure 1.21(a)) is the region of primary or initial wear. The relatively high wear rate (an increase of tool wear per unit time or length of the cutting path) in this region is explained by accelerated wear of the tool layers damaged during manufacturing or re-sharpening. The second region (region II in Figure 1.21(a)) is the region of steady-state wear. This is the normal operating region for the cutting tool. The third region (region III in Figure 1.21(a)) is known as the tertiary or accelerated wear region. Accelerated tool wear in this region is usually accompanied by high cutting forces, temperatures and severe tool vibrations. Normally, the tool should not be used in this region. In practice, the cutting speed is of prime concern in the consideration of tool wear. As such, tool wear curves are constructed for different cutting speeds keeping other machining parameters constant. In Figure 1.21(b), three characteristic tool wear curves (mean values) are shown for three different cutting speeds, v_1 , v_2, and v_3 . Because v_3 is greater than the other two, it corresponds to the fastest wear rate. When the amount of wear reaches the permissible tool wear VB_{Bc}, the tool is said to be worn out.

Typically VB_{Bc} is selected from the range 0.15–1.00 mm depending upon the type of machining operation, the condition of the machine tool and the quality requirements of the operation. It is often selected on the grounds of process efficiency and often called the criterion of tool life. In Figure 1.21(b), T_1 is the tool life when the cutting speed v_1 is used, T_2 – when v_2, and T_3 – when v_3 is the case. When the integrity of the machined surface permits, the curve of maximum wear instead of the line of equal wear should be used (Figure 1.21(b)). As such, the spread in tool life between lower and higher cutting speeds becomes less significant. As a result, a higher productivity rate can be achieved, which is particularly important when high-speed CNC machines are used.

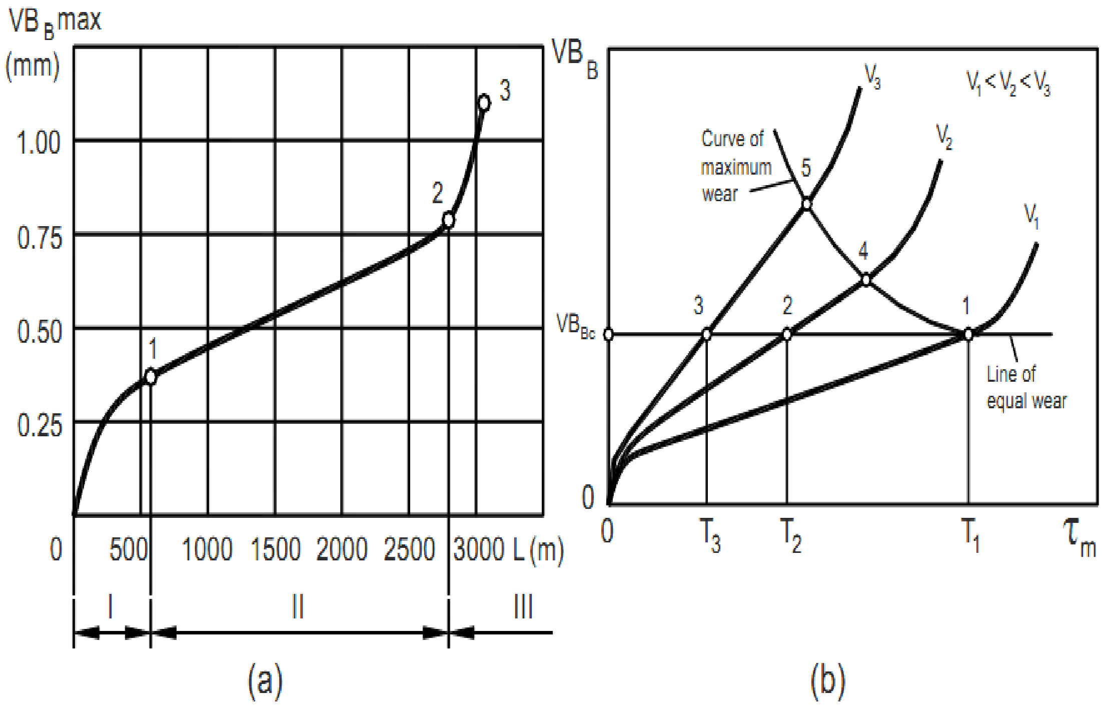


Fig. 1.21 : Wear curves: (a) normal wear curve, (b) evolution of flank wear land V_B as a function of cutting time for different cutting speeds

MECHANISM OF TOOL WEAR:

The general mechanisms that cause tool wear, summarized in Figure 1.22, are

(i) Abrasion

(ii) Diffusion

(iii) Oxidation

(iv) Fatigue and

(v) Adhesion

The fundamentals of these tool wear mechanisms are explained for several authors, for example, Shaw and Trent and Wright . Most of these mechanisms are accelerated at higher cutting speeds and consequently cutting temperatures.

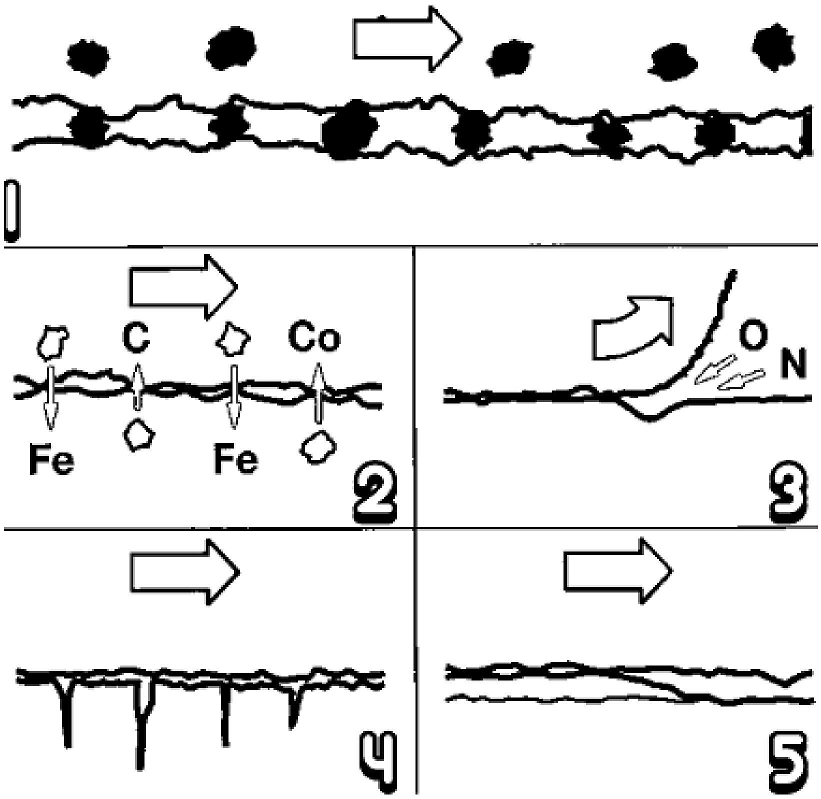


Fig. 1.22: Evolution of the flank wear land V_B as a function of cutting time for different cutting speeds

1.2.3 : EFFECT OF TOOL WEAR ON PERFORMANCE MEASURES

Consequences of Tool Wear:

(i) Increase the cutting force

(ii) Increase the surface roughness

(iii) Decrease the dimensional accuracy

(iv) Increase the temperature

(v) Vibration

(vi) Lower the production efficiency, component quality

(vii) Increase the cost

Influence on cutting forces:

Crater wear, flank wear (or wear-land formation) and chipping of the cutting edge affect the performance of the cutting tool in various ways. The cutting forces are normally increased by wear of the tool. 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.

Surface finish (roughness):

The surface finish produced in a machining operation usually deteriorates as the tool wears. This is particularly true for a tool worn by chipping and generally the case for a tool with flank-land wear; although there are circumstances in which a wear land may burnish (polish) the work piece and produces a good finish.

Dimensional accuracy:

Flank wear influences the plan geometry of a tool; this may affect the dimensions of the component produced in a machine with set cutting tool position or it may influence the shape of the components produced in an operation utilizing a form tool. (If tool wear is rapid, cylindrical turning could result in a tapered work piece)

Vibration or chatter:

Vibration or chatter is another aspect of the cutting process which may be influenced by tool wear. A wear land increases the tendency of a tool to dynamic instability. A cutting operation which is quite free of vibration when the tool is sharp may be subjected to an unacceptable chatter mode when the tool wears.

1.2.4 : TOOL LIFE

There is no single universally accepted definition of tool life. The life needs to be specified with regard to the process aims. A common way of quantifying the end of a tool life is to put a limit on the maximum acceptable flank wear, V_B or $V_{B\ max}$. Typical figures are given in table 1.1 . Tool wear is almost always used as a lifetime criterion because it is easy to deter-mine quantitatively. The flank wear land V_B is often used as the criterion because of its influence on work piece surface roughness and accuracy. Figure 1.23 shows the wear curves (V_B versus cutting time) for several cutting velocities (1, 2 and 3) and the construction of the life curve (cutting velocity vs. tool life). Taylor [4] presented the following equation:

$$V_c T^n = C \qquad \textbf{(1.4)}$$

where V_c is the cutting speed (m/min), T is the tool life (min) taken to develop a certain flank wear (V_B), n is an exponent that depends on the cutting parameters and C is a constant. C is equal to the cutting speed at T = 1 min. Therefore, each combination of tool material and work piece and each cutting parameter has it is own n and C values, to be determined experimentally.

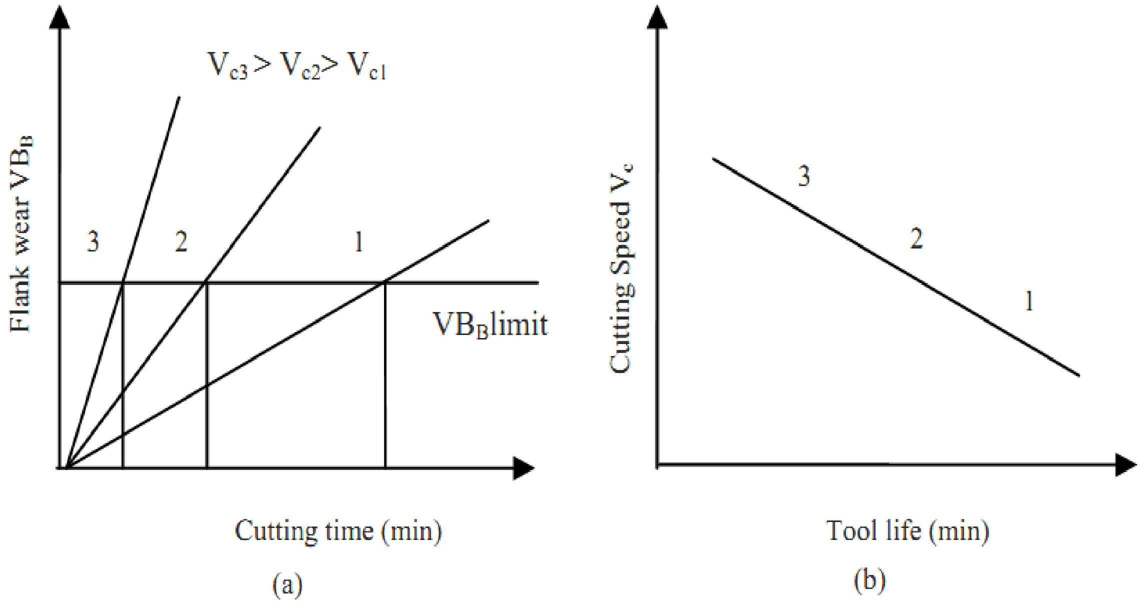


Fig. 1.23: (a) Wear curves for several cutting speeds (1, 2 & 3) an (b) tool life curve

Table 1

HSS tools, roughing	1.50 mm
HSS tools, finishing	0.75 mm
Carbide tools	0.70 mm
Ceramic tools	0.60 mm

1.2.5 EXPANDED TAYLOR'S TOOL LIFE FORMULA:

According to the original Taylor tool life formula, the cutting speed is the only parameter that affects tool life. This is because this formula was obtained using high-carbon and high-speed steels as tool materials. With the further development of carbides and other tool materials, it was found that the cutting feed and the depth of cut are also significant. As a result, the Taylor's tool life formula was modified to accommodate these changes as:

$$V_c\, T^{\,n}\, f^{\,a}\, d^{\,b} = \mathrm{C} \qquad \textbf{(1.5)}$$

Where d is the depth of cut (mm) and f is the feed (mm/rev). The exponents *a* and *b* are to be determined experimentally for each combination of the cutting conditions. In practice, typical values for HSS tools are $n = 0.17$, $a = 0.77$ and $b = 0.37$ [4]. According to this information, the order of importance of the parameters is: cutting speed, then feed, then depth of cut. Using these parameters, Equation (1.5) for the expanded Taylor's tool life formula model can be rewritten as:

$$T = C^{\frac{1}{n}} V_c^{\frac{-1}{n}} f^{\frac{-a}{n}} d^{\frac{-b}{n}} \text{ or } T = C^{5.88} V^{-5.88} f^{-4.53} d^{-2.18} \qquad \textbf{(1.6)}$$

Although cutting speed is the most important cutting parameter in the tool life equation, the cutting feed and the depth of cut can also be the significant factors. Finally, the tool life depends on the tool (material and geometry); the cutting parameters (cutting speed, feed, depth of cut); the brand and conditions of the cutting fluid used; the work material (chemical composition, hardness, strength, toughness, homogeneity and inclusions); the machining operation (turning, drilling, milling), the machine tool (for example, stiffness, run out and maintenance) and other machining parameters. As a result, it is nearly impossible to develop a universal tool life criterion.

1.2.6 RECENT TRENDS IN TOOL LIFE EVALUATION:

Although Taylor's tool life formula is still in wide use today and lies at the very core of many studies on metal cutting, including at the level of national and inter-national standards, one should remember that it was introduced in 1907 as a generalization of many years of experimental studies conducted in the 19th century using work and tool materials and experimental technique available at that time. Since then, each of these three components has undergone dramatic changes. Tool life is not an absolute concept but depends on what is selected as the tool life criteria. In finishing operations, surface integrity and dimensional accuracy are of primary concern, while in roughing operations the excessive cutting force and chatter are limiting factors. In both applications, material removal rate and chip breaking could be critical factors. These criteria, while important from the operational point of view, have little to do with the physical conditions of the cutting tool. To analyze the performance of cutting tools on CNC machines, production cells and manufacturing lines, the dimension tool life is understood to be the time period within which the cutting tool assures the required dimensional accuracy and required surface integrity of the machined parts. Although there are a number of representations of the dimension tool life, three of them are the most adequate .

- The dimension wear rate is the rate of shortening of the cutting tip in the direction perpendicular to the machined surface taken within the normal wear period (region II in Figure 1.21(a)), i.e.,

$$v_h = \frac{dv_r}{dT} = \frac{h_r - h_{r-i}}{T - T_i} = \frac{vh_{l-r}}{1000} = \frac{vfh_s}{100} \quad (\mu m/min)$$

Where h_{r-i} and l_i are the initial radial wear and initial length of the tool path, respectively, and l is the total length of the tool path. It follows from Equation (1.6) that the surface wear rate is reverse proportional to the overall machined area and, in contrast, does not depend on the selected wear criterion.

- The specific dimension tool life is the area of the work piece machined by the tool per micron of radial wear

$$T_{UD} = \frac{dS}{dh_r} = \frac{1}{h_s} = \frac{(l - l_i)f}{(h_r - h_{r-i})100} \quad (10^3 cm^2/\mu m)$$

- The surface wear rate and the specific dimension tool life are versatile tool wear characteristics because they allow the comparison of different tool materials for different combinations of the cutting speeds and feeds using different criteria selected for the assessment of tool life.

1.3: SURFACE ROUGHNESS

1.3.1 SURFACE STRUCTURE OF METALS

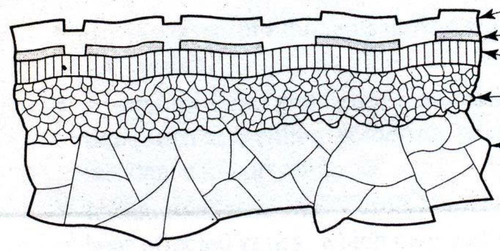


Fig. 1.24: Cross section of surface structure of metals

The characteristics of different layers of the surface of a metal are discussed below:

- The bulk metal, also known as the metal substrate, has a structure that depends on the composition and processing history of the metal.

- Above "metal substrate", the layer is known as "work-hardened layer". The depth and properties of the work-hardened layer depend on such factors as the processing method used and how much frictional sliding the surface undergoes. The use of sharp tools and the selection of appropriate processing parameters result in surfaces with little or no disturbance.

Unless the metal is processed and kept in an inert (oxygen-free) environment, or is a noble metal such as gold or platinum, an oxide layer forms over the work hardened layer. Iron has an oxide structure with FeO adjacent to the bulk metal, followed by a layer of Fe3O4 and then a layer of Fe2O3, which is exposed to the environment. Aluminum has a dense, amorphous (without crystalline structure) layer of Al2O3, with a thick, porous hydrated aluminum-oxide layer over it.

- Under normal environmental conditions, surface oxide layers are generally covered with absorbed layers of gas and moisture. Finally, the outermost surface of the metal may be covered with contaminants such as dirt, dust, grease, lubricant residues, cleaning-compound residues, and pollutants from the environment.

1.3.2: FACTORS AFFECTING THE SURFACE ROUGHNESS

Whenever two machined surfaces come in contact with one another the quality of the mating parts plays an important role in the performance and wear of the mating parts. The height, shape, arrangement and direction of these surface irregularities on the work piece depend upon a number of factors such as:

A) The machining variables which include

a) Cutting speed

b) Feed, and

c) Depth of cut.

B) The tool geometry

Some geometric factors which affect achieved surface finish include:

a) Nose radius

b) Rake angle

c) Side cutting edge angle, and

d) Cutting edge.

C) Work piece and tool material combination and their mechanical properties

D) Quality and type of the machine tool used,

E) Auxiliary tooling, and lubricant used, and

F) Vibrations between the work piece, machine tool and cutting tool.

1.4 : ULTRASONIC SOUND WAVE:

Ultrasound is an oscillating sound pressure wave with a frequency greater than the upper limit of the human hearing range. Ultrasound is thus not separated from 'normal' (audible) sound based on differences in physical properties, only the fact that humans cannot hear it. Although this limit varies from person to person, it is approximately 20 kilohertz (20,000 hertz) in healthy, young adults. Ultrasound devices operate with frequencies from 20 kHz up to several gigahertz.

Ultrasound is used in many different fields. Ultrasonic devices are used to detect objects and measure distances. Ultrasonic imaging (sonography) is used in both veterinary medicine and human medicine. In the nondestructive testing of products and structures, ultrasound is used to detect invisible flaws. Industrially, ultrasound is used for cleaning and for mixing, and to accelerate chemical processes. Organisms such as bats and porpoises use ultrasound for locating prey and obstacles.

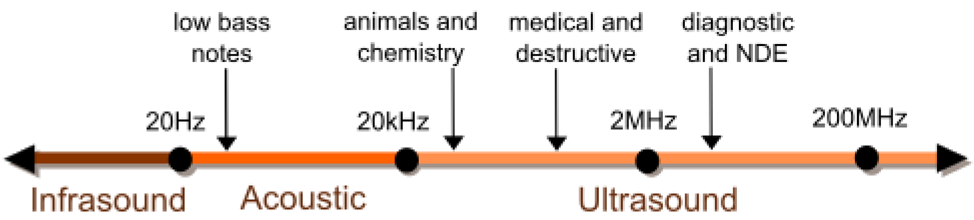
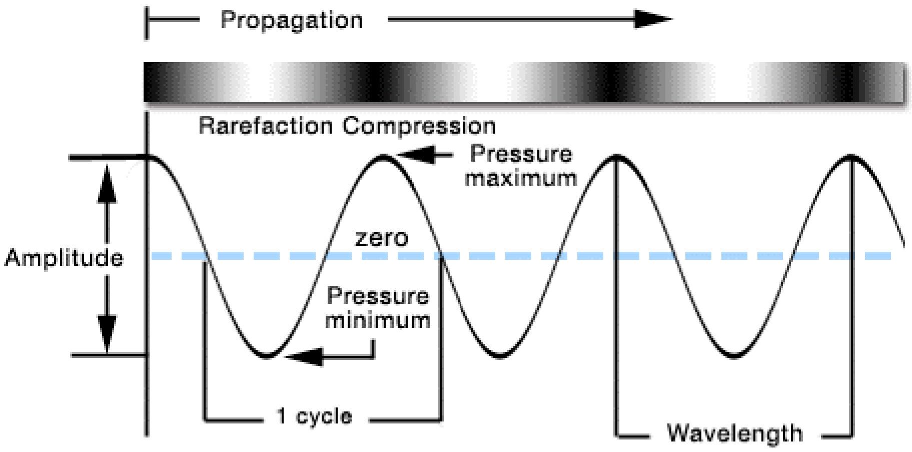


Fig 1.25-Range Of sound wave

1.4.1: ULTRASONIC SOUND WAVE PROPERTIES:



• Mechanical waves are longitudinal compression waves

• "Ultrasound" refers to frequencies greater than 20kHz, the limit of

human hearing

• For Medical imaging typically 100 Times higher frequency than audible by human typically 2 to 20 MHz

1.4.2:PROPAGATION OF ULTRASOUND WAVES IN TISSUE:

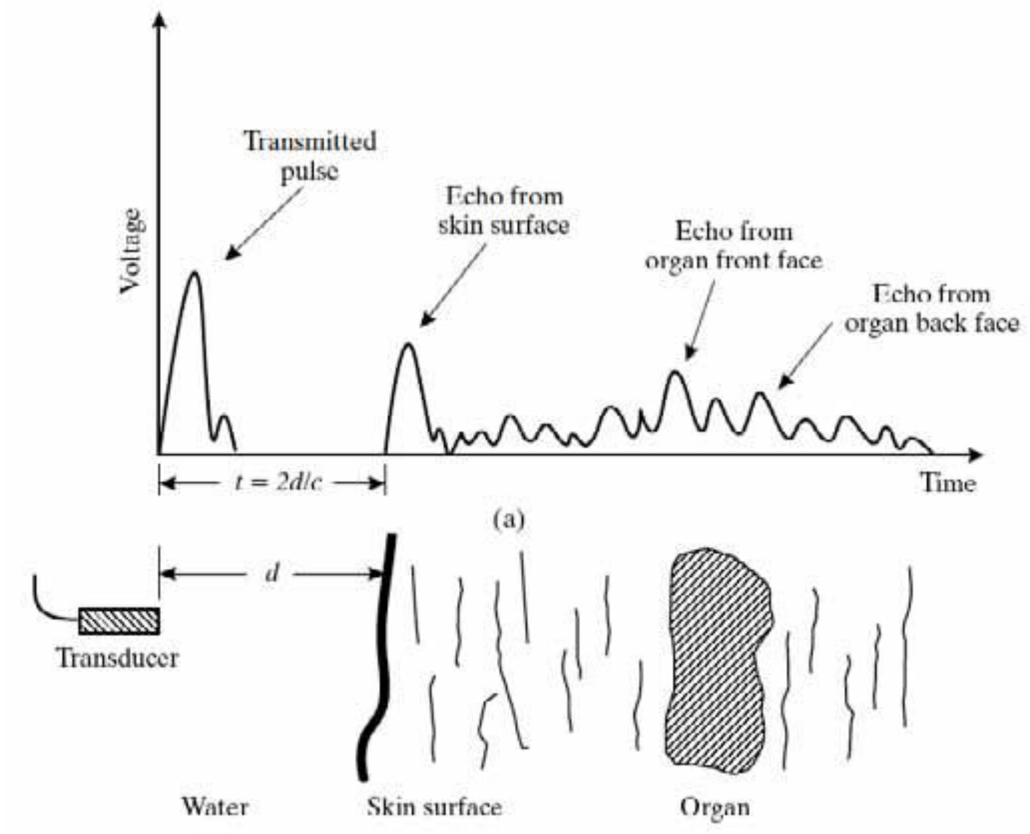
Scattering:

• Specular reflector is a smooth boundary between media (conventional view of reflections

• Acoustic scattering arises from objects that are size of wavelength or smaller

Specular - echoes originating from relatively large, regularly shaped objects with smooth surfaces. These echoes are relatively intense and angle dependent. (i.e. valves) **-Reflection from large surfaces**

Scattered - echoes originating from relatively small, weakly reflective, irregularly shaped objects are less angle dependant and less intense. (i.e.. blood cells) - Reflection from small surfaces.



1.4.3:THE SPEED OF SOUND:

• The compressibility and density of a material, combined with the laws of conservation of mass and momentum, directly imply the existence of acoustic waves

• Ultrasound waves travel at a speed of sound c, given by,

$$c = \sqrt{\frac{1}{\rho k}}$$

1.4.4:VARIATION OF SPEED:

Acoustical Properties of Various Materials

Material	Density, ρ [kg m^{-3}]	Speed, c [m s^{-1}]	Characteristic Impedance, Z [kg m^{-2} s^{-1}] ($\times 10^6$)	Absorption Coefficient, α [dB cm^{-1}] (at 1 MHz)	Approximate Frequency Dependence of α
Air at STP	1.2	330	0.0004	12	f^2
Aluminum	2700	6400	17	0.018	f
Brass	8500	4490	38	0.020	f
Castor oil	950	1500	1.4	0.95	f^2
Mercury	13,600	1450	20	0.00048	f^2
Polyethylene	920	2000	1.8	4.7	$f^{1.1}$
Polymethyl-methacrylate	1190	2680	3.2	2.0	f
Water	1000	1480	1.5	0.0022	f^2
Blood	1060	1570	1.62	[0.15]	
Bone	1380–1810	4080	3.75–7.38	[14.2–25.2]	
Brain	1030		1.55–1.66	[0.75]	
Fat	920	1450	1.35	[0.63]	
Kidney	1040	1560	1.62	—	
Liver	1060	1570	1.64–1.68	[1.2]	
Lung	400		0.26	[40]	
Muscle	1070		1.65–1.74	[0.96–1.4]	
Spleen	1060		1.65–1.67	—	
Water	1000	1484	1.52	[0.0022]	

Source: Data above the line are from P. N. T. Wells, *Biomedical Ultrasonics*, (New York: Academic Press, 1977). Data in square brackets below the line are taken from A. B. Wolbarst, *Physics of Radiology* (Norwark, CT: Appleton and Lange, 1993).

CHAPTER 2

LITERATURE REVIEW AND PRESENT WORK

Average principal flank wear (VB) of cutting tools is often selected as the tool life criterion as it determines the diametric accuracy of machining, its stability and reliability. The productivity of a machining system and machining cost, as well as quality, the integrity of the machined surface and profit strongly depend on tool wear and tool life. Sudden failure of cutting tools leads to loss of productivity, rejection of parts and consequential economic losses. Flank wear occurs on the relief face of the tool and is mainly attributed to the rubbing action of the tool on the machined surface during turning operation During turning operation the average principal flank wear (VB) predominantly occurs in cutting tool, so the life of a particular tool used in the machining process depends upon the amount of average principal flank wear. The surface finish of the machined component primarily depends upon the amount of average principal flank wear (VB). An increase in the amount of average principal flank wear (VB) leads to reduction in nose radius of the cutting insert which in turn reduces the surface quality along the job axis. The maximum utilization of cutting tool is one of the ways for an industry to reduce its manufacturing cost. Hence tool wear has to be controlled and should be kept within the desired limits for any marching process [1].

The researches on tool wear and surface roughness of the work piece and other machinability factors during the machining operation are significant in number. The quality and productivity has a lot of importance in the field of manufacturing which are listed below:

- Keeps costs down to improve profits and reduce the prices.
- Enables firms to spend more on improving customer service and supplementary services.
- Increase repeat purchases from loyal customers.
- Enables a firm to differentiate its offerings.

For years, quality and productivity have been viewed as two important indexes of company performance, especially in manufacturing industries. However, they are always emphasized separately.

To fulfill the need of a certain cutting condition, tool design focuses on the specialized insert. But by designing such specialized tool inserts an extra cost will be added up with the overall manufacturing cost. Moreover it sufficiently complex and specialized training is required to determine the specific insert under a unique cutting condition. The optimization of the cutting processes consists of establishing a simple functional dependency between input process variables such as cutting conditions, tool geometry, etc., and output parameters-amount of tool wear, tool life and thereby adjusting the cutting conditions as required. This trial and error process is usually time consuming and requires constant fine tuning. The other common process depends on the application of hard and thin wear resistant coatings to improve the tool life of inserts. Nevertheless, problems such as sudden failure of coatings and poor adhesion between thin surface coatings and insert material remains to be a challenge.

Tool wear is of many different types and also depend on the type of tool material chosen and the cutting conditions used. For this study, flank wear was measured as the maximum land wear "$V_{B\ max}$". For continuous turning the maximum tool wear land width ($V_{B\ max}$) shows a near linear increase with cutting distance after initial rapid wear. Flank wear typically results due to erosion of the flank face and excessive chipping on flank side of tool. Such flank wear compromises the stability of the cutting edge, causing reduction dimensional tolerance and tool life, increased roughness, and tool breakage in the extreme case.

It is well accepted that, during machining of steel work materials with WC tools, several wear mechanisms such as abrasion, adhesion, oxidation, diffusion, etc. can operate simultaneously [2-7].

There is an extensive research interest in the application of ANNs in modeling and monitoring Of machining operations [8,9]. Applications of neural networks in computer-integrated production are adaptive control of cutting process, prediction of surface roughness, cutting forces, vibrations, prediction of tool wear and tool failure, solving of optimization problems [10-12]. Elanayar and Shin [13] proposed a model, which approximates flank and crater wear propagation and their effects on cutting force by using radial basis function neural networks. Ghasempoor et al. [14] proposed a tool wear classification and continuous monitoring neural network system for turning by employing recurrent neural network. Liu and Altintas [15] derived an expression to calculate flank wear in terms of cutting force ratio and other machining parameters. The calculated flank wear, force ratio, feed rate and cutting speed are used as an input to a neural network to predict the flank wear. . Sick [8] demonstrated a new hybrid technique, which combines a physical model describing the influence of cutting conditions on measured force signals with neural model describing the relationship between normalized force signals and the wear of the tool. Time-delay neural networks were used in his studies. Azouzi and Guillot [16] examined the feasibility of neural network based sensor fusion technique to estimate the surface roughness and dimensional deviations during machining. This study concludes that depth of cut, feed rate, radial and z-axis cutting forces are the required information that should be fed into neural network models to predict the surface roughness successfully.

Tool wear, the gradual failure of cutting tools due to regular use, is an inevitable impediment in machining processes [17]. High speed machining uses high cutting speed and feed rate. This produces high temperature in the tool and the work piece. This high temperature not only reduces the tool life but also deteriorates the product quality, thereby affecting directly on the manufacturing cost of the product [18]. However tool life can be improved satisfactorily by using a suitable tool material and proper cutting conditions. So, there can be more number of factors like this which affect the tool wear mechanism during turning operation and this can be controlled in order to improve the tool life [19-22].

The effects of external superimposed electric current with an aim of thermo-electric compensation and consequent improvement in wear resistance of cutting tools have been studied by Bobrovoskii [23], Kanji and Pal [24]. In their study an improvement in the tool life has been noticed, but they did not give any detailed reasons for this improvement. Zhou et al. [25] investigated on tool life criteria in raw turning. A new tool-life criterion depending on a pattern-recognition technique was proposed and neural network and wavelet techniques were used to realize the new criterion. The experimental results showed that this criterion was applicable to tool condition monitoring in a wide range of cutting conditions.

Bisht et al. [26] developed a back propagation neural network model for the prediction of flank wear in turning operations. Process parametric conditions including cutting speed, feed-rate, depth of cut, and the measured parameters such as cutting force, chip thickness and vibration signals are used as inputs to the neural network model. Jang et al. [27] applied ANN in surface roughness study and correlate surface roughness with cutting vibrations. Grzesik [28] used the minimum un-deformed chip thickness to predict surface roughness in turning. Polynomial networks were considered in the work of Lee et al [29] to construct the relationships between the cutting parameters (cutting speed, feed rate, depth of cut) and cutting performance (tool life, surface roughness and cutting force). Li et al. [30] developed a hybrid machining model that integrated analytical models and neural network models for predicting all of the machining characteristic factors. Matsumura et al [31] adopted an approach that could evaluate the influence of machine tool characteristics on cutting processes using adaptive prediction was presented.

The network for predicting surface roughness had as inputs the cutting speed, the affinity between cutting tool and workpiece, the chip discontinuity (evaluated by the chip strain), the builtup- edge formation (evaluated by average temperature around the cutting edge), the width of flank wear and the theoretical roughness considering tool wear. An adaptive neuro-fuzzy inference system (ANFIS) and computer vision were used to predict surface roughness by Ho et al. [32] in turning. The computer vision system, comprising a digital camera connected to a PC and the appropriate light sources, provided surface images that were analyzed to calculate the arithmetic average of gray levels (number of shades of gray). This information as well as the cutting parameters was given, for a total of four inputs, to the ANFIS and the roughness value could then be obtained.

Braghini et al [33] studied the wear behavior of Polycrystalline Cubic Boron Nitride (PCBN) and cemented carbide tool in end milling of hardened steels. They found that the minimal wear mechanism was a combination of adhesion and abrasion. It was also stated that wear occurred predominantly on the flank face. Kumar et al [34] investigated the wear morphology of alumina based ceramic tools in the machining hardened stainless steel and found that the flank wear affects the tool wear at lower speed. Ghani et al [35] studied about the performance of TiN coated carbide inserts in semi-finish and finished end milling of hardened tool steel at high cutting speeds. Their results compared the effectiveness of TiAlN inserts under preheated room temperature condition. Once factor in the variation of performance was concluded to be tool wear.

Honet et al. reviewed contemporary work on heat generation and heat dissipation in high speed metal turning on coated materials and also briefly reviewed some temperature measurement techniques in metal cutting[36]. Considerable research effort has been made on the thermal problem in metal cutting, but the accuracy of the readings and the means by which the temperatures are measured are in question[37].

The unique tribological contact phenomenon, which occurs in metal cutting is highly localized and non-linear, and occurs at high temperatures, high pressures, and high strains. This has made it extremely difficult to predict in a precise manner or even assess the performance of various models developed for modelling the machining process. Even though thermal aspects are equally important, it is beyond the scope of this research. Astakhov and Shvets studied force variations and their effects in metal-deforming technological processes[38]. They suggest that interaction of the energy waves propagating in the medium might affect the cutting force. They experimented and studied on the interaction between the deformation and the heat waves. The conclusions drawn from this paper reveals that the study of cutting force and the interaction between the deformation and heat waves can be very helpful in adopting the process which involves the least energy consumption. The study on MDN250 steel using coated ceramic tool by Lalwani et al. also portrays the significance of accounting for surface roughness and cutting force[39].

MDN 250 steel finds its applications in Aerospace industry, Naval industry, etc., and hence, the results and the conclusions drawn here will prove to be helpful in the selection of optimum manufacturing conditions, thus contributing towards larger productivity[40,41]. Having realized the importance of the choice of most appropriate cutting conditions in metal cutting, this research primarily focuses on machining mild steel using HSS owing to its lower cost, ready availability, and a wide range of applications from automotives to domestic goods to constructional steel and many other machine elements such as keys, rings, fence posts etc. The influence of cutting parameters on cutting force and surface roughness can be studied effectively using Adjusted statistical approach[42-45].

Amin et al. [46] proposed a predictive model for the estimation of tool life under different cutting conditions in end milling of tool steel using TiAlN (Titanium Aluminium Nitride). In their investigation on tool wear, Takeyama and Murata [47] studied that the amount of tool flank wear is given by abrasive wear thermal diffusion. They considered abrasive wear to be proportional to the cutting distance and independent of tool temperature. Thermal diffusion was considered to be temperature dependent. Tool temperature and tool life results were obtained when machining steel and cast iron using P10 grade WC tools. It has been noticed that the experimental results for temperature above 800^{o} C could be represented well by equations thus indicating that wear of tested tools was dominated by diffusion. Muju and Radhakrishna [48] proposed a generalization of the model represented by Muju and Ghosh [49-51] using a more fundamental approach by taking into account the influence of the temperature. The conclusion of the generalized model were that the application of a magnetic field to a contacting pair reduces the activation energy of wear and diffusion and is advantageous only when (H_2/H_1) is greater than or equal to 0.2, where H_1 and H_2 are the hardness's of the bodies with the lowest and highest magnetic permeability, respectively.

Muju and Ghosh [49-51] presented a physical model to explain some results obtained when conducting tool wear experiments with magnetized HSS turning tools on mild steel and brass. The wear experiments consisted of the use of mild steel tools to cut aluminium. Additional tests with the mild steel tools rubbing against brass and mild steel were also performed. The tools were magnetized using a d.c. source and an auxiliary tool was used to keep the machined surface fresh. In their observations, they found an increase in tool life by approximately 40% and a reduction of the size of wear particles, but no phase change. The authors discussed the effects of an external magnetic field from a mechanical point of view. Their analysis was performed as a phenomenological approach based on dislocation mobility during a two-body interaction in the presence of an external magnetic field. To establish a physical model, the authors assumed the uniformity of dislocation density and velocity. However, the repulsion and the temperature effect on dislocations are neglected. Predictions of the proposed model confirm that the magnetic field influences the adhesive wear behavior in such a way as to reduce the wear rate of the body with the lowest magnetic permeability.

Oxley [52] and Arsecularatne [53-54] studied about the change in tool life in combination with the temperature. When compared with empirical methods, the theoretical method appears far more effective in predicting tool life as it allows tool geometrical parameters and cutting conditions to be combined into the single parameter of temperature. This approach was initially applied to orthogonal and oblique conditions with plane face tools investigated by Trent et al [57]. Later it was extended to tools with restricted contact and commercial chip grooves with considerable success carried out by Kitagawa et al [55]. In these investigations carried out by the authors mentioned above, diffusion was considered to be the dominant tool wear mechanism. Trent et al. [57] and Hastings et al. [3] investigated that when machining steel work materials, these mechanisms are unlikely to be dominant under the conditions normally used in practice (i.e. at relatively high cutting speeds). This is due to- the in sufficient amount of abrasions present in the work piece, insufficient hardness of abrasives to abrade WC and inability to detect any significant signs of abrasive wear in extensive metallurgical studies. However, there are certain conditions under which abrasive wear of WC tools have been observed.

Kitagawa et al. [55] studied that, under practical conditions, wear of WC tools was due to adhesion, that wear rate could be represented by a relation and that wear should increase with the normal stress on the tool flank. This is one of the major drawbacks of these studies since reliable experimental results or an analytical method to determine this stress is not yet available. Another is that the predicted results indicate elastic contact at flank/work interface in spite of experimental evidence of plastic contact investigated by Trent and Wright [57]. Iwata et al. [56] showed that adhesion between WC and steel (hence adhesive wear rate) becomes a maximum at 600^{o} C and thereafter falls off rapidly with further increase in temperature.

Srikanth and Kamala [58] evaluated optimal values of cutting parameters by using a Real Coded Genetic Algorithm (RCGA) and explained various issues of RCGA and its advantages over the existing approach of Binary Coded Genetic Algorithm (BCGA). They concluded that RCGA was reliable and accurate for solving the cutting parameter optimization and construct optimization problem with multiple decision variables. These decision variables were cutting speed, feed, depth of cut and nose radius. The authors highlighted that the faster solution can be obtain with RCGA with relatively high rate of success, with selected machining conditions thereby providing overall improvement of the product quality by reduction in production cost, reduction in production time, flexibility in machining parameter selection.

The productivity of a machining operation is not only determined by the use of low cost-high performance but also by the capability to transform specific steel alloys to the required surface finish and geometry by machining at sufficiently high speed. Surface roughness is the dimensional accuracy of the finished product and is one of the most important quality requirements of the finished product. Therefore in most machining situations, minimization of surface roughness is a prime issue which is carried out by optimizing the machining process parameters in order to attain minimal surface roughness.

Lin et al. [59] adopted an abdicative network to construct a prediction model for surface roughness and cutting force. Once the process parameters: cutting speed, feed rate and depth of cut were given; the surface roughness and cutting force could be predicted by this network. Regression analysis was also adopted as second prediction model for surface roughness and cutting force. Comparison was made on the results of both models indicating that adductive network was found more accurate than that by regression analysis. Investigation was also carried out for the prediction of surface roughness in finish turning operation by developing an empirical model through considering working parameters: work piece hardness (material), feed, cutting tool point angle, depth of cut, spindle speed, and cutting time. Data mining techniques, nonlinear regression analysis with logarithmic data transformation were employed for developing the empirical model to predict the surface roughness.

Kirby et al. [600] developed the prediction model for surface roughness in turning operation. The regression model was developed by a single cutting parameter and vibrations along three axes were chosen for in-process surface roughness prediction system. By using multiple regression and Analysis of Variance a strong linear relationship among the parameters (feed rate and vibration measured in three axes) and the response (surface roughness) was found. The authors demonstrated that spindle speed and depth of cut might not necessarily have to be fixed for an effective surface roughness prediction model.

Őzel and Karpat [61] studied for prediction of surface roughness and tool flank wear by utilizing the neural network model in comparison with regression model. The data set from measured surface roughness and tool flank wear were employed to train the neural network models. Predictive neural network models were found to be capable of better predictions for surface roughness and tool flank wear within the range in between they were trained. They also carried out theoretical and experimental studies to investigate the intrinsic relationship between tool flank wear and operational conditions in metal cutting processes using carbide cutting inserts. The authors developed the model to predict tool flank wear land width which combined cutting mechanics simulation and an empirical model. The study revealed that cutting speed had more dramatic effect on tool life than feed rate.

Sing and Kumar [62] studied on optimization of feed force through setting of optimal value of process parameters namely speed, feed and depth of cut in turning of EN24 steel with TiC coated tungsten carbide inserts. The authors used Taguchi's parameter design approach and concluded that the effect of depth of cut and feed in variation of feed force were affected more as compare to speed.

Ahmed [63] developed the methodology required for obtaining optimal process parameters for prediction of surface roughness in Aluminium turning. For development of empirical model nonlinear regression analysis with logarithmic data transformation was applied. The developed model showed small errors and satisfactory results. The study concluded that low feed rate was good to produce reduced surface roughness and also the high speed could produce high surface quality within the experimental domain.

Abburi and Dixit [64] developed a knowledge-based system for the prediction of surface roughness in turning process. Fuzzy set theory and neural networks were utilized for this purpose. The authors developed rule for predicting the surface roughness for given process variables as well as for the prediction of process variables for a given surface roughness.

Zhong et al. [65] predicted the surface roughness of turned surfaces using networks with seven inputs namely tool insert grade, work piece material, tool nose radius, rake angle, depth of cut, spindle rate, and feed rate.

Doniavi et al. [66] used response surface methodology (RSM) in order to develop empirical model for the prediction of surface roughness by deciding the optimum cutting condition in turning. The authors showed that the feed rate influenced surface roughness remarkably. With increase in feed rate surface roughness was found to be increased. With increase in cutting speed the surface roughness decreased. The analysis of variance was applied which showed that the influence of feed and speed were more in surface roughness than depth of cut.

Kassab and Khoshnaw [67] examined the correlation between surface roughness and cutting tool vibration for turning operation. The process parameters were cutting speed, depth of cut, feed rate and tool overhanging. The experiments were carried out on lathe using dry turning (no cutting fluid) operation of medium carbon steel with different level of aforesaid process parameters. Dry turning was helpful for good correlation between surface roughness and cutting tool vibration because of clean environment. The authors developed good correlation between the cutting tool vibration and surface roughness for controlling the surface finish of the work pieces during mass production. The study concluded that the surface roughness of work piece was observed to be affected more by cutting tool acceleration; acceleration increased with overhang of cutting tool. Surface roughness was found to be increased with increase in feed rate.

Biswas et al. [68] studied that on-line flank wear directly influenced the power consumption, quality of the surface finish, tool life, productivity etc. The authors developed a model for prediction of the tool wear. From the orthogonal machining of aluminium with high-speed steel tool for various rake angles, feed and velocity the experimental data were obtained and input along with other machining parameters ratio between cutting force and tangential forces was collected. These were used to predict the tool wear. The final parameters of the model were obtained by tuning the crude values obtained from mountain clustering method by using back-propagation learning algorithm and finally predicted the flank wear with reasonable accuracy and proved it to be a potent tool in estimating flank wears on-line.

Close monitoring of the vibration signal of the machine during the machining operation is considered as a common practice for distinguishing the status of the tool wear . Modeling of features using singular value decomposition (SVD), is one of the most basic and important method of numerical linear algebra, is finding increasing applications in digital signal processing [69]

SCOPE OF THE PRESENT WORK:

The study will give a lot of idea to do this work carefully. All of the researches carried out on the field of cutting have shown a significant improvement of tool life, surface roughness and other machinability factors during turning operation. This project aims to investigate the effects of ultrasonic sound signal on the machinability control of mild steel during turning operation. The machinability responses include tool wear, surface roughness, temperature, chip morphology. A control experiment was also done where no ultrasonic sound is applied at all. The main purpose of this research is to send sound signal in the cutting processes and to investigate the effect of ultrasonic sound waves signal during turning operation on the machinability responses such as tool wear, surface roughness, and chip behavior. The ultrasonic sound wave that has been used is 40 KHZ. There are two ultrasound modules from where that sound wave has formed.

CHAPTER 3

DETAILS OF THE EXPERIMENTATION

3.1 : INTRODUCTION

This paper actually represented the effect of ultrasonic sound signal during turning operation of mild steel.Suitable result has found after using the effect of ultrasound.There are two module for creating ultrasonic sound effect.In normal cutting the result was found ,thats showed a quite bad result than the ultrasonic sound effect. In tool wear,surface roughness and in chip,there are a lot of change has found.Not only these it also create effect on temperature also.Temperature are less than the normal cutting.

3.2 :EXPERIMENTAL SET UP

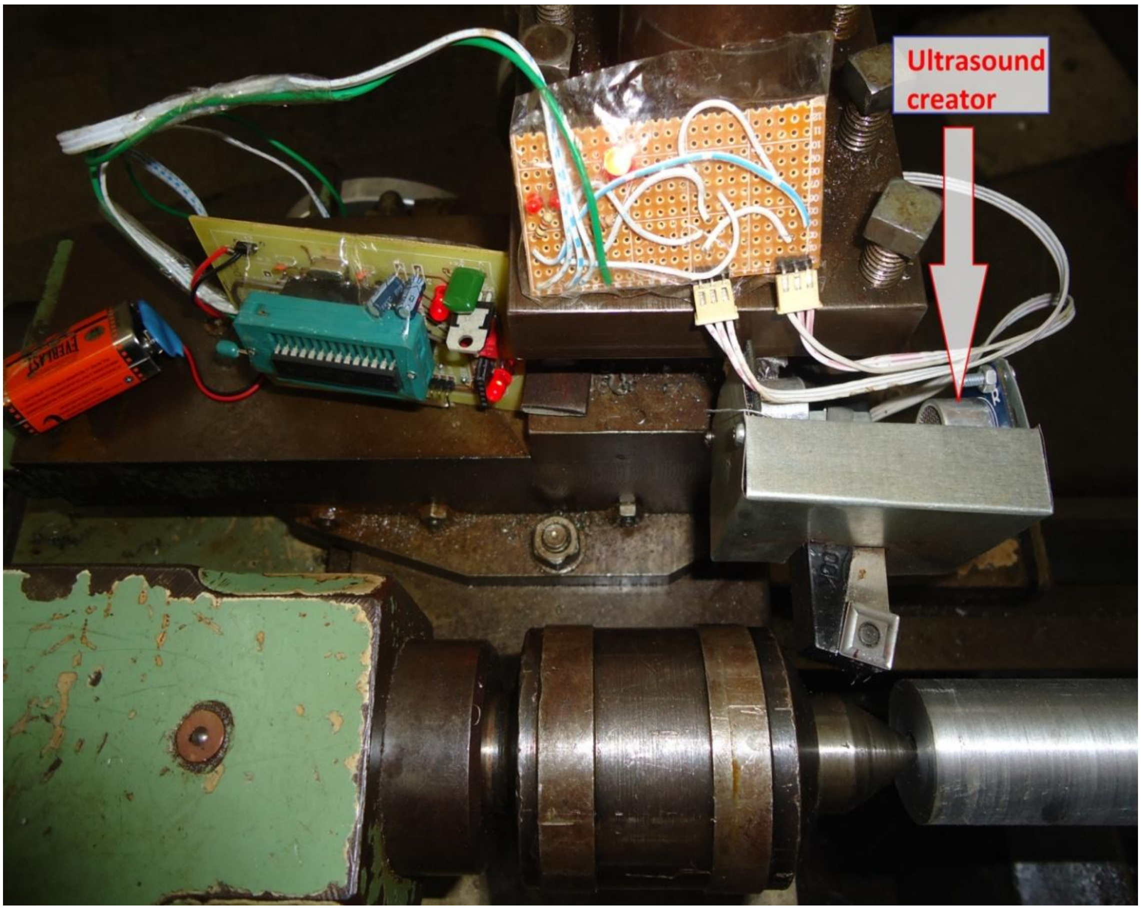


Fig. 3.1 : Experimental set up with ultrasonic sound wave

3.3 : MACHINING PARAMETERS

In any basic turning operation speed, feed and depth of cut are the three primary factors. Though there are some other parameters that influence the cutting condition such as kind of material, tool material, coolant used but these three are the ones which can be changed by adjusting the controls in the machine.

Feed has been kept constant throughout the experiment. The changing cutting parameters used in this experiment are the cutting speed and the depth of cut.

The kind of speed in turning operation is rotational and it is expressed in revolution per minute (rpm). The important feature for a particular turning operation is the surface speed or the speed at which the work piece material is moving past the cutting tool. It is simply the product of the rotating speed times the circumference of the work piece before the cut is started.

Though rpm can be fixed by the desire of operator but there are some limitations of using it. The lathe used for the experiment allows 9 different rpm to be used during turning operation.

Feed always refers to the cutting tool, and it is the rate at which the tool advances along its cutting path. On most power-fed lathes, the feed rate is directly related to the spindle speed and is expressed in mm (of tool advance) per revolution (of the spindle), or mm/rev. Lathe machine allows feed to be fixed by operator and different charts having variable value of feed is written in the body of the machine.

Depth of cut refers to the amount of material that is to be removed in each cutting (in a single pass of the cutting tool). It is the thickness of the layer being removed from the work piece or the distance from the uncut surface of the work to the cut surface. It is expressed in mm.

Operator fixes the depth of cut by rotating the circular scale attached in the carriage of the lathe machine. Once it is fixed, the tool is allowed to move axially past the job piece and it removes the given distance around the job piece as long as it is in action.

3.4 : EXPERIMENTAL DETAILS

The scope and objectives of the present work have already been mentioned in the previous chapter. Accordingly the present study has been done through the following plan of experiment.

- One particular lathe is selected for carry out whole operation.
- Checking and preparing the centre lathe before starting operation.
- Cutting MS bars of desired length by power saw and to fix it in the three jaw chuck.
- Performing facing and centre drilling of job piece for fixing it in between chuck and tail stock.
- Performing straight turning operation on specimens in various cutting environments involving various combinations of process control parameters like: spindle speed, feed, depth of cut and magnetic field.
- Measuring tool flank wear using microscope and image processing.
- Determining surface roughness using image processing algorithms in MATLAB or using scopetech software.
- Collecting chip in each condition and calculating chip serration frequency.
- Analysis and comparison of collected data

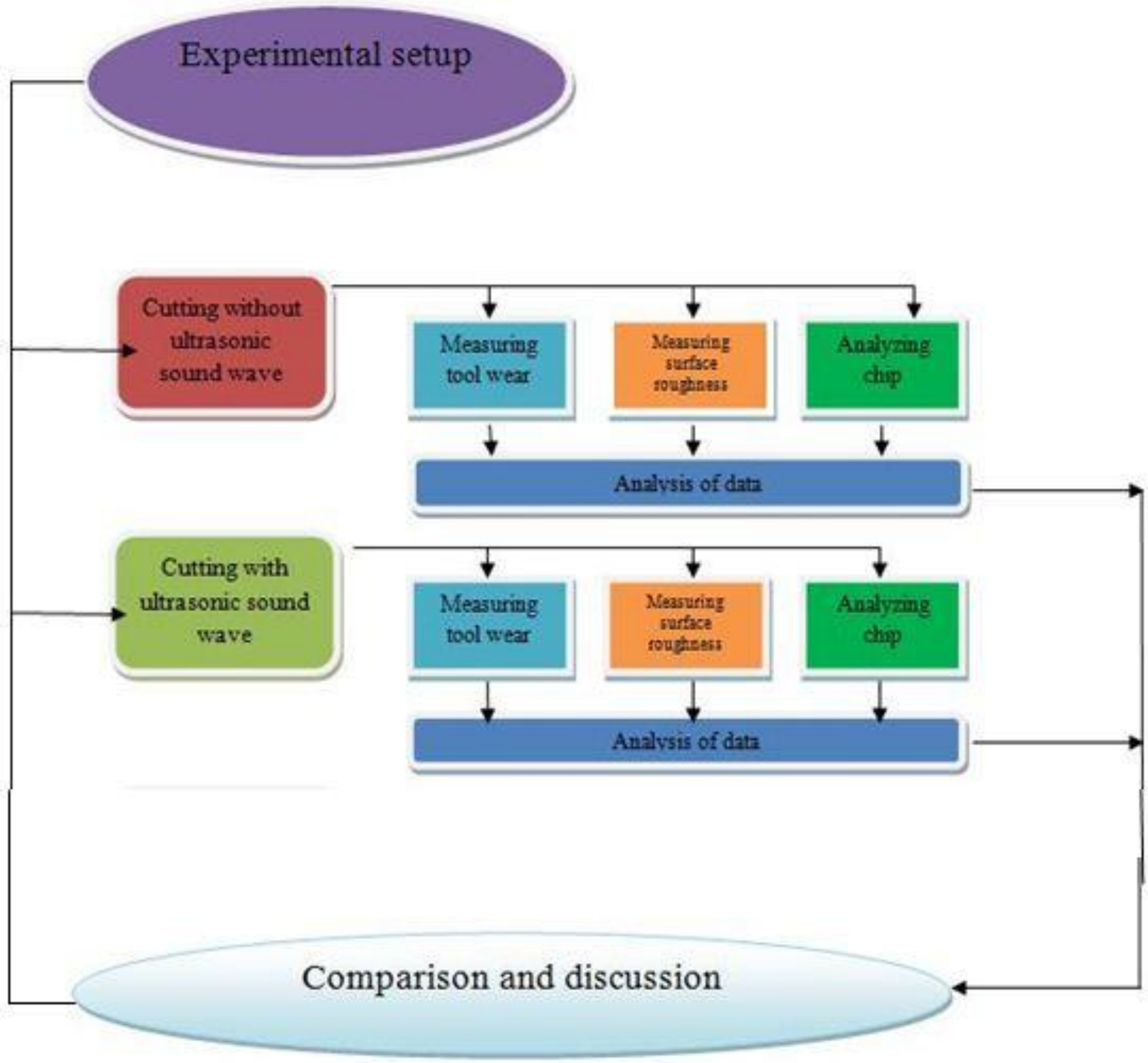


Fig 3.2 : Flow sequence of the experimentation

3.5 : PROCESS VARIABLES AND THEIR VALUES

Table: 3.1 Process variables and their values

Process Variables		
Spindle Speed (N) (RPM)	Feed (f) (mm/sec)	Depth of cut (D) (mm)
530	0.95	0.75
530	0.95	1.0

3.6 : EQUIPMENT USED

3.6.1 : CENTER LATHE

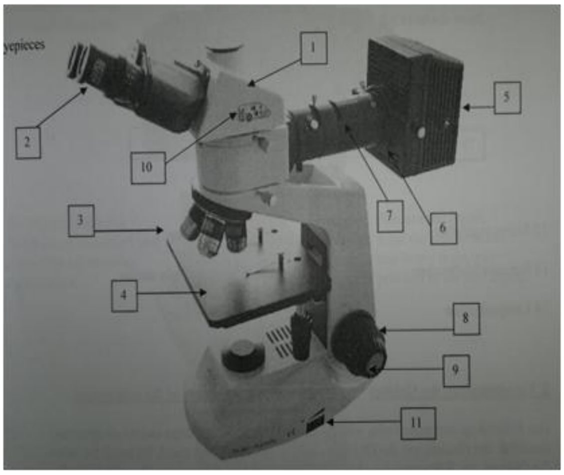
The turning machines are, of course, every kind of lathes. Lathes used in manufacturing can be classified as engine, turret, automatics, and numerical control etc. They are heavy duty machine tools and have power drive for all tool movements. They commonly range in size from 12 to 24 inches swing and from 24 to 48 inches center distance, but swings up to 50 inches and center distances up to 12 feet are not uncommon. Many lathes are equipped with chip pans and built-in coolant circulating system. The lathe used in this study is

Manufactured by: GATE INC. (United Kingdom)

Model: L-1/180

3.6.2 : OPTICAL MICROSCOPE

The model of the microscope used for the DIP technique is Metallurgical Microscope MMB2300. Figure 3.3 and table 3.3 give more details of the microscope.



1. Eyepiece head with photo/video connection
2. Eyepieces
3. Objective
4. Stage with clips
5. Illumination
6. Diaphragm
7. Colour filters
8. Coarse adjustment knob
9. Fine adjustment knob
10. Change between eyepiece head and photo/video connection
11. On/off and brightness control

Figure: 3.3: Photograph and details of the optical microscope

Plano eyepieces	10X
Lenses	Plan achromatic 4X,10X,40X
Magnification	40 to 400
Filter	Blue
Power supply	90 to 240 VAC
Fuse	3.15 A
Illumination	Built in lamp 6V 30W, bright-field condenser
Stage moving range	132 x 140 mm

Table: 3.2 Detail specification of the microscope

Optical microscope is used to take the image of wear of the tool insert, surface roughness and chip structure. Image processing software is used to capture the microscopic view and the image taken and saved in the laptop for further analysis. The microscope along with the laptop used during the experiment is shown below

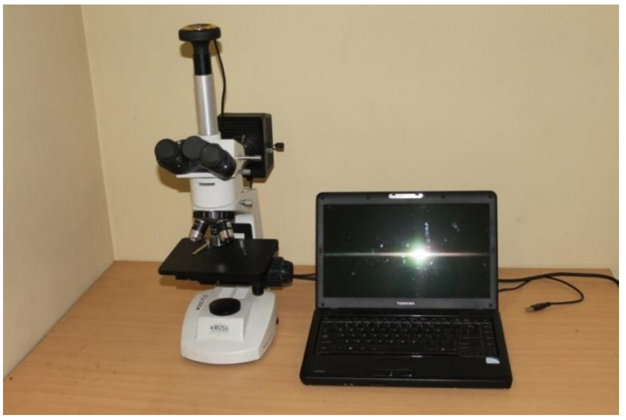


Fig 3.4: Optical microscope connected with laptop for taking image.

3.6.3 : WORK PIECE USED

Mild steel shafts (Diameter 30mm and length 260mm) were used as the work piece material of the experiments. The steel contains 0.25% Carbon and little impurities.

Figure: 3.5: Work piece

Shaft length: 260 mm

Cutting length: 200 mm each time (total 9 times i.e. 1800mm for one side of insert)

Shaft diameter: 30 mm

Shaft material: mild steel

3.6.4 : CUTTING TOOL USED:

Tool: Tungsten carbide coated insert

Model: TX 20

Dimension: 10mm ×10mm ×5mm

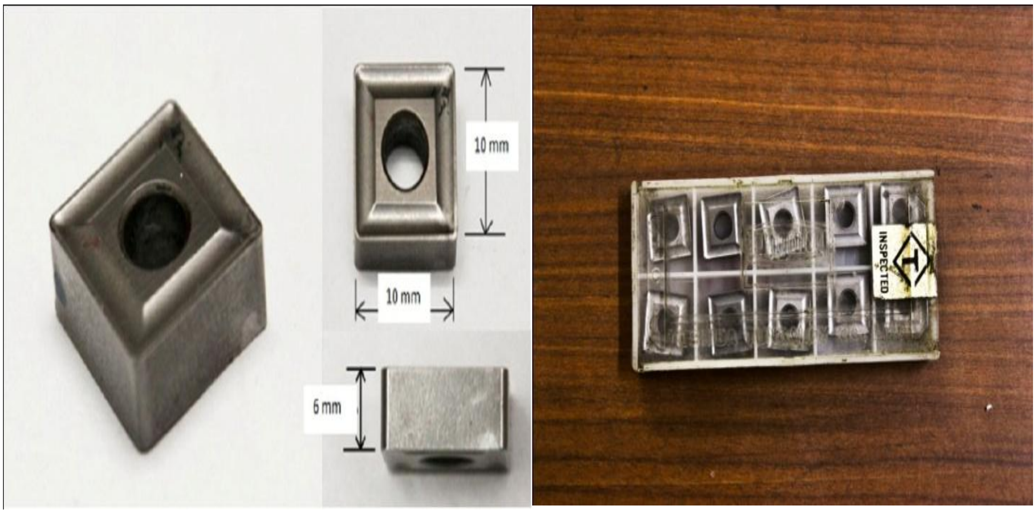
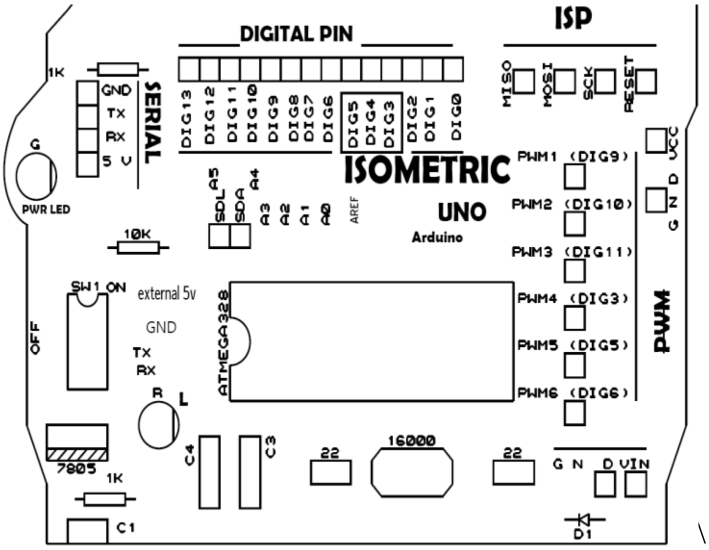


Figure: 3.6:Insert with dimension

3.6.5 : ULTRASONIC SOUND WAVE CREATOR CIRCUIT



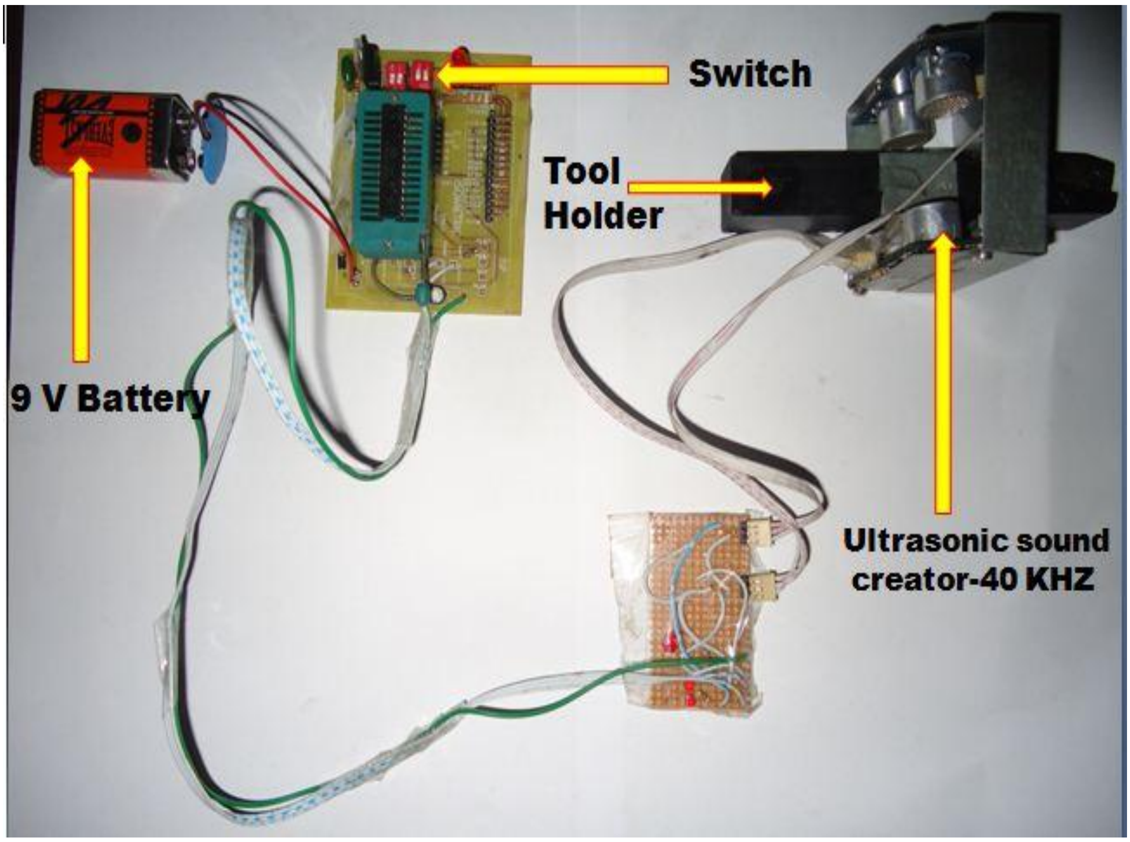


Figure: 3.7:Electrical Circuit to produce ultrasonic sound wave

3.7 : MEASUREMENT TECHNIQUE USED IN THIS STUDY

3.7.1 : MEASUREMENT OF TOOL WEAR

The sequence used in the analysis is illustrated by figure 3.10 below. The flank wear observed were always hemispherical in shape and thus, utilization of image processing for wear analysis was possible.

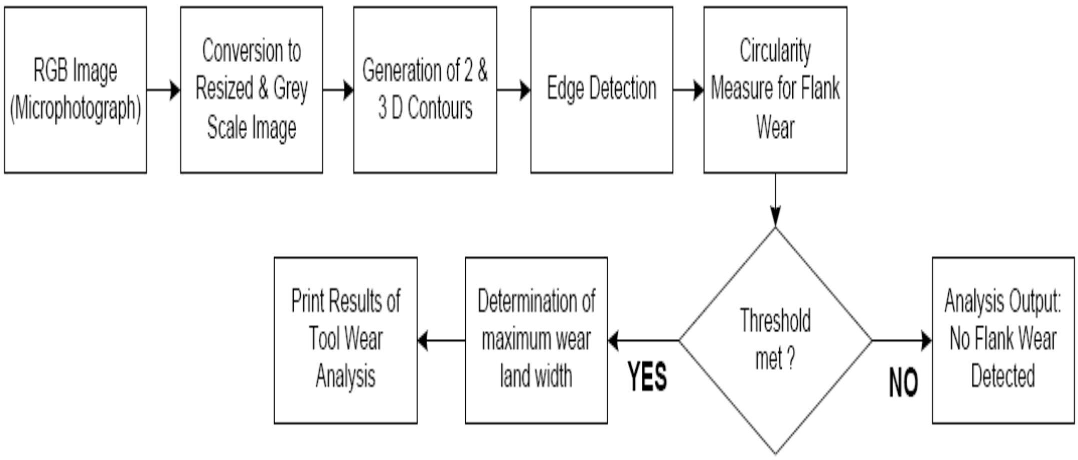


Figure: 3.8: Process logic sequence flowchart for measuring tool wear

Digital image processing comprises the application of computer algorithm and logic to process and analyze digitized images. It is a subcategory of digital signal processing and has many advantages over analog image processing, such as: application of a wider range of algorithms to the input data and avoidance of signal distortion build-ups. An additional advantage is that images are defined over two or more dimensions, in digital image processing, and thus, can be easily modeled in the form of multidimensional systems in software dealing with Matrices, like MATLAB. For their analysis, the authors used MATLAB 2008a image processing toolbox, which can efficiently process the samples‟ images, in *n* by *m* 2-D matrices form.

The microphotograph of interest, obtained at 10x zoom, was obtained and saved as an RGB digital image. The image is subsequently resized and converted to grayscale for standardization in comparison and reducing the calculation load by a third, respectively. The surface topography and contour, in 2 and 3-D respectively, were then generated using the algorithm developed by Patwari et al. [70].

The resized grayscale image was then analyzed for edge detection. The sharp edge of the tool, defined by the principal and auxiliary flank surfaces, was clearly identified by the algorithm along with the measure of its uniform straightness. The algorithm then was then used to detect and evaluate the circularity of the flank wear, which manifests as small craters. The principal axis of the crater was then determined in number of pixels. This pixel information along with the edge detection and original tool dimensions were then used to calculate the maximum flank wear land width, „V_{Bmax},‟ in millimeters.

The results of the wear analysis are then compared by the software against a 'threshold' land wear value, obtained from Patwari et al. [70] work, to determine whether the wear is a flank wear. This is achieved by a decision subroutine in the software. The utility of this screening process for flank wear is that most tools display other types of wear such as: built-up edge, rake wear, and edge wear etc. which are not very significant to cutting edge stability. Depending upon the evaluation of the decision subroutine, the software outputs either that 'no flank wear is detected' or that 'flank wear detected' along with the calculated value of land wear V_{Bmax}. The same analysis was conducted for eight different lengths of cut and compared with the results obtained by Patwari et al. [70].

A new measure, called the circularity metric '*CM'*, was developed to detect and analyze flank tool wear land width V_B. The metric evaluates the extent to which feature in the tool's image is circular and decides that it is a flank wear if the metric threshold of 0.80 was reached. Once the wear is detected the algorithm then determines the length of the wears principal axis in pixels; which is subsequently converted to millimeters by the process already mentioned above. Equation (1), below, is the mathematical definition of the circularity metric used.

$$CM = \frac{4\pi(area)}{(Perimeter)^2} \qquad (\mathbf{3.1})$$

Figure 3.13, below, shows the sample results of image processing for tool (with flank wear) used for turning with length of cut 800 mm.

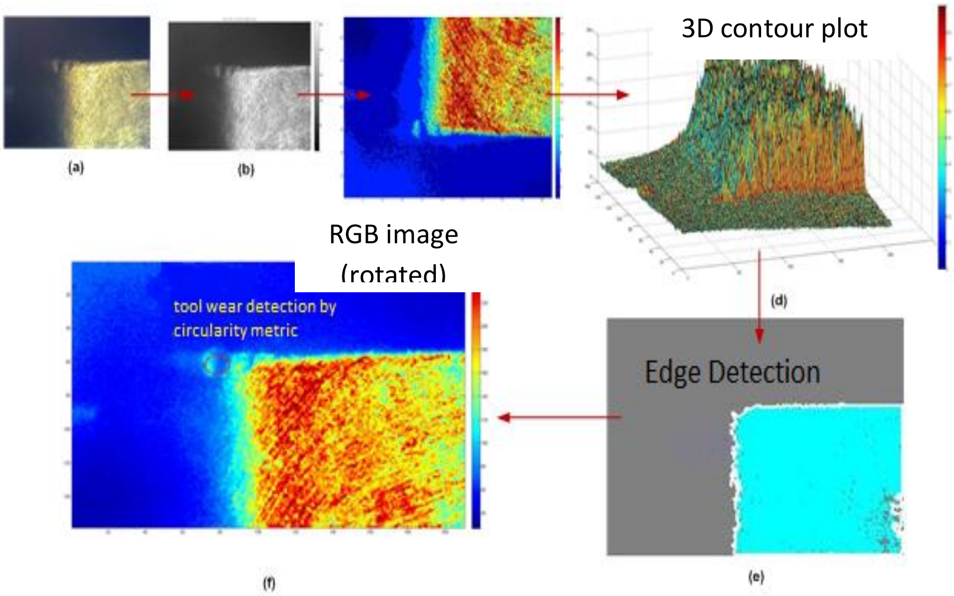


Figure: 3.9:Image processing result sample for measuring tool wear [70]

Another method used in case of measuring some image of tool wear was the software named scopetek. The measurement of tool wear using this software is described below.

1. The image of the tool wear that is to be measured is opened in the window.

2. From the layout bar new layer is selected.

3. Then from the bar we have to go in draw option. Here we have to select vertical line.

4. Now putting the cursor on the image will allow drawing vertical line. The vertical line drawn upon the wear will give the measurement of the tool wear in pixel.

5. This value is then converted to mm using a standard converter.

3.7.2 : MEASUREMENT OF SURFACE ROUGHNESS

The image processing technique for determining surface roughness is described below:

1. Optical microscope was used to take the image of surface roughness after cutting 1000 mm length of work piece.

2. The work piece was cut by power saw to make it small so that it can be placed under the eyepiece of the microscope and can be focused.

3. Same magnification and illuminating conditions were used for maintaining same quality and environment in all photographs

4. The photographs are converted to grey scale and then to binary images in order to speed up the calculation process. As the process is dependent on the intensity of the reflected light from the surface to the microscope it is convenient to convert the image to grayscale image in order to compare the intensity of each point with others. The binary image stores the values of each point as binary values. This way it is easier to analyze the image later.

5. The binary images are then analyzed using a digital image processing algorithm to generate profile plot and colored contour plot.

6. First the program adds up all the values of each point over the whole region and then finds out the average value. This average value is the average surface roughness of the work piece.

7. Then a profile plot is generated by plotting the average value of light intensity on each plane against distance. This helps to understand the waviness of the surface in two dimensional views.

8. Next a colored contour plot of the whole region is generated to observe the location of peak points and bottom points. The contour color map thus gives an overall idea of the surface quality.

9. Finally a 3D contour plot of the surface is generated for the whole region to reconstruct the real surface in the software. This 3D contour plot represents as the 3D model of the actual surface that has been taken in the study.

The whole sequence is illustrated by the following flowchart

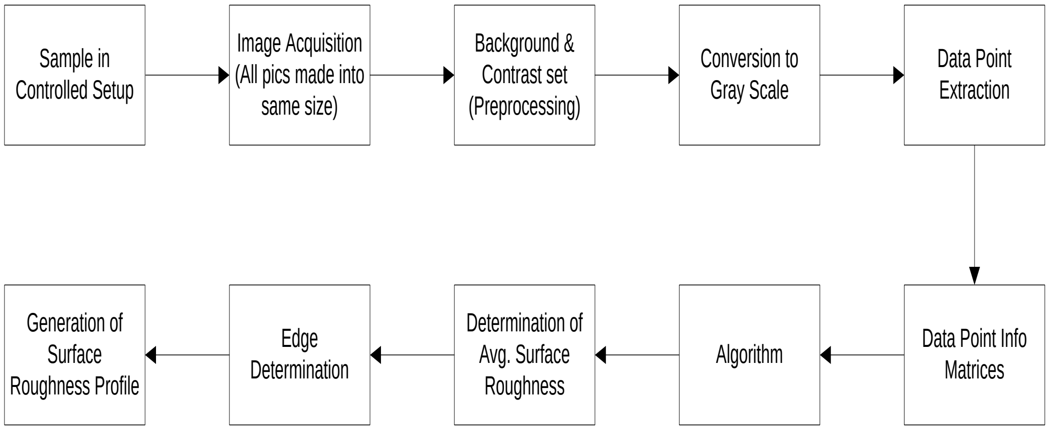


Figure: 3.10: Flow diagram of image processing for surface roughness

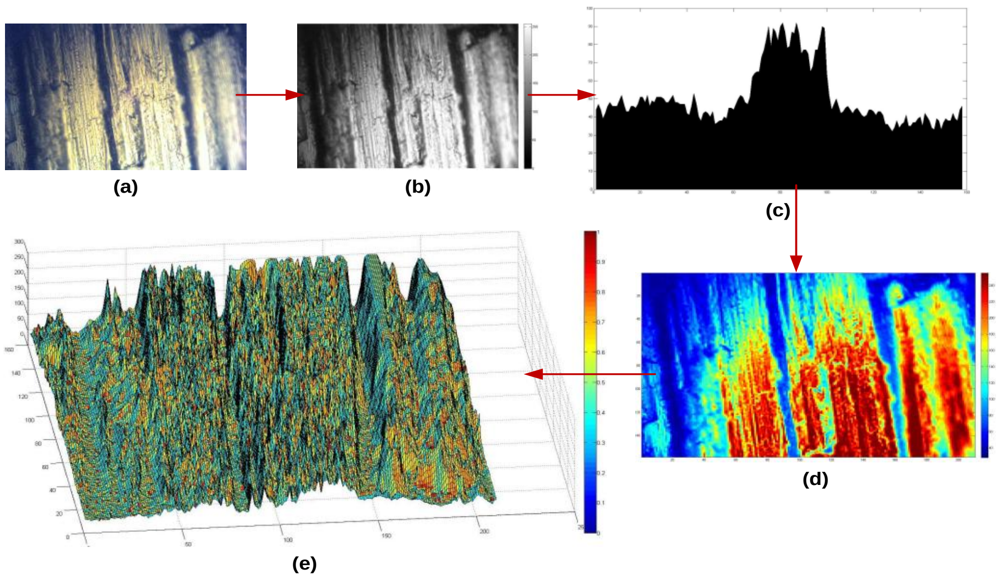


Figure: 3.11 DIP results (work-piece surface roughness, without magnet) (a) 10x zoom RGB microphotograph, (b) grayscale, (c) profile plot, (d) 2-D colored contour plot, (e) 3-D colored contour plot [71-72]

3.7.3 : OBSERVATION OF CHIP BEHAVIOR

The chips formed during turning were mainly investigated and it has been found that at some specific cutting conditions chip formation presents extreme cases of secondary and primary chip serration. Firstly, the chip at different cutting conditions were collected, labeled and kept accordingly. Then each chip was mounted using a mixture of resin and hardener. The mixture was stirred for about one minute and left to solidify. The solidified mixture is called mounting. The next step is to grind the mounting surface in order to reveal the chip to the surface. Various grade of abrasive paper are used starting with grade 240 followed by 400, 800 and 1200. In order to remove the scratches on the surfaces, the mounting is then polished using alumina solution starting from grain size 6.0 μ, followed by 1.0 μ, 0.3 μ and 0.01μ. As a safety precaution, before polishing; the mounting is viewed under the microscope to ensure that the chip is visible on the surface. Finally, nitol is applied to the surface to reveal the grain boundaries of the ferrite and pearlite. Then the mounting is ready to be viewed under the microscope to capture the structure of the chip.

Figure: 3.12: Samples of mounted chip

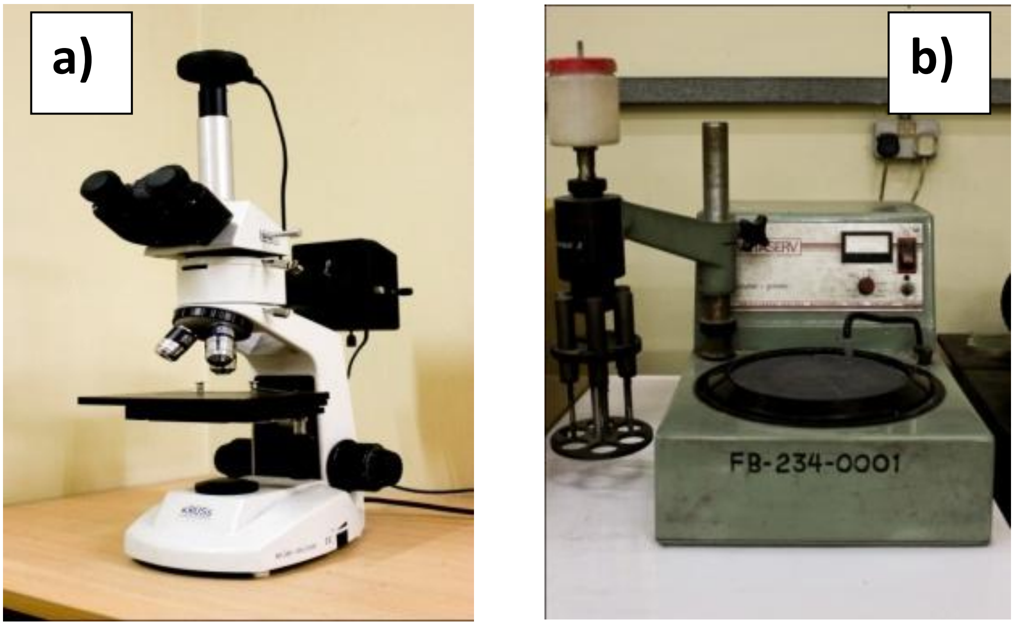


Figure: 3.13: Instruments used for chip analysis. a) Polishing wheel, b) optical microscope

3.7.4 : MEASUREMENT OF TEMEPRATURE

Digital thermocouple was used to measure the temperature of the tip of the insert. The hot end of the thermocouple was welded to the tip of the insert. Readings were continuously displayed on the screen of the thermocouple as the turning process is carried on. Final Reading is taken from the display of the thermocouple after cutting 200mm at different cutting speed and depth of cut.

Fig. 3.14: Set up for temperature measurement

CHAPTER 4

RESULTS AND DISCUSSION

4.1 : TOOL WEAR:

The image processing tool for determining flank wear developed by Patwari et al. [70] has been verified. The results of the analysis were compared with those previously determined by Patwari et al. [70], who used Kruss metallurgical microscope's analysis software to determine V_{Bmax}. Table 4.1 lists the average accuracy and repeatability of the analysis technique. From the table, it was observed that, the accuracy was higher for greater wear or larger wear land V_{Bmax}.

No.	Cut Length (mm)	Actual Wear (mm)	Calc. Wear (mm)	Error %	Repeatability %
1	0	0	0	0	100
2	200	0	0	0	100
3	400	0.0057	0.0063	10.52631579	100
4	500	0.0281	0.0298	6.049822064	100
5	600	0.0323	0.031	-4.024767802	100
6	700	0.0374	0.036	-3.743315508	100
7	800	0.0393	0.039	-0.763358779	100
8	1000	0.0412	0.04105	-0.36407767	100
			Avg. Error % =	3.183957201	

Table: 4.1 Accuracy and repeatability of the automated tool wear analysis technique

The image processing technique for tool wear measurement showed good accuracy and consistency. It was observed that the technique was simple, fast, and economical. The only major investment is the requirement for an optical microscope and laptop, hardware that is readily available in most modern industries or research institutes. The shortcoming observed was that the software was less precise in evaluating tool wear when the flank land wear was very small (V_{Bmax} < 0.3 mm approx.). For detection of larger tool flank wear the accuracy of the system was markedly improved. Also, the algorithm displayed a tendency to overestimate small tool wear and underestimate larger tool wear. The consistency to detect tool wear, however, was always 100%, as shown by the first two data points. The explanation for this behavior is that the software relies on contrast difference or grey level intensity variation to detect and evaluate tool wear. Hence, when small amount of wear is concerned, the contrast is less, which leads to increased chances of error.

The following table shows the sample picture of the flank wear of the tool insert for different length cut at a cutting condition of 530 rpm and 0.75 mm depth of cut. The pictures are shown for without ultrasonic sound wave and with ultrasonic sound wave

Length of cut(mm)	**Without sound wave (mm)** **Tool wear**	**With sound wave** **Tool wear**
600	0.34	0.21
1200	0.39	0.26
1800	0.49	0.33

Table 4. 2 : 530 rpm, depth of cut: 0.75 mm(VALUE)

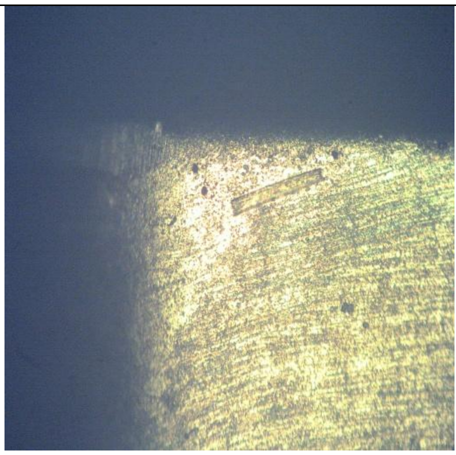
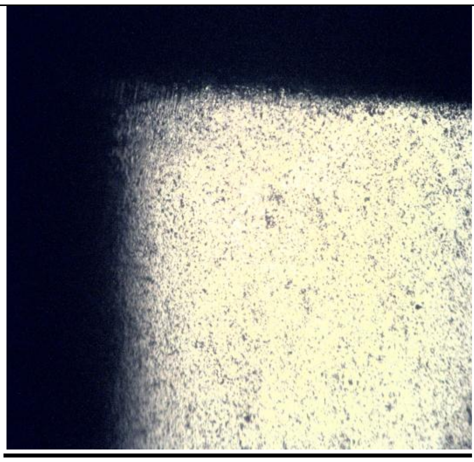
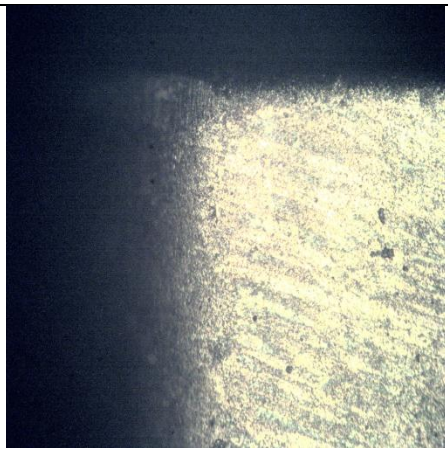
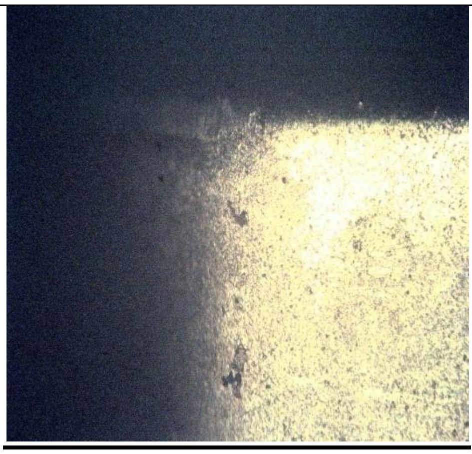
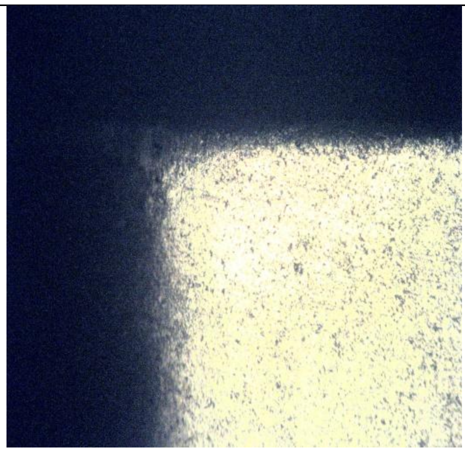
Length of cut(mm)	Without sound wave	With sound wave
600		
1200		
1800		

Table 4.3 : 530 rpm, depth of cut: 0.75 mm(Microscopic View)

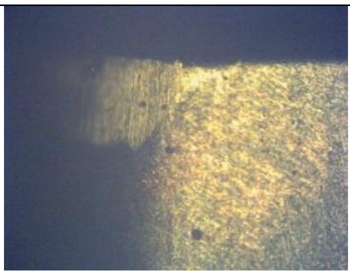
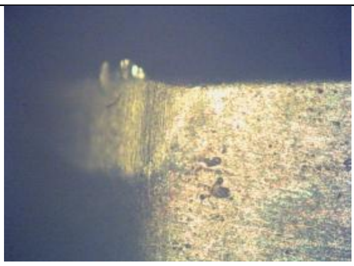
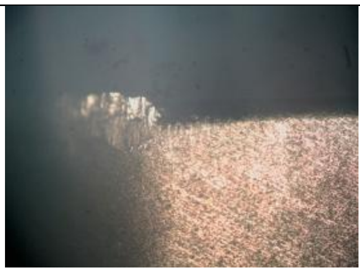
Length of cut(mm)	Without Sound wave	With sound wave
600		
1200		
1800		

Table 4.4 : 530 rpm, depth of cut: 1 mm(Microscopic View)

The table 3,4 shows that there is always significant reduction in the tool wear when ultrasonic sound wave is used during the machining operation.

I have to cut with 2 type depth of cut whether the RPM,feed are same in 2 case.In 2 case there is a significant improvement of the tool wear.when the depth of cut is 0.75mm,the tool wear with sound wave is 0.33 mm at 1800 mm length of cut,at the same time tool wear without sound wave is 0.34 mm at only 600 mm length of cut.

Again,when depth of cut is 1 mm,the tool wear with sound wave is 0.38 mm at 1800 mm length of cut, at the same time tool wear without sound wave is 0.36 mm at only 600 mm length of cut.

The values of the tool wear measured are plotted in graph to show the comparison between the tool wear found for different cutting condition using ultrasonic sound wave and non ultrasonic soun wave..

From the graphs showing the tool wear with the change in the length of cut of the work piece at different cutting condition during without ultrasonic sound wave and with ultrasonic sound wave. It has been observed that the tool wear increases with the increase in the cutting speed. The tool wear is always reduced when external ultrasonic sound wave is applied during machining operation.

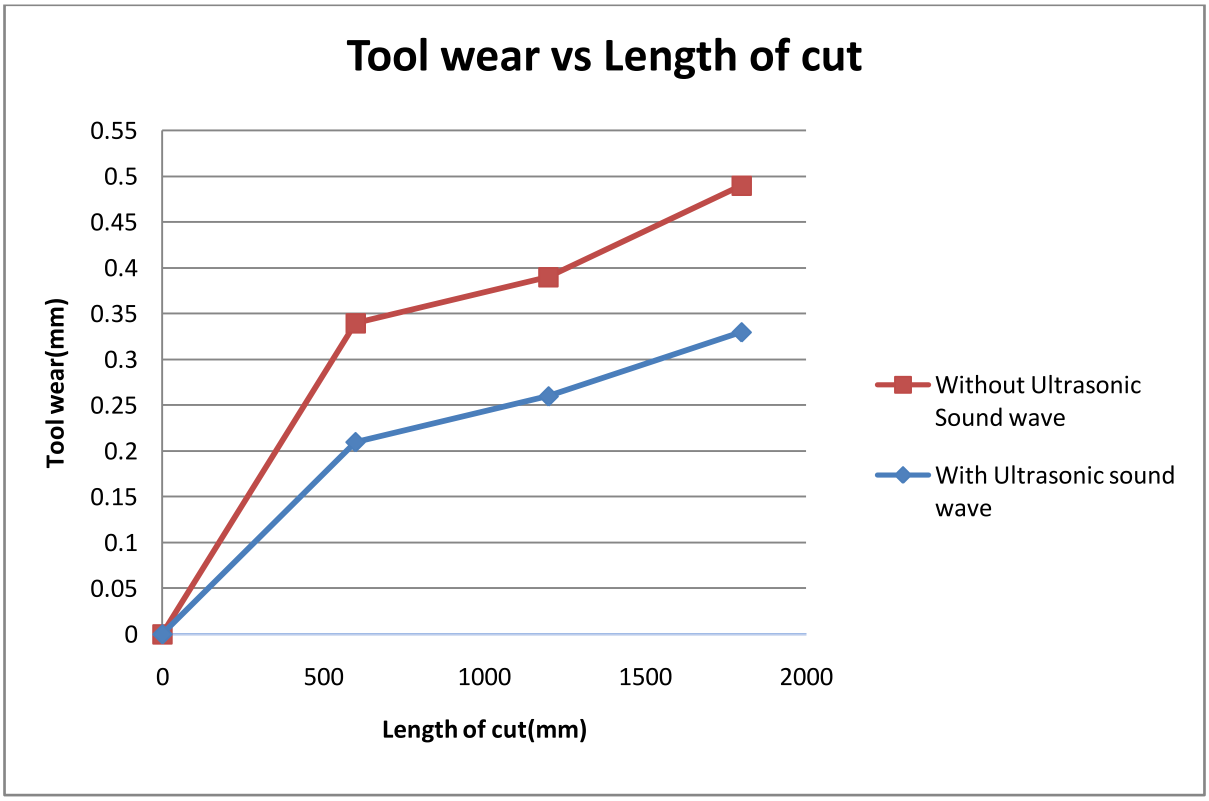


Fig. 4.1: Comparison of tool wear at 530 rpm and 0.75 mm depth of cut

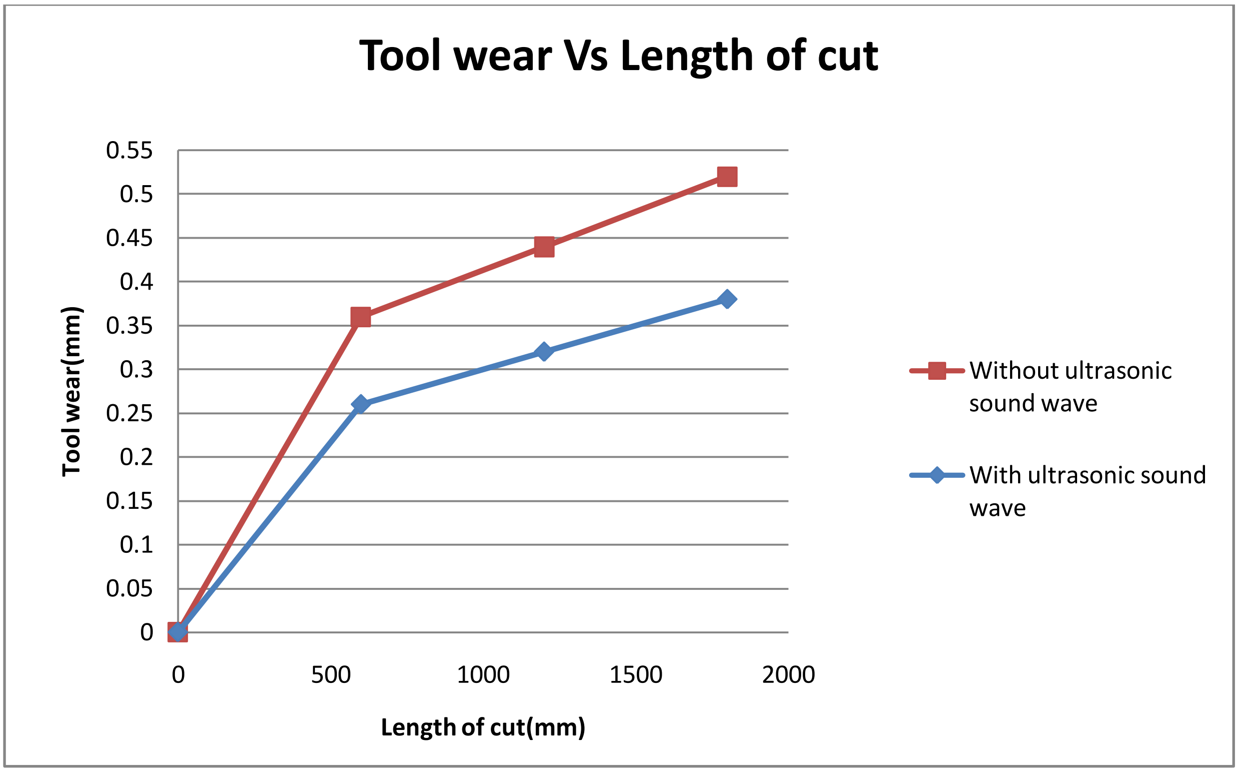


Fig. 4.2: Comparison of tool wear at 530 rpm and 1.00 mm depth of cut

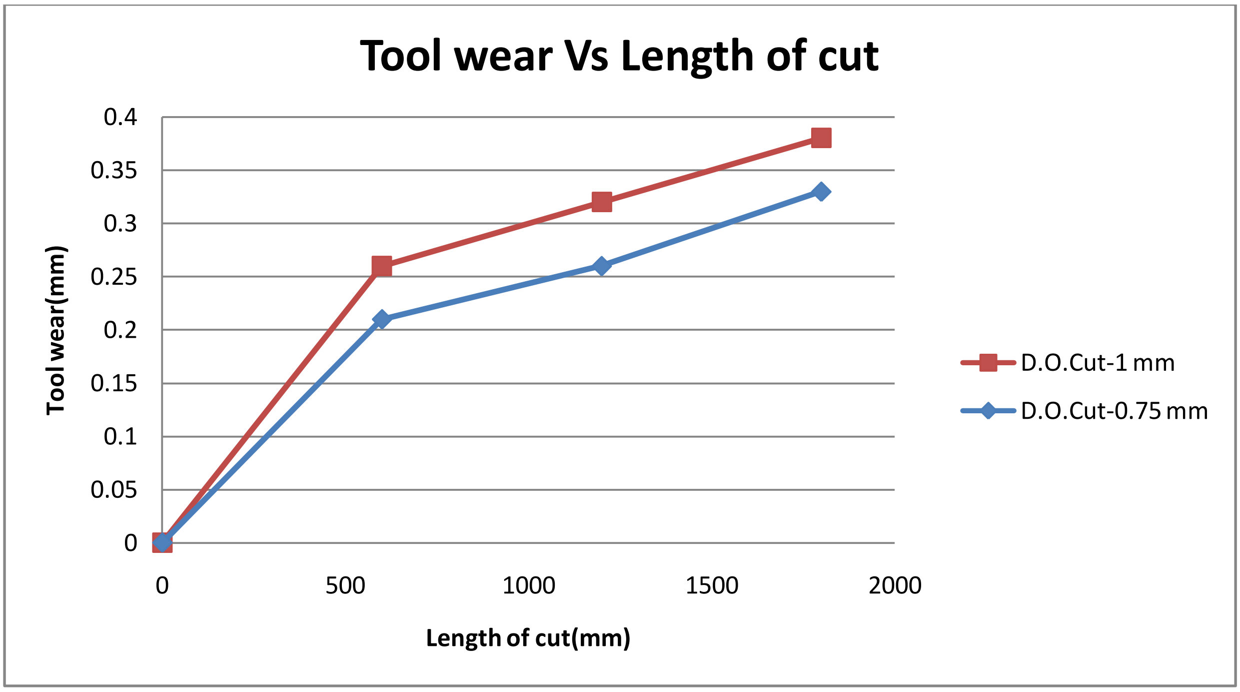


Fig. 4.3: Cutting with ultrasonic sound wave at 530 rpm

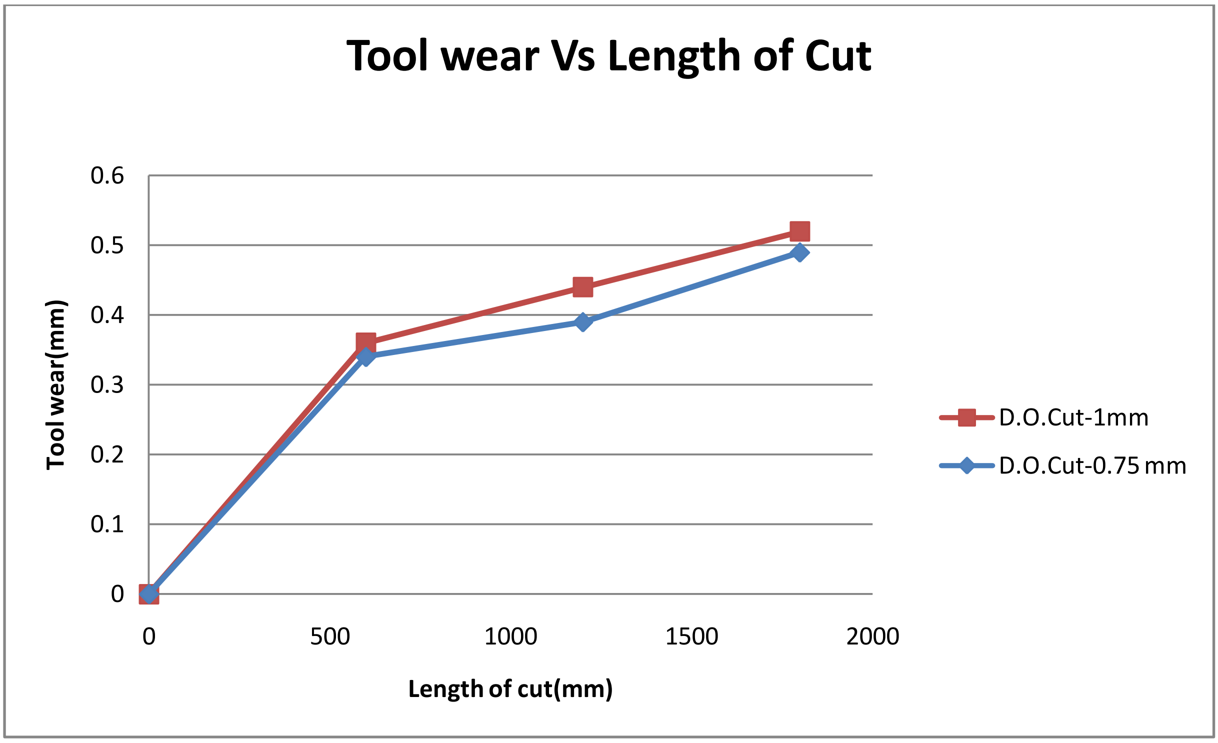


Fig. 4.4: Cutting without ultrasonic sound wave at 530 rpm

Almost all the graphs show a consistent trend, however some points have deviated from its expected position. This may occur due to any error during experimentation, and beside this the experiments are huge in number for which it is very difficult to maintain constant experimental condition every time the machining operation is performed. For example the depth of cut has been given by using a rotating wheel in the carriage. This may cause some variation in the depth of cut.

The accuracy of tool wear measurement also depends on the quality of the captured image by the microscope. The built up edge also created some problem. As tool wear occurs on the edge of insert it is very difficult to focus at the exact point of the maximum flank wear. Because of these reasons some points in the graphs may have. But as each experimental condition is compared against several numbers of other experimental conditions and the characteristic of each graphs is almost similar to the ideal cases the minor dislocation of some points have little effect on the overall result. Due to the quality of the captured image of the tool flank wear, image processing technique developed by Patwari el al [70] could not be used in many of the experimental results. In this case the software “Scopetek”, which have been mentioned in the experimentation part, has been used.

In this experiment, when the tool wear showed too much deviation from the ideal position, the whole cutting was repeated by using a new corner of the tool insert. In some cases it has been done several times for the same experiment and the average has been taken.

It would give more precise results if each experiment was performed several times and the average would be taken. However, since too many cutting operation have been carried out in this experiment, it was not possible to repeat all the experiments.

4.2: SURFACE ROUGHNESS

The image of the surface was captured by the metallurgical microscope after cutting 1000 mm of the work piece. This image is then processed in MATLAB to find out the average roughness of the surface. The following figure shows the comparison among the images of the surfaces obtained for each cutting condition: non magnetic cutting and cutting with all three designs of electromagnets. The contour plots are given for the corresponding surfaces, which is obtained from the analysis using the image processing technique.

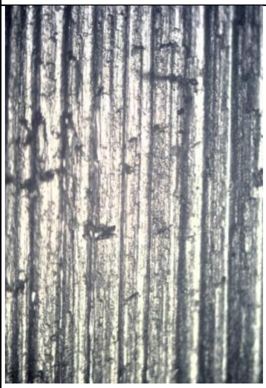
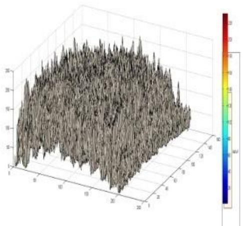
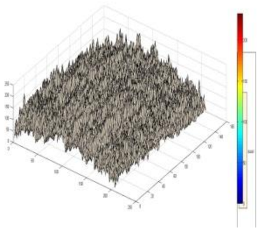
	Without Sound Wave	With Sound wave
Images of the Surface After machin-ing		
Cont-our plot		
Rough-ness (µm)	**0.1**	**0.083**

Table 4.5: Images of the surface of the work piece and corresponding contour plot for the cutting under different condition at 0.75 mm depth of cut

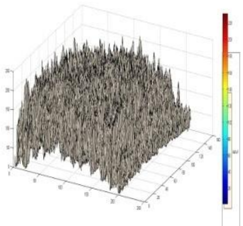
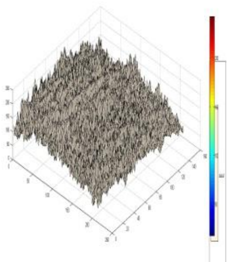
	Without Sound Wave	**With Sound wave**
Images of the Surface After machin-ing		
Cont-our plot		
Rough-ness (μm)	**0.11**	**0.104**

Table 4.6: Images of the surface of the work piece and corresponding contour plot for the cutting under different condition at 1 mm depth of cut

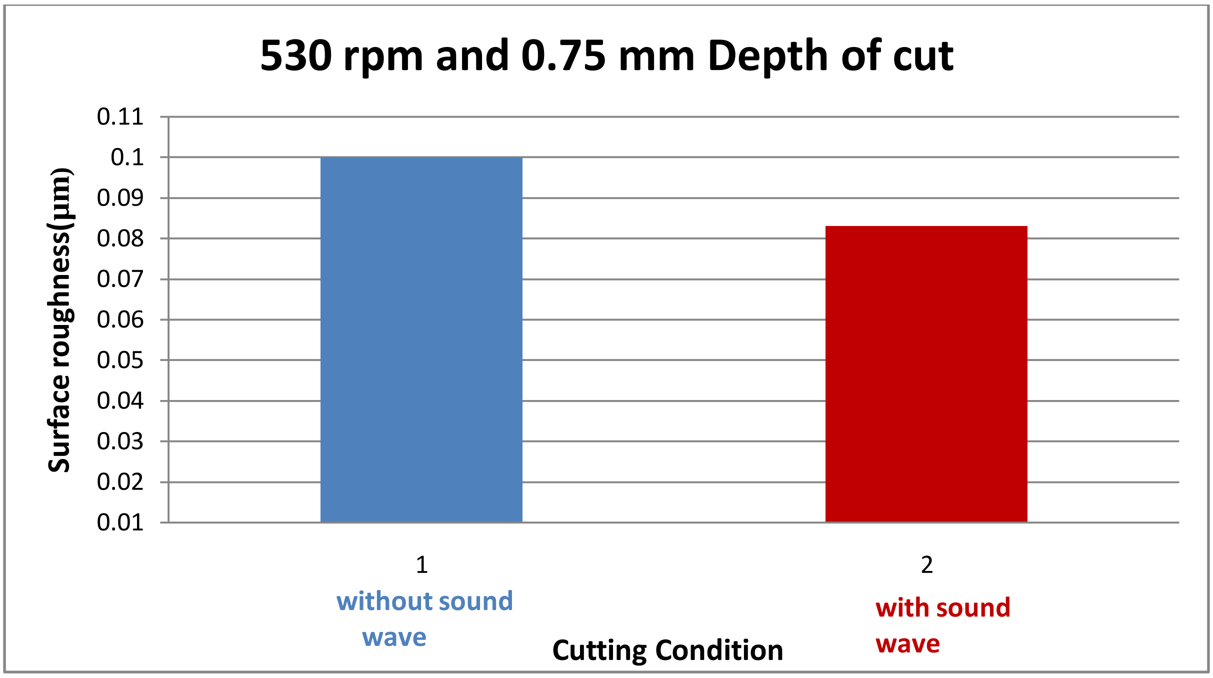


Fig. 4.5: Comparison of surface roughness at 530 rpm and 0.75 mm depth of cut

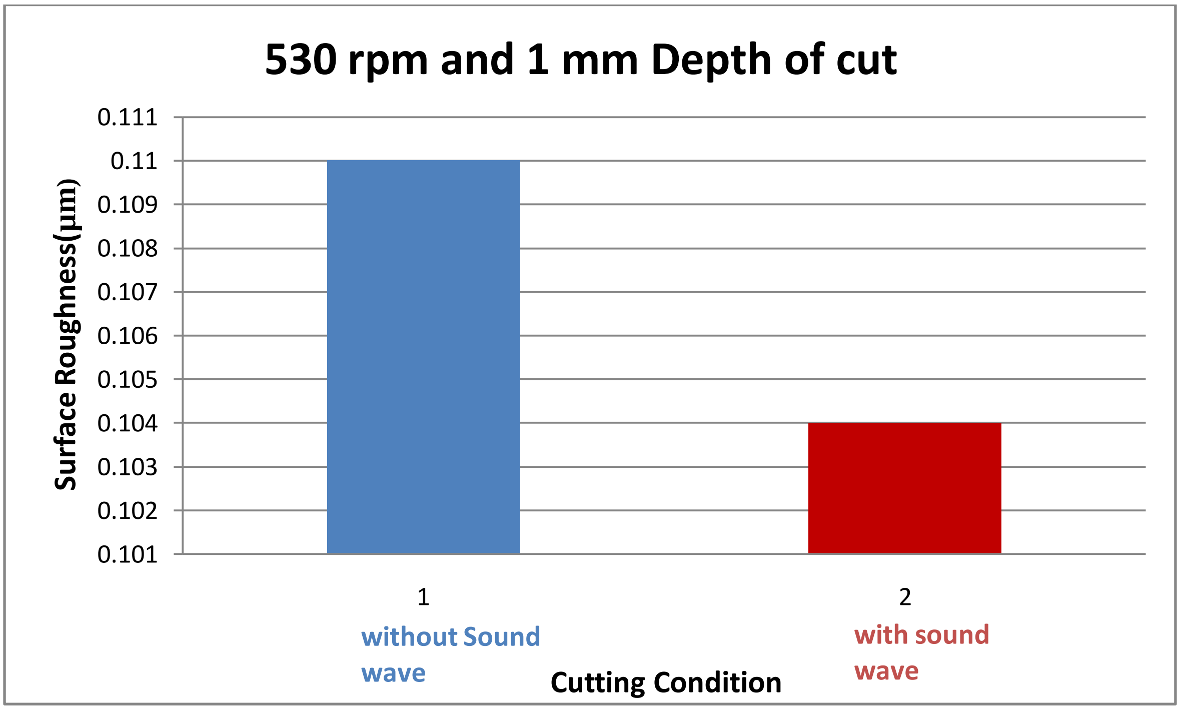


Fig. 4.6: Comparison of surface roughness at 530 rpm and 1 mm depth of cut

4.3: CHIP MORPHOLOGY

The chips produced during the cutting operation after cutting 1000 mm of the work piece with a single corner of the insert for each cutting condition, are collected and then analyzed as described in the experimentation part. In each case several behavior of the chips have been studied.

4.3.1: CONTINUITY OF CHIPS

Chips collected during without ultrasonic sound wave is discontinuous and with ultrasonic sound wave it is continuous and very closely packed. The figure below illustrates this.

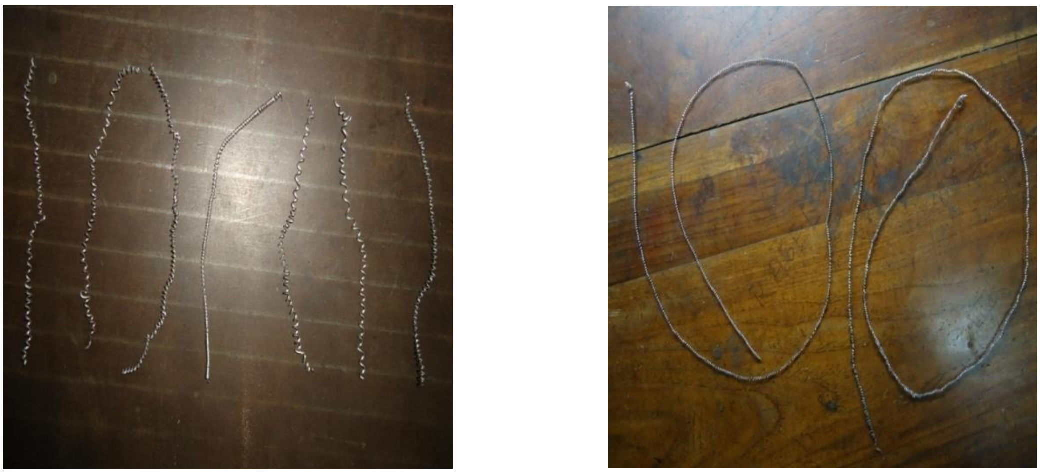


Fig. 4.7 (a) Discontinuous chips, without sound wave cutting

(b)continuous chips, with sound wave cutting

4.3.2 : TOOTH FORMATION OF THE CHIPS

The chips produced during machining operation consist of some teeth along their side. The figure below shows the magnified view of the teeth of the chips. This illustrates the serration behavior of the chips. In our experiment we have taken the length wise view of the chips under optical microscope.

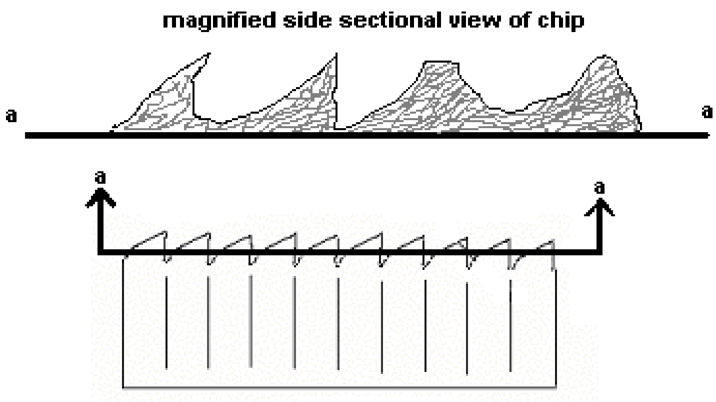


Fig. 4.8: Cross section of chips

The cross section of the chips obtained in my experiment has shown in the figure below which illustrates the behavior of chips. It is clearly visible that the tooth of serrated chips is larger in case of without sound wave. The size is much smaller when ultrasonic wave is used during turning process. The comparative serration nature of the chip is guven below-.

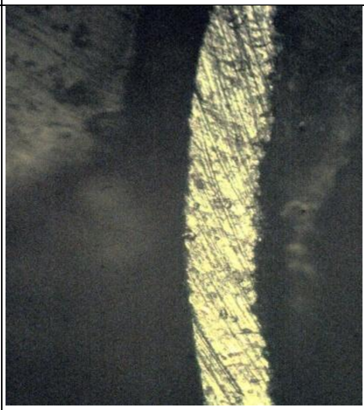
Without ultrasonic sound wave	**With ultrasonic sound wave**
	

Fig. 4.9: Microscopic view of the chip cross section at 530 rpm and 0.75 mm depth of cut

4.4 : Temperature:

During turning operation temperature has a lot of effect.After cutting some portion of the jobpiece the temperature will increase.Temperature will increase when the length of cut will increase.It has been found that there has been a lot of effect of ultrasonic sound wave on temperature.It has found in experiment that ,when ultrasonic sound wave has been used the temperature of the jobpiece is less than the temperature of the normal cutting.The following table shows the temperature without ultrasonic sound wave and without ultrasonic sound wave:

Length of cut(mm)	**Temp-in celcius** For Without ultrasonic sound wave	**Temp-in celcius** For With ultrasonic sound wave
0	35	35
200	76	71
400	128	110
600	153	127

Table 4.7:Temperature of the jobpiece

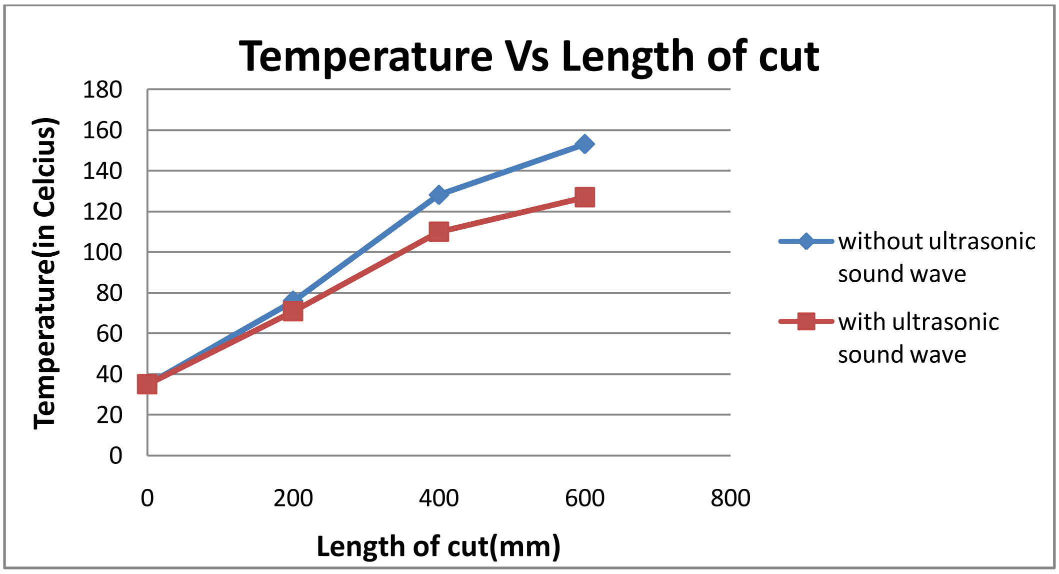


Fig. 4.10: Variation of temperature without sound effect and with sound effect at 530 rpm,0.75 mm depth of cut

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER STUDY

5.1 : CONCLUSIONS

The surface quality improves with the presence of ultrasonic sound wave. This can be explained by the reduction of the vibration of tool and work piece system in case of ultrasonic sound wave. The improvement of tool life is another factor for this improvement. However the improvement of surface quality is not always achieved. Built up edge formation during ultrasonic sound wave cutting is a problem for the surface finish since it scratches the work piece surface. At higher depth of cut during machining the surface quality is better for ultrasonic sound wave.Therefore to obtain a better surface finish the proper frequency of ultrasonic sound wave is selected depending on the cutting parameter.

Tool wear decreases by using ultrasonic sound wave.Tool life is very important issue in turning operation.The cost of tool is high.So cost should be reduced by doing some operation.In this project, ultrasonic sound wave has been used to decrease the cost of tool as well as to decrease the tool wear.

Not only the lubrication effect of the built up edge is responsible for the improvement of tool life but also other factors like the reduction in chatter is one of the main reasons for this reduction of tool wear. The effect of ultrasonic sound wave applied on the tool holder, ensures this phenomenon.

The tool wear increases with the increase in cutting speed and the depth of cut and this is independent of the cutting parameters and external environment for cutting operation e.g. without sound wave cutting and with sound wave cutting ..

The increase in temperature also effect on ultrasonic sound wave. This phenomenon support the reduction of tool wear.

The effect ultrasonic sound wave is not only confined to the improvement of tool life and improving the surface quality, it also affects the chip behavior during the turning operation. The chips produced are less serrated in nature when ultrasonic sound wave is applied.

5.2 : RECOMMENDATIONS FOR FURTHER STUDY

The experiment carried out in this study uses only mild steel as the work piece. Experiments with other materials as the work piece like conducting material, non ferrous, or non conducting and ferrous, can be done.

Here in this study I have used only carbide tools. Other tool materials can be used for further study.

Only 40 KHZ frequency of ultrasonic sound wave with d.c. source of current is used only. An alternating source of current can be used to obtain a further understanding of the mechanism behind the reduction of tool wear by the application of ultrasonic sound wave.

Today the manufacturing industries are investing huge amount of money only to optimize the processes involved. This is because a little bit of savings in the tool insert of machining process can greatly influence the overall production cost. Since ultrasonic sound wave can improve the tool life, there is a great potential to use it in industries, although still now no industry uses ultrasonic sound wave to improve the machinability factor. On the other hand, if this phenomenon is developed further, the machine tools can be designed having integrated ultrasonic sound wave in them. Therefore to apply this technique in the machining process of various types of manufacturing industries, further study should be carried out to find out the feasibility in terms cost of production.

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