THERMAL ANALYSIS OF COBALT AND HSS TOOL DURING TURNING OPERATION ON LATHE MACHINE

A Thesis

Submitted

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for the degree of

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In

PRODUCTION & INDUSTRIAL ENGINEERING

Submitted by

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CERTIFICATE

This is to certify that **Mr. Ravi Singh (Enrollment no-1900103703)** has carried out the research work presented in the thesis titled "**Thermal analysis of cobalt and HSS tool during turning operation on Lathe machine"** submitted for partial fulfillment for the award of the **Degree of Master of Technology** in **Production & Industrial Engineering** from **Integral University, Lucknow** under my supervision.

It is also certified that:

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Prof (Dr.) P.K Bharti
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Date:
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DECLARATION

I hereby declare that the thesis titled "**Thermal analysis of cobalt and HSS tool during turning operation on Lathe machine**" is an authentic record of the research work carried out by me under the supervision of **Prof(Dr.) P.K Bharti (Head, Department of Mechanical Engineering)** for the period from **August-2019 to December-2022** at **Integral University, Lucknow.** No part of this thesis has been presented elsewhere for any other degree or diploma earlier.

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ABSTRACT

Lathe machine is the machine on which unwanted material is removed in the form of chips during the operations such as turning, facing, drilling, boring, etc. Lathe machine holds the workpiece in chuck or collet, the chuck is held in spindle which is rotated by motor through gear mechanism (for speed reduction)

Above process of removing the unwanted material from workpiece is called machining.

During machining a cutting tool is required which removes the unwanted material from the workpiece. During this process of removing material temperature gets generated ranging from low to high when cutting tool (single point cutting tool) comes in direct contact with workpiece due to friction at primary, secondary and tertiary cutting zone and that temperature is termed as tool-chip interface temperature.

The tool-chip interface temperature was experimentally determined and modeled at different cutting speeds in lathe operation. Specifically the analysis was conducted at three different speeds - low medium and high. The machining process of the HSS tool and the cobalt bit was analyzed at three different cutting speeds in order to compare with the experimental results developed as part of this study. The heat generation in the cutting tool was investigated with different cutting parameters under suitable cutting tool geometry. The experimental result shows that the factors that increase the cutting temperature gradually are the cutting speed, the depth of cut and the feed. Various techniques are available to measure product cutting temperature during machining.

“Infrared Thermometer” is used for measuring temperature at tool-chip interface.

CHAPTER 1

INTRODUCTION

1.1 General

A large amount of thermal energy is generated during the process as well as during the various processes of degradation of the material. Temperature is generated at the surface of the tool when the tool tip contacts the work piece.

Heat is a factor that greatly affects tool performance. Energy consumed in machining metal parts is mostly converted to heat. The amount of heat generated during the processing of parts depends mostly on the contact between the tool and the work piece surface and the force on the contact between the tool and the work piece. Normally all the heat generated is transferred to the tool and work piece material and some of it is distributed to the chip.

Heat generated in the deformation zone during machining affects the work piece and tool by affecting the grain characteristics.

As in all metal working operation the energy dissipated in cutting operations is converted into heat which in turn raises the temperature in the cutting zone. Knowledge of the temperature rise is important because of the following phenomena:

- Excessive temperature adversely affects the strength, hardness and wear resistance of the cutting tool
- Increased heat causes dimensional changes in the part being machined. Making it difficult to control dimensional accuracy.
- Heat can induce thermal damage to the machined surface adversely affecting its properties.

- The machine tool itself may be subjected to elevated and uneven temperatures causing distortion of the machine and therefore poor dimensional control of the workpiece [1]

Because of the work done in shearing and in overcoming friction on the rake face of the tool, the main sources of heat generation are the primary shear zone and the tool-chip interface. Additionally, if the tool is dull or worn heat is also generated when the tool tip rubs the machined surface [1]

The greatest source of errors in machining processes occurs at high temperatures and contributes to thermal degradation of cutting tool and greatly affects machine tool wear life.

Temperatures and their distribution in the cutting zone may be determined from thermocouple embedded in the tool and the workpiece. This technique has been used successful, although it involves considerable effort. It is easier to determine the average temperature with the thermal emf at the tool-chip interface, which acts as a hot junction between two different materials [1]

The infrared radiation from the cutting zone may also be monitored with a radiation pyrometer. However this technique indicates only surface temperatures the accuracy of the results depends on the emissivity of the surfaces, which is difficult to determine accurately [1]

Much research is being done to develop analytical and numerical models to simulate metal cutting processes and the effect of machining parameters such as cutting speed and depth of cut.

Numerical models are very important to predict the stress, temperature distribution, chip formation. Specifically advanced simulation techniques were used to study the effect of tool edge geometry and cutting conditions on surface integrity under machine-induced stress.

1.2 Objective

Heat is a factor that greatly affects the performance of the tool during operation. Therefore knowledge of cutting tool heat distribution is required to facilitate machine operations.

Therefore the main objectives of this project are as follows:

1. To study and compare the temperature distribution of single point machining tools made of different materials with different parameters.

2. Comparison of experimental data.

3. Applying Taguchi's method to minimize the chances of error and optimizing the result.

4. Getting to know which parameter has the greatest influence on tool-chip interface temperature.

Other materials are used for cutting tools such as diamond, carbide. The various parameters associated with these tools are the feed, speed and cut depth. Therefore different materials and parameters can be selected to study the temperature distribution of single-point machining tools.

CHAPTER 2

LATHE MACHINE

2.1 Lathe machine

A lathe machine is a machine tool that removes the undesired material from a rotating work piece in the form of chips with the help of a tool that is traversed across the work and can be feed deep into the work. This is also known as the ‘Mother of all Machines’. Nowadays, Lathe Machine has become a general-purpose machine tool, employed in production and repair work, because it permits a large variety of operations to be performed on it. It one of the most versatile and widely used machine tools all over the world.(Ref-www.google.com)

Types of Lathe Machine

- Engine Lathe or Center Lathe
- Speed Lathe
- Turret lathe
- Capstan Lathe
- Tool room Lathe
- Bench Lathe
- Gap bed lathe
- Hollow spindle Lathe
- Vertical Turret Lathe and
- CNC Lathe Machine.

Parts of lathe machine

The Lathe Machine consists of following Main Parts:

- Bed
- Headstock
- Tail stock
- Carriage
- Saddle
- Cross Slide
- Compound rest
- Tool Post
- Apron
- Chuck
- Feed rod
- Lead Screw
- Spindle

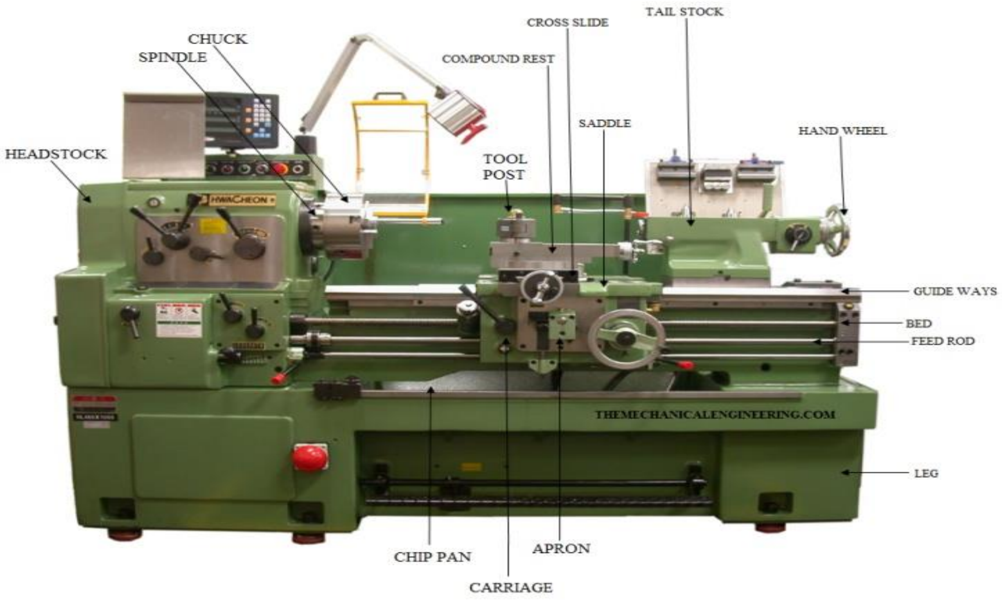


Fig 1: Schematic Diagram of Lathe Machine (Ref-www.google.com)

Bed: The bed is the base for the working parts of the lathe. The bed is made from cast iron or nickel cast iron alloy. The main feature of the bed is the ways which are formed on the bed's upper surface and which run the full length of the lathe. The tailstock and carriage slide on the ways in alignment with the headstock. The headstock is normally permanently bolted at one end (at the operator's left). The ways are accurately machined parallel to the axis of the spindle and to each other. The V-ways are guides that allow the carriage and the tailstock to move over them only in their longitudinal direction. The flat way takes most of the downward thrust. The carriage slides on the outboard V-ways which, because they are parallel to the V-ways, keep the carriage in alignment with the headstock and tailstock at all times. This is an absolute necessity if accurate lathe work is to be done. Some lathe beds have two V-ways and two flat ways, while others have four V-ways. (Ref-www.google.com)

Headstock: The headstock carries the head spindle and the mechanism for driving it. In the belt-driven type headstock, the driving mechanism consists merely of a cone pulley that drives the spindle directly or through the back gears. When the spindle is driven directly, it rotates the cone pulley. When the spindle is driven through the back gears, it rotates more slowly than the cone pulley, which in this case turns freely on the spindle. Thus two speeds are available with each position of the belt on the cone; if the cone pulley has four steps, eight spindle speeds are available. This headstock is similar to an automobile transmission except that it has more gear-shift combinations and, therefore, has a greater number of speed changes.

Tailstock: The primary purpose of the tailstock is to hold the dead center to support one end of the work being machined between centers. However, it can also be used to hold live centers, tapered shank drills, reamers, and drill chucks. The tailstock moves on the ways along the length of the bed to accommodate work of varying lengths. It can be clamped in the desired position by the tailstock clamping nut. The dead center is held in a tapered hole (bored to a Morse taper) in the tailstock spindle. The spindle is moved back and forth in the tailstock barrel for longitudinal adjustment. The hand wheel is turned which turns the spindle-adjusting screw in a tapped hole in the spindle.

Carriage: The carriage carries the cross feed slide and the compound rest which in turn carries the cutting tool in the tool post. The carriage slides on the ways along the bed the wings of the H-shaped saddle contain the bearing surfaces which are fitted to the Ways of the bed.

Saddle: It is an H-shaped casting mounted on the top of the lathe ways. It provides support to cross-slide, compound rest, and tool post.

Crossslide: Cross slide is provided with a female dovetail on one side and assembled on the top of the saddle with its male dovetail. The top surface of the cross slide is provided with T slots to enable fixing of rear tool post or coolant attachment. Carriage basically provides a mounted or automatic cross-movement for the cutting tool. (www.google.com)

Compound Rest: Compound rest is present on the top of the cross slide. It supports the tool post and cutting tool in its various positions. Compound rest is necessary for turning angles and boring short tapers and forms on forming tools.

Tool Post: The tool post is mounted on the compound rest. It is used to hold various cutting tool holders. The holders rest on a wedge which is shaped on the bottom to fit into a concave-shaped ring (segmental type), which permits the height of the cutting edge to be adjusted by tilting the tool. It is fixed on the top slide. It gets its movement by the movement of the saddle, cross slide, and top slide. (Ref-www.google.com)

The three types of tool post which are commonly used are:

- Ring and rocker tool post
- Quick change tool post
- Square head tool post.

Apron: The Apron is fastened to the saddle and hangs over the front of the bed**.** Apron consists of the gears and clutches for transmitting motion from the feed rod to the carriage, and the split nut which engages with the lead screw during cutting threads.

Two types of Apron are extensively used:

- Incorporating drop worm mechanism.
- Friction or dog clutches.

Chuck: Chuck is basically used to hold the work piece, particularly of short length and large diameter or of irregular shape which can't be conveniently mounted between centers. It can be attached to the lathe by screwing on the spindle nose.

Four different types of chucks are most commonly used in Lathe:

- Independent or four-jaw chuck
- Three jaw or universal chuck
- Collect chuck and
- Magnetic Chuck

Feed rod: Feed rod is a power transmission mechanism used for precise linear movement of the carriage along the longitudinal axis of the lathe. In some lathe machines instead of feed rod lead screws are used. (Ref-www.google.com)

Lead screw: The lead screw is used mostly in the case when the threading operation is to be performed on a lathe. As we know for threading operation requires rotational movement of the job (work piece) and the linear movement of the tool (tool post). So rotation of the job is obtained by the chuck and the desired linear motion of the tool-post (as the lead screw drives the saddle when it is engaged) is provided with the help of a lead screw.

2.2 Lathe Operations:

In order to perform operations in lathe, work piece may be supported and driven by any one of the following methods:

1. Held between centers and driven by carriers and catch plates.

2. Held on mandrel which is supported between centers and driven by carriers and catch plates.

3. Held and driven by chuck with the other end supported on the tailstock center.

4. Held and driven by chuck or faceplate or an angle plate.

Such operations carried out in lathe machines are:

- centering
- turning,
- taper turning,
- facing,
- knurling,
- Eccentric turning etc.

1. Centering

When work is required to be turned between centers or between a chuck and center, conical shaped holes must be provided at the ends of the work piece to provide bearing surface for lathe centers. To prepare a cylindrical work piece for centering, it is first necessary to locate the center hole. Center holes are produced by using combined drill and counter shank tool.

This is held on drill chuck and may be mounted on headstock or in tailstock. The included angle of the hole should be exactly 60 to fit 60-point angle of lathe center.

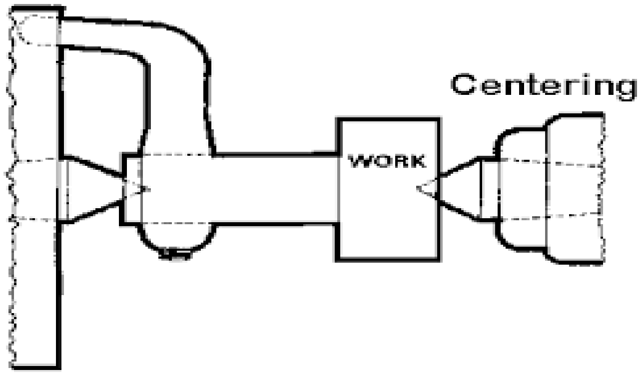


Fig 2: Centering (Ref-www.google.com)

2. Turning

Turning in a lathe is to remove excess amount of material from work piece to produce a cone shaped or a cylindrical surface. Turning Round turning is the process of removal of excess material from work piece in a minimum time by applying high rate of feed and heavy depth of cut. The depth of cut for rough turning operation in average machine shop work is from 2 to 5 mm and rate of feed from 0.3 to 1.5 mm per revolution of workpiece. Whereas finish turning requires high cutting speed, small feed and a very small depth of cut to generate a smooth surface. In finish turning depth of cut rages from 0.5 to 1 mm and rate of feed is from 0.1 to 0.3 mm per revolution of workpiece. When workpiece having different diameter is turned, the surface forming the step from one diameter to other is called shoulder, and machining this part of the workpiece is called shoulder turning.

There are four types of shoulders; Square shoulder, angular or beveled shoulder, radius shoulder and undercut shoulder.

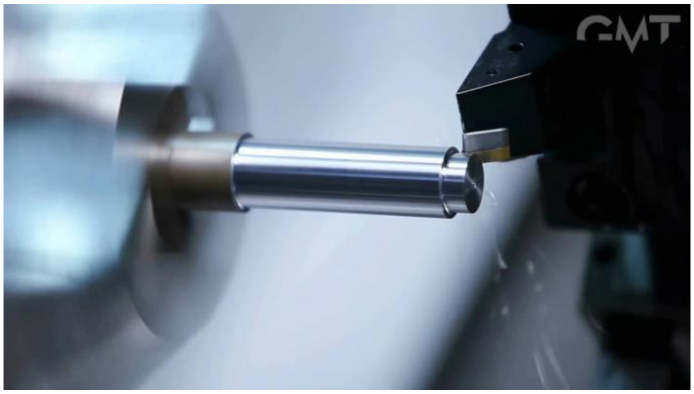


Fig 3: Turning (Ref-www.google.com)

3. Taper turning

A taper defined as a uniform increase or decrease in diameter of workpiece measured along its length. It produces conical surface by gradual reduction in diameter. Tapering of a part has wide application in construction of the machine. Almost all machine spindles have taper holes which receive taper shank of various tool and work holding devices.

Fig 4: Taper Turning (Ref-www.google.com)

4. Facing

Facing is an operation of machining the end of the workpiece to produce a flat surface. This is also used to cut the workpiece to the required length. A properly ground facing tool is mounted in a tool holder in the tool post. A regular turning tool may also be used for facing a large workpiece. The surface is finished to size by giving usual roughing and finishing cuts. For roughing the average of cross feed from 0.3 to 0.7 mm per revolution and depth of cut from 2 to 5 mm. For finishing the average of cross feed from 0.1 to 0.3 mm per revolution and depth of cut 0.7 to 1 mm.

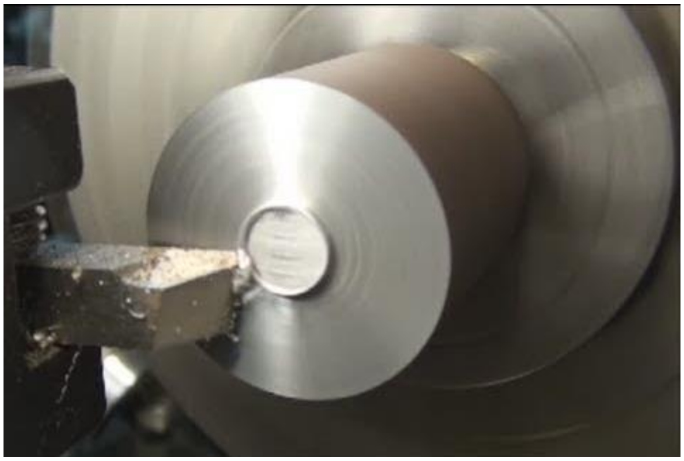


Fig 5: Facing (Ref-www.google.com)

5. Knurling

Knurling is the process of embossing a diamond shaped pattern on a surface of the workpiece. The purpose of the knurling is to provide an effective gripping surface on the workpiece to prevent it from slipping when operated by hand. The operation is performed by a special knurling tool which consist of one set of hardened steel rollers in a holder with the teeth cut on their surface in a definite pattern. When single roller is used to generate parallel grooves and when two rollers are used, one right hand and one left hand to generate the diamond shaped pattern. Knurling is done at slowest speed available in lathe. Usually speed is reduced to one forth that of turning and some amount of oil is required. Speed varies from 1 to 2 mm per revolution.

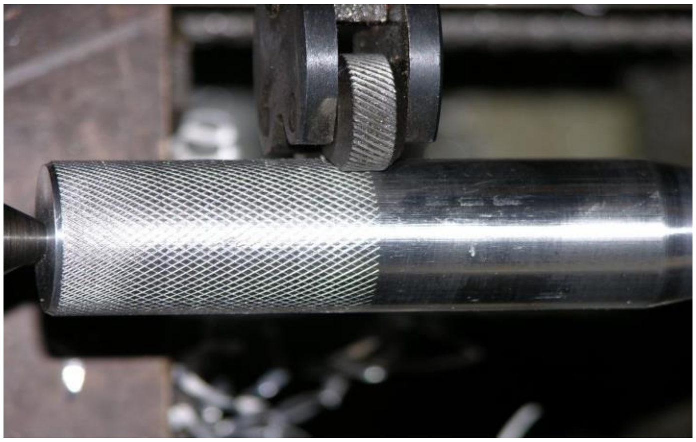


Fig 6: Knurling (Ref-www.google.com)

6. Eccentric turning

If a cylindrical workpiece has two separate axis of rotation one being out of center to the other center, the workpiece is termed eccentric and turning of different surface of workpiece ids known as eccentric turning. Crank shaft is the common ex ample of eccentric turning. In eccentric turning counter balance weights are mounted on the faceplate to get uniform turning.

Fig 7: Ecenctric Turning (Ref-www.google.com)

2.3 Lathe Cutting Tools

a) General.

A machine tool is no more efficient than its cutting tool. There is nothing in shop work that should be given more thoughtful consideration than cutting tools. Time is always wasted if an improperly shaped tool is used. The cutting action of the tool depends on its shape and its adjustment in the holding device. Lathe cutter bits may be considered as wedges which are forced into the material to cause compression, with a resulting rupture or plastic flow of the material. The rupture or plastic flow is called cutting. To machine metal efficiently and accurately, it is necessary that the cutter bits have keen, well-supported cutting edges, and that they be ground for the particular metal being machined and the type of cut desired. A cutting tool can be defined as a part of a machine tool that is responsible for removing the excessive material from the work piece by direct mechanical abrasion and shear deformation. An efficient cutting tool should have the following characteristics –

a) Hardness: The tool material should be harder than the work material.

b) Hot hardness: The tool must maintain its hardness at elevated temperatures encountered during the machining process.

c) Wear Resistance: The tool should have served to its acceptable level of life before it wears out and needs to be replaced.

d) Toughness: The material should be strong enough so as to withstand shocks and vibrations. During interrupted cutting, the tool should not chip or fracture (Ref-www.google.com)

Cutter bits are made from several types of steel, the most common of which are described in the following subparagraphs.

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

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

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

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

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

Common Types Of Cutter Bits.

(1) General. Cutter bits are made from standard sizes of bar stock to fit into cutting tool holders which in turn are fastened to the tool post of the lathe. If the cutter bit is to be used for heavy roughing, where a finished surface is not expected, the nose should be ground with a very small radius (approximately 1/64 inch). If the cutter bit is to be used for general shaping and finishing, the nose should be more rounded (approximately 1/32-to 1/16 inch radius). The following cutter bits are identified by their function.

(2) Right-Hand Turning Cutter Bit. The right-hand turning cutter bit is shaped to be fed from right to left. The cutting edge is on the left side of the bit and the face slopes down away from the cutting edge. The left side and the end of the tool are ground with sufficient clearance to permit the cutting edge to bear upon the workpiece without the heel of the bit rubbing against the workpiece. The right-hand turning cutter bit is ideal for taking light roughing cuts as well as general all-around machine work. (Ref-www.google.com)

(3) Left-Hand Turning Cutter Bit. The left-hand turning cutter bit is just the opposite of the right-hand turning cutter bit, being designed to cut the metal when fed from left to right. It is used for all around machine work when right-to-left turning is impractical.

(4) Round-Nose Turning Cutter Bit. The round-nose turning cutter bit is used for all around machine work and may be used for taking light roughing or finishing cuts. Usually the face is ground with a right sloping side rake so that the bit may be fed from right to left, although it is often ground without any side rake so that the feed may be in either direction.

(5) Right-Hand Facing Cutter Bit. The right-hand facing cutter bit is intending for facing on right-hand shoulders and the right end of the workpiece. The cutting edge is on the left-hand side of the bit, and the nose is sharp to permit machining a square corner. The direction of feed for the facing bit should be away from the axis of the workpiece.

(**6) Left-Hand Facing Cutter Bit.** The left-hand facing cutter bit is just the opposite of the right-hand facing cutter bit; it is intended for facing the left side of the shoulders.

(7) Parting Cutter Bit. The parting cutter bit has its principal cutting edge at the end. Both sides must have sufficient clearance to prevent binding and should be ground slightly narrower at the back than at the cutting edge. The bit is convenient for machining necks and grooves, square corners, etc., as well as for cutting-off operations. (Ref-www.google.com)

(8) Thread Cutter Bit. The thread cutter bit has its cutting edge ground to a 60° angle. This form will cut sharp V-threads. Usually the face of this bit is ground flat and has clearance ground on both sides so that it will cut on both sides. For American (National) Standard screw threads, the bit is ground with a flat at the nose to cut the flat root of the thread. The width of the flat at the nose is determined by the pitch of the screw thread that is to be cut.

2.4 Machining parameters

The turning operation is governed by geometry factors and machining factors. This study consists of the three primary adjustable machining parameters in a basic turning operation viz. speed, feed and depth of cut. Material removal is obtained by the combination of these three parameters. Other input factors influencing the output parameters such as surface roughness and tool wear also exist, but the latter are the ones that can be easily modified by the operator during the course of the operation. (Ref-www.google.com)

1) Cutting Speed

Cutting speed may be defined as the rate at which the uncut surface of the work piece passes the cutting tool. It is often referred to as surface speed and is ordinarily expressed in m/min, though ft./min is also used as an acceptable unit. Cutting speed can be obtained from the spindle speed. The spindle speed is the speed at which the spindle, and hence, the work piece, rotates. It is given in terms of number of revolutions of the work piece per minute i.e. rpm. If the spindle speed is "N" rpm, the cutting speed Vc (in m/min) is given as

$$Vc = \frac{\pi D N}{1000} \qquad \text{………..………(1)}$$

Where, D = Diameter of the work piece in mm

2) Feed

Feed is the distance moved by the tool tip along its path of travel for every revolution of the work piece. It is denoted by"f" and is expressed in mm/rev. Sometimes, it is also expressed in terms of the spindle speed in mm/min as

$$F\,m = f\,N \qquad \text{…………(2)}$$

where, f = Feed in mm/rev, N = Spindle speed in rpm

3) Depth of cut

Depth of cut (d) is defined as the distance from the newly machined surface to the uncut surface. In other words, it is the thickness of material being removed from the work piece. It can also be defined as the depth of penetration of the tool into the work piece measured from the work piece surface before rotation of the work piece. The diameter after machining is reduced by twice of the depth of cut as this thickness is removed from both sides owing to the rotation of the work. (www.google.com)

$$D = \frac{D1 - D2}{2} \qquad \text{...........(3)}$$

Where, D1 = Initial diameter of job

D2 = Final diameter of job

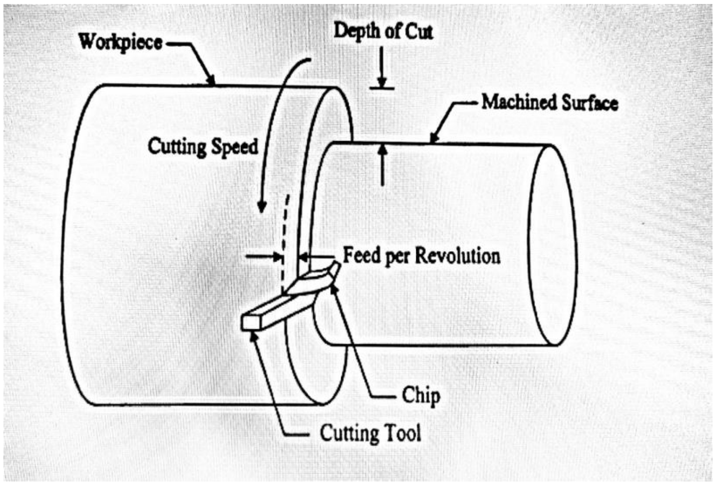


Fig 8: Machining Parameters (Ref-www.google.com)

CHAPTER 3

THERMAL STUDY

3.1 Thermal study of metal machining process

The effects of cutting temperature are often detrimental to both the tool and the work piece. Most of the heat is removed by the chips. But the chips are thrown away carrying good amount of heat. Therefore efforts should be made to remove excess heat in terms of chip and leaving tool and work piece least affected. Friction creates three heat zones.

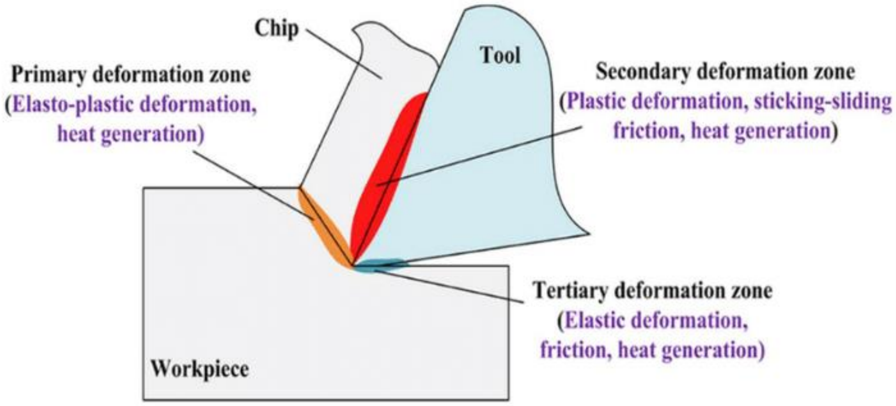


Fig 9: Evolution of heat at three zones (Ref-www.google.com**)**

At the cutting edge the plastic deformation of the metal generates more heat and all this heat is removed through the chip. A small part of this heat is transferred to the work piece. Heat in the friction zone is generated by the friction between the moving chip and the tool surface and visually by the secondary deformation of the built-up edge. Heat is generated due to friction between the tool and the work piece in the tool contact area. Note that the maximum temperature is not at the cutting edge but slightly away from it.

While machining, large amount of heat is generated from the cutting point at three distinct points of sources. In cutting, almost all the energy dissipated in plastic deformation is converted into heat which causes raise in the temperature in the cutting zone. To some extent, it can enhance the tool wear and then decrease the tool life. This temperature generation in the cutting zone is closely related to the plastic deformation and the friction exerted between the chip and the tool, tool and workpiece and various cutting forces. As a large amount of plastic strain is involved in metal cutting, almost 99% of heat is transferred to chip, cutting tool and the workpiece, while more than 1% of work is stored as an elastic energy.[2]

The three sources of heat generation are

1. Shear-plane, where the actual plastic deformation occurs

2. Tool-chip interface, due to the friction between tool and chip

3. Tool-workpiece interface, which occurs at flank surface

Heat generation at shear plane The mechanism of shearing of metal is the reason to generate the heat around the shear plane. During machining, when the tool is passed over the workpiece, the region in the work piece which is ahead of the cutting edge of the cutting tool gets compressed and severely stressed. Where, this stress is maximum along a plane called shear plane, in which actual plastic deformation occurs. The disturbance caused in the atoms of workpiece during plastic deformation along the shear plane where the friction is involved in sliding the atoms over one another are the responsible for the heat generation in the shear plane. When a material is deformed resinously, the energy used is stored in the workpiece as strain energy and no heat is liberated. However, when the workpiece is deformed plastically almost all the energy used is converted into heat. A portion of the heat generated in the shear plane is carried away by the chip. A very minor portion of heat is retained by the workpiece. Shear plane also known as primary deformation zone [2]

Heat generation at tool chip interface Heat generated at tool-chip interface in an important factor considered in metal cutting. This is the region where maximum heat is generated among all the three sources. Because of the high shear stress and the frictional forces dissipated during machining, the temperatures in the primary and secondary zones are very high. Experiments show that the heat generated at each of three sources leads to rise of temperature at too chip interface. When the cutting tool advances and passed over the workpiece, material near the cutting edge gets separated and removed in the form of chips. As the chips move upwards along the rake face of the cutting tool, friction occurs between chip and tool face which gives rise to heat. Some part of heat is carried by chip, and the rest is transferred to the cutting tool. The rate of tool wear and the crater wear on the rake face of the cutting tool are greatly influenced by the temperature at chip-tool interface.

Heat generation at tool work interface As the cutting tool is not perfectly sharp, there exists friction between the tool and the newly machined surface. To avoid this, clearance angle is provided. The function of clearance angle is to avoid rubbing between flank surface and the machined surface. But still some portion of flank surface will be in contact with workpiece which rubs against each other, which is another source of heat generation. Heat produced is transferred to both tool and the workpiece. However, heat generated at this source is small and can be neglected. Heat generated at this region may influence on the quality of the workpiece.[2]

Distribution of heat generation in metal cutting From the basic study of heat transfer, heat can be transferred via three ways viz., conduction, convection and radiation. The study of temperature distribution can be made through these three modes. Figure 2 shows the distribution of heat during machining. Distribution of temperature depends on the heat conductivity and the specific heat capacity of the tool and the workpiece and finally the based on radiation and convection the amount of heat loss depends. The maximum temperature occurs in the contact zone between the chip and the tool. In the entire heat generated, 80% of the total heat is carried away by the chip, about 10% is transferred to the tool and the remaining 10% is retained by the workpiece. The shear angle also affects the heat generation. A larger shear angle leads to a smaller heat generation in the primary deformation zone.

Influence of machining parameters on heat generation Cutting temperature depends upon several machining parameters such as cutting speed, feed and depth of cut. Cutting speed has a superior effect on the temperature. From the figure 3it is observed that with an increase in the cutting speed a higher amount of heat is absorbed by the chip and lesser amount is transferred to the tool and the work piece. It is also observed that with increase in cutting speed forces decreases but temperature increases. Feed rate has a very little effect on heat generation whereas depth of cut had least affect. These machining parameters also affect the size of shear zone and tool-chip contact length [2]

Influence of cutting tool geometry on heat generation Among all the angles which favour the cutting tool, rake angle has the mixed effect. The increase in the rake angle in the positive direction leads to the less amount heat generation at tool chip interface but on the other hand it weakens the cutting tool. Thus it necessitates a balance in the value of rake angle which varies between-5° to +10°. Another important angle is clearance angle which avoids rubbing which in turn helps in lowering the amount of heat generation. These angles normally vary from 5° to 8°. There needs an optimum value for rake and clearance angle in order to balance between the strength of the tool and heat generation. While there will be a minor effect on heat generation with both the cutting edge angles. Another interesting factor is cutting tool nose radius. Some studies have shown that with increase in the cutting tool nose radius may decrease the cutting temperature. A proper combination of feed, speed, depth of cut may minimize the heat generation and may maximize the tool life

Effect of heat generation on cutting tool As already been described, during the machining process heat is generated at various elements, among which cutting tool is the prominent element. Due to the intimate contact of the chip and workpiece with cutting tool, severe temperature gradients are developed that causes several losses to the cutting tool. The temperature rise in all the three zones has significance in the generation of heat near the tool. However, cutting tool material is hard and able to withstand at high elevated temperatures, but every material has a limited value to withstand up to a certain temperature without demolishing its hardness. When the cutting tool has crossed its limit, its ability to perform machining will be lost and is said to be failure due to softening. Cutting tool may also fail due to the mechanism called thermal cracking. This is due to the expansion and contraction which gives rise to setting up thermal stresses due to which cracks are developed. After a while of machining it is seen that there will be some reduction in weight of tool, which is due to wear at the face. As machining is concerned two types of wear are generally seen viz., crater wear and flank wear. With the excess heat on the rake face of the tool, there is a chance for the formation of the built-up-edge. All these factors results in the reduction in the tool life. [2]

Effect of heat generation on job Heat generated during machining had combined effect on tool and the job. Major part of the heat is carried away by the chips and the remaining heat is retained by tool and the job. As all the machining process is done for the better surface finish and the dimensional accuracy of the workpiece, some amount of heat is also transferred to the workpiece which has some losses in its performance. Due to the thermal distortion and thermal expansion during cutting, there may chance of dimensional inaccuracy of the job Because of the oxidation, there is a chance of surface damage. In some cases microcracks at the surface, corrosion and burning of job can also be seen.[2]

3.2 Tool-Chip interface temperature

Interface temperature must be measured to determine tool wear and tool life**.** There are several techniques from which cutting temperature at tool-chip interface can be measured:

- Thermocouple
- Infrared thermometer
- Infrared photography
- Thermal paints etc

3.2.1 Thermocouple

It consists of two identical but electrically conductive metals formed between the tool and the workpiece. Whenever one of the junctions is heated the temperature difference between the hot and cold junctions produces a proportional current that is detected and measured by a milivoltmeter. The hot end of the tool and the work piece and there cold end act as thermocouples and change the temperature in proportion to the temperature. The working part is isolated and sterile from the center of the floor. The tip of the work piece is connected to a copper wire which is immersed in a mercury bath and allows further connection as a cold tip. A connection from this point and instrument provides an output for connection to a milivoltmeter.

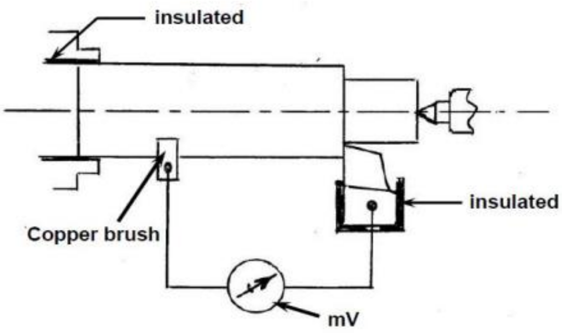


Fig 10: Thermocouple **(**Ref- www.google.com**)**

3.2.2 Infrared Thermometer

A thermometer that measures the temperature of a point or small area using a highly focused infrared laser. It is called a non-contact thermometer or heat gun to describe its ability to measure temperature over long distances. The temperature of an object can often be determined by knowing the infrared energy emitted by the object and its emissivity. Sometimes false readings can be caused by radiation reflections and stray emissions from a warm body or person holding the instrument rather than radiation from the object under test at room temperature. It consists of a lens that focuses infrared thermal radiation onto a detector that converts the radiant power into an electrical signal that can be displayed in temperature units after compensation for ambient temperature.

This allows you to measure the temperature remotely without touching the object.

Fig 11: Infrared Thermometer (Ref-www.google.com)

3.2.3 Infrared photography

In this technique images of the side face of a tool-chip are acquired during cutting and compared with known temperature value.

Fig 12: Infrared photography (Ref-www.google.com**)**

3.3 Factor influencing temperature of cutting zone

The size of the shear zone and the tool contact length and thus the area over which the heat is distributed are influenced by various factors that lead to the development of the maximum temperature. The short contact length of the chip with the tool leads to an increase in temperature and vice versa. Various factors that affect the temperature section are:

3.3.1 Tool geometry

The Rake angle of the tool has little effect on the temperature generated. A temperature difference of only 20°C was recorded for rack angle variations from -10° to 30°. Increases with angle of approach and tool radius.

3.3.2 Cutting Fluid

If the cutting speed is kept high then cutting fluid does not affect the temperature of the tool-chip interface since the cutting fluid cannot reach the tool-chip interface. A chip thrown away from the machining zone will absorb liquid faster than it should have forced between the device and the chip.

3.3.3 Cutting conditions

Cutting speed has a significant effect on the generated temperature. The depth of cut has less impact and feed contributes least one can say. High cutting speed generates high heat through friction. A higher feed rate and depth of cut results in higher friction and higher heat.

3.3.4 Tool and Work Materials

Cutting temperature greatly affects the strength and life of the workpiece. Also high tensile strength material with good hardness requires more energy to create chips and therefore generates more heat. Materials with high thermal conductivity generate less heat than devices with low thermal conductivity.

CHAPTER 4

LITERATURE REVIEW

The purpose of this chapter is to review previous research efforts related to single point cutting tool shear. An overview of other relevant research studies is also provided. Previous research efforts are reviewed as to see how they have laid the foundation for future studies as well as current research efforts. The review was designed to extend the existing literature as well as to justify the scope and direction of current efforts.

M. PradeepKumar etal [2] In this paper a review has been done on various temperatures that are generated during machining process. A study was conducted on the various aspects of heat generation, as it is caused due to the cutting edge of the tool slides across the surface of the work. Because of this, heat is generated at three different sources (Shearzone, tool-chip interface, tool-work interface). From this study it can be concluded that heat distribution in the chip, workpiece and tool are in the ratio 80:10:10. This shows the heat generated at tool-chip interface is more and diverts to focus on that region. The influence of machining parameters and cutting tool geometry on the temperature is also a vital aspect. Among all the parameters, cutting speed has a major influence and then rake angle. The adverse effects on the tool and job due to the heat generation have also been discussed. The reduction in the life of tool and the poor quality of the job is the cause for temperature generation. Lastly in this study various methods which are prominent in determining the temperature have also been reviewed.

Rogério Fernandes Brito, etal [3] studies the effect of heat in cutting tools with regard to changes in coating thickness and heat flow. A K10 substrate and diamond tools with TiN and Al_2O_3 coatings were used. The numerical methodology uses ANSYS CFX software. The boundary conditions and constant thermophysical properties of the solids involved in the numerical analysis are known. An experiment is used to verify the proposed methodology.

L.B.Abhang, etal [4] developed the first-order and second -order empirical models of the chip-tool interface temperatures for turning of EN-31 steel alloy. They also investigated that the established equation in their work clearly revealed that the cutting speed is main influencing factor on chip-tool interface temperature as compared to others. It has been observed that increasing cutting speed, feed rate and depth of cut gives rise to the increase in cutting temperature. But increasing the tool nose radius may predominantly decrease the cutting temperature. The appropriate aggregation among the cutting speed, feed rate, depth of cut and tool nose radius can generate minimum cutting temperature during steel turning. They pointed out that the surface methodology coupled with factorial design of experiments actually save a lot of time and cost of experiments. Finally they suggested that the tool-work thermocouple technique is the best method for measuring the average chip-tool interface temperature during metal cutting. The benefits of using the tool-work thermocouple are its ease of implementation and its low cost as compared to other thermocouples.

A. G. F. Alabi etal [5] conducted the study on finite element modelling which was utilized to simulate the temperature distribution for orthogonal cutting of medium carbon steel subjected to various form of heat treatment operations. For all the samples that they have been conducted, Very high and localized temperatures were observed at the tool-chip interface because of a detailed friction model and the shearing action within the cutting zone. The temperature profile along the shear plane was also analytically simulated. The temperature were however, expressed as a fraction of the instantaneous distance, located by the coordinate axis in the nodal grids structure for both the tool, chip and the workpiece to obtain the temperature profile. The temperature profile obtained indicated that the tool has a higher machining temperature when machining steel materials.

Majumdar etal [6] studied the influences of the heat generation during machining operation processes and their effects on cutting forces and tool wear. In order to study this they have built a fem based computational model to determine the temperature distribution in a metal cutting process on high-speed carbon steel. Results shows that as cutting speed increases from 29.6 m/min to 155.4 m/min maximum temperature in the tool will also increase from 709.36 K to 1320 K. Their experiment model also infers that significant effect of conduction and convection losses in heat dissipation and temperature rise in the cutting tool.

Sushil D. Ghodamin [7] his paper advocates that the Tool-Work thermocouple is the best way to obtain the temperature at the tool rake face because of its easiness to install and inexpensive as compared to other methods. His paper also states that with the increase in a cutting speed or a feed rate, the temperature at the tool rake face also increases that is found in the machining tests. He pointed that generation of high temperature at the tool rake face takes place due to the enormous frictional forces caused at tool-chip interface. This generation of heat can be resisted by using a coated tool. Reduction in the temperature of the tool improves the tool strength and also improves the surface roughness of work piece. From his experimental data, it is found that as compared to uncoated tool the coating of the tool increases the life of a tool for the same cutting velocity or for the same tool life, coated tool can be used at higher cutting speed as compared to uncoated tool.

Uzorh Augustine .C ,etal [8] addressed a concept to determine the problem of temperature and heat flux at tool-chip interface they used a technique called Inverse heat conduction, proved that at any cutting interface heat flux estimation can calculate temperature field from any region of tool set.They also proposed algorithms that can also be used in selecting various parameters in order to reduce excess thermal load on tool. They also used partial differential equations for chip and the tool to get the Heat balance equations. Hence that leads to decreasing accelerated wear of cutting tools and edge chipping.

AbdilKus, etal [9] concluded that vital effecting factor with regards to tool-chip interface is cutting speed.As the speed increases major changes can be seen in chip formation and curvature while feed rate is not so important. Cutting parameters can be optimized by heat distribution of cutting tool, work piece and interface of tool-chip. This leads to the relation between the cutting parameters and heat distribution. They used the Techniques like IR pyrometer and a K-type thermocouple to measure the temperature of the tool and contact behaviour between tool-chip in turning process of heat treated AISI 4140 alloy steel 50 HRC. By using multi sensor application they have studied the behaviour of cutting parameters during heat distribution. In order to verify the test FEM results will be playing curial role in future studies these results are obtained based on estimated heat over the tool chip interface.

Vamsi Krishna Mamidi,etal [10] from their paper it is noticed Machining process, work piece materials and cutting tool material are the three major factors affecting the cutting fluid during machining process proper selection of cutting fluids provides longer tool life, higher surface finish etc.., along with uninterrupted cutting speeds, high depth and high feed rates. Dry machining process is the new machining process produced from the concept of applying less cutting fluid during the machining process. Cutting fluid cost and disposals cost can also be reduce by using a method of regeneration of fluids which will leads to the decrease in environmental pollution to maximum extent.

Mr. Lathiya Dharmeshkumar ,etal [11] stated that for increasing the tool life and to reduce production costs, Study of temperature in various fields in machining are very prominent. Quality of machined part and tool life can be influenced and predicted by the temperature produced during machining process along rake surface. MATLAB is a program written for the determination and distribution of temperature. Five different types of metal cutting, namely, conventional machining verified andresults presented in the literature manner are found in good agreements. The analytical method provides good physical bond with thermal.

A.A. Sri Rama Krishna,etal [12] stated that the Maximum temperature is found at chip-tool interface with the cutting speed 50m/min is 3150C. Along radial and tangential to the direction to the tool contact temperature will be gradually decreases along with reduced temperature from the chip tool mating point to the tool flank. All the views and reports given by Sri Rama Krishna and Dr. P. Ravinder Reddy with variation of 1.25% were observed are correlated with finite element

Yash R. Bhoyar, etal [13] studied approaches to model the turning process for steel EN-24. Deform 3D finite element analysis software is used to study the effects of cutting speed, feed rate and type of alloy steel on thermal behavior. The workpiece is modeled as an Elastic-plastic material that has a thermal, elastic, plastic effect. The workpiece is represented by an insert model with a different length for each condition. Optical infrared pyrometer is used to measure the temperature. This thermal device detects the temperature of the object by calculating the emitted, reflected and transmitted energy using the means optical sensors and detectors and temperature display on the display panel.

Maheshwari N Patil, etal [14] presented a methodology for determining tool forces and temperatures for use in finite element simulations of metalworking processes. From the experimental setup, it is clearly seen that as the depth of cut increases, the temperature generated in the tool at the tool tip also increases. It has also been observed that as the depth of cut increases, the tool forces also increase. This is the main reason for tool failure. It is also observed that the tool begins to vibrate at a depth of cut of 2.5 mm. Under these conditions, more heat is dissipated through the tool, resulting in dulling of the tool. An experimental setup is made to measure the cutting force using a dynamometer and analyze the effect on the tool.

S. H. Rathod, etal. [15] performed three analysis using a HSS and a carbide-tipped tool at three different cutting speeds to compare the obtained experimental results. Experimental results show that the main factors responsible for the increase in cutting temperature are cutting speed (v), feed rate (f) and depth of cut (d). The "Fluke 62 max infrared thermometer" is used to measure the temperature at the tool tip interface. The single-point cutting tool was volumetrically modeled using CAD Modeller Pro/E and FEA performed using ANSYS Workbench 14.5. By changing various parameters, the effect of these on temperature is compared with experimental and FEA results. After comparison, a deviation of almost 4% was found IN the results.

CHAPTER 5

METHOD AND EXPERIMENTS

5.1 Experimental setup

The experiment was conducted on a three-jaw lathe under dry conditions. Lathes remove unwanted material in the form of chips from the rotating workpiece using a tool that moved through and traversed deep into the workpiece. Workpiece is centre drilled so as to get supported by tail stock.

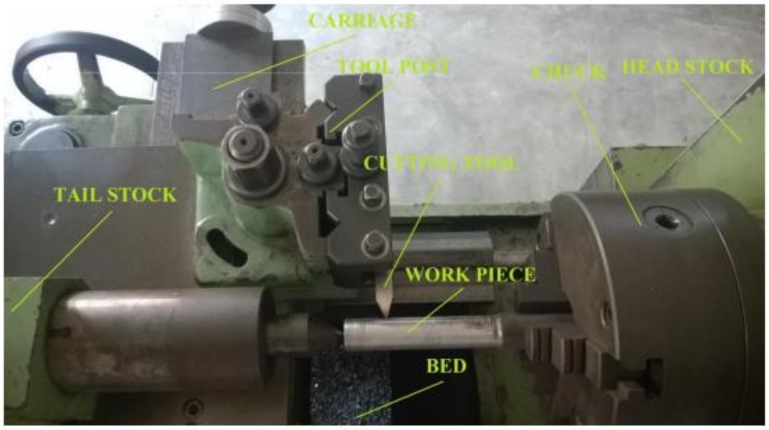


Fig 13: Experimental Setup (Ref:-www.google.com**)**

The workpiece is used as a cylindrical mild steel rod (Ø40 * 100mm). The cutting tool is used as a high speed steel and cobalt tool. Machining takes place at different speeds and at different depths of cut keeping feed constant. The table summarizes the settings for the most important machining parameters

PARAMETERS	**VALUE**
FEED (mm/rev)	0.4
SPEED (rpm)	180,450,740
DEPTH OF CUT (mm)	0.2,0.4,0.6

Table 1: Parameters considered in Experiments

We know that the highest temperatures during processing occur at the tool-chip interface. So we use an infrared thermometer to measure this temperature. Infrared thermometers detect transmitted or reflected infrared energy emitted by all materials (at temperatures above absolute zero) and convert the energy into a temperature reading. Measurements are made here using an infrared thermometer (-20°C to 600°C).A stopwatch is used to measure machining time.

5.2 Experimental Design

In a whole block randomized design it is possible to reduce error variance by creating blocks in which the experimental units of the block are relatively more similar than the dependent variable of interest to the user. The main goal of block generation is to eliminate variations due to experimental errors and block variations. An experimental unit or subject corresponds to a plot and a block consists of k subjects that are identical for a given variable. Here each block consists of k items matching a given variable. Subjects within a block are therefore more homogeneous than randomly selected subjects. The purpose of this local control is to create uniformity within each r block and consequently heterogeneity between blocks. Variations due to block differences are eliminated by experimental error.

The experiment was designed using the Taguchi method which uses OA (orthogonal arrays) to explore the parametric space with some experiments. Two parameters were selected in this study: cutting speed and depth.

Selection of a particular OA (orthogonal array) is based on the number of levels of various factors. Here, 4 parameters each at 3 levels, therefore Degree of Freedom (DOF) can be calculated as:

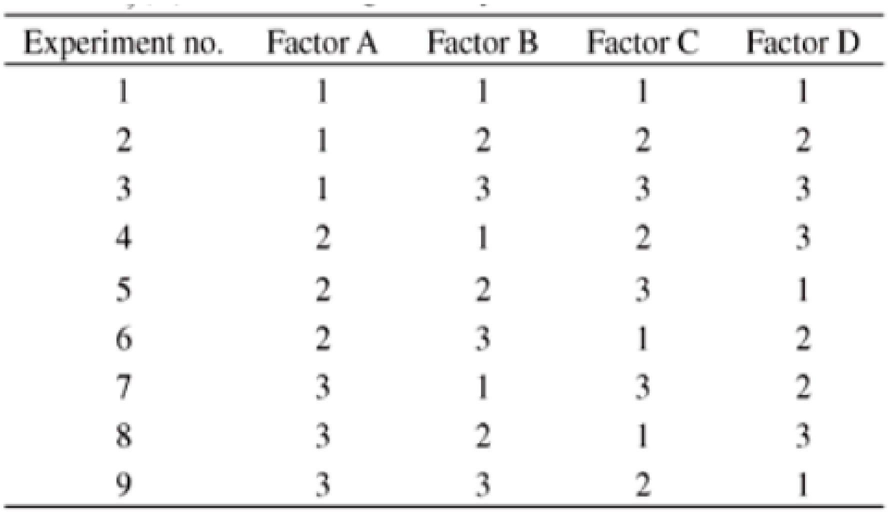
$$\mathbf{(DOF)_R = P\,(L - 1)}$$

Where, P = number of factors

L = number of levels

$$\mathbf{(DOF)_R = 4\,(3 - 1) = 8}$$

The total DOF for OA must be greater than or equal to the total DOF required for the test where L_9 (3^4) OA is specified (see table 2). Each processing parameter is assigned to a column of OA and 9 groups of processing parameters are generated. The response variables selected for this study were: surface roughness and tool tip temperature.



Experiment no.	Factor A	Factor B	Factor C	Factor D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Table 2: L_9 (3^4) Standard orthogonal Array

5.2.1 Experimental design of high-speed steel tool

In this case the experimental results are the temperature generated at the tool tip during machining at different cutting speeds and depths. Here we analyze the error using the temperature obtained for the HSS tool 10 seconds after the start of processing.

SPEED (RPM)	**DEPTH OF CUT(mm)**			**TOTAL SUM**
	0.2	**0.4**	**0.6**	
180	35	71	116	**952**
	34	73	117	
	33	71	115	
	36	71	116	
	35	73	117	
450	74	97	149	**1466**
	73	95	147	
	74	96	146	
	72	95	147	
	73	96	146	
740	82	124	166	**2159**
	83	126	170	
	84	126	169	
	81	125	170	
	83	127	168	
TOTAL SUM	**1113**	**1580**	**1884**	**4577**

Table 3: Experimental result for HSS tool

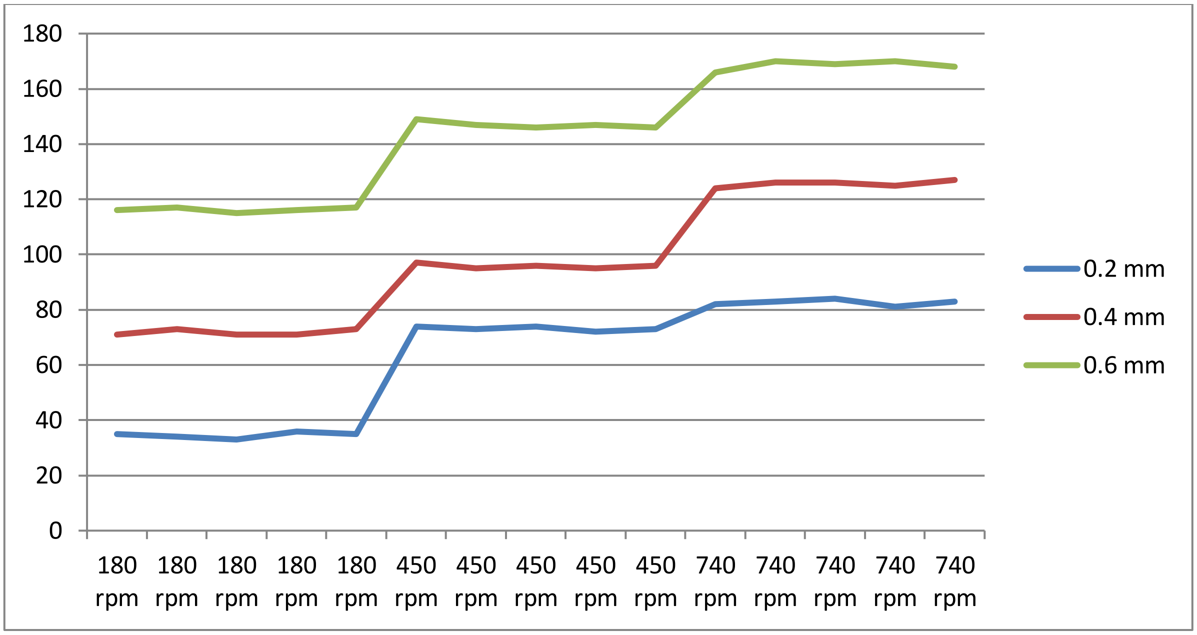


Fig 14: Graphical representation of variation of temperature for HSS tool wrt. feed and speed

S.NO	SPEED	DOC	TEMPERATURES					AVG TEMP
			T1	T2	T3	T4	T5	
1	**180**	**0.2**	35	34	33	36	35	**34.6**
2	**180**	**0.4**	71	73	71	71	73	**71.8**
3	**180**	**0.6**	116	117	115	116	117	**116.2**
4	**450**	**0.2**	74	73	74	72	73	**73.2**
5	**450**	**0.4**	97	95	96	95	96	**95.8**
6	**450**	**0.6**	149	147	146	147	146	**147**
7	**740**	**0.2**	82	83	84	81	83	**82.6**
8	**740**	**0.4**	124	126	126	125	127	**125.6**
9	**740**	**0.6**	166	170	169	170	168	**168.6**

Table 4: Experimental result for HSS tool as per Taguchi's method

The computation procedures of the design of experiment for HSS tool are given below:

i) Correction Term, C = $(4577)^2 /45$ = **465531.76**

ii) Total sum of squares, SS_{Total} = $(35)^2 + (34)^2 + \ldots\ldots\ldots + (168)^2 - C$

= 584744 – 512000 = **69633.24**

iii) DOC sum of squares, SS_{DOC} = $(1113)^2 /15 + (1580)^2 /15 + (1884)^2 /15 - C$

= **20109.92**

iv) Speed sum of squares, SS_{Spd} = $(952)^2 /15 + (1466)^2 /15 + (2159)^2 /15 - C$

= **48917.66**

v) $SS_{SPEED}*SS_{DOC}$ = $(173)^2/5 + (366)^2/5 + \ldots\ldots + (843)^2/5 - C - SS_{DOC} - SS_{Spd}$

= **559.63**

vi) Error sum of squares, SS_{error} = $SS_{Total} - (SS_{DOC} + SS_{Spd} + (SS_{DOC}*Spd))$

=72744 - (48933.73+23210.53+ 544.14)

= **46.04**

5.2.2 Experimental design of cobalt tool

SPEED (RPM)	**DEPTH OF CUT(mm)**			**TOTAL SUM**
	0.2	**0.4**	**0.6**	
180	36	70	117	**991**
	38	70	118	
	39	71	119	
	38	72	118	
	37	71	118	
450	74	101	152	**1494**
	75	101	152	
	76	102	153	
	74	103	152	
	75	103	154	
740	86	126	175	**2224**
	87	127	174	
	85	126	175	
	85	127	173	
	86	126	174	
TOTAL SUM	**1132**	**1647**	**1930**	**4709**

Table 5: Experimental result for Cobalt tool

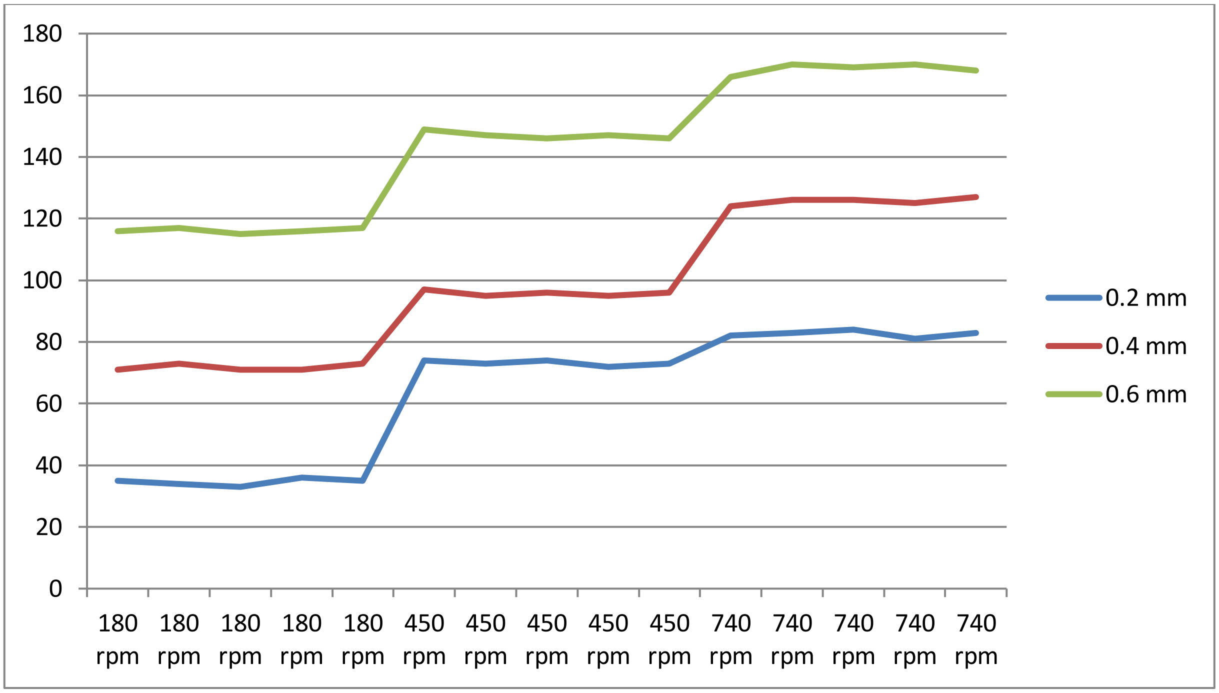


Fig 15: Graphical representation of variation of temperature for cobalt tool wrt. feed and speed

S.NO	SPEED	DOC	TEMPERATURES					AVG TEMP
			T1	T2	T3	T4	T5	
1	**180**	**0.2**	36	38	39	38	37	**37.6**
2	**180**	**0.4**	70	70	71	72	71	**70.8**
3	**180**	**0.6**	117	118	119	118	118	**118**
4	**450**	**0.2**	74	75	76	74	75	**74.8**
5	**450**	**0.4**	101	101	102	103	103	**102**
6	**450**	**0.6**	152	152	153	152	154	**152.6**
7	**740**	**0.2**	86	87	85	85	86	**85.8**
8	**740**	**0.4**	126	127	126	127	126	**126.4**
9	**740**	**0.6**	175	174	175	173	174	**174.2**

Table 6: Experimental result for cobalt tool as per Taguchi's method

The computation procedures of the design of experiment for Cobalt tool are given below:

i) Correction Term, C = $(4709)^2$ /45

= **492770.68**

ii) Total sum of squares, SS_{Total} = $(36)^2$ + $(38)^2$ +……… + $(174)^2$ – C

= 575588N– 502233.69

= **74554.32**

iii) DOC sum of squares, SS_{DOC} = $(1132)^2$ /15 + (1647$^{)2}$ /15 + $(1930)^2$ /15 – C

= 524058.53 – 502233.69

= **21824.85**

iv)Speed sum of squares, SS_{SPEED} = $(991)^2$ /15 + $(1494)^2$ /15+ $(2224)^2$ /15 – C

= 553487.52 – 502233.69

= **51248.85**

v) SS_{DOC}* SS_{SPEED} = $(188)^2$ /5 + $(374)^2$ /5 + …...+ $(871)^2$ /5 - C - SS_{DOC} –SS_{SPEED}

= 575560.4 – 502233.69 – 21824.84 – 51248.84

= 253.03

vi) Error sum of squares, SSerror = SSTotal - (SSDOC -SSSpdSSDOC*Spd)

= 73354.31- (51248.84+21824.84+ 253.03)

= 27.6

CHAPTER 6

RESULTS AND DISCUSSION

6.1 Variance of the design of experiment for HSS tool

The analysis of variance of the design of experiment for HSS tool is summarized in table:

SOURCE OF VARIATION	**SUM OF SQUARE**	**%C**
SPEED	48917.66	70.26
DOC	20109.92	28.87
SPEED*DOC	559.63	0.803
ERROR	46.03	0.066
TOTAL SUM	69633.24	100

From the ANOVA table, it is clear that speed is the most significant parameter followed by depth of cut. However the interaction of speed*depth of cut has least effect

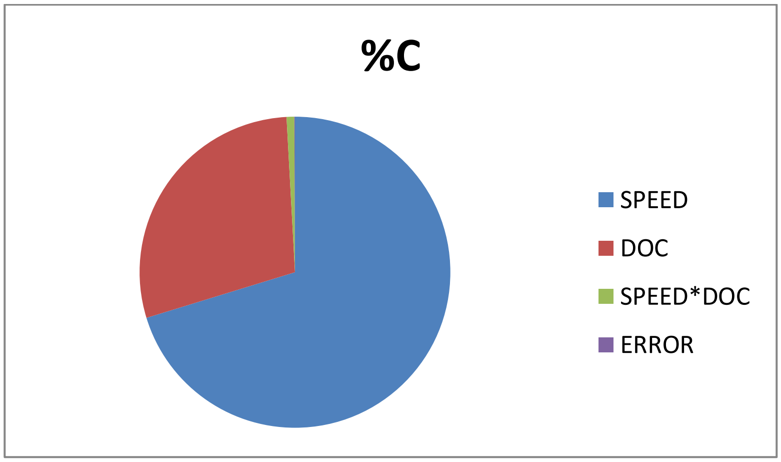


Fig 16: Pie chart representing percentage contribution of parameters for raising temperature for HSS tool

6.2 Variance of design of experiment for Cobalt tool

The analysis of variance of the design of experiment for Cobalt tool is summarized in table:

SOURCE OF VARIATION	**SUM OF SQUARE**	**%C**
SPEED	51248.84	69.87
DOC	21824.86	29.742
SPEED*DOC	253.03	0.35
ERROR	27.6	0.038
TOTAL SUM	73354.31	100

From the ANOVA table, it is clear that speed is the most significant parameter followed by depth of cut. However the interaction of speed*depth of cut has least effect.

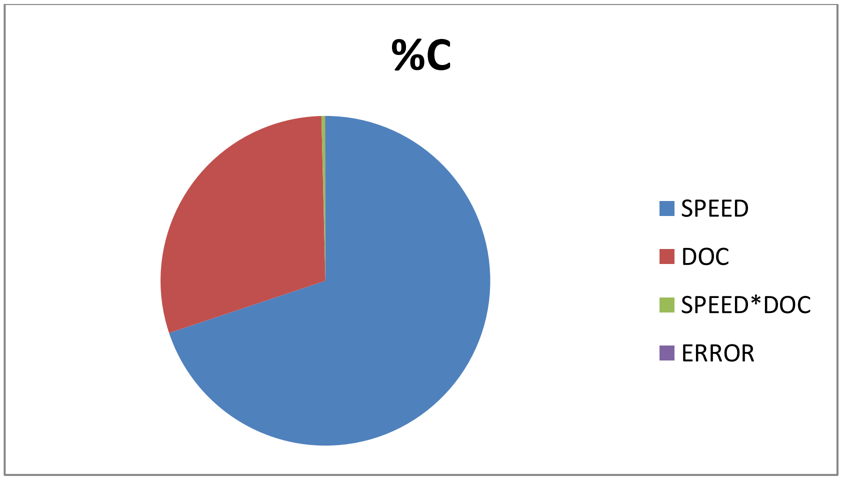


Fig 17: Pie chart representing percentage contribution of parameters for raising temperature for cobalt tool

CHAPTER 7

CONCLUSION

The temperature of tool-chip interface temperatures of high-speed steel and cobalt bit were determined during turning operation at low-speed medium-speed and high-speed machining processes. Infrared thermometer is used to measure temperature in the tool-chip interface. The result shows that the most important factors that increase cutting temperature are cutting speed followed by depth of cut.

1. Using ANOVA table we concluded that speed was the most important parameter followed by depth of cut to increase the temperature during machining.

2. It can be seen that an increase in cutting speed produces an increase in cutting temperature. This result is due to the fact that increasing the cutting speed increases the cutting forces. Increasing the cutting temperature requires more energy to remove material.

3. It can be seen that an increase in the depth of cut results in an increase in the cutting temperature. When the material is more plastically deformed the energy is converted into heat as the material is exposed to the most severe deformations; since the deformation is elastic they represent a fraction of the total deformation.

4. Cobalt tools generate higher temperatures during machining than high speed steel tools under the same cutting conditions.

Scope for future work

In this study three different analyzes were compared with experimental temperature measurements at low to medium and high speed machining processes and tool material was chosen HSS and cobalt bit. Similarly this analysis can be done for different combinations of cutting tools and work pieces or different tool geometries. It is also possible to perform machining analysis by changing the cutting conditions.

We can also use various simulation techniques like ANSYS for verifying above results in experiments.

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