Evaluation of Turning Performance Characteristics Using Grey Relational Grade Analysis

A project report submitted in partial fulfilment of the requirement for

the award of the degree of

BACHELOR OF TECHNOLOGY

IN

MECHANICAL ENGINEERING

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Autonomous status accorded by UGC and Andhra University
(Approved by AICTE, Permanently Affiliated to Andhra University,
Accredited and reaccredited by NBA, accredited by NAAC- 'A' Grade)
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(2017- 2021)

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CERTIFICATE

This is to certify that the Project Report entitled **"EVALUATION OF TURNING PERFORMANCE CHARACTERISTICS USING GREY RELATIONAL GRADE ANALYSIS"** being submitted by DOGGA RAKESH (317126520074), SHASHANK ACHANTA (317126520114), BURADA SIVA (317126520070), AMBATI RAM SHARVANI (317126520062), ADARI TEJA (317126520061) in partial fulfillments for the award of degree of **BACHELOR OF TECHNOLOGY** in **MECHANICAL ENGINEERING**. It is the work of bona-fide, carried out under the guidance and supervision of **MR.CH.MAHESWARA RAO**, Assistant Professor, Department Of Mechanical Engineering, ANITS during the academic year of 2017-2021.

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Abstract

The present work is to identify the effect of turning process parameters on the performance measures during wet turning of AA7075. The work material predominantly used for aircraft fittings, gears and shafts, missile parts, worm gears and aerospace/defense applications etc. Number of experiments were conducted based on Taguchi's mixed L9 orthogonal array (OA) using coated tungsten carbide tools. The multiple responses of material removal rate (MRR) and Surface Roughness characteristics (R_a, R_q and R_z) were estimated and analyzed using Taguchi based Grey analysis in order to find the optimal combination of cutting parameters.

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Chapter-1
Introduction

Turing is the machining operation that produces cylindrical parts. In its basic from, it can be defined as the machining of external surfaces:

- With the workpiece rotating
- With a single-point cutting tool
- With the cutting tool feeling parallel to the axis of the workpiece and at a distance that will remove the outer surface of the work.

Taper turning is practically the same, except that the cutter path is at an angle to the work axis. Similarly, in contour turning the distance of the cutter from the work axis is varied to produce the desired shape. Even though a single-point tool is specified, this does not exclude multiple-tool setup, which is often employed in turning. In such setups, each tool operates independently as a single-point cutter.

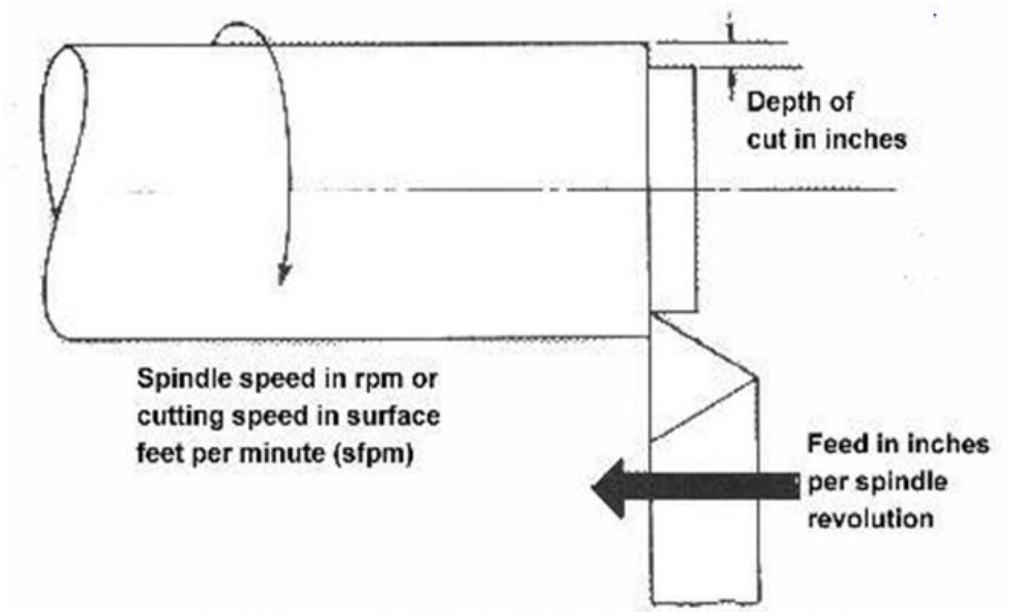

Figure 1.1. Turning Operation

1.1 Lathe Machine Operations:

The machine operations are classified into three main categories and are as follows.
Following are the lathe machine operations done either by holding the workpiece between centres or by a chuck:

- ➢ Turning operation
- ▪ Plain or straight turning
- ▪ Rough turning
- ▪ Shoulder turning
- ▪ Taper turning
- ▪ Eccentric turning
- ➢ Facing operation
- ➢ Chamfering operation

- Knurling operation
- Thread cutting operation
- filing operation
- Polishing operation
- Grooving operation
- Spinning operation
- Spring winding
- Forming

Lathe machine operations which are performed by holding the work by a chuck or a faceplate or an angle plate are:

- Drilling
- Reaming
- Boring
- Contour boring
- Taper boring
- Tapping
- Under cutting
- Internal thread cutting
- Parting-off

1.1.3 The operation which is performed by using special attachments is:

- Grinding
- Milling

Turning:

It is the most common type of operation in all lathe operations. Turning is the operation of removing the excess material from the workpiece to produce a cylindrical surface to desired length.

The job held between the centre and a chuck and rotating at a required speed. The tool moves in a longitudinal direction to give the fees towards the headstock with proper depth of cut. The surface finish is very good.

Facing:

It is an operation of reducing of reduction the length of the workpiece by feeding the perpendicular to the lathe axis. This operation of reducing a flat surface on the end of the workpiece. For this operation, regular turning tool or facing tool may use. The cutting edge of the tool should set to the same height as the centre of the workpiece.

Facing consists of 2 operations

Roughing: Here the depth of cut is 1.3mm
Finishing: Here the depth of cut is 0.2-0.1mm.

Chamfering Operation:

It is the operation of getting a bevelled surface at the edge of a cylindrical workpiece. This operation is done in case of bolt ends shaft ends. Chamfering helps to avoid damage to the sharp edges and protect the operation by hands. Chamfering on bolt helps to screw the nut easily.

Knurling Operation:

It is an operation of obtaining a diamond shape on the workpiece for the gripping purpose. This is done to provide better gripping surfaces when operated by hands. It is done using a knurling tool. The tool consists of a set of hardened steel roller, roller and it is held rigidly on the tool post.

Knurling is done at the lowest speed available on a lathe. It is done on the handles and also in case of ends of gauges. The feed varies from 1 to 2mm per revolution. Two or three cuts may be necessary to give the full impression.

Thread Cutting:

It is the important operation in the lathe to obtain the continuous "helical grooves" or "threads".

When the threads or helical grooves are formed on the surface of the workpiece is called external thread cutting. When the threads or helical grooves are formed on the inner surface of the workpiece is called internal thread cutting. The workpiece is rotating between the two centres i.e., live centre and dead centre so the lathe.

Here the tool is moved longitudinally to obtain the required type of thread. When the tool is moved from the right to left, we get the left-hand thread. Similarly, when the tool is moved from left to right, we get the right-hand thread.

Here the motion of the carriage is provided by the lead screw. A pair of change gears drives the lead screw and by rotating the handle the depth if cut can be controlled.

Grooving:

It is the process of reducing the diameter of a workpiece over a very narrow surface. It is done by a groove tool. A grooving tool is similar to the parting-off tool. It is the often done at the end of a thread or adjacent to a shoulder to leave a small margin.

Forming:

It is the process of turning a convex, concave or any irregular shape. Forming-turning may be accomplished by the following method:

- Using a forming tool.
- Combining cross and longitudinal feed.
- Tracing or copying a template.

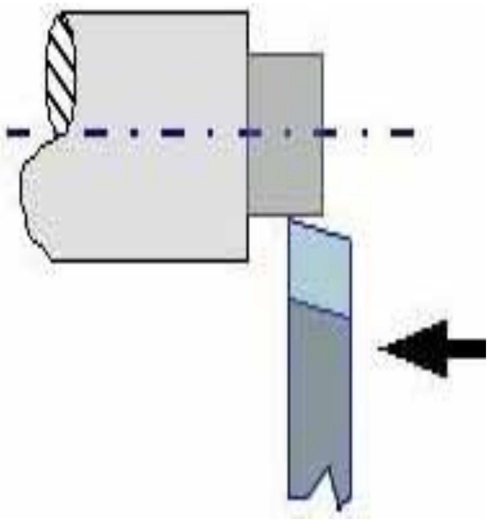

Figure 1.2a. Producing a Cylindrical Surface

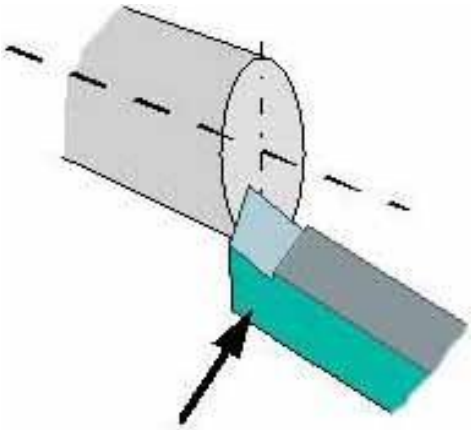

Figure 2b. Producing a Flat Surface

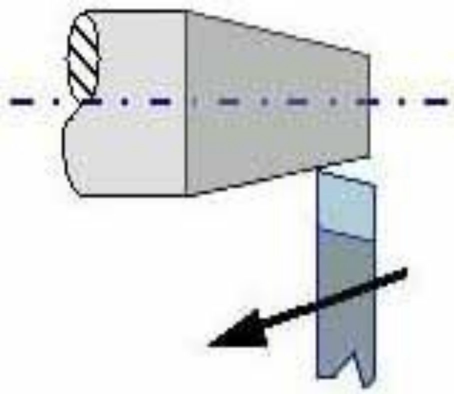

Figure 2c. Taper Turning

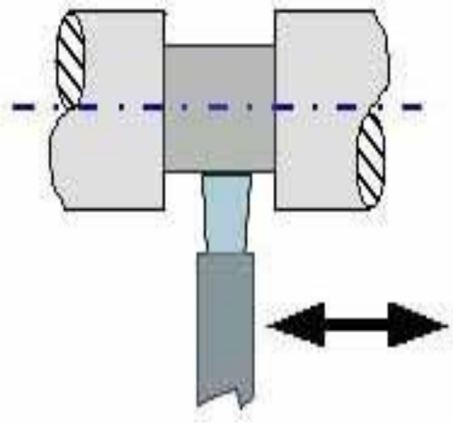

Figure 2d. Parting Off / Under Cutting

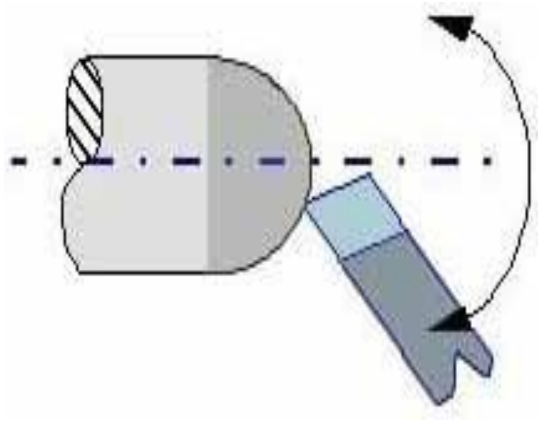

Figure 2e. Radius Turning Attachment

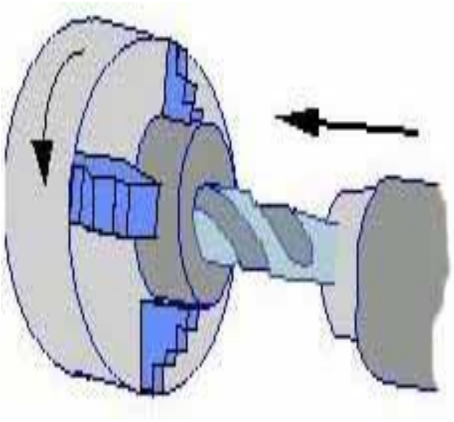

Figure 2f. Drilling on a Lathe

Cutting Tools

The tool used in a lathe is known as a single point cutting tool. It has one cutting edge or point whereas a drill has two cutting edges and a file has numerous points or teeth.

The lathe tool shears the metal rather than cuts as will be seen later and it can only do so if there is relative motion between the tool and the workpiece. For example, the work is rotating and the tool is moved into its forms an obstruction and shearing takes place. Of course the amount of the movement is of paramount importance – too much at once could for instance result in breakage of the tool.

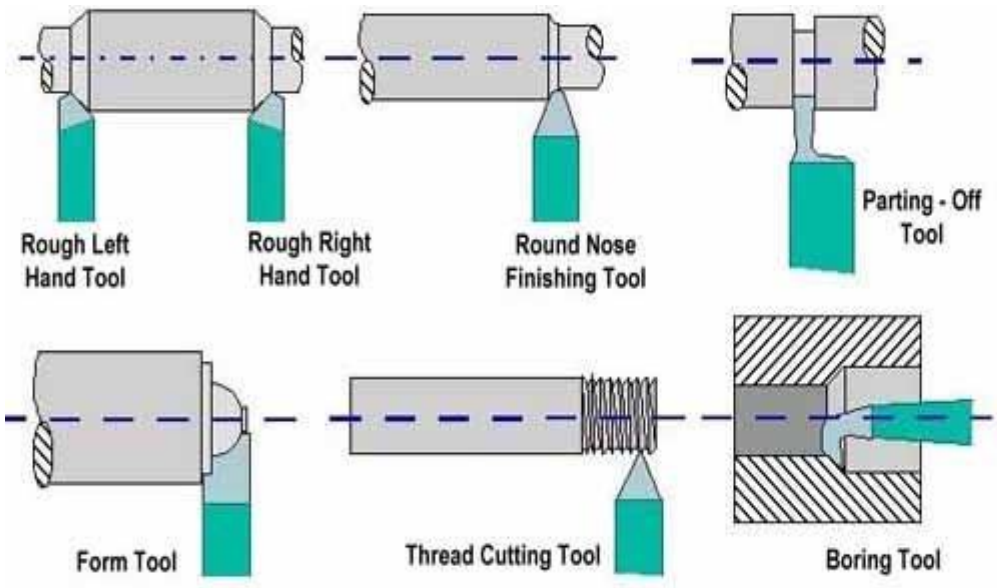

Figure 1.3. Types of Cutting Tool

The type and design of the tools selected will depend on the job in hand, the machining operation selected and material to be cut. The correct tool especially.

The various face angles are essential if the operation is to be dine in a cost effective (i.e., productive) way. The tools used in the lathe are various, some of which are shown in figure 3.

1.2.1 Tool Angle

There are three important angles in the construction of a cutting tool rake angle, clearance angle and plan approach angle.

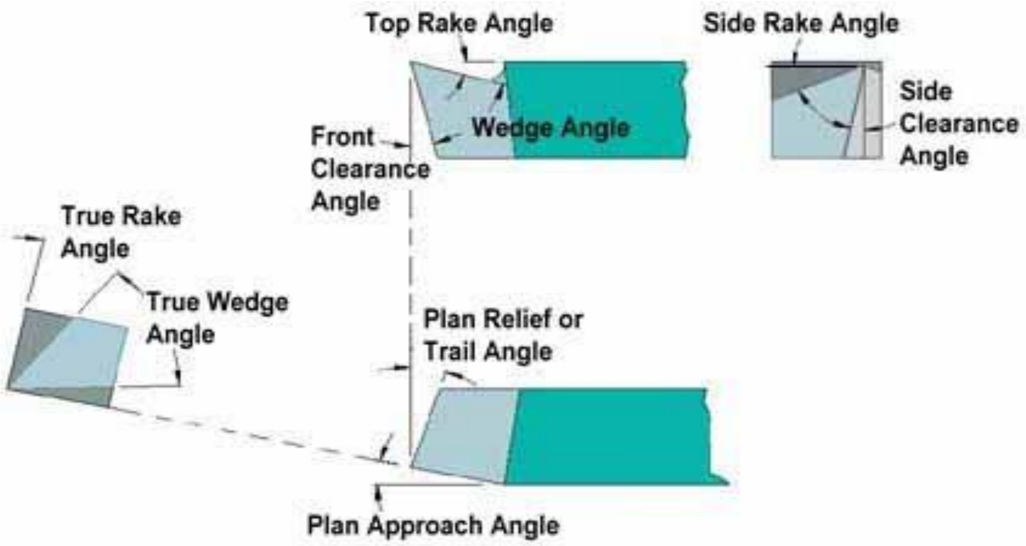

Figure 1.4. Main Features of a Single Point Cutting Tool

Rake Angle

Rake angle is the angle between the top face of the tool and the normal to the work surface at the cutting edge. In general, the larger the rake angle, the smaller the cutting force on the tool, since for a given depth of cut the shear plane AB, shown in Figure 4 decreases as rake angle increases. A large rake angle will improve cutting action, but would lead to early tool failure, since the tool wedge angle is relatively weak. A compromise must therefore be made between adequate strength and good cutting action.

Table 1.1 Typical value for top rake angle

Metal Being Cut	Cast Iron	Hard Steel/ Brass	Medium Carbon Steel	Mild Steel	Aluminium
Total Rake Angle	0^o	8^o	14^o	20^o	40^o

Clearance Angle

Clearance angle is the angle between the flank or front face of the tool and a tangent to the work surface originating at the cutting edge. All cutting tools must have clearance to allow cutting to take place. Clearance should be kept to a minimum, as excessive clearance angle will not improve cutting efficiency and will merely weaken the tool. Typical value for front clearance angle is 6° in external turning.

Plan Profile of Tool

The plan shape of the tool is often dictated by the shape of the work, but it also has an effect on the tool life and the cutting process. Figure 6 shows two tools, one where a square edge is desired and the other where the steps in the work end with a chamfer or angle. The diagram shows that, for the same depth of cut, the angled tool has a much greater length of cutting edge in contact with the work and thus the load per unit length of the edge is reduced. The angle at which the edge approaches the work should in theory be as large as possible, but if too large, chatter may occur. This angle, known as the Plan Approach Angle, should therefore be as large as possible without causing chatter.

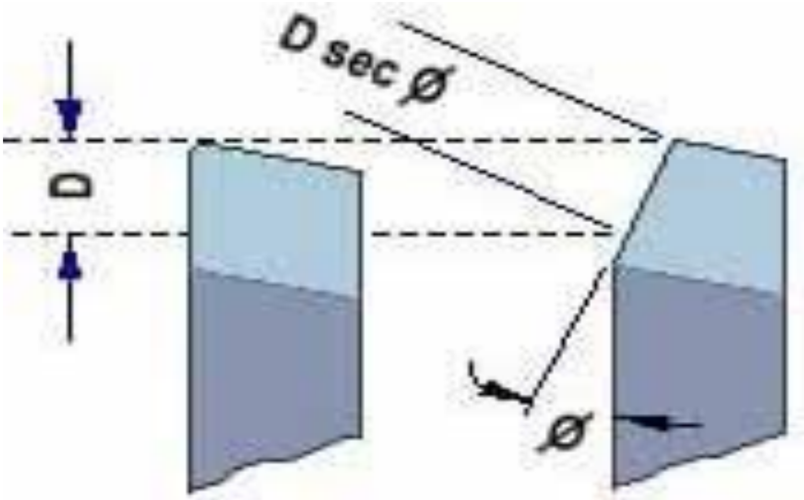

Figure 1.5. Plan Approach Angle.

The trailing edge of the tool is ground backwards to give clearance and prevent rubbing and a good general guide is to grind the trailing edge at 90° to the cutting edge. Thus the Trail Angle or Relief Angle will depend upon the approach angle.

A small nose radius on the tool improves the cutting and reduces tool wear. If a sharp point is used it gives poor finish and wears rapidly.

1.3. Basic Metal Cutting Theory

The usual conception of cutting suggests clearing the substance apart with a thin knife or wedge. When metal is cut the action is rather different and although the tool will always be wedge shaped in the cutting area and the cutting edge should always be sharp the wedge angle will be far too great for it to be considered knife shaped. Consequently a shearing action takes place when the work moves against the tool.

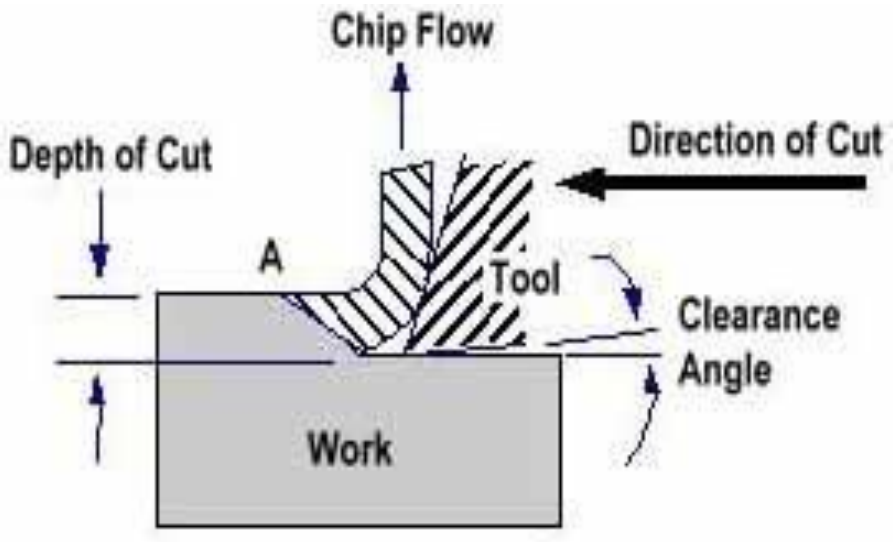

Figure 1.6. Basic Metal Cutting Theory

Figure 1.6 shows a tool being moved against a fixed work piece. When the cut is in progress the chip presses heavily on the top face of the tool and continuous shearing takes place across the shear plane AB. Although the Figure shows a tool working in the horizontal plane with the workpiece stationary, the same action takes place with the work piece revolving and the tool stationary.

1.3.1 Chip Formation &Chip Breaker

The type of chip produced depends on the material being machined and the cutting conditions at the time. These conditions include the type of tool used tool, rate of cutting condition of the machine and the use or absence of a cutting fluid.

Continuous Chip

This leaves the tool as a long ribbon and is common when cutting most ductile materials such as mild steel, copper and Aluminium. It is associated with good tool angles, correct speeds and feeds, and the use of cutting fluid.

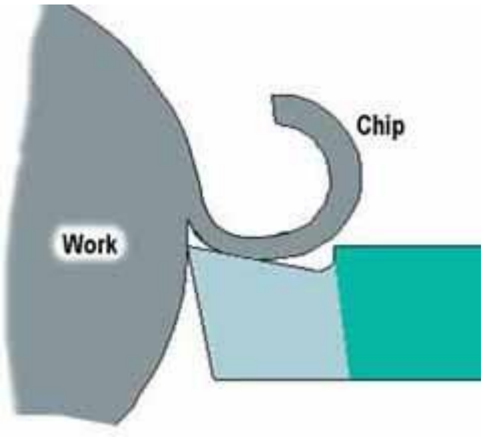

Figure 1.7. Continuous Chip

Discontinuous Chip

The chip leaves the tool as small segments of metal resulted from cutting brittle metals such as cast iron and cast brass with tools having small rake angles. There is nothing wrong with this type of chip in these circumstances.

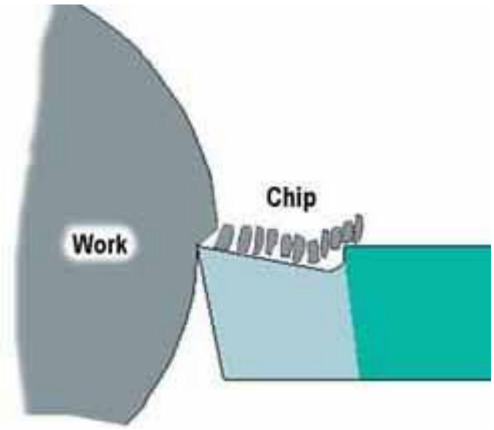

Figure 1.8. Discontinuous Chip

Continuous Chip with Builtup Edge

This is a chip to be avoided and is caused by small particles from the workpiece becoming welded to the tool face under high pressure and heat. The phenomenon results in a poor finish and damage to the tool. It can be minimised or prevented by using light cuts at higher speeds with an appropriate cutting lubricant.

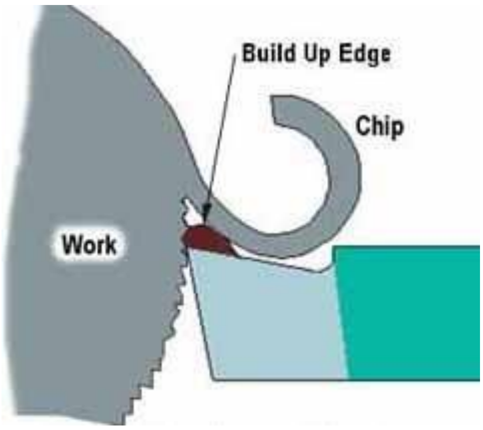

Figure 1.9. Continuous Chip with Buildup Edge

Chip Breaker

A chip breaker is used to break the continuous chip into sections so that the chips cannot tangle around the cutting tool. The simplest form of chip breaker is made by grinding a groove on the tool face a few millimeters behind the cutting edge.

1.4. Cutting Parameters

As you proceed to the process of metal cutting, the relative `speed' of work piece rotation and `feed' rates of the cutting tool coupled to the material to be cut must be given your serious attention. This relationship is of paramount importance if items are to be manufactured in a cost-effective way in the minimum time, in accordance with the laid down specifications for quality of surface finish and accuracy. You, as a potential supervisory / management level engineer, must take particular note of these important parameters and ensure that you gain a fundamental understanding of factors involved.

1.4.1. Cutting Speed

All materials have an optimum Cutting Speed and it is defined as the speed at which a point on the surface of the work passes the cutting edge or point of the tool and is normally given in meters/min. To calculate the spindle Speed required,

$$N = \frac{Cs\ X\ 1000}{\pi d}$$

Where:

N = Spindle Speed (RPM)
CS = Cutting Speed of Metal (m/min) d = Diameter of Work piece.

Table 2 shows the cutting speed recommended for some common metals. It may be possible to exceed these speeds for light finishing cuts. For heavy cuts they should be reduced.

Table 1.2. Recommended Cutting Speeds for different steels.

Metal	Meters /Min
Cast Iron	20-28
Mild Steel	18-25
High Speed Steel	12-18
Brass	45-90
Bronze	15-21
Aluminium	up to 300

1.4.2. Feed

The term `feed' is used to describe the distance the tool moves per revolution of the workpiece and depends largely on the surface finish required. For roughing out a soft material a feed of up to 0.25 mm per revolution may be used. With tougher materials this should be reduced to a maximum of 0.10 mm/rev. Finishing requires a finer feed then what is recommended.

1.4.3 Depth of Cut

The depth of cut is the perpendicular distance measured from the machined surface to the uncut surface of the work piece.

1.5. Cutting Fluid & Lubricant

The aims in metal cutting are to retain accuracy, to get a good surface finish on the workpiece and at the same time to have a longer tool life.

However, during the metal cutting process heat is generated due to:

- The deformation of the material ahead of the tool
- Friction at the tool point

Heat generated due to friction can readily be reduced by using a lubricant. Heat caused by deformation cannot be reduced and yet it can be carried away by a fluid. Thus the use of a cutting fluid will serve to reduce the tool wear, give better surface finish and a tighter dimensional control.

The proper selection, mixing and application of cutting fluids is however often misunderstood and frequently neglected in machining practice. In order that the cutting fluid performs its functions properly it is necessary to ensure that the cutting fluid be applied directly to the cutting zone so that it can form a film at the sliding surfaces of the tool.

Cutting fluids in Common Use

Water:

It has a high specific heat but is poor in lubrication and also encourages rusting. It is used as a cooling agent during tool grinding.

Soluble oils:

Oil will not dissolve in water but can be made to form an intimate mixture or emulsion by adding emulsifying agents. The oil is then suspended in the water in the form of tiny droplets. These fluids have average lubricating abilities and good cooling properties. Soluble oils are suitable for light cutting operations on general purpose machines where high rates of metal removal are often not of prime importance. There are many forms of soluble oil in the market and the supplier’s instruction should be followed regarding the proportions of the `mix'.

Mineral Oils:

They are used for heavier cutting operations because of their good lubricating properties and are commonly found in production machines where high rates of metal removal are employed. Mineral oils are very suitable for steels but should not be used on copper or its alloys since it has a corrosive effect.

Vegetable Oils:

They are good lubricants but are of little used since they are liable to decompose and smell badly.

1.6. CNC Lathe

Numerical-control lathes differ from hydraulically controlled tracer lathes primarily in that their cutting tools are controlled electronically. All tool movements during cuts, as well as all tool indexing, cross-slide operations, and changes of speed and feed, are pre-engineered and programmed on a punched tape for electronic control of all machine movements. Advantages of the NC lathe include low inventory of tooling and fully controlled cutting conditions. For copying work, NC lathes have the capability of machining any cylindrical form without the need for a template. However, compared to tracer lathes, NC machines can be quite expensive.

An important advance in the philosophy of machine tool numerical control that took place in the early 1970s was the shift toward the use of computers instead of controller units in NC systems. This produced both computer numerical control (CNC) and direct numerical control (DNC). Computer numerical control is a self-contained NC system for a single machine tool including a dedicated computer controlled by stored instructions to perform some or all of the basic NC functions. With DNC, several machine tools are directly controlled by a central computer. Of the two types of computer control, CNC has become much more widely used for manufacturing systems, machine tools, welders, and laser beam cutters mainly because of its flexibility and the lower investment required. The preference of CNC over DNC is increasing as a result of the availability and declining costs of minicomputers and microcomputers.

One of the objectives of CNC systems is to replace as much of the conventional NC hardware as possible with software and to simplify the remaining hardware. There are many ways in which functions can be shared between software and hardware in such systems, but all involve some hardware in the controller dedicated to the individual machine. This hardware must contain at least the servo amplifiers, the transducer circuits, and the interface components, as shown in Fig. 1.10

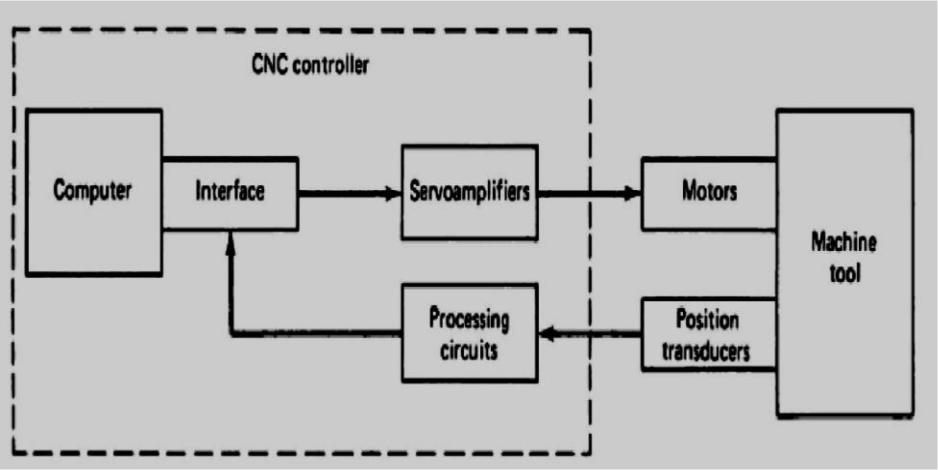

Fig. 1.10. Block diagram of a CNC machine

The software of a CNC system consists of at least three major programs: A part program, A service program, A control program The part program contains a description of the geometry of the part being produced and the cutting conditions, such as spindle speed and feed rate. The service program is used to check, edit, and correct the part program and to run system diagnostics. The control program accepts the part program as input data and produces signals to drive the axes of motion of the machine.

The CNC controllers of the 1980s are more powerful and more user friendly than earlier units. They incorporate troubleshooting features such as on-board diagnostics, which allow self-testing of the controller, and simulation mode, which is used to test part programs without generating axes motions. Many controllers offer high-level programming facilities, three-dimensional tool path animation with graphics, tool data base, and pre-selection of cutting parameters. The modern machine controller is a workstation. It is capable of communicating with other controllers and of being integrated into a flexible manufacturing system in the future, thus permitting the gradual construction of a full flexible manufacturing system. Numerical control was introduced and developed in the metalworking industry, and the largest concentration of NC equipment remains in metalworking shops. Numerical control has been successfully implemented for turning, milling, drilling, grinding, boring, punching, and electrical discharge machines. It is interesting to note that numerical control has made possible the development of machines with basic capabilities that far surpass those of conventional machines. For example, sophisticated NC milling machines maintain control over five axes of motion and can literally sculpt complex surfaces. A new breed of NC machine tool is the machining center and the turning center, which incorporate the functions of many machines into a single device. A machining center can access multiple tools to perform such operations as milling, drilling, boring, and tapping. A turning center is a powerful lathe equipped with an automatic tool changer. Other types of NC machines include welding machines, drafting machines, tube benders, inspection machines, and wiring machines in the electronics industry.

A common feature in numerical control and robotics is that the required path of the tool is generated by the combined motion of the individual axes. In numerical control, the tool is the cutting tool, such as a milling cutter or a drill; in robotics, the tool is the instrument at the far end of the manipulator, which might be a gripper, a welding gun, or a paint spraying gun. Robot systems, however, are more complex than machine tool CNC systems for the reason discussed below.

Machine tools require control of the position of the tool cutting edge in space. In many cases, the control of three axes is adequate. Robots require the control of both the position of the tool center point and the orientation of the tool; this is achieved by controlling six axes of motion (or degrees of freedom). Some robot systems use more than six axes, and some CNC machines use more than three axes of motion. A typical example is the addition of a rotary table to a three-axis milling machine. On the other hand, many robot systems use fewer than six axes, and in such cases the wrist section contains fewer than three degrees of freedom. Similarly, there are CNC machines with only two numerically controlled axes of motion.

1.6.1. Fundamentals of Numerical Control

Numerical control equipment has been defined by the Electronic Industries Association (EIA) as a system in which actions are controlled by the direct insertion of numerical data at some point. The system must automatically interpret at least some portion of these data. In a typical NC or CNC system, the numerical data required for producing a part are maintained on a disk or on a tape and called the part program. The part program is arranged in the form of blocks of information. Each block contains the numerical data required to produce one segment of the work-piece profile. The block contains, in coded form, all the information needed for processing a segment of the work- piece: the segment length, its cutting speed, feed rate, and so on. Dimensional information such as length, width, and radii of circles and the contour form such as linear, circular, or other are taken from an engineering drawing. Dimensions are given separately for each axis of motion i.e., X, Y, and so on. Cutting speed, feed rate, and auxiliary functions such as coolant on and off, spindle direction, clamp, and gear changes are programmed according to surface finish, tolerance, and machining requirements.

Compared to a conventional machine tool, the NC system replaces the manual actions of the operator. In conventional machining, a part is produced by moving a cutting tool along a work- piece by means of powered slides that are engaged and disengaged by an operator. Contour cuttings are performed by an expert operator by sight. On the other hand, the operators of NC machine tools need not be skilled machinists. They only have to monitor the operations of the machine, operate the tape reader, and load and remove the work-piece. Most intellectual operations that were formerly done by the operator are now included in the part program. However, because the operator works with a sophisticated and expensive system, intelligence, clear thinking, and good judgment are essential qualifications of a good NC operator.

Preparing the part program of an NC machine tool requires a part programmer. The part programmer should possess knowledge and experience in mechanical engineering fields. Knowledge of tools, cutting fluids, fixture design techniques, machinability data, and process engineering are all of considerable importance. The part programmer must be familiar with the function of NC machine tools and machining processes and must decide on the optimum sequence of operations. The part program can be written manually, or a computer-assisted language, such as the automatically programmed tool language, can be used. In NC machines, the part dimensions are presented in part programs by integers. In CNC machines, the dimensions in part programs are sometimes expressed as numbers with a decimal point, but are always stored in the computer as integers. Each unit of these integers corresponds to the position resolution of the axes of motion and is referred to as the basic length unit (BLU). The BLU is also known as the increment size or bit weight, and in practice it corresponds approximately to the accuracy of the NC system.

In NC and CNC machine tools, each axis of motion is equipped with a separate driving device, which replaces the hand wheel of the conventional machine. The driving device may be a dc motor, a hydraulic actuator, or a stepping motor. The type selected is determined by the power requirements and the machine.

An axis of motion in numerical control means an axis in which the cutting tool moves relative to the work-piece. This movement is achieved by the motion of the machine tool slides. The main three axes of motion are referred to as the X-, Y-, and Z-axes. The Z axis is perpendicular to both X and Y in order to create a right-hand coordinate system. For example, in a vertical drilling machine (as one faces the machine), a +X command moves the worktable from left to right, a +Y command moves it from front to back, and a +Z command moves the drill up, away from the work-piece. The X-, Y-, and Z-axes are always assigned to create a right-hand Cartesian coordinate system.

Each axis of motion also has a separate control loop. The control loops of NC or CNC systems use two types of feedback devices shown in fig. 3, tachometers to monitor velocity and encoders or other position transducers (for example, resolvers) to measure position. The controller compares the actual position with the required one and generates an error. The control loop is designed in such a way as to reduce the error, that is, the loop is a negative-feedback type. A common requirement of continuous-path NC and CNC systems is the generation of coordinated movement of the separately driven axes in order to achieve the desired path of the tool. This coordination is accomplished by interpolators. Numerical control systems contain hardware interpolators, but in CNC systems interpolators are implemented by software.

1.6.2. Advantages of NC Systems

It has been clearly shown that NC manufacturing reduces the number of direct employees because fewer multipurpose NC machines are required and, in some cases, one operator can operate more than one machine. However, the ratio of indirect to direct employees might increase, and in turn, overall employment in the industry might rise despite increased automation and mechanization[6]. Output would of course also increase. Realistically, then, the advantage is not in lowering labor costs but in increasing the output per man-hour. Handling costs with NC technology have decreased, in some cases remarkably. Setup times have been substantially reduced, and actual productive time has been substantially increased. A further savings of time is achieved while passing from one operation to another during the machining of the work-piece. With a conventional machine tool, the work must be stopped at such points because the operator must go to the next step. The operator must stop the cutting process frequently and measure the part dimensions to ensure that the material is not overcut. It has been proved that the time wasted on measurements is frequently 70 to 80% of the total working time[7]. The rate of production is also decreased because of operator fatigue. In NC systems, these problems do not exist. Because the accuracy is repeatable with numerical control, inspection time is also reduced.

Numerical control produces higher-quality parts and makes possible the accurate manufacture of more complex designs without the usual loss in accuracy encountered in conventional manufacturing. Producing a part that must be cut with an accuracy of 0.01 mm or better may take a considerable amount of time using conventional methods. In numerical control using single-axis motion, obtaining such accuracies is the state-of-the-art, and they are maintained throughout the entire range of cutting speeds and feed rates. Another intangible advantage of numerical control is the production of complex parts that are not feasible in conventional manufacturing. Complex- contour cutting in three dimensions cannot be performed by manual operation. Even when it is possible, the operator must manipulate the two hand wheels of the table simultaneously while maintaining the required accuracy; thus, it becomes possible only when the part is simple and requires relatively low accuracies. It is obvious that in such work the NC machines save a considerable amount of time. Compared to conventional machining methods, the

NC machine tool has the following advantages:

- complete flexibility; a part program is needed only for producing a new part
- Accuracy is maintained through the full range of speeds and feeds
- The possibility of manufacturing a part of complicated contour
- A shorter production time
- 5. Higher productivity achieved by saving indirect time, such as setting up and adjusting the machine and using one operator to monitor several machining operations, or by using completely automatic operation in unmanned production.

1.6.3. NC Programming

Most NC and CNC machine tools use off-line programming methods, which can be either manual or computer assisted, such as programming with the aid of the automatically programmed tool language. During off-line programming, the machine remains in operation while a new part program is being written. Typically, when a part program is ready, it is stored on a punched tape or a floppy disk. The tape or disk is taken to the machine shop and loaded into the machine tool controller, and the part is subsequently produced. Manual part programs are written by programmers. First, the programmers must determine the machining parameters and the optimum sequence of operations to be performed. Based on this sequence, they calculate the tool path and write a manuscript. Each line of the manuscript, which is referred to as a block, contains the required data for transferring the cutting tool from one point to the next, including all machining instructions that should be executed either at the point or along the path between the points. A typical line Program according to this standard is as follows:

N10

G01

X-52000

Y9100

F315

S717

T65432

MO3 (EB)

The letter and the number that follows it are referred to as a word. For example, X- and M03 are words. The first letter of the word is the word address. Word addresses are denoted as follows: N, sequential number, G, preparatory function; X and Y, dimensional words; F. feed rate code; S, speed code; T, tool code; M, miscellaneous function; and EB, end-of-block character. The EB character is not printed but only punched or coded, and it is usually the carriage return code, thus permitting a new line to begin immediately afterward. The EB character indicates to the NC controller that the current reading is completed and that the axes of motion must start up. When this motion is accomplished, the next block is read.

1.7. Cutting Tools

Cutting tool is any tool that is used to remove material from the work-piece by means of shear deformation. Cutting may be accomplished by single-point or multipoint tools. Single-point tools are used in turning, shaping, planing and similar operations, and remove material by means of one cutting edge. Milling and drilling tools are often multipoint tools. Grinding tools are also multipoint tools. Each grain of abrasive functions as a microscopic single-point cutting edge, and shears a tiny chip. Cutting tools must be made of a material harder than the material which is to be cut, and the tool must be able to withstand the heat generated in the metal-cutting process. Also, the tool must have a specific geometry, with clearance angles designed so that the cutting edge can contact the work-piece without the rest of the tool dragging on the work-piece surface. The angle of the cutting face is also important, as is the flute width, number of flutes or teeth, and margin size. In order to have a long working life, all of the above must be optimized, plus the speeds and feeds at which the tool is run.

Principal categories of cutting tools include single point lathe tools, multipoint milling tools, drills, reamers, and taps. All of these tools may be standard catalog items or tooling designed and custom- built for a specific manufacturing need.

The number one error when selecting tooling is calculating monetary savings based on lowest cost per tool, rather than on maximized productivity and extended tool life. To effectively select tools for machining, a machinist or engineer must have specific information about the following:

- 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

Changes in any of these conditions may require a thorough review of any cutting tool selection.

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

No single cutting tool material incorporates all these qualities. Instead, trade-offs occur among the various tool materials. For example, ceramic cutting tool material has high heat resistance, but has a low resistance to shock and impact. Every new and evolving tool development has an application where it will provide superior performance over others. Many newer cutting tool materials tend to reduce, but not eliminate the applications of older cutting tool materials.

1.7.1. Single Point HSS Tool

Single point cutting tools ground to specific shapes are frequently used to produce contours on work-pieces when tool travel is limited to straight-line movement, most metal removal in lathe turning is accomplished with single-point tools. Single-point tools may be produced from a solid bar of tool steel by grinding the appropriate cutting edge on one end, or they may be made of less- costly stock and provided with a tip, or insert, of carbide or other cutting material. The insert may be held in place mechanically or by brazing, soldering, or welding. Brazed, soldered, or welded inserts are resharpened after becoming dull through use; inserts held in place mechanically are usually of the disposable type.

Design of Single-Point Tools

Standard angles for single-point tools are illustrated and named in Fig. 4 which shows how back rake angle, side rake angle, end relief angle, side relief angle, end cutting edge angle, side cutting- edge angle, and nose radius are related in order to aid engineers in designing single-point cutting tools.

Back rake angle

It is the angle between the cutting face of the tool and the shank or holder, measured parallel to the side of the shank or holder. The angle is positive if, as shown in Fig. 4, it slopes from the cutting point downward toward the shank, and negative if it slopes upward toward the shank.

Side rake angle

It is the angle between the cutting face of the tool and the shank or holder, measured perpendicular to the side of the shank or holder. The angle is positive if, as shown in Fig. 4, it slopes downward away from the cutting edge to the opposite side of the shank, and negative if it slopes upward.

End relief angle

It is the angle between the end face of the tool and a line drawn from the cutting edge perpendicular to the base of the shank or holder and usually is measured at right angles to the end cutting edge.

Side relief angle

It is the angle between the side flank immediately below the side cutting edge and a line drawn through the side cutting edge perpendicular to the base of the tool or tool holder and usually is measured at right angles to the side flank.

End cutting-edge angle

It is the angle between the end cutting edge of the tool and a line perpendicular to the side of the shank. Side cutting-edge angle, also called lead angle, is the angle between the side cutting edge and the projected side of the shank or holder.

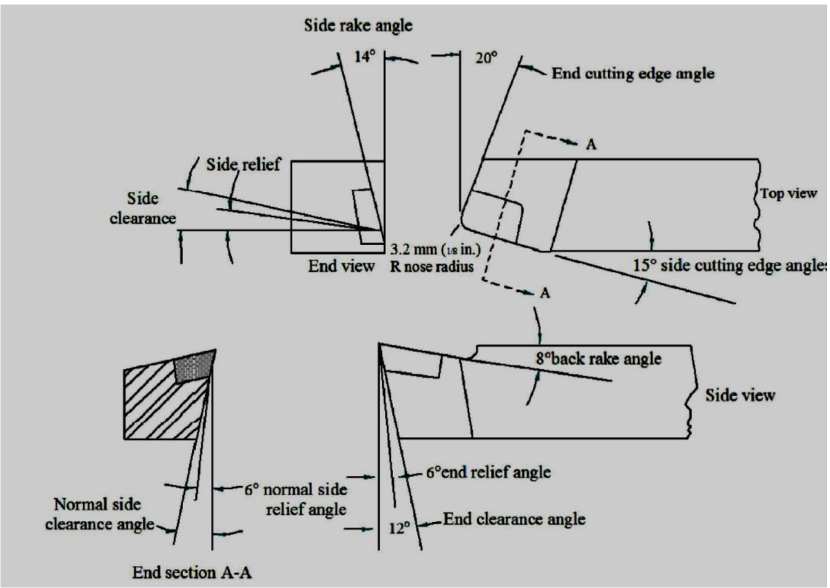

Fig. 1.11 Geometry of single point cutting tool

Nose radius

It is the radius on the tool between the end and the side cutting edges. The nose contour, normally specified as a radius, removes the fragile corner of the tool, prolongs tool life, and improves finish. The radius may be large for maximum strength or for rough cutting tools, but it may be reduced for light feeds. A radius too large may cause chatter, but the larger it is without chattering, the better the finish.

Tool design influences the power required at the tool point for turning. The side rake angle has the greatest effect. Tool design is particularly important in tracer lathe turning, for which only one tool is used to make all cuts. Because the minimum number of passes is desirable, so is the fastest rate of metal removal that is compatible with maintenance of dimensional and finish requirements. The use of only one cutting tool imposes severe restrictions on the shape of the tool. A tool often must be provided with a -3° side cutting edge angle and a 30° minimum end cutting-edge angle, resulting in a weak structure at the nose of the cutting edge. For this reason, heavy feed forces often must be avoided, if they have not already been ruled out because of required finish. Thus, surface speed becomes the criterion for determining maximum rate of metal removal, and the design of the cutting tool becomes vitally important in obtaining maximum metal removal and tool life. Increasing the surface cutting speed increases tool temperatures and results in premature tool wear.

1.8. Cutting Tool Materials

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. Developed around the year 1900, 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. Since the 1960s the development of powdered metal high-speed steel has allowed the production of near-net shaped cutting tools, such as drills, milling cutters and form tools. The use of coatings, particularly titanium nitride, allows high-speed steel tools to cut faster and last longer. Titanium nitride provides a high surface hardness, resists corrosion, and it minimizes friction.

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. Each type of carbide affects the cutting tool's characteristics differently. For example, a higher tungsten content increases wear resistance, but reduces tool strength. A higher percentage of cobalt binder increases strength, but lowers the wear resistance. Carbide is used in solid round tools or in the form of replaceable inserts. Every manufacturer of carbide tools offers a variety for specific applications. The proper choice can double tool life or double the cutting speed of the same tool. Shock resistant types are used for interrupted cutting. Harder, chemically-stable types are required for high speed finishing of steel. More heat-resistant tools are needed for machining the super-alloys, like Inconel and Hastelloy.

There are no effective standards for choosing carbide grade specifications so it is necessary to rely on the carbide suppliers to recommend grades for given applications. Manufacturers do use an ANSI code to identify their proprietary carbide product line. Two thirds of all carbide tools are coated. Coated tools should be considered for most applications because of their longer life and faster machining. Coating broadens the applications of a specific carbide tool. These coatings are applied in multiple layers of under .001 of an inch thickness. The main carbide insert and cutting tool coating materials are titanium carbide, titanium nitride, aluminium oxide, and titanium carbonitride. 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 available are 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. Ceramic tools are produced from the materials used to coat the carbide varieties such as titanium carbides and nitrides. They are especially useful in chemically reactive machining environments, for final finishing and some turning and milling operations.

Super-hard tool materials are divided into two categories: cubic boron nitride and polycrystalline diamond. Their cost can be 30 times that of a carbide insert, so their use is limited to well-chosen, cost effective applications. Cubic boron nitride is used for machining very hard ferrous materials such as steel dies, alloy steels and hard-facing materials.

Polycrystalline diamond is used for non-ferrous machining and for machining abrasive materials such as glass and some plastics. In some high volume applications, polycrystalline diamond inserts have outlasted carbide inserts by up to 100 times. All cutting tools are "perishable," meaning they have a finite working life. It is not a good practice to use worn, dull tools until they break. This is a safety hazard which creates scrap, impacts tool and part costs, and reduces productivity. Apart from breakage, cutting tools wear in many different ways, including:

- Edge wear and flank wear
- Cratering or top wear
- Chipping
- Built-up edge
- Deformation
- Thermal cracking

Edge and flank wear are both normal, slow types of tool wear. If the work material is highly abrasive, as with certain cast-irons, this type of wear will accelerate. Cratering occurs behind the cutting edge, and happens often in machining long chipping steels. If the crater grows large enough and contacts the cutting edge, the tool fails immediately. Cratering can be overcome by using titanium or tantalum carbide tools.

on a tool edge is an unpredictable form of tool failure. It is sometimes started when a high point on an edge breaks away. A stronger carbide grade, different edge preparation, or lead angle change may eliminate chipping. Built-up edge is a deposit of work-piece material adhering to the rake face of an insert.

These deposits can break off, pulling out pieces of carbide from the tool. Ductile materials, such as softer steels, aluminium, and copper cause this problem. The use of higher rake angles, faster cutting speeds, and high pressure cutting fluid all help eliminate built-up edge. Deformation of a tool or insert is due to heat build-up. Although very detrimental to the machining process, deformation is difficult to detect without the use of a microscope. Using a heat-resistant tool or reducing the cutting speed often help to prevent deformation. Thermal cracking occurs when inserts go through rapid heating and cooling cycles. Causes include interrupted cutting and poor application of cutting fluids.

1.8.1. Characteristics of Tool Material

For efficient cutting a tool must have the following properties:

Hot Hardness

This means the ability to retain its hardness at high temperatures. All cutting operations generate heat, which will affect the tool¡¦s hardness and eventually its ability to cut.

Strength and Resistance to Shock

At the start of a cut the first bite of the tool into the work results in considerable shock loading on the tool. It must obviously be strong enough to withstand it.

Low Coefficient of Friction

The tool rubbing against the workpiece and the chip rubbing on the top face of the tool produce heat which must be kept to a minimum.

1.8.2. Tool Materials in Common Use

High Carbon Steel Contains 1 - 1.4% carbon with some addition of chromium and tungsten to improve wear resistance. The steel begins to lose its hardness at about 250° C, and is not favoured for modern machining operations where high speeds and heavy cuts are usually employed.

High Speed Steel (H.S.S.)

Steel, which has a hot hardness value of about 600° C, possesses good strength and shock resistant properties. It is commonly used for single point lathe cutting tools and multi point cutting tools such as drills, reamers and milling cutters.

Cemented Carbides

An extremely hard material made from tungsten powder. Carbide tools are usually used in the form of brazed or clamped tips. High cutting speeds may be used and materials difficult to cut with HSS may be readily machined using carbide tipped tool.

Tool life

As a general rule the relationship between the tool life and cutting speed is $VT^n = C$

where;

V = cutting speed in m/min
T = tool life in min
C = a constant
For high-speed steel tools the value of C ranges from 0.14 to 0.1 and for carbide tools the value would be 0.2.

1.9. Effect of Cutting Parameters on Responses

Surface finish is one of the most important quality characteristics in manufacturing industries which influences the performance of mechanical parts as well as production cost. In recent times, modern industries are trying to achieve the high quality products in a very short time with less operator input. For that purpose, the computer numerically controlled machine tools with automated and flexible manufacturing systems have been implemented. In order to improve the product quality and efficiency in machining, recently, there has been intensive computation focusing on surface roughness at international level. This computation can be observed in turning processes especially in aerospace and automotive industry by increasing the alternative solution for obtaining better surface roughness. A good quality turning surface can lead to improvement in strength properties such as fatigue strength, corrosion resistance and thermal resistance. In addition, the final surface roughness also affects several function attributes of parts like friction, wearing, light reflection, heat transmission, coating and ability of distributing and holding a lubricant. Right selection of tool geometry and cutting parameters that affect surface roughness are important factors especially in providing tolerance. The desired finish surface is usually specified and the appropriate processes are selected to reach the required quality.

Surface roughness is one of the prime factors in evaluating the quality of a component as it affects all the dimensions of quality mentioned above. Since it is a very important factor of quality it has received serious attention for many years. It has formulated an important design feature in many situations such as parts subject to fatigue loads, precision fits, fastener holes and aesthetic requirements. Surface roughness imposes one of the most critical constraints for selection of machines and cutting parameters in process planning.

Surface Roughness is generally the vertical elevations made on the surface of the metal, for example, grooves from the tool or from each grinding granule on a grinding wheel. Although roughness is usually undesirable, it is difficult and expensive to control in manufacturing. Decreasing the roughness of a surface will usually increase exponentially its manufacturing costs. This often results in a trade-off between the manufacturing cost of a component and its performance in application.

Therefore, it is necessary to develop methods, which can be used for the prediction of the surface roughness according to technological parameters.

Measuring surface roughness is a crucial concern for an immense range of industries and applications, from auto component wear to medical implant efficacy, from micro electro-mechanical systems inspection to semiconductor thin-film uniformity. The performance and value of thousands of products and systems – from designer sunglass to advanced personal digital devices is governed by characterizing and controlling micro scale surface features, including micro-inch surface roughness. Many of the major advances in science and industry over the past half century would not have been possible without accurate surface roughness metrology.

The parameter most used for general surface roughness is Ra. It measures average roughness by comparing all the peaks and valleys to the mean line, and then averaging them all over the entire cut-off length.

1.9.1. Effect of Feed Rate and Depth of Cut on Surface Roughness

As expected, the roughness increases with feed rate. On the roughness profiles, the feed marks also become clearer and prominent. At lower feed rates the roughness becomes independent of feed rate and is a function of nose radius only. This causes higher micro roughness i.e. superimposed irregularities over the grooves generated by chip removal. The plastic flow component is comparatively more. Similarly, when feed rate is large and nose radius small, the surface roughness depends mainly on feed rate compared to nose radius. The plastic flow is opposite to feed direction with higher height at low feed rate which can also lead to higher roughness at low feed rate[11]. Similar difference has been reported whereby lower roughness occurred at higher feed rates owing to pure cutting action and relative absence of swelling.

In the same way at low feed rate material gets ploughed rather than form chips. In this way there exists a possibility of the existence of optimum feed rate. Though the theory suggests roughness to be a function of square of feed rate, in practice it is more like directly related to feed rate. This can be due to flattening of ridges due to side flow or tool work relative vibrations. These effects are corroborated by the Fourier transforms. The generation of several harmonics at lower feed rates due to ploughing action are clearly seen which conforms to the arguments presented for the micro roughness at low feed rates. The reduction in micro roughness and pronounced periodicity is seen with the diminishing corroborates the previous argument that at high feed rate the dominant mechanism is of chip removal rather than plastic flow.

1.9.2. Effect of Cutting Speed and Nose radius on surface roughness

The surface finish decreases with cutting speed of up to 100 m/min. With increasing the cutting speed further, the surface roughness of the machined work pieces seams to increase for both the grades. This is due to the increased friction between work piece and tool interface, which eventually increases the temperature in the cutting zone. Hence the shear strength of the material reduces and the material behaves in a ductile fashion. Moreover, the duplex stainless steel is sticky in nature which makes the chips to detach from the work piece with utmost difficulty, thereby increasing the surface roughness.

The decrease in surface roughness with increasing cutting speed up to 100 m/min is due to the decreasing built up edge formation tendency with increasing cutting speed. However, further increase in cutting speed causes an increase in surface roughness. This can be attributed to the increasing cutting tool nose wear at higher cutting speeds of 120, 140 and 180 m/min. It can also be observed that the minimum Ra of machined surfaces is obtained when cutting speed is at 100 /min.

1.9.3. Effect of cutting parameters on material removal rate

The material removal rate[21], MRR, can be defined as the volume of material removed divided by the machining time. Another way to define MRR is to imagine an "instantaneous" material removal rate as the rate at which the cross-section area of material being removed moves through the work- piece. Since the depth of cut is changing the material removal rate changes continuously during the process. In some cases this may be important. For example, if cutting forces and the resulting work- piece and tool deflections are of interest. The changing amount of material being removed along the tapered shaft means the cutting force and so the deflections will change during the process.

The material removal rate is the volume of material removed per unit time. Volume of material removed per unit time. Volume of material removed is a function of speed, feed and depth of cut. Higher the values of these more will be the material removal rate. It can be calculated by using the following equations 3, 4, and

Let, Di = initial diameter of the workpiece, mm,

d = Depth of cut, mm and

f = Feed, mm/revolution.

Volume of material removed in one revolution = $\pi D_i \times d \times f$ mm^3

MRR = $\pi D_i \times d \times f \times N$ mm^3/min.

In terms of cutting speeds V in m/min;
MRR = 1000 x v x d x f in mm^3/min

1.9.4. Effect of Cutting Parameters on Machining Time

The time during which a piece of equipment like machine, lathe, unit, or apparatus without direct participation of an operator, produces a change in the dimensions, shape, or state of a work-piece. The machining time depends on the characteristics of the manufacturing process; on the qualitative features of the raw material, semi-finished product, or stock; on the type of equipment and tool; and on the mechanization and automation of labour.

For machining time are calculated by determining the optimum operating schedule for the equipment, which ensures maximum output, minimum prime cost of the articles being processed, and the required quality level. For example, for metal cutting machine tools the standard machining time is determined according to well-grounded conditions of cutting (depth of cut, feed, cutting speed, and number of passes). Machining time may be reduced through the introduction of high speed processing methods and by using high-performance equipment and instruments. As the level of mechanization and automation of production rises, the proportion of machining time in the standards of piece rate time for completing a unit or for completing one manufacturing operation increases. The machining time can be calculated by using the equations 6, and 7.

$L = l + l_1 + l_2$

l = Length of surface tube machined.

l1 = Distance required for feeding the tool cross wise to incraese the depth of cut in mm

l2 = over travel of the tool at the end of each cut in mm

L = Distance travelled by the tool in the direction of the feed in single cut

f = feed mm/rev, N = rpm

Machining time = $\frac{L}{fN}\ min$

1.9.5. Effect of Cutting Parameters on Machining Force

To machine metal at a specified speed, feed, and depth of cut, with a specified lubricant, cutting tool material, and geometry, generates cutting forces and consumes power. A change in any of the variables alters the forces, but the change is indirect in that the engineer does not specify the forces, only the parameters that generate those forces. Forces are important in that they influence the deflections in the tools, the work pieces, and the work holders, which in turn affect the final part size. Forces also play a role in chatter and vibration phenomena common in machining.

Obviously, the manufacturing engineer would like to be able to predict forces (and power) so that he can safely specify the equipment for a manufacturing operation, including the machine tool, cutting tool, and work holding devices. The relation to calculate force[94] is given in equation 8.

F = k x d x f N

Where,

D = depth of cut in mm

F = feed per rotation in mm

K = specific cutting energy coefficient.

1.9.6. Effect of Cutting Parameters on Machining Power

Although one may wish to describe the energy per unit volume needed to form the chip, machine tools are typically rated in terms of power. Unit (or specific) power values can be calculated by dividing the power input to the process, F_cV, by the volumetric rate at which material is removed and then dividing this quantity by 33,000 to convert to horsepower. The specific power, P_s, is a measure of the difficulty involved in machining a particular material and can be used to estimate the total cutting power, *P*.

The specific power is the power required to remove a unit volume per unit time. Therefore, the specific and total powers are related as follows:

Where MRR is the material removal rate, or volume of material removed per unit time. The material removal rate can be computed as the uncut area multiplied by the rate at which the tool is moved perpendicular to the uncut area. Thus, the cutting parameters and machine tool kinematics define the material removal rate. There are many standard sources for specific power values for a variety of materials. Unfortunately, machine tools are not completely efficient. Losses due to component wear, friction, and other sources prevent some power from reaching the tool. Therefore, the gross

Power, P_g, needed by the motor can be defined as:

$$P_g = \frac{P}{\eta}$$

Where η is the efficiency of the machine

Power in Turning is the total power required in a turning operation can be calculated as

However, the material removal rate must be redefined for turning. Consider the turning operation, in which a billet of diameter *D* is turned with depth of cut *d* to diameter *D*1. The billet is rotated at *N* revolutions per minute, while the tool is fed at *f* r units (millimetres or inches) per revolution, which can be set directly on the machine. Recommended cutting speeds (in meters or feet per minute) are generally available from handbooks and can be converted to rotational speed where *V* = *DN*. Suggested feeds are also available.

Cutting power is an important parameter, especially in the case of rough operations, as it makes it possible to:

- Select and invest in a machine with a power output suited to the operation being carried out.

- Obtain the cutting conditions that allow the machines power to be used in the most effective way possible, so as to ensure optimal material removal rate while taking into account the capacity of the tool being used.

The required cutting power P, KW can be estimated using the following formula:

$$P = \frac{F\ X\ v}{60000}\ W$$

CHAPTER-2
LITERATURE SURVEY

Several experimental investigations have been carried over the years in order to study the influence of various cutting parameters on the surface finish of the workpiece, tool life using workpieces of different materials.

M.Nalbant et al.[1] implemented the Taguchi method to find out optimum cutting parameters for surface roughness in turning. ANOVA method was employed to study the performance characteristics in turning of AISI 1030 steel bar using TiN-coated tools. The study reveals that the feed rate and the insert radius were the main machining parameters that affect the surface roughness in turning of AISI 1030.

Ilhan Asilturk et al. [2] focuses on optimization of turning parameters based on Taguchi method to minimize surface roughness (Ra&Rz). Experimental have been carried out using L9 orthogonal array in CNC turning. Dry turning tests were carried out on hardened AISI 4140 with coated carbide tools. It has been observed that feed rate has the most significant effect on the surface roughness.

M. Antony Xavior et al. [3] carried out an experimental investigation to determine the influence of different cutting fluids on tool wear and surface roughness in turning of AISI 304 with carbide cutting insert. Additionally, an attempt was made to determine the influence of coconut oil as cutting fluid in reducing the tool wear and surface roughness in the turning process. The performance of coconut oil was in contrast with another two cutting fluids namely an emulsion and neat cutting oil (immiscible with water). The investigation results indicated that coconut oil as a cutting fluid performed better than the other two cutting fluids by improving the surface finish and reducing the tool wear.

M.Z.A. Yazid et al.[4] observed surface integrity when finish turning Inconel 718, a highly corrosive resistant, nickel-based super alloy, under three cutting conditions (DRY, MQL 50 mL/h and MQL 100 mL/h). The microstructure analysis using SEM on the machined surface suggests that severe deformation took place, leading to microstructure alteration at subsurface level measuring from a few to several micron in thickness. Work hardening under the machined surface was evident from the microhardness. The results of this study show that MQL may possibly improve surface integrity characteristics. Table-1 Shows Tabulated Literature Survey.

K Adarsh Kumar et. al. [5],The purpose of this research paper is focused on the analysis of optimum cutting conditions to get lowest surface roughness in facing by regression analysis. This present paper presents an experimental study to investigate the effects of cutting parameters like spindle speed, feed and depth of cut on surface finish on EN-8. A multiple regression analysis (RA) using analysis of variance is conducted to determine the performance of experimental measurements and to it shows the effect of cutting parameters on the surface roughness. Multiple regression modeling was performed to predict the surface roughness by using machining parameters. The investigation of influence of cutting conditions in facing operation of EN-8 in this paper. Machining was done using cemented carbide insert. The objective was to establish correlation between cutting speed, feed rate and depth of cut and optimize the turning conditions based on surface roughness. These correlations are obtained by multiple regression analysis (RA).

Mittal P Brahmbhatt et. al. [6],The present study illustrates the performance of MTCVD multicoated carbide insert in dry turning of EN9 steel. The effect of insert and cutting parameter on surface roughness and MRR is investigated. The experiments were conducted at three different spindle speed, feed and depth of cut. The cutting parameters are optimized using Taguchi method and the effect of cutting parameters and tool material on surface roughness was evaluated by the analysis of variance. The analysis indicated that the parameter that have the biggest effect on surface roughness and MRR is feed.

Anand S.Shivade, et. al. [7],This paper presents the single response optimization of turning parameters for Turning on EN8 Steel. Experiments are designed and conducted based on Taguchi's L9 Orthogonal array design. This paper discusses an investigation into the use of Taguchi parameter Design optimize the Surface Roughness and Tool tip temperature in turning operations using single point carbide Cutting Tool. The Analysis of Variance (ANOVA) is employed to analyze the influence of Process Parameters during Turning. The useful results have been obtained by this research for other similar type of studies and can be helpful for further research works on the Tool life.

Neeraj sharma et. al. [8],The present study applied extended Taguchi method through a case study in straight turning of mild steel bar using HSS tool for the optimization of process param. The study aimed at evaluating the best process environment which could simultaneously satisfy requirements of both quality as well as productivity with special emphasis on reduction of cutting tool flank wear, because reduction in flank wear ensures increase in tool life. The predicted optimal setting ensured minimization of surface roughness. From the present research of ANOVA it is found the Depth of cut is most significant, spindle speed is significant and feed rate is least significant factor effecting surface roughness.

K Saravan kumar et. al. [9],This paper is aimed at conducting experiments on Inconel 718 and investigation the influence of machining process parameters such as cutting speed (X1, m/min), feed rate(X2, mm/rev), and depth of cut (X3, mm) on the output parameters such as material removal rate and surface roughness.

P.P.Shirpurkar et. al. [10],In this study, the effects of cutting speed, feed rate,depth of cut, nose radius and cutting condition on surface roughness and vibration chatter in the turning were experimentally investigated. EN 24 steel was machined using carbide tool on CNC lathe machine.The settings of turning parameters were determined by using Taguchi's experimental design method. Orthogonal arrays of Taguchi, the signal-to-noise (S/N) ratio, the analysis of variance (ANOVA) are employed to find the optimal levels and to analyze the effect of the turning parameters. Results show that Nose Radius and the Cutting Speed and cutting condition are the three Parameters that influence the Surface Roughness more effectively. Finally, the ranges for best cutting conditions are proposed for serial industrial production.

F Jafarian et. al. [11],The goal is to propose a useful and effective method to determine optimal machining parameters in order to minimize surface roughness, resultant cutting forces and maximize tool life in the turning process. At first, three separate neural networks were used to estimate outputs of the process by varying input machining parameters. Then, these networks were used as optimization objective functions. Moreover, the proposed algorithm, namely, GA and PSO were utilized to optimize each of the outputs, while the other outputs would also be kept in the suitable range. The obtained results showed that by using trained neural networks with genetic algorithms as optimization objective functions, a powerful model would be obtained with high accuracy to analyze the effect of each parameter on the output(s) and optimally estimate machining conditions to reach minimum machining outputs.

P Venkata Ramaiah et. al. [12],In this paper an attempt is made to obtain optimum turning parameters for minimum cutting forces and cutting temperature by using Fuzzy Logic. In this work, turning is performed on Al 6061 work material under dry conditions with CNMG cutting tool according to Taguchi experimental design. The Experimental responses like cutting temperature and cutting force are measured for different influential parameter combinations. The Experimental data is analyzed using Fuzzy Logic and optimum parameters combination is determined. The optimum parameters combination is tested by confirmation experiment and the result is satisfactory.

M Adinarayana et. al. [13],The paper envisages the study to optimize the effects of process variables on surface roughness, MRR and power consumption of En24 of work material using PVD coated tool. In the present investigation the influence of spindle speed, feed rate, and depth of cut were studied as process parameters. The experiments have been conducted using full factorial design in the design of experiments (DOE) on a conventional lathe. A Model has been developed using regression technique. The optimal cutting parameters for minimum surface roughness, maximum MRR and minimum power consumption were obtained using Taguchi technique. The contribution of various process parameters on response variables have been found by using ANOVA technique.

Yacov sahijpaul et. al. [14],The purpose of this experimental investigation was to analyse the effect of controlled cutting parameters namely cutting speed, feed rate, depth of cut, cutting fluid concentration and two cutting fluids with different base oils on surface roughness (Ra) of EN8 or AISI 1040 steel during turning operation by applying design of experiments, custom design method, analysis of variance, leverage plots and desirability profiling using JMP software to optimize surface roughness during wet CNC turning operation. The analysis reveals that feed rate has the most significant effect on surface roughness (Ra) and value of surface roughness does not significantly differ for two different cutting fluids used.

Vaibhav B. Pansare et. al. [15],In this paper, attempt is made to obtain optimum turning parameters for minimum surface roughness value by using Ant Colony Optimization (ACO) algorithm in multipass turning operation. The cutting process has roughing and finishing stage. Also the relationship between the parameters and the performance measures were determined using multiple linear regression, this mathematical model is used to determine optimal parameters. The experimental results shows that the proposed technique is both effective and efficient.

Er Sandeep Kumar et. al. [16], Engineering materials are presently in use at a very vast range in today's industries. As Mild steel 1018 has a wide variety of applications in construction of pipelines, products, construction as structural steel, car manufacturing industries and other major industries. The machining of these types of materials requires very important consideration. There are a number of parameters like cutting speed, feed and depth of cut etc. which must be given consideration during the machining of this alloy. So it becomes necessary to find out the ways by which it can be machined easily and economically. For the present work the parameter to be optimised selected is material removal rate that is optimised by using selected combination of machining parameters by using taguchi orthogonal array.

Girish Tilak Shet et. al. [17],This paper presents the optimization of surface roughness parameters in turning EN1A steel on a CNC lathe. In this work, the Taguchi methods, a powerful statistical tool to design of experiments for quality, is used to find the optimal cutting parameters for turning operations. Analysis of Variance has been used to determine the influencing parameters on the output responses. Using Taguchi technique, we have reduced number of experiments from 27 to 9 there by the total cost of the project is reduced by 66.66%. The results obtained are encouraging and the concluding remarks are helpful for the manufacturing industries.

Krishankant et. al. [18],This paper reports on an optimization of turning process by the effects of machining parameters applying Taguchi methods to improve the quality of manufactured goods, and engineering development of designs for studying variation. EN24 steel is used as the work piece material for carrying out the experimentation to optimize the Material removal rate.

K. P. Warhode et. al. [19] have optimized process parameter for material remove rate, power utilization and machining time using response surface methodology. The work piece material used for in progress investigation is Al6063 aluminium alloy. The experiments were conducted by using Taguchi L27 orthogonal array by in view of the machining restriction such as speed, feed and depth of cut. The result has indicated that it is feed rate which has significant influences both MRR and machining time and for power utilization speed is most chief parameter.

An Nithyanandhan T. et. al. [20] have investigated the property of progression parameters on surface finish and material removal rate (MRR) to obtain the best setting of progression parameters. And the analysis of Variance (ANOVA) is also used to analyze the influence of cutting parameters throughout machining. In this work, AISI 304 stainless steel work pieces are turned on conventional lathe by using tungsten carbide tool. The results exposed that the feed and nose radius is the most notable process parameters on work piece surface roughness. though, the depth of cut and feed are the significant factors on MRR.

D. Philip Selvaraj et. al. [21] have studied the Taguchi optimization method was functional to find the most favourable process parameters, which minimizes the surface roughness for the duration of the dry turning of AISI 304 Austenitic Stainless Steel. The Taguchi orthogonal array, the signal to noise S/N ratio and the investigation of variance ANOVA were used for the optimization of cutting parameters. The ANOVA results shows that feed rate, cutting speed and depth of cut affects the surface irregularity by 51.84%, 41.99% and 1.66% respectively. A verification experiment was also conducted and confirmed the success of the Taguchi optimization process.

Madhav Murthy A et. al. [22] has studied the result of changing cutting constraint on surface finish using Taguchi method. In this learn the selected cutting parameter are cutting speed, feed, depth of cut and nose radius. Taguchi method with L16 orthogonal array (four factors and two levels) was used for experimentation and Analysis was done by Analysis of variance and regression equation has been adopted for predicting the surface roughness. Result show that, the factor feed rate is the most significant in influencing the surface roughness while the left over three factors measured are not significant. It was found that minimum surface roughness obtained at minimum nose radius, feed rate and maximum cutting speed.

Ravindra Thamma [23] have developed and comparing multi regression models by collecting data pertaining to depth of cut, nose radius, feed rate, surface roughness and cutting speed during turning of AL6061 aluminium alloy. Full factorial design of experiment procedure was used to develop the surface roughness regression model, within the range of selected parameter. The study reveals that cutting speed, feed and nose radius have major impact on surface roughness. Also depth of cut has significant impact on surface roughness in an interaction with other parameter.

K. krishanamurthy et. al. [24] performed experiment to investigate the effect of machining parameter on surface roughness and material remove rate of TiB2 particles reinforced aluminum (Al6063) metal. Four parameter namely cutting speed, feed, depth of cut and material are varied to study their effect on surface roughness and material remove rate. Experiment were conducted based on Taguchi L27 orthogonal array and then followed by optimization of the result using Analysis of variance to find out maximum material remove rate and minimum surface roughness. The best MRR was got when locating the cutting speed and feed rate at high values but low surface roughness obtained at high cutting speed and low feed rate.

JitendraVerma et. al. [25] have taken ASTM A242 type-1 ALLOY steel of 250 mm lenghth as well as 50 mm diameter of material for testing using a CNC lathe machine. L9 array taken and for analysed the data not only Taguchi but also ANOVA approach used. They done that speed (57.47% contribution) is the most noteworthy factor affecting surface roughness as well as followed by feed (23.46% contribution). Cutting speed is the least momentous factor affecting surface roughness.

Hari Singh et. al. [26] optimized setting of turning process parameters as depth of cut ,cutting speed as well as feed rate giving in an optimal value of the feed force when machining EN24 steel among TiC-coated tungsten carbide inserts. The material of EN24 is a medium-carbon lowalloy steel and gets its typical applications in the manufacturing of machine tool parts. The L27 orthogonal array used for the study. They found that the percent help of depth of cut (55·15 %) and feed rate (23·33 %) in distressing the variation of feed force are notably larger as compared to the contribution of the cutting speed (2·63 %).

Tian –syung Lan [27] present the optimization of cutting parameter –speed, feed, depth of cut and nose radius in order to improve surface finish and MRR orthogonal array has been adopted for planning of trial and multi objective optimization by using TOPSIS. It was observing that superior cutting speed, feed, depth of cut and minimum nose radius gives better surface finish and higher MRR. The result achieved by proposed multi purpose optimization technique, show that surface roughness and MRR increases about 27.80 %and 21.45 % respectively.

Tejinder pal singh [28] has investigated influence of cutting tool parameter such as tool rake angle, nose radius, and the clearance angle on surface roughness in turning operation using single point cutting tool. Aluminium was used for testing. The arithmetical models were developed to predict the effect of various tool parameters on surface roughness. Coefficient and adequacy of the urbanized model has been checked using student's't' and 'f' test respectively at 95%. From this study it was found that surface roughness decreases with the increases in rake angle and also increase with increases in the nose radius.

Table 2.1. Literature Review

S.No	Authur	Material	Tool/Insert material	Machining Method	Machining Parameters					Output Parameters	Optimisation Methods	Most Significant Factor	
					Cutting speed V_c (m/min)	Feed f(mm/rev)	D.O.C(mm)	Other	Cutting fluid			1st	2nd
1	Michael Jacobson, Patrik Dahlman(2002)	Bainite steel	CBN 100 insert	Dry Turning (CNC)	50 to 999	0.1	0.1	-	Conventional Cooling	Surface Roughness, Residual Stress	-	Cutting Speed	-
2	N.R. Dhar, M. Kamruzzaman(2006)	AISI 4340	Carbide insert	Dry & Wet Turning (Lathe Machine)	110	0.16	1.5	-	Air: 7.0 bar, Lubricant: 60 ml/h	Surface Roughness, Tool Wear, MQL	-	Coolant	-
3	M. Nalbant, H. Gokkaya(2006)	AISI 1030	TiN-coated tools	-	-	0.15, 0.25, 0.35	0.5, 1.5, 2.5	0.4, 0.8, 1.2 *Insert Radius (mm)	-	Surface Roughness (Ra)	Taguchi	Insert Radius	Feed Rate
4	Tugrul Ozel, Yigit Karpat(2007)	AISI D2	PCBN insert	Dry Turning (CNC)	80, 115, 150	0.05, 0.10, 0.15	0.2	(5, 10, 15)min *Cutting Time	Conventional Cooling	Roughness Parameters(R_a, R_t), Tool flank wear	Multiple Linear Regression Models, Neural network models	Feed Rate	Cutting Speed
5	R.S. Pawade, Suhas S. Joshi(2008)	Inconel 718	PCBN insert	Dry Turning (CNC)	125, 300, 475	0.05, 0.10, 0.15	0.50, 0.75, 1.00	-	Conventional Cooling	Residual Stress, Degree of work hardening	Taguchi	Cutting Edge	Depth Of Cut
6	D.I. Lalwani, N.K. Mehta(2008)	MDN250 18Ni(250)	Ceramic Coated Insert (TNMA160408S 01525)	Lathe Machine	55, 74, 93	0.04, 0.08, 0.12	0.1, 0.15, 0.2	-	Conventional Cooling	Surface Roughness, Cutting forces	Taguchi	Depth of Cut	Feed Rate
7	M. Anthony Xavior, M. Adithan(2008)	AISI 304	Carbide insert (CNMG)	Lathe Machine	38.95, 61.35, 97.38	0.2, 0.25, 0.28	0.5, 1.0, 1.2	-	Coconut oil, Soluble oil, Straight cutting oil	Effect of cutting fluid, Surface Roughness	Taguchi	Cutting Speed	Feed Rate

8	Khaider Bouacha, Mohamed Athmane Yallese(2010)	AISI 52100	CBN insert	Lathe Machine	125, 176, 246	0.08, 0.12, 0.16	0.15, 0.3, 0.45	-	Conventional Cooling	Surface Roughness, Cutting forces	Taguchi	Feed Rate	Cutting Speed
9	A. Devillez, G. Le Coz(2011)	Inconel 718		Dry & Wet Turning (CNC)	40, 60, 80	0.1	0.5	-	5% emulsion	Surface Roughness, Residual Stress	-	Coolant	-
10	S. Bissey-Breton, J. Graviera(2011)	Copper	Carbide insert	Dry & Wet Turning (CNC & Lathe Machine)	138, 86	0.05, 0.2	0.05 to 0.3	0.4, 0.8 *Insert Radius (mm)	Not specified	Surface Roughness, Quadratic Stress, Crystallographic anisotropy	Taguchi	-	-
11	J. Guddat, R. M'Saoubi(2011)	AISI 52100	PCBN inserts	Dry Turning (CNC)	120 - 180	0.1 - 0.3	0.15	0.4 - 1.2 *Insert Radius (mm)	Conventional Cooling	surface integrity, Cutting forces	-	Cutting Edge	-
12	M.Z.A.Yazid, C.H. CheHaron(2011)	Inconel 718	PVD coated carbide insert	Dry & Wet Turning (CNC)	90, 120, 150	0.10, 0.15	0.30, 0.50	-	MQL 50 mL/h, MQL 100 mL/h	Surface Roughness & Texture, Microstructure Alteration	-	Coolant	-
13	A. Esteves Correia, J. Paulo Davim(2011)	AISI 1045	Cemented carbide conventional and wiper insert	Dry Turning (CNC)	345, 410, 470	0.075, 0.15, 0.25	0.5	-	Conventional Cooling	Surface Roughness, Influence of the wiper inserts	-	Cutting Edge	Feed Rate
14	Ilhan Asilturk, Harun Akkus(2011)	AISI 4140	TiC-coated Carbide insert	Dry Turning (CNC)	90, 120, 150	0.18, 0.27, 0.36	0.2, 0.4, 0.6	-	Conventional Cooling	Surface Roughness (Ra), (Rz)	Taguchi	Feed Rate	-
15	Adem Cicek, Turgay Kıvak(2012)	AISI 316	HSS, (M35)	Vertical Drilling	12, 14	0.08, 0.1	-	CHT, CT *Tool Material	Conventional Cooling	Surface Roughness (Ra), Roughness Error	Taguchi, Multiple regression analysis	Cutting Speed	Tool Material
16	Srinivas Athreya, Dr Y.D.Venkatesh(2012)	Mild Steel	Tungsten Carbide Tipped tool	Lathe Machine	960, 640, 1280 (RPM)	145, 130, 160 (mm/min)	0.3, 0.2, 0.4	-	Conventional Cooling	Surface Roughness (Ra)	Taguchi, Full Factorial Analysis	Cutting Speed	Depth Of Cut

17	Dr. C. J. Rao, Dr. D. Nageswara Rao(2013)	AISI 1050	Ceramic (Al2O3+TiC matrix)	Dry Turning (CNC)	50, 75, 95	0.05, 0.10, 0.15	0.25, 0.50, 0.75	-	Conventional Cooling	Surface Roughness (Ra), Cutting Forces	Taguchi, Full Factorial Analysis	Depth of Cut	Feed Rate
18	Yacov sahijpaul, Gurpreet singh(2013)	EN8 or AISI 1040	Carbide (CNMG 431-PF4225)	Wet Turning (CNC)	1000, 2000 (RPM)	0.125, 0.250	0.5, 1.0	-	Cool-cut-Nirma 40 A, Cool-cut-Nirma 30 A	Surface Roughness (Ra), Effect of cutting fluid	Taguchi	Feed Rate	Coolant
19	P Subhash, Chandra Bose(2013)	NIMONIC 75	PVD coated carbide insert	Dry Turning (CNC)	100, 175, 250	0.02, 0.03, 0.04	0.01, 0.125, 0.15	-	Conventional Cooling	Surface Roughness (Ra), MRR	Response Surface Methodology	Feed Rate	Depth Of Cut
20	Rajendra Singh, Rahul kr.Gupta(2014)	SS 316L	Carbide insert	-	110, 150, 190	0.10, 0.15, 0.20	0.10, 0.15, 0.20	-	-	Surface Roughness (Ra)	Full Factorial Analysis, MRA, ANN	Feed Rate	-
21	Prajwalkumar M. Patil, Rajendrakumar V. Kadi(2015)	AISI 316	Carbide insert (CVD Coated)	Dry Turning (CNC)	120, 150, 180	0.20, 0.25, 0.30	0.5, 1.0, 1.5	-	Conventional Cooling	Surface Roughness (Ra, Rz), Hardness	Taguchi	Feed Rate	Cutting Speed
22	Aswathy V G, Rajeev N,(2015)	Ti-6Al-4V	Carbide insert (CVD Coated)	Wet Turning (CNC)	50, 60, 70	0.010, 0.020, 0.030	0.02, 0.035, 0.05	0.1, 0.4, 0.5 *Insert Radius (mm)	Not specified	Surface Roughness (Ra), MRR, Roughness Error	Taguchi	Feed Rate	Depth Of Cut
23	Roopa K Rao, Vinay Murgod(2015)	EN19	Carbide Tip	Dry Turning (CNC)	420, 630, 1000 (rpm)	0.040, 0.048, 0.054	0.04, 0.08, 0.12	-	Conventional Cooling	Surface Roughness (Ra), MRR (with and without HT)	Taguchi, Full Factorial Analysis, Linear Regression Model	Depth of Cut	Feed Rate
24	Mehmet Alperince, Ilhan Asilturk(2015)	Co28Cr6Mo ASTM F 1537	PVD coated carbide insert	Dry Turning (CNC)	318, 477, 636 (RPM)	0.1, 0.15, 0.25	0.5, 0.7, 0.9	0.4, 0.8, 1.2 *Insert Radius (mm)	Conventional Cooling	Surface Roughness (Ra)	Full Factirial Analysis	Insert Radius	-

25	Devendra Singh, Vimanyu Chadha(2016)	Al 6061	Carbide insert	Dry Turning (CNC)	1600, 1900, 2200 (RPM)	0.12, 0.18, 0.24	0.25, 0.50, 0.75	0.4, 0.8, 1.2 *Insert Radius (mm)	Conventional Cooling	Surface Roughness (Ra)	Response Surface Methodology	Insert Radius	Feed Rate

There is a need of a tool that should allow the evaluation of the surface roughness before machining of the part and which, at the same time, can easily be used in the production floor environment contributing to the minimization of required time and cost and the production of desired surface quality. In order to obtain better surface finish, the proper setting of cutting parameters is crucial before the process takes place. Several factors influence the final surface roughness in CNC lathe turning operation. The final surface roughness might be considered as the sum of two independent effects: 1) the ideal surface roughness is a result of the geometry of cutting tool and feed rate, 2) the natural surface roughness is a result of irregularities in the cutting operation. MRR is an important control factor of turning operation. The non-linear nature of turning process has compelled to engineers to search for more effective methods to attain optimization. It is therefore imperative to investigate the turning behavior of different materials by changing the turning parameters to obtain optimal results. Process modeling and optimization are the two important issues in manufacturing products. The selection of optimum parameters like depth of cut, feed and spindle speed, tool nose radius, turning environment are very important issues for turning process on CNC lathe machine. Taguchi technique offers simple and systematic optimal design at relatively low cost.

Table 2.2. Summary of Literature Review

Sr. No	Author Name	Material Used	Tool Used	Input Process Used	Input Parameter	Output Parameter	Results/Significant Parameters
1	B Kumaragurubaran et al.(2013)	EN9 Steel	Tungsten Carbide Inserts	Taguchi Design of Experiment	Feed Rate and Depth of Cut	Surface Finish, MRR	Surface Roughness, MRR
2	Amit Phogot et al.(2013)	Mild Steel	HSS	DOE, RSM	Spindle Speed, Depth of Cut, Feed Rate, Tool NoseRadius, Cutting Environment.	Surface Finish	Application/use/limitations ofRSM
3	Maharhi Patel et al.(2013)	EN9	Tungsten Carbide	Taguchi, ANOVA	Cutting Speed, Depth of Cut, Feed Rate	Surface Finish, MRR	Surface Roughness and MRR increases with speed.
4	Hardeep Singh et al.(2013)	EN9	HSS, Infrared Thermometer	Force Components, Mean plot	Spindle Speed, Feed Rate, Depth of Cut	Workpiece Temperature Optimization	Feed
5	Kaushal Pratap Singh et al.(2014)	EN9 Alloy Steel	Tin coated Tungsten Carbide tool	L18,O A, S/N ratioand Analysis of Variance (ANOVA)	Spindle Speed, Feed Rate, Depth of Cut, Nose Radius, Cutting Environment	Surface Finish, MRR	Improved Surface Finish andMRR
6	Jayesh Patel et. Al.(2014)	EN9 Steel	Coated (Tin) Carbide Tool	Regression Analysis, ANOVA	Side Rake Angle, Feed, Depth of Cut	Surface Roughness	Feed Rate
7	Narinder Gupta et al.(2014)	EN9	CNMG Carbide	Metal Working Fluid Applicator.	Speed, Feed, Depth of Cutand Environment	Surface Roughness, Workpiece Surface Temperature	Cutting Fluid
8	Mr. Prateek Harinkhereet al.(2015)	EN9 Forging	Carbide Insert Tool	Taguchi Orthogonal Array Design Method, Design of Experiment	Depth of Cut, Feed Rate, Cutting Condition, Nose Radius.	MRR, Surface Roughness, Avg. Chip Thickness, ToolVibration, Tool Flank Wear, Cutting Temp.	Surface Roughness, ProductionTime, Cutting forces, MRR

9	Ashish Bhateja et al. (2013)	EN 24 Alloy	Tungsten Carbide	Taguchi Analysisusing Statistical Approach	Speed , Feed Rate and Depth of Cut	Surface Roughness,Tool Wear Rate & (MRR)	TNMG (triangular) has the leasvalue of tool wear (TWR),
10	Mohamed Khaisar et al.(2014)	EN9	Coated Carbide Insert	Taguchi's L8 Orthogonal Array, Regression Analysis.	Speed, Feed and Depth ofCut	Tool Wear, Vibration	Know how to tool flank wear progresses towards failure.
11	A.M. Badade et al.	EN9	Cemented Carbide Insert	ANOVA, Taguchi L9	Spindle Speed, Feed, Depth of Cut and L/ D ratio	Surface Finish, M/cTime	Feed followed by Spindle Speed
12	Kaushal Pratap Singh etal.	EN9 & Aluminium	Carbide Tool	ANOVA, Taguchi	Cutting Speed, Feed Rateand Depth of Cut	Cutting Speed, Feed Rate and Depth ofCut	Depth of Cut and Speed a significant parameters affecting hardness of the material.
13	Divyangsingh N Rana et al.(2014)	Stainless Steel Solid Bar	1.Carbide, 2.Ceramic 3. CBN	Design of Experiments	Cutting Speed, Depth ofCut and Feed Rate	Surface Roughness	CBN Tool gives more finish
14	Jagadale Amitkumar Hanamantrao et al.(2014)	EN9	Sandvik Inserts (CNMA & CNMM)	ANOVA	Cutting Speed, Depth ofCut	Surface Roughness	Wiper Cutting Insert has a better performance.
15	Anand S. Shivde et al. (2014)	EN8	Carbide Cutting Tool	Taguchi's L9 Orthogonal Array design	Spindle Speed, Depth ofCut, Feed	Surface Roughnessand Tool Tip Temperature	Improved Surface Finish.
16	Neeraj Saraswat et al.(2014)	Mild Steel		ANOVA, Taguchi Method	Spindle Speed, Depth of Cut, Feed	Surface Roughness	Improved Surface Finish.
17	Upinder Kumar Yadav et al. (2012)	AISI 1045	Tungsten Carbide	ANOVA, Taguchi method	Cutting Speed, Feed rate, Depth of cut	Surface Roughness	Feed Rate
18	Er. Manpreet Singh et al. (2014)	Review on machining of different materials with CNC			Depth of cut, Feed and Speed	Surface Roughness	For: Surface Roughness: Speed ; for MRR: DOC
19	Mihir T. Patel et al.(2014)	Review on machining of different materials with CNC			Depth of Cut, Feed and Speed	Surface Roughness, MRR	Surface Roughness: Speed, Feed and Depth of Cut, For MRRDOC, Feed and Speed
20	Ranganath M.S. et al. (2013)	Review on machining of different materials with CNC			Depth of Cut, Feed and Speed	Surface Roughness	Cutting Speed followed by Feed Rate and Depth of Cut.
21	Ranganath et al. (2015)	Aluminium (6061)	HSS	ANOVA,	Cutting Speed, Feed and	Surface Roughness	Cutting Speed

TAGUCHI METHOD

Taguchi method is statistical method developed by Professor Genichi Taguchi of Nippon Telephones and Telegraph Company Japan for the production of robust products. According to Taguchi, total loss generated by a product to the society after shipped is the quality of the manufactured product. Taguchi has used experimental design as a tool to make products more robust – to make them less sensitive to noise factors. Currently, Taguchi method is applied to many sectors like engineering, biotechnology, marketing and advertising. Taguchi developed a method based on orthogonal array experiments, which reduced "variance" for the experiment with "optimum settings" of control parameters. Hence, the optimal results can be achieved by implementing the combination of Design of Experiments (DOE) with optimization of control parameters. Signal-to-noise (S/N) ratio and orthogonal array are two major tools used in robust design. Signal to noise ratio, which is log functions of desired output measures quality with emphasis on variation, and orthogonal arrays, provide a set of well balanced experiments to accommodate many design factors at the same time.

Table 2.3. Taguchi Method

Sr. No.	Author	W/P Material	Experimental run	Input	Output	Most significant
1	Ankit Dogra, Hartaj Singh et.al,2016	EN- 8	27	Speed, feed, depth of cut	Tool wear rate	Spindle speed
2	Anshul Sen, Dr. Shailesh Dewangan et.al,2016	AISI 4320	18	Cutting speed, depth of cut	MRR, surface roughness,	Cutting speed
3	Srinivas Athreya, Dr. Y. D. Venkatesh et.al,2012	Mild Steel	27	Speed, feed, depth of cut	Surface finish	Cutting speed
4	Sujit Kuman Jha et al	Aluminium	9	Spindle speed, feed, depth of cut, cutting speed	MRR	Cutting speed
5	Mr. Amar Kawale et,al,	Mild steel	5	Depth of cut, cutting force	Temperature	Depth of cut
6	L B Abhang et.al,	En- 31 steel alloy	24	Cutting speed, feed rate, depth of cut, tool nose radius	Surface roughness	Feed rate
7	Mr. Balaji et.al,	AISI 304 steel	8	Cutting speed, feed rate, helix angle	Surface roughness, and drill bit variation	Helix angle
8	Ch. Maheswara Rao et.al,	Aluminium alloy 7075	9	Feed, cutting speed, depth of cut	Surface roughness	Feed & cutting speed
9	Shivam Goyal et.al	AISI 1020 mild steel	9	Depth of cut, feed, cutting speed	MRR & surface roughness	Depth of cut & cutting speed
10	Krishnakant et al	EN 24 steel	27	Speed, feed, DOC	Surface roughness, MRR	speed

Literature On Different Optimization Techniques

TAGUCHI METHOD: Taguchi's parametric design is the operational tool for robust design it proposals a simple and organized qualitative ideal design to a comparatively low cost. The Taguchi method of offline (Engineering) quality control encompasses all stages of product/process development. However the key component for attaining great value at low cost is Design of Experiments.

ANOVA: Since there are a great number of variables governing the process, some mathematical simulations are required to represent the process. However, these models are to be developed using only the significant parameters influencing the process rather than including all the parameters. In order to achieve this, statistical analysis of the experimental results will have to be processed using the analysis of variance ANOVA is a computational method that allows the estimation of the comparative assistances of each of the control aspects to the overall calculated response. ANOVA can be beneficial for defining effect of any given input constraint from a series of experimental outcomes by design of experiments for machining process and it can be used to translate experimental data.

ANN: ANN is an interconnected gathering of simple managing elements, units or nodes, whose functionality is loosely built on animal neuron. The processing capability of the network is kept in the inter-unit linking strengths, or weights, attained by a method of adaptation to, or learning from, a set of training patterns. In its most general form, ANN is a machine that is planned to model the way in which the brain implements a specific task or function of interest; the network is frequently executed by using electronic constituents or is simulated in software on a digital computer.

Table 2.4. Literature On Different Optimization Techniques

Researchers	Tool Material	Work piece Material	Techniques	Key Findings
JANG.D.et al. [6]	Carbide	AISI 1020	On Line	The roughness along the work piece without chatter, has specific frequency components that are determined by the feed marks in the lower frequency range. They are narrowly related to the natural frequencies of a machine tool structure.
Davim. J et al. [7]	Cemented Carbide	Free Machining Steel	ANN	The roughness is highly sensitive to both cutting speed and feed rate whereas depth of cut has the least

				effect. The surface roughness has a tendency to reduce with the increase in cutting speed and also with the reduction in feed rate.
I.A. Choudhury et al.[8]	Uncoated Tungsten Carbide	EN 24T	Factorial Design	Effect of feed is much more pronounced than the effects of cutting speed and depth of cut, on the roughness. Though, a higher cutting speed improves the surface finish.
W.H. Yang et al. [4]	Uncoated Tungsten Carbide	S45C	Taguchi Method	The tool life and surface roughness from increases to about 250% from the initial cutting parameters to the optimal cutting parameters
M. Nalbant et al. [2]	TiN Coated	AISI 1030	Taguchi Method	Greater insert radius (1.2 mm), low feed rate (0.15 mm/rev) and low depth of cut (0.5 mm) leads to better surface roughness. The surface roughness improves to about 335% form initial cutting parameters to the optimal cutting parameters
IlhanAsilturk et al. [5]	Coated Carbide	AISI 4140	Taguchi Method	Optimum cutting conditions which correspond for the smaller surface roughness in hard turning method were found to be 120 m/min for the cutting speed, 0.18 mm/rev for the feed rate and 0.4 mm for the depth of cut.
HamdiAouici et al. [9]	CBN 7020	AISI H11	ANOVA	Feed rate and work piece hardness have major statistical influences on the surface roughness. Lower feed rate and the high cutting speed lead to best surface roughness.
S. Ramesh et al. [10	Round Coated Carbide	Titanium Alloy (gr5)	ANOVA	The order of importance was feed, followed by depth of cut and cutting speed. Feed has a great effect on roughness.
Upadhyay.V et al. [11]	Uncoated Cemented Carbide	Ti–6Al–4V alloy	ANN	Surface roughness within reasonable accuracy
Günay.M et al. [12]	CBN	High-alloy white cast iron (Ni-Hard)	Taguchi Method	The most significant variable for Ni-Hard with 62 HRC was found the feed rate while the variable that was

				the most significant for Ni-Hard with 50 HRC was the cutting speed.
Bouacha.K et al. [13]	CBN	AISI 52100	ANOVA	The surface roughness is highly affected by feed rate, whereas the cutting speed has a negative effect and the depth of cut a negligible influence.
N.R. Abburi et al. [14]	TiN-Coated Carbide	Mild Steel	ANN	Reducing the ranges and increasing the number of training data is expected to improve the accuracy of the surface roughness.
B.Y. Lee et al. [15]	Tungsten Carbide	S45C	Polynomial Network	The accuracy of the surface roughness can be predicted once the image of the turned surface and turning conditions (cutting speed, feed rate, and depth of cut) are given.
JanezKopac et al. [16]	Cermet	C15 E4	Taguchi Method	A higher cutting speed results in a smoother surface
P.V.S. Suresh et al. [17]	Mild steel	Mild steel	GA	Surface quality can be greatly controlled using Genetic Algorithms
Shinn-Ying Ho et al. [18]	S45C	S45C	ANFIS	The advantages of the proposed method are non-contact measurements, ease of automation, and high accuracy
Tugrul Ozel et al. [19]	AISI 52100	AISI 52100	ANN	The developed prediction system is found to be capable of accurate surface roughness prediction.
W.S. Lin et al. [20]	Carbide	S55C	Regression analysis	Feed rate is the significant factor that affects the roughness, where increasing feed rate will increase the roughness, while a regression multiplier proves that the cutting speed does not have a major impact on surface roughness.
O.B.Abouelatta et al. [21]	Cemented Carbide	Free cutting Steel	Mathematical Model	The maximum height roughness parameter depends greatly on the rotational cutting speed.
K.A. Risbood et al. [22]	TiN-Coated Carbide	Steel	ANN	Artificial neural networks can be used to find out the effective estimates of surface finish
M.Y. Noordin et al. [23]	Coated Carbide	AISI 1045	ANOVA	The ANOVA revealed that feed is the most significant factor influencing the surface roughness.
D.I. Lalwani et al. [24]	Coated Ceramic	MDN250	ANOVA	Good surface roughness can be achieved when cutting speed and depth of cut are

				in range (93m/min and 0.2mm) and feed rate is at low level of (0.04mm/rev).
M. Anthony Xavior et al. [25]	Carbide	AISI 304	ANOVA	Coconut oil was found to be a better cutting fluid than the conventional mineral oils in reducing surface roughness
Jeffrey D. Thiele et al. [26]	CBN	AISI 52100	ANOVA	The effect of work piece hardness and edge geometry interaction on the surface roughness was found to be very significant. The effect of edge hone on the surface roughness decreased with increase in work piece hardness
Davim. J et al. [27]	PCD	GFRP	ANOVA	The roughness increases with the feed rate and decreases with the cutting velocity. The feed rate has the highest physical and statistical effect on surface roughness
A.Kohli et al. [28]	Carbide	Mild Steel	ANN	The experimental value is close to the most likely estimate and within the upper and lower estimates
Tugrul Ozel et al. [29]	CBN	AISI H13	ANOVA	Honed edge geometry and lower work piece surface hardness resulted in better surface roughness
Eyup Bagci et al. [30]	MTT3000	GFRP	ANN	It was found that the maximum test errors were 6.30% and 6.36% by comparing roughness values predicted from ANN model with those predicted RSM.
Dilbag Singh et al. [31]	Ceramic	AISI 52100	ANOVA	Feed is the governing factor affecting the surface roughness
Ahmet Hasçalhk et al. [32	CNMG 12040-833	Ti-6Al-4V	Taguchi Method	Feed rate is the key factor that has the highest importance on the roughness and it is about 1.72 times more vital than depth of cut. The cutting speed does not seem to have much of an influence on the roughness.
Surjya K. Pal et al. [33]	HSS	Mild Steel	ANN	The predicted surface roughness from the neural network model is very close to the measured values
Vishal S. Sharma et al. [34	Coated Carbide	Adamite	ANN	Surface roughness is positively influenced with feed and it shows negative trend speed and depth of cut
Hardeep Singh et al. [35]	Carbide	EN-8	Taguchi Method	The feed has the variable effect on surface roughness. It is interesting to note that spindle speed, feed rate and depth of cut for Material Removal Rate have increasing trend.
Ranganath M.S. et al. [41]	HSS	Aluminium 6061	ANOVA	The minimum surface roughness is obtained at 1.2mm depth of cut, 156rpm

				speed and 0.05mm/rev feed rate.
Ranganath M.S. et al. [42]	CNMG	Aluminium 6061	Taguchi Method	The optimal roughness is obtained at 1900rpm speed, 0.25mm depth of cut and 0.12mm/rev feed rate.
Ranganath M.S. et al. [43]	Carbide	Aluminium 6061	ANN	The surface roughness value increases as the feed and depth of cut increases and as spindle speed increases the roughness value decreases

CHAPTER-3
METHODOLOGY

Taguchi Method

Basically, traditional experimental design procedures are too complex and not easy to use. A large number of experimental works have to be carried out when the number of the process parameters increases with their levels. To solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with only a small number of experiments. The greatest advantage of this method is to save the effort in performing experiments, to save the experimental time ,to reduce the cost, and to find out significant factors which effecting the responses. Taguchi robust design method is a most powerful tool for the design of a high-quality system. He considered three steps in a process's and product's development: system design, parameter design, and tolerance design. In system design, the engineer uses scientific and engineering principles to determine the fundamental configuration. In the parameter design step, the specific values for system parameters are determined and tolerance design is used to determine the best tolerances for the parameters.

3.1. The Steps Involved in Taguchi Method are

- Determination of the quality characteristics to be optimized.
- Identification of the noise factors and test conditions.
- Identification of the control factors and their levels.
- Designing the matrix experiment and defining the data analysis procedure.
- Conducting the matrix experiment.
- Analysing the data and determining the optimum levels of control factors.
- Predicting the performance at these levels.

Taguchi method is basically given for single objective optimization not for multi objective hence; for the multi objective optimization Taguchi based Grey method has been invented. In the year of 1980, Grey systems theory was brought forward by Professor Deng Ju-long from China Grey analysis uses a specific concept of information. It defines situations with no information as black, and those with perfect information as white. However, neither of these idealized situations ever occurs in real world problems. In fact, situations between these extremes are described as being grey, hazy or fuzzy. Therefore, a grey system means that a system in which part of information is known and part of information is unknown. With this definition, information quantity and quality form a continuum from a total lack of information to complete information from black through grey to white. Since uncertainty always exists, one is always somewhere in the middle, somewhere between the extremes, somewhere in the grey area. Grey analysis then comes to a clear set of statements about system solutions. At one extreme, no solution can be defined for a system without any information. At the other extreme, a system with perfect information has a unique solution. In the middle, grey systems will give a variety of available solutions. Grey analysis does not attempt to find the best solution, but does provide techniques for determining a good solution, an appropriate solution for real world problems.

3.2. Steps Involved in Grey Relational Analysis

- Identification of performance characteristics and process parameters with their levels to be evaluated.
- Selection of orthogonal array and assign the process parameters to the array.
- Experimentation as per the orthogonal array.
- Normalization of the experimental results.
- Determination of deviation sequences.
- Determination of Grey relational coefficient (GRC).
- Determination of Grey relational grade (GRG).
- Determination of optimal parameters.

In Grey relational analysis, experimental data i.e. measured features of quality characteristics are first normalized ranging from zero to one. The process is known as Grey relational generation. Next, based on normalized experimental data, Grey relational coefficient is calculated to represent the correlation between the desired and actual experimental data. Then overall Grey relational grade is determined by averaging the Grey relational coefficient corresponding to selected responses. The overall performance characteristic of the multiple response process depends on the calculated Grey relational grade. This approach converts a multiple response process optimization problem into a single response optimization situation with the objective function is overall Grey relational grade. The optimal parametric combination is then evaluated which would result into highest Grey relational grade. The optimal factor setting for maximizing overall Grey relational grade can be performed by Taguchi method.

3.3. Calculation Procedure of Grey Relational Grade Method

- **Step 1:** Normalize the experimental values y_{ij} as Z_{ij} ($0 \le Z_{ij} \le 1$) by following formulae to avoid the effect of using different units and to reduce variability.

$$Z_{ij} = \frac{Y_{ij} - \min(Y_{ij}, i=1,2,\ldots,n)}{\max(Y_{ij}, i=1,2,\ldots,n) - \min(Y_{ij}, i=1,2,\ldots,n)} \quad \text{Eq (3.1)}$$

For the S/N ratio with Higher-the-Better case.

$$Z_{ij} = \frac{\max(Y_{ij}, i=1,2,\ldots,n) - Y_{ij}}{\max(Y_{ij}, i=1,2,\ldots,n) - \min(Y_{ij}, i=1,2,\ldots,n)} \quad \text{Eq (3.2)}$$

For S/N ratio with Lower-the-Better case.

$$Z_{ij} = \frac{|Y_{ij} - \text{Target}| - \min(|Y_{ij} - \text{Target}|, i=1,2,\ldots n)}{\max(|Y_{ij} - \text{Target}|, i=1,2,\ldots n) - \min(|Y_{ij} - \text{Target}|, i=1,2,\ldots,n)} \quad \text{Eq (3.3)}$$

For the S/N ratio with Nominal-the-Better case.

- **Step 2:** Determine quality loss functions by using

  Delta (Δ) = (Quality loss) = $|y_o - y_{ij}|$…………………………… Eq (3.4)

- **Step 3:** Compute Grey relational coefficient for normalized experimental values,

  $GC_{ij} = \frac{\Delta_{min}+\delta\Delta_{max}}{\Delta_{ij}+\delta\Delta_{max}} \begin{cases} i = 12, \dots . n \\ j = 1,2, \dots k \end{cases}$……………………………….. Eq (3.5)

  Where, GC_{ij}= Grey relational coefficient for the i^{t} replicate of j^{th} response.

  Δ= quality loss $|Y_0 - Y_{ij}|$

  Δ_{min}= minimum value of Δ

  Δ_{max}= maximum value of Δ

  δ = distinguishing coefficient which is in range of 0≤δ≤1 (assume δ=0.5)

- **Step 4:** Find the Grey relational grade by using,

  $G_i = \frac{1}{m} \sum GC_{ij}$... Eq (3.6)

  Here 'm' is the number of process responses.

The higher value of Grey relational grade means that the corresponding parameter combination is closure to the optimal. The mean response for the Grey relational grade with its grand mean and the Main effect plot of Grey relational grade are very important because optimal process condition can be evaluated from this plot. For getting the contribution of each parameter ANOVA is performed by using Statistical tool, and Taguchi analysis is done to find out S/N ratio, for each Grey relational grade value. Optimal process parameters and their predicted values are calculated.

CHAPTER-4

EXPERIMENTAL SETUP

A number of experiments are conducted to study the effects of various cutting parameters on CNC Turret lathe. These studies have been under taken to investigate the effects of cutting speed, feed and depth of cut on Material Removal Rate and Surface Roughness characteristics for Aluminium 7075 which is machined by using tungsten carbide tool. The experiments were carried out by using Taguchi's L9 Orthogonal Array Design matrix. This chapter deals with the experimental setup details used in the present work.

4.1. CNC MACHINE & ITS SPECIFICATIONS

Specifications of CNC lathe		
Machine	:	CNC lathe
Model	:	JOBBER Xl
Capacity		
Swing over bed	:	500mm
Swing over carriage	:	260mm
Distance between centers	:	425 mm
Maximum machining diameter	:	270 mm
Maximum longitudinal travel(Z-axis)	:	400mm
Maximum longitudinal travel(X-axis)	:	140mm
Maximum power required	:	16 KVA
Approximate weight	:	4000kg
Spindle centre height from floor	:	1050mm
Spindle		
Spindle nose	:	A2-5
Bore through spindle	:	47 mm
Maximum capacity	:	36mm
Front bearing I.D.	:	80mm
Spindle speed	:	50-4000 rpm
Spindle motor (A.C.motor)cont./5	:	fanucBeeta 6/6000i,5.5KW/7.5KW
Tailstock		
Tailstock quill diameter	:	80mm
Tail taper in quill	:	MT-4
Tailstock base stroke	:	100mm
Tailstock base travel	:	235mm
Thrust (maximum recommended)	:	300 kg@12kg/cm^2
X&Z Axes		

Cross slide inclination	:	30deg
Number of turret stations	:	8
Standard cutting tools	:	25*25mm
Ball screw diameter X-axis	:	32mm: pitch=10mm
Ball screw diameter Z-axis	:	32mm:pitch=10mm
Feed motor X–axis & Z-axis	:	Fanuc Beeta 8s/3000i
Paid traverse rate X-axis & Z- axis	:	20m/min
Power capacity		
Spindle &servo drives	:	12.04 KVA
Electrical control unit	:	1.00 KVA
Hydraulic pump motor	:	1.40 KVA
Coolant pump motor	:	0.30 KVA
Lubricant pump motor	:	0.15 KVA
Chip conveyer	:	0.20 KVA
Air cooler	:	1.00 KVA

4.2. SPECIFICATIONS OF WORK PIECE

7000 series alloys such as 7075 (as shown in figure 4.1) are often used in transport applications, including marine, automotive and aviation, due to their high strength-to-density ratio. Their strength and light weight is also desirable in other fields. Rock climbing equipment, bicycle components, inline skating-frames and hang glider airframes are commonly made from 7075 aluminium alloy. Hobby grade RC models commonly use 7075 and 6061 for chassis plates. 7075 is used in the manufacture of M16 rifles for the American military. In particular high quality M16 rifle lower and upper receivers as well as extension tubes are typically made from 7075-T6 alloy. Desert Tactical Arms, SIG Sauer, and French armament company PGM use it for their precision rifles. It is also commonly used in shafts for lacrosse sticks, such as the STX sabre, and camping knife and fork sets. Due to its high strength, low density, thermal properties, and its ability to be highly polished, 7075 is widely used in mold tool manufacture. This alloy has been further refined into other 7000 series alloys for this application, namely 7050 and 7020. The chemical composition and properties of selected AA7075 material are mentioned in tables 4.1 and 4.2 respectively.

Work piece material	:	Aluminum 7075
Dimensions	:	30mm (ϕ), 60mm (L)
Quantity	:	9 no’s

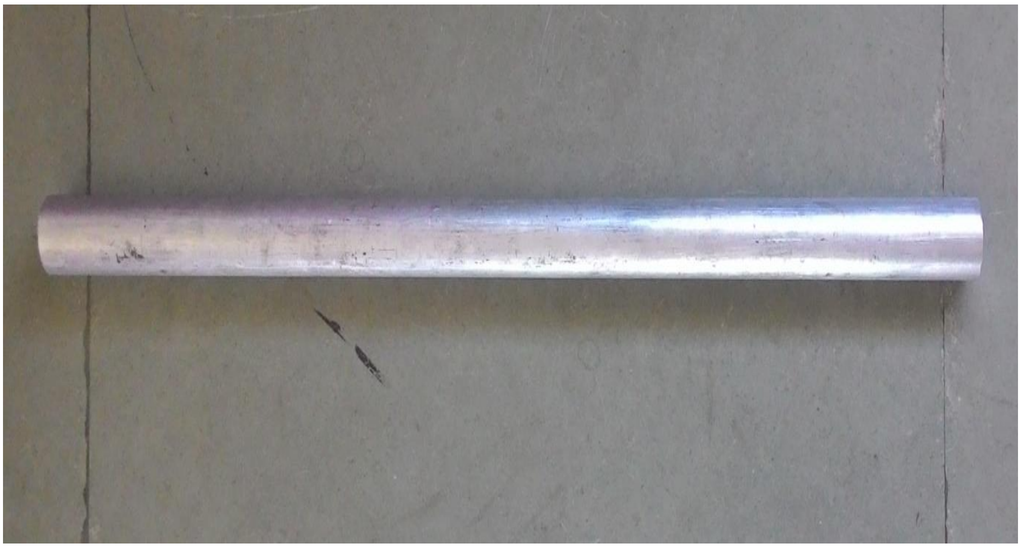

Figure 4.1. AA7075 Work piece

Table 4.1. Chemical Composition of AA7075

Element	Al	Zn	Cu	Cr	Fe	Mg	Mn
Wt %	87.1-91.4	5.1-6.1	1.2-2.0	0.18-0.28	0.5 max	2.1-2.9	0.3 max

Table 4.2. Mechanical Properties of AA7075

Parameter	Ultimate Tensile Strength (psi)	Yield Strength (psi)	Brinell's (BHN)	Rockwell	Density (gm/cm^3)
Value	83000	73000	150	1387	2.8

4.3. EXPERIMENTAL PROCEDURE

In the present work, Aluminum 7075 work pieces of each 30mm diameter and 60mm length (as shown in figure 4.3) were taken and the experimentation was conducted on CNC DX-200 turning center under dry and wet conditions. The machining length was 60mm to allow fixation of work pieces with a length 25mm. The work pieces were trued by removing 0.3 mm depth of cut from the outside surface, prior to the actual machining tests. The Experiments were carried out with a coated Tungsten carbide tool for different levels of speeds, feeds and depth of cut as per Taguchi's L9 orthogonal array given in the table 4.3.The machined work pieces are as shown in the figure 4.4. The Surface Roughness parameters were measured using a SJ-301 instrument as shown in the figure 4.6. The Surface Roughness values were measured at three points on the each machined work piece and average of those was taken as final Surface Roughness value.

4.3.1. Cutting Tool and Tool Holder Specifications

Cutting Tool : DNMG160404
Tool Holder : PDJNL2525
Coolant : Viscool 5096
Nose radius : 0.4 mm
Clearance angle : 0º

Table 4.3. Taguchi L9 Orthogonal Array

S.No.	Speed (rpm)	Feed (mm/rev)	Doc (mm)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 4.4. Parameters with Levels

Parameter	Units	Levels		
		1	2	3
Speed, s	rpm	1000	1500	2000
Feed, f	mm/rev	0.2	0.3	0.4
Depth of cut, d	mm	0.5	0.75	1

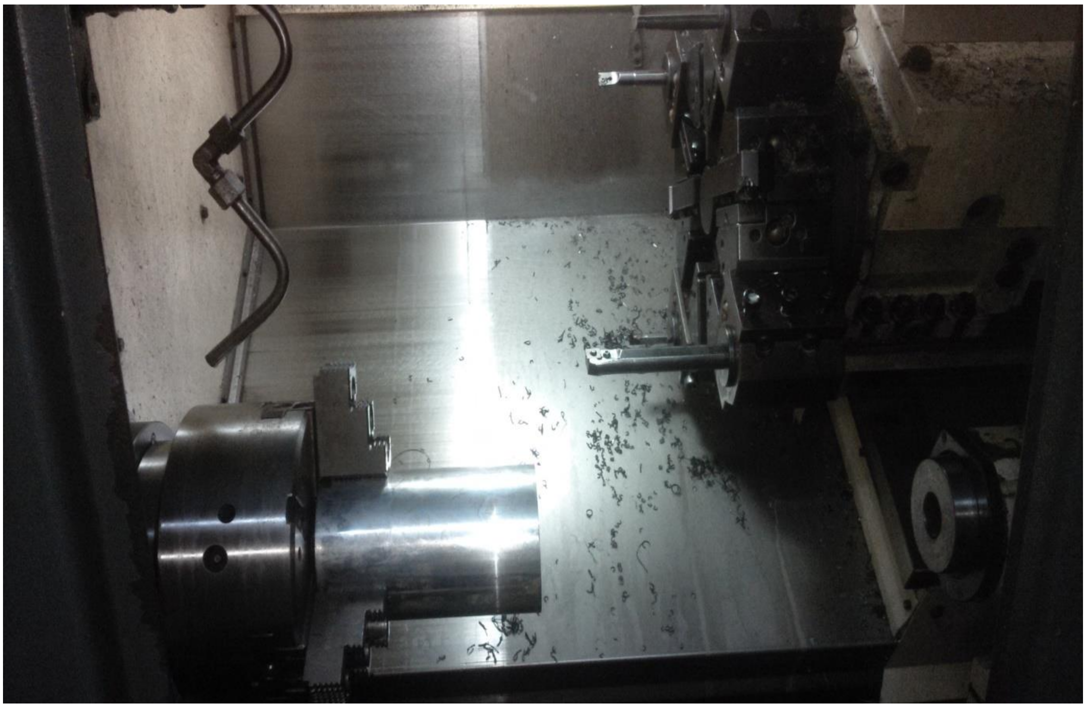

Figure 4.2. Jobber XL CNC Machining

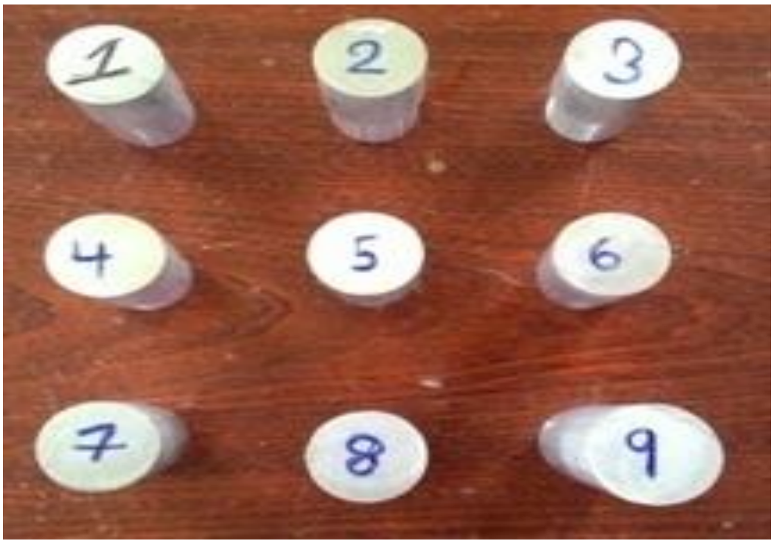

Figure 4.3. Work Pieces Before Machining

Figure 4.4. Work Pieces after Machining

Figure 4.5. Cutting Tool with Tool Holder

4.3.2. CNC Machining Program

Example program

```
O0073;
T0000;
N1;
G21   G40  G0;
G28   U0  W0;
M03 S2000;
M07;
T0707;
G0   X33.0   Z1.2;
G01  X28.25   F0.1;
G01 Z 0.0   F 0.1;
G01 Z-30.0   F 0.4;
```

4.4. Output Measurements

Material Removal Rate and Surface Roughness are the most important parameters for evaluating the productivity and quality of the products. Material Removal Rate in general increases with an increase in cutting parameters like speed, feed and depth of cut.

4.4.1. Material Removal Rate (MRR)

Material Removal Rate for the experimental data was calculated by using below formula.

MRR = (Weight loss)/ (ρ*t)
Weight loss = (Weight of work piece before machining) – (Weight of the work piece after machining).

ρ = density and
t = machining time

4.4.2. Surface Roughness

The Measurement of Surface Roughness has been done by using SJ-301(Mitutoyo) gauge as shown in Figure 4.6. Three readings were taken at three different places on each finished products as setup shown in the Figure 4.7 and the average of the three readings is taken as final Surface Roughness value.

Table 4.5. Specifications of Mitutoyo SJ-301

Model no.	SJ-301 (Measuring force:4mN)	SJ-301 (Measuring force:0.75mN)
Detection method	Differential inductance method	
Measuring range	350µm(-200 to +150µm) ,14000µin(-8000 to +6000µin)	
Detector unit	178-390	178-296
Tip radius	5µm	2µm
Drive unit	178-230	
Stylus material	Diamond	
Radius of skid curvature	40mm(1.57in)	

Figure 4.6. Surface Roughness Measurement Set-up

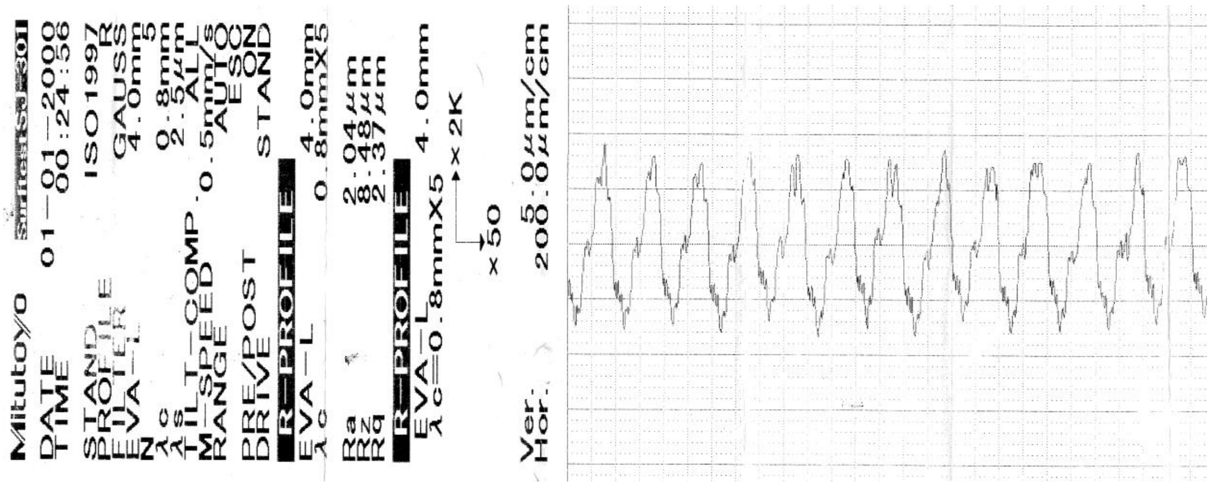

Figure 4.7. Surface Roughness Profile Sheet

CHAPTER-5

RESULTS AND DISCUSSIONS

This chapter presents the Experimental results obtained from machining on CNC lathe as per the Taguchi's L9 orthogonal array. A series of experiments are conducted on medium carbon steel Aluminium 7075 with a coated tungsten carbide tool. The components after machining are tested for Surface roughness as per the testing procedure explained in chapter 4 and Material Removal Rate is also calculated. S/N ratios are obtained for MRR is Larger-the-better and for Surface roughness is Smaller-the-better. The experimental results of Material Removal Rate (MRR) and Surface quality characteristics (R_a, R_q and R_z) of each sample and corresponding S/N ratios are given in the tables 5.1 and 5.2. respectively.

Table 5.1. Experimental Results of Responses

Run no.	Speed (rpm)	Feed (mm/rev)	Depth of cut(mm)	MRR (cm^3/min)	Average R_a (μm)	Average R_q (μm)	Average R_z (μm)
1	1000	0.2	0.5	11.25	3.25	3.9	15.28
2	1000	0.3	0.75	20.7	7.45	8.46	27.85
3	1000	0.4	1	41.25	12.71	14.59	48.91
4	1500	0.2	0.75	21.07	3.75	4.42	15.71
5	1500	0.3	1	40.71	7.87	9.01	29.69
6	1500	0.4	0.5	26.42	12.59	14.56	50.16
7	2000	0.2	1	41.25	3.69	4.37	15.52
8	2000	0.3	0.5	27.85	7.97	9.09	29.27
9	2000	0.4	0.75	61.07	12.37	14.11	46.63

Table 5.2. S/N Ratios of Responses

Run no.	S/N (MRR)	S/N (R_a)	S/N (R_q)	S/N (R_z)
1	21.0231	-10.2377	-11.8213	-23.6825
2	26.3194	-17.4431	-18.5474	-28.8965
3	32.3085	-22.0829	-23.2811	-33.7880
4	26.4733	-11.4806	-12.9084	-23.9235
5	32.1940	-17.9195	-19.0945	-29.4522
6	28.4387	-22.0005	-23.2632	-34.0072

7	32.3085	-11.3405	-12.8096	-23.8178
8	28.8965	-18.0292	-19.1713	-29.3285
9	35.7166	-21.8474	-22.9905	-33.3733

5.1. RESULTS BASED ON GREY RELATIONAL GRADE METHOD

Taguchi analysis method can optimize single objective function, it cannot solve multi-objective optimization problem. So, MRR and Surface roughness can be optimized individually by using this Taguchi technique. But it may so happen that, the optimal setting for a response variable cannot ensure other response variables within acceptable limits. So, one should go for such an optimal parameter setting so that all the objectives should fulfill simultaneously. This will be achieved by using Taguchi based Grey method. This method can convert several objective functions into an equivalent single objective function. The calculations have been done as explained in chapter 3.

Step 1: Normalizing the data: The obtained process responses are pre-processed in the first step as explained. Table 5.3 shows the Normalized data for individual responses by using the formulae discussed in chapter 3.

Table 5.3. Normalized data for Responses (X_i (k))

Run no.	**MRR**	**R_a**	**R_q**	**R_z**
1	0	1	1	1
2	0.1896	0.556	0.5734	0.6396
3	0.6021	0	0	0.0358
4	0.197	0.9471	0.9513	0.9876
5	0.5913	0.5116	0.5219	0.5868
6	0.3044	0.0126	0.0028	0
7	0.6021	0.9534	0.956	0.9931
8	0.3331	0.501	0.5144	0.5989
9	1	0.035	0.0449	0.1012

Step 2: Sequencing deviation (Δ_{oi}): Deviation sequencing is calculated for the obtained normalized data by considering ideal value 1. Results of sequencing deviation are given in the table 5.4.

Table 5.4. Sequencing Deviation $\Delta_{oi}=|Xo(K)-Xi(K)|$

Run no.	MRR	R_a	R_q	R_z
1	1	0	0	0
2	0.8104	0.444	0.4266	0.3604
3	0.3979	1	1	0.96417
4	0.803	0.0529	0.04865	0.0124
5	0.4087	0.4884	0.4781	0.4132
6	0.6956	0.9874	0.99719	1
7	0.3979	0.0466	0.044	0.00689
8	0.9999	0.499	0.4856	0.4011
9	0	0.9641	0.9551	0.8988

Step 3 & 4: Grey Relational Coefficient & Grey Relational Grade: In step 3 Grey relational coefficients is calculated for all the obtained deviational sequencing data individually as explained in the chapter 3. In step 4, Grey relational grade for each experiment is calculated by averaging all the coefficient values for responses of corresponding experiments. S/N ratios for the Grey relational grades calculated and the ranking was given from the higher to lower values of the S/N ratios. The calculated values of Grey relational coefficient and Grey relational grade its S/N ratios are given in the table 5.5.

Table 5.5. Grey Relation Coefficient and Grey Relational Grade of Responses

Run no.	Grey Relational Coefficient (GRC)				Grey Relational Grade (GRG)	S/N ratio of Grey Relational Grade	Rank
	MRR	R_a	R_q	R_z			
1	0.3333	1	1	1	0.83333	-1.5840	2
2	0.38156	0.52966	0.5396	0.58113	0.50799	-5.8844	6
3	0.55685	0.3333	0.3333	0.34149	0.39123	-8.1520	8
4	0.38372	0.90432	0.91132	0.9758	0.79379	-2.0069	3
5	0.55023	0.50586	0.5112	0.54753	0.5287	-5.5358	4
6	0.4182	0.33615	0.33395	0.13333	0.30541	-10.3026	9

7	0.55685	0.91475	0.91912	0.98641	0.84429	-1.4711	1
8	0.3333	0.5005	0.50731	0.55488	0.47399	-6.4863	7
9	1	0.34151	0.34362	0.35747	0.51065	-5.8384	5

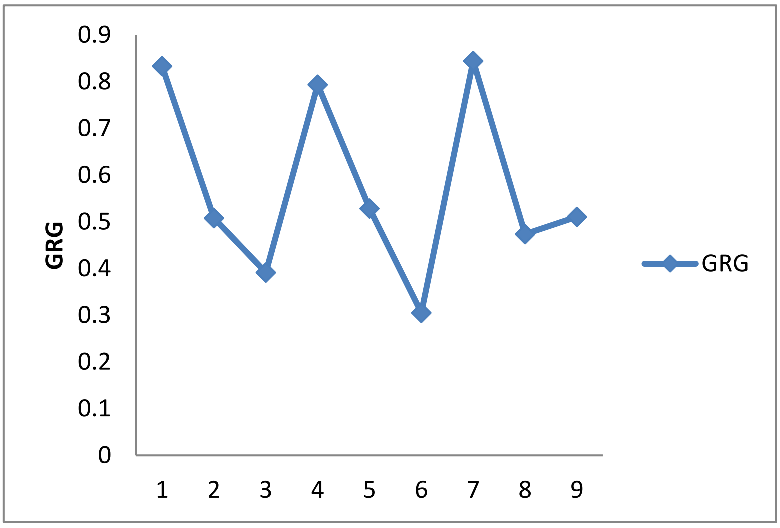

Figure 5.2. GRG & Experimental Number

Graph is plotted by taking Experimental number on X-axis and Grey relational grade on Y-axis and shown in the figure 5.2. From the figure, it is observed that seventh experiment gives the best multi performance characteristics among the nine experiments.

Step 5: Finding the optimal process parameters and their levels: optimal process parameters for the multiple responses can be founded out by using response mean grey relational grade (Table 5.6) and Main effect plots for S/N ratios of GRG are shown in figures 5.1. and 5.2.

Table 5.6. Response for S/N ratios of Mean Grey Relational Grade

Factors	**Mean Grey relational grade**			**Max-min**	**Rank**
	Level-1	**Level-2**	**Level-3**		
Cutting speed(v)	-5.207	-5.948	-4.599	1.350	3
Feed(f)	-1.687	-5.969	-8.098	6.410	1
Depth of cut(d)	-6.124	-4.577	-5.053	1.549	2

Total mean grey relational grade = -5.251

Optimal combination of process parameters for Grey relational grade is: v3-f1-d2.

Cutting speed at level 3 : 2000 rpm
Feed at level 1 : 0.2 mm/rev
Depth of cut at level 2 : 0.75 mm

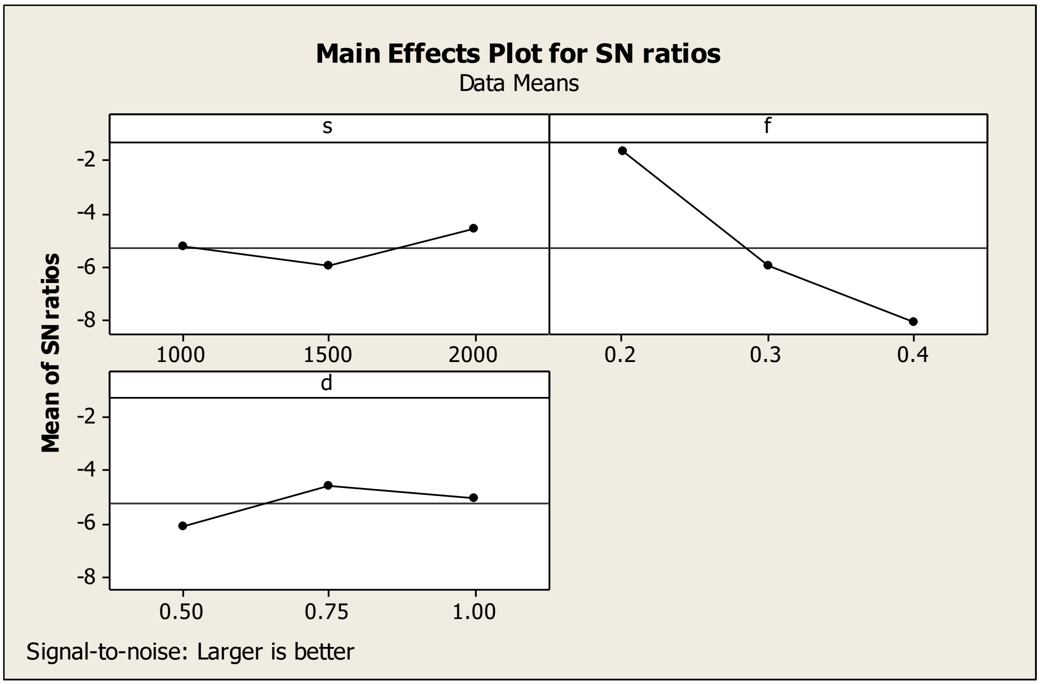

Figure 5.1. Main effect Plot for S/N ratio for Grey Relational Grade

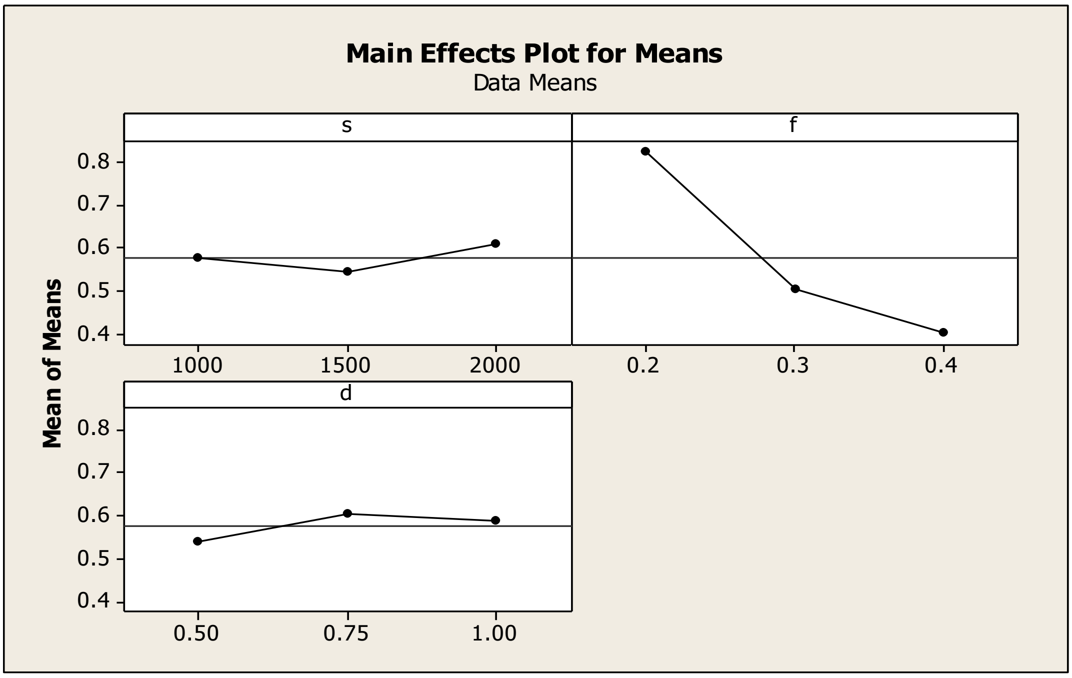

Figure 5.2. Main effect plot for S/N ratio for Grey Relational Grade

Table 5.7. Analysis of variance (ANOVA) for Grey relational grade (GRG)

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cutting speed(v)	2	0.006731	0.006731	0.003365	0.66	0.603
Feed(f)	2	0.290292	0.290292	0.145146	28.40	0.034
Depth of cut(d)	2	0.007234	0.007234	0.003617	0.71	0.586
Error	2	0.010220	0.010220	0.005110		
Total	8	0.314477				

S=0.0714843 R-sq=96.75% R-sq (adj) =87.00%

From the table 5.7., i.e. results of ANOVA it is observed that feed has statistical and more significance (F=28.40, P=0.034<0.05) on the Material Removal Rate, R_a, R_q and R_z together. Depth of cut has moderate significance (F=0.71, P=0.586) and cutting speed has very less significance (F=0.66, P=0.603) on the combined effect. The residual plots are plotted and shown in figure 5.3. indicating that the residuals are following normality and constant variance as they do not following any regular pattern.

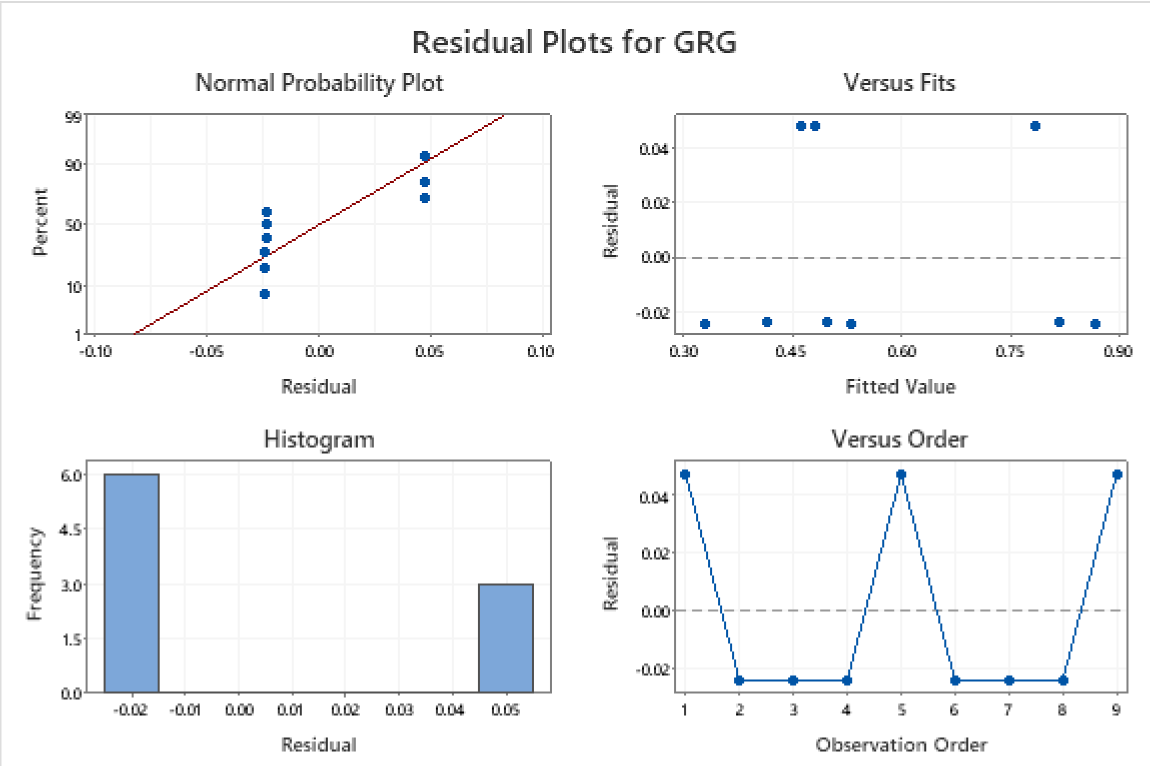

Figure 5.3. Residual Plots for Grey Relational Grade

CHAPTER-6

CONCLUSIONS

From the experimental and Grey analysis results the following conclusions can be drawn.

1. From the Grey Analysis, the optimum combination of process parameters was found at v3-f1-d2.

   Cutting speed at level 3 : 2000 rpm
   Feed at level 1 : 0.2 mm/rev
   Depth of cut at level 2 : 0.75 mm

2. From ANOVA results of GRG, it is concluded that feed has high influence, depth of cut has moderate influence and speed has the least influence in achieving the optimum values of multiple responses.

3. From the residual plots for Grey relational grade it is confirmed that the residuals are following normality and constant variance hence the model prepared is accurate and adequate.

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