IDENTIFICATION OF OPTIMAL PROCESSING PARAMETERS IN CNC TURNING OF AA6061 USING TAGUCHI TECHNIQUE

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ABSTRACT

AA6061 aluminium alloys have a variety of aircraft and automotive applications due to their high strength and good corrosion resistance. In this paper, Taguchi technique has been used to identify the optimal combination of influential factors in the CNC turning process. Turning experiments was performed on AA6061 material, for various combinations of controllable parameters like speed, feed and depth of cut. The process parameters were optimized using Taguchi L9 orthogonal design of experiments. The surface roughness and MRR were measured and recorded for each experimental run and this data are analyzed for obtaining the optimum controllable parameter combination. Confirmation experiment is conducted for this combination and the result is found to be satisfactory.

Keywords: *Taguchi method, S/N ratio, Surface roughness (Ra), Material removal rate (MRR)*

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INTRODUCTION

CHAPTER-I

INTRODUCTION

Today, what Industries want the most is quality and productivity. The rising in the purchaser requirements for quality metal cutting merchandise has driven the metal cutting business to continuous improvement in the control of metal cutting method. The turning method by lathe is one amongst the foremost basic methods of metal cutting process. The lathe could be a machine that is employed for manufacturing elements which are symmetrical to particular axis. Lathe is used for machining cylindrical surfaces, each external and internal, and conjointly for the turning of conic surfaces or tapers. In order to get higher surface roughness, the right setting of cutting parameters is crucial before the operation takes place.

Many factors can influence the ultimate surface roughness during a lathe operation. The natural surface roughness could be a result of the irregularities within the cutting operation factors like speed, feed and depth of cut that also manages the chip formations, or the material properties of each tool and work piece measure even within the prevalence of chatter or vibrations of the machine, defects within the structure of the work material. In turning operation, surface finish and material removal rate are 2 necessary aspects, that need attention each from industry personnel further as well as in research & Development, as a result of these 2 factors greatly influence machining performances. In trendy business, one amongst the trends is to manufacture low value, prime quality merchandise in brief time.

Effect of machining parameters on surface roughness of AA6061 specimens are turned on a lathe using HSS single point cutting tool for 27 combinations of spindle speed (s), depth of cut (d) and feed rate (f). The surface roughness of all the work pieces is going to be measured using Talysurf surface roughness tester and the corresponding Ra(surface roughness) values are obtained for lathe machine.

In turning operation, these three parameters are important and more responsible for good surface finish and high MRR. Now by experimental analysis on aluminium 6061, feed rate is most important factor for MRR (metal removal rate) and cutting speed is most important factor for high surface finish (low surface roughness).

1.1 Selection of Material:

6061 (Unified Numbering System (UNS) designation A96061) is a precipitation-hardened aluminium alloy, containing magnesium and silicon as its major alloying elements. Originally called "Alloy 61S", it was developed in 1935. It has good mechanical properties, exhibits good weldability, and is very commonly extruded (second in popularity only to 6063). It is one of the most common alloys of aluminum for general-purpose use. It is commonly available in pre-tempered grades such as 6061-O (annealed), tempered grades such as 6061-T6 (solutionized and artificially aged) and 6061-T651 (solutionized, stress-relieved stretched and artificially aged).

Fig. 1.1 AA6061 Pieces

The mechanical properties of 6061 depend greatly on the temper, or heat treatment, of the material. Young's Modulus is 69 GPa (10,000 ksi) regardless of temper.

1.1.1 Physical Properties of AA6061:

Type 6061 aluminum is of the 6xxx aluminum alloys, which entails those mixtures which use magnesium and silicon as the primary alloying elements. The second digit indicates the degree of impurity control for the base aluminum.

When this second digit is a “0”, it indicates that the bulk of the alloy is commercial aluminum containing its existing impurity levels, and no special care is needed to tighten controls. The third and fourth digits are simply designators for individual alloys (note thatthis is not the case with 1xxx aluminum alloys).

The nominal composition of type 6061 aluminum is 97.9% Al, 0.6% Si, 1.0%Mg, 0.2%Cr, and 0.28% Cu. The density of 6061 aluminum alloy is 2.7 g/cm^3 (0.0975 lb/in^3).6061 aluminum alloy is heat treatable, easily formed, weld-able, and is good at resisting corrosion. The physical properties of Aluminium / Aluminum 6061 alloy are outlined in the following table.

Table: 1.1 - Physical Properties of AA6061

Properties	**Metric**	**Imperial**
Density	2.7 g/cm^3	0.0975 lb/in^3
Melting point	588°C	1090°F

1.1.2 Chemical Composition:

The following table shows the chemical composition of Aluminium / Aluminum 6061 alloy.

Table: 1.2 - Chemical Composition of AA6061

Element	**Content (%)**
Aluminium / Aluminum, Al	97.9
Magnesium, Mg	1
Silicon, Si	0.60
Copper, Cu	0.28

1.1.3 Mechanical Properties

The mechanical properties of Aluminium / Aluminum 6061 alloy are tabulated below.

Table: 1.3 - Mechanical Properties of AA6061:

Properties	Metric	Imperial
Tensile strength	310 MPa	45000 psi
Yield strength	276 MPa	40000 psi
Shear strength	207 MPa	30000 psi
Fatigue strength	96.5 MPa	14000 psi
Elastic modulus	68.9 GPa	10000 ksi
Poisson's ratio	0.33	0.33
Elongation	12-17%	12-17%
Hardness, Brinell	95	95

1.1.4 Thermal Properties

The thermal properties of Aluminium / Aluminum 6061 alloy are given in the followingtable.

Table: 1.4 - Thermal Properties of AA6061:

Properties		Conditions	
		T (°C)	**Treatment**
Thermal expansion co-efficient	23.2 (10^{-6}/°C)	20-100	-
Thermal conductivity	167 W/mK	25	-

1.2 USES:

6061 is commonly used for the following:

- construction of aircraft structures, such as wings and fuselages, more commonly in homebuilt aircraft than commercial or military aircraft. 2024 alloy is somewhat stronger, but 6061 is more easily worked and remains resistant to corrosion even when the surface is abraded, which is not the case for 2024, which is usually used with a thin Alclad coating for corrosion resistance
- yacht construction, including small utility boats.
- automotive parts, such as the chassis of the Audi A8 and the Plymouth Prowler.

- flashlights
- aluminum cans for the packaging of food and beverages.
- Scuba tanks and other high pressure gas storage cylinders (post 1995)

1.3 TURNING OPERATION:

Turning is a machining process in which a cutting tool, typically a non-rotary tool bit, describes a helix toolpath by moving more or less linearly while the workpiece rotates. Usually the term "turning" is reserved for the generation of external surfaces by this cutting action, whereas this same essential cutting action when applied to internal surfaces (holes, of one kind or another) is called "boring". Thus the phrase "turning and boring" categorizes the larger family of processes known as lathing.

Turning can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using an automated lathe which does not. Today the most common type of such automation is computer numerical control, better known as CNC. (CNC is also commonly used with many other types of machining besides turning.)

When turning, the workpiece (a piece of relatively rigid material such as wood, metal, plastic, or stone) is rotated and a cutting tool is traversed along 1, 2, or 3 axes of motion to produce precise diameters and depths. Turning can be either on the outside of the cylinder or on the inside (also known as boring) to produce tubular components to various geometries. Although now quite rare, early lathes could even be used to produce complex geometric figures, even the platonic solids; although since the advent of CNC it has become unusual to use non-computerized toolpath control for this purpose.

The turning processes are typically carried out on a lathe, considered to be the oldest of machine tools, and can be of different types such as straight turning, taper turning, profiling or external grooving. Those types of turning processes can produce various shapes of materials such as straight, conical, curved, or grooved workpieces. In general, turning uses simple single-point cutting tools. Each group of workpiece materials has an optimum set oftool angles that have been developed through the years.

The bits of waste metal from turning operations are known as chips (North America), or swarf (Britain). In some areas they may be known as turnings.

The tool's axes of movement may be literally a straight line, or they may be along some set of curves or angles, but they are essentially linear (in the non-mathematical sense).

A component that is subject to turning operations can be termed as a “Turned Part” or “Machined Component”. Turning operations are carried out on a lathe machine which can be manually or CNC operated.

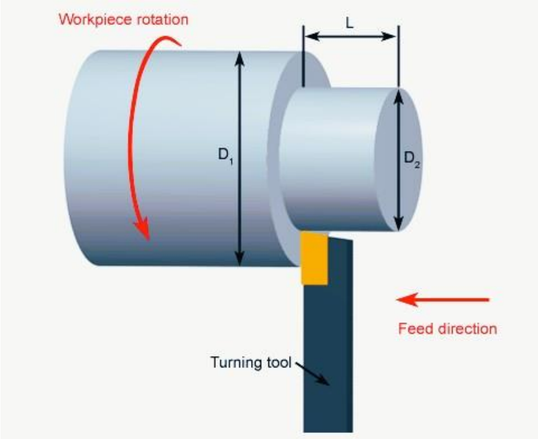


Fig – 1.2 Illustration of Turning

1.4 LATHE:

Lathe Machine is a machine tool that uses a cutting tool for removing the material from the surface of the workpiece which is held in the chuck for holding the workpiece and feed was provided by the tool on to the workpiece for the removal of material. It is the most versatile and widely used machine in industries, institutions, etc..

1.4.1 Parts of a Lathe

The main parts of a lathe are the bed, headstock, tailstock, spindles, toolrest, and motor.

1.4.2 Bed Holds It All Together

All parts of the lathe are attached to the bed. This forms the base of the lathe and is one of the factors that determine the size of the piece. That is, the distance from the main spindle to the bed will tell you the maximum diameter limit.

1.4.3 Proper Orientation

The headstock should be on the left, and the tailstock should be on the right. If you're seeing the opposite, check and make sure you're not standing on the wrong side of the lathe.

The headstock is where the main action happens. This is where the power of the motor is applied to the workpiece. Part of its purpose it to hold the main spindle, so you should see this spindle here as well.

The motor can be found on the underside of the lathe bed, on the left near the headstock. It is often some type of electric motor, but a lathe can have a hydraulic motor as well.

1.4.4 Adjustable Parts

You can adjust the tool rest for height and rotation, but for safety reasons, you should only do this when the machine is off. Once you loosen it to adjust, double-check to make sureit's tightened again before continuing.

The tailstock is also adjustable, and you'll likely be able to remove it entirely. Just like with the tool rest, you should never make these adjustments when the lathe is in operation. There's more on this in the Lathe Safety section of this post.

1.4.5 Attachments and Accessories

The spindles, including the rotating main spindle that holds the workpiece, can be outfitted with different attachments and accessories. To allow for these fittings, the main spindle is often hollow and threaded on the outside.

Some useful attachments for the main spindle include centers, chucks, and faceplates. You can use these to position the workpiece and hold it in place.

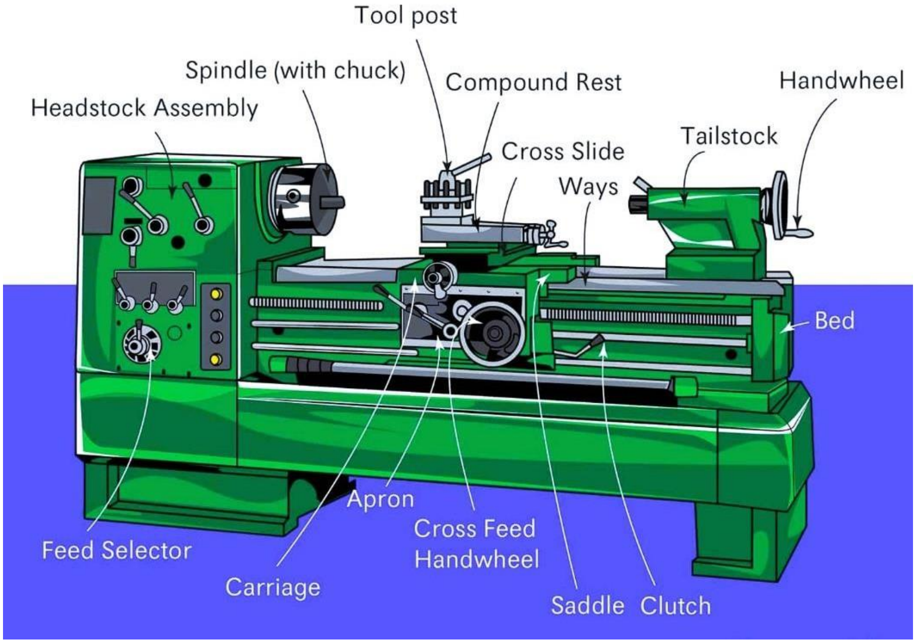


Fig. 1.3 Lathe Machine

1.5 CNC LATHE MACHINE:

CNC stands for computer numerical control and refers to a machine operated by a computer system. A CNC lathe is operated with precise design instructions to machine parts of precise specifications. A CNC lathe is a machine tool where the material or part is held in place and rotated by the main spindle as the cutting tool that works on the material is mounted and moved on various axes.

The material being worked by a CNC lathe machine is slowly sheared away. The result is a precisely finished product or an intricate part. Because these machines are so versatile, many industries use them, including automotive, electronics, aerospace, firearm manufacturing, sporting, and others.

A CNC lathe can produce plane surfaces and screw threads or, in the case of ornate lathes, three-dimensional products that are quite complex. They can be used on both small and large parts with extreme accuracy. The workpiece is typically held firmly in place by one or two centers, but the material can also be secured with collets or clamps.

Some examples of items a CNC lathe machine can make include baseball bats, camshafts, bowls, crankshafts, cue sticks, sign boards, musical instruments, and table and chair legs.

Fig. 1.4 CNC Lathe Machine

1.5.1 Working Principle of Lathe Machine:

The basic function of the Lathe machine is to remove the material from the surface of the workpiece by the usage of cutting tools providing the necessary amount of feed and this can be done by placing the workpiece in the chuck which rotates with the help of a motor.

For Circular workpieces, Three Jaw Chuck will be used whereas for the Rectangular/Square workpieces, Four Jaw Chuck will be used for better stability.

The headstock consists of a Power transmission system where the action will be providedby engaging with suitable levers. It also consists of a chuck where it can hold the workpiece firmly.

For smaller workpieces, there is no need for Tailstock whereas, for larger workpieces/specimens, there is a need for it for supporting such that the workpiece can be fixed firmly without anyvibrations during machining.

The tool is placed in the Toolpost and is perpendicular to the workpiece for removingthe material from the circumference of the workpiece such that the diameter can be reduced.

When the power supply is given, the chuck starts rotating with the help of a power transmission system and the workpiece placed inside the chuck also rotates. With respect tothe workpiece, the Tailstock is used. Now w.r.t. the type of operation, the tool is placed either perpendicular or angular to the workpiece.

For Turning operation, the workpiece and the tool are perpendicular to each other whereas, in the Taper turning operation, the tool and the workpiece are inclined to each other.

In this way, by giving the necessary amount of feed, material removal takes place. The speed can be increased by the levers in the Headstock by changing them w.r.t. the material removal.

The lathe machine can be performed Manually or Automatically. In small scale industries, we can go with manual operation whereas, in large scale industries, CNC machines are used where they can run automatically with the help of the program.

1.5.2 Applications of CNC Lathe Machine:

The Applications of Lathe Machine are as follows

- It is mainly used in industries to shape change the metal components as well as wooden components by machining lathe and wood lathe.
- It is used in Thermal spraying and Metal spinning.
- A CNC lathe finds its applications in the fields of Aerospace, Automotive, Medical, Textile, industries of automobiles, etc.
- The lathe is also used in various institutions for doing lab experiments.

1.5.3 Advantages of CNC Lathe Machine are as follows.

- The accuracy is very high in the case of CNC lathes compared to Normal Machining lathes.
- The flow of production is more.
- It requires few operators in a manual lathe.
- The machining in the lathe and CNC lathe was very fast.

- Due to the CNC lathes, the time to carry out the experiment was very less than conventional machines.
- The lead time will be very less.

1.6 Processing parameters of lathe

For any machining or metal cutting operation, three relative motions between the workpiece and cutting tool are indispensably necessary for gradual removal of material from the workpiece. In fact, the simultaneous action of all three relative motions causes advancement of cutting tool towards work material along the intended path generating a finished surface with intended shape, size and tolerance. These three relative motions are called Cutting Parameters.

There process parameters in machining are all those parameters that are inherent to any machining operation and should have a suitable finite value to smooth and efficient removal of materials. Such parameters directly affect machining performance. In machining, three process parameters are (i) cutting speed or cutting velocity, (ii) feed rate and (iii) depth of cut. More details about these parameters are elaborated in the following sections.

1.6.1 Speed:

Cutting velocity is the most important cutting parameter that provides necessary cutting motion (CM). In case of either rotating tool (such as milling, drilling, grinding) or rotating workpiece (such as turning), the peripheral velocity of cutter or workpiece (as the case) is considered as the cutting velocity. The rotational speed is called the Cutting Speed (denoted by N and measured in rpm); whereas, the tangential velocity is called Cutting Velocity (denoted by V_c and measured in m/min).

1.6.2 Feed:

The auxiliary cutting motion is provided by the feed rate or feed velocity. Usually the direction of feed velocity is perpendicular to that of the cutting velocity; however, not necessary. The primary objective of feed velocity is to advance the cutter with respect to the workpiece to remove material from a wider surface. Basically it helps in covering the entire surface of the workpiece by moving either cutting tool or workpiece. Feed rate can be imparted either on the cutter or on the workpiece.

1.6.3 Depth of cut:

The tertiary cutting motion that provides necessary depth within work material that is intended to remove by machining. It is given in the third perpendicular direction and the simultaneous action of three cutting parameters results in removal of excess material from workpiece.

1.7 Surface Roughness Tester:

Surface Roughness is like a fingerprint left behind bythe manufacturing process. The surface irregularities of small wavelength are called primary texture or roughness these are caused by direct action of the cutting elements on the material i.e., cutting tool shape, feed rate or by some other disturbances such as friction, wear or corrosion.

The surface considerable wavelength of a periodic character is called secondary texture or waviness. These irregularities result due to inaccuracies of slides, wear of guides, misalignment of centers, non-linear feed motion, vibrations of any kind etc.

Elements of Surface Texture Actual Surface: It refers to the surface of apart which is actually obtained after manufacturing process.

Nominal surface: A nominal surface is theoretical, geometrically perfect surface which does not exist in practice, but it is an average of the irregularities that are superimposed on it.

1.7.1 Profile: It defined as contour of any section through a surface.

1.7.2 Lay: It is the direction of predominant surface pattern produced by the tool marks or scratches, generally surface roughness is measured perpendicular to the lay.

1.7.3 Sampling Length: It is the length of the profile necessary for the evaluation of the irregularities to be taken in to account.

1.7.4 Roughness Height: This is rated as the arithmetical average deviation expressed in micrometers normal to an imaginary center line, running through the profile.

1.7.5 Roughness Width: Roughness width is the distance parallel to the normal surface between successive peaks or ridges that constitute the predominant pattern ofthe roughness.

1.8 Measuring instruments:

1.8.1 Talysurf surface meter:

The surface roughness of a component is examined by the observation of its surface. In the direct measurement method, a stylus type device is used for inspecting the roughness parameter. One of the various types of instruments used for the direct measurement method isTaylor Hobson Talysurf surface roughness tester.

Talysurf is used to measure the surface roughness by using an electronic principle, this surface meter consist of stylus and skid type instrument used for measuring the surface ofthe give product.

This type of talysurf surface meter contains an Electronic means which is exact and high accurate than different types of surface meter.

The measuring head consist of sharply pointed diamond stylus on it in talysurf surface meter stylus has a very small radius of 0.002 mm tip and with the help of motor present in it helps to move the skid on the surface.

In this instrument, the stylus point out's the profile of the surface and any deflections of a stylus is converted into electric current to identify the measurements ofthe object. It consist of stamping above the armature which consist of coils on both the sides of stamping, this coils helps to forms an oscillator. In this surface meter the armature present onthe stamping is in fixed position when this fixed armature causes any vibrations of stylus it produces an air gap by this the current passing from a coil get changed due to this changes in the amplitude of current the output gets to demodulate due to this discontinuous current passing the measurement of surface is given by an electronic system present in it. constructionand working principle:

1.8.2 Description of Surftest SJ-210:

This is a portable measuring instrument that allows you to easily and accurately measure surface roughness.

Fig.1.5 Surface roughness tester

The Surftest SJ-210 offers you the following benefits:

- Skid system gives you user friendly and intuitive menu navigation.
- It works independently of mains power, allowing youto make on-site measurements.
- The 6.0 cm [2.4“] colour graphic, back-lit LCD gives you excellent readability.
- It performs roughness analyses conform to various international standards (EN ISO, VDA, ANSI, JIS) and customized settings.
- Different drivers expanding the range of applications.
- Calculation results, assessed profiles, bearing and amplitude curves can be displayed.
- Support of 21 languages.
- Operation by keys on the front and under the sliding cover.

1.8.3 Advantages: The main advantage of such instruments is that the electrical signal available can be processed to obtain any desired roughness parameter or can be recorded for display or subsequent analysis. Therefore, the stylus type instruments are widely used for surface texture measurements inspite of the following disadvantages.

1.8.4 Disadvantages: These instruments are bulky and complex. They are relatively fragile. Initial cost is high. Measurements are limited to a section of a surface. (v) Needs skilled operators for measurements. Distance between stylus and skid and the shape of the skid introduce errors in measurement for wavy surfaces

1.8.5 Applications: Low-coherence profilometers deliver fast, reliable, and non-contact 3D surface measurements – with precision better than 1 µm. Surfaces are rapidly characterized in terms of shape, roughness, flatness, waviness, and other surface qualities High-speed scanning: 1,000 to 30,000 points/sec and higher Real-time feedback on manufacturing or coating processes: application data is typically forwarded to process control software Easy visual inspection: depth profiles, 2D cross-sections (B-scans or C-scans) and3D surface maps.

1.9 Design of Experiments:

Design of Experiment or parameter and level setting were design for experiment to conducting on turning machine of three level and four parameter for the optimization of lower surface roughness throughthe experimental setup by using Taguchi methodology.
L-9 orthogonal array is using for this experiment. This method is used for three parameter levels such as Cutting Speed, feed of workpiece and depth of cut. Experimental design consists of three types of cutting tool speeds, three types of feed rates and three type of depth of cuts. Taguchi's method of experimentation is best suitable for this study.

This method gives means (average) and variation of experimental results for calculating S/N (Signal to Noise ratio) which describe the test results. From need of specific application, by using this S/N ratio, the range of level can be calculated by design of experiment via Taguchi method. The S/N ratio is considered as smaller is better, larger is better, nominal is best for different output machine response variables. In this study, the value of S/N ratio for surface roughness is considered as smaller is better and metal removal rate is considered as larger is better.. The selection of proper S/N ratio also depends upon the physical properties of the problem.

This analysis is based upon the averages of the experimental result at each level for each parameter. The effect of each parameter (cutting speed, feed rate and depth of cut) can be found by experimentation on each level. In this way, the effect of each parameter is evaluated. From S/N ratio, experimental results evaluate the average response analysis.

CHAPTER–II

LITERATURE REVIEW

CHAPTER-II

LITERATURE REVIEW

2.1 INTRODUCTION

Before going with the project a brief study on papers related to optimization of machining parameters using taguchi technique for MRR and Surface Roughness of AA6061 ALUMINIUM ALLOY.

- **JOEL J AND ANTHONY XAVIOUR M** ,“ Optimization on machining parameters of aluminium alloy hybrid composite using carbide insert ”. Three different aluminium alloy based composites were developed by using Al 6061, AA 2024 and AA 7075 as matrix materials and Graphene (2 wt%) as reinforcement material.

In this paper, three different aluminium alloy based composites were developed by using Al 6061, AA 2024 and AA 7075 as matrix materials and Graphene (2 wt%) as reinforcement material. The fabrication of nano composites were carried out using powder metallurgy route followed by hot extrusion. The extruded samples of the three composites were subjected to turning experiments to explore its machinability. Five parameters namely, type of work material, cutting tool material, cutting speed, feed rate and depth of cut are considered for the turning experiments. Taguchi L18 mixed orthogonal array with three levels of cutting speeds (35, 50 and 65 m min^{-1}), feed rates (0.1, 0.2, 0.3 mm/rev), depth of cut (0.6, 0.8, 1 mm), three different work (composite) materials and two levels of cutting tool (Uncoated and DLC Coated carbide) materials was used for the design of experiment. Cutting force generated during the machining process, surface roughness and surface hardness obtained on the machined surface of the specimen and flank wear on the tool subsequent to machining are recorded for further analysis. Analysis of Variance (ANOVA) was carried out using the experimental data to determine the significance of each variable parameter on the response parameter. From ANOVA, it has been noted that AA6061 based composite has encountered significant cutting force when compared to other two composite. Likewise work material have more influence on surface roughness while comparing the other machining parameters and AA7075 based composite was found to result in better surface finish. Cutting speed has significantly influenced the flank wear followed by the tool material and it was found that uncoated carbide has undergone more wear than the

DLC coated carbide insert. Further, it is evident from micro structural and FESEM analysis that there is a homogeneous distribution of Graphene particles in aluminium matrix after hot extrusion.[1]

- **VLADIMIR ALEKSANDROVICH ROGOV, GHORBANI** " Optimization of Surface Roughness and Vibration in Turning of Aluminium Alloy AA2024 Using Taguchi Technique ". Determination of optimal conditions of machining parameters is important to reduce the production cost and achieve the desired surface quality.

This paper investigates the influence of cutting parameters on surface roughness and natural frequency in turning of aluminium alloy AA2024. The experiments were performed atthe lathe machine using two different cutting tools made of AISI 5140 and carbide cutting insert coated with TiC. Turning experiments were planned by Taguchi method L9 orthogonal array. Three levels for spindle speed, feed rate, depth of cut and tool overhang were chosen as cutting variables. The obtained experimental data has been analyzed using signal to noise ratio and analysis of variance. The main effects have been discussed and percentage contributions of various parameters affecting surface roughness and natural frequency, and optimal cutting conditions have been determined. Finally, optimization of the cutting parameters using Taguchi method was verified by confirmationexperiments.[2]

- **M.RAVICHANDRAN M.MEIGNANAMOORTHY AND S.SAKTHIVELU**, " To investigate the influence of process parameters in drilling of AA6063 in a CNC lathe by using high speed steel drill bit ".

In this paper, they investigated the influence of process parameters in drilling of AA6063 in a CNC lathe by using high speed steel drill bit. The input parameters namely the spindle speed, feed rate and depth of cut are wide-ranging to experiment their influence on material removal rate (MRR). The experiments were conducted using L16 orthogonal array. Consequence of quality of CNC drilling process was found by Design of Experiments (DOE) and analysis of variance (ANOVA). The investigations exposes that the material removal rate is directly influenced by the Spindle speed, feed rate and depth of cut. It was identified thatthe MRR increase and increases with related to feed rate, spindle speed and frequently for all depth of cut and also monitor the machining time.[3]

- **ANAND S.SHIVADE, SHIVRAJ BHAGAT, SURAJ JAGDALE, AMIT NIKAM, PRAMOD LONDE**, “ Optimization of Machining Parameters for Turning using Taguchi Approach ”. Modern manufacturers, seeking to remain competitive in the market, rely on their Manufacturing engineers and production personnel to quickly and effectively set up manufacturing processes for new products.

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.[4]

- **V. ROGOV, GHORBANI SIAMIK**, “ Optimization of Surface Roughness and Vibration in Turning of Aluminium Alloy AA2024 Using Taguchi Technique ”.

Determination of optimal conditions of machining parameters is important to reduce the production cost and achieve the desired surface quality.

This paper investigates the influence of cutting parameters on surface roughness and natural frequency in turning of aluminium alloy AA2024. The experiments were performed atthe lathe machine using two different cutting tools made of AISI 5140 and carbide cutting insert coated with TiC. Turning experiments were planned by Taguchi method L9 orthogonalarray. Three levels for spindle speed, feed rate, depth of cut and tool overhang were chosen as cutting variables. The obtained experimental data has been analyzed using signal to noise ratio and analysis of variance. The main effects have been discussed and percentage contributions of various parameters affecting surface roughness and natural frequency, and optimal cutting conditions have been determined. Finally, optimization of the cutting parameters using Taguchi method was verified by confirmation experiments.

Keywords— Turning, Cutting conditions, Surface roughness, Natural frequency, Taguchi method, ANOVA, S/N ratio.[5]

- **ARPIT SRIVASTAVA1, MUKESH KUMAR VEMA1 , RAMENRA SINGH NIRANJAN1 , ABISHEK CHANDRA1 , PRAVEEN BHAI PATEL1**, "Experimental Investigation and Optimization of Machining Parameters in Turning of Aluminium Alloy 075-T651 ". Aluminium alloy 7075-T651 is a widely used material in the aviation, marine, and automobile sectors. The wide application marks the importance of this material's research in the manufacturing field.

This paper focuses on optimizing input process parameters of the turning process in the machining of Aluminium 7075-T651 with a tungsten carbide insert. The input machining parameters are cutting speed, feed, and depth of cut for the output response parameters cutting force, feed force, radial force, material removal , and surface roughness of the work piece. For optimization of process parameters, the Taguchi method, with standard L9 orthogonal array, is used. ANOVA is applied to obtain significant factors and optimal combinations of process parameters.[6]

- **KRISHNAVENI A1 , JEBAKANI, D1 ,JEYAKUMAR, K2 and PITCHIPOO P3** " Turning Parameters optimization using Copras -Taguchi technique ". Optimization of machining parameters plays a vital role in the quality of the product and the reduction of the cost. The quality of surface finish, durability of tool and dimensional accuracy are depending on the selection of optimum parameters.

In this paper, five process parameters such as cutting speed, feed, depth of cut, tool insert and type of coolant are considered as input parameters and material removal rate, surface roughness, machining time and tool nose radius wear are taken as the expected output responses. Taguchi based COPRAS (Complex Proportional Assessment of alternatives) is proposed to find the optimal combination of parameters. L8 orthogonal array is used to conduct the experiments. The weightage of the output responses are computed using entropy measurement method. [7]

- **1GULFAM GUL, 2RAHUL KUMAR MITTAL,** "Optimization of Turning Process Parameters for Surface Roughness of EN-31 Steel using Taguchi Robust Method ". In the modern world, the quality of surface finish is most important requirement for any turned work-piece due to which manufacturers are seeking to remain competitive in market. Present paper presents a study that investigates the effect of turning three process parameters such as rotational speed, feed rate and depth of cut each at level three on surface roughness of EN-31 steel using Taguchi robust method. Surface roughness is selected as the quality target. The experimental plan is based on Taguchi's L9 Orthogonal array and was used for designing the experiments and optimization of turning process parameters. Nine experiments were conducted as per L9 (O.A). The experiments were conducted on CNC-lathe machine using carbide cutting tool. The analysis of variance (ANOVA) technique is employed to study the significance and contribution percentage of each factor on surface roughness. Results revealed that factor (B) i.e., feed-rate has a significant effect on surface roughness in turning process and it is the most dominating factor affecting the surface roughness with contribution of 87.49 %. The optimal turning process parameter combination for minimum surface roughness is found to be A1B1C1.[8]

- **RAVI ARYAN, FRANCIS JOHN, SANTOSH KUMAR, AMIT KUMAR**, "Optimization of Turning Parameters of AL-Alloy 6082 using Taguchi Method ". Every manufacturing industry aims at producing a large number of products within lesser time.

In this paper, the optimization of cutting parameters for surface roughness & material removal rate in the turning process to obtain the optimal setting for the process parameters and analysis of variance is used to analysis the influence of cutting parameters while turning. Orthogonal array is also beenused and prepared to obtain the optimal levels and to analyse the effect of each turning parameters. The S/N ratio is been calculated to structure the ANOVA table and study the performance characteristics in turning process. ANOVA analysis gives the contribution percentage of every process parameter. The number of experiments are to be obtained using full factorial design for optimal result.[9]

- **M. VINOTH KUMAR , M. MEIGNANAMOORTHY , S. SAKTHIVELU , S. DINESH KUMAR , C. CHANAKYAN , S.V. ALAGARSAMY**, "Optimization of material removal rate in CNC turning of AA2024 via Taguchi technique ".

The aim of the research work is to achieve higher material removal rate in CNC Turning of AA2024 via Taguchi Technique. The present work examines the effects of cuttingparameters like speed, feed and depth of cut on material removal rate of AA2024. Taguchi methodology has been applied to optimize cutting parameters. The experiments were conducted using L16 orthogonal array. The research exposures that the material removal rate is directly driven by the speed, feed rate and depth of cut. It was identified that the material removal rate increases with related to feed rate, spindle speed and frequently for all depth of cut.[10]

- **K.B.G.TILAK, DEGA NAGARAJU**, "Investigation on Aluminium Alloy 1100 Using Taguchi Robust Design Methodology on CNC Milling ". The machining process is reliant on the material characteristics and the machining parameters.

This paper summaries a comprehensive investigational study to upgrade the test impacts of cutting parameters on Surface roughness of Aluminium Alloy 1100 by utilizing Taguchi robust design system. The work is concentrate on the ideal parameters for processing i.e. Spindle Speed, Feed, Depth of Cut and Coolant Flow. Taguchi orthogonal Array is considered with three positive levels of machining parameters and trials are facilitated by utilizing L9 (34) orthogonal cluster which contains nine columns addresses nine unique tests with a blend of 9 particular parameters to be driven and estimations of every operation were perceived. After powerful machining work surface roughness is determined on each piece of the material. Anticipated estimation of Surface to Noise ratio (S/N) is closer to the trial ideal qualities. The target of the work is satisfied through S/N ratio estimations of confirmation test is inside the points of confinement of predicted value.[11]

- **B. RAMAREDDY AND GOPAL VARVATTE**, "Optimization of process parameters in CNC turning of aluminium alloy 7075 by Taguchi method using regression analysis". In these days scientists and technocrats are developing newer materials and production processes to cater the needs of consumers of different categories of the industries. The industries need the materials and processes which are of economical.

This paper makes an attempt to optimize turning process parameters by applying

Taguchi methods which in turn is employed to improve the quality of manufactured products, and development of designs for studying the variation which is present in all production processes. Aluminum alloy 7075 is used as the work piece material for carrying out the experimentation to optimize the material removal rate and surface roughness. The work pieces used are of 25mm diameter and 50mm length. The important three machining parameters considered for the studies are speed, feed and depth of cut. Experiments were conducted based on the Taguchi design of experiments with L9 orthogonal array and Minitab-14 software is used to analyze the data. The S/N ratio and ANOVA are employed to study the performance characteristics in CNC turning operation. The MRR was considered as the quality characteristic with the concept of "larger-the-better" where as surface roughness is viewed as "smaller-the- better" type of quality characteristics. The S/N ratio value is calculated with the help of minitab-14. Surface roughness is measured and the MRR values are calculated and their optimum levels were determined. It is also predicted that Taguchi method is an effective method for optimization of various machining parameters as it reduces the number of experiments. In this work the turning of Aluminum alloy 7075 is done in order to optimize the turning process parameters for maximizing the MRR and minimization of surface roughness.[12]

- **T VIJAYA BABU**, "Optimization of Machining Parameters on 7075 Aluminium Alloy using Taguchi and ANOVA". Optimization of the parameter to provide best solution to minimize tool wear, surface roughness, cutting forces presented using optimization technique.

In this paper, an experimental study is made in this Taguchi design of experiment methodology for optimization of parameters on 7075Aluminium alloy using tungsten coated electrode. Experiments have been carried based on L27 standard orthogonal array with 3 processes parameters cutting speed, feed, and depth of cut. Electrical discharge machining performance is generally evaluated on the basis of Surface Roughness (SR), Tool wear rate (TWR) and cutting force (CF). The ANOVA were employed to study the performance characteristics in turning operation. ANOVA is plays an important role for producing higher roughness. Finally the relationship between cutting parameters and response was developed by using MINITAB-17 software. The prediction values are compared with the experimental values.[13]

- **V. ALAGARSAMY.S., AROKIA VINCENT SAGAYRAJ, TAMIL VENDAN** ,"Optimization of Machining Parameters for Turning of Aluminium alloy 7075using Taguchi method. Every manufacturing industry aims at producing a large number of products within relatively lesser time.

This study applies Taguchi design of experiment methodology for optimization of process parameters in turning of Aluminium Alloy 7075 using tungsten coated carbide tool.Experiment have been carried out based on L27 standard orthogonal array design with threeprocess parameters namely Cutting Speed, Feed, Depth of Cut for Material removal rate andMachining time. The signal to noise ratio and analysis of variance were employed to study the performance characteristics in turning operation. ANOVA has shown that the speed has significant role to play in producing higher material removal rate and lesser machine time. Thus, it is possible to increase machine utilization and decrease production cost in anautomated manufacturing environment.[14]

- **BHONAGIRI RAMESH, CH BANDHAVI, RAM SUBBIAH, N.SATEESH,** "Optimizing the Process Parameters of Drilling on Aluminium Alloy 7075 using taguchi and Anova Techniques". In many material processing and manufacturing industries quality and productivity are two important requirements but these are more antithetical criteria in any machining operations. So, it is vital to optimize the productivity and quality simultaneously.

The main objective of this paper is to optimize the process parameters of drilling operations such as cutting speed, feed, and point angle on aluminum alloy 7075. Al 7075 is one of the multifunctional materials in various applications. Taguchi is mostly used for data analysis and optimization of process parameters for getting maximum material removal rate and least surface roughness factor. Machining operations were conducted on CNC milling machine. The number of drilling experiments was performed on aluminum 7075 using HSS drill bit on CNC milling machine. The investigation of variance (ANOVA) was engaged to find the most notable control factors affecting the material removal rate & surface roughness. The conclusions of present work were drawn from several experimental trails; it was found that at the 9th experimental trail, point angle was most significant x factor for surface roughness and feed is the most affecting factor for material removal rate.[15]

- **SAHIRA HASSAN IBHRAHIM, SAHAR HUSSEIN AHMED , IMAN AHMED HAMEED**, "Evaluated of Mechanical Properties for Aluminium Alloy Using Taguchi Method". AA7075 is one of significant industrial aluminium alloys, its special mechanical properties such as strength and ductility has makes it used in varying applications.

In this investigation a heat treatment process has been done after quenching in water in deferent temperatures and times, the mechanical properties (tensile strength & hardness) have been tested and the results have been designed by Taguchi method to predict the optimum strength and hardness values. The process parameters which a key role in deciding this study, were three tempering temperature (100,200,300) ^{o}C, three time holding (1,2,3)hr, three temperature rise rate (5,10,15) ^{o}C/min. Taguchi parametric design and optimization approach was used Minitab17 program to analyze the data find the optimal strength and hardness for improvement mechanical behaviour of AA7075 aluminium alloy.[16]

From the above works , it has been observed that much work is not reported so far to investigate the Optimization of Machining Parameters using Taguchi technique for MRR and Surface Roughness of AA6061 Aluminium Alloy. In present study optimization was done by using Taguchi technique and the results are validated .Analysis was done on AA6061 at different speed, feeds and depth of cuts to study the surface roughness and material removal rate and results were compared.

CHAPTER–III

OBJECTIVES

CHAPTER - III

OBJECTIVES

3.1 Objectives:

Surface roughness is affected by many factors such as machining parameters, cutting tool properties, work piece properties and cutting phenomena. Surface roughness is known to be significantly affected by the machining parameters such as depth of cut, spindle speed, and feed rate.

1. To conduct a set of machining tests using AA6061 aluminum alloy as work piece material using various machining parameters to provide original data pertaining to surface roughness and MRR.
2. To obtain and optimize the surface roughness from all the cutting conditions by conducting machining tests.
3. To utilize the statistical prediction methods, such as Taguchi, to establish the relationship model between the surface roughness and the parameters, so that the desired levels of machining parameters will be achieved.
4. To analyze and optimize the sensitivities of material removal rate to the parameters.

CHAPTER - IV

EXPERIMENTATION DETAILS

CHAPTER – IV

EXPERIMENTATION DETAILS

4.1 CNC Lathe: Turning tests have been performed on AA6061 work material using CNC Lathe with cutting tool made of HSS by considering different processing parameter combinations. The CNC Lathe is as shown in the Fig. 4.1.

Fig. 4.1 CNC Lathe

The specifications of the CNC Lathe are as follows:

a. Specification of CNC XL turn Lathe Machine

1. Maximum turning diameter = 32 mm
2. Maximum turning length of the billet = 120 mm
3. Distance between the centres = 210 mm
4. Swing over the bed = 150 mm Ø
5. Swing over cross-slide = 50 mm Ø

b. Spindle Specifications

1. Spindle power = 1 H.P.
2. Spindle speed range = 100 – 3000 RPM
3. Spindle taper = MT3
4. Bore through spindle = 20 mm Ø
5. Chuck size = 100 mm Ø

c. CNC Slider Specification

1. Maximum longitudinal travel of tool [Z-Axis] = 180 mm
2. Maximum cross travel to tool [X-Axis] = 80 mm
3. Rapid traverse rate Z-axis = 1.2 m/min

4. Rapid traverse rate X-axis = 1.2m/min
5. Tail stock base strove = 150 mm

d. Turret Specification

1. No. of stations = 8
2. Maximum boring bar diameter = 16 mm
3. Tool cross-section = 12 mm X 12 mm

e. Machine Dimensions

1. Length of the machine = 880 mm
2. Width of the machine = 575 mm
3. Height of the machine = 615 mm
4. Weight of the machine = 150 Kg

f. Machine Specification

1. Spindle speed:
   a. Range : 100- 3000 RPM
   b. For roughing operation : 1200 – 1500 RPM
   c. For finishing operation : 1800 – 2000 RPM
   d. For thread cutting : 500 – 600 RPM
   e. For drilling operation : 1000 – 2000 RPM
2. Tool specification :
   a. No of tools inserted turret : 1-8 tools
   b. 4 tools fitted in internal and 4 in external
3. Feed rate :
   a. For roughing operation : 60 – 80 mm/min
   b. For finishing operation : 32 – 40 mm/min
4. Depth of cut
   a. Maximum depth of cut : 1.5 mm

4.2 Surface Roughness Tester: The surface roughness is selected as index to evaluate cutting performance in milling. The surface roughness and MRR are selected as responses to evaluate cutting performance in CNC turning. Therefore they are considered as response characteristics of this study. The portable surface roughness tester (SJ-210 model) is as shown in Fig. 4.2. Basically surface roughness should be minimized in any metal cutting process for better performance and MRR should be maximized.

Fig. 4.2 Portable Surface Roughness Tester

4.3 Taguchi Experimental Design:

Taguchi experimental design is widely used to optimize the process parameters in order to improve the quality characteristics of components. Classical experimental design becomes more complex with increase in the number of process parameters, as this would lead to a dramatic increase in the number of experiments to be performed. Taguchi addresses quality in two main areas: offline and online quality control. This method facilitates the use of a unique design of orthogonal arrays (OAs) to study the whole parameter space with a limited number of experiments. The most important difference between a classical experimental design and a Taguchi design technique is that the former tends to focus solely on the mean of the quality characteristic while the latter reduces the variability of the quality characteristic. The steps in Taguchi experimental design are as follows:

(a) Selection of the response variable(s) to be optimized

(b) Identification of the factors (input variables) affecting response (output variables) and their respective factor levels

(c) Selection of the appropriate OA

(d) Assignment of factors and interactions to the columns of the OA

(e) Conduction of the matrix experiment

(f) Analysis of the data using S-N (signal-to-noise) ratio and ANOVA (analysis of variance)

(g) Determination of the optimal levels of process parameters

(h) Performing the confirmatory experiments.

In this experiment three controllable parameters are considered and each parameter is set at three levels. The parameters and its levels are shown in Table 1. For full factorial design, the experimental runs required are (levels) (factors) equal to 3^3 = 27. To minimize the experimental cost, fractional factorial design is chosen, ie.3^{3-1} = 9 runs. Therefore Taguchi experimental design L9 is chosen for conducting experiments (Table 2). Experiments are performed according to this design and the values of surface roughness are recorded (Table 2) for each experimental run.

CHAPTER – V

RESULTS AND DISCUSSION

CHAPTER – V

RESULTS AND DISCUSSION

5.1 Taguchi S/N ratio analysis:

S/N ratios for the corresponding response values (surface roughness) are calculated according to the required quality characteristics as follows.

i) Larger - the – better

ii) Smaller - the – better

Where n-number of replications, y_{ij}= Observed response value where i=1, 2...n; j-1,2...k, Larger the better applied for problem where, maximization of the quality characteristic is sought and Smaller the better is applied were minimization of quality characteristic is sought. For the present problem, smaller the better is applicable for surface roughness as it should be minimum. Larger the better is applicable for material removal rate as it should be maximum.

Table 5.1: Process Parameter and their levels

S.No.	Cutting Parameters	Low level	Medium level	High level
1	Cutting speed (v). rev/min	835	1330	2000
2	Feed rate (f). mm/rev	32	36	40
3	Depth of cut (d). mm	0.3	0.6	0.9

Table 5.2: Experimental design and data

S.No	Speed (RPM)	Feed (mm/rev)	Depthof Cut(mm)	MRR (cc/min)	Ra (µm)
1	835	32	0.3	629.568	2.788
2	835	36	0.6	1416.28	1.344
3	835	40	0.9	2360.88	0.622
4	1330	32	0.6	2004.48	1.7510
5	1330	36	0.9	3382.56	0.7355
6	1330	40	0.3	1252.8	0.3620
7	2000	32	0.9	4522.17	2.9330
8	2000	36	0.3	1695.816	1.4165
9	2000	40	0.6	3769.68	0.6582

In this paper S/N ratio analysis is performed using mini-tab software (Ref. Fig.5.1, Fig.5.2, Fig. 5.3, Fig. 5.4, Fig.5.5, Fig. 5.6, Fig.5.7)

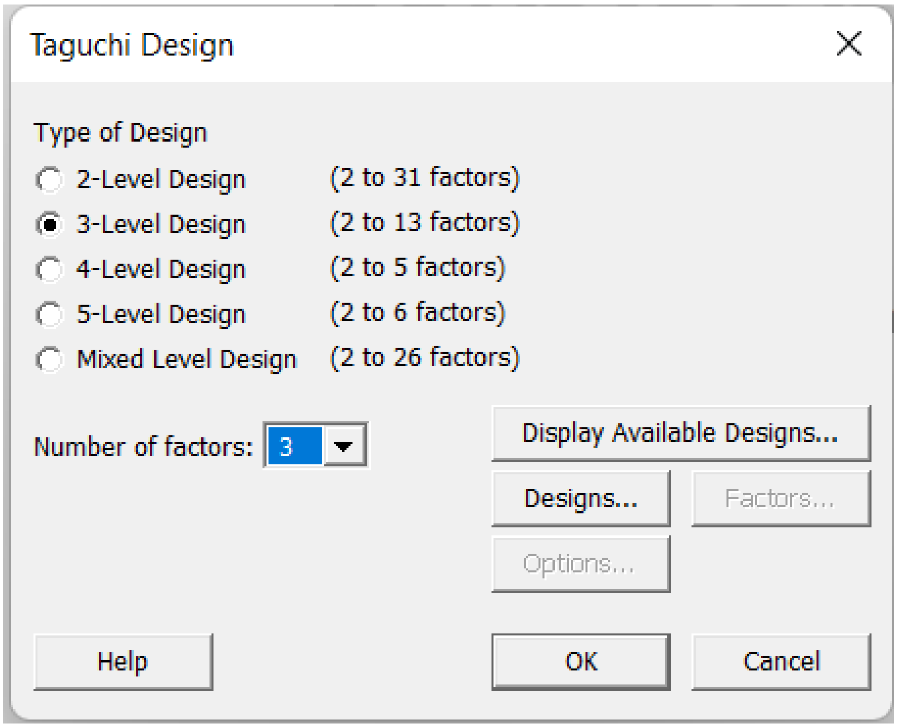


Fig 5.1 Level Selection

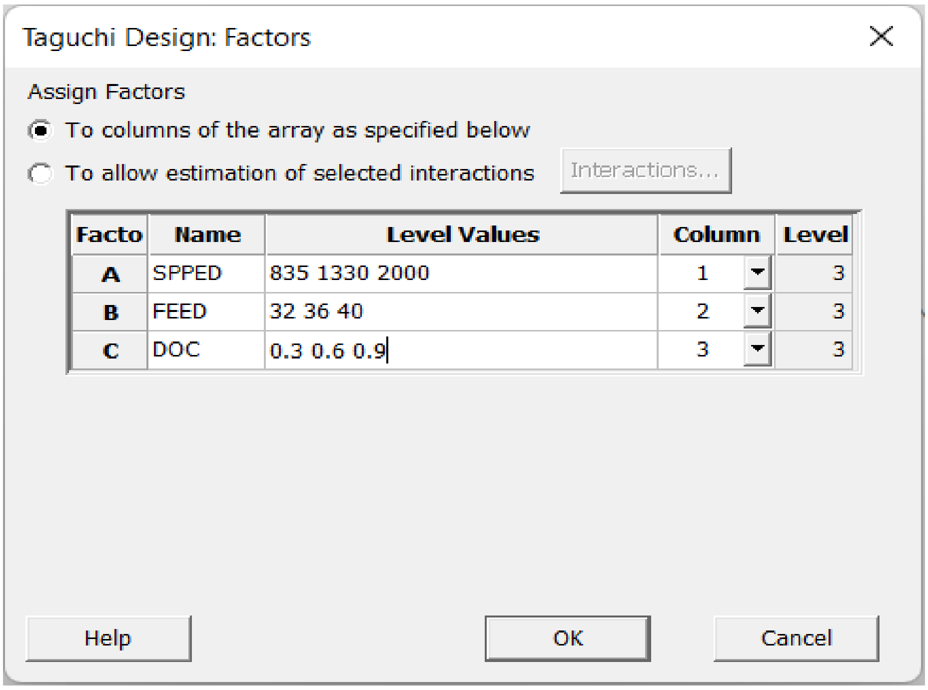


Fig 5.2 Input Parameters

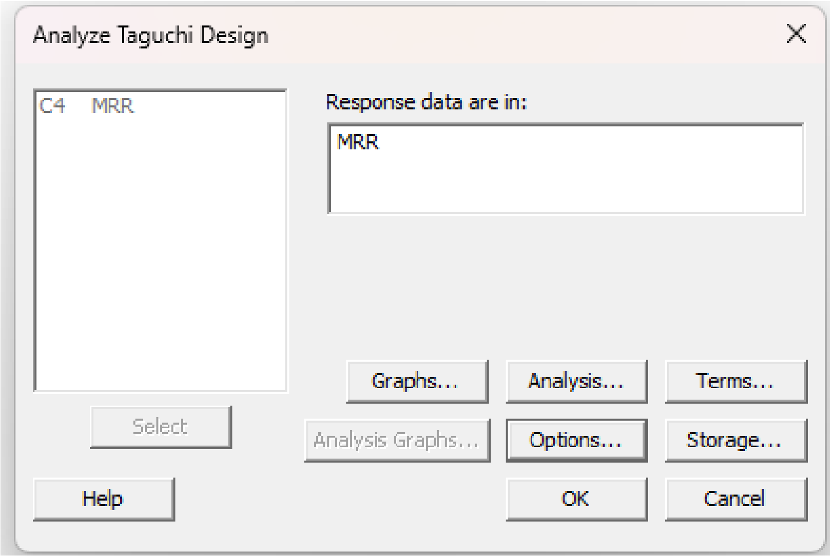


Fig 5.3 Output Parameters for MRR

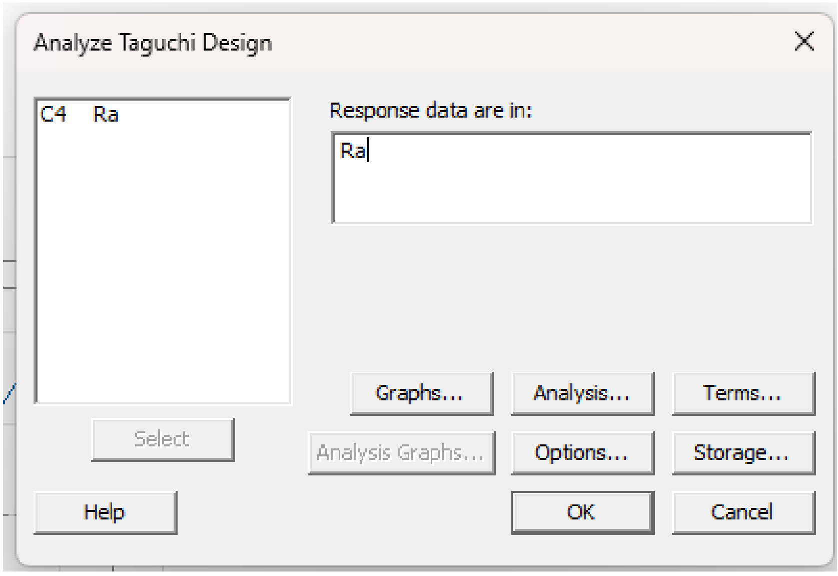


Fig 5.4 Output Parameters for Ra

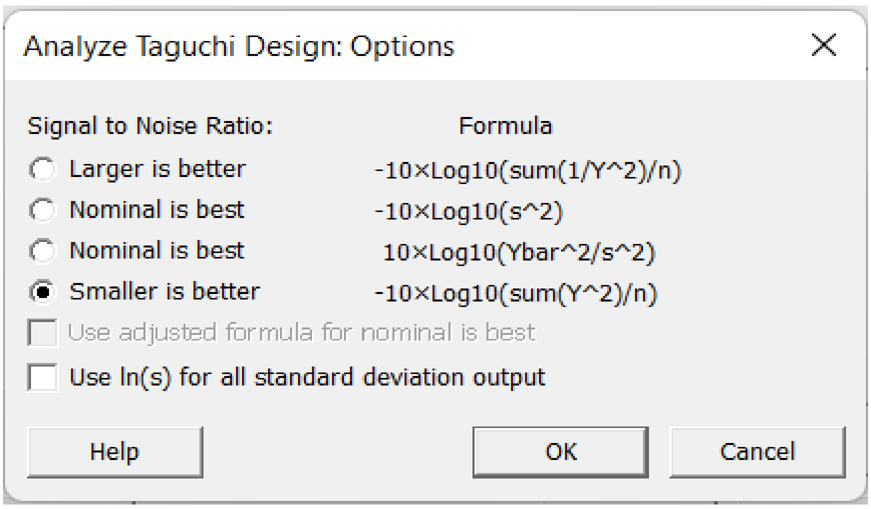


Fig 5.5 Analyzing Taguchi Design for Ra

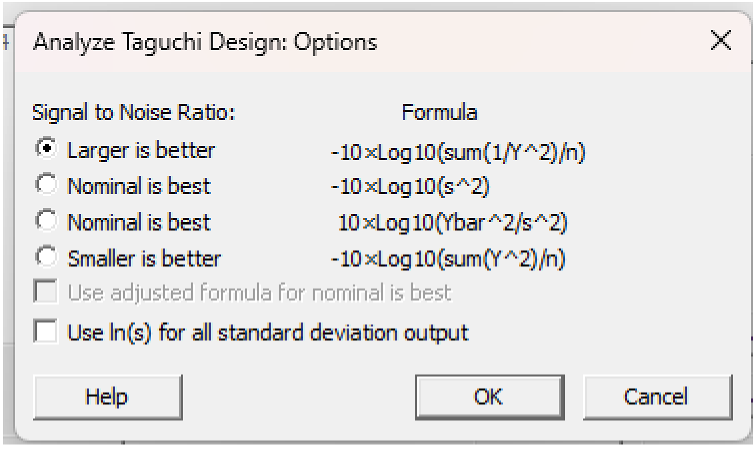


Fig 5.6 Analyzing Taguchi Design for MRR

Response Table for Signal to Noise Ratios

Smaller is better

Level	speed	feed	doc
1	62.16	65.04	60.84
2	66.16	66.07	66.86
3	69.74	66.98	70.38
Delta	7.58	1.94	9.54
Rank	2	3	1

Table 5.3 S/N ratios for each parameter at each level for MRR

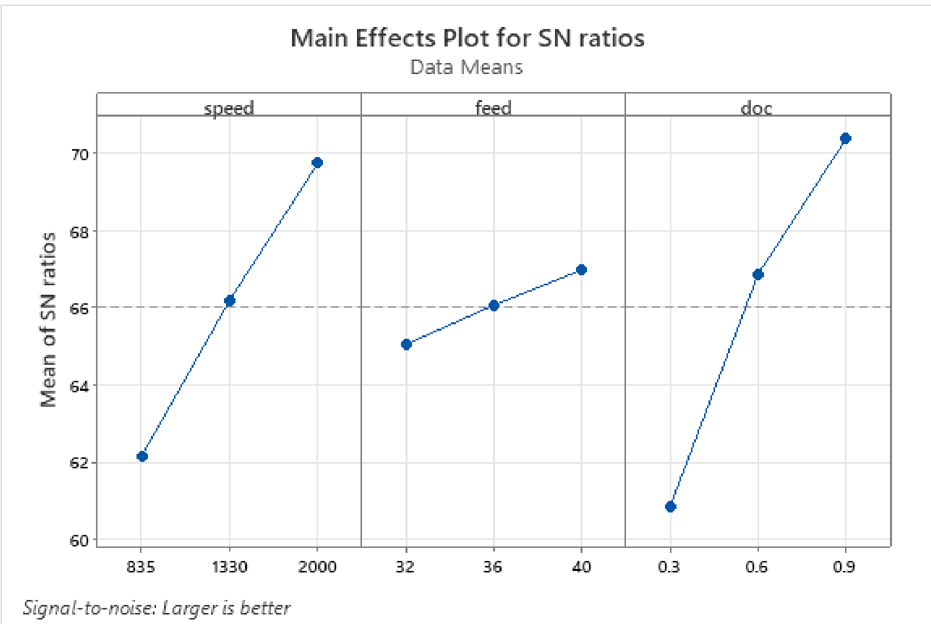


Fig 5.7 Main effect plot for S/N ratio for MRR

Response Table for Signal to Noise Ratios

Smaller is better

Level	speed	feed	doc
1	-2.4499	-7.7059	-1.0348
2	2.2095	-0.9747	-1.2670
3	-2.9126	5.5276	-0.8512
Delta	5.1221	13.2336	0.4157
Rank	2	1	3

Table: 5.4 S/N ratios for each parameter at each level for Ra.

Taguchi Analysis: Ra versus speed, feed, doc

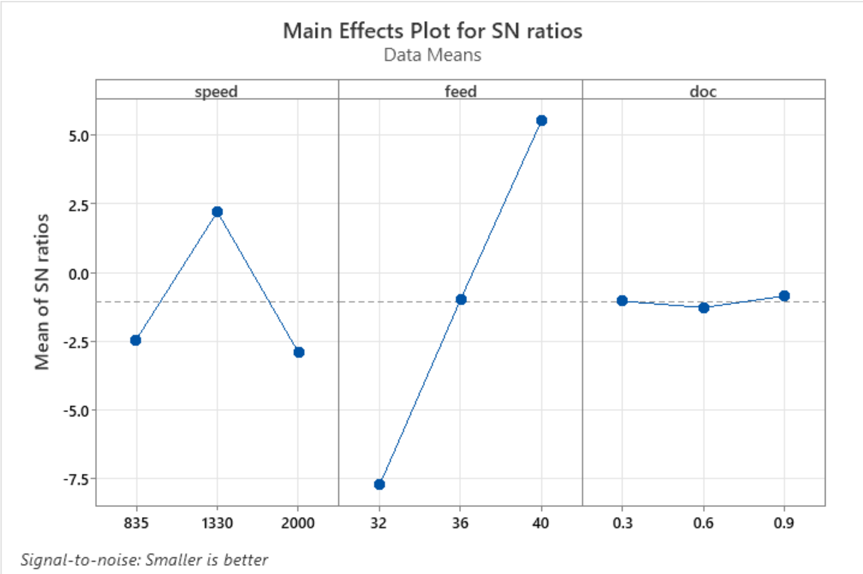


Fig 5.8 Main effect plot for S/N ratio for Ra

5.2 Results from Taguchi S/N ratio analysis:

The Taguchi method can be used to determine the experimental condition having the least variability as the optimal condition. This variability can be expressed by signal-to-noise ratio (S/N ratio). The experimental condition that has the maximum S/N ratio is considered as the optimal condition because the variability of the characteristics is inversely proportional to S/N ratio. The experiments were conducted at random as per the principles of design of experiments. The objective function described in this investigation is maximization of material removal rate and minimization of surface roughness. So, the S/N ratios were calculated using the "larger the better" and "smaller the better" approach.

After determining the S/N ratio, the effect of each cutting parameter is separated for levels. The mean values of S/N ratios for each level of the controllable parameters and the effect of parameter on responses in rank wise are summarized in Table-5.3 for Ra and Table -5.4 for MRR. Main effects plot for S/N ratio's is shown in Fig- 5.5 for Ra and Fig.5.6 for MRR. Optimal parameter levels are chosen from Table-5.3 for Ra and Table-5.4 for MRR which are corresponding to maximum values of S/N ratios of particular parameter. From the Table 5.3, parameters with optimum level: spindle speed at level 2 (i.e. 1330 rpm), feed at level 3 (i.e.40 mm/min) and Depth of cut at level 3 (i.e. 0.9 mm) for Ra. From the Table 5.4, parameters with optimum level: spindle speed at level 3 (i.e. 2000 rpm), feed at level 3 (i.e.40 mm/min) and Depth of cut at level 3 (i.e. 0.9 mm) for MRR. The optimal levels for the controllable parameters obtained from this methodology are verified.

Basing on graphical results, the optimum values are obtained at speed=1330, Feed = 40, Doc =0.9 for Ra and at speed=2000, Feed = 40, Doc =0.9 for MRR. The experiment is conducted at the above optimum condition and the surface roughness value Ra is obtained as 0.287 satisfying the results obtained from the taguchi analysis and MRR as 5427.716.

Speed (mm/min)	Feed (mm/rev)	Depth of cut (mm)	Ra
1330	40	0.9	0.287
Speed (mm/min)	Feed (mm/rev)	Depth of cut (mm)	MRR
2000	40	0.9	5427.716

5.3 Regression Analysis: ra versus speed, feed, doc

Regression Equation

Ra = 10.06 + 0.000130 speed - 0.2429 feed - 0.153 doc

Coefficients

Term	Coef	SE Coef	95% CI	T-Value	P-Value	VIF
Constant	10.06	2.04	(4.82, 15.30)	4.93	0.004	
Speed	0.000130	0.000365	(-0.000808, 0.001068)	0.36	0.737	1.00
Feed	-0.2429	0.0533	(-0.3800, -0.1058)	-4.55	0.006	1.00
Doc	-0.153	0.711	(-1.982, 1.675)	-0.22	0.838	1.00

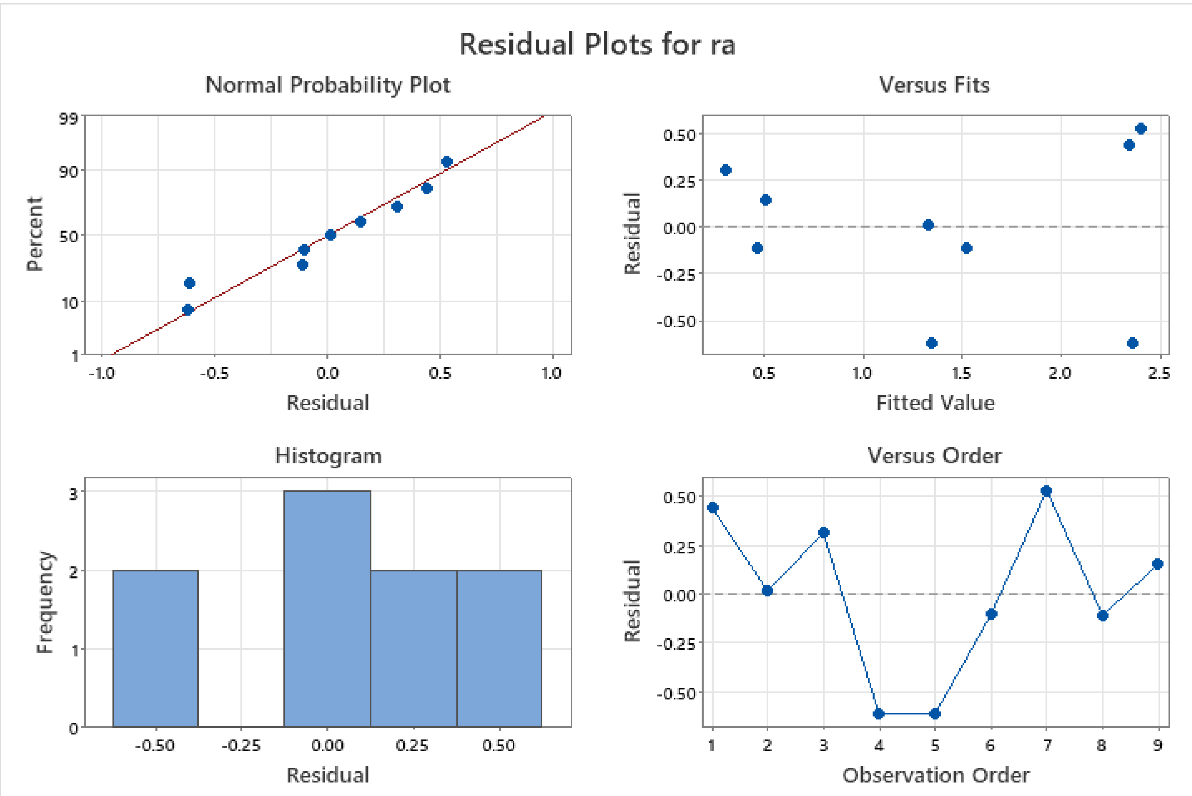
Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)	AICc	BIC
0.522701	80.70%	69.12%	5.35832	24.29%	38.57	19.56

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Regression	3	5.71171	80.70%	5.71171	1.90390	6.97	0.031
Speed	1	0.03458	0.49%	0.03458	0.03458	0.13	0.737
Feed	1	5.66443	80.03%	5.66443	5.66443	20.73	0.006
Doc	1	0.01270	0.18%	0.01270	0.01270	0.05	0.838
Error	5	1.36608	19.30%	1.36608	0.27322		
Total	8	7.07779	100.00%				

The analysis of variance (ANOVA) gives a clear picture of the extent to which a particular process parameter affects the response. Hence ANOVA was used to statistically distinguish the significant factors from insignificant ones. The ANOVA for means of surface roughness and material removal rate are shown in the above Table.



5.4 Regression Analysis: mrr versus speed, feed, doc

Regression Equation

mrr = -2455 + 1.601 speed + 9.5 feed + 3715 doc

Coefficients

Term	Coef	SE Coef	95% CI	T-Value	P-Value	VIF
Constant	-2455	1421	(-6107, 1197)	-1.73	0.145	
speed	1.601	0.254	(0.947, 2.254)	6.29	0.001	1.00
feed	9.5	37.2	(-86.1, 105.0)	0.25	0.809	1.00
doc	3715	496	(2441, 4989)	7.50	0.001	1.00

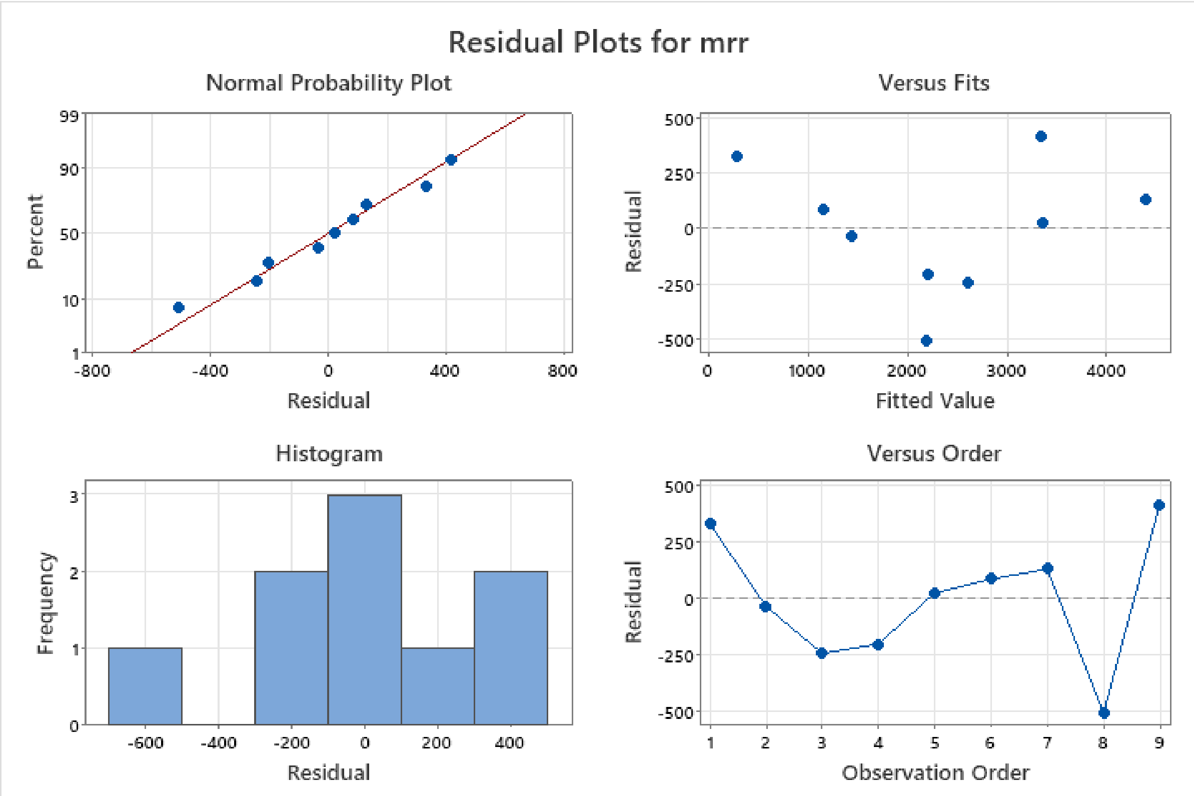
Model Summary

S	R-sq	R-sq(adj)	PRESS	R-sq(pred)	AICc	BIC
364.236	95.04%	92.07%	2715807	79.70%	156.41	137.40

Analysis of Variance

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value
Regression	3	12717761	95.04%	12717761	4239254	31.95	0.001
speed	1	5255538	39.28%	5255538	5255538	39.61	0.001
feed	1	8598	0.06%	8598	8598	0.06	0.809
doc	1	7453624	55.70%	7453624	7453624	56.18	0.001
Error	5	663340	4.96%	663340	132668		
Total	8	13381101	100.00%				

The analysis of variance (ANOVA) gives a clear picture of the extent to which a particular process parameter affects the response. Hence ANOVA was used to statistically distinguish the significant factors from insignificant ones. The ANOVA for means of surface roughness and material removal rate are shown in the above Table.


Residual Plots for mrr
Normal Probability Plot
Percent
99
90
50
10
1
-800
-400
0
400
800
Residual
Versus Fits
Residual
500
250
0
-250
-500
0
1000
2000
3000
4000
Fitted Value
Histogram
Frequency
3
2
1
0
-600
-400
-200
0
200
400
Residual
Versus Order
Residual
500
250
0
-250
-500
1
2
3
4
5
6
7
8
9
Observation Order

CHAPTER - VI

CONCLUSIONS

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CONCLUSIONS

The results revealed that the proposed method provides an effective methodology for optimizing the cutting parameters. The confirmation test proved that the performance characteristics of the turning process such as surface roughness is minimized through the use of optimal combination of the controllable parameters, which in turn reduce manufacturing cost and greatly enhance manufacturing efficiency. In light of the discussion in the earlier chapter, the following conclusions are drawn:

1. The levels of the parameters of the CNC turning process were optimized with respect to surface roughness and material removal rate.
2. ANOVA elucidated that all the three process parameters i.e. Speed, feed and depth of cut have contribution towards the surface roughness, while the feed was found to be the dominant factor contributing towards the surface roughness whereas depth of cut is the dominating factor towards the MRR.
3. It was inferred from the Taguchi analysis that the parameters with optimum level: spindle speed at level 3 (i.e. 2000 rpm), feed at level 3 (i.e.40 mm/min) and Depth of cut at level 3 (i.e. 0.9 mm) for MRR; and the parameters with optimum level: spindle speed at level 2 (i.e. 1330 rpm), feed at level 3 (i.e.40 mm/min) and Depth of cut at level 3 (i.e. 0.9 mm) for Ra.
4. The experiments conducted at the above optimum conditions and the surface roughness value Ra is obtained as 0.287 satisfying the results obtained from the Taguchi analysis and MRR as 5427.716.

CHAPTER – VII

REFERENCES

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REFERENCES

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