CHAPTER 1

INTRODUCTION

1.1 END MILLING

End milling is the most important machining operations which is used for making flat surfaces, curved profiles, engraves pockets, etc. In end milling operation, heat energy is generated at the tool chip interface in deforming chip and overcoming friction between the tool and work piece. The power utilized during end milling is mostly converted into heat energy near the cutting edge of the tool. The heat energy produces high temperature in the deformation zones and surrounding regions of the chip, tool and work piece. This temperature rise propagates tool wear, degrades the work piece quality and increases the tooling cost. The temperature rise affects the work material properties, as moderate temperature rise induces residual stress in the machined surface, while high temperature rise may leave a hardened layer on the machined surface. The cutting tool which possesses high hardness at room temperature cannot retain the hardness at high temperature during milling. Hence, temperature rise on the rake face of the tool have a strong influence on tool life. As temperature in this area increases, the tool softens and wears more rapidly, the tool material diffuses into chip and leads to tool failure and the work piece material adhere to the tools, which causes rapid wear. The softening of the tool due to high temperature rise propagates wear rapidly. Therefore, determining the critical value of the temperature becomes important for the reduction of tool wear. Temperature rise on the relief face of the tool affect the surface finish and metallurgical state of the machined surface. Cutting temperature is an important factor that influences tool wear and surface finish in the machining performance. The temperature at the tool cutting edge is affected by properties of work piece material, cutting condition of the machine tool, tool geometry and many other variables .The process of abrading materials has existed for thousands of years. Whether by hand or machine, materials have been cut, ground or crushed to create a wide-variety of products. Since the 1800s, this process has been referred to as “milling”.End milling is facilitated by cuts done in several directions, in contrast to the axial directional cutting that is typical of drill bits.

End mills can be categorized based on the sort of tools that are affixed to them, number of flutes, helix angle, compositional material and even coating material. Specifications can vary depending on the intended purpose of the mill and the properties of the metal to be treated.

Protective coatings, such as titanium nitride, increase tool efficiency. For example, TiAIN coated tools reduce or eliminate the need for lubrication because the coating prevents aluminium from adhering to the tool.

Today, the milling process is entirely automated. Manufactured rotary cutters and drills are attached to a large milling machine and used to remove material from a given work piece. Due to the unlimited selection of varying drill bits and milling ends, the milling process is capable of producing nearly anything, including, gun parts, circuit boards, jewellery and much more.

Through the use of different milling techniques and tools, distinct milling processes have been established in today’s milling industry. One such process is end milling .End milling primarily differs from other milling processes due to the type of tooling that is used for abrading a given material. Unlike cutters and drill bits, end mills have cutting teeth on the sides and end of the mill. Additionally, the milling applications for the end mill are unique. End mills are typically used in applications requiring profile milling, tracer milling, shape milling, face milling and plunging. For non-conventional or unique applications, CGS Tools specializes in designing custom carbide end mills.

In addition to temperature vibration is also produced during end milling. Increased vibration amplitude during end milling leads to poor dimensional accuracy and degrades machined surface texture. Under unfavourable conditions, the vibration may become unstable, leading to chatter, which can cause accelerated tool wear. Chatter causes poor surface finish on the work part and damages and significantly reduces the life of the end mills. Different components of machine tool are subjected to various loadings dueto change in tool geometry, cutting conditions, and change in tool and work part.It results in complete vibratory system with complex dynamic behaviour. In addition to speed, feed, and depth of cut, tool geometry was the prominent parameter that impacts machine productivity. Accessing vibration amplitude during machining becomes important to ensure the machining performance. A tool monitoring system is required to predict the vibration with respect to cutting parameters to ensure good quality surface and reduced tool wear.

Fig 1.1 End Milling

Aluminium alloys (Al 6082) have high corrosion resistance and find application in aircraft structures. It is easily machinable and has a wide variety of surface finishes.

To obtain better quality in machining, selection of optimum parameters becomes important. In general, tool geometry and cutting conditions were determined by trial and error, based on handbook values and manufacturers' recommendations. However, this selection may not yield optimal or in the vicinity of optimal machining performance. Hence, it is needed to develop a mathematical model to predict the vibration amplitude in terms of machining parameters. Even smaller changes in the machining parameters may cause unexpected machining performance. Therefore it is important to study the stability of machining performance to achieve better machining performance.

1.2 PROCESS PARAMETERS

Optimum process parameter selection and predicting machining performance based on surface roughness, tool wear, material removal rate, etc., were explored by many researchers. Several investigations have been performed on vibration analysis in end milling using various tools, work materials, and experimental designs.Predicting the influence of minor changes in the process parameters fetches useful information in engineering design. Mathematical relations (statistical equations) between geometrical and machining parameters relating with temperature and vibration amplitude picked at single position one fixed in the work piece fixture. The model was constructed by conducting experiments based on central composite rotation design plan comprising of four parameters and four levels.

The investigations were performed to study the influence of machining parameters on temperature rise and vibration amplitude and their sensitivity. The sensitivity equations were derived from the basic mathematical relations.

The objective functions was chosen as temperature and vibration amplitude (acquired along feed and axial direction during machining) and the process parameters (rake angle, cutting speed, feed rate, and depth of cut) are the constraint variables. The sensitivity of machining parameters and the prediction of incremental tuning requirements of these parameters in end milling operation was the main focus in these investigations.

The present investigation reveals considerable information on machining parameter tendencies and optimum machining conditions.

Two tests are conducted using 2 flute and 4 flute HSS tool with same process parameters to study the effect of temperature rise and vibration during end milling of Aluminium 6082 T6 alloy.

1.3VERTICAL MACHINING CENTRE

In the vertical mill the spindle axis is vertically oriented. Milling cutters are held in the spindle and rotate on its axis. The spindle can generally be extended (or the table can be raised/lowered, giving the same effect), allowing plunge cuts and drilling. There are two subcategories of vertical mills: the bed mill and the turret mill.

A turret mill has a stationary spindle and the table is moved both perpendicular and parallel to the spindle axis to accomplish cutting. The most common example of this type is the Bridgeport, described below. Turret mills often have a quill which allows the milling cutter to be raised and lowered in a manner similar to a drill press.

This type of machine provides two methods of cutting in the vertical (Z) direction: by raising or lowering the quill, and by moving the knee .In the bed mill, however, the table moves only perpendicular to the spindle's axis, while the spindle itself moves parallel to its own axis.

Turret mills are generally considered by some to be more versatile of the two designs. However, turret mills are only practical as long as the machine remains relatively small. As machine size increases, moving the knee up and down require considerable effort and it also becomes difficult to reach the quill feed handle (if equipped). Therefore, larger milling machines are usually of the bed type.

A third type also exists, a lighter machine, called a mill-drill, which is a close relative of the vertical mill and quite popular with hobbyists. A mill-drill is similar in basic configuration to a small drill press, but equipped with an X-Y table. They also typically use more powerful motors than a comparably sized drill press, with potentiometer-controlled speed and generally have more heavy-duty spindle bearings than a drill press to deal with the lateral loading on the spindle that is created by a milling operation.

A mill drill also typically raises and lowers the entire head, including motor, often on a dovetailed vertical, where a drill press motor remains stationary, while the arbor raises and lowers within a driving collar. Other differences that separate a mill-drill from a drill press may be a fine tuning adjustment for the Z-axis, a more precise depth stop, the capability to lock the X, Y or Z axis, and often a system of tilting the head or the entire vertical column and power head assembly to allow angled cutting.

As well, a mill-drill often uses a standard drill press-type Jacob's chuck, rather than an internally tapered arbor that accepts collets.

These are frequently of lower quality than other types of machines, but still fill the hobby role well because they tend to be bench top machines with small footprints and modest price tags.

Vertical Machining Centres, also referred to as Vertical Milling Machines are preferred for flat parts that must have through holes. The Vertical Machine is preferred where three-axis work is done on a single face as in mould and dies work. Vertical Machining Centres (VMC) has been leaders in Machine Tools for the past 20 years in Aerospace, Die Mould, Medical and Energy Industries. For these reasons:

- Increased Productivity
- High efficiency - short tool changing times
- High rigidity - stability completing heavy-duty cutting
- High speed - high spindle speed and rapid feed speed
- High accuracy - high precision, high rigidity in axis direction and radial direction
- High volume or low volume applications
- Small part and large part machining
- On-machine probing for inspection / setup

CHAPTER 2

LITERATURE SURVEY

B. Rajeswari et. Al [1]

In their work on Experimental investigation of machinability characteristics and multi-response optimization of end milling in aluminium composites using RSM based grey relational analysis they used RSM methodology for optimizing the parameters like surface roughness, cutting force, toll wear, MRR in end milling of al7075 material. From their analysis they found that machining at 1000rpm, 0.03 mm per rev, 5% of sic, 1mm depth of cut produced better result. From ANOVA table they found that spindle speed and Wight percentage place a vital role in affecting the machinability

M.Subramanian et. Al [2]

In their work on optimization of end mill tool geometry parameters for Al7075-T6 machining operations based on vibration amplitude by response surface methodology they have conducted the experiment and found that the vibration amplitude decreases with high cutting speed, low feed rate high nose radius and high radial rake angle. The optimal cutting parameters for the minimal vibration amplitude are: c = 12_, R = 0.8 mm, Vc = 115 m/min, fz = 0.04 mm/tooth and ap = 2.5 mm. From their experiment they found that the feed rate and axial depth of cut have major physical influence in vibration**.**

David K. Aspin wall et. Al [3]

In their work on cutting temperatures when ball nose end milling g-TiAl inter metallic alloys they have conducted the experiment and found that when machining at 45^{o} with a cutting speed of 120 m/min, axial and radial depths of cut of 0.2 mm, a feed of 0.12 mm/tooth is most reliable.

Sen Lin et. Al [4]

In their work on investigation of work piece temperature variation in end milling considering flank rubbing effect they investigated that the temperature variations at various cutting condition and found that the flank wear has major influence in cutting forces and temperature and the workpiece temperature rise at the measuring point increases from 20 to 50ºC when the spindle speed varies from 800 to1600 rev/min. They also found that flank accounts for 25 to 30 % of heat generated.

Nick Masmiatiet. Al [5]

In their work on Optimization of Cutting Conditions for Minimum Residual Stress, Cutting Force and Surface Roughness in End Milling of S50C Medium Carbon Steel they have used the ANOVA table for determining the significant parameters and for obtaining the optimum cutting conditions.

The obtained values were residual stress of -619.50 MPa, cutting force of 36.48 N and surface roughness of 0.66 μm.

Lohithaksha M Maiyar et.Al [6]

In their work on optimization of Machining Parameters for End Milling of Inconel 718 Super Alloy Using Taguchi Based Grey Relational Analysis they found that the optimal cutting parameters for the machining process lies at 75m/min for cutting velocity, 0.06 mm/tooth for feed rate and 0.4 mm for depth of cut. Further they observed that there is a 64.8%increase in material removal rate and at the same time a 9.52% decrease in surface roughness.

From the analysis it has been found that the cutting velocity is the most significant machining parameter followed by feed rate affecting the multiple performance characteristics with 56.88% and 34.64% influence respectively.

P. S. Sivasakthivel et.Al [7]

In their work on optimization and sensitivity analysis of geometrical and process parameters to reduce vibration during end milling process they found that all five parameters have an effect in determining the acceleration amplitude. Sensitivity of parameters such as rake angle, cutting speed, feed, and depth of cut in most cases exhibits positive value to acceleration amplitude.

Sensitivity of nose radius exhibits negative which infers that an increase in nose radius /decreases the rate of change of acceleration amplitude.

The sensitivity of nose radius which is varying between 30 × 103 and −50 ×103, sensitivity of cutting speed which is varying between 18 × 103 and −4× 103 and sensitivity of depth of cut which is varying between 15 × 103 and−3 × 103 influence the rate of change of acceleration amplitudes comparatively.

Tao Huang et.Al [8]

From their project of Tool orientation optimization for reduction of vibration and deformation in ball-end milling of thin-walled impeller blades have found that the most flexible direction changes along the tool path in ball-end milling of thin-wall blades, which may caused effects especially at the front and rear edges, their paper presents a tool orientation optimization method for reduction of vibration and deformation in the process.

Their aim was to minimize the cutting force component in the most flexible direction at the cutting point by changing tool inclination angles.

The optimization procedure is formulated as a sequential linear programming problem.

Experiments indicate that the optimized tool orientations can reduce machining deformation and improve surface quality.

SzymonWojciechowski et.Al [9]

In their project on Application of signal to noise ratio and grey relational analysis to minimize forces and vibrations during precise ball end milling

They have focused on the optimal selection of surface inclination angle $\alpha$and tool's overhang *l*, in order to minimize the vibrations, cutting forces, and machined surface roughness, generated during precise ball end milling of hardened steel. The conducted research involved the minimization

ParametBaowan et.Al [10]

In their project on Influence of helix angle on tool performances of TiAlN and DLC-coated carbide end mills for dry side milling of stainless steel the results were considerably improved with increasing helix angle.

In addition, DLC-coated tools exhibited chip-built-up and rapid chipping wear problems on cutting and side edges because of graphitization induced by high cutting temperature while TiAlN -coated end mills displayed gradual flank wear due to typical abrasive wear mechanisms.

In addition, the number of ACP and effective cutting length increased with increasing helix angle, leading to less tool wear and thinner milled chips but higher workpiece temperature.

Lastly, the DLC-coated end mill with the high helix angle of 60° gave the lowest surface roughness of 0.26 µm within the cutting length of 20mwhile the corresponding TiAlN-coated end mill offered longer tool cutting length of more than 50 m with comparable surface finish and could be considered to be more useful fo rmost high-quality milling of stainless steels.

CHAPTER 3

OBEJECTIVES OF PROJECT

3.1 NEED FOR OPTIMIZATION

Study Influence of individual factors on the performance and determine which factor has more influence, which ones have less.

You can also find out which factor should have tighter tolerance and which tolerance should be relaxed.

The information from the experiment will tell you how to allocate quality assurance resources based on the objective data. It will indicate whether a supplier's part causes problems or not, and how to combine different factors in their proper settings to get the best results.

3.2 EFFECTS OF TEMPERATURE IN MACHINING

During machining heat is generated at the cutting point from three sources. Those sources and causes of development of cutting temperature are:

• Primary shear zone where the major part of the energy is converted into heat

• Secondary deformation zone at the chip – tool interface where further heat is generated due to rubbing and / or shear

• At the worn out flanks due to rubbing between the tool and the finished surfaces .The heat generated is shared by the chip, cutting tool and the blank.

The apportionment of sharing that heat depends upon the configuration, size and thermal conductivity of the tool – work material and the cutting condition.

The maximum amount of heat is carried away by the flowing chip. From 10 to 20% of the total heat goes into the tool and some heat is absorbed in the black.

3.2.1 EFFECTS OF HIGH TEMPERATURE ON TOOL AND JOB

The effect of the cutting temperature, particularly when it is high, is mostly detrimental to both the tool and the job. The major portion of the heat is taken away by the chips. But it does not matter because chips are thrown out. So attempts should be made such that the chips take away more and more amount of heat leaving small amount of heat to harm the tool and the job.

The possible detrimental effects of the high cutting temperature on cutting tool (edge) a rapid tool wear, which reduces tool life plastic deformation of the cutting edges if the tool material is not enough hot-hard and hot-strong thermal flaking and fracturing of shocksthe cutting edges due to thermal,built-up-edge formation .The possible detrimental effects of cutting temperature on the machined job are:

- Dimensional inaccuracy of the job due to thermal distortion and expansion-contraction during and after machining
- Surface damage by oxidation, rapid corrosion, burning etc.
- Induction of tensile residual stresses and micro cracks at the surface/ subsurface

However, often the high cutting temperature helps in reducing the magnitude of the cutting forces and cutting power consumption to some extent by softening or reducing the shear strength, of the work material ahead the cutting edge. To attain or enhance such benefit the work material ahead the cutting zone is often additionally heated externally. This technique is known as Hot Machining and is beneficially applicable for the work materials which are very hard and hardenable like high manganese steel, Hadfield steel, Ni- hard,and Nimonic etc.It is already seen that high cutting temperature is mostly detrimental in several respects. Therefore, it is necessary to control or reduce the cutting temperature as far as possible.

3.3 EFFECTS OF VIBRATION ON MACHINING

Vibration is a repetitive, periodic, or oscillatory response of a mechanical system. The rate of the vibration cycles is termed “frequency.” Repetitive motions that are somewhat clean and regular, and that occur at relatively low frequencies, are commonly called oscillations, while any repetitive motion, even at high frequencies, with low amplitudes, and having irregular and random behavior falls into the general class of vibration.

In a machining operation, vibration is problem. Vibration affects the machining performance and in particular, the surface finishes and tool life. In all thecutting operations like turning, drilling and milling, vibrations occur in the machining due to a dynamic motion between the cutting tool and the work piece.

The excessive wear on cutting tools leads to distortions in dimension of manufactured components. Atthe same time it increases scrapped levels thereby incurring additional costs. Therefore, it is crucial to detect and monitor the wear on a cutting tool in most metal cutting processes and several research efforts have doneto develop on-line tool condition monitoring systems. Inonline metal cutting tool condition monitoring, the cutting force (Static and Dynamic) analysis and vibration analysis is done for tool wear monitoring. The main purpose of this study was to develop a Tool Condition Monitoring System based on analytical modeling of online sensor signals. Effects of tool vibration on surface roughness during lathe dry turning process on mild carbon steel samples at different levels of speed feed, depth of cut, tool nose radius, tool length and work piece length. Safeen studied the effect of cutting tool vibration on surface roughness of work piece in dry turning operation .The surface roughness of the work piece is proportional to cutting tool acceleration. This effect interact with other independent variable such feed rate, depth of cut, speed. Surface roughness of work piece increases parallel to the tool vibration with increasing tool over hang.

CHAPTER 4

METHODOLOGY

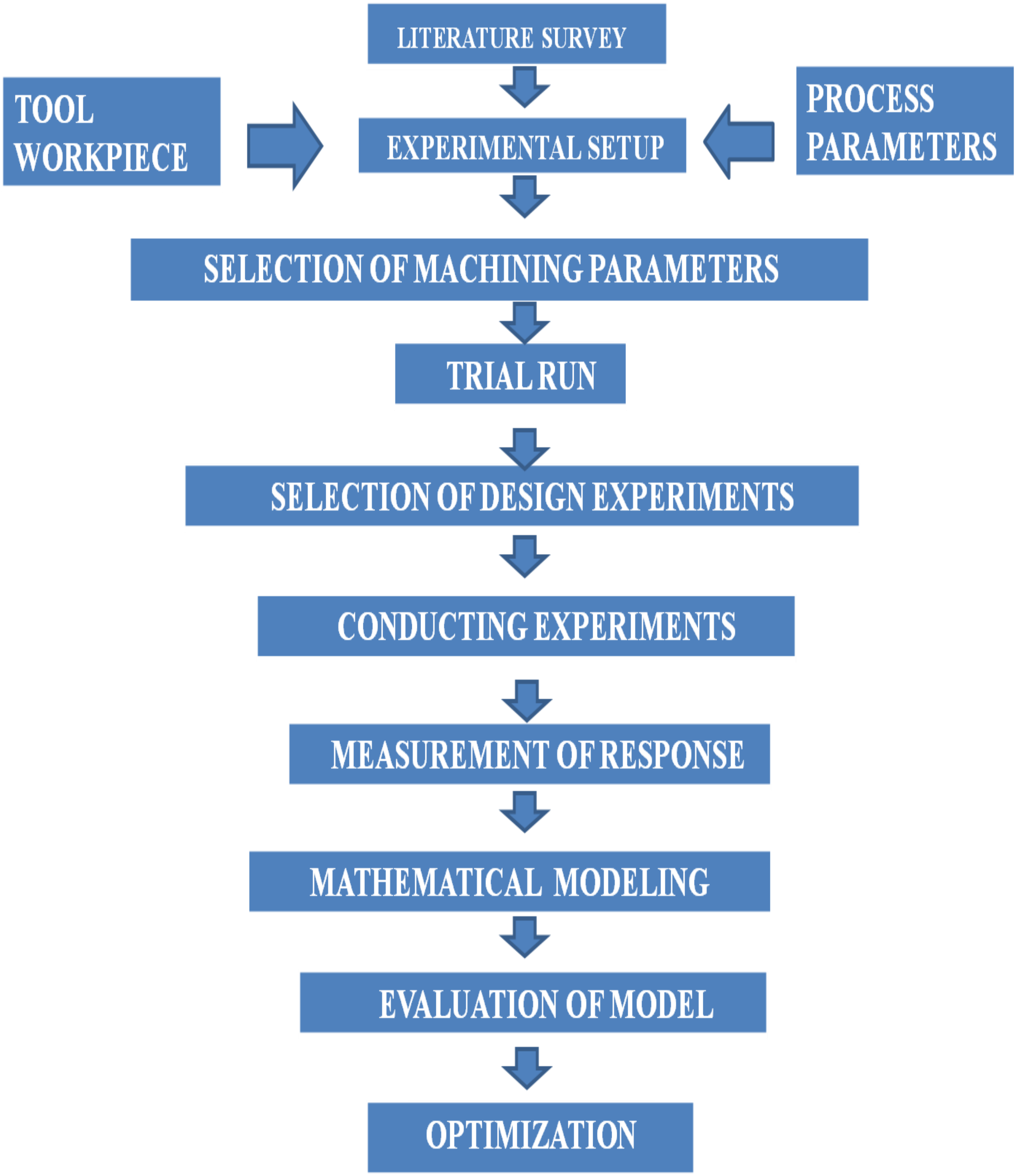


Fig 4.1 Project Methodology

CHAPTER 5

EXPERIMENTAL SETUP

5.1 VERTICAL MACHINING CENTRE

We have used STMVL 610 CNC vertical machining centre for our project for machining the work pieces.

FEATURES

VL DIE MOULD SERIES

- BT-40 / CAT40 / DIN40 spindle (Φ120mm). 100% balanced with low vibration performs high precision machining. Air blow function is standard to keep chips from falling into Spindle.

- Optional spindle speed: 10,000 / 12,000 / 15,000 / 24,000 / 30,000 RPM

- Positioning accuracy: ± 0.005mm / 300mm Repeating accuracy: ± 0.003mm / 300mm

Fig 5.1 Vertical Machining Centre

SPECIFICATIONS

Travel	
X / Y / Z travel	610 / 460 / 510 mm
X / Y / Z guideways	2 / 2 / 2 LM Guide Ways
Spindle nose to table surface	120 ~ 630 mm
Spindle centre to column surface	535 mm
Table size	800 X 450 mm
T slot (Size / Qty / Dist.)	18 mm X 3 X 100 mm
Max. table load	400 Kgs
Spindle Speed	8000 RPM
Taper	BT 40
Transmission	Belt
Rapid feed rate of XYZ	36 / 36 / 36 M / min
Cutting feed rate	1 ~ 10 M / min
Tool storage capacity	Armless 16
Max. tool diameter	Full : 100 mm Next empty : 150 mm
Max. tool length	300 mm
Max. tool weight	6 Kgs
CNC controller	Mitsubishi
Spindle motor	5.5 / 7.5 kW (10 HP)
Axes motor	2 Kw

Coolant pump	0.75 kW
Coolant tank capacity	200 L
Air source	6 Kg / cm2
Power supply	15 KVA
Dimension	2160 X 2435 X 2550 mm
Net weight	4000 Kgs

5.2 THERMOCOUPLE

A thermocouple is an electrical device consisting of two dissimilar electrical conductors forming electrical junctions at differing temperatures. A thermocouple produces a temperature-dependent voltage as a result of the thermoelectric effect, and this voltage can be interpreted to measure temperature .Thermocouples are a widely used type of temperature sensor Thermocouples are widely used in science and industry. Applications including temperature measurement for kilns, gas turbine exhaust, diesel engines, and other industrial processes.

5.2.1 K TYPE THERMOCOUPLE

Type K thermocouples usually work in most applications as they are nickel based and exhibit good corrosion resistance. It is the most common sensor calibration type providing the widest operating temperature range. Due to its reliability and accuracy the Type K thermocouple is used extensively at temperatures up to 2300°F (1260°C). This type of thermocouple should be protected with a suitable metal or ceramic protection tube, especially in reducing atmospheres.

In oxidizing atmospheres, such as electric furnaces, tube protection is not always necessary when other conditions are suitable; however, it is recommended for cleanliness and general mechanical protection. Type K will generally outlast Type J because the JP wire rapidly oxidizes, especially at higher temperatures.

Composed of a positive leg, which is approximately 90% nickel, 10% chromium and a negative leg, which is approximately 95% nickel, 2% aluminium, 2% manganese and 1% silicon. Type K Thermocouples are the most common general purpose thermocouple with a sensitivity of approximately 41µV/°C, chromel positive relative to alumel. It is inexpensive, and a wide variety of probes are available in its -200°C to +1260°C / -328°F to +2300°F range.

Type K was specified at a time when metallurgy was less advanced than it is today, and consequently characteristics vary considerably between samples. One of the constituent metals, nickel, is magnetic; a characteristic of thermocouples made with magnetic material is that they undergo a step change in output when the magnetic material reaches its Cure Point (around 354 °C for type K thermocouples).

A coupling of Chromel and Alumel wires has a range of -270 °C to 1260 °C and an output of -6.4 to 54.9 mV over maximum temperature range. This is one of the major advantages of thermocouple type k over other thermocouples in general or other temperature transducers such as the thermistor or the resistance temperature detector (RTD).

Its capability to function in rugged environmental conditions and in various atmospheres makes it a preference over other temperature transduction devices.

Special Limits of Error: ± 1.1C or 0.4%Deviations in the alloys can affect the accuracy of thermocouples. For type K thermocouples the tolerance class one is given as ± 1.5 K between -40 and 375 °C.

5.2.2 SIGNIFICANCE OF K TYPE THERMOCOUPLE

- Like all thermocouples, they are inexpensive, have a fast reaction time, are small in size and are dependable.
- They can accurately measure extreme temperatures. Depending on where they are manufactured, these range from −270° to 1,370° degrees C or Celsius, with errors within 0.5 to 2 degrees C.
- K types are more generally used at temperatures above 540 degrees C. To limit excessive error, the recommended usage is in oxidizing or completely inert atmospheres with a range of −200° to 1,260° C.
- Their output signals are very small and so they may have a problem with noise.
- They are prone to stress, strain and corrosion, particularly as they age.
- K types, however, have special problems.

5.2.3 APPLICATION

- Type K thermocouples are used for measurements in many different types of environments such as water, mild chemical solutions, gases and dry areas.
- Engines, oil heaters and boilers are examples of places where they may be found.
- They are used as thermometers in hospitals and the food industry.

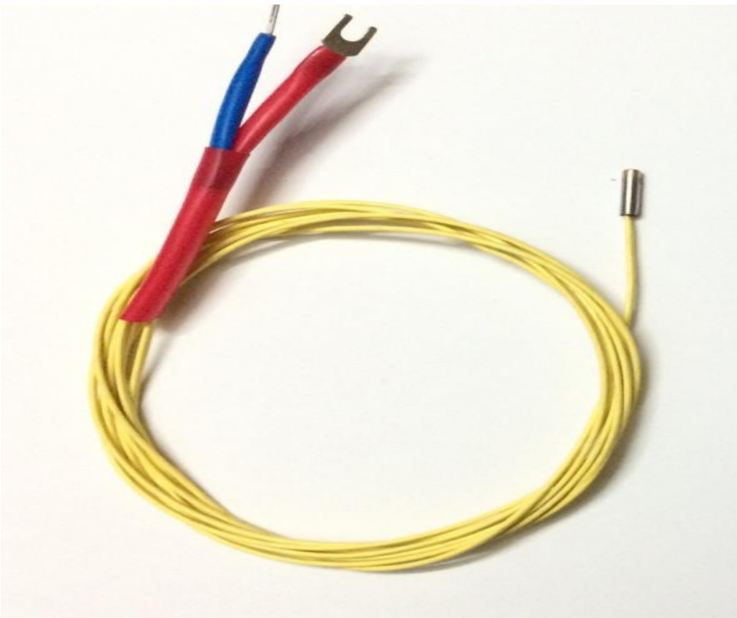


Fig 5.2 K-Type Thermocouple

5.3 ACCELEROMETER

An accelerometer is a device that measures proper acceleration. Proper acceleration, being the acceleration (or rate of change of velocity) of a body in its own instantaneous rest frame, is not the same as coordinate acceleration, being the acceleration in a fixed coordinate system.

For example, an accelerometer at rest on the surface of the Earth will measure acceleration due to Earth's gravity, straight upwards of g ≈ 9.81 m/s2. By contrast, accelerometers in free fall (falling toward the centre of the Earth at a rate of about 9.81 m/s2) will measure zero.

Accelerometers have multiple applications in industry and science.

Highly sensitive accelerometers are components of inertial navigation systems for aircraft and missiles .Accelerometers are used to detect and monitor vibration in rotating machinery.

Accelerometers are used in tablet computers and digital cameras so that images on screens are always displayed upright. Accelerometers are used in drones for flight stabilisation.

Coordinated accelerometers can be used to measure differences in proper acceleration, particularly gravity, over their separation in space; i.e., gradient of the gravitational field. This gravity radiometry is useful because absolute gravity is a weak effect and depends on local density of the Earth which is quite variable.

5.3.1 KISTLER 8776 A50

Small envelop size and light weight, the Type 8776A… are general purpose vibration measuring accelerometers designed for OEM applications. Containing identical sensing elements, the five models in this family of accelerometers differ inmounting attachment (adhesive or stud), envelope configuration(side or top connector) and frequency response.

- Low impedance voltage mode
- High sensitivity, high resolution, low transverse sensitivity
- Rugged connector for repeated connections
- Priced for OEM or low cost/channel applications
- Conforming to CE

5.3.2 APPLICATION

These accelerometers provide2, 5mg threshold suitable for use in low level measurement applications. The wide bandwidth and rugged construction are ideal for impact and vibration related applications including condition monitoring and vehicle testing.

Reliable and accurate measurements require that the mounting surface be clean and flat. The sensors can be attached to the structure utilizing the integral stud, wax or adhesive.

Fig 5.3 Kistler 8776 A50 Accelerometer

5.3.3 SPECIFICATIONS

Table 5.1 Accelerometer Specifications

Specification	**Unit**	**Type 8776A50**
Acceleration range	G	±50
Acceleration limit	Gpk	±500
Threshold, nom. (noise 300 µVrms)	Grms	0.003
Sensitivity, ±15 %	mV/g	100
Resonant frequency mounted, nom.	kHz	40 (M3: 38)
Phase shift, <5°	Hz	4 ... 2000
Amplitude non-linearity	%FSO	±1
ENVIRONMENT		
Type 8776A...M6	g/µe	0.002
Shock limit (1 ms pulse)	Gpk	5000

Temperature coefficient of sensitivity	%/°F	–0.07
Operating temperature range	°F	–65 ... 250
OUTPUT		
Bias, nom.	VDC	11
Impedance	Ω	≤100
Voltage full scale	V	±5
Current	mA	2
SOURCE		
Voltage	VDC	18 ... 30
Constant Current	Ma	2 ... 20

CONSTRUCTION		
Sensing element	Type	ceramic-shear
Housing/base	Material	Titanium
Degree of protection case/connector	Type	Epoxy
Connector		no (M3: yes)
Ground isolated	G	4 (M3: 4,3/M6: 4,5)
Mass	G	4 (M3: 4,3/M6: 4,5)
Mounting torque (Type 8774A50, 8776A50M6)	lbf-in	18

5.4 ALUMINIUM 6082

We have chosen aluminium 6082 as work piece due to its various applications Aluminium alloy 6082 is a medium strength alloy with excellent corrosion resistance.

It has the highest strength of the 6000 series alloys. Alloy 6082 is known as a structural alloy. In plate form, Aluminium alloy 6082 is the alloy most commonly used for machining.

As a relatively new alloy, the higher strength of Aluminium alloy 6082 has seen it replace 6061 in many applications.

The addition of a large amount of manganese controls the grain structure which in turn results in a stronger alloy.

The tighter chemical band ensures more consistent anodizing between batches. In the T6 and T651 temper, Aluminium

5.4.1 CHEMICAL COMPOSITION

Table 5.2 Chemical Composition of Al 6082

Element	% Present
Si	0.7 – 1.3
Fe	0.0 – 0.5
Cu	0.0 – 0.1
Mn	0.4 – 1.0
Mg	0.6 – 1.2
Zn	0.0 – 0.2
Ti	0.0 – 0.1
Cr	0.0 – 0.25
Al	Balance

5.4.2 PHYSICAL PROPERTIES

Table 5.3: Physical Properties of Al 6082

Physical Property	Value
Density	2700 km/m3
Melting Point	555 ^{o}c
Modulus of Elasticity	70 GPa
Electrical Resistivity	$0.038x10^{-8}$ ohm.m
Thermal Conductivity	180 W/m.K
Thermal Expansion	$24x10^{-8}$/K

5.4.3 APPLICATIONS

- Bridges
- Trusses
- High stress applications
- Cranes
- Beer barrels
- Milk churns
- Transport applications

The most common tempers for Aluminium alloy 6082 are:

- O– annealed wrought alloy
- T4 – Solution heat treated and naturally aged
- T6 – Solution heat treated and artificially aged
- T651 – Solution heat treated, stress relieved by stretching and then artificially aged

We have purchased AL6082 T6 32mm square rod for about 2 kg in order to cut it to our required dimensions

Fig 5.4 Aluminium 6082 Rod

5.5 END MILLL CUTTER

An end mill is a type of milling cutter, a cutting tool used in industrial milling applications. It is distinguished from the drill bit in its application, geometry, and manufacture. While a drill bit can only cut in the axial direction, a milling bit can generally cut in all directions, though some cannot cut axially.

Several broad categories of end- and face-milling tools exist, such as centre-cutting versus non-centre-cutting (whether the mill can take plunging cuts); and categorization by number of flutes; by helix angle; by material; and by coating material.

Each category may be further divided by specific application and special geometry.

It is becoming increasingly common for traditional solid end mills to be replaced by more cost-effective inserted cutting tools (which, though more expensive initially, reduce tool-change times and allow for the easy replacement of worn or broken cutting edges rather than the entire tool).

End mills are sold in both imperial and metric shank and cutting diameters. In the USA, metric is readily available, but it is only used in some machine shops and not others; in Canada, due to the country's proximity to the US, much the same is true. In Asia and Europe, metric diameters are standard.

End mills are used in milling applications such as profile milling, tracer milling, face milling, and plunging.

We have purchased end mill cutter of 12mm diameter with 2 flutes and 4 flutes having a cutting edge of about 35mm and holding length for about 35mm.Through the use of different milling techniques and tools, distinct milling processes have been established in today's milling industry. One such process is end milling. End milling primarily differs from other milling processes due to the type of tooling that is used for abrading a given material. Unlike cutters and drill bits, end mills have cutting teeth on the sides and end of the mill.

Additionally, the milling applications for the end mill are uniqueAdvances in end mill coatings are being made, however, with coatings such as Amorphous Diamond and nano composites.

Fig 5.5 End Mill Cutter

CHAPTER 6

DESIGN OF EXPERIMENT

6.1 TAGUCHI'S DESIGN OF EXPERIMENTS

The DOE using Taguchi approach can economically satisfy the needs of problem solving and product/process design optimization projects. By learning and applying this technique, engineers, scientists, and researchers can significantly reduce the time required for experimental investigations.

DOE can be highly effective when we wish to:

- Optimize product and process designs, study the effects of multiple factors (i.e.- variables, parameters, ingredients, etc.) on the performance, and solve production problems by objectively laying out the investigative experiments. (Overall application goals).
- Study Influence of individual factors on the performance and determine which factor has more influence, which ones have less. You can also find out which factor should have tighter tolerance and which tolerance should be relaxed. The information from the experiment will tell you how to allocate quality assurance resources based on the objective data. It will indicate whether a supplier's part causes problems or not (ANOVA data), and how to combine different factors in their proper settings to get the best results (Specific Objectives).

6.2 ADVANTAGES OF DOE USING TAGUCHI APPROACH

The application of DOE requires careful planning, prudent layout of the experiment, and expert analysis of results. Based on years of research and applications Dr. Genechi Taguchi has standardized the methods for each of these DOE application steps described below.

Experiment planning and problem formulation- Experiment planning guidelines are consistent with modern work disciplines of working as teams. Consensus decisions about experimental objectives and factors make the projects more successful.

Experimental layout High emphasis is put on cost and size of experiments... Size of the experiment for a given number of factors and levels is standardized... Approach and priority for column assignments are established. Clear guidelines are available to deal with factors and interactions (interaction tables).Uncontrollable factors are formally treated to reduce variation. Discrete prescriptions for setting up test conditions under uncontrollable factors are described. Guidelines for carrying out the experiments and number of samples to be tested are defined.

Data analysis - Steps for analysis are standardized (main effect, ANOVA and Optimum).Standard practice for determination of the optimum is recommended... Guidelines for test of significance and pooling are defined.

Interpretation of results- Clear guidelines about meaning of error term discrete indicator about confirmation of results (Confidence interval). Ability to quantify Improvements in terms of dollars (Loss function).

Overall advantage - DOE using Taguchi approach attempts to improve quality which is defined as the consistency of performance. Consistency is achieved when variation is reduced. This can be done by moving the mean performance to the target as well as by reducing variations around the target. The prime motivation behind the Taguchi experiment design technique is to achieve reduced variation (also known as ROBUST DESIGN). This technique, therefore, is focused to attain the desired quality objectives in all steps. The classical DOE does not specifically address quality.

6.3 FACTORS AND LEVELS

Factors are:

- Design parameters that influence the performance.
- Input that can be controlled.
- Included in the study for the purpose of determining their influence and control upon the most desirable performance

Levels are:

- Values that a factor assumes when used in the experiment

6.4INTERACTION BETWEEN FACTORS

Two factors (A and B) are considered to have interaction between them when one has influence on the effect of the other factor respectively.Interaction:

- Is an effect (output) and does not alter the trial condition.
- Can be determined even if no column is reserved for it.
- Can be fully analyzed by keeping appropriate columns empty.
- Affects the optimum condition and the expected result

6.5NOISE FACTORS

Noise factors are those factors:

- That is not controllable.
- Whose influences are not known.
- Which are intentionally not controlled.

6.6AVAILABLE ORTHOGONAL ARRAYS

The following Standard Orthogonal Arrays are commonly used to design experiments:

- 2-Level Arrays: L-4 L-8 L-12 L-16 L-32 L-64
- 3-Level Arrays: L-9 L-18 L-27 (L-18 has one 2- level column)
- 4-Level Arrays: L-16 & L-32 Modified.

6.7 SCOPE AND SIZE OF EXPERIMENTS

- The scope of the study, i.e., cost and time availability, is factors that help determine the size of the experiment.
- The number of experimentsthat can be accomplished in a given period of time, and the associated costs are strictly dependent on the type of project under study.
- The total number of samples available divided by the number of repetitions yields the size of the array for design. The array size dictates the number of factors and their appropriate levels included in the study.

6.8 ANALYSIS USING SIGNAL TO NOISE RATIOS

The traditional method of calculating average factor effects and thereby determining the desirable factor levels (optimum condition) is to look at the simple averages of the results. A better way to compare the population behavior is to use the mean- squared deviation, which combines effects of both average and standard deviation of the results. For convenience of linearity and to accommodate wide- ranging data, a logarithmic transformation of MSD (called the signal-to-noise ratio) is recommended for analysis of results.

CHAPTER 7

PROJECT WORK

7.1 CUTTING OF Al6082

We have purchased 32mm AL6082 square rod of 2 metres and we have machined that in saw machine to a dimension of 32*32*40mm in order to make 32 workpieces for our project

Fig 7.1 Cutting of Al6082 Rod

7.2 DRILLING OPERATION

In order to measure the temperature during end milling we have the drilled the workpiece with a 3.5mm drill bit with various height from the top surface to measure the temperature occurrence in various depth of cut.To predict the interior temperature during machining,we used a thermocouple of 3mm probe.

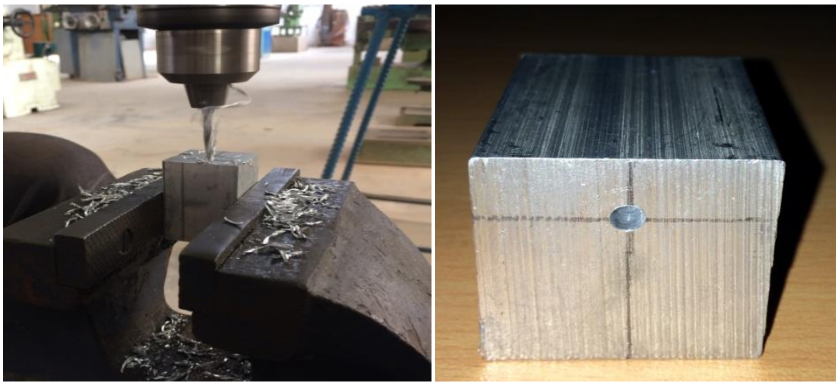


Fig 7.2 Drilling of Aluminum Work piece

7.3 WORKPIECE

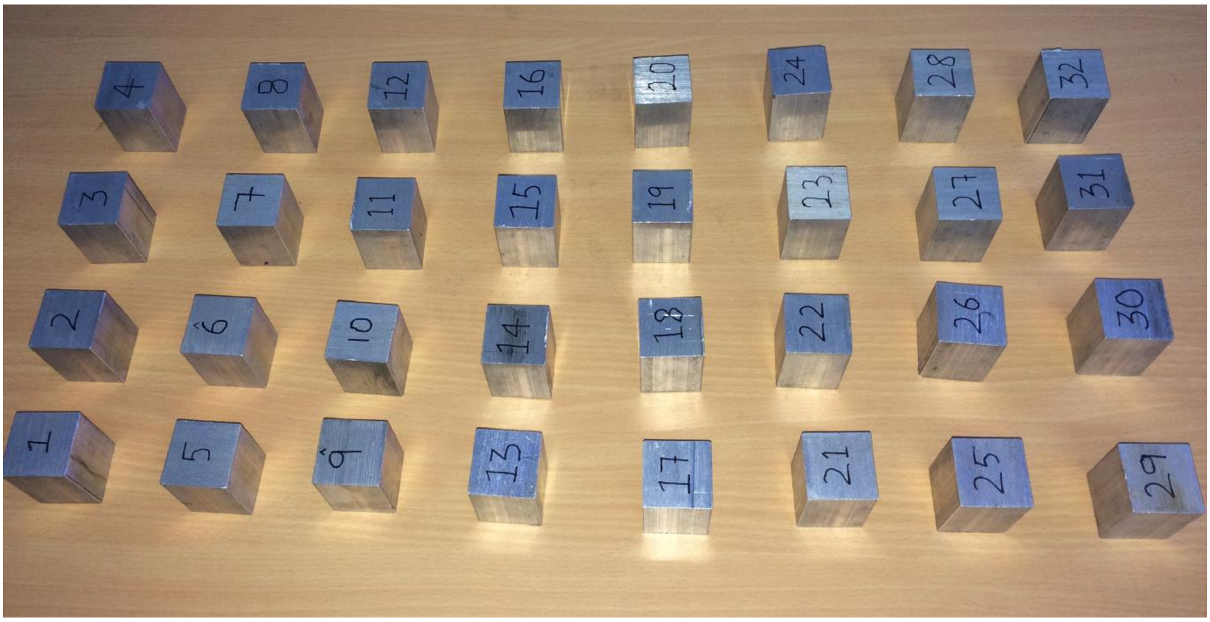


Fig 7.3 32 Aluminum Workpieces

7.4MACHINING PARAMETERS AND ITS LEVELS

Table 7.1: Machining Parameters and its Levels

Parameter	Units	Factor Levels			
Rake angle(α)	Degree(°)	4	8	12	16
Spindle Speed (N)	Rpm	2000	2500	3000	3500
Feed Rate (Z)	mm/rev	0.02	0.03	0.04	0.05
Axial Depth of Cut (X)	Mm	1.5	2	2.5	3

7.5 MEASUREMENT OF RESPONSE

We have machined the workpieces with the process parameters and in various levels and we have measured the responses in form of temperature in °c and vibration in the form of acceleration (m/s²).

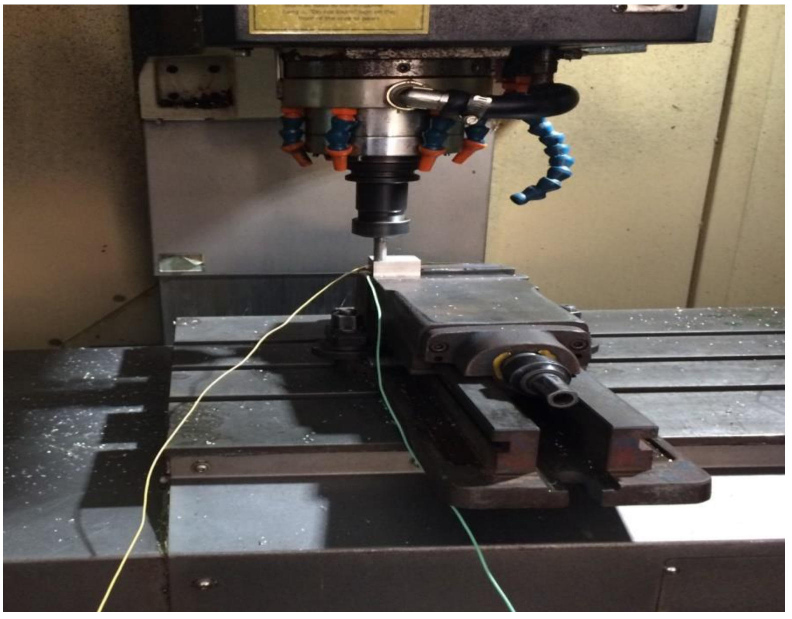
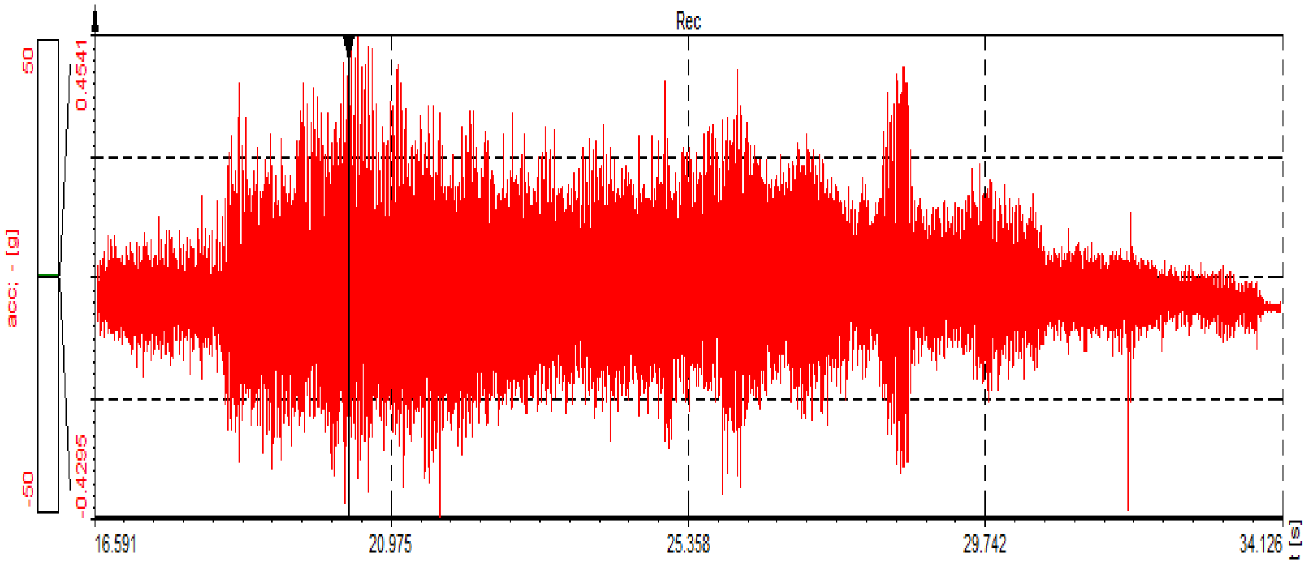


Fig 7.4 Milling Operation of Al6082

7.5.1 TEMPERATURE RESPONSE

Fig 7.5 Temperature Response

7.5.2 VIBRATION RESPONSE



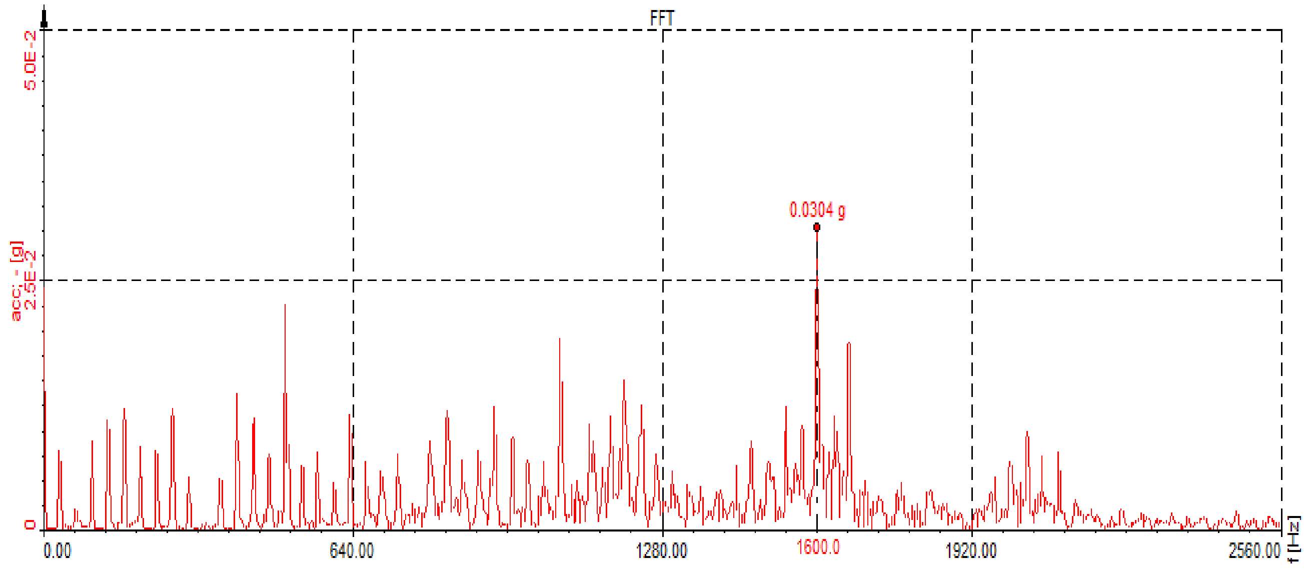


Fig 7.6 Vibration Response

CHAPTER 8

OPTIMIZATION CALCULATION

8.1 OUTPUT RESPONSES AND CALCULATIONS FOR 4 FLUTE

We have conducted the experiments and measured the responses.

Table 8.1: Output Responses and Calculations for 4 Flute

EXPERIMENT	A	B	C	D	TEMPERATURE °C	VIBRATION m/s^2
1	1	1	1	1	75.1	4.41
2	1	2	2	2	84.8	6.076
3	1	3	3	3	87.2	2.058
4	1	4	4	4	98.2	3.724
5	2	1	2	3	73.2	4.998
6	2	2	1	4	77.5	5.39
7	2	3	4	1	74.5	2.646
8	2	4	3	2	76.2	4.41
9	3	1	3	4	84.3	3.626
10	3	2	4	3	74.7	2.646
11	3	3	1	2	72.3	2.058
12	3	4	2	1	77.5	1.274
13	4	1	4	2	78.8	1.568
14	4	2	3	1	76.9	1.372
15	4	3	2	4	95.3	3.43
16	4	4	1	3	93.4	2.352

8.1.1 SIGNAL TO NOISE RATIO FOR 4 FLUTES

Formula for calculating signal to noise ratio $S/N = 10*\log(\Sigma(Y^2)/N)$

Where Y = Responses for the given factor level combination

N = No of responses in factor level combination

Table 8.2: Signal to Noise Ratio for 4 Flutes

EXP	A	B	C	D	T °C	A m/s²	S/N T	S/N A
1	1	1	1	1	75.1	4.41	-37.5128	-12.8888
2	1	2	2	2	84.8	6.076	-38.5679	-15.6724
3	1	3	3	3	87.2	2.058	-38.8103	-6.2689
4	1	4	4	4	98.2	3.724	-39.8422	-11.4202
5	2	1	2	3	73.2	4.998	-37.2902	-13.9759
6	2	2	1	4	77.5	5.39	-37.7860	-14.6318
7	2	3	4	1	74.5	2.646	-37.4431	-8.4518
8	2	4	3	2	76.2	4.41	-37.6391	-12.8888
9	3	1	3	4	84.3	3.626	-38.5166	-11.1886
10	3	2	4	3	74.7	2.646	-37.4664	-8.4518
11	3	3	1	2	72.3	2.058	-37.1828	-6.2689
12	3	4	2	1	77.5	1.274	-37.7860	-2.1034
13	4	1	4	2	78.8	1.568	-37.9305	-3.9069
14	4	2	3	1	76.9	1.372	-37.7185	-2.7471
15	4	3	2	4	95.3	3.43	-39.5819	-10.7059
16	4	4	1	3	93.4	2.352	-39.4069	-7.4287

8.1.2 TEMPERATURE PREDICTED VALUE AND VARIATIONS

Table 8.3: Temperature Predicted Value and Variations

EXP	A	B	C	D	TEMP	PREDICTED	VARIATIONS
1	1	1	1	1	75.1	76.01875	0.012234
2	1	2	2	2	84.8	81.79375	-0.03545
3	1	3	3	3	87.2	88.19375	0.011396
4	1	4	4	4	98.2	99.29375	0.011138
5	2	1	2	3	73.2	74.29375	0.014942
6	2	2	1	4	77.5	78.49375	0.012823
7	2	3	4	1	74.5	71.49375	-0.04035
8	2	4	3	2	76.2	77.11875	0.012057
9	3	1	3	4	84.3	81.29375	-0.03566
10	3	2	4	3	74.7	75.61875	0.012299
11	3	3	1	2	77.3	73.39375	-0.05053
12	3	4	2	1	77.5	78.49375	0.012823
13	4	1	4	2	78.8	79.79375	0.012611
14	4	2	3	1	76.9	77.99375	0.014223
15	4	3	2	4	95.3	96.21875	0.009641
16	4	4	1	3	93.4	90.39375	-0.03219

8.1.3 VIBRATION PREDICTED VALUE AND VARIATIONS

Table 8.4: Vibration Predicted Value and Variations

EXP	A	B	C	D	VIBRATION	PREDICTED	VARIATIONS
1	1	1	1	1	4.41	3.9384	0.106944
2	1	2	2	2	6.076	5.6534	0.069556
3	1	3	3	3	2.058	2.7379	-0.33036
4	1	4	4	4	3.724	3.9384	-0.05757
5	2	1	2	3	4.998	5.2124	-0.04289
6	2	2	1	4	5.39	6.0699	-0.12614
7	2	3	4	1	2.646	2.2234	0.159722
8	2	4	3	2	4.41	3.9384	0.106944
9	3	1	3	4	3.626	3.2034	0.116554
10	3	2	4	3	2.646	2.1744	0.178241
11	3	3	1	2	2.058	2.2724	-0.10417
12	3	4	2	1	1.274	1.9539	-0.53365
13	4	1	4	2	1.568	2.2479	-0.43359
14	4	2	3	1	1.372	1.5864	-0.15625
15	4	3	2	4	3.43	2.9584	0.1375
16	4	4	1	3	2.352	1.9294	0.179688

8.1.4 ANOVA TABLE FOR TEMPERATURE

Table 8.5: ANOVA Table for Temperature

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	3	401.96	401.96	133.99	8.33	0.058
B	3	184.69	184.69	61.562	3.83	0.15
C	3	20.03	20.03	6.677	0.42	0.755
D	3	384.44	384.44	128.15	7.97	0.061
Residual Error	3	48.26	48.26	16.087		0.2231
Total	15	1039.4				1

FROM F RATIO TABLE FOR (3 , 3) = 9.2766 < OBTAINED VALUE RESULT ADEQUATE

8.1.5 ANOVA TABLE FOR VIBRATION

Table 8.6: ANOVA Table for Vibration

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	3	15.066	15.066	5.022	4.14	0.137
B	3	4.54	4.54	1.513	1.25	0.43
C	3	4.343	4.343	1.448	1.19	0.444
D	3	5.764	5.764	1.921	1.58	0.357
Residual Error	3	3.637	3.637	1.212		0.017
Total	15	33.349				1

FROM F RATIO TABLE FOR (3 , 3) = 9.2766 < OBTAINED VALUE RESULT ADEQUATE

8.1.6 PREDICTED AND RECORDED TEMPERATURE

Table 8.7: Predicted and Recorded Temperature

Levels	Temperature prediction	Temperature experimented
S/N RATIO	-39.965	-38.155
RESPONSE	80.7	99.0688

8.1.7 PREDICTED AND RECORDED VIBRATION

Table 8.8: Predicted and Recorded Vibration

Levels	Vibration prediction	Vibration experimented
S/N RATIO	-6.76425	-9.31248
RESPONSE	2.05187	3.252375

8.1.8 TAGUCHI OPTIMIZATION USING LOSS FUNCTION CONCEPT

Table 8.9: Taguchi Optimization Using Loss Function Concept

EXP	A	B	C	D	T °C	V m/s²	LOSS FN T°C	LOSS FN A m/s²	NORM LOSS T°C	NORM LOSS A m/s²
1	1	1	1	1	75.1	4.41	5640.01	19.4481	1.05286	11.8225
2	1	2	2	2	84.8	6.076	7191.04	36.9177	1.34053	22.4556
3	1	3	3	3	87.2	2.058	7603.84	4.23564	1.41993	2.69467
4	1	4	4	4	98.2	3.724	9643.24	13.8818	1.79703	8.54379
5	2	1	2	3	73.2	4.998	5358.24	24.98	1	15.3953
6	2	2	1	4	77.5	5.39	6006.25	29.0521	1.12097	17.8941
7	2	3	4	1	74.5	2.646	5550.25	7.00116	1.03535	4.13609
8	2	4	3	2	76.2	4.41	5806.44	19.4481	1.08647	1.19825
9	3	1	3	4	84.3	3.626	7106.49	13.1488	1.36273	8.10592
10	3	2	4	3	74.7	2.646	5580.09	7.00116	1.41404	4.31609
11	3	3	1	2	72.3	2.058	5975.29	4.23564	1.15159	2.60967
12	3	4	2	1	77.5	1.274	6006.25	1.62376	1.10937	1
13	4	1	4	2	78.8	1.568	6209.44	2.45624	1.18858	1.54793
14	4	2	3	1	76.9	1.372	5913.61	1.82384	1.13648	1.15763
15	4	3	2	4	95.3	3.43	9082.09	11.7649	1.69976	7.24521
16	4	4	1	3	93.4	2.352	8723.56	5.53194	1.68064	3.40284

8.1.9 MAIN EFFECTS OF TEMPERATURE FOR 4 FLUTES

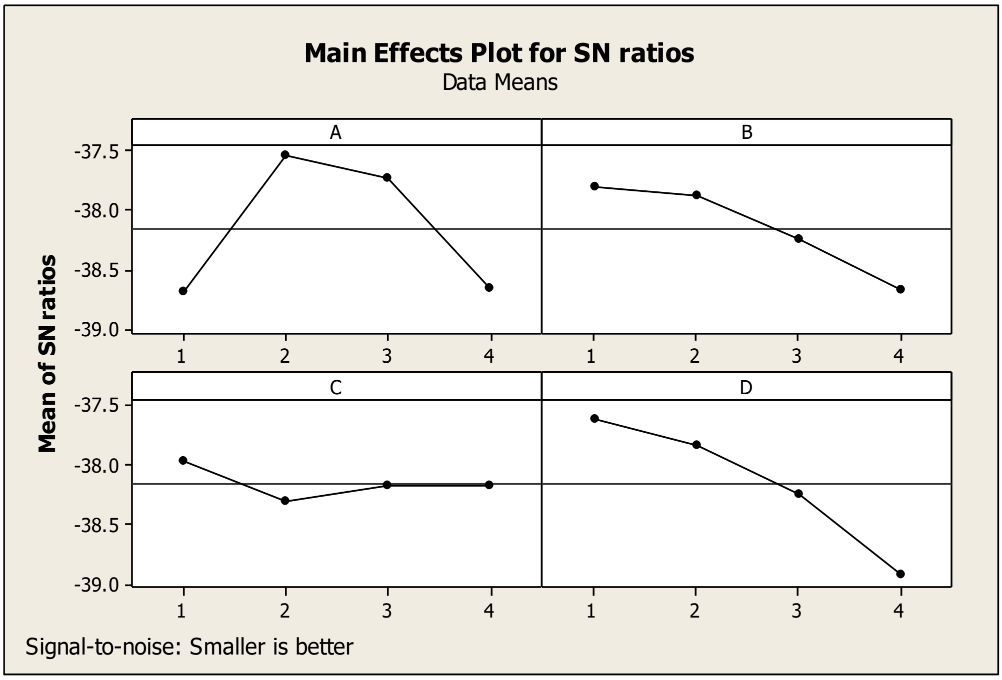


Fig 8.1 Main Effects Of Temperature for 4 Flutes

8.1.10 MAIN EFFECTS OF VIBRATION FOR 4 FLUTES

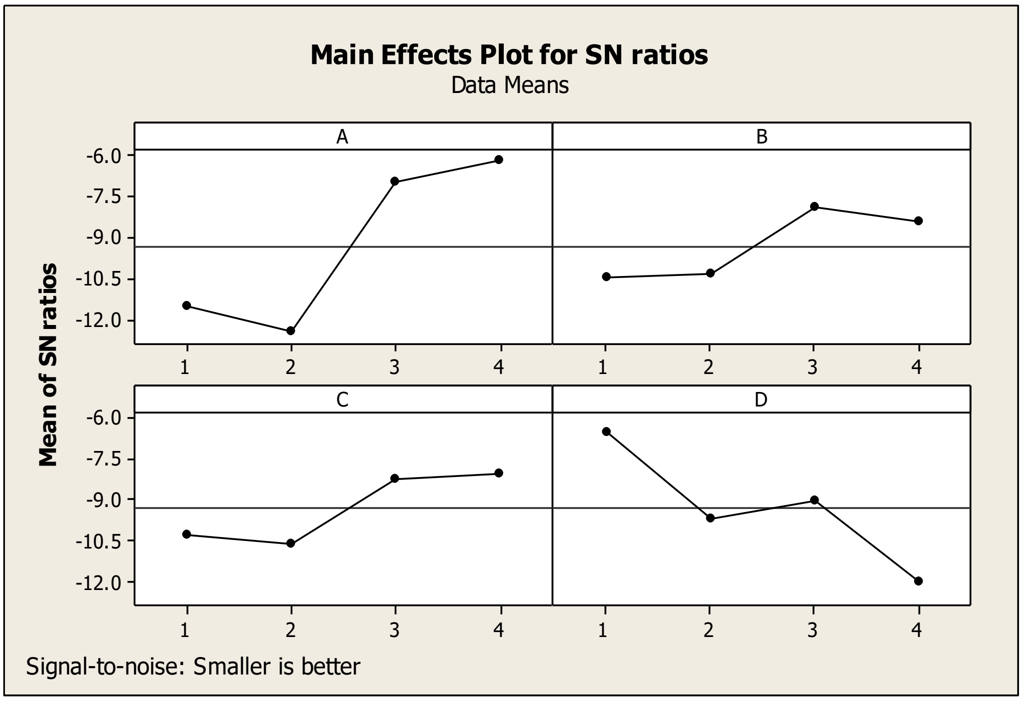


Fig 8.2 Main Effects Of Vibration for 4 Flutes

8.2 OUTPUT RESPONSES AND CALCULATIONS FOR 2 FLUTES

We have conducted the experiments and measured the responses for every component.

Table 8.10: Output Responses and Calculations for 2 Flutes

EXPERIMENT	A	B	C	D	TEMPERATURE °C	VIBRATION m/s^2
1	1	1	1	1	79.8	3.332
2	1	2	2	2	81	3.213
3	1	3	3	3	81.8	3.234
4	1	4	4	4	83.6	3.43
5	2	1	2	3	80.8	2.646
6	2	2	1	4	81.6	3.234
7	2	3	4	1	78.8	1.568
8	2	4	3	2	80.4	1.96
9	3	1	3	4	89.2	6.076
10	3	2	4	3	87.6	4.018
11	3	3	1	2	86	3.92
12	3	4	2	1	84.4	3.332
13	4	1	4	2	85.2	3.038
14	4	2	3	1	86.4	3.142
15	4	3	2	4	85.6	4.214
16	4	4	1	3	84.4	4.324

8.2.1 SIGNAL TO NOISE RATIO FOR 2 FLUTES

Formula for calculating signal to noise ratio S/N = 10*log (Σ(Y^2)/N)

Where Y = Responses for the given factor level combination

N = No of responses in factor level combination

Table 8.11: Signal to Noise Ratio for 2 Flutes

EXP	A	B	C	D	T °C	A m/s²	S/N T	S/N A
1	1	1	1	1	79.8	3.332	-38.0401	-10.4541
2	1	2	2	2	81	3.213	-38.1697	-10.1382
3	1	3	3	3	81.8	3.234	-38.2551	-10.1948
4	1	4	4	4	83.6	3.43	-38.4441	-10.7059
5	2	1	2	3	80.8	2.646	-38.1482	-8.4518
6	2	2	1	4	81.6	3.234	-38.2338	-10.1948
7	2	3	4	1	78.8	1.568	-37.9305	-3.90692
8	2	4	3	2	80.4	1.96	-38.1051	-5.84512
9	3	1	3	4	89.2	6.076	-39.0073	-15.6724
10	3	2	4	3	87.6	4.018	-38.8501	-12.0802
11	3	3	1	2	86	3.92	-38.69	-11.8657
12	3	4	2	1	84.4	3.332	-38.5268	-10.4541
13	4	1	4	2	85.2	3.038	-38.6088	-9.65176
14	4	2	3	1	86.4	3.142	-38.7303	-9.94412
15	4	3	2	4	85.6	4.214	-38.69	-12.4939
16	4	4	1	3	84.4	4.324	-38.5268	-12.7177

8.2.2 PREDICTED TEMPERATURE AND VARIATIONS

Table 8.12: Predicted Temperature and Variations

8.2.3 PREDICTED VIBRATION AND VARIATIONS

EXP	A	B	C	D	TEMP	PREDICTED	VARIATIONS
1	1	1	1	1	79.8	79.9125	0.001408
2	1	2	2	2	81	81.2125	0.002617
3	1	3	3	3	81.8	82.1125	0.003806
4	1	4	4	4	83.6	82.9625	-0.00768
5	2	1	2	3	80.8	80.1625	-0.00795
6	2	2	1	4	81.6	81.9125	0.003815
7	2	3	4	1	78.8	79.0125	0.002689
8	2	4	3	2	80.4	80.5125	0.001397
9	3	1	3	4	89.2	89.4125	0.002377
10	3	2	4	3	87.6	87.7125	0.001283
11	3	3	1	2	86	85.3625	-0.00747
12	3	4	2	1	84.4	84.7125	0.003689
13	4	1	4	2	85.2	85.5125	0.003654
14	4	2	3	1	86.4	85.7625	-0.00743
15	4	3	2	4	85.6	86.1125	0.005952
16	4	4	1	3	84.4	84.6125	0.002511

Table 8.13: Predicted Vibration and Variations

EXP	A	B	C	D	VIBRATION	PREDICTED	VARIATIONS
1	1	1	1	1	3.332	3.362625	-0.00919
2	1	2	2	2	3.213	2.946125	0.083061
3	1	3	3	3	3.234	3.436125	-0.0625
4	1	4	4	4	3.43	3.583125	-0.04464
5	2	1	2	3	2.646	2.799125	-0.05787
6	2	2	1	4	3.234	3.436125	-0.0625
7	2	3	4	1	1.568	1.182125	0.246094
8	2	4	3	2	1.96	1.990625	-0.01562
9	3	1	3	4	6.076	5.690125	0.063508
10	3	2	4	3	4.018	4.048625	-0.00762
11	3	3	1	2	3.92	4.073125	-0.03906
12	3	4	2	1	3.332	3.534125	-0.06066
13	4	1	4	2	3.038	3.240125	-0.06653
14	4	2	3	1	3.142	3.191125	-0.01563
15	4	3	2	4	4.214	4.244625	-0.00727
16	4	4	1	3	4.324	3.828125	0.11468

8.2.4 ANOVA TABLE FOR TEMPERATURE

Table 8.4: ANOVA Table for Temperature

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	3	113.148	113.148	37.7158	5.34	0.15
B	3	2.727	2.727	0.9092	1.21	0.439
C	3	5.928	5.928	1.9758	2.64	0.223
D	3	16.047	16.047	5.3492	7.14	0.17
Residual Error	3	2.247	2.247	1.186	0.7492	0.03
Total	15	140.098				1

FROM F RATIO TABLE FOR (3, 3) = 9.2766 < OBTAINED VALUE
RESULT ADEQUATE

8.2.5 ANOVA TABLE FOR VIBRATION

Table 8.15: ANOVA Table for Vibration

Source	DF	Seq SS	Adj SS	Adj MS	F	P
A	3	8.247	8.247	2.749	7.06	0.045
B	3	0.739	0.739	0.2462	0.9	0.533
C	3	1.133	1.133	0.3777	1.38	0.398
D	3	4.682	4.682	1.5608	5.71	0.093
Residual Error	3	0.82	0.82	0.8199	0.2733	0.0456
Total	15	15.62				1

FROM F RATIO TABLE FOR (3 ,3) = 9.2766 < OBTAINED VALUE
RESULT ADEQUATE

8.2.6 PREDICTED AND EXPERIMENTED TEMPERATURE

Table 8.16: Predicted and Experimented Temperature

Levels	Temperature prediction	Temperature experimented
S/N RATIO	-11.44339515	-10.28569933
RESPONSE	86.9125	83.5375

8.2.7 PREDICTED AND EXPERIMENTED VIBRATION

Table 8.17: Predicted and Experimented Vibration

Levels	Vibration prediction	Vibration experimented
S/N RATIO	-11.4434	-10.2982
RESPONSE	3.87712	3.411625

8.2.8 TAGUCHI OPTIMIZATION USING LOSS FUNCTION CONCEPT

Table 8.18: Taguchi Optimization Using Loss Function Concept

EXP	A	B	C	D	T °C	V m/s²	LOSS FN T°C	LOSS FN A m/s²	NORM LOSS T°C	NORM LOSS A m/s²
1	1	1	1	1	79.8	3.332	6368.04	11.10222	1.025542	4.516
2	1	2	2	2	81	3.213	6561	10.32337	1.056617	4.199
3	1	3	3	3	81.8	3.234	6691.24	10.45876	1.077592	4.254
4	1	4	4	4	83.6	3.43	6988.96	11.7649	1.125538	4.785
5	2	1	2	3	80.8	2.646	6528.64	7.001316	1.051406	2.848
6	2	2	1	4	81.6	3.234	6658.56	10.45876	1.072329	4.254
7	2	3	4	1	78.8	1.568	6209.44	2.458624	1	1
8	2	4	3	2	80.4	1.96	6464.16	3.8416	1.041021	1.563
9	3	1	3	4	89.2	6.076	7956.64	36.91778	1.281378	15.02
10	3	2	4	3	87.6	4.018	7673.76	16.14432	1.235822	6.566
11	3	3	1	2	86	3.92	7396	15.3664	1.19109	6.25
12	3	4	2	1	84.4	3.332	7123.36	11.10222	1.147182	4.516
13	4	1	4	2	85.2	3.038	7259.04	9.229444	1.169033	3.754
14	4	2	3	1	86.4	3.142	7464.96	9.872164	1.202195	4.015
15	4	3	2	4	85.6	4.214	7327.36	17.7578	1.180036	7.223
16	4	4	1	3	84.4	4.324	7123.36	18.69698	1.147182	7.605

8.2.9 MAIN EFFECTS OF TEMPERATURE FOR 2 FLUTES

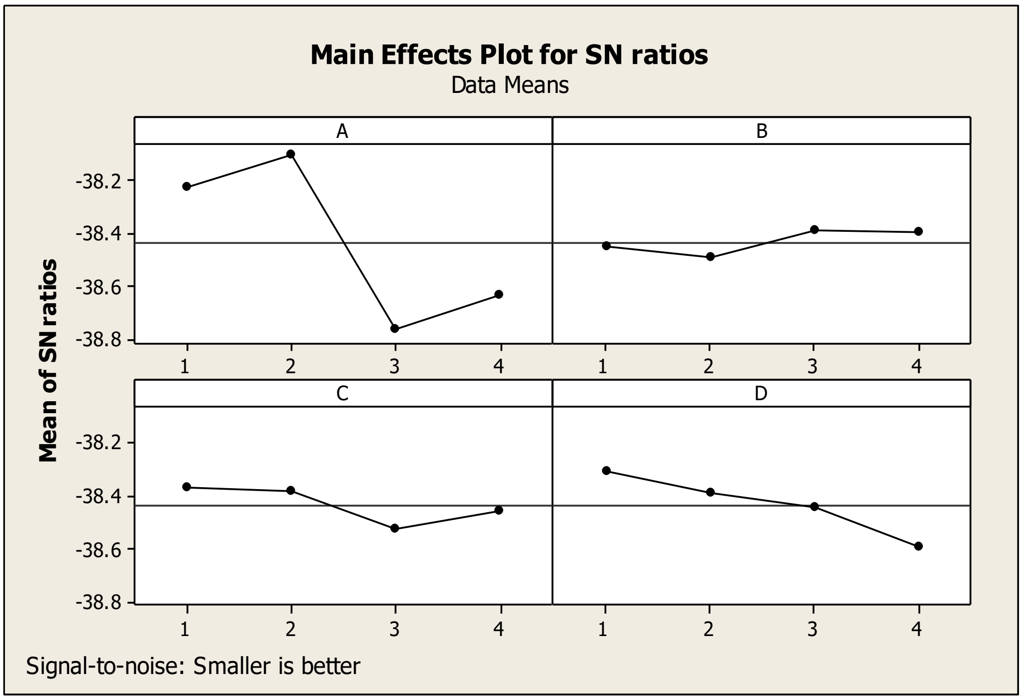


Fig 8.3 Main Effects Of Temperature for 2 Flutes

8.2.10 MAIN EFFECTS OF VIBRATION FOR 2 FLUTES

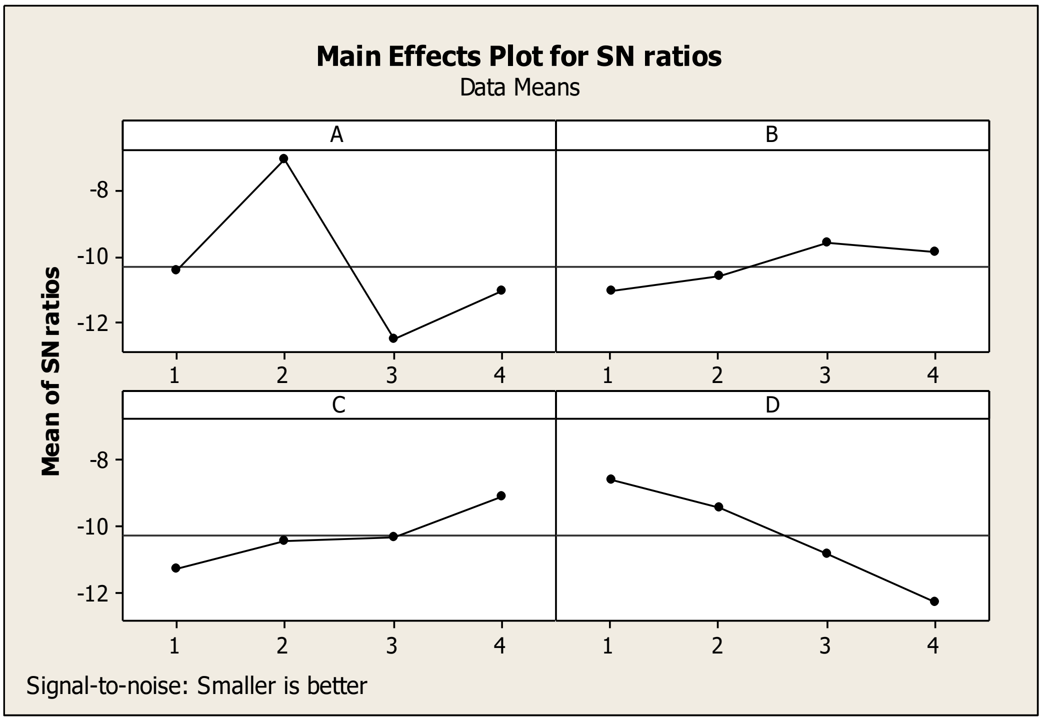


Fig 8.4 Main Effects Of Vibration for 2 Flutes

CHAPTER 9

CONCLUSION

The following conclusions can be drawn from the above investigations

- All the four process parameters have an effect in determining the temperature rise and also in acceleration amplitude.
- Effects of process parameters such as cutting speed, depth of cut, spindle speed exhibits positive value to the temperature rise and increase in frequency of vibration.
- The effect of rake angle place a major role in machining as the increase in rake angle results in high temperature and in normal frequency of vibration.
- While machining with 4 flute HSS tool the optimal parameter for end milling is spindle speed 2000 rpm, feed rate 0.03 mm/rev, depth of cut 2 mm, and rake angle 4 degree for minimal temperature and for minimal vibration the spindle speed is 3500 rpm, feed rate 0.03 mm, depth of cut 0.25 mm and rake angle 12 degree.
- While machining with 2 flute HSS toll the optimal parameter for milling with minimal temperature and with low frequency of vibration is spindle speed 3000 rpm, feed rate 0.05 mm/rev, depth of cut 1mm and rake angle 8 degree.
- Among the 2 flutes and 4 flutes HSS tool the 2 flute tool has minimal temperature rise and low frequency of vibration.

APPENDIX

COST ESTIMATION

MATERIAL COST

SL.NO.	MATERIAL	QUANTITY	COST(RS)
1	Aluminium rod	6 Kgs	2000
2	HSS end mill cutter	8 pieces	1500
3	3.5 mm DRILL BIT	8	200
4	K-type thermocouple	2	600
		TOTAL	4300

COST TO LABOUR

SL.NO	OPERATION	HOURS	COST(RS)
1	VMC milling	4	2000
2	Vibration setup	4	6000
3	Temperature setup	4	500
		TOTAL	8500

TOTAL COST = MATERIAL COST + COST TO LABOUR

= 4300 + 8500

= RS 12800

TOTAL COST OF THIS PROJECT = RS 12800/-

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ME6811 – PROJECT WORK

DEPARTMENT VISION

To provide a world class education in mechanical engineering through innovation, excellence in teaching and research

DEPARTMENT MISSION

To impart high quality technical education and develop Mechanical Engineers with all round knowledge of multi-disciplinary branches of engineering and technology to foster skill sets required to be a global professional in the areas of industry, research and technology management.

PROGRAMME EDUCATIONAL OBJECTIVES

PEO I

To provide students with sound foundation in the mathematical, scientific and engineering fundamentals necessary to formulate, analyze and solve engineering problems and to prepare them for graduate studies and for successful careers in industry.

PEO II

To impart students with skills for design, improvement and installation of Mechanical and allied integrated systems of men and material.

PEO III

To educate the students on designing the modern mechanical systems and expose them to industrial practices for better employability and adaptability.

PEO IV

To instil the values, skills, leadership and team spirit for comprehensive and wholesome personality, to promote entrepreneurial interest among students and to create a fervor for use of Engineering in addressing societal concerns.

PROGRAM OUTCOMES(POs)

Engineering Graduates will be able to:

1. **Engineering knowledge :** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems**: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

6. **The engineer and society**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics**: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning:** Recognize the need for and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

PROGRAM SPECIFIC OUTCOMES (PSOs)

1. To innovate a Mechanical System which meets the desired specifications and requirements using CAE tools.

2. To explore alternate materials for automobile, manufacturing and process industries
3. To lead professional career in industries or an entrepreneur by applying Engineering and Management principles and practices.

COURSE OBJECTIVE

1. To relate the theoretical and experimental studies.
2. To solve new problem in design and manufacture of a device, a research investigation, a computer or management project with a concern for society.
3. To apply engineering knowledge to solve real time problems in engineering industry.
4. To develop teamwork, lifelong learning, communication and project management capabilities.

COURSE OUTCOME

1. Ability to relate the theoretical and experimental studies.
2. Ability to solve new problem in design and manufacture of a device, a research investigation, a computer or management project with a concern for society.
3. Ability to apply engineering knowledge to solve real time problems in engineering industry.
4. Ability to develop teamwork, lifelong learning, communication and project management capabilities.
5. Ability to demonstrate the progress/ completion of the project in conferences.