DESIGN, DEVELOPMENT AND INSPECTION OF METALLIC COMPONENTS FOR AEROSPACE AND DEFENCE APPLICATION

A Graduate Project Report submitted to Manipal Academy of Higher Education in partial fulfilment of the requirement for the award of the degree of

BACHELOR OF TECHNOLOGY

In

Mechanical & Industrial Engineering

Submitted by

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DEPARTMENT OF MECHANICAL AND INDUSTRIAL ENGINEERING

MANIPAL INSTITUTE OF TECHNOLOGY

MANIPAL

(A constituent unit of MAHE, Manipal)

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CERTIFICATE

This is to certify that the project titled **DESIGN, DEVELOPMENT AND INSPECTION OF METALLIC COMPONENTS** is a record of the bonafide work done by **THAKUR PRANAV GOPAL SINGH** (*Reg. No. 200909426*) submitted in partial fulfilment of the requirements for the award of the Degree of Bachelor of Technology (BTech) in **MECHANICAL AND INDUSTRIAL ENGINEERING** of Manipal Institute of Technology, Manipal, Karnataka, (A Constituent Unit of Manipal Academy of Higher Education), during the academic year 2022 - 2023.

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ABSTRACT

BALAJI CNC TECHNOLOGIES (BCT) is an aerospace and defense manufacturing and assembly unit, the roles and responsibilities involved learning to operate CNC turning, CNC milling, EDM, and optimizing production planning. These precision manufacturing machines are crucial for developing high-quality metal components for aerospace and defense vehicles and systems.

The aerospace and defense parts that have been designed in this project hold utmost importance due their functionality in their domains of weapons and space vehicles. The job valve is used in the missiles propulsion system, synth module is used in the avionics systems for the printed circuited boards and the lock washer is used in every fastening systems.

The process involved three simple steps: observing, learning, and operating each machine. During the observation phase, it was important to understand the process, note changes, and prepare for new learning. The learning phase required studying each machine's software, manuals, and recommended books. In the operation phase, adherence to machine parameters, completing jobs within the stipulated cycle time, and writing inspection and production reports were essential.

Following these procedures, various components were operated on, models were drafted, CNC programs were generated in Mastercam, NC programs were edited in CIMCO, the first job was operated on the machine, and a thorough inspection was performed throughout. The finished jobs were well within the tolerance range and satisfied the constraints of geometric dimensioning and tolerance. Final inspections using different gauges, height master, and profile projector confirmed that the jobs were ready for dispatch.

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ABBREVIATIONS

CNC - Computer aided Numerical Control

CAD - Computer-Aided Design

CAM - Computer-Aided Manufacturing

G-code - Geometric Code

M-code - Machine Code

VMC - Vertical Machining Centre

HMC - Horizontal Machining Centre

RPM - Revolutions per Minute

IPM - Inches per Minute

DNC - Direct Numerical Control

CNC Router - Computer Numerical Control Router

CNC Lathe - Computer Numerical Control Lathe

ATC - Automatic Tool Changer

CNC Milling - Computer Numerical Control Milling

PLC - Programmable Logic Controller

DRO - Digital Read Out

BCT – Balaji CNC Technologies

HAL – Hindusthan Aeronautical limited

CHAPTER 1

INTRODUCTION

Manufacturing is the process of converting raw materials, components, or parts into finished goods that meet a customer's expectations or specifications. It involves a series of steps including designing, engineering, prototyping, production, quality control, and distribution. The manufacturing process can vary widely depending on the product being made and the technologies involved. Traditional manufacturing methods include casting, moulding, machining, and assembly, while modern manufacturing often incorporates advanced technologies such as robotics, computer aided design (CAD), computer-aided manufacturing (CAM), 3D printing, and automation.

This project will be discuss the usage of modern manufacturing methods, its suitable machines, and production line functioning including quality control analysis on the developed metal components. The following figure shows the industry flow chart in brief.

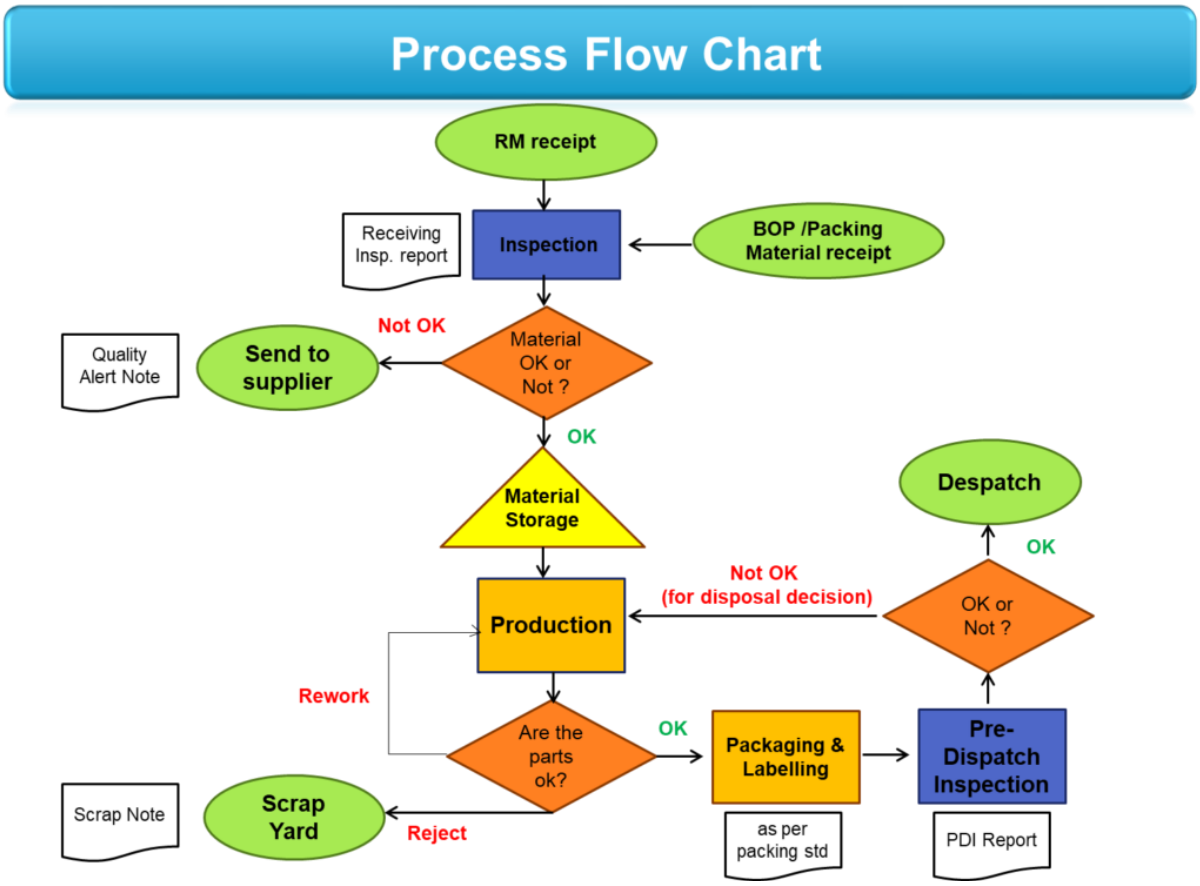


Figure 1: Manufacturing flow chart [6]

At Balaji CNC Technologies (BCT) modern manufacturing technology is applied and implemented for the development of defence and aerospace metal components and assembly. While dealing with components from this field, ISO practices are implied thus it is an IS0 9001:2015 certified, and each component must go through each stated step. The manufacturing operations turning, boring, threading, milling, grooving is all performed on CNC Turning centre and CNC Milling (3,4,5 axis), advanced EDM facility is utilized for special operations and time saving operations, very accurate CMM inspection is utilized for having no form of error at BCT.

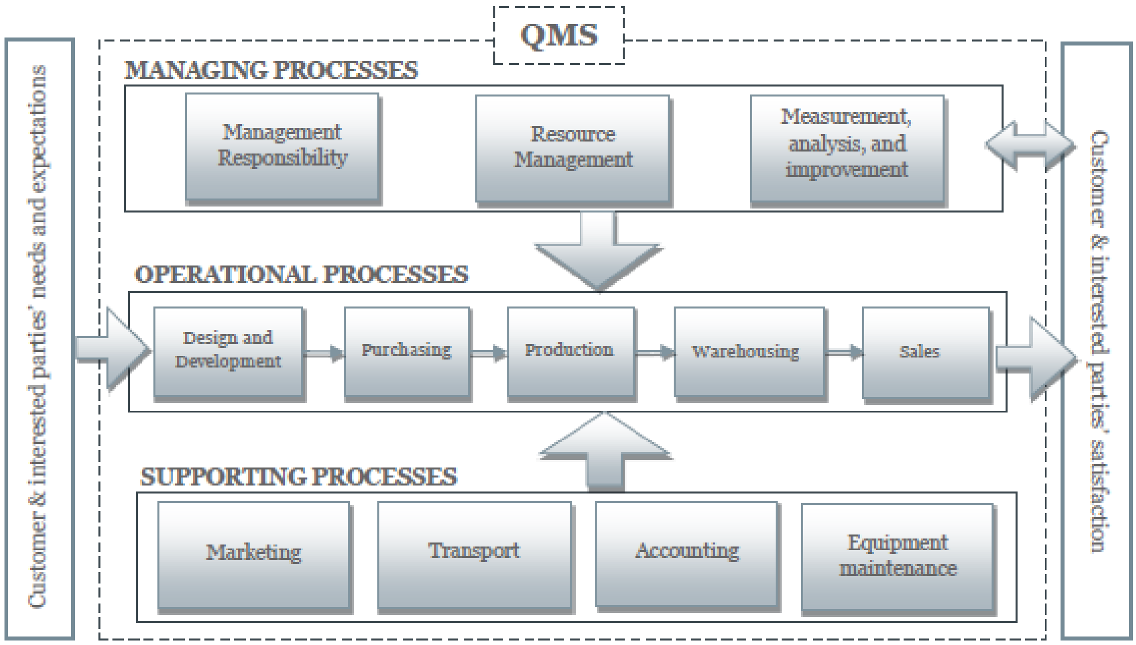


Figure 2: ISO 9001:2015 Process Flow

1.1 PRODUCTION LINE

To produce the precision components with a number of machines involved with varied skilled workers and within the stipulated time, production line management plays a crucial role. Effective production line management ensures that these machines operate seamlessly and efficiently, minimizing downtime and maximizing productivity. The key elements of production line management include,

1. **Planning and Scheduling:** Determining the sequence of operations, allocating resources, and scheduling machine activities to meet production targets and deadlines.

2. **Workflow Optimization:** Streamlining processes to reduce waste, enhance efficiency, and improve overall productivity. This involves analysing production data and continuously seeking improvements.
3. **Inventory Management:** Managing the supply of raw materials and components to ensure that the production line is adequately stocked without overburdening inventory costs.
4. **Quality Control:** Implementing stringent quality checks at various stages of the production process to ensure that the final products meet the required specifications and standards.
5. **Maintenance and Troubleshooting:** Regular maintenance of CNC machines to prevent breakdowns and swift troubleshooting to resolve any issues that arise, ensuring minimal disruption to the production flow.

Figure 3: Production Line management flow [4]

1.2 MACHINING & ASSEMBLY

One of the important steps in the line that consumes a majority of cycle time of the sequence of operations. Due to the advancements in the field of electronics and programming, computer numeric control (CNC) have tremendously shortened the time.

With a few lines of geometric code (G-code) and machine code (M-code), along with a suitable fixtures and standard tools, a highly precise and lot of finished product is obtained efficiently and consistently.
The assembly process follows machining, where the machined components are systematically put together to form a complete product. This stage involves various techniques, such as welding, fastening, and gluing, depending on the product requirements. Efficient CNC machining and assembly ensure high-quality products with minimal defects, significantly enhancing productivity and reducing costs in manufacturing.

At BCT unit 2, there are currently 5 cnc turning machines to produce cylindrical jobs and 7 milling machines up till 5 axis for producing complex parts. The facility also includes newer machinery like EDM’s for optimising time consuming jobs. To thoroughly inspect the completed jobs, the firm has plenty of gauges, measuring instruments, pins, probes, profiles projector, height master and a CMM. The machines are capable to calculate deviations up to 3-5 microns.

1.3 QUALITY CONTROL

According manufacturing company norms, quality control on batch production is a must and the initial first article inspection (FAI) ensures green signal to the batch yet to be loaded on the production line. The importance of the quality control is as following:

1. **Consistency and Reliability**: Ensures products meet consistent standards, maintaining reliability and performance, which is crucial for customer satisfaction and brand reputation.
2. **Defect Reduction**: Identifies and eliminates defects early in the production process, reducing waste and rework costs, and ensuring that only high-quality products reach the market.
3. **Compliance**: Ensures products comply with industry standards, regulations, and specifications, which is crucial for legal and market acceptance.
4. **Customer Satisfaction**: High-quality products increase customer satisfaction and loyalty, leading to repeat business and positive word-of-mouth referrals.
5. **Cost Efficiency**: Prevents costly recalls, returns, and repairs by catching issues before products reach customers, ultimately saving the company money.

6. **Safety**: Ensures that products are safe for use, which is critical for protecting consumers and avoiding liability issues.

Quality control is thus a vital component of the production process, safeguarding the company's reputation and profitability while ensuring customer trust and satisfaction.

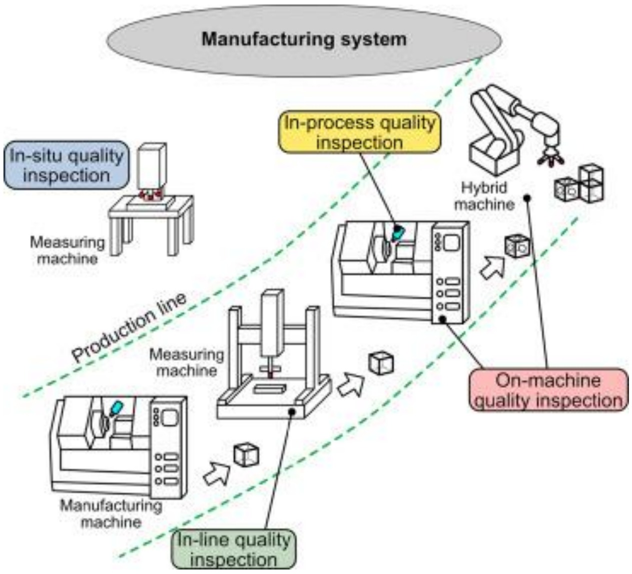


Figure 4: Quality Control at various divisions [4]

1.4.1 IMPORTANCE OF PROPOSED WORK

CNC manufacturing plays a crucial role in aerospace and defence industries due to its precision, efficiency, and versatility. In aerospace, CNC machining ensures the production of complex components with tight tolerances, vital for aircraft engines, structural parts, and avionics. It enables the fabrication of lightweight materials like titanium and composites, essential for enhancing fuel efficiency and performance. Similarly, in defence, CNC machining is indispensable for producing critical components for weapons systems, vehicles, and communication devices, ensuring reliability and interoperability in the field. Overall, CNC manufacturing's ability to deliver high-quality parts rapidly contributes significantly to innovation, safety, and strategic capabilities in aerospace and defence sectors.

Modelling, designing and developing components of aerospace field would enhance technical skills. To work with CNC machines and as a part of work to produce a component with a least cycle time which means to incorporate the best tooling, fixture, lesser stages of operation to increase the efficiency and repeatability of the production items. This would help gain experience in assembly lines and production planning along with the technical knowledge.

CHAPTER 2

ABOUT MACHINERY, SOFTWARES & ITS PARAMETERS

2.1 CNC TURNING

CNC turning is a precision manufacturing process used to create cylindrical parts by removing material from a rotating workpiece using cutting tools. In this automated process, a CNC lathe or turning centre is programmed to control the movement of the workpiece and the cutting tools, ensuring high precision and repeatability. The machine is highly precise, versatile, and can solve complex operations in single setup.

The basic/standard machine is generally having 8 turret slots for attaching the job based tooling, a single spindle, tailstock and a controller along with a digital display. [3]

BCT currently has machines that fit jobs till diameter of 400 mm and length 600 mm. All the machines are operated by FANUC controllers and cut high grade alloys such as Inconel, titanium. The tooling is one of the important parameters in the machining process. In general the tooling requires a cutting material that is harder than the workpiece/job. This can be easily identified based on the chip formation, chatter and finish on the job. [2]

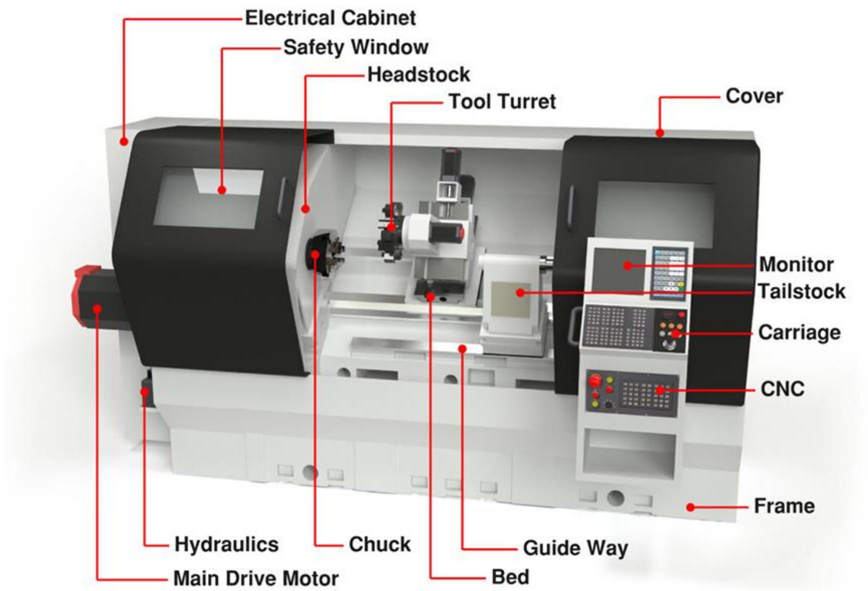


Figure 5: CNC turning machine [1]

2.1.1 BASIC TURNING TOOL NOMENCLATURE

The tools that we generally prefer in turning operations are called inserts. These inserts have different shapes, form, structure, tolerance range and suitable attachments for different set of operations. These inserts are generally made up of carbides, ceramics, PCD and HSS, with coating to increase tool life according to Taylor's equation VT^n = constant. Carbide coating are generally made up of tungsten carbide and chromium carbide increasing their hardness and wear resistance. These inserts are held by suitable holders which then fit in tool station according to the right hand or left hand side. [1]

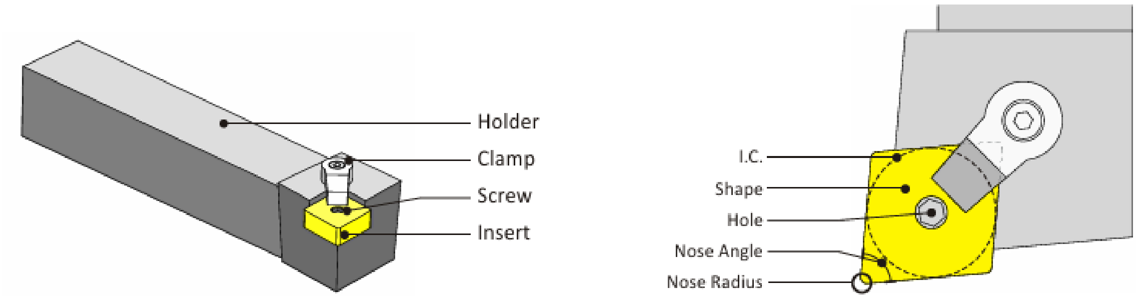


Figure 6: Insert Holder and insert features.

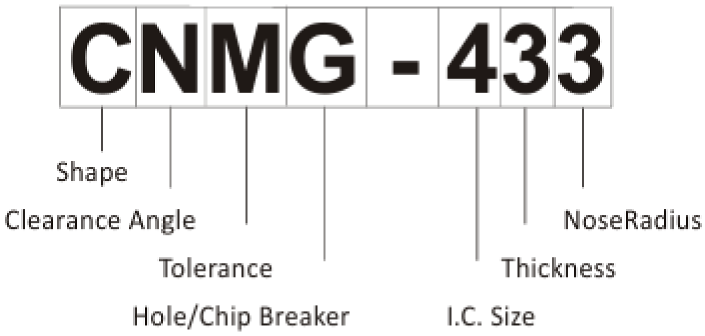


Figure 7: Insert Nomenclature [1]

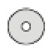
	Shape	
T	Triangle	
S	Square	
C	80 degree diamond	
D	55 degree diamond	
V	35 degree diamond	
R	Round	

Figure 8: Common insert shape codes [1]

Table 1: Common insert clearance angles.

Designation	Clearance Angle
N	0 degrees (no draft)
A	3 degrees
B	5 degrees
C	7 degrees
P	11 degrees

Table 2: Common insert tolerance (inch)

Designation	Corner point	Thickness	IC
M	0.002-0.005	0.005	0.002
G	0.001	0.005	0.001
E	0.001	0.001	0.001
K	0.0005	0.001	0.002-0.005

2.2 CNC MILLING

CNC (Computer Numerical Control) milling is a machining process that utilizes computerized controls to operate rotary cutting tools to remove material from a workpiece, creating complex shapes and features. This type of machine helps us in providing precise, efficient and complex geometries. Milling machines are versatile and multi axis capable (3, 4, 5 axis). [3]

BCT currently has 7 milling machines and up till 5 axis, all of them are 24 ATC's with varied bed length, max bed length is 1000mm. All these machines are FANUC operated and each have its set of cutters/cutting tools. [2]

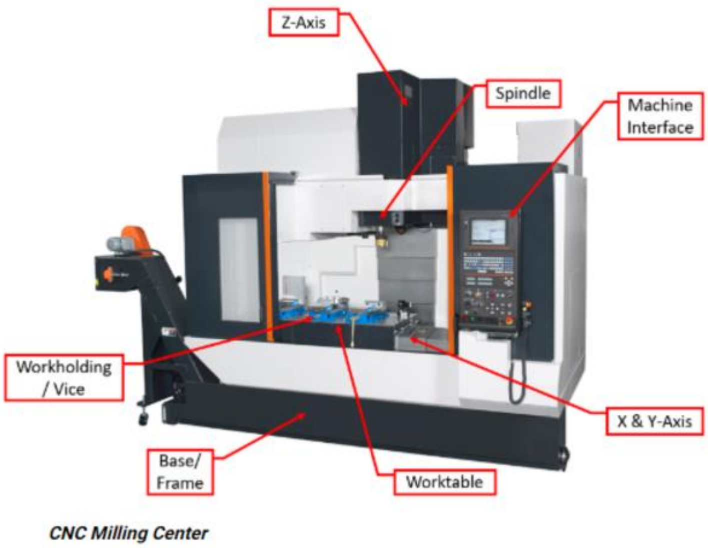


Figure 9: CNC Milling Centre [1]

2.2.1 BASIC MILLING TOOL NOMENCLATURE

The tools that we generally prefer in milling are called cutters. The cutters sit in holders called collets to support varied diameters which then fit in collet chuck in ATC turret. These cutting tools are either made up of high speed steel (HSS) for less tougher metals like aluminium or of carbide for tougher metals like titanium. [1]

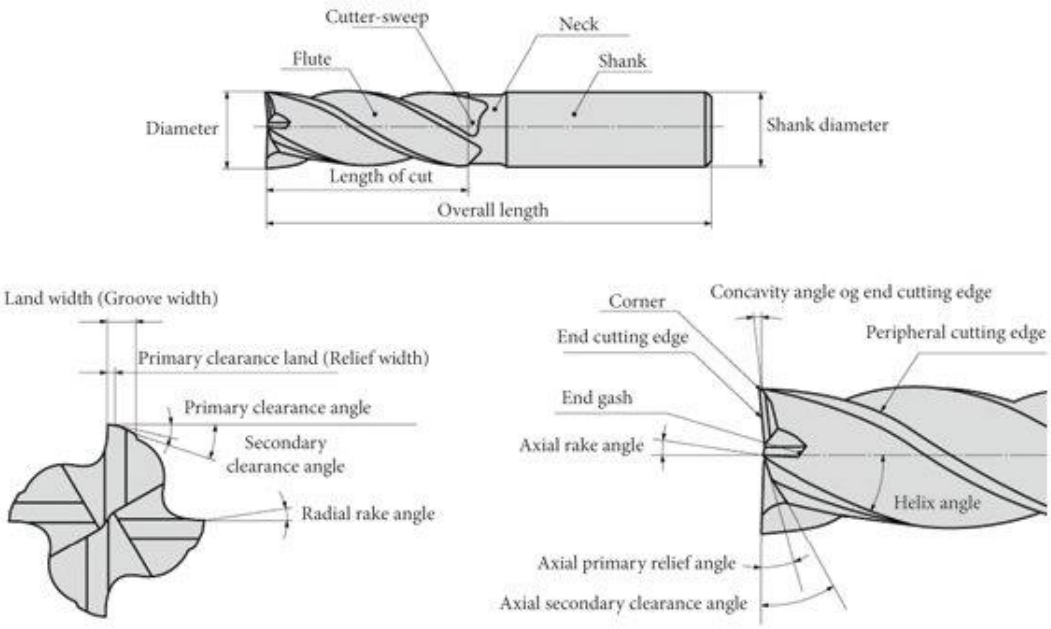


Figure 10: Milling Cutter Nomenclature [1]

2.2.2 CLIMB VS CONVENTIONAL MILLING

Milling tools can advance through the material so that the cutting flutes engage the material at maximum thickness and then decreases to zero. This is called Climb Milling. (Towards the feed direction)

Cutting in the opposite direction causes the tool to scoop up the material, starting at zero thickness and increasing to maximum. This is called Conventional Milling. (Against the feed direction)

The following figure 11 shows the difference between the two parameters which effects the tool life to a great extent.

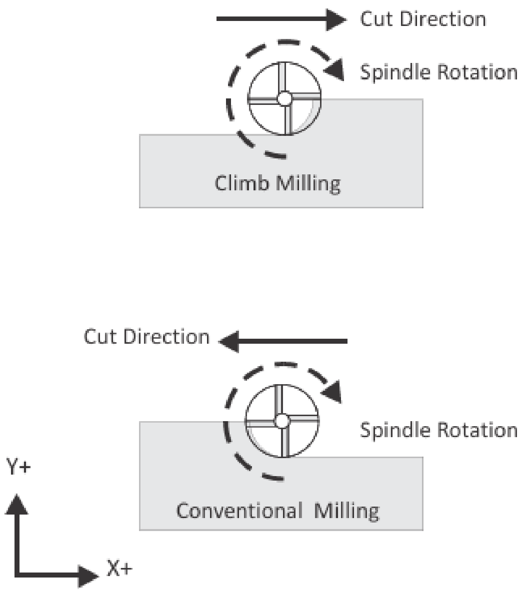


Figure 11: Climb vs Conventional Milling [2]

2.2.3 BASIC FORMULAS FOR CUTTING SPEED AND FEED RATE

Cutting speeds and feed rate are primary important parameters that are programmer has to have knowledge about based on the type of workpiece, operations and dimension (diameter, length) [2]

$$Speed\ \left(\frac{rev}{min}\right) = \frac{SMM\ (\frac{mm}{\mathrm{min}})}{Circumference\ (mm)}$$

Speed – The rotational speed of the spindle

SMM – Surface mm per min is the speed at which the material moves past the cutting edge (outside diameter) of the tool in mm per minute. SMM values depend on the tool type, tool material, and material being machined [2]

$$Feed\ \left(\frac{in}{min}\right) = Speed\ \left(\frac{rev}{\mathrm{min}}\right) * CL\left(\frac{\frac{in}{rev}}{flute}\right) * no\ of\ flutes$$

Feed is the linear feed of the tool through the material in inches per minute.

Speed is the result of the speed formula in revolutions per minute.

CL is the chip load, or how much material each cutting edge of the tool removes per revolution. Chip load is sometimes referred to as feed per tooth (FPT) or inches per rev (IPR).

Number of Flutes is the number of cutting flutes. (For a twist drill, this value is one.) [2]

Table 3: Milling speed data (SFM)

Milling cutting speeds (SFM/MIN)		
MATERIAL	**HSS**	**CARBIDE**
Aluminium	600	800
Brass	175	200
Delrin	400	800
Polycarbonate	300	500
Stainless steel	80	300
Steel 4140	70	350

Table 4: Feed Data (IPR)

Cutting Feeds (IPR) *in/rev*					
Operation	**Tool Diameter Range** (*in*)				
	<.125	*.125-.25*	*.25-.5*	*.5-1.*	*>1.*
Milling					
Aluminum	.002	.002	.005	.006	.007
Brass	.001	.002	.002	.004	.005
Delrin	.002	.002	.005	.006	.007
Polycarbonate	.001	.003	.006	.008	.009
Stainless Steel (303)	.0005	.001	.002	.003	.004
Steel (4140)	.0005	.0005	.001	.002	.003
Drilling	.002	.004	.005	.010	.015
Reaming	.005	.007	.009	.012	.015

Table 5: Machining Parameters

Operation	**Parameter**	**Value**
All	Clearance Height	1 inch
All	Feed Height	0.1 inch
All	Rapid Height	To clear clamps & fixtures
Mill roughing	Stepover (XY)	50-80 % tool dia
Mill roughing	Stepdown (Z)	25 – 50 % tool dia
Drill	Peck Increment	0.05 inch
Spot Drill	Dwell	0.5 seconds

2.3 ELECTRICAL DISCHARGE MACHINING (EDM)

EDM (Electrical Discharge Machining) Wire Cut is a precision machining process that uses electrical discharges (sparks) to cut and shape hard metals and conductive materials. It is particularly useful for creating intricate and complex shapes that are difficult to achieve with traditional machining methods. The primary advantage of this type of machining over the others is it doesn’t require additional tools but just a wire passing over pulleys to cut the job according to the coded profile. Its other distinctive features include no mechanical stress on the workpiece ensuring the integrity of delicate parts, helps us cut through tough and hard materials providing a good surface finish on the complex geometries as well.

Figure 12: EDM wire cut [2]

Table 6: EDM wire and job material.

Wire Material	Workpiece
Brass	Aluminium, Steel
Molybdenum	Titanium

2.4 QUALITY CONTROL

Quality control in a CNC manufacturing firm is a critical process that ensures the precision, reliability, and consistency of the machined components. It involves a series of systematic checks and procedures to maintain high standards throughout the production cycle. Inspection and measurement is one of the key aspects of quality control.

A height master machine, also known as a height gauge or height master, is a precision measuring instrument used in quality control for accurately determining the dimensions of components and verifying drawing measurements. It plays a crucial role in ensuring that manufactured parts meet specified tolerances and quality standards. It is a highly precise machine with a stable digital and analog options along with its user friendly mechanism which reduces the risk of human error.

Figure 13: Height Master/Gauge [2]

A profile projector, also known as an optical comparator, is a precision measuring instrument used in quality control and inspection processes to visually and dimensionally inspect the contours and profiles of manufactured parts. It projects the silhouette of a part onto a screen at a magnified scale, allowing for detailed examination and measurement. This is a non-contact inspection machine which has an optical magnification up to 100x and is user-friendly as well as to store data.

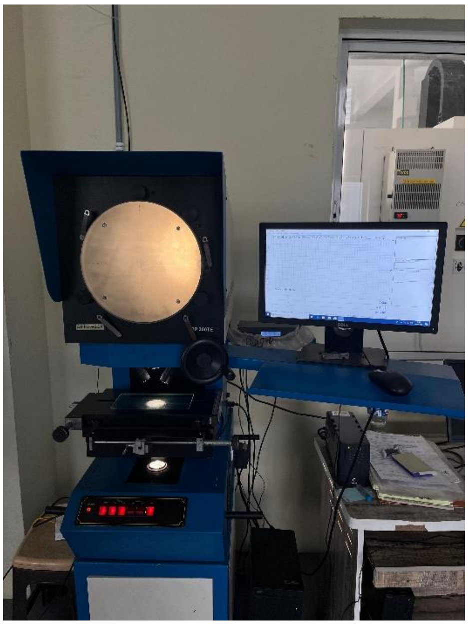


Figure 14: Profile Projector [2]

Measuring instruments include micrometre and Vernier calliper which are frequently used to measure the linear dimensions. There are different reports revolving around quality control such as: first article inspection (FAI), production sheet, critical dimension, tool planning, raw material sheet, process layout, schedule which are generated for each and every job after PO generation.

Gauges are essential tools in quality control for measuring and verifying the dimensions and tolerances of manufactured parts. Few common type of gauges used in QC are as follows:

a. Plug gauges: To measure the diameter of holes and cylinders.
b. Ring gauges: Measure the external diameter of the shaft.
c. Thread gauges: To measure the pitch and diameter of threaded parts.
d. Bore gauges: To measure the internal diameter of the bore or cylinder.
e. Radius gauges: Measure the radius of curves and rounded edges.

2.5 MASTERCAM & CIMCO

Mastercam is a leading computer-aided manufacturing (CAM) software widely used in the manufacturing industry for programming CNC (Computer Numerical Control) machines. Developed by CNC Software, Inc., it provides a comprehensive suite of tools for designing and machining parts with high precision and efficiency.

Benefits include:

a. **Versatile toolpaths:** Supports a wide range of machining operations, including milling, turning, wire EDM, and multi-axis machining. Offers advanced toolpath strategies like 2D, 3D, and 5-axis milling, ensuring optimal machining performance and efficiency.

b. **CAD Integration**: Includes built-in CAD capabilities for creating and modifying geometric designs. Seamlessly integrates with popular CAD software such as SolidWorks, AutoCAD, and Inventor, allowing for easy import and export of designs.

c. **Simulation and Verification**: Offers detailed simulation features to visualize toolpaths and detect potential collisions or errors before actual machining.

d. **Tool Management**: Provides comprehensive tool libraries and management systems, allowing users to define and organize tools and cutting conditions.

e. **Post-Processing:** Includes a wide range of post-processors for different CNC machines, ensuring compatibility and optimized G-code generation. Customizable post-processors allow for fine-tuning to meet specific machine requirements.

CIMCO is a suite of software tools designed to enhance and support computer-aided manufacturing (CAM) processes, particularly focusing on CNC machine data management, program editing, and machine communication. Developed by CIMCO A/S, it provides a range of solutions to improve efficiency, accuracy, and productivity in manufacturing environments. Seamlessly integrates with various CAM systems and CNC machines, providing a unified platform for CNC program management and communication. [2]

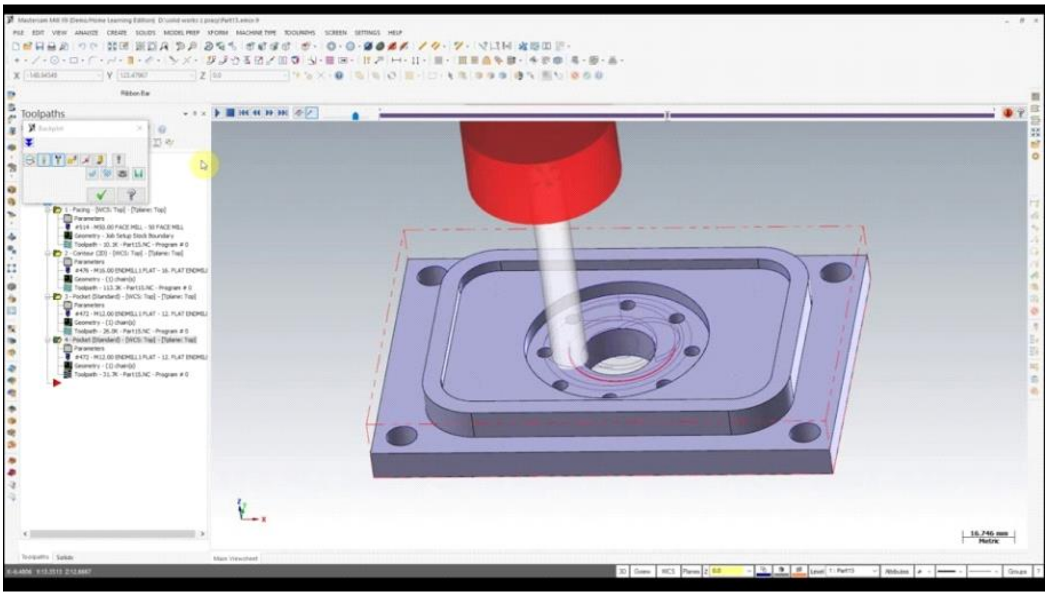


Figure 15: Mastercam software [2]

CHAPTER 3

METHODOLOGY

3.1 WORKFLOW OF THE PRESENT SYSTEM

1. **Approvals and documents:** The Company provides the necessary documents and certificates to be certified to quote for a particular set of components.
2. **Tender:** Initially the suitable class companies registered with the government quote for the components and the least bidder gets the job.
3. **Component details:** The vendor who gets the tender receives the drawings/drafts, the raw material sheet, the process layout, purchase order and all the specifications for a component that it quoted to.
4. **Production Planning:** The cad engineers study the specifications and draft a planning schedule in the production line. They allot the components to different machines stage wise with the least cycle time.
5. **First Article Inspection:** The operators then machine the first component inspecting the component thoroughly at each stage checking the tolerances, finish and dimensions. The operators along with quality control engineers use gauges, CMM, measuring instruments to validate the machined component/Job is in according to the drawing provided.
6. **Quality Approvals:** Once the job clears the quality approvals or certifications, then it goes out for production.
7. **Manufacturing:** The approved job then is mass produced batch wise and sent to the fitting section.
8. **Fitting & Dispatch:** The last stage where deburring and polishing of the components occurs, assembling of components, final quality checks with gauges, CMM is done for the components and the finished jobs are then packed and dispatched to the customer. The invoice for the same is given along with the jobs from the accounts section and the vendor receives the payment in the stipulated period for their service from the customer.

3.1.1 LIMITATIONS OF THIS SYSTEM

As this project deals only which manufacturing and quality control sections. The limitations and solutions for the same will only be addressed. Each job requires a lot of fixtures and tools which consume time to develop wherein if proper planning isn't ensured increases the cycle time reducing the productivity of the cycle.

Limitations:

a. Lot of setups and fixtures which cost time.
b. Improper tool planning causes prolongation of time.
c. Human errors at quality dept causes multiple checks before production.

Solutions:

a. Involving the same fixtures for different setting to save time as well as material.
b. Use efficient tooling like higher grade of carbide and refer catalogue for special tools.
c. To reduce human errors, ensure proper probes for inspecting and double check during FAI.

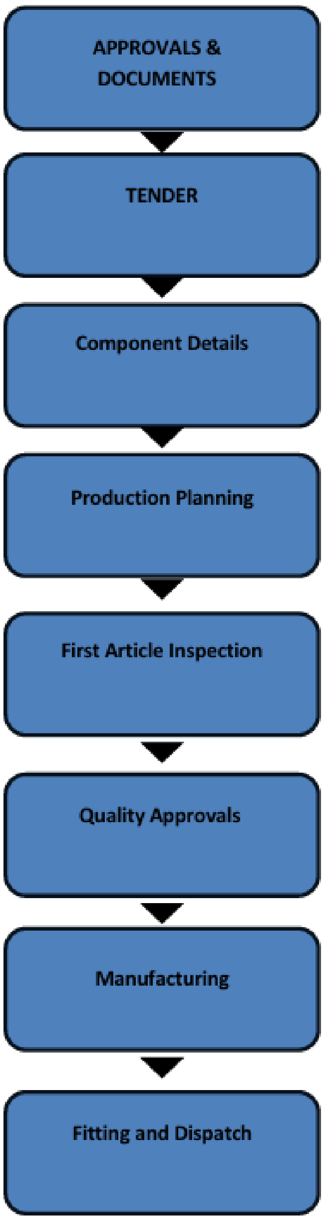


Figure 16: Flow chart from raw material to finished job

3.2 PROBLEM STATEMENT & OBJECTIVES

To complete one full cycle of operations for a turning, milling and EDM components along with their intermediate and final inspections overcoming the limitations stated earlier.

- Design in Mastercam Software with lesser settings and edit in CIMCO.
- Cut the raw material into stock and plan tooling. (minimal layer of stock)
- Machine the stock to finished part on CNC machines. (Maximum feed percentage)
- Quality control analysis providing inspection report and NC program.

3.3 LITERATURE STUDY

The following reference books and manuals will be used to understand the efficient principles and procedures that can be used to execute the methods to overcome the limitations. The complex multi-use fixtures, tools that sustain higher feed rate and supporting quality control gauges to improve intermediate inspections by operators to avoid multiple checks at in-situ inspection as in figure 4.

- **Autodesk Textbook for Programming**: This book offers a solid foundation in programming, crucial for understanding how to create and modify CNC programs. It covers the basics of CAD (Computer-Aided Design), which is fundamental for drafting precise models used in CNC manufacturing.
- **Mastercam and CIMCO Manuals and Udemy Courses**: Mastercam and CIMCO are essential software tools in CNC manufacturing. The manuals provide detailed instructions and technical guidance, while Udemy courses offer practical tutorials and hands-on experience. Finally, it helps in generating NC programs for the toolpaths provided.
- **GD&T by Henzold (McGraw Hill)**: This book provides a comprehensive understanding of geometric dimensioning and tolerancing, which is vital for ensuring that components meet precise specifications. Knowledge of GD&T ensures interpretation and create accurate technical drawings, critical for quality control in manufacturing.
- **FANUC Manuals**: FANUC controllers are widely used in CNC machines. The manuals provide in-depth knowledge of the controller's functions, programming, and troubleshooting. Familiarity with FANUC controllers ensures efficient operation and maintenance of CNC machines.
- **Kyocera Tooling Textbook**: This textbook offers insights into the selection and use of cutting tools, which is essential for optimizing machining processes. Understanding tooling helps choose the right tools for specific materials and machining tasks, improving efficiency and product quality

3.4 CNC TURNING JOB – VALVE

The raw material for component valve is aluminium alloy with the obtained raw material size of diameter 50 mm and length 800 mm. This job had be cut to minimal stock size for each piece and loaded on to the machine, the drawing for the same is in figure 17. The suitable length with sufficient stock was 32 mm and this can either be cut on the band saw or directly on the machine by parting operation. The total batch quantity to be made was 150 nos. Initially we had to model the job and generate toolpaths in a setting wise manner. Then tool planning for the job in similar manner had be done and necessary fixtures, bushes if needed were to be made. [4][5]

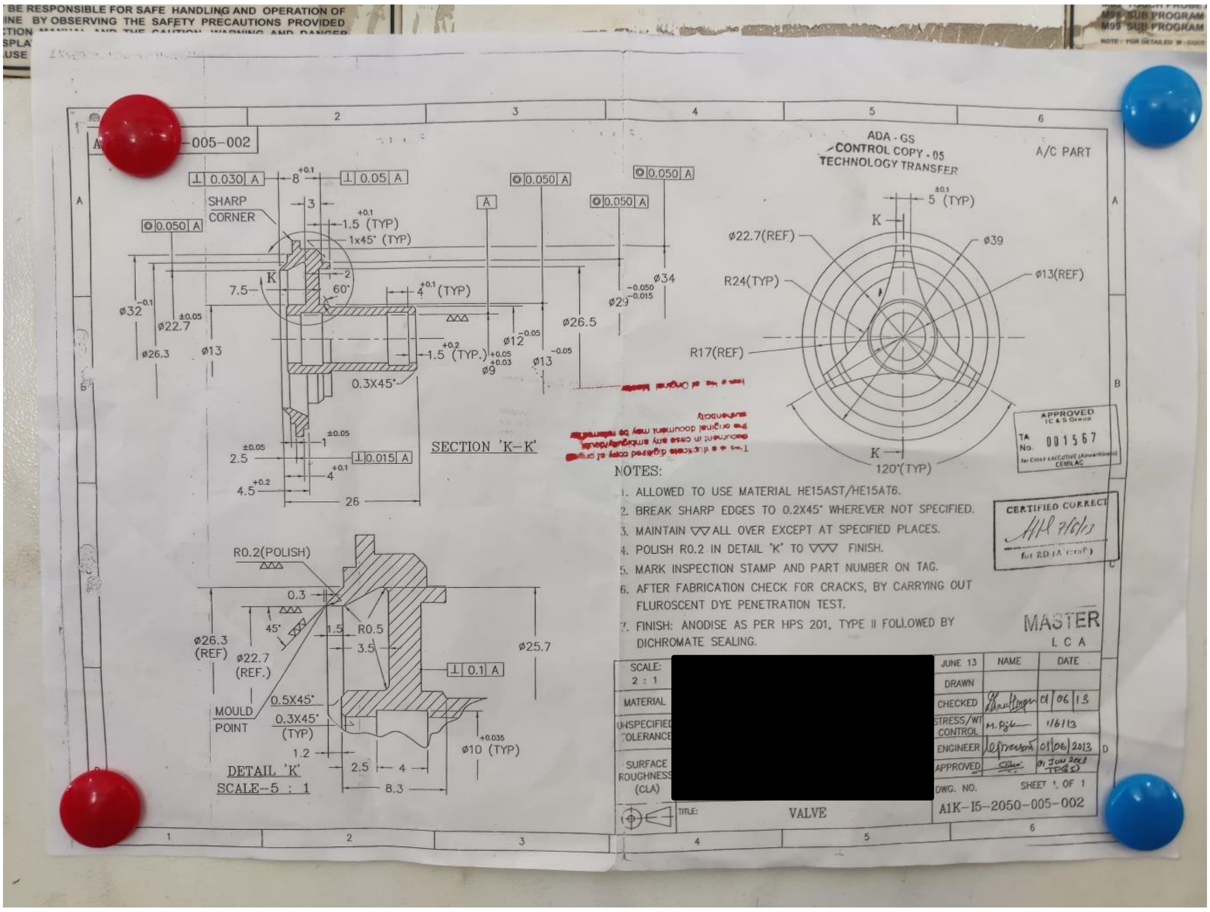


Figure 17: Drawing for component valve

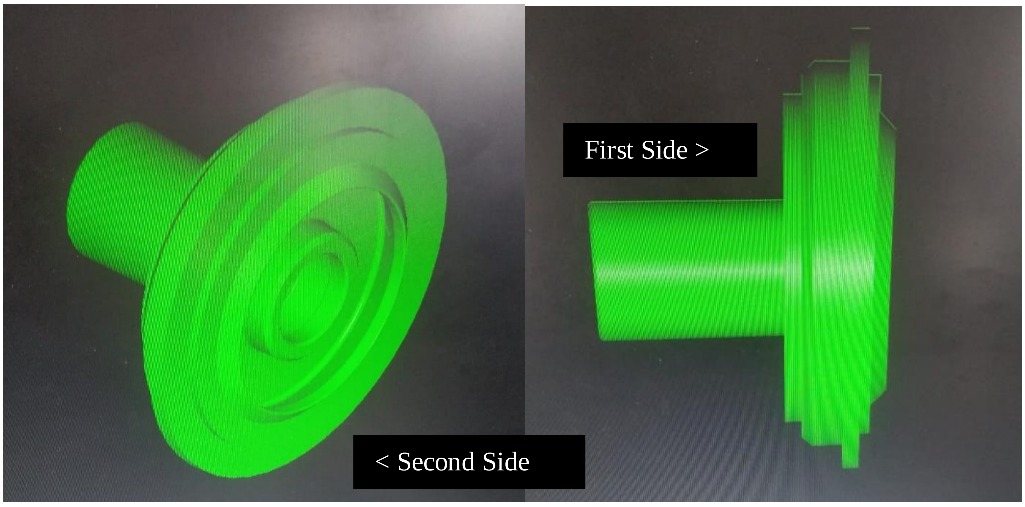


Figure 18: Model of Valve created in Mastercam

3.4.1 TOOLPATHS AND OPERATIONS FOR COMPONENT VALVE

1. Setting 1:
   a. Facing: The operation where the stock is removed from the face of the job. Diametrical surface in x- direction had to be cleaned with a horizontal z depth of 1mm.
   b. Turning: The operation where the stock is removed from the horizontal/diametrical surface along z axis. The turned diameter was 40 mm and total length maintained was 26.5 mm.
   c. Centre Drill: The operation where a small hole is created with minimal depth before drilling a required diameter hole. This hole is created to make sure the 6mm boring bar can be inserted to finish the ID operations in later settings.
   d. Parting: The final operation where the job is separated from the raw material rod. Here groove on the OD is created up till half diameter of the rod and separation occurs. [1]

- **Cycle Time** – Total time to complete the sequence of operations was around 1hr 40 mins for first article inspection (FAI) and 35 mins from the second job.
- **Setting time** – The time used to complete the setup with job and tools along with each of the tools offsets. FAI required 60 mins and 5 mins for the second jobs.
- **Machine time** – The time utilized to complete the machine the job which was around 40 mins for FAI due to feed percentage reductions and 30 mins thereafter.

The following tables and figures show the tool planning, job at this stage and toolpaths.

Table 7: Tool planning setting 1

MACHINE	LMW T1
JOB	Valve setting 01
T1	Roughing CNMG 12 04 04
T2	Centre Drill
T3	Drill 8mm
T4	Parting Penta cut 2.5mm

Figure 19: Raw material to setting 01

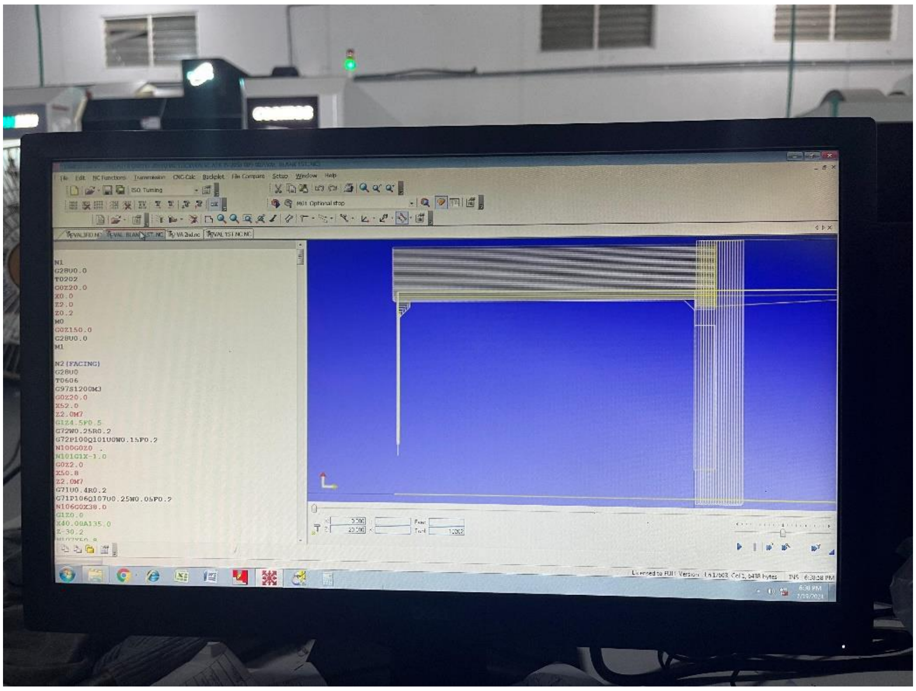


Figure 20: Toolpath in CIMCO for valve setting 01

2. Setting 2:
    a. ID Bore Roughing: The operation where ID bore roughing is made to diameter 9mm. A customised tool was designed to compete this and the following operation.[2]
    b. ID Groove: The centre hole had two grooves 1mm in depth which were completed by the similar tool.
    c. Facing: The operation where the facing for second side is done and total length is made to 26.5 mm whereas the finish size has 26 mm.

- **Cycle time:** Total time for the sequence of operations was 2hrs 30 mins for FAI and 15 mins thereafter.
- **Setup time:** Total setup time for FAI was 120 mins and 3 mins thereafter.
- **Machine time:** Total machine time for FAI was 30 mins and 11 mins thereafter. [5]

The following tables and figures show the tool planning, job at this stage and toolpaths.

Table 8: Tool planning setting 02 valve

MACHINE	LMW T2
JOB	Valve setting 02
T1	Facing CNMG 12 04 04
T2	ID Bore Roughing
T3	ID Bore Grooving

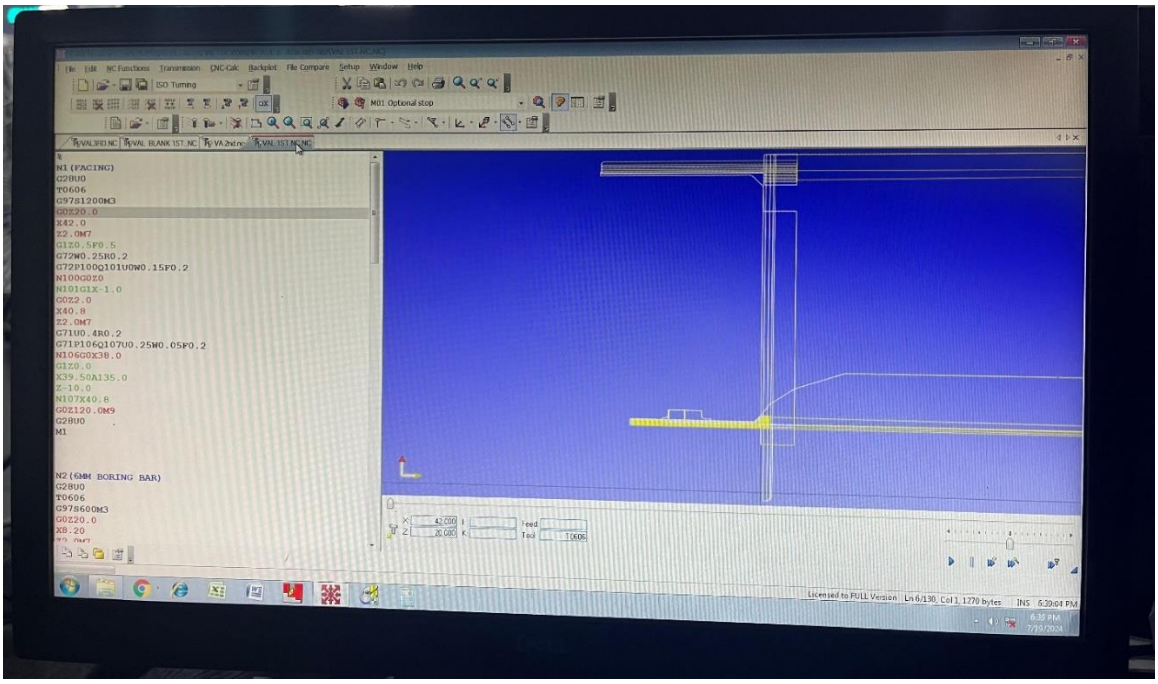


Figure 21: Toolpaths for setting 02 valve

3. Setting 3:
    a. Boring: ID finishing on the second side for the hole and internal groove. The setup had be done in this manner because the ID and OD had concentricity constraint.
    b. Facing: Total length maintenance before we start the next set of operations.
    c. Step turning: OD roughing and maintaining the step on the second side as well as passing a finishing cycle.
    d. Face groove: The operation where you create a groove on the face of the job of required depth. The diameter till which the groove is present is $22.7^{\pm 0.05}$ mm and depth is $5^{+0.1}$ mm. similar tool is used for finishing as well.
    e. Face groove till diameter 25.7 mm: A customized tool with R0.5, length 3mm and at an angle of 45 degrees was made to create the face groove on the second side.

- **Cycle Time:** Total time for the sequence of operations was 1 hr 20 mins for FAI and 18 mins thereafter.
- **Setup Time:** The setup time for FAI was 1hr and then 3 mins afterwards.
- **Machine Time:** Total machine time for FAI was 20 mins and 15 mins thereafter.

The following tables and figures show the tool planning, job at this stage and toolpaths.

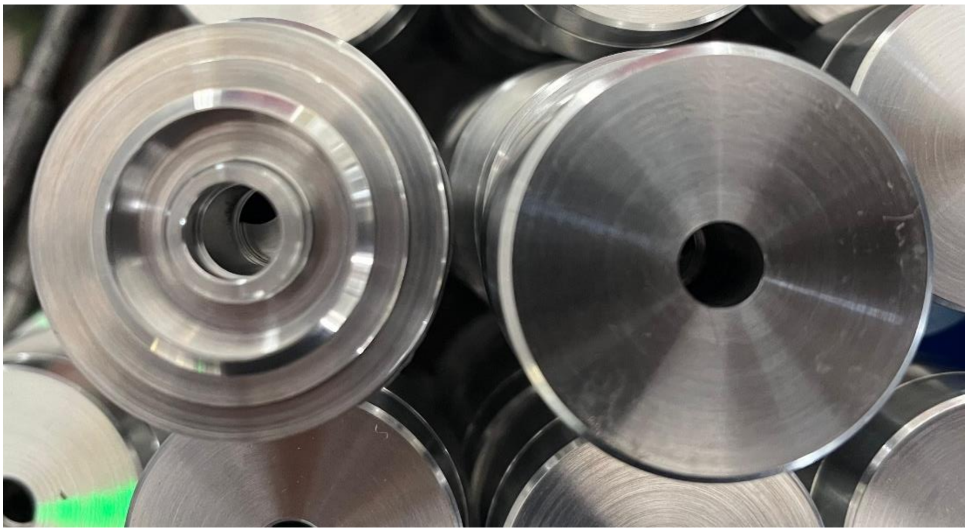


Figure 22: Setting 03 valve

Table 9: Tool planning setting 03 valve

MACHINE	ACE JR
JOB	Valve Setting 03
T1	OD rough CNMG 12 04 04
T2	OD Finish TNMG 16 04 02
T3	ID groove 6mm bore bar
T4	Face groove width 1.5 mm
T5	Face groove (45 degree, R0.5)

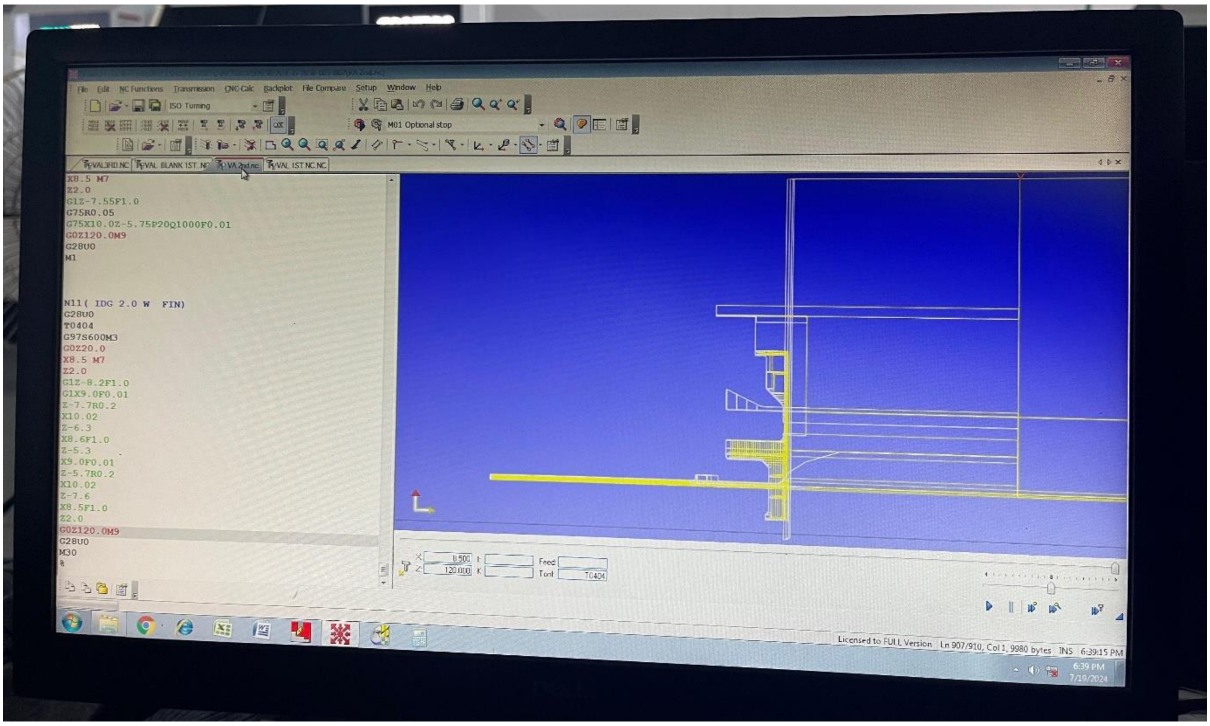


Figure 23: Toolpath for valve setting 03

4. Setting 4:
   a. Turing: OD roughing and finishing on the first side to maintain concentricity. To not to disturb the second side features the mandrel with the same impression is made and the piece is locked in the centre hole. The piece is butted to the mandrel on the flat diameter of $32^{-0.1}$ mm to lock position.
   b. Face groove: A 1.5 $^{+0.1}$ mm deep face groove on the first side till diameter 26.5 mm.
   c. Chamfer: The operation where the curved edges are made flat at a certain angle generally 45 degrees to avoid sharp and brittle edges.

- **Cycle Time:** FAI: 1hr 15 mins, following pieces: 12 mins
- **Setup Time:** FAI: 1hr, following pieces: 4 mins
- **Machine Time:** FAI: 15 mins, following pieces: 8 mins

The following tables and figures show the tool planning, job at this stage and toolpaths.

Table 10: Tool planning for valve setting 04

MACHINE	LMW T1
JOB	Valve setting 04
T1	OD rough CNMG 12 04 04
T2	OD finish TNMG 16 04 02
T3	Face groove 1 mm width

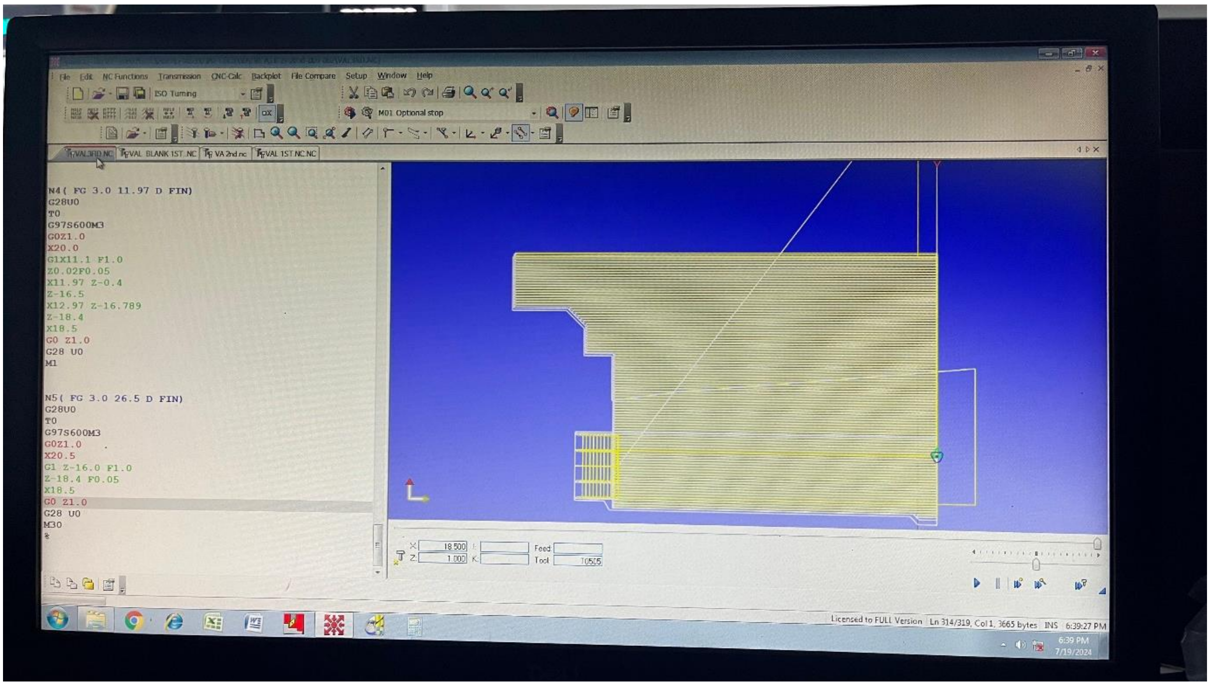


Figure 24: Toolpath for valve setting 04

5. Setting 5: (Milling Operation)
   a. Contour: The milling operation where the curved stock is removed keeping three slots at 120 degrees each with a width of $5^{\pm 0.1}$ mm (TYP) and till the diameter 34 mm. The block fixture with a contour impression of second side is used to butt the job on the vice which in clamped to the machine bed as seen in figure 25.

      Machine: Cosmos 3 axis.

      Job: Valve Setting 5

      T1: 6 End mill. Length 30 mm flute length.

- **Cycle Time:** FAI: 1hr 15mins, Following jobs: 14 mins
- **Setup Time:** FAI: 1hr, Following jobs: 3mins
- **Machine Time:** FAI: 15 mins, Following jobs: 11 mins.

Figure 25: Fixture for valve in milling operation

3.5 CNC MILLING JOB – SYNTH MODULE

The raw material for component synth module is aluminum alloy with the obtained raw material size of 1000mm * 1000mm * 50 This job had be cut to minimal stock size for each piece and loaded on to the machine. The suitable length, width and height with sufficient stock was 285*100*50 mm. The obtained raw material plate was then cut into stock size on the band saw. The total batch quantity to be made was 30 nos. Initially I had to model the job and generate toolpaths in a setting wise manner. Then tool planning for the job in similar manner had be done and necessary fixtures, clamps if needed were to be made. [4]

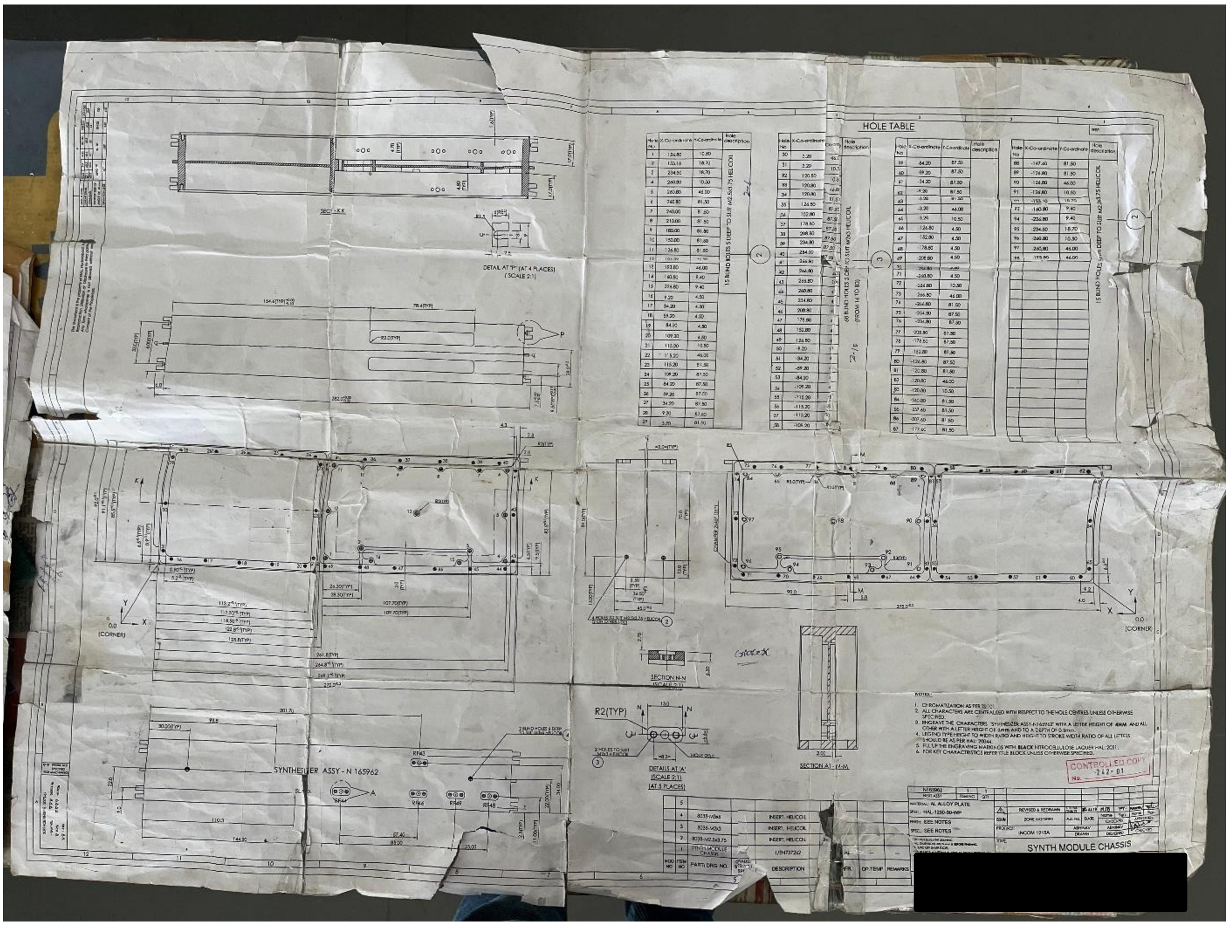


Figure 26: Drawing of Synth Module

The synth module chassis was then modelled in Mastercam software after which toolpath for each setting was generated as seen in figure 27. The job had operations on all the six sides thus a total of six settings were needed for completion. [5]

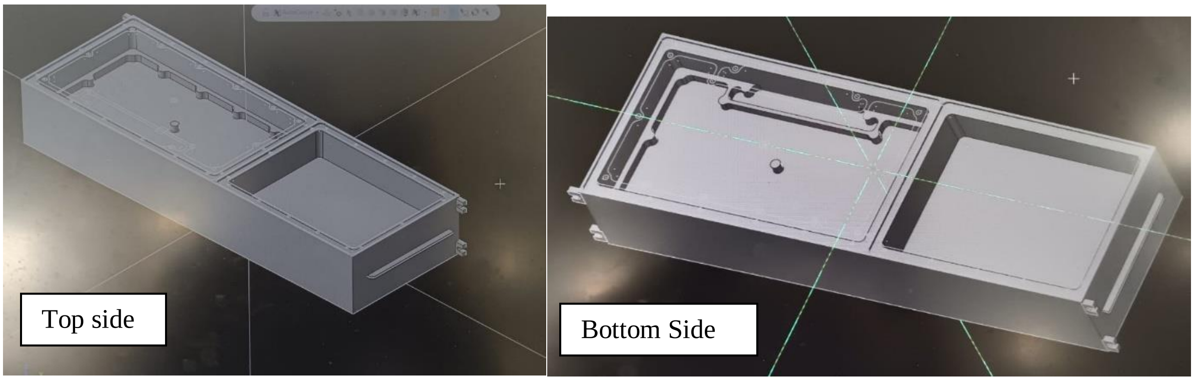


Figure 27: Model of Synth Module chassis

3.5.1 TOOLPATHS AND OPERATIONS FOR COMPONENT SYNTH MODULE

1. Setting 01:
   a. Facing: Removal of stock during the roughing operation from the top face with a help of 12mm carbide end mill.
   b. Contour: Removal of stock from the walls to maintain the width to $92.0^{-0.1}$ mm.
   c. Pocket: Operation where a suitable profile to required stock depth is removed as seen in the figure 27.
   d. Drill: Centre drill Ø1.5mm all the holes on the top plate for M2.5 * 3.75 helicoil. Then similarly for M2*3 helicoil holes.
   e. Pocket: Finish the inner walls of the two pockets with the required corner radius of R3 mm. finishing stock clearance of 0.15 to 0.2 mm on both wall and floor. [1]

The following tables and figures show the tool planning, job at this stage and toolpaths.

Figure 28: Synth Module raw material to setting 01

Table 11: Tool planning for synth module 1st setting

MACHINE	COSMOS 3axis
JOB	Synth Module 1st setting
T1	Ø12mm carbide end mill
T2	Ø10mm carbide end mill
T3	Ø6mm carbide end mill
T4	Ø4mm carbide end mill
T5	Centre Drill
T6	Ø2.6mm carbide drill
T7	Ø2.1mm carbide drill

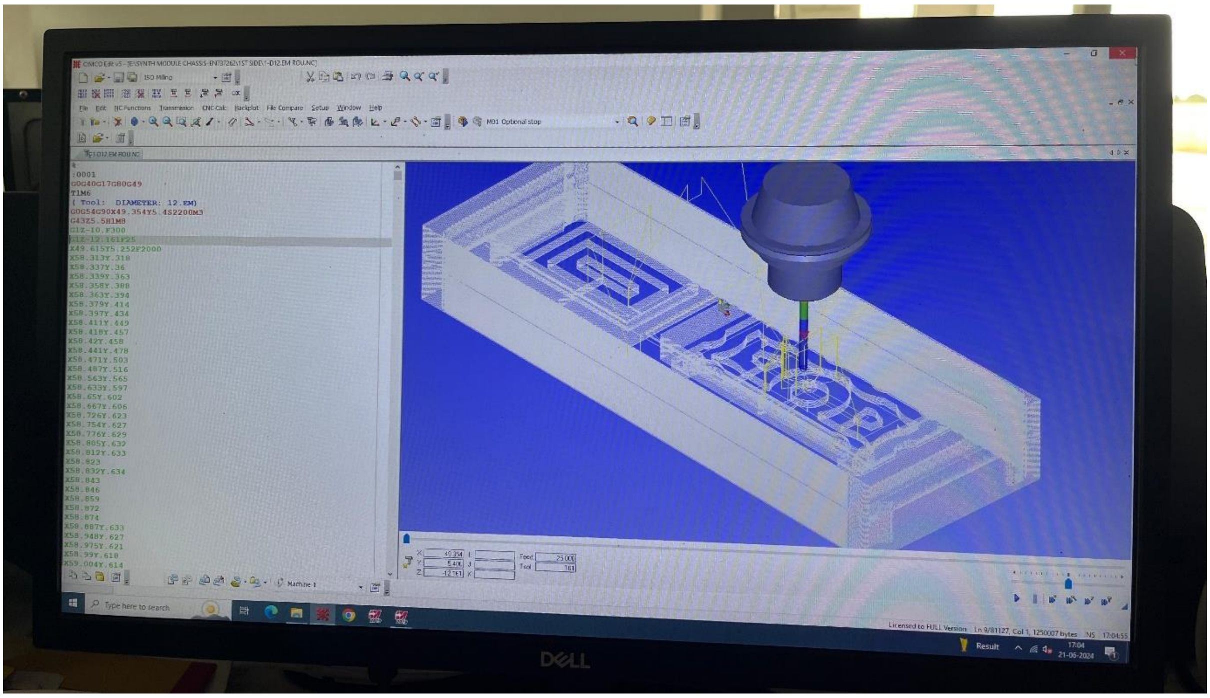


Figure 29: Tool path for Setting 01

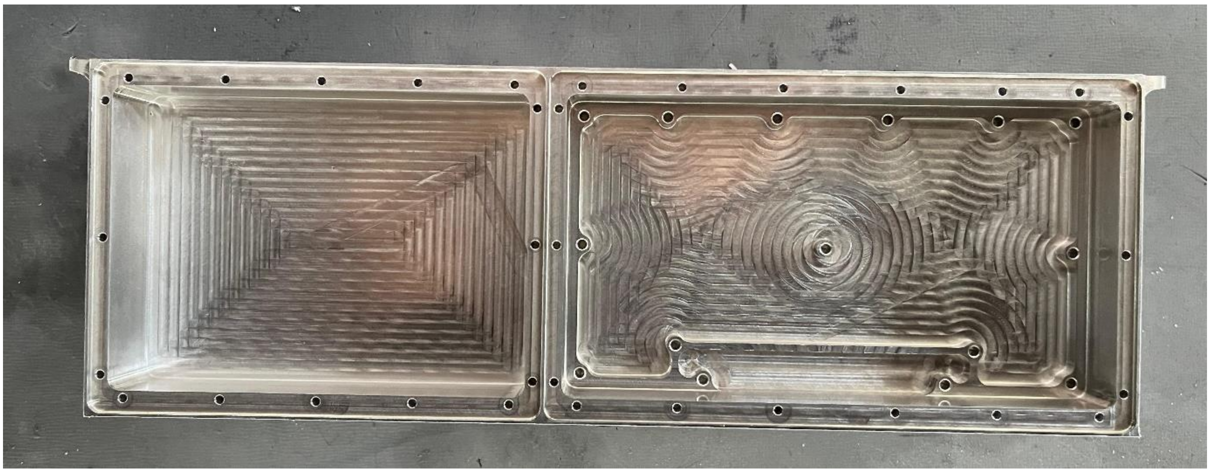


Figure 30: Synth Module 1st setting completion

2. Setting 02:
    a. Facing: The bottom face stock needs to be faced to complete the second setting operations.
    b. Contour: The operation to remove the stock on the wall of the job on the second side.
    c. Pocket: The removal of material within the body for create the form according to the drawing with R3 corner radius and holes.
    d. Drill: Centre drill Ø1.5mm all the holes on the top plate for M2.5 * 3.75 helicoil. Then similarly for M2*3 helicoil holes. [2][5]

The following tables and figures show the tool planning, job at this stage and toolpaths.

Table 12: Tool planning for synth module 2nd setting

MACHINE	COSMOS 5axis
JOB	Synth Module 2nd setting
T1	Ø50 mm 25 flute length cutter
T2	Ø12mm End Mill
T3	Ø6 End Mill
T4	Ø4 End Mill
T5	Centre drill
T6	Ø2.6mm carbide drill
T7	Ø2.1 Carbide drill

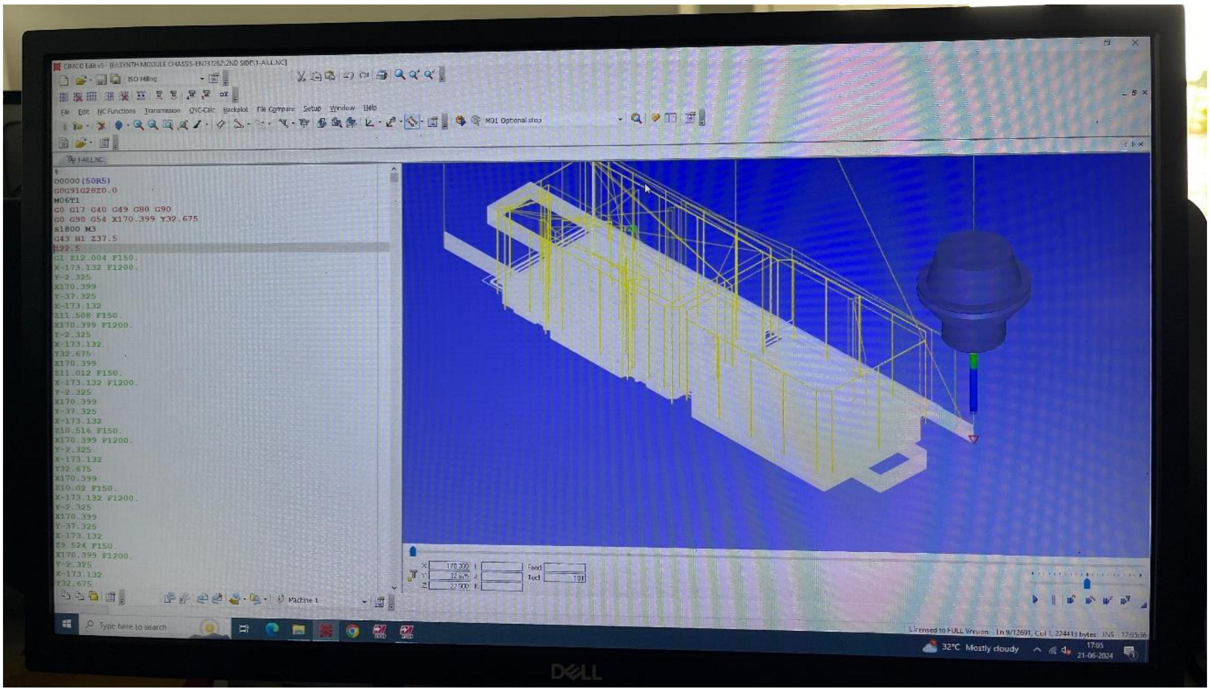


Figure 31: Toolpath for setting 02 synth module

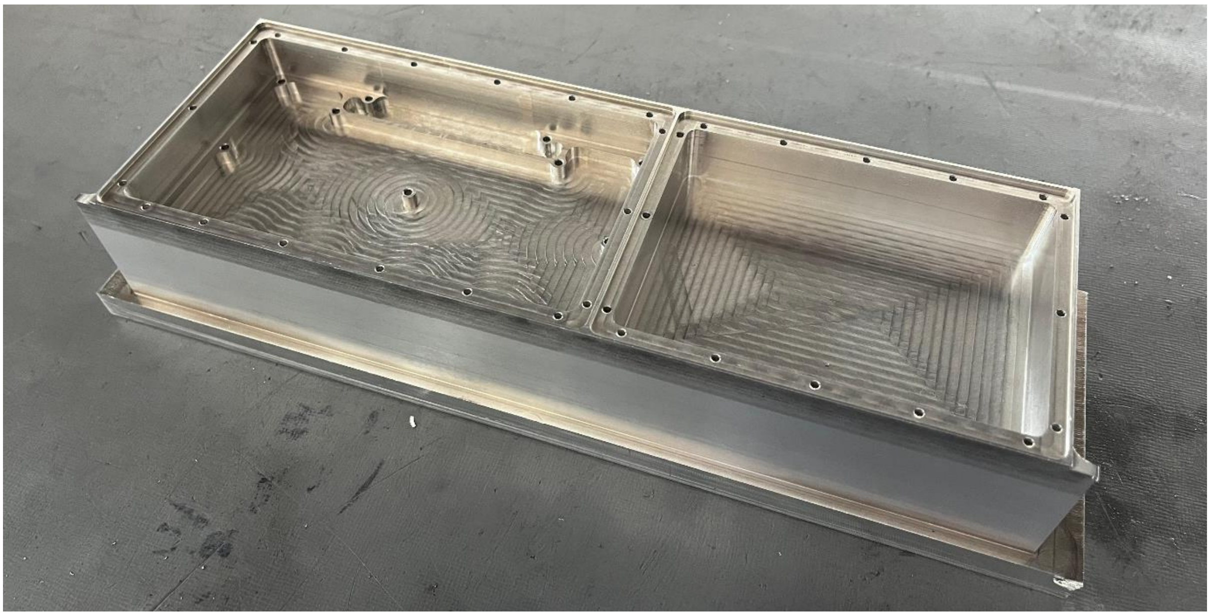


Figure 32: Synth Module job after setting 02

3. Setting 03:
   a. Contour: This operation is used to remove the top right faces finishing stock of the job with the help of 6mm end mill.[5]
   b. Drill: The operation is used to drill 2.6mm helicoil holes on the face.

Table 13: Tool planning for setting 03 synth module

MACHINE	COSMOS 3axis
JOB	Synth Module 3rd Setting
T1	Ø8mm End Mill
T2	Ø6mm End Mill
T3	Centre drill
T4	Ø2.6 mm drill

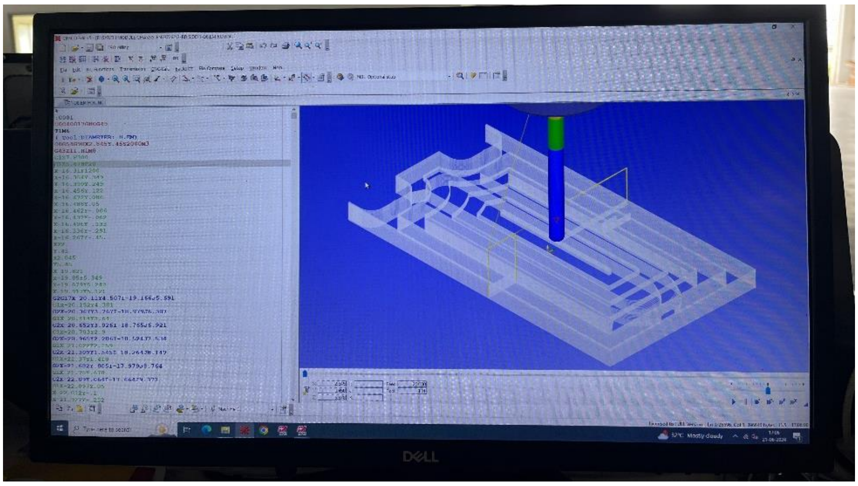


Figure 33: Toolpath for setting 03 synth module

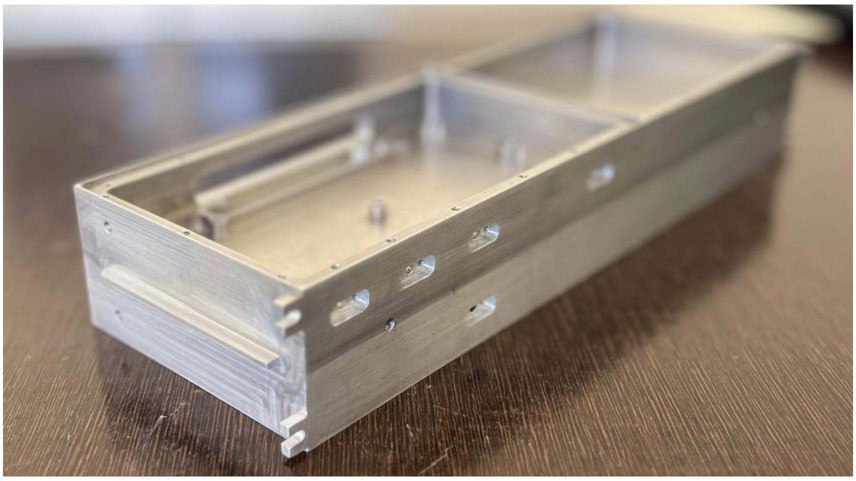


Figure 34: Synth Module after job completion

4. Setting 04:
   a. Contour: This operation is used to remove the top right faces finishing stock of the job with the help of 6mm end mill.
   b. Drill: The operation is used to drill 2.6mm helicoil holes on the face.

   (Similar to third setting, this is added advantage to the objective needed to be attained)

5. Setting 05:
   a. Centre drill: To create the interpolation point for the drill that is the sequenced operation.
   b. Slot: To create 4 slots of R3 corner radius at the required pitches from top face.
   c. Drill: To drill three holes of Ø2.1 mm in the slots which open on the inner pockets.

   The following tables and figures show the tool planning, job at this stage and toolpaths.

Table 14: Tool planning for synth module 5th setting

MACHINE	COSMOS 3axis
JOB	Synth Module 5^{th} Setting
T1	Centre drill
T2	Ø3mm End mill
T3	Ø2mm End Mill
T4	Ø2.1 Drill

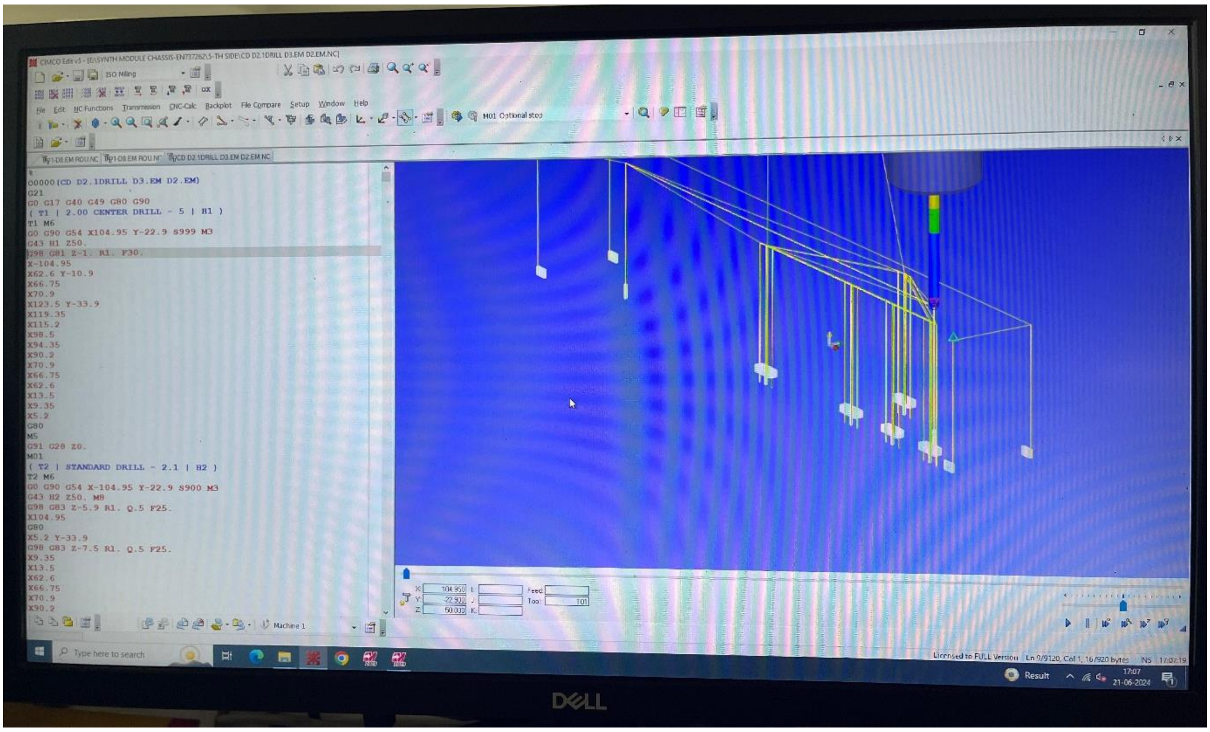


Figure 35: Toolpaths for 5th setting synth module

Figure 36: Synth module after setting 05

6. Setting 06:
    a. Centre drill: To create the interpolation point for the drill that is the sequenced operation.
    b. Slot: To create 2 slots of R2 corner radius at the required pitches from top face and a total length of 78.4 mm.

Table 15: Tool planning for synth module 6th setting

MACHINE	COSMOS 5axis
JOB	Synth Module 6th Setting
T1	Centre drill
T2	Ø3mm End mill
T3	Ø2mm End Mill

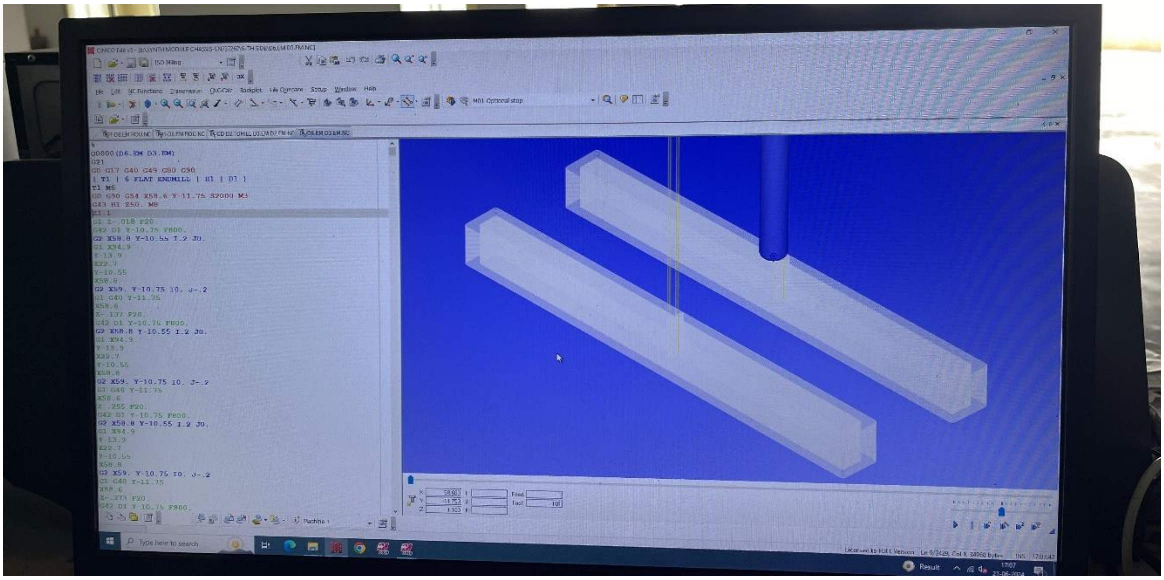


Figure 37: Toolpath for synth module setting 06

Figure 38: Synth module after setting 06.

3.6 CNC EDM JOB – LOCKWASHER

The raw material for component lock washer with the obtained raw material size of 100*50*0.8. The suitable length, width and height to finish size was cut according to profile. The total batch quantity to be made was 575 nos. Initially I had to model the job and generate toolpaths in a setting manner as well as prepare the fixtures and clamps for the same. [4]

The brass wire was suggested to cut the stainless steel material. The parameter for this-

Table 16: EDM lock washer parameter

Input voltage	32 volts
Output Voltage	35 volts
Current IP	3 amps
Roller RPM	80 rpm
Sensitivity	50
Gap voltage	50

The following tables and figures show the tool planning, job at this stage and toolpaths.

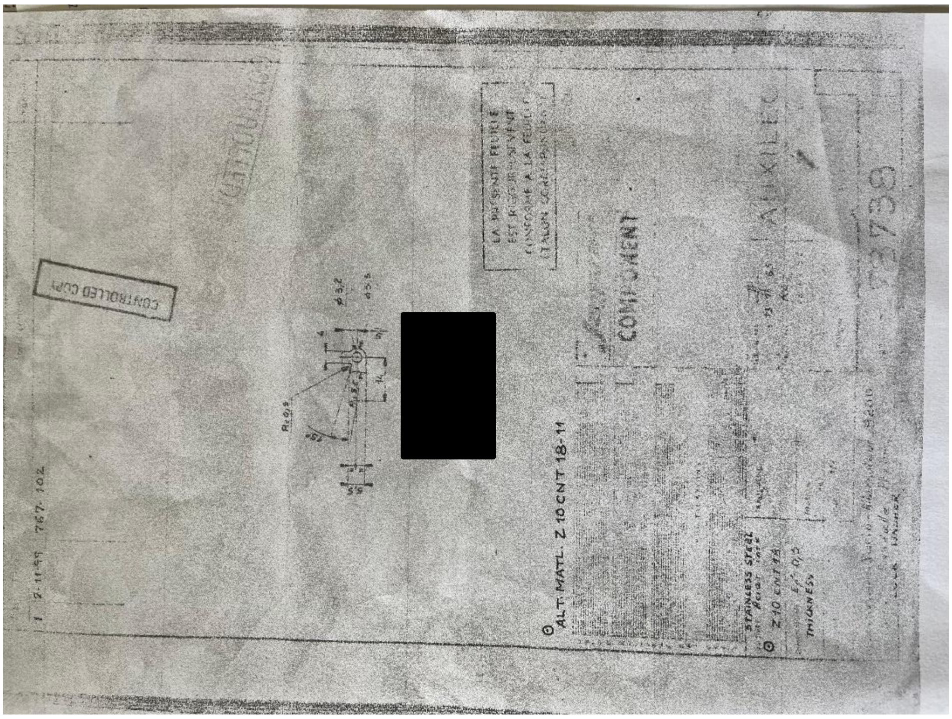


Figure 39: Drawing of lock washer [3]

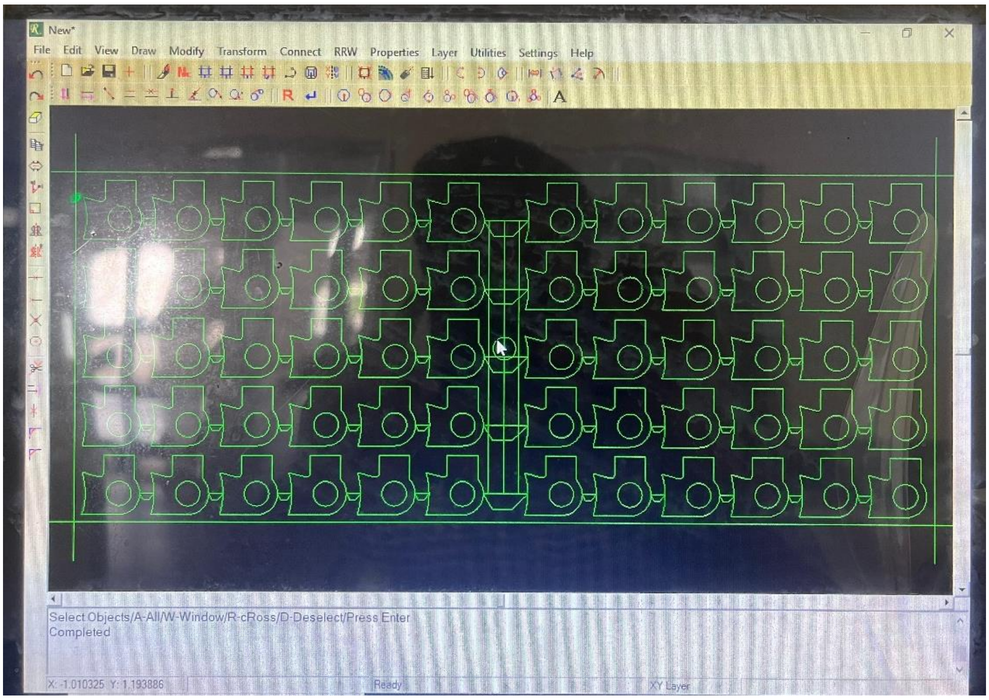


Figure 40: Model of Lock Washers in RRCAD

(Each sheet comprised of 60 pieces of lock washers)

Figure 41: Setting for job lock washer

Initially the wire has to pass through the cavity and then the wire should be vertical with respect to job in both X and Y axis. Then the wire break sensor has to be turned on along with the coolant and the cycle can start. The final cut pieces are collected in the sponge which is placed on the bed.

PTO for Results.

CHAPTER 4
RESULT ANALYSIS

4.1 NC CODE AND INSPECTION – VALVE

Table 17: FAI Valve

	FIRST ARTICLE INSPECTION REPORT								Drawing no: A1K-15-2050-005-002			
DESCRIPTION: VALVE									Date: 01/06/2024 – Shift Day			
M/C	OPERATOR NAME	PRODUCT DESCRIPTION	TOTAL QTY	PROCESS NAME	SETUP TIME (MIN)	M/C TIME (MIN)	TOTAL CYCLE TIME (MIN)	TOTAL PRODUCTION HOURS	OK MATERIAL QTY	RE-WORK	REJECT	REMARKS
T1	Pranav	Valve (setting 01)	1	OD CD	60	40	100	1hr 40mins	1	-	-	Stock dia 40 mm
				DRILL PARTING								
T2	Pranav	Valve (setting 02)	1	ID BORE ID GROOVE FACING	120	30	150	2hr 30mins	1	-	-	Groove depth 1mm
T3	Pranav	Valve (setting 03)	1	ID FINISH OD TURN	60	20	80	1hr 20mins	1	-	-	
				FACE GROOVE FACE GROOVE 2								2nd groove R0.5
T4	Pranav	Valve (setting 04)	1	OD TURN FACE GROOVE CHAMFER	60	15	75	1hr 15mins	1	-	-	Maintain OD diameter
M3	Pranav	Valve (setting 05)	1	Contour (slots)	60	15	75	1hr 15mins	1	-	-	Till dia 34mm
TOTAL PRODUCTION HOURS FOR COMPLETION: 8hrs EXPECTED DATE OF COMPLETION: 02/06/2024												
BREAKDOWN DETAILS & TIME IF ANY:												
AUTHORISED BY: Jamshid Sk												

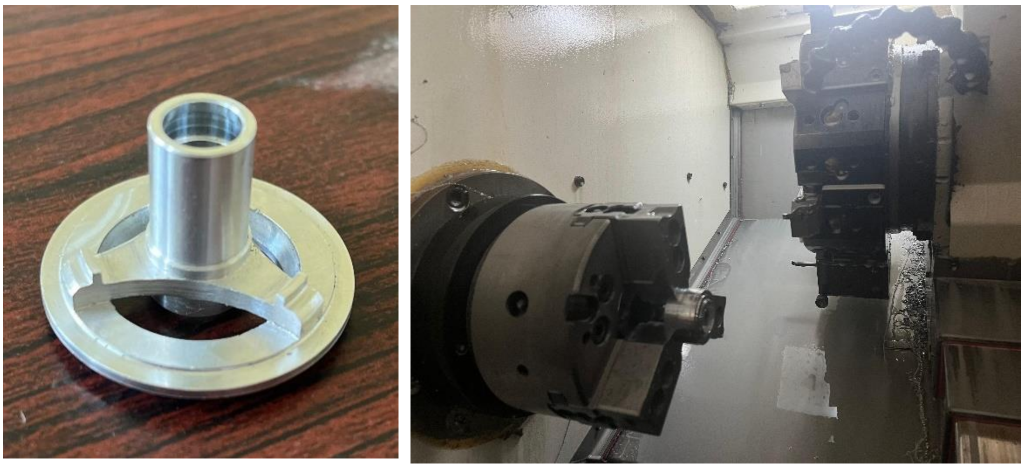


Figure 42: Final Valve component [4]

Table 18: Production report Valve

MACHINE SHOP PRODUCTION REPORT									Drawing no: A1K-15-2050-005-002			
DESCRIPTION: VALVE									Date: 01/06/2024 – Shift Day			
M/C	OPERATOR NAME	PRODUCT DESCRIPTION	TOTAL QTY	PROCESS NAME	SETUP TIME (MIN)	M/C TIME (MIN)	TOTAL CYCLE TIME (MIN)	TOTAL PRODUCTION HOURS (QTY)	OK MATERIAL QTY	RE-WORK	REJECT	REMARKS
T1	Pranav	Valve (setting 01)	150	OD CD	5	30	35	87.5	150	-	-	Stock dia 40 mm
				DRILL PARTING								
T2	Pranav	Valve (setting 02)	150	ID BORE ID GROOVE FACING	3	11	14	35	150	-	-	Groove depth 1mm
T3	Pranav	Valve (setting 03)	150	ID FINISH OD TURN	3	15	18	45	150	-	-	
				FACE GROOVE FACE GROOVE 2								2nd groove R0.5
T4	Pranav	Valve (setting 04)	150	OD TURN FACE GROOVE CHAMFER	4	8	12	30	150	-	-	Maintain OD diameter
M3	Pranav	Valve (setting 05)	150	Contour (slots)	3	11	14	35	150	-	-	Till dia 34mm
TOTAL PRODUCTION HOURS FOR COMPLETION: 232.5 HRS EXPECTED DATE OF COMPLETION: 12/06/2024												
BREAKDOWN DETAILS & TIME IF ANY:												
AUTHORISED BY: Jamshid SK												

Table 19: QC report valve

BALAJI CNC TECHNOLOGIES

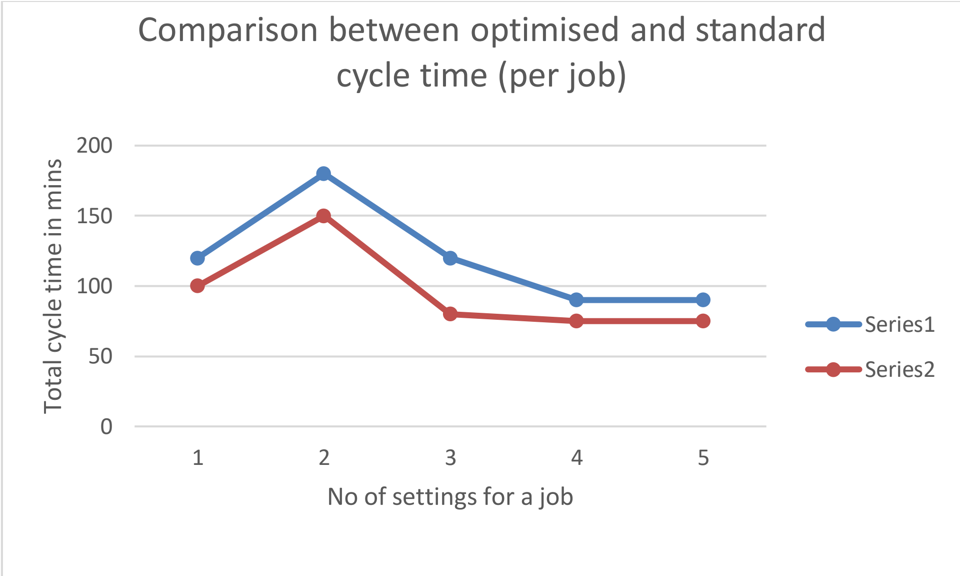
QC INSPECTION REPORT

PART NAME: Valve **UNIT 1**

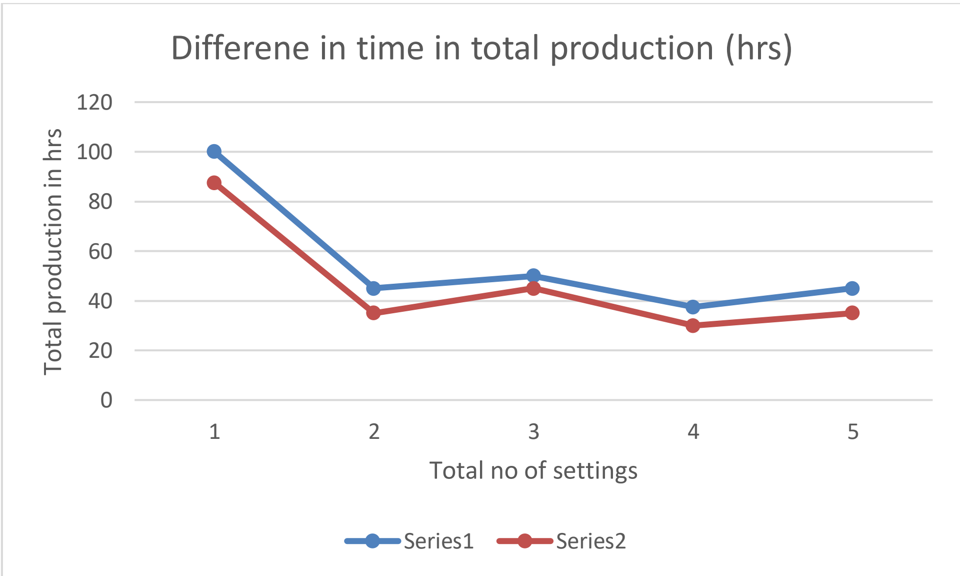
CUSTOMER NAME: **UNIT 2**

SI NO	DRAWING DIMENSION	MEASURED DIMENSION							
		1	2	3	4	5	6	7	8
1	$5^{\pm0.1}$ (TYP)	5.06							
2	$4.5^{+0.2}$	4.65							
3	R24(TYP)	Ok							
4	$26^{\pm0.01}$	26.005							

Link for NC File: TURNING[3]



The difference seen was 120 mins which is 20% reduction compared to the normal standard process. Inculcating the combinational fixtures, higher grade tooling and providing more intermediate inspections helped in attaining the least cycle time.



The difference in the total production in hrs was 45 hrs thus saving us two days which could be utilised in fast tracking the other operations or move ahead with other jobs.

4.2 NC CODE AND INSPECTION – SYNTH MODULE

Table 20: FAI Synth Module

	FIRST ARTICLE INSPECTION REPORT								Drawing no: EN737262			
DESCRIPTION: SYNTH MODULE									Date: 8/06/2024 – Day shift			
M/C	OPERATOR NAME	PRODUCT DESCRIPTION	TOTAL QTY	PROCESS NAME	SETUP TIME (MIN)	M/C TIME (MIN)	TOTAL CYCLE TIME (MIN)	TOTAL PRODUCTION HOURS	OK MATERIAL QTY	RE-WORK	REJECT	REMARKS
M1	Pranav	Synth Module	1	Facing Contour Drill, Pocket	120	360	480	8hrs	1	-	-	Check hole pitch
M2	Pranav	Synth Module	1	Facing Contour Drill, Pocket	120	300	420	7hrs	1	-	-	Check hole pitch
M1	Pranav	Synth Module	1	Finish, contour, drill	60	60	120	2hrs	1	-	-	Check the extrudes
M2	Pranav	Synth Module	1	Finish, contour, drill	60	60	120	2hrs	1	-	-	Check the extrudes
M1	Pranav	Synth Module	1	Drill, Slots	30	60	90	1hr 30min	1	-	-	Check Hole depth
M2	Pranav	Synth Module	1	Slots	40	40	80	1hr 20min	1	-	-	
TOTAL PRODUCTION HOURS FOR COMPLETION: 21hrs 50mins EXPECTED DATE OF COMPLETION: 11/06/2024												
BREAKDOWN DETAILS & TIME IF ANY:												
AUTHORISED BY: Sai Krishna												

Figure 43: Synth Module during machining [3]

Table 21: Production sheet report

		MACHINE SHOP PRODUCTION REPORT							Drawing no: EN737262			
DESCRIPTION: Synth Module									Date: 08/06/2024 – Day Shift			
M/C	OPERATOR NAME	PRODUCT DESCRIPTION	TOTAL QTY	PROCESS NAME	SETUP TIME (MIN)	M/C TIME (MIN)	TOTAL CYCLE TIME (MIN)	TOTAL PRODUCTION HOURS	OK MATERIAL QTY	RE-WORK	REJECT	REMARKS
M1	Pranav	Synth Module	30	Facing Contour Drill, Pocket	60	300	360	180hrs	30	-	-	Check hole pitch
M2	Pranav	Synth Module	30	Facing Contour Drill, Pocket	30	210	240	120hrs	30	-	-	Check hole pitch
M1	Pranav	Synth Module	30	Finish, contour, drill	25	35	60	30hrs	30	-	-	Check the extrudes
M2	Pranav	Synth Module	30	Finish, contour, drill	30	30	60	30hrs	30	-	-	Check the extrudes
M1	Pranav	Synth Module	30	Drill, Slots	30	40	70	35hrs	30	-	-	Check Hole depth
M2	Pranav	Synth Module	30	Slots	30	40	70	35hrs	30	-	-	
TOTAL PRODUCTION HOURS FOR COMPLETION: 430hrs EXPECTED DATE OF COMPLETION: 26/06/2024												
BREAKDOWN DETAILS & TIME IF ANY:												
AUTHORISED BY: **Sai Krishna**												

Table 22: Synth Module QC Inspection report

BALAJI CNC TECHNOLOGIES

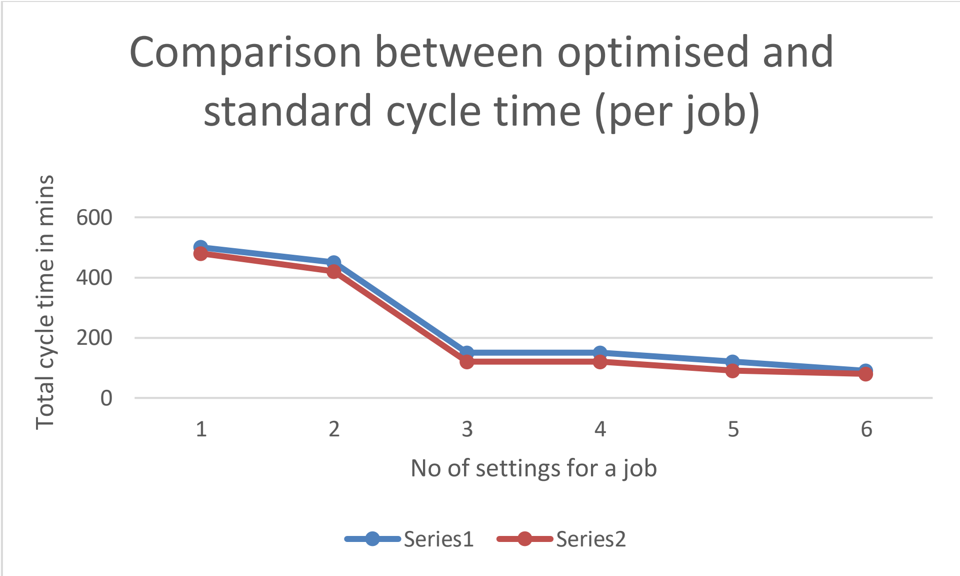
QC INSPECTION REPORT

PART NAME: Synth Module **UNIT 1** ☐

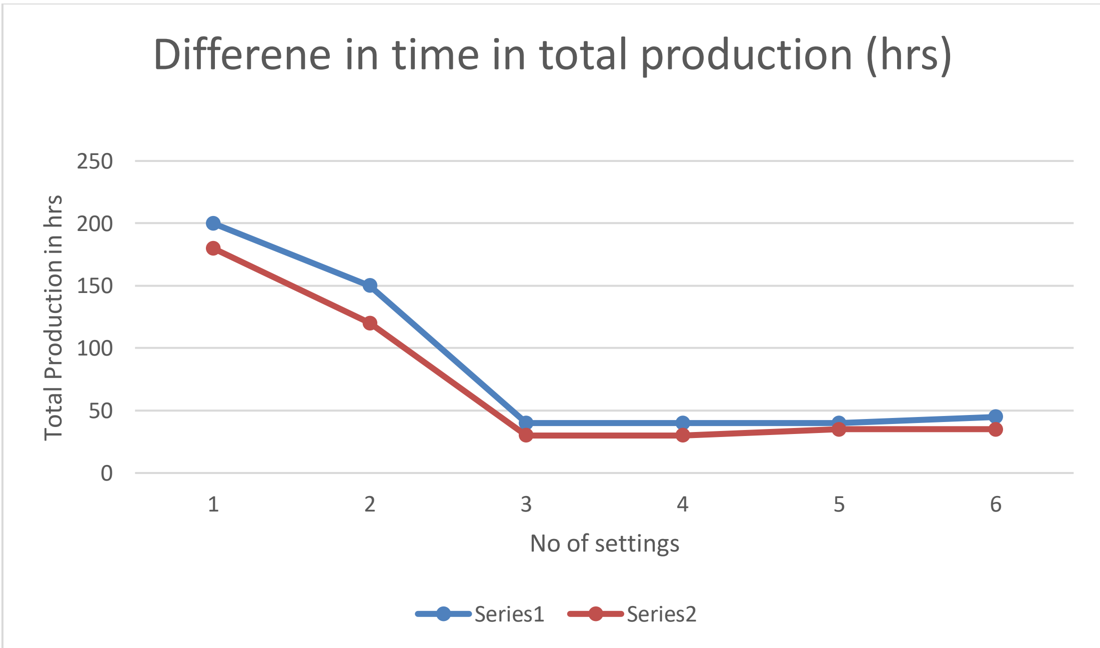
CUSTOMER NAME: **UNIT 2** ■

SI NO	DRAWING DIMENSION	MEASURED DIMENSION							
		1	2	3	4	5	6	7	8
1	92-0.1	92.95							
2	6.5-0.1	6.42							
3	112.8-0.1	112.78							
4	109.2	109.2							
5	2.5 Go Gauge	Ok							
6	Thickness 1	0.91							
7	70 (TYP)	70.04							
8	diameter 2.6 for M2.5	2.6							

Link for NC CODE: MILLING [3]



The difference seen was 150 mins which is 10% reduction compared to the normal standard process. Inculcating the combinational fixtures, higher grade tooling and providing more intermediate inspections helped in attaining the least cycle time.



The difference in the total production in hrs was 75 hrs thus saving us three days which could be utilised in fast tracking the other operations or move ahead with other jobs.

4.3 NC CODE AND INSPECTION – LOCK WASHER

Lock Washer was earlier done in milling and it required 14 hrs to complete 60 jobs whereas in EDM wire cut the same process finished in 5-6 hrs maximizing efficiency and productivity.

Table 23: FAI and Production Report

		MACHINE SHOP PRODUCTION REPORT							Drawing no: 78738				
DESCRIPTION: LOCK WASHER									Date: 14/06/2024 – Day Shift				
M/C	OPERATOR NAME	PRODUCT DESCRIPTION	TOTAL QTY	PROCESS NAME	SETUP TIME (MIN)	M/C TIME (MIN)	TOTAL CYCLE TIME (MIN)	TOTAL PRODUCTION HOURS	OK MATERIAL QTY	RE-WORK	REJECT	REMARKS
1	Pranav	Lock washer	60	WIRECUT	60	300	360	6hrs	55	-	5	Bending of plate
		Lock Washer	540	WIRECUT	15	300	315	47.5hrs	-	-	-	-
TOTAL PRODUCTION HOURS FOR COMPLETION: 54hrs EXPECTED DATE OF COMPLETION: 20/06/2024													
BREAKDOWN DETAILS & TIME IF ANY:													
AUTHORISED BY: Sai Krishna													

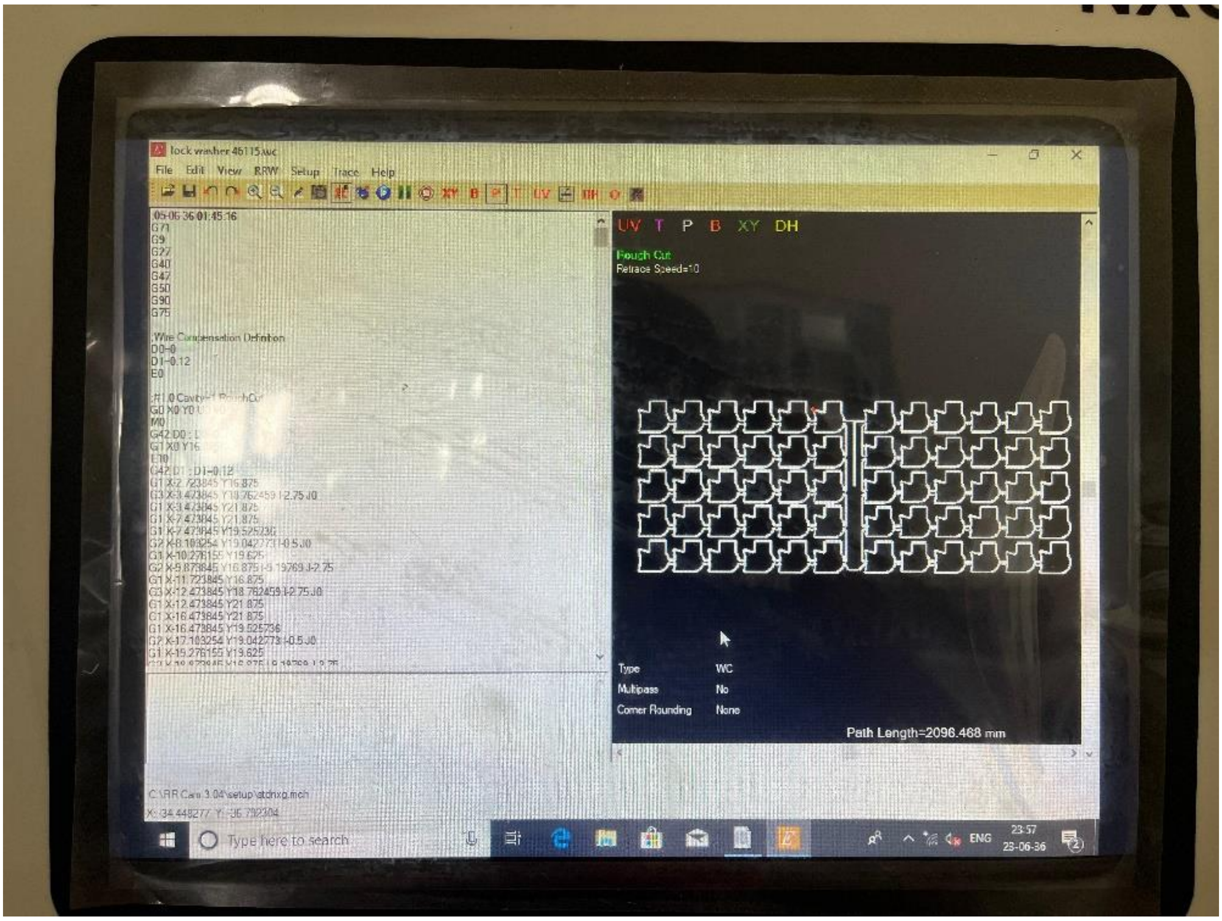


Figure 44: NC Program Lock Washer


Figure 45: Lock Washer job [4]

CHAPTER 5
CONCLUSION AND FUTURE SCOPE OF WORK

5.1 WORK CONCLUSION

In conclusion, the 8th semester project provided a comprehensive exploration into Design, Development and Inspection of Metallic Components encompassing significant theoretical and practical aspects that are crucial in today's industrial and technological landscape. The objectives set at the beginning of the project were successfully met, demonstrating the project's alignment with contemporary needs and advancements.

Throughout the course of this project, we adopted a structured methodology that included thorough research, meticulous planning, and systematic implementation. This approach ensured that the project not only achieved its goals but also maintained a high standard of quality and reliability. The use of advanced tools and technologies, such as CNC, Mastercam, Inspection machines was instrumental in enhancing the efficiency and accuracy of our work.

The results obtained from this project were well within the tolerance range, providing valuable insights and practical solutions to setting of job works, designing and input suitable parameters to different materials with its respective tools and cutters. These results underscored the importance of fits, finish, and assemblies which have significant implications for future research and development in this field.

The successful completion of this project underscores the importance of quality control, precision, and innovation in engineering and manufacturing. It also highlights the collaborative efforts and support received from various individuals and departments. The experience and knowledge gained from this project have been invaluable, preparing us for future professional challenges and endeavors.

This project has been a vital learning experience, bridging the gap between academic knowledge and practical application. It has laid a strong foundation for further exploration and development in the field of mechanical engineering, contributing to the advancement of technology and industry.

5.2 FUTURE SCOPE OF WORK

In my tenure ahead I will taking part in learning the major quality control equipment Coordinate Measuring Machine (CMM), and CNC bending machines as well as be a part of the research and development team. Another set of strategies and process optimization techniques to streamline the production cycle.

Innovations in additive manufacturing (3D printing) combined with CNC machining will enable more complex and precise part production. Enhanced automation and robotics will streamline operations and reduce human error. Additionally, advancements in materials science will allow CNC machines to work with a broader range of materials, improving durability and performance. Sustainability efforts will focus on reducing waste and energy consumption, making CNC machining more environmentally friendly.

Figure 46: CMM

CHAPTER 6
HEALTH, SAFETY, RISK AND ENVIRONMENT ASPECTS

For the vendors to be applicable to these jobs, they require certain certifications which then make them eligible to the job tender. BCT was an ISO 45001:2015 certified so the following measures were necessary on the production floor and for employees:

Health and Safety:

1. **Personal Protective Equipment (PPE)**: Ensure employees wear appropriate PPE such as safety goggles, ear protection, gloves, and steel-toed boots to prevent injuries from flying debris, loud noises, and heavy equipment.
2. **Machine Safeguards**: Install proper machine guards on all CNC machines to protect operators from moving parts, sharp tools, and other hazards.
3. **Training**: Provide comprehensive training on machine operation, emergency procedures, and first aid to all employees.
4. **Ergonomics**: Design workstations to reduce strain and prevent repetitive stress injuries, ensuring operators maintain good posture and minimize physical strain.
5. **Ventilation**: Ensure adequate ventilation to remove dust, fumes, and other airborne contaminants, protecting workers' respiratory health.

Risk Management:

1. **Regular Maintenance**: Conduct routine maintenance and inspections of CNC machines to prevent breakdowns and accidents.
2. **Emergency Preparedness**: Develop and regularly update emergency response plans, including fire drills and evacuation procedures.
3. **Hazard Identification**: Continuously monitor the workplace for potential hazards and implement corrective actions to mitigate risks.
4. **Accident Reporting**: Establish a system for reporting and investigating accidents and near-misses to improve safety measures and prevent future incidents.
5. **Compliance**: Ensure compliance with occupational health and safety regulations and standards, such as ISO in the INDIA or similar regulations in other countries.

Environmental Aspects:

1. **Waste Management**: Implement waste reduction strategies, such as recycling metal scrap/chips and using environmentally friendly coolants and lubricants.
2. **Energy Efficiency**: Invest in energy-efficient machinery and practices to reduce energy consumption and lower the carbon footprint.
3. **Pollution Control**: Use filtration and extraction systems to minimize emissions of pollutants and particulates into the environment.
4. **Resource Management**: Optimize the use of raw materials to reduce waste and promote sustainable manufacturing practices.
5. **Environmental Compliance**: Adhere to environmental regulations and standards to minimize the environmental impact of manufacturing activities.

By prioritizing health, safety, risk management, and environmental protection, a CNC manufacturing firm can ensure a safer workplace, reduce operational risks, and contribute to sustainable manufacturing practices.

REFERENCES

[1] Kyocera Cutting tool reference catalog

[2] Programming on-site and autodesk textbook

[3] Fanuc controller- fanuc manual

[4] Drawings (GD&T) – Mc Graw Hill by Henzold for GD&T

[5] MASTERCAM MANUAL PDF

[6] https://techqualitypedia.com/process-flow-chart-in-manufacturing/

ANNEXURE

Annexure 1
PO &PSO Mapping

Student Name: THAKUR PRANAV GOPAL SINGH
Register no: 200909426

Note: use a tick mark if you have addressed that PO in your report

PO	✓ Tick	Pg. No	Section No	Guides Observation
PO1	✓	3	1.3	
PO2	✓	18	3.2	
PO3	✓	35	4.1	
PO4	✓	36	4.1	
PO5	✓	7	2.1.1	
PO6	✓	42	6	
PO7	✓	42	6	
PO8				
PO9	✓	41	5.2	
PO10	✓	37	4.2	
PO11	✓	5	1.4.1	
PO12	✓	41	5.2	

PSO	✓ Tick	Pg. No	Section No	Guides Observation
PSO1	✓	25	3.3	
PSO2	✓	18	3.2	
PSO3				
PSO4	✓	32	3.4	
PSO5				
PSO6	✓	4	1.4	
PSO7				

Pranav Thakur

26/06/2024
Date and signature of Student: Name and Signature of Guide:

Annexure 2
LO Mapping

Student Name: THAKUR PRANAV GOPAL SINGH
Register no: 200909426

Note: use a tick mark if you have addressed that LO in your report

Sl No	LO	✓ Tick	Pg. No	Section No	Guides Observation
1	C1.	✓	10	2.2.3	
2	C2.				
3	C3.	✓	18	3.2	
4	C4.				
5	C5.	✓	25	3.3	
6	C6.	✓	35	4.1	
7	C7.	✓	42	6	
8	C8.				
9	C9.	✓	42	6	
10	C10.				
11	C11.				
12	C12.	✓	35	4.1	
13	C13.	✓	32	3.4	
14	C14.	✓	13	2.4	
15	C15.				
16	C16.	✓	18	3.2	
17	C17.	✓	16	3.1	
18	C18.	✓	1	1.1	

Pranav Thakur

26/06/2024
Date Signature of Student: Name and Signature of Guide:

Annexure 3

Mapping of IET learning outcomes during project period

Answer the following questions with relevant to your Project work.

1. Explain the steps you followed to Investigate and define the problem in your project work (C4, evaluate level)

   Analyze, comprehend, define, compare various methods, choose the optimal one.

2. What is the science, mathematics, statistics, engineering principles and other basic technology you identified for design (Mechanical, Electronic, Physics, Chemistry, Automation) in your project work? (C1, C2, C3, Application, Analysis, Evaluation of Science and Mathematics in the project)

   As science, about materials to cut, as math, the equations to find parameter and dimensions. Engineering principles for the production line such as division of labor, sequential organization, and continuous flow.

3. Have you considered the Environmental and sustainability limitations in your project work? (C7, evaluate)

   Yes, in as many ways as possible like scrap recycle, reuse of tools, providing proper ventilation and air filters for cleaner air. Recycling the kits and implementing waste management principles

4. Have you considered ethical dilemma, health, safety, security, and risk issues; intellectual property; codes of practice and standards? Did you address any of these issues in your project work? If so, Explain in detail. (C5, create)

   Yes as an ISO 45001:2015 certified firm, all code of conducts from machine to employees are implemented like maintenance, safety equipment (glasses, gloves, fire extinguisher) also providing the security to premises.

5. What were the esthetical issues faced and how it is addressed in your project in the design phase? (C5, analysis)

   Learning the way a drawing needs to be understood. It is addressed in the quality control section with required no critical dimensions and constraints.

6. Were there any health issues considered during design process. How it is addressed in your project in the design phase? (C5, create)

   No, all safety principles were followed.

7. What were the safety, security and risk issues needed to be taken care of in the design stage? (C10, create)

Yes as an ISO 45001:2015 certified firm, all code of conducts from machine to employees are implemented like maintenance, safety equipment (glasses, gloves, fire extinguisher) also providing the security to premises.

8. Were there any intellectual property issues needed to be taken care off? Have you come across IP issues in the project phase? (C5, create)

   Yes, planning the setting for the job, the height of the clamps for the tools to pass, design with suitable parameters. All these add up to idle time which needs to be minimal.

9. What are the codes of conduct and standards you needed to use in design phase and in other phases of your project as well? (It may include codes of practice and standards for safety, security, health, risk) Explain the legal issues, ISO standards, IEC standards, etc. (C8, evaluate)

   As part of ISO standards, the firm had all floor demarcations, safety kits, equipment according to the needed level. The systematic cycle for material in and out was practiced with no human involvement. All NDA clauses were maintained with its respective customers.

10. What is the general safety measure regulated in the institution where you did the project work? (C8, evaluate)

    Yes as an ISO 45001:2015 certified firm, all code of conducts from machine to employees are implemented like maintenance, safety equipment (glasses, gloves, fire extinguisher) also providing the security to premises.

11. What were the professional ethics needed to be followed in general while you are doing the project? (C8, evaluate)

    Prioritize safety above all else, adhering strictly to industry standards and regulations. Ensure transparency and integrity in reporting progress and issues. Respect and promote fair treatment of employees, suppliers, and stakeholders throughout the project lifecycle.

12. Do you think ethics and professionalism needs to be paid attention by students during study? If, yes, explain how it can be inculcated/introduced/implemented? (C8, evaluate)

    Yes, ethics and professionalism are crucial for students. They can be fostered through case studies, role-playing scenarios, and discussions on real-world dilemmas to cultivate ethical decision-making and professional conduct from an early stage.

13. Do you think environmental and sustainability limitations; ethical, health, safety, security, and risk issues; intellectual property; codes of practice and standards are sufficiently covered in the courses you have studied in your curriculum? (C8, evaluate)

Yes as an ISO 45001:2015 certified firm, all code of conducts from machine to employees are implemented like maintenance, safety equipment (glasses, gloves, fire extinguisher) also providing the security to premises.

14. Have you gone through online classes, or a crash course in which you are familiarized with intellectual property rights as well as risk issues in professional environment? (C8, evaluate)

    Yes, I have through courses during my project work as well, learning the Mastercam software, code of conducts and studied the documents meant for these.

15. In the beginning of your project did you evaluate environmental effects and sustainability factors in your work? (C7, evaluate)

    Yes, implementing 5S principle considers standardization of

16. Did you address any of limitations of your project work and have you improved the results through continuous improvements in your project work? (C5, create)

    The limitations in the project were to maintain the tight tolerance ranges and overcome the constraints which I have improved by performing the operation on different left over/extra material and continuously inspecting the whole process throughout.

17. How did you plan your project, deadlines, maintaining dairy of each stage and improved the quality of the project (C14, understand)

    Yes, I could keep track of the work done on a day to day basis, also helped me in planning the works ahead systematically. It improved the way I did things eventually by organizing the rest of the things.

18. Are you aware of the ethical clearance when you work in the field of health/medical applications? (C8, evaluate)

    Yes, mandatory first aid kit for the safety of the employees, hygiene in the surroundings and uphold the moral standards in research and practice.

19. Could you understand how they tackle project management and what tools, techniques is adopted? (C14, understand)

    Project management in health and medical applications often utilizes specialized tools like Gantt charts, Agile methodologies for flexibility, and risk assessment techniques to manage complexities and ensure timely delivery while prioritizing patient safety and regulatory compliance.

20. Did you adopt any quantitative technique for any engineering activity related to your project? (C3, evaluate)

    Yes, I often use quantitative techniques such as statistical analysis for quality control, cost estimation models like parametric estimating, and numerical simulations (e.g., finite element analysis) for structural analysis in various engineering projects.

21. What are the elements of your project work which addresses sustainable development and were you able to apply quantitative techniques to analyze and achieve your project goals? (C7, evaluate)

    In our project work, we focused on sustainable development by incorporating life cycle assessment (LCA) to evaluate environmental impacts, using quantitative techniques like carbon footprint analysis and energy efficiency calculations. These helped us analyze and achieve our project goals of reducing environmental impact and promoting sustainability.

22. How the institute takes green initiative, environment related factors. (C7, evaluate)

    Institutes took green initiatives by implementing practices such as reducing energy consumption, recycling programs, sustainable building designs, promoting paperless operations, and educating stakeholders about environmental conservation

23. Did your project need the understanding of relevant legal requirements governing engineering activities you carried out as a part of your project work? Explain in detail. (C8, evaluate)

    Understanding relevant legal requirements governing engineering activities is crucial for ensuring compliance and avoiding legal issues. This involves studying regulations related to safety, environmental impact, zoning, permits, and intellectual property rights to ensure all aspects of the project align with legal standards and requirements.

24. What are the legal, ethical practices you followed while working on project? (C8, evaluate)

    During the project, we adhered to legal standards by obtaining necessary permits, respecting intellectual property rights, and ensuring compliance with safety and environmental regulations. Ethically, we prioritized transparency, fairness in collaboration, and honesty in reporting results and challenges.

25. Are you sure that you abide IPR/copy right issues? (C15, apply)

    We strictly adhered to intellectual property rights (IPR) and copyright laws by attributing sources properly, obtaining permissions where necessary, and avoiding plagiarism in all project-related materials and outputs

26. Have you observed any national/international standards in the workplace? How many are relevant to your project work? List them. (C8, evaluate)

    Yes, I have observed national and international standards like just in time production, lean methodology, Toyotas production line strategies and also clients from international workplaces were here to collaborate/register as customers.

27. What online course you attended to improve your communication skills. Report writing, Oral presentation, Software used for writing report. (c17, apply)

I have attended the webinars, seminars and expo events to improve my social responsibility and communication skills. For my report writing I have used MS office and power point presentation.

28. In your project, was it needed to tackle risk issues, including health & safety, environmental and commercial risk, and of risk assessment and risk management techniques? Explain in detail. (C5, create)

    Yes as an ISO 45001:2015 certified firm, all code of conducts from machine to employees are implemented like maintenance, safety equipment (glasses, gloves, fire extinguisher) also providing the security to premises.

29. How is an organization addressing a fire accident/human safety when working with machines? (C9, evaluate)

    Organizations address fire accidents and human safety when working with machines by implementing rigorous safety protocols, conducting regular risk assessments, providing comprehensive training to personnel, maintaining firefighting equipment, and adhering to relevant safety standards and regulations such as OSHA (Occupational Safety and Health Administration) guidelines.

30. Process of teamwork. How each of you are involved in the team? What part the work is addressed by you.? (C16, evaluate)

    In teamwork, each member contributes based on their strengths and expertise. My role involves generating and synthesizing information, providing insights, and ensuring clarity and coherence in communication. I assist in research, planning, and decision-making processes, contributing to the overall project goals effectively.

31. Have you filed patent, IPR, or published your work? Give more details. (C17, evaluate)

    Yes, this is related to my other field of work regarding rocketry. Two of the papers are in process of publishing and one patent is process as well.

32. How you documented the literature review, your analysis on their results, discussion with the guide and team members, provide the documents on weekly basis. Put as one chapter in final report. (C4, evaluate).

    In documenting the literature review, analysis, and discussions, I maintained a structured approach. I compiled relevant sources using reference management software (e.g., Zotero), drafted summaries and analyses, and shared them with my guide and team weekly. These inputs were integrated into a comprehensive chapter in the final report, focusing on synthesizing findings and aligning with project objectives.

33. Have you sensitized about inclusion and diversity in the team? If yes, what are the diversification in the team in terms of religion, gender, ethnicity, etc. What challenges you come across in the team. (C11, apply). Indian constitution and acts related to caste, gender, race discrimination.

In our team, we are sensitized about inclusion and diversity, ensuring representation across genders, religions, and ethnicities. Challenges include addressing biases, promoting equal participation, and navigating cultural differences sensitively.

34. How were you able to keep yourself updated with the technology? How you incorporated advanced technology in your project. (C18, lifelong learning)

    I keep myself updated with technology through continuous learning via online courses, industry publications, and attending seminars. In our project, we incorporated advanced technology such as AI algorithms for data analysis, IoT sensors for real-time monitoring, and CAD software for design optimization to enhance efficiency and accuracy in our outcomes.

35. Which are the laboratory skill you found applicable to your project. Explain. (C12, apply)

Key laboratory skills applicable to our project included experimental design for structured testing, precise measurement techniques for accurate data collection, and proficient data analysis using statistical methods to draw meaningful conclusions.

Annexure 4
Project classification

Student Name: THAKUR PRANAV GOPAL SINGH
Register no: 200909426

Note: Use a tick mark to specify under which domain your project work falls into.
Table 1: classification based on project domain classification

Domain	✓ **Tick**
Product	✓
Application	✓
Review	
Research	
Management	✓

Note: Use a tick mark to specify Societal impacts you considered during your project.
Table 2: classification based on societal consideration

Societal Impact	✓ **Tick**
ethics	
safety	✓
environmental	✓
commercial	✓
economic	✓
social	

Signature of Student: Name and Signature of Guide:

RE-2022-315227-plag-report

ORIGINALITY REPORT

5%	3%	0%	4%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Middle East College of Information Technology Student Paper	1%
2	Submitted to 87988 Student Paper	<1%
3	Submitted to University of Portsmouth Student Paper	<1%
4	Submitted to The Manchester College Student Paper	<1%
5	docshare.tips Internet Source	<1%
6	Submitted to American University of Beirut Student Paper	<1%
7	Submitted to Aston University Student Paper	<1%
8	microfluidics.cnsi.ucsb.edu Internet Source	<1%
9	Submitted to North Warwickshire & Hinckley College	<1%

Student Paper

10	www.hanboost.com Internet Source	<1 %
11	Submitted to SP Jain School of Global Management Student Paper	<1 %
12	Submitted to Western International College (WINC London) Student Paper	<1 %
13	Submitted to Student Paper	<1 %
14	pubs.sciepub.com Internet Source	<1 %
15	www.slideshare.net Internet Source	<1 %
16	www.imarcgroup.com Internet Source	<1 %
17	Submitted to Higher Education Commission Pakistan Student Paper	<1 %
18	Submitted to Swindon College, Wiltshire Student Paper	<1 %

Exclude quotes On Exclude matches Off

PROJECT DETAILS

Student Details			
Student Name	**THAKUR PRANAV GOPAL SINGH**		
Register Number	200909426	Section / Roll No	D/46
Email Address	Thakur4pranav@gmail.com	Phone No (M)	8142693336
Project Details			
Project Title	**DESIGN, DEVELOPMENT AND INSPECTION OF METALLIC COMPONENTS**		
Project Duration	20 WEEKS	Date of reporting	JAN 14TH 2024
Organization Details			
Organization Name	**BALAJI CNC TECHNOLOGIES**		
Full postal address with pin code	2/B-IP NADERGUL, TSIIC AEROSPACE PARK, ADIBATLA, RR DIST, HYDERBAD, TELANGANA, INDIA - 501510		
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Supervisor Details			
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Internal Guide Details			
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Designation	**ASSISTENT PROFESSOR- SELECTION GRADE**		
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