DESIGN AND MANUFACTURING OF CUTTING TOOL FOR MACHINING PROFILE ON INCONEL SHELL

A Project Submitted by

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CENTRAL MANUFACTURING TECHNOLOGY INSTITUTE

MAY-2023

BONAFIDE CERTIFICATE

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ABSTRACT

This report focuses on the design and manufacturing of a cutting tool for machining profiles on an Inconel shell. The cutting tool is designed to provide a precise and repeatable machining process in order to achieve the desired profile in the shell. The design process is carried out using Computer Aided Design (CAD) software, which is used to create a 3D model of the cutting tool. The 3D model is then used to generate the necessary parameters for the tool design, such as the cutting edge geometry and cutting surface area. The cutting tool is then manufactured using a CNC machine, which is capable of producing the desired tool geometry. The cutting tool is then tested and evaluated for its performance in cutting the profile on the Inconel shell. The results of the evaluation are then used to further refine the cutting tool design. Finally, the cutting tool is applied to the Inconel shell and the profile is machined successfully.

Keywords

Inconel shell, Cutting profile, IWCEP, Tungsten Carbide

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CHAPTER 1

INTRODUCTION

1.1 GENERAL INTRODUCTION

The design and manufacturing of a cutting tool for machining a profile on an Inconel shell requires careful consideration of the material properties of Inconel and the tooling requirements for a successful machining operation. Inconel is a high-heat resistant superalloy, which is highly resistant to corrosion and is typically used in aerospace, nuclear, and chemical applications. The cutting tool must be designed to provide the necessary cutting-edge geometry, cutting forces, and wear resistance to effectively machine the profile into the Inconel shell. The cutting tool must also be designed to ensure that the cutting forces are properly distributed across the cutting edge in order to avoid excessive wear and tear on the tool. Additionally, the cutting tool must be designed to accommodate the specific profile design of the Inconel shell. Once the cutting tool has been designed, it must be manufactured using the proper material selection and machining techniques to ensure the desired performance and reliability.

1.2 PROBLEM STATEMENT

The goal of this project is to design and manufacture a cutting tool for machining a profile on an Inconel shell. The cutting tool must be able to effectively machine the Inconel material while also providing a smooth finish and leaving a clean surface. The cutting tool must also be designed to prevent damage due to heat and wear, as well as being cost effective to produce. The cutting tool must also be designed in a way that ensures a fast and efficient machining process.

1.3 OBJECTIVE

- Designed the cutting tool for Inconel shell
- Process planned for manufacturing a cutting tool
- Manufactured the cutting tool for the inconel shell

1.4 MOTIVATION OF THE RESEARCH

The main motivation for designing and manufacturing a cutting tool for machining profiles on Inconel shells is to reduce manufacturing costs and improve efficiency. Inconel shells are difficult to machine due to their high hardness and strength. Special cutting tools are required to machine them, and these tools must be designed specifically for the job. The cutting tool must be designed to ensure that it cuts effectively and efficiently, and that the profile of the Inconel shell is accurately achieved. Additionally, the tool must be designed and manufactured to ensure that it is durable and capable of withstanding the high temperatures and pressures that are associated with machining Inconel shells. Finally, the cutting tool must also be designed and manufactured to be cost-effective and to provide the highest level of quality and performance.

1.5 SINGLE POINT TURNING OPERATION

Single-point turning is a machining process used to create cylindrical parts. The process involves using a single-point cutting tool to cut away material from a rotating workpiece, usually in a single pass. In this process, the cutting tool is fed along the axis of the rotating workpiece in a straight line, creating a cylindrical surface. This process is used for a variety of applications, including the production of parts with outside diameters, internal diameters, and grooves. Single-point turning is also commonly used for small parts and simple geometric shapes.

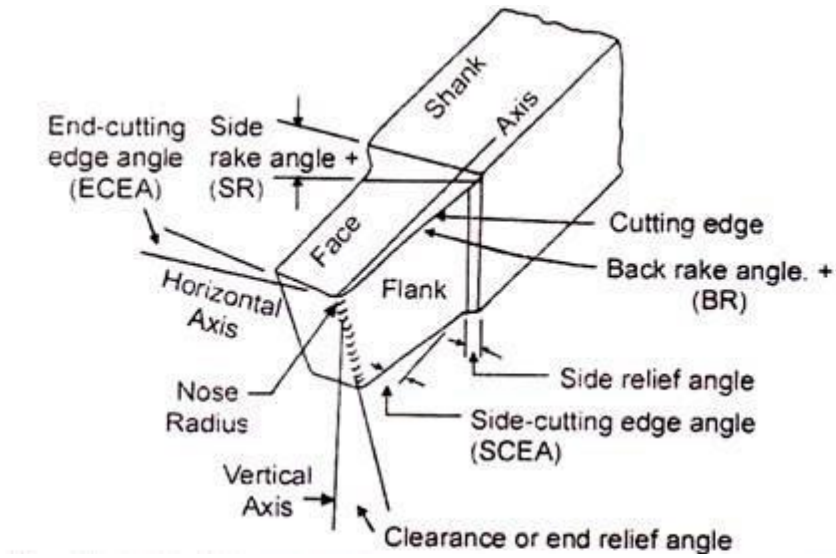

Fig 1.1 TOOL GEOMETRY OF SINGLE POINT CUTTING TOOL

1.6 PROJECT DETAILS

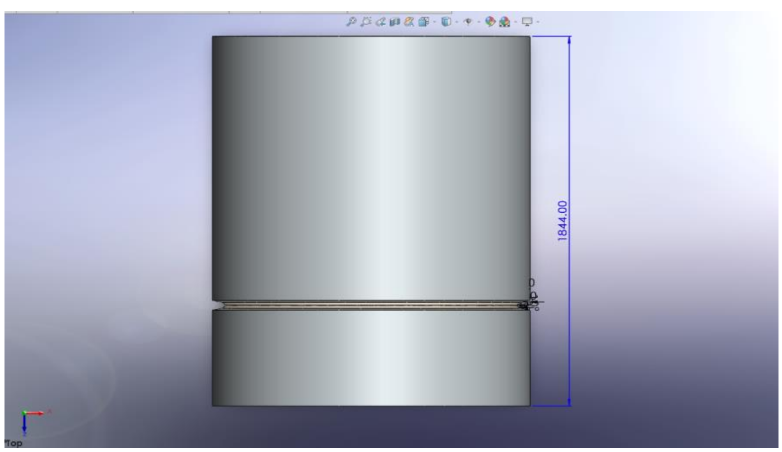

Fig 1.2 CUTTING PROFILE IN INCONEL SHELL DESIGN

Fig 1.1 shows the 3D model of an Inconel shell, which is machined to the required cutting profile.

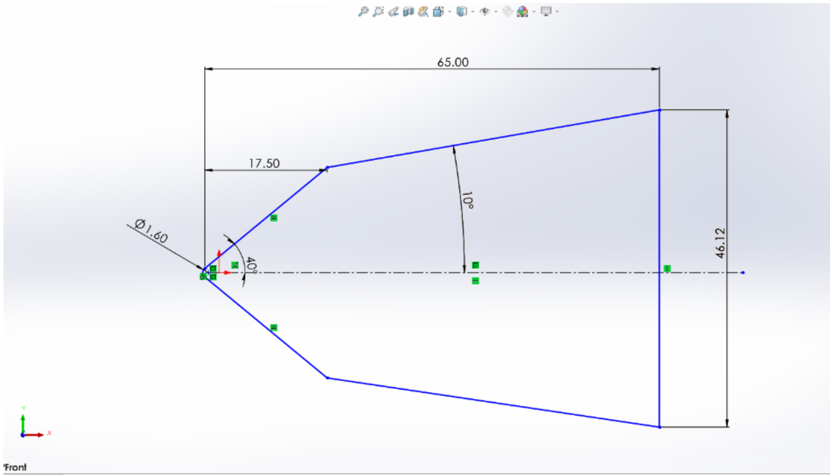

Fig 1.3 CUTTING PROFILE

Fig 1.2 is the cutting profile, which is machined in the Inconel shell.

1.7 Inconel 600

Inconel 600 workpiece has excellent corrosion resistance and oxidation resistance in a wide range of media, including sulfuric and hydrochloric acids, alkalis, salt solutions, and many organic acids. It has good mechanical properties even at cryogenic temperatures and can be used in temperatures ranging from -423°F to 2000°F. Inconel 600 has superior creep-rupture strength and stress-rupture strength at high temperatures, making it suitable for applications that require high temperature performance. It is also resistant to chloride ion stress-corrosion cracking, making it a good choice for applications in chloride-containing environments. Inconel 600 is a nickel-chromium alloy that has excellent resistance to aqueous corrosion, excellent metallurgical stability, and is non-magnetic.

Table1.1 Chemical composition of Inconel 600

Name of the Elements	% Weight
Nickle (Ni)	76.11
Chromium (Cr)	15.48
Iron (Fe)	7.49
Other elements	0.92

APPLICATION:

- Retorts
- Muffles
- Roller hearths
- Furnace components
- Heat treating baskets and trays
- Jet engines
- Airframe components
- Lockwire
- Exhaust liners and,
- Turbine seals

Retorts

Retorts are vessels used in engineering and manufacturing processes that are designed to withstand high temperatures and pressures. They are commonly used for distillation, evaporation, and sterilization.

Muffles

Muffles are devices used in engineering to reduce or muffle the sound of an exhaust system or other machinery. They are often used to reduce the noise from engines, compressors, and other machinery. Muffles can also be used to reduce the sound of high-pressure exhausts, such as those used in turbocharged engines.

Roller hearths

Roller hearths are a type of engineering tool used in the manufacturing process, consisting of a series of rollers that are used to move material along a conveyor belt. They are used to both transport material and to help with the formation of materials during the manufacturing process.

Furnace components

Furnace components in engineering include a heating element, a blower, a control system, an air filter, a heat exchanger, a humidifier, and an air handler.

Heat treating baskets and trays

Heat treating baskets and trays in engineering is a process of subjecting the baskets and trays to an elevated temperature for a specified period of time to alter their physical and/or mechanical properties. The goal of the process is generally to increase the baskets and trays strength, hardness, wear resistance, or corrosion resistance. Heat treating is typically accomplished by heating the baskets and trays to a specific temperature then cooling them down at a controlled rate.

Jet engines

Jet engines are a type of propulsion system that creates thrust by propelling a jet of hot exhaust gas from the back of the engine. Jet engines are used in aircraft and are an integral part of modern air travel. Jet engines use a combination of fuel, air, and an ignition source to create thrust. The air is compressed and mixed with fuel, and then ignited to create a combustion reaction. The combustion reaction produces exhaust gases that are then forced out of the engine at high speeds, creating thrust.

Airframe components

Airframe components are the structural elements of an aircraft that provide support for the engine, landing gear, and other components. They include fuselage, wings, empennage, flight control surfaces, and landing gear.

Lockwire

Lockwire, also known as safety wire, is a technique used to secure a fastener or other components to ensure it does not come loose or vibrate off from vibration, movement, or other external forces. It is typically made of stainless-steel wire and is used extensively in the aerospace, automotive, and marine industries.

Exhaust liners

Exhaust liners are components of an engine's exhaust system. They are typically made of a ceramic material, such as ceramic fiber, and are designed to reduce the amount of heat that is transferred from the exhaust gases to the engine components. By reducing the amount of heat that is transferred, exhaust liners can help reduce wear and tear on the engine components, which can extend the life of the engine and improve its overall performance.

Turbine seals

Turbine seals are mechanical seals used to prevent the leakage of steam, gas, or liquid between two rotating parts in a turbine. They are typically used in gas turbines, steam turbines, and water turbines to prevent the leakage of exhaust gases or process fluid from the turbine system. Turbine seals can be made of a variety of materials, including metal, rubber, and composite materials.

1.8 MACHINE DETAILS

IWCEP (IN-SITU WELDING AND CUTTING-EDGE PREPARATION)

IWCEP is developed by CMTI and this machine was made up only for machining special cutting profiles.

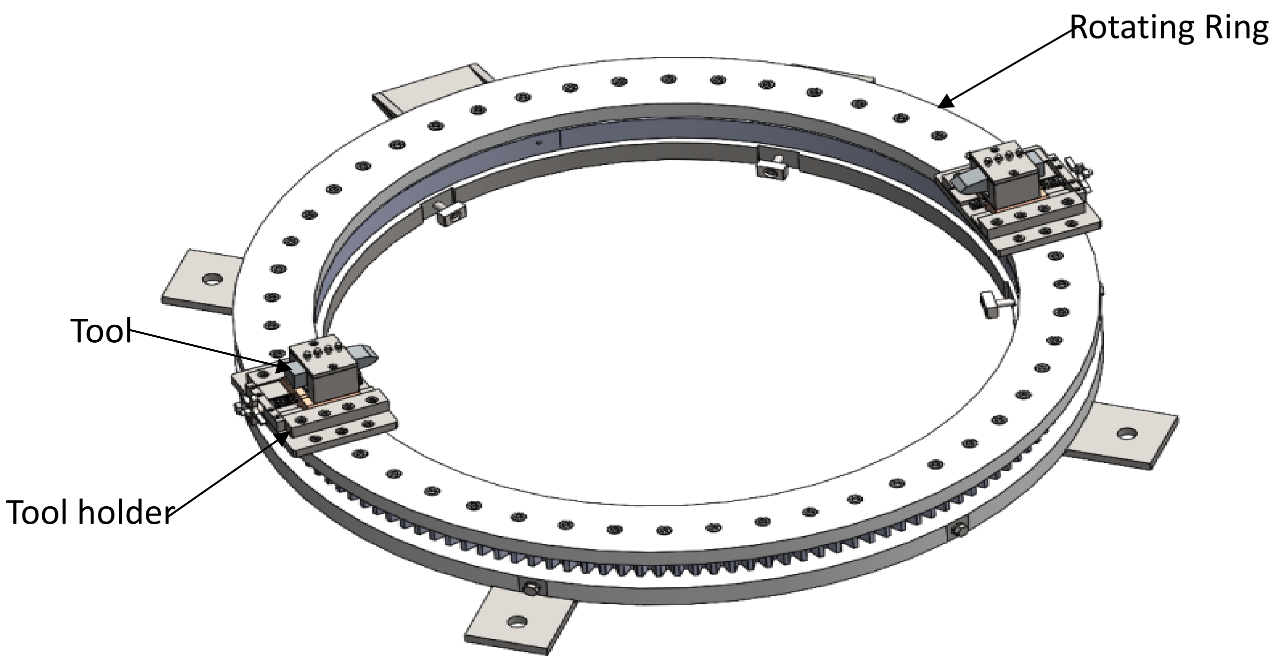

Fig 1.4 In-Situ Welding and Cutting Edge Preparation

Inconel (nickel-chromium-iron) is a superalloy material, and it is hard to cut. So CMTI developed a new machine. This machine is called IWCEP (In-Situ Welding and Cutting-Edge Preparation). This is a non-regular conventional machining process, and it is for machining a special cutting profile. Because of the special cutting profile, we need to design and manufacture the cutting tool and profile tool based on the cutting profile and machine tool holder.

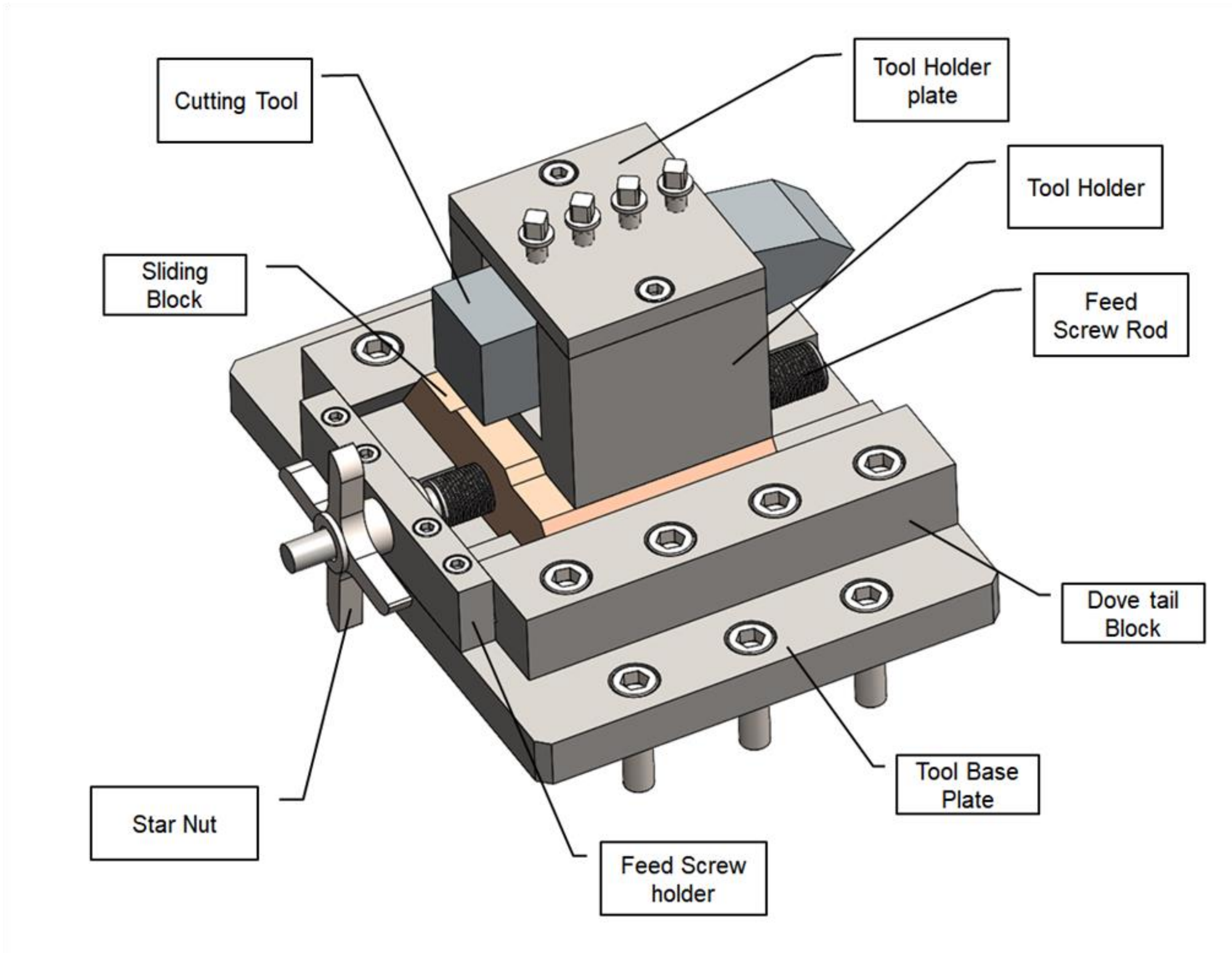

Fig 1.5 Machine Tool Holder and Feeder

CHAPTER 2

LITERATURE REVIEW

Cutting performance of cubic boron nitride-coated tools in dry turning of hardened ductile iron (29 April 2020) Luqiang Tua, Shuai Tiana, Feng Xua, Xue Wanga, Chenhui Xua, Bin Hebc, Dunwen Zuoa, Wenjun Zhangb

This paper examines how the cutting performance of cubic boron nitride (CBN)-coated tools affects the dry turning of hardened ductile iron. Through experiments, the researchers found that the cutting performance of the CBN-coated tools could be improved by increasing cutting speed, feed rate, and depth of cut. The results showed that the cutting efficiency and tool life of the CBN-coated tools were higher than those of uncoated tools, particularly when cutting at high cutting speeds. Additionally, the surface roughness of the workpiece was lower for the CBN-coated tools than for the uncoated tools. The cutting performance of the CBN-coated tools was affected by the cutting parameters, and the optimal cutting parameters for the CBN-coated tools were determined. The findings of this study can be used to improve the cutting performance of CBN-coated tools in dry turning of hardened ductile iron.

Surface roughness and insert wear in turning Ti-6Al-4 V and Inconel 600 alloys with tungsten carbide inserts under dry conditions (16 January 2023) M. Dhananchezian

This study investigates the effects of surface roughness and insert wear during the dry turning of Ti-6Al-4V and Inconel 600 alloys using tungsten carbide inserts. The results showed that the surface roughness of Ti-6Al-4V was lower than that of Inconel 600, and the highest surface roughness of Ti-6Al-4V was obtained at a cutting speed of 50 m/min and a feed rate of 0.15 mm/rev. The insert wear of Ti-6Al-4V was lower than that of Inconel 600, and the lowest wear of Ti-6Al-4V was achieved when the cutting speed was 50 m/min and the feed rate was 0.10 mm/rev. It was also found that the cutting temperature was higher for Inconel 600 than for Ti-6Al-4V, indicating the higher thermal resistance of Inconel 600. The results of this study provide valuable insight into the surface roughness and insert wear during the dry machining of Ti-6Al-4V and Inconel 600, which can be utilized to optimize the machining process and prolong the life of the cutting tool.

Experimental investigation on machining behavior in dry turning of nickel based super alloy-Inconel 600 and analysis of surface integrity and tool wear in dry machining (19 May 2022)

G. Veerappan, D. Pritima, N.R. Parthsarathy, B. Ramesh, S. Jayasathyakawin

This paper presents the results of an experimental investigation on the machining behavior of Inconel 600, a nickel-based super alloy, in dry turning. The authors studied the surface integrity and tool wear of the alloy under various cutting parameters, such as cutting speed, feed rate, and depth of cut. Results showed that an increase in cutting speed and depth of cut caused an increase in cutting force, surface roughness, and tool wear. However, an increase in feed rate reduced cutting force and surface roughness. The authors concluded that Inconel 600 can be machined using dry turning with adequate cutting parameters and tool wear can be minimized by reducing cutting speed and depth of cut.

A tool wear analysis of an Inconel 600 turned TiAlN coated carbide insert at various cutting speeds (16 January 2023) M. Dhananchezian

This paper presents the results of an experimental investigation on the machining behavior of Inconel 600, a nickel-based super alloy, in dry turning. The authors studied the surface integrity and tool wear of the alloy under various cutting parameters, such as cutting speed, feed rate, and depth of cut. Results showed that an increase in cutting speed and depth of cut caused an increase in cutting force, surface roughness, and tool wear. However, an increase in feed rate reduced cutting force and surface roughness. The authors concluded that Inconel 600 can be machined using dry turning with adequate cutting parameters and tool wear can be minimized by reducing cutting speed and depth of cut.

Durability of Cutting Tools during Machining of Very Hard and Solid Materials (24 February 2015) Tomáš Bakša, Tomáš Kroupa, Pavel Hanzl, Miroslav Zetek

This research paper examines the durability of cutting tools during machining of very hard and solid materials. The authors conducted a series of tests to measure the durability of cutting tools when machining a selection of materials, including stainless steel, titanium alloys, and cobalt-based alloys. The tests included measurements of the forces and temperatures generated during machining, as well as the wear rates of the cutting tools. The results of the tests showed that the wear rates were significantly higher for harder materials, and that the temperatures generated during machining were significantly higher for the titanium alloys. The authors also discussed the potential for using coolants and lubricants to reduce the wear rates and temperatures generated during machining. Overall, the results of the tests and analyses suggest that cutting tools may need to be specifically designed to suit the individual material being machined in order to ensure the highest levels of durability.

Chip formation, cutting temperature and forces measurements in hard turning of Gcr15 under the influence of PcBN chamfering parameters (29 October 2022) Ghulam Hussain, Mohammed Alkahtani, Marwan Alsultan, Johannes Buhl, Munish Kumar Gupta

This article by Hussain et al. (2022) focuses on the study of chip formation, cutting temperature, and forces as they relate to hard turning of Gcr15 with different chamfering parameters of PCBN. The authors explore the influence of the chamfering parameters on the cutting performance of the Gcr15 material. The research was conducted by carrying out machining experiments in a CNC lathe and measuring the cutting forces, temperatures, and chips generated. The authors found that the cutting performance of the Gcr15 material was enhanced by the use of the chamfering parameters, resulting in improved chip formation, cutting temperature, and cutting forces. The authors conclude that the use of chamfering parameters can improve the cutting performance of Gcr15 and that further research should be conducted to further improve the cutting performance of this material.

Influence of variation in cutting velocity on temperature, surface finish, chip form and insert after dry turning Inconel 600 with TiAlN carbide insert (18 August 2021) M. Dhananchezian

This study examined the influence of cutting velocity on temperature, surface finish, chip form, and insert after dry turning Inconel 600 with TiAlN carbide insert. Results showed that the cutting velocity had a significant influence on temperature, surface finish, chip form, and insert wear. It was found that a higher cutting velocity led to an increase in the cutting temperature, a decrease in the surface roughness, the formation of short and thick chips, and an increase in the insert wear rate. The results suggest that the cutting velocity should be adjusted to regulate the cutting temperature, surface finish, chip form, and insert wear.

Online Monitoring of Metal cutting of Inconel 600 with Al_2O_3 coated carbide tools (2017) M. Sivaramakrishnaiah, P. Nanda Kumar, G. Rangajanardana

This paper examines the online monitoring of metal cutting of Inconel600 using Al2O3 coated carbide tools. The experimental tests were designed to evaluate the effects of cutting parameters, such as cutting speed, feed rate and depth of cut, on cutting forces, tool wear, chip morphology and surface roughness. The results showed that increasing cutting speed, feed rate and depth of cut resulted in higher cutting forces, increased tool wear and increased surface roughness. The chip morphology was found to be affected by the cutting speed and depth of cut. The paper concluded that increasing cutting speed and depth of cut resulted in higher cutting forces and increased tool wear, while increasing feed rate had the opposite effect on the cutting forces.

Improvement mechanical properties of Inconel and Monel alloys synthesis by laser coating (1 August 2018) Abdulhussain K. Elttayef, Laith Nadhim Abass, Lubna Ghazi Abd Al-Latif

This paper discusses the use of laser coating to improve the mechanical properties of Inconel and Monel alloys. The authors conducted experiments to compare the mechanical properties of the alloys after laser coating. They tested the hardness, wear rate, and corrosion rate of the alloys. The results of the experiments showed that the laser coating significantly improved the mechanical properties of the alloys, including higher hardness and lower wear and corrosion rates. The authors concluded that laser coating is an effective way to improve the mechanical properties of Inconel and Monel alloys. This research provides valuable information for materials engineers and other professionals who are looking for ways to improve the performance of these alloys.

Interrupted cutting of Inconel 718 with AlTiSiN coated cemented carbide tool under high pressure coolant supply (31 July 2022) Chi Hsin Liu, Tatsuya Sugihara, Toshiyuki Enomoto

This paper discusses a study conducted by Liu, Sugihara, and Enomoto (2022) on the interrupted cutting of Inconel 718 with an AlTiSiN-coated cemented carbide tool under high pressure coolant supply. The study aimed to evaluate the effects of cutting speed, feed rate, and coolant pressure on the cutting forces, tool wear, and surface roughness of the workpiece. The results showed that increasing the coolant pressure decreased the cutting forces and improved the surface roughness. However, increasing the coolant pressure had no effect on the tool wear. The authors concluded that the AlTiSiN coating on the tools allowed them to remain sharp even under high pressure coolant supply, thus resulting in improved cutting performance.

Wear mechanisms of ultra-hard cutting tools materials (28 September 2001) Farhad Nabhani

The paper by Faisal Nabhani (2001) investigates the wear mechanisms of ultra-hard cutting tool materials. It evaluates the performance of three different cutting tool materials: cemented carbide, ceramic, and polycrystalline diamond. The paper examines the wear behavior of each material under different cutting conditions, including cutting speed, feed rate, and depth of cut. It also considers the effects of tool wear on the surface finish, cutting edge geometry, and cutting forces. The paper provides a detailed overview of the various wear mechanisms of ultra-hard cutting tool materials, and suggests ways to minimize tool wear and extend the life of the tool. Furthermore, the paper concludes with a discussion of the potential applications of ultra-hard cutting tool materials in the manufacturing industry.

A study on machinability of nickel-based superalloy using micro-textured tungsten carbide cutting tools (6 January 2020) M Adam Khan1 and Kapil Gupta1

This study explores the machinability of nickel-based superalloy using micro-textured tungsten carbide cutting tools. The study used a milling operation to analyze the machinability performance of the superalloy. Results showed that the micro-textured cutting tool was effective in increasing the cutting speed and reducing the cutting force, which in turn improved the machinability of the nickel-based superalloy. Additionally, the study found that the micro-textured cutting tool had a low risk of tool wear and provided good surface finish. These results suggest that micro-textured cutting tools are a viable option for improving the machinability of nickel-based superalloys.

Failure modes and wear mechanisms of M35 high-speed steel drills when machining inconel 901 (20 March 2000) E.O. Ezugwu, C.J. Lai

This paper examines the failure modes and wear mechanisms of M35 high-speed steel drills when machining Inconel 901. It begins by discussing the properties of Inconel 901 and M35 high-speed steel and their machinability. It then presents the experimental results of drilling Inconel 901 with different cutting parameters. From the results, four different failure modes were identified: plastic deformation, chipping, flank wear, and crater wear. The paper then discusses the wear mechanisms and the influence of machining parameters on tool life. Finally, it suggests ways to improve tool life and reduce wear.

Outcomes from the Literature Survey

The effective cutting tool material for Inconel shell was selected from a literature survey. The materials are

1. Tungsten Carbide (WC)
2. HSS M48(High Speed Steel)
3. CBN (Cubic Boron Nitride)
4. Al2O3(Aluminium Oxide)
5. TiAlN (Titanium Aluminium Nitride)
6. AlCrN (Aluminium Chromium Nitride)
7. Ti-6Al-4V (Titanium Aluminium Vanadium)

Properties of Tungsten Carbide (WC)

1. High Hardness: Tungsten carbide has a hardness of 8.5-9.5 on the Mohs scale. This is one of the hardest materials available, making it very resilient and suitable for industrial applications.

2. High Strength and Density: Tungsten carbide is about twice as strong as steel but much denser. Its density is about 15.63 g/cm3, which is much higher than most other metals. 3. Corrosion and Wear Resistance: Tungsten carbide is highly resistant to corrosion and wear. This makes it a great material for industrial applications where it is exposed to harsh environments.

4. Thermal and Electrical Conductivity: Tungsten carbide has relatively low thermal and electrical conductivity. This property makes it suitable for applications where electrical and thermal properties are not important.
5. Chemical Stability: Tungsten carbide is chemically very stable and does not react with most acids and bases. This makes it a great material for industrial applications where it is exposed to aggressive chemicals.

Properties of HSS M48 (High Speed Steel)

High Speed Steel M48 is a cobalt-alloyed, molybdenum high speed steel that has a high red hardness, excellent hot hardness, and good wear resistance. It is especially suitable for cutting tools for machining of hot-work steels, high-temperature alloys, stainless steels, and carbon steels. It also has superior edge retention and toughness. Properties of M48 include:

- High red hardness
- Excellent hot hardness
- Good wear resistance
- Superior edge retention
- High toughness
- Cobalt-alloyed
- Molybdenum-based

Properties of CBN (Cubic Boron Nitride)

Cubic boron nitride (CBN) is an ultra-hard material that can be used as an abrasive and is known for its extreme hardness, chemical inertness, and high thermal stability. It is second only to diamond in terms of hardness and is commonly used to manufacture abrasive tools, cutting tools, and grinding wheels. Its properties include:

- Exceptionally high hardness: CBN is second only to diamond in terms of hardness, with a Vickers hardness value of 2800-3300 HV.

- High thermal stability: CBN can withstand temperatures up to 1300°C without significant degradation. -Chemical inertness: CBN is highly resistant to chemical attack and does not react with most acids and bases.
- High melting point: CBN has a melting point of 3650°C, which is higher than most other abrasive materials.
- Good electrical insulation: CBN has a high resistivity to electric current, making it useful for electrical insulation.
- High thermal conductivity: CBN has a high thermal conductivity, which is useful for transferring heat away from cutting tools.
- Good thermal shock resistance: CBN can withstand sudden temperature changes without breaking or cracking.

Properties of Al_2O_3 (Aluminium Oxide)

Al203 is an aluminum oxide compound with a molecular weight of 101.96 g/mol and a density of 3.97 g/cm3. It is an amphoteric compound, meaning it can act as an acid or a base depending on the pH of its environment. It is insoluble in water, but soluble in acids and bases. It has a melting point of 2072°C and a boiling point of 2977°C. It is a white powdery solid with a low electrical conductivity. Its hardness is 8 on the Mohs scale and its refractive index is 1.611.

Properties of TiAlN (Titanium Aluminium Nitride)

TiAlN is a hard, wear-resistant, corrosion-resistant alloy that is used for a variety of applications. It has a high hardness rating of 4,000 Vickers, making it one of the hardest materials available for machining. It is resistant to oxidation up to 800°C and is thermally stable up to 1,200°C, making it suitable for high-temperature applications. TiAlN has a low coefficient of friction, making it a good choice for use in sliding applications. Additionally, it is non-magnetic, making it suitable for use in applications that require non-magnetic properties. TiAlN is also resistant to a variety of chemicals, making it useful in chemical processing applications. Additionally, it is resistant to radiation and can be used in nuclear applications.

Properties of AlCrN (Aluminium Chromium Nitride)

AlCrN is a type of hard coating material with a wide range of properties. It has excellent wear and oxidation resistance, high hardness, low coefficient of friction, and good thermal and electrical properties. AlCrN coatings offer high hardness, good adhesion, and exceptional corrosion and abrasion resistance. They also have a low coefficient of friction and a high thermal conductivity. AlCrN coatings also have good thermal stability, low outgassing, high thermal shock resistance, and good electrical conductivity.

Properties of Ti-6Al-4V (Titanium Aluminium Vanadium)

Ti6Al4V is an alpha-beta alloy of titanium and is the most widely used of all the titanium alloys. It has high strength, low density, good corrosion resistance, good weldability and excellent toughness. It has a high modulus of elasticity and high fatigue properties, and is often used for aerospace applications. It has a melting point of 1660°C and a density of 4.43 g/cm3. Ti6Al4V has excellent corrosion resistance to a wide range of corrosive media, including most organic acids, alkalis, and salt solutions. It is also very resistant to pitting and crevice corrosion.

Explanation for the selection of the cutting tool insert

From the above seven cutting tool materials, the first selected tool insert material is HSS M48 because of its availability and cost efficiency, but machining Inconel is so tough because of its hardness that we changed to tungsten carbide instead of HSS M48.

Table 2.1 Hardness of the materials

Material	Hardness
Inconel 600	35 HRC
HSS M48	62 to 64 HRC
Tungsten Carbide	90 to 91 HRC

CHAPTER 3

EXPERIMENTAL DETAILS

3.1 Introduction

In this present work, an effort was made to machine the Inconel shell based on the required cutting profile, so CMTI developed the IWCEP machine for machining special cutting profiles. Based on the cutting profile, material selection, tool geometry, cutting parameters, and machining tests are done.

3.2 Methodology

The methodology for this project is given in the figure 3.1

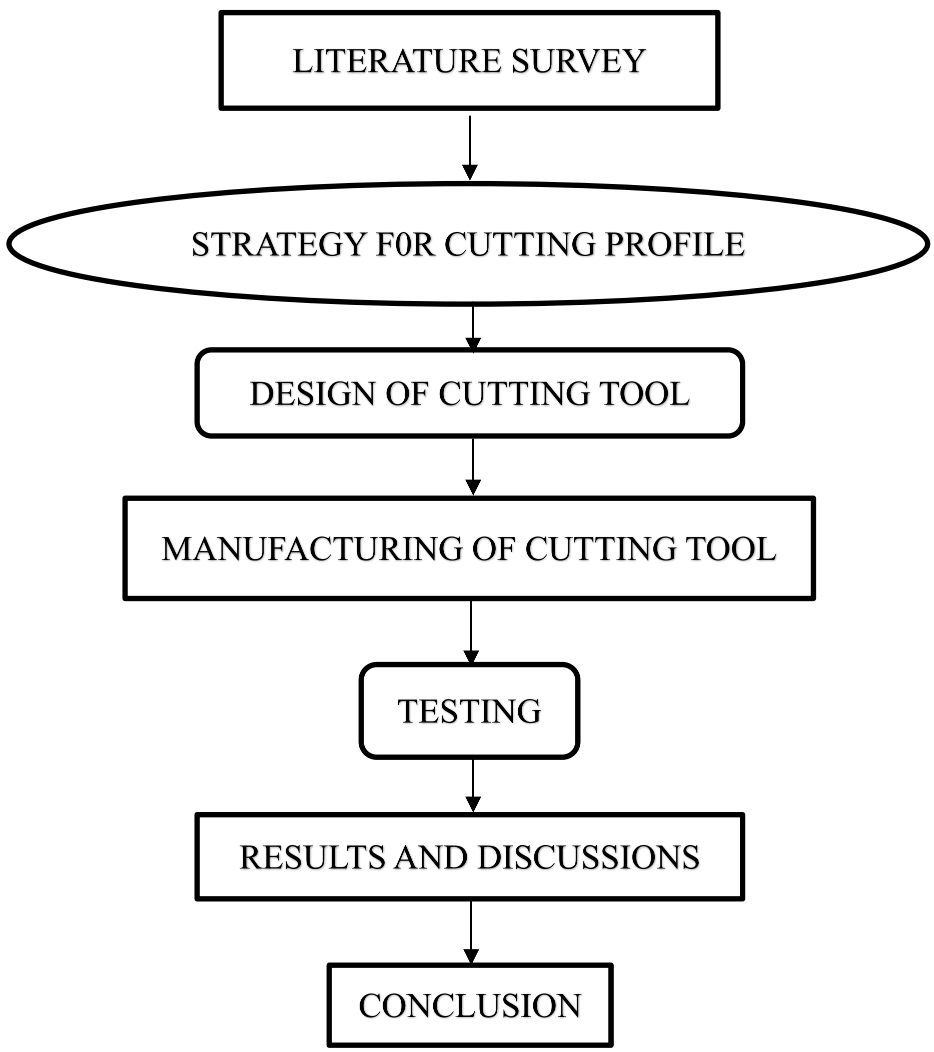

Fig 3.1 Methodology

3.3 Strategy for Machining the Cutting profile

To align the longitudinal axis of the tool with axisymmetric profile which has been already grooved profile, and thereby plunging the profile tool with depth of cut of 0.1mm

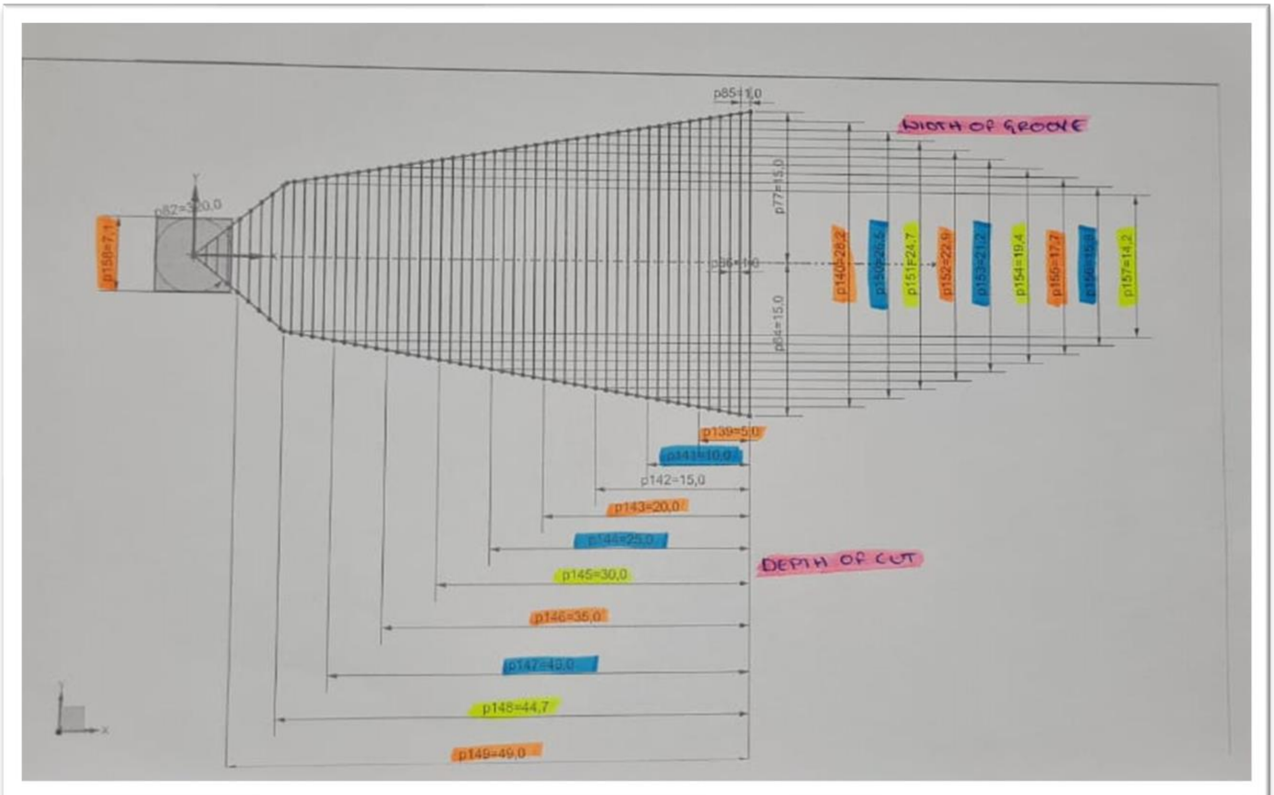

Fig 3.2 Strategy for Machining the Cutting profile

Fig 3.2 is the cutting profile strategy;

Step 1: Cut the inconel shell centre part narrowly using a grooving cutting tool.

Step 2: After grooving, cut the left side of the profile using the left side profile cutting tool with a depth of cut of 0.1 mm.

Step 3: After the left side profile is finished, cut the right-side profile with the cutting tool with a depth of cut of 0.1 mm.

Step 4: After finishing left and right-side profile cutting, plunge the full profile cutting tool for the required cutting profile.

The above four steps are a cutting strategy for inconel shell.

3.4 Design of Cutting tool

3.4.1 Design of Profile tool holder

A cutting tool holder is a device used to hold and position a cutting tool relative to the workpiece. It must be designed to securely hold the cutting tool in place, while also allowing for easy removal and replacement of the cutting tool. The design of the cutting tool holder is typically based on the type of cutting tool and the application in which it will be used. Generally, cutting tool holders are composed of a base or body, clamping mechanism, cutting tool shank, and a cutting edge or tip. The base or body of the cutting tool holder must be designed to securely mount the holder to the machine and provide a stable platform for the cutting operation. The clamping mechanism must be designed to securely hold the cutting tool in place and provide a means of adjusting the cutting tool position. The cutting tool shank must have a means of securely attaching the cutting tool to the holder. The cutting edge or tip must be designed to provide the correct cutting geometry for the application.

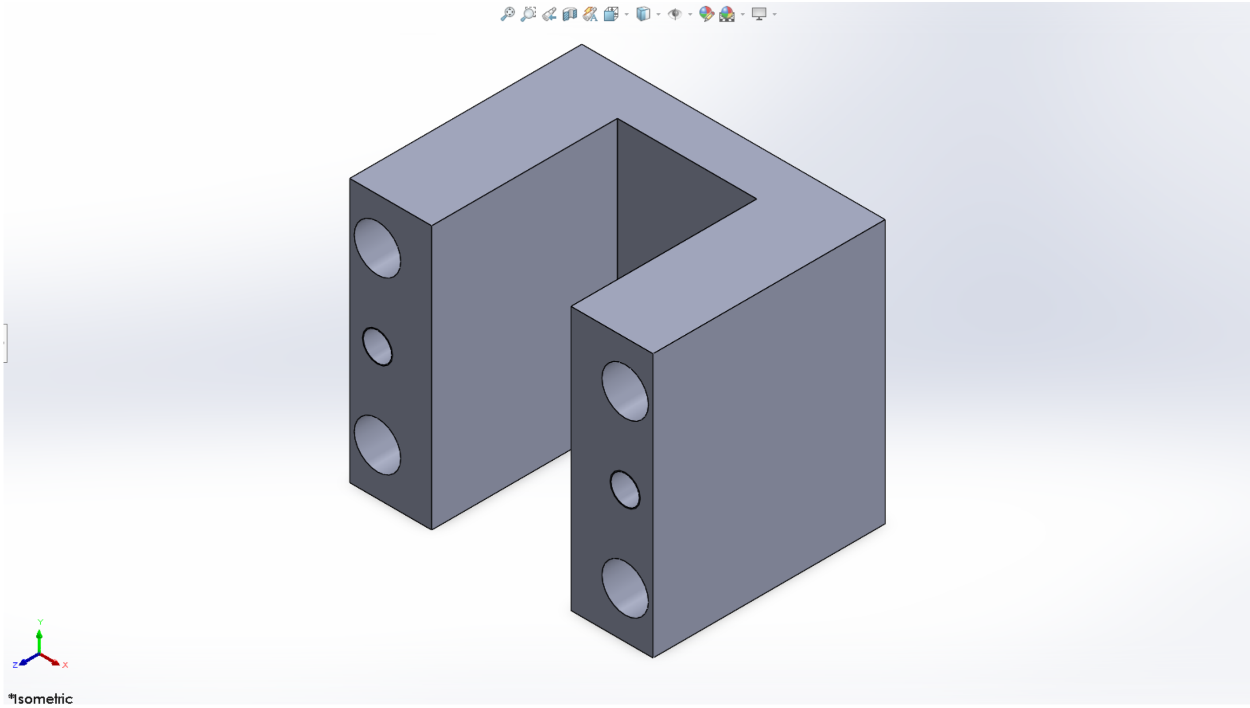

Fig 3.3 IWCEP Machine tool holder

Fig. 3.3 shows the tool holder in the IWCEP machine. Based on the tool holder, the cutting tool holder is designed and manufactured.

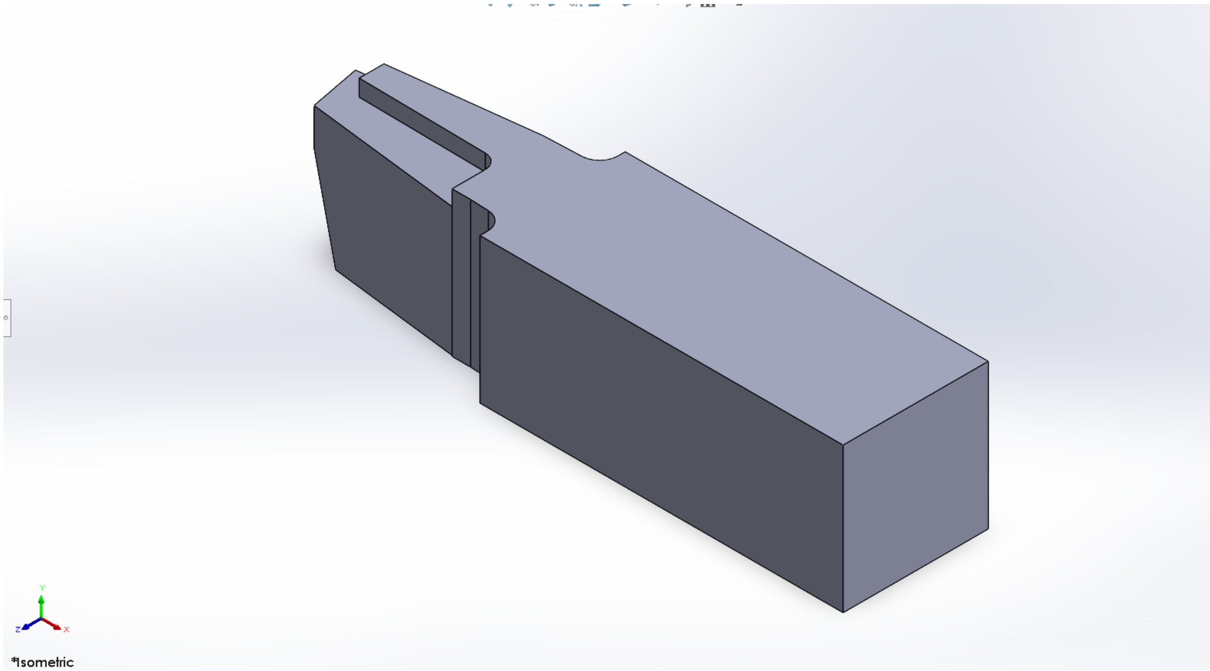

Fig 3.4 Design of Profile tool holder (LS)

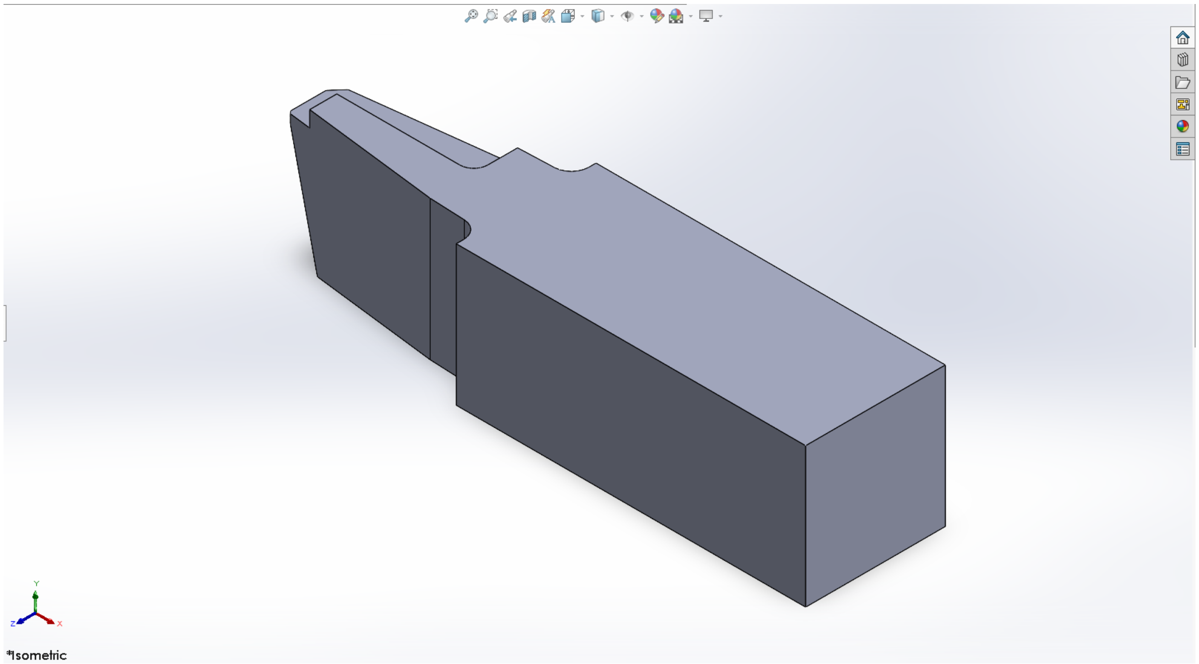

Fig 3.5 Design of Profile tool holder (RS)

3.4.2 Design of Cutting tool insert

The design of cutting tools is based on the specific material to be machined and the desired finished product. The cutting tool must be designed to be strong enough to withstand the forces of cutting, yet sharp enough to effectively remove material. The tool must also have an appropriate geometry to produce the desired surface finish and curvature. Additionally, the cutting tool must have a cutting edge that can withstand the particular cutting conditions, such as the cutting speed, feed rate, and chip load.

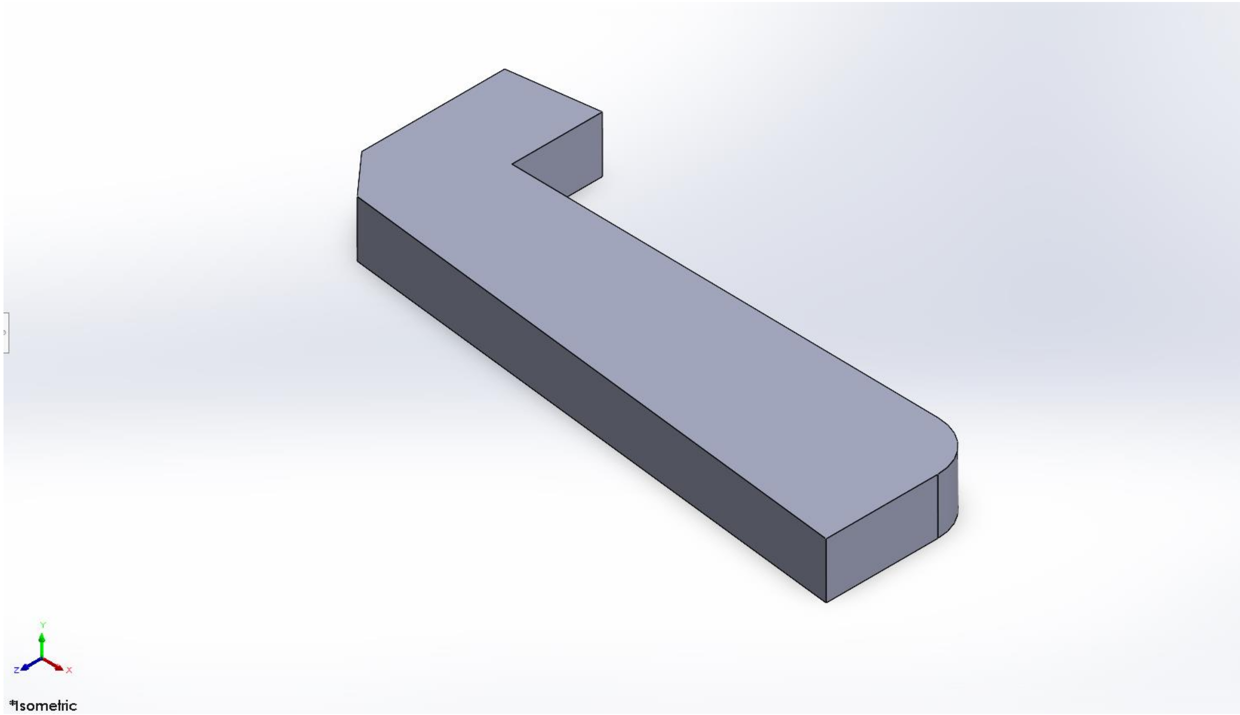

Fig 3.6 Design of Cutting tool insert (LS)

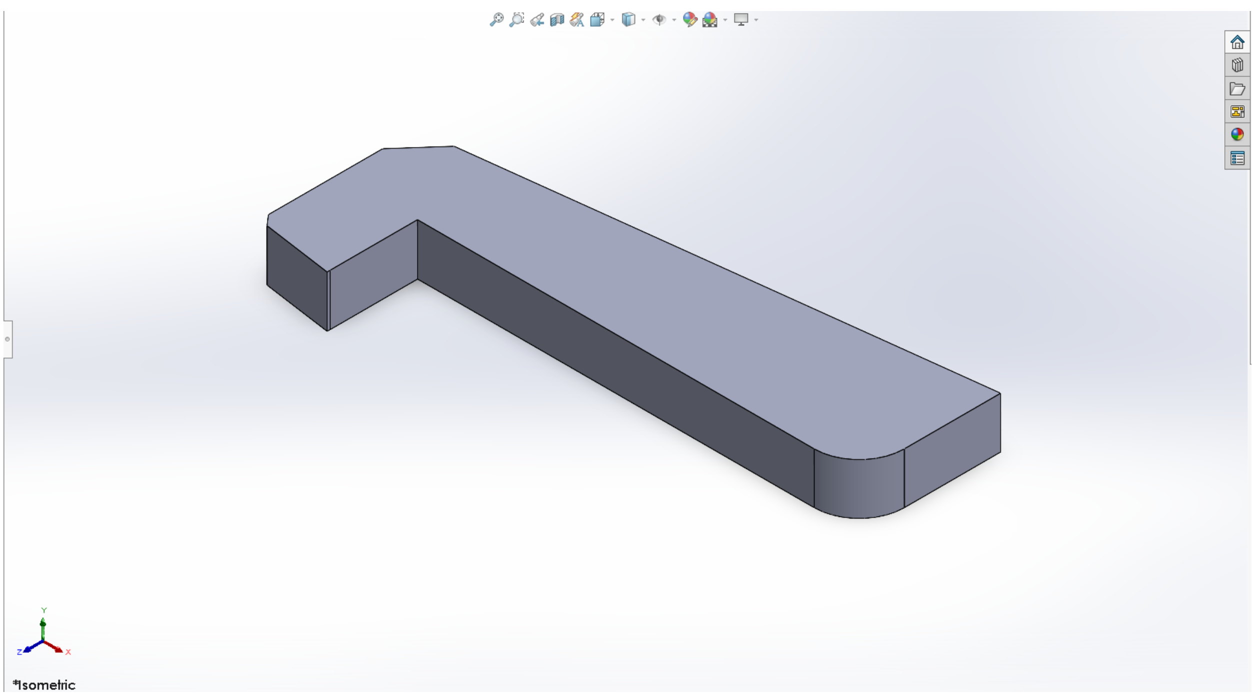

Fig 3.7 Design of Cutting tool insert (RS)

3.4.3 CAD Assembly of Profile tool holder and Cutting tool insert

CAD assembly of a profile tool holder and cutting tool insert involves creating a 3D model of the two components and using a CAD program to assemble them together. This is typically done by placing the profile tool holder into a virtual workstation, then adding the cutting tool insert into the profile tool holder. The CAD program can then be used to rotate and manipulate the components, allowing the user to view the assembly from any angle. The program can then be used to check that the components fit correctly and that there are no clearance issues. Once the assembly is complete, it can then be exported to a 3D printer or CNC machine for further production.

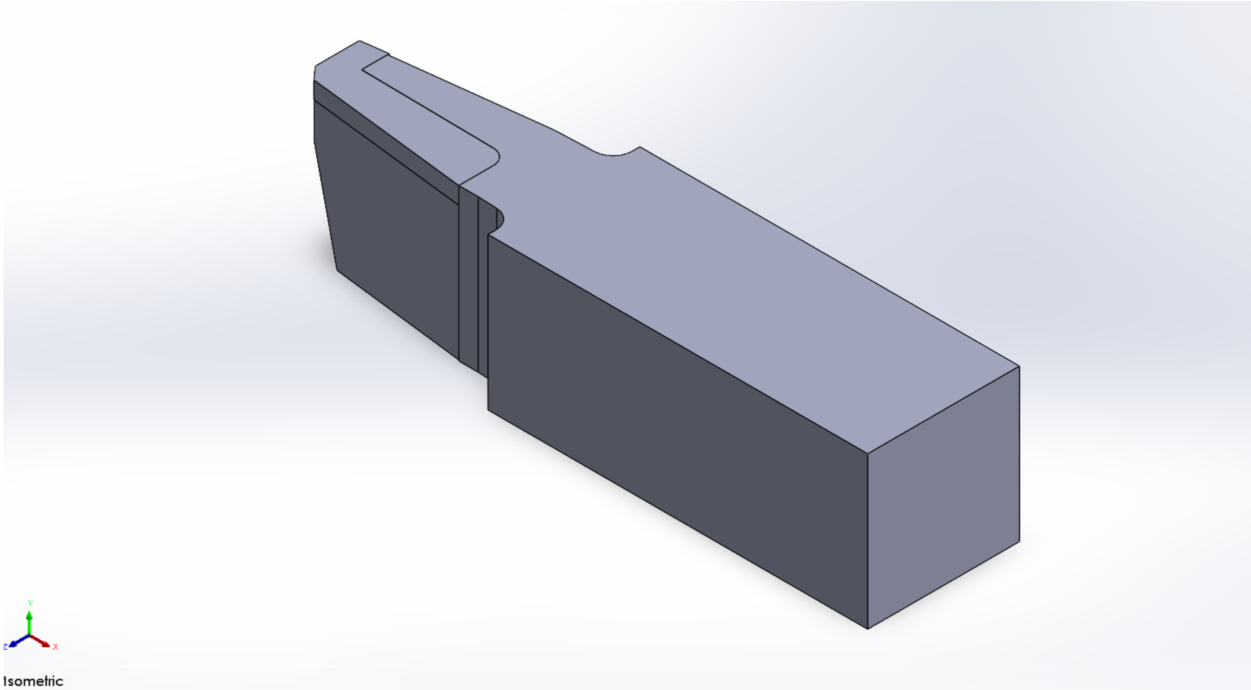

Fig 3.8 CAD Assembly of Profile tool holder and Cutting tool insert (LS)

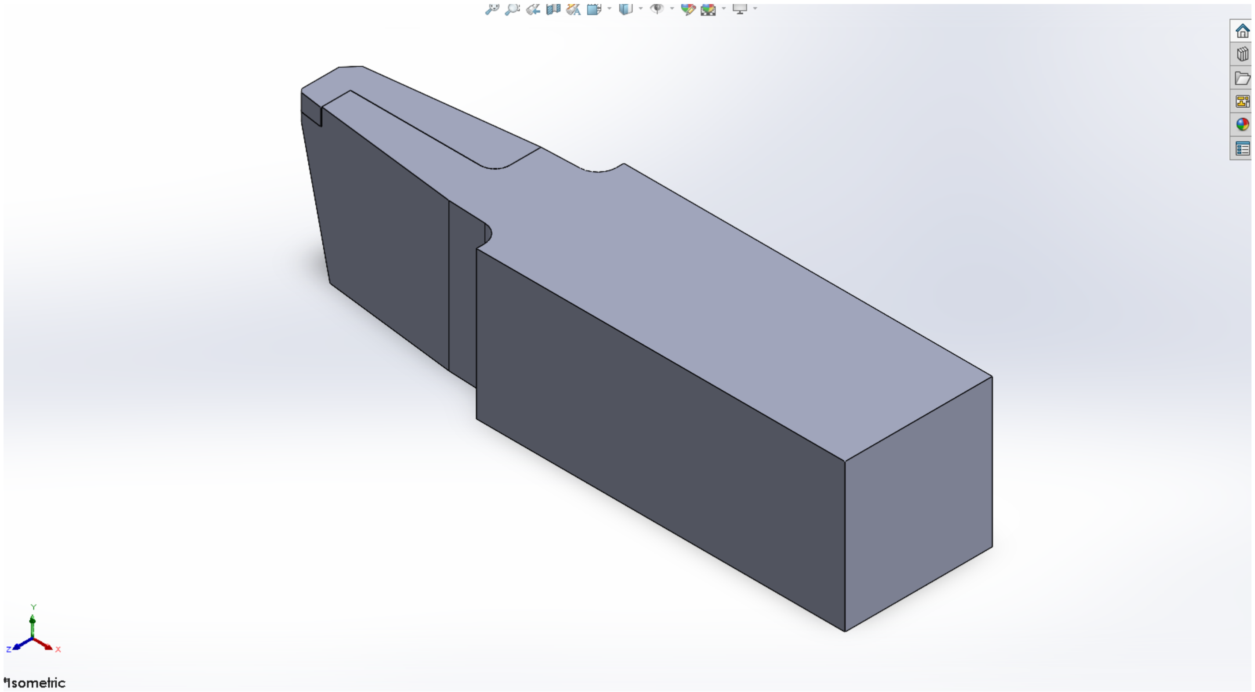

Fig 3.9 CAD Assembly of Profile tool holder and Cutting tool insert (RS)

3.5 CAM for Profile tool holder

Computer-aided manufacturing (CAM) is a type of manufacturing process that involves the use of computer software to control the production of a cutting tool holder. CAM software helps to automate processes such as generating tool paths, controlling cutting machines, and optimizing the cutting process. The process begins with the design of a cutting tool holder, which is then analyzed using CAM software to determine the necessary tool paths and cutting parameters. The software then sends instructions to the machine, which then cuts the tool holder according to the instructions. This process helps to ensure that the cutting tool holder is produced with the highest accuracy, consistency, and speed.

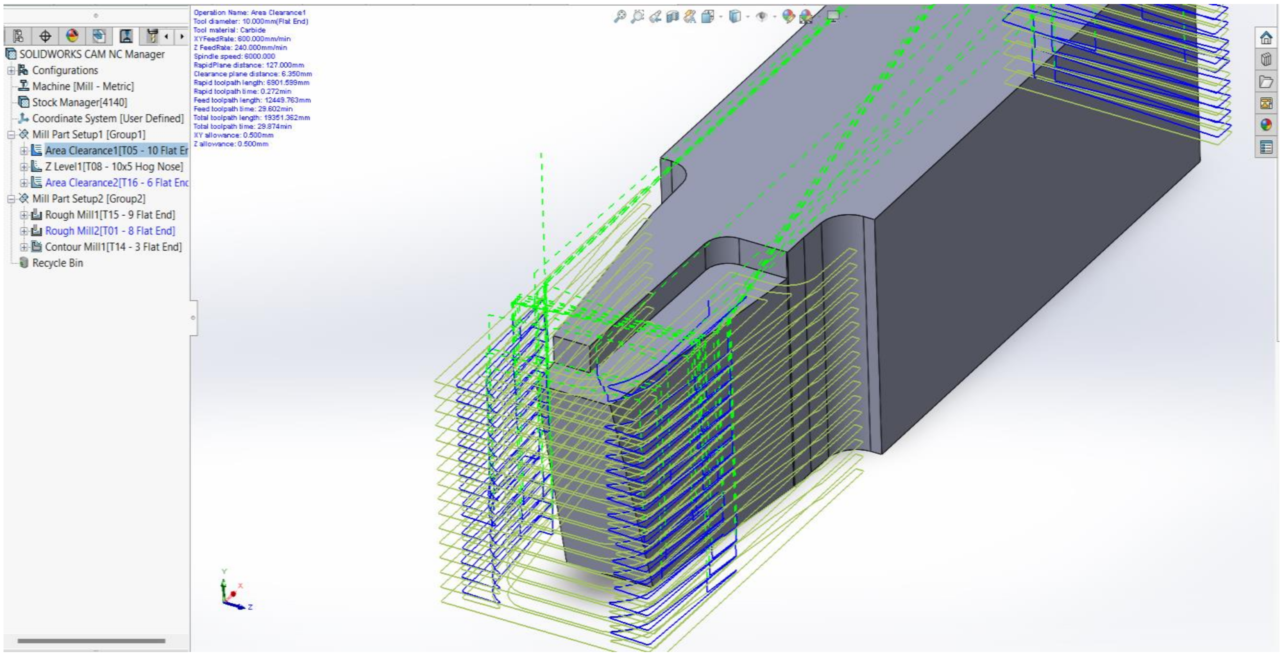

Fig 3.10 CAM for Profile tool holder

Table 3.1 Cutting parameters

Cutting speed	1100 rpm
Feed rate	0.5mm
Depth of cut	1mm

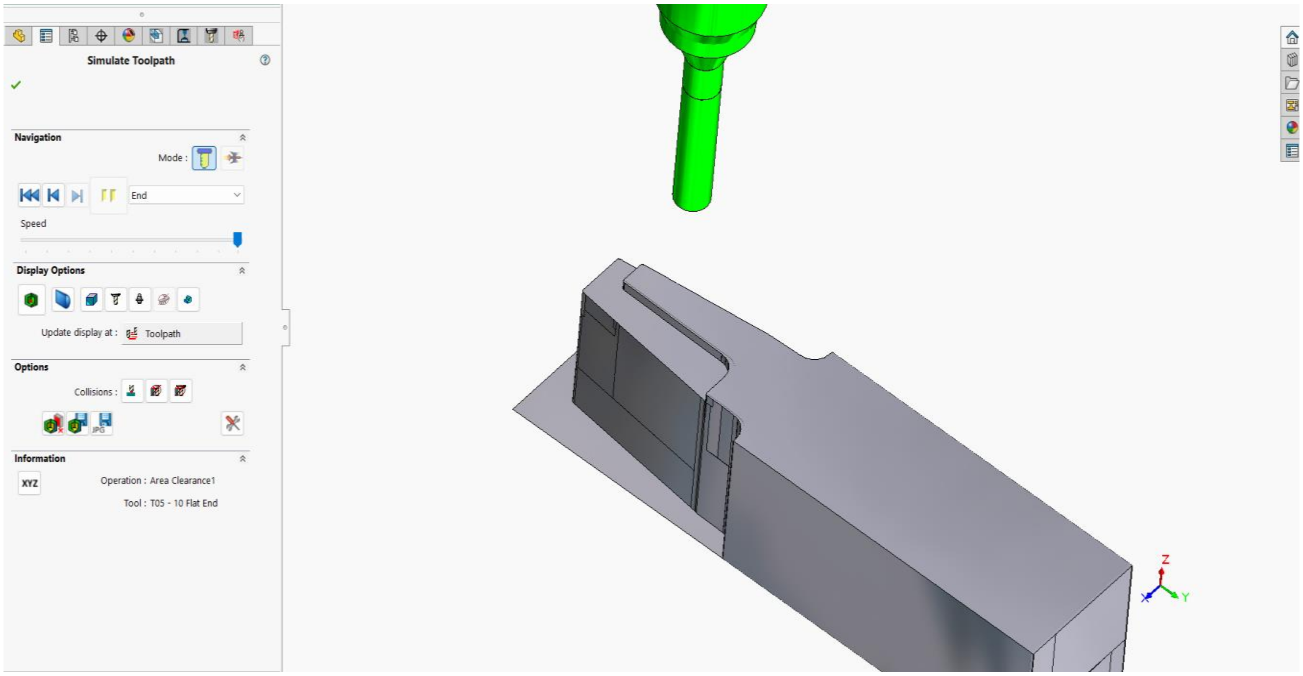

Fig 3.11 CAM Simulation of a Profile tool holder

3.6 Full Cutting Profile tool

The full cutting profile tool is the last process of machining Inconel shell and is used to plunge the full profile cutting tool into the Inconel shell for the required cutting profile.

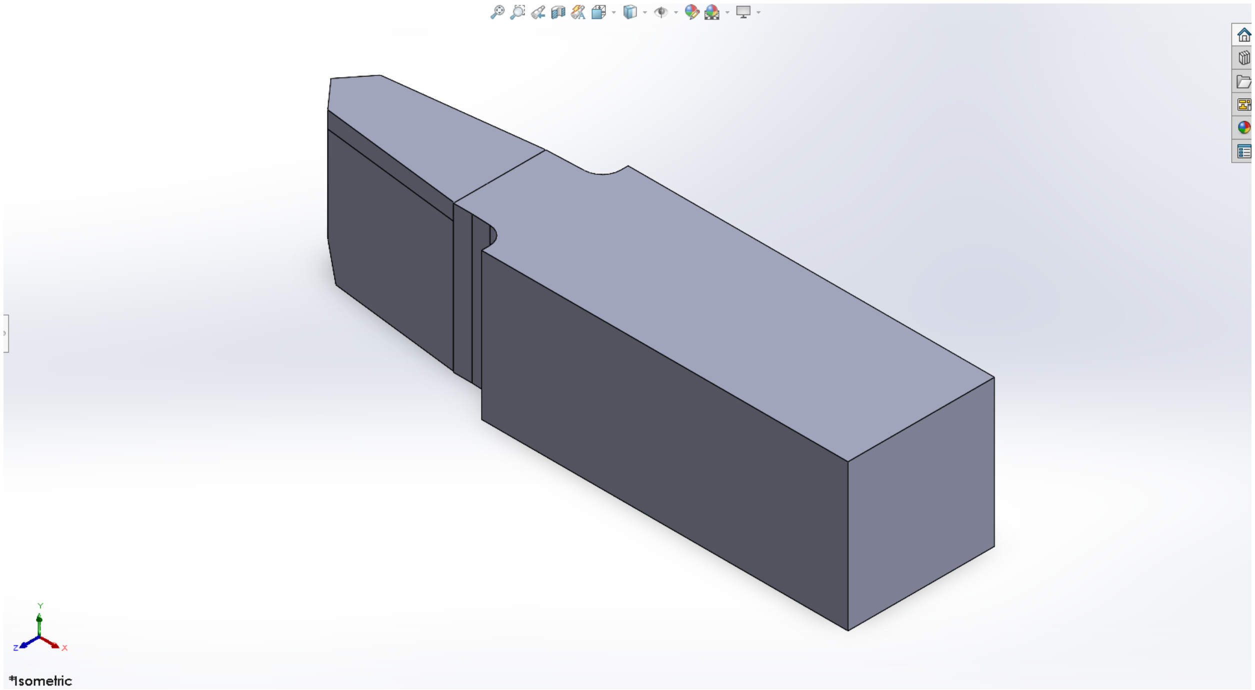

Fig 3.12 Full Cutting Profile Tool

3.7 Machining Processes

3.7.1 Process planning for manufacturing cutting tool holder and cutting tool

Based on the requirements, the below process planning is done

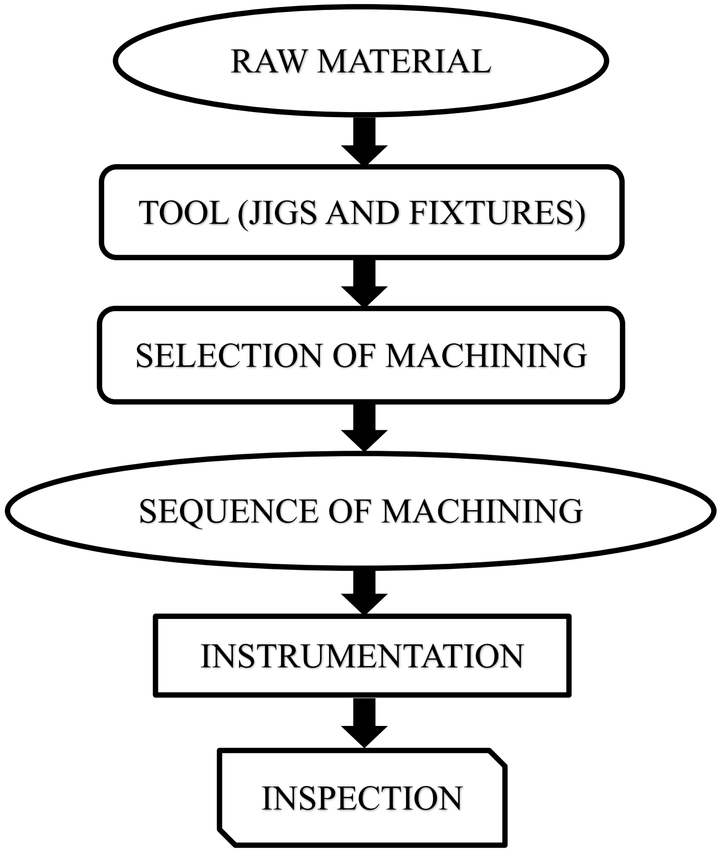

Fig 3.13 Process planning

3.8 Selection of Materials

3.8.1 EN24

EN24 is a type of cutting tool holder designed to hold and secure cutting tools in a machine tool. It is made from high-grade steel and is typically used in milling, drilling, and tapping machines, but in that case, a special cutting profile requires a tool holder designed to hold cutting tools in a machine tool. EN24 to be hardened to 45 – 50 HRC.

Fig 3.14 EN24

Table 3.2 Chemical composition of EN24

Country (Region)	Standard	Steel Grade	C	Si	Mn	P, ≤	S, ≤	Cr	Ni	Mo
Britain	BS 970-1955	En24 (En24T)	0.35-0.45	0.10-0.35	0.45-0.70	0.050	0.05	0.90-1.40	1.3-1.8	0.20-0.35
	BS 970-1991	817M40	0.36-0.44	0.10-0.40	0.45-0.70	0.035	0.04	1.00-1.40	1.3-1.7	0.20-0.35

3.8.2 Tungsten Carbide (WC)

Tungsten carbide is a chemical compound made up of equal parts tungsten and carbon atoms. It is extremely hard and has a high melting point, making it ideal for use in cutting tools and wear-resistant parts. It is used in a variety of industrial applications, including mining, drilling, and manufacturing. Due to its hardness and corrosion resistance, it is also used to make jewelry and decorative items.

Fig 3.15 Tungsten Carbide (WC)

Table 3.3 Specifications of WC

Properties	**Range**
Hardness	90 to 91 HRC
Melting Point	2,870 °C (5,200 °F)

3.9 Machines used

3.9.1 CNC Vertical Boring and Milling Machine

The BMV 50 CNC vertical boring and milling machine is a heavy-duty machine designed for machining large and heavy components. It is equipped with a CNC (Computer Numerical Control) system that can be programmed to carry out complex machining operations, such as cutting, drilling, and milling. The heavy-duty spindle can be used for both boring and milling operations simultaneously. The machine is also equipped with a variety of tooling and accessories, including a vertical head, side heads, a rotary table, and a milling head. The machine's advanced CNC system allows for precise control of the machining process, enabling it to produce high-quality parts with minimal waste. The BMV 50 CNC vertical boring and milling machine is an ideal choice for machining large and complex components.

Fig 3.16 CNC Vertical Boring and Milling Machine

Table 3.4 Specifications of CNC Vertical Boring and Milling

Required floor space	2900mm × 700mm
Net weight	9000kg
Air supply	6bar
Total connected loads	22.5 kVA
Spindle speed	2,500 rpm
Spindle Taper	BT40
Axis Travel (X-axis)	1020mm
Axis Travel (Y-axis)	510mm
Axis Travel (Z-axis)	560mm

Fig 3.17 Machining of Profile tool holder

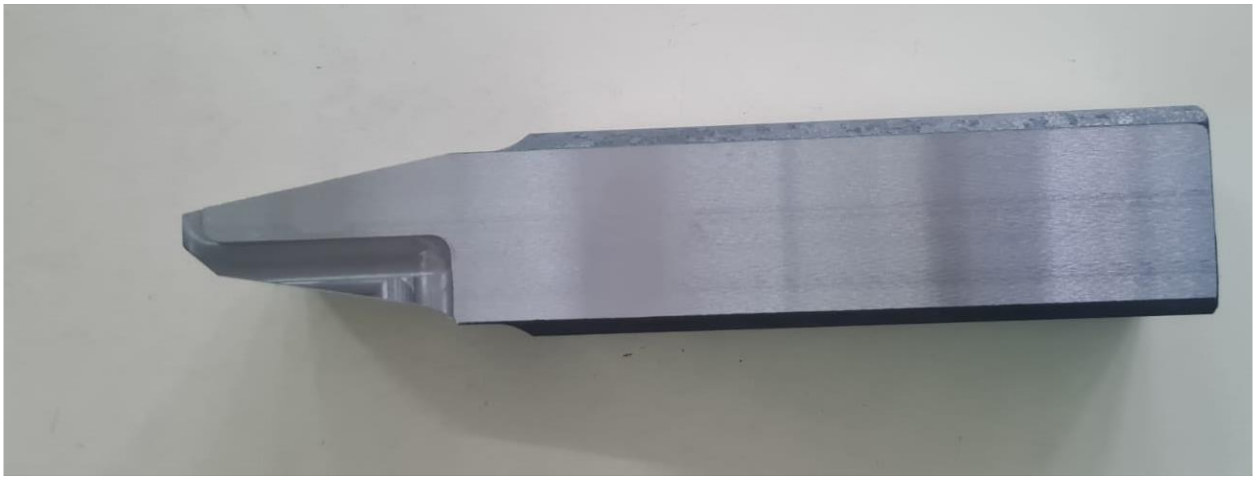

Fig 3.18 Machined EN24 Profile tool holder

3.9.2 Wire Cut EDM

Charmilles Wire EDM is a type of electrical discharge machining (EDM) process used to cut intricate, complex shapes from electrically conductive materials. It uses a thin single strand of wire that is continually fed through the workpiece, creating a spark between the wire and the material. This spark rapidly melts the material, allowing the wire to cut through it. Due to its accuracy and ability to cut complex shapes, EDM is used in a variety of industries including automotive, aerospace, medical, and tool and die.

Fig 3.19 Wire Cut EDM

Table 3.5 Specifications of Wire cut EDM

Table size	500mm × 500mm
Maximum workpiece weight	500 kg
Cutting speed	up to 3000 mm^2/min
Cutting accuracy	0.002mm
Axis travel (X axis)	500mm
Axis travel (Y axis)	500mm
Axis travel (Z axis)	300mm
Power supply	380 V

Fig 3.20 Machined WC Cutting tool insert

Fig 3.21 Assembly of Profile tool holder and cutting tool

The assembly of a cutting tool holder and cutting tool involves attaching the cutting tool to the holder in the required orientation. This is typically done using a set screw, which is tightened using a wrench or Allen key. The cutting tool can then be adjusted in the holder to the desired angle, which is often set using a gauge or dial indicator. Once the tool is securely in place, it can be locked in position using a locking screw. But in this case, the cutting tool holder and cutting tool is welded to attach with one another. Finally, the tool holder is mounted onto the machine tool spindle, and the spindle is then rotated to the desired speed.

Using the brazing process to assemble the profile tool holder and tool insert

3.10 BRAZING PROCESS

Brazing is a metal joining process that uses a filler metal to join two or more workpieces by heating them above their melting point and then flowing a filler metal between the pieces. The filler metal has a lower melting point than the workpieces, so when it melts, it bonds the pieces together. The brazing process can be performed with a variety of tools, including torches, furnaces, and induction heating. The filler metal is usually a brass, bronze, or silver-based alloy, but other metals, including aluminum, can also be used. The process is used to join a variety of metals, including steel, aluminum, copper, and brass.

Fig 3.22 ASSEMBLY OF CUTTING TOOL AFTER BRAZING

3.11 Testing

Testing the cutting tool by fixing it into the IWCEP machine holder and machining the Inconel used the left side profile tool. During machining, the profile tool had chip flow interference because of chip clogging in the side clearance. As a result of chip clogging, tool chatter occurred, so the design had to be updated to change the side clearance angle from 7^0 to 9^0, and then because of noises in the machine caused by the cutting tool, the depth of cut also changed from 0.1mm to 50 microns.

Table 3.6 Cutting parameters

Cutting speed	10 to 15 rpm
Feed rate	0.1mm/rev
Depth of cut	0.1mm

Fig 3.23 IWCEP Machine

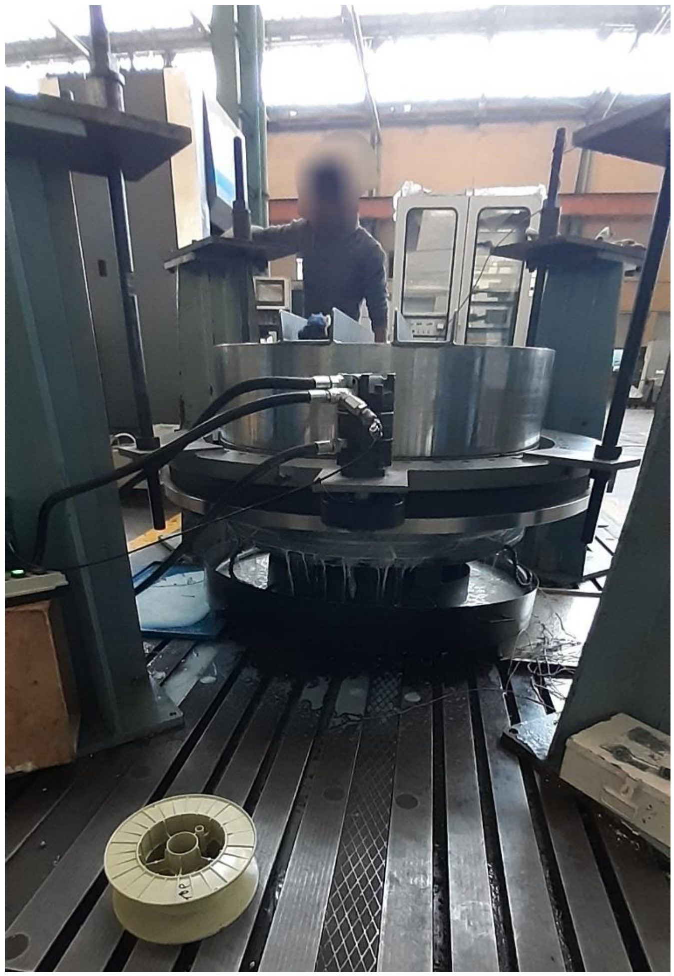

Fig 3.24 Machining Inconel shell

Fig 3.25 Machining profile on the Inconel shell

Fig 3.26 Cutting Profile

Fig 3.27 Before machining

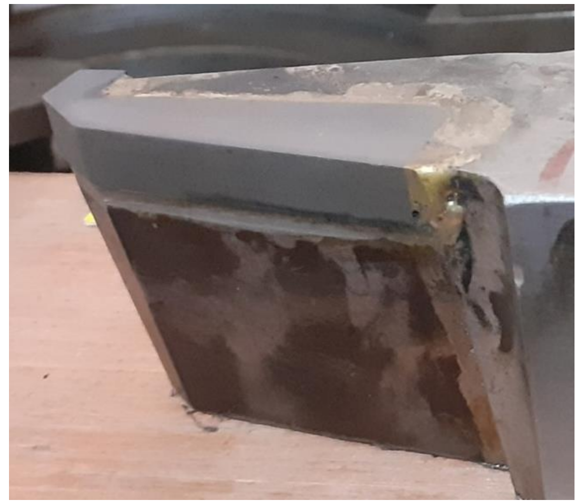

Fig 3.28 After machining

Chip clogging is a major issue in cutting tool manufacturing. It occurs when chips generated during the machining process become stuck in the cutting tool, reducing its effectiveness and leading to a decrease in the quality of the cut. The result of chip clogging is increased tool wear, reduced cutting speeds, and higher cutting forces, all of which can lead to poor surface finish, poor dimensional accuracy, and even tool breakage. To prevent this from occurring, manufacturers must ensure that the cutting tool has a chip breaker designed to reduce chip clogging. This involves optimizing the cutting tool design to ensure that chips can escape easily and quickly, minimizing the likelihood of clogging. Additionally, manufacturers must also consider the materials being used, the cutting parameters, and the coolant to maximize the effectiveness of the chip breaker. By taking all of these factors into consideration, manufacturers can ensure that the cutting tool is able to remain effective and efficient over time, without the risk of clogging. Because chip clogging and noises occur during machining, the cutting tool side clearance angle and machining parameters are to be changed.

Changed side clearance angle- 7^0 to 9^0 and

Changed machining parameter- 0.1mm to 50microns

3.12 Calculations of Cutting Velocity and Force

Cutting velocity, $V_c = \frac{\pi DN}{1000}$

D- Diameter of the workpiece

D= 1500mm

N- Spindle speed

$V_c = \frac{3.14 \times 1500 \times 13}{1000}$

V_c=61.23m/min

Force acting on the cutting tool, $F = \frac{2\pi N}{60}$

N- Spindle speed

N= 13rpm

$F = \frac{2 \times 3.14 \times 13}{60}$

F= 1.36 N

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Static Analysis

Static analysis of a cutting tool in design software is the process of running a simulation to determine how a cutting tool will behave in a given situation. It involves analyzing the forces, stresses, and deformations that occur while the tool is cutting a material. The analysis can help determine the optimum cutting parameters and help identify areas of potential failure or instability. It can also help to identify the best material for the tool, as well as the best cutting speeds and feeds. The results of the static analysis can be used to improve the design and performance of the cutting tool.

Name	Type	Min	Max
Stress1	VON: von Mises Stress	1.539e-01N/m^2 Node: 13608	1.495e+04N/m^2 Node: 6856

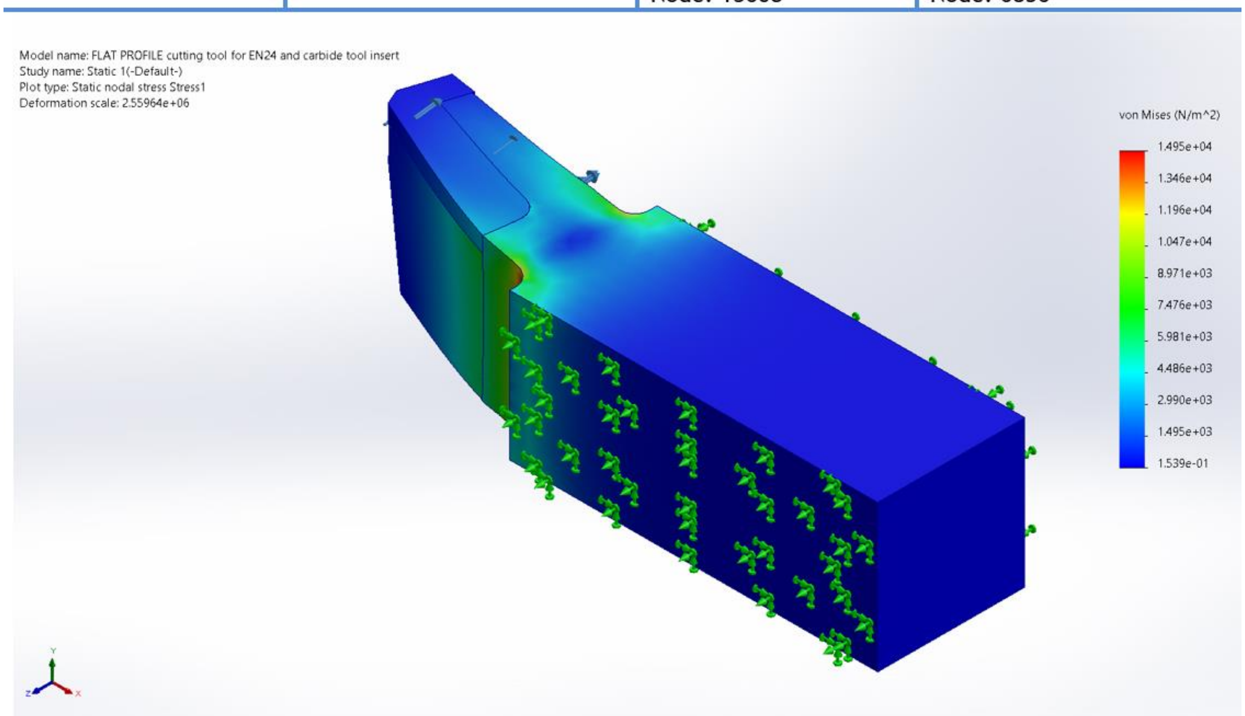

Fig 4.1 Stress (Load-1.36N)

Cutting tool stress is the strain placed on a cutting tool as it cuts through a material. It is caused by the high temperatures and pressures that result from the friction between the cutting tool and the workpiece, as well as the force of gravity. Cutting tool stress can cause the cutting tool to wear down prematurely, leading to poor performance and reduced cutting quality. It can also cause fractures and other damage to the cutting tool. To reduce cutting tool stress, proper cutting tool design, cutting speed, and feed rate should be used.

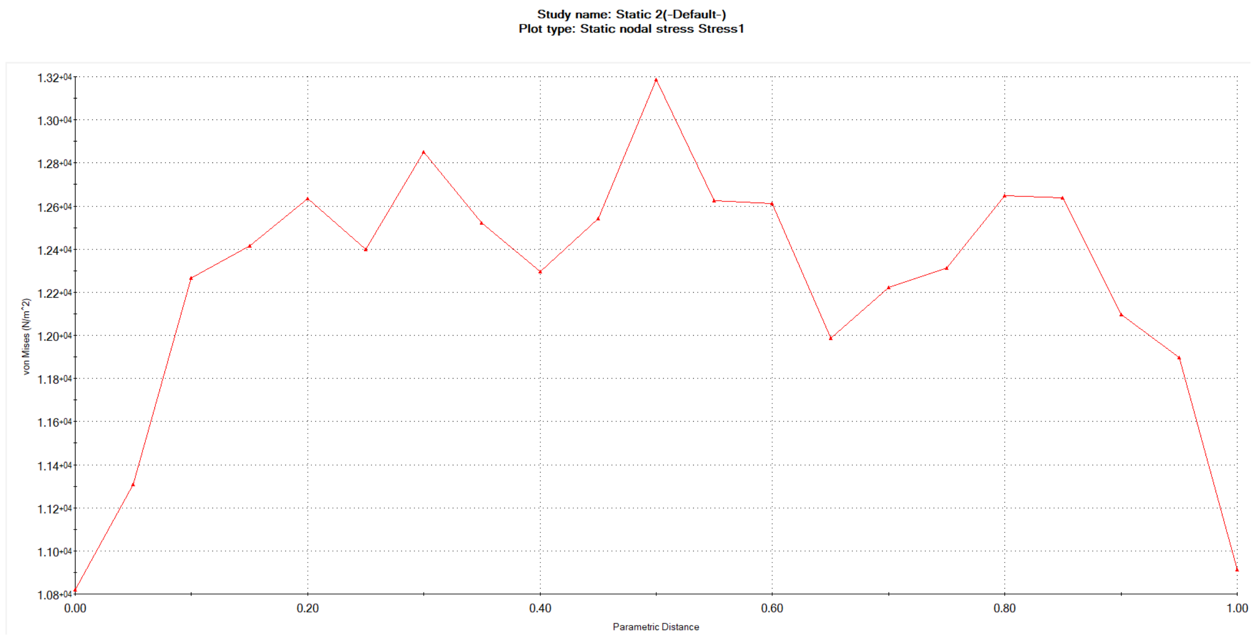

Fig 4.2 Parametric Distance vs Von mises

The graph of parametric distance vs Von Mises for stress of a cutting tool shows the relationship between the distance travelled by the cutting tool across a work piece and the Von Mises stress exerted on the cutting tool. As the distance travelled by the cutting tool increases, the Von Mises stress also increases. This is because the cutting tool has to exert more force to cut through the material, resulting in more stress being applied to the tool. The graph shows that the Von Mises stress increases rapidly as the distance travelled by the cutting tool increases, indicating a linear relationship between the two parameters.

Name	Type	Min	Max
Displacement1	URES: Resultant Displacement	0.000e+00mm Node: 8	6.347e-06mm Node: 15633

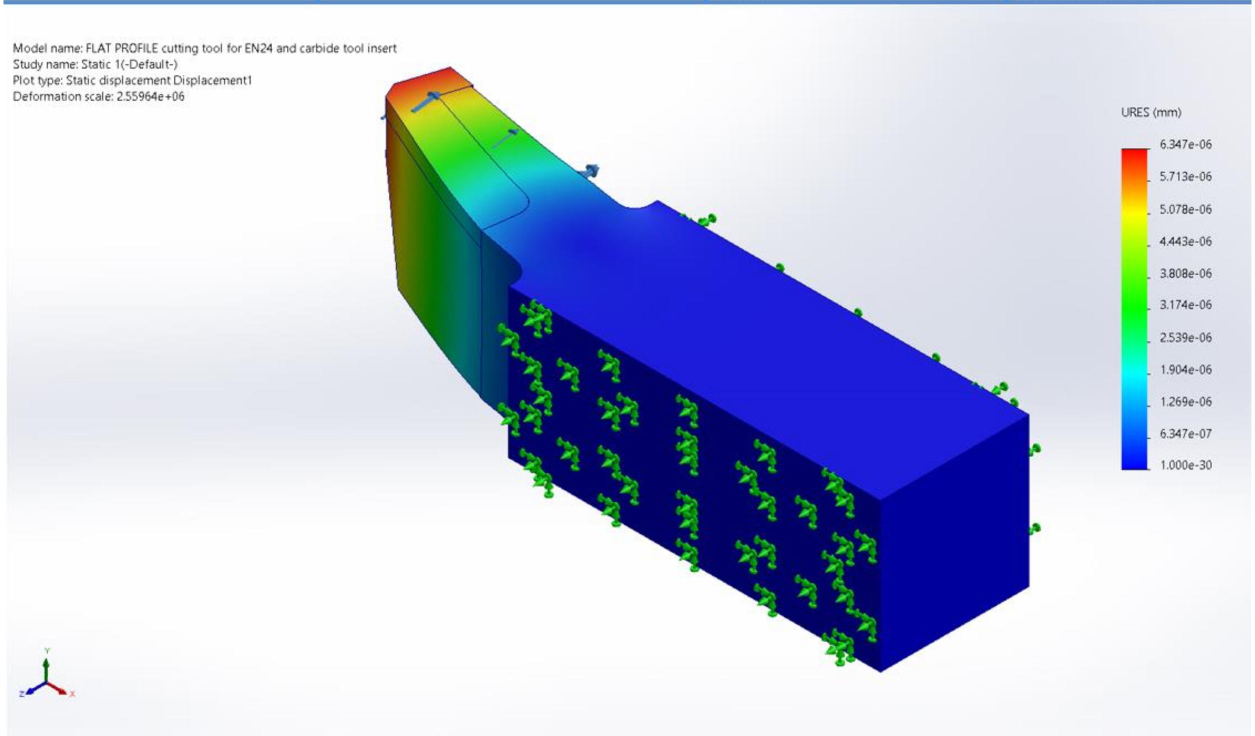

Fig 4.3 Displacement (Load-1.36N)

Displacement refers to the movement of a cutting tool away from its original position. This can occur due to a variety of factors, including vibration, tool deflection, and the cutting forces that are generated during the machining process. Displacement can cause an increase in cutting forces, which can lead to poor surface finish, tool wear, and decreased tool life. To prevent this, careful selection of machine tool and cutting parameters, as well as regular maintenance, is essential.

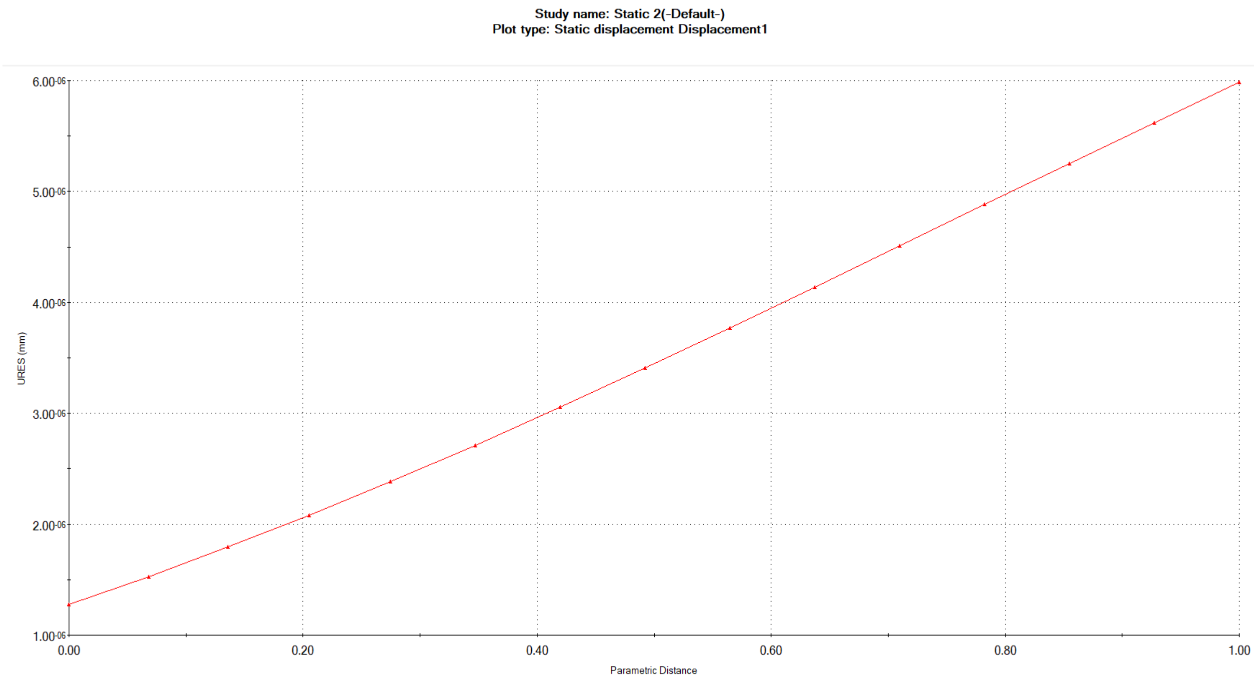

Fig 4.4 Parametric distance vs URES

The graph of parametric distance vs URES for displacement of cutting tool shows the relationship between the two variables. The parametric distance is the distance the cutting tool has moved relative to its starting position, while the URES (Uniformly Rated Error) is the error in the displacement of the cutting tool. As the parametric distance increases, the URES also increases, indicating that as the cutting tool moves further away from its initial position, the likelihood of error increases.

Name	Type	Min	Max
Strain1	ESTRN: Equivalent Strain	1.905e-12 Element: 4445	5.180e-08 Element: 2202

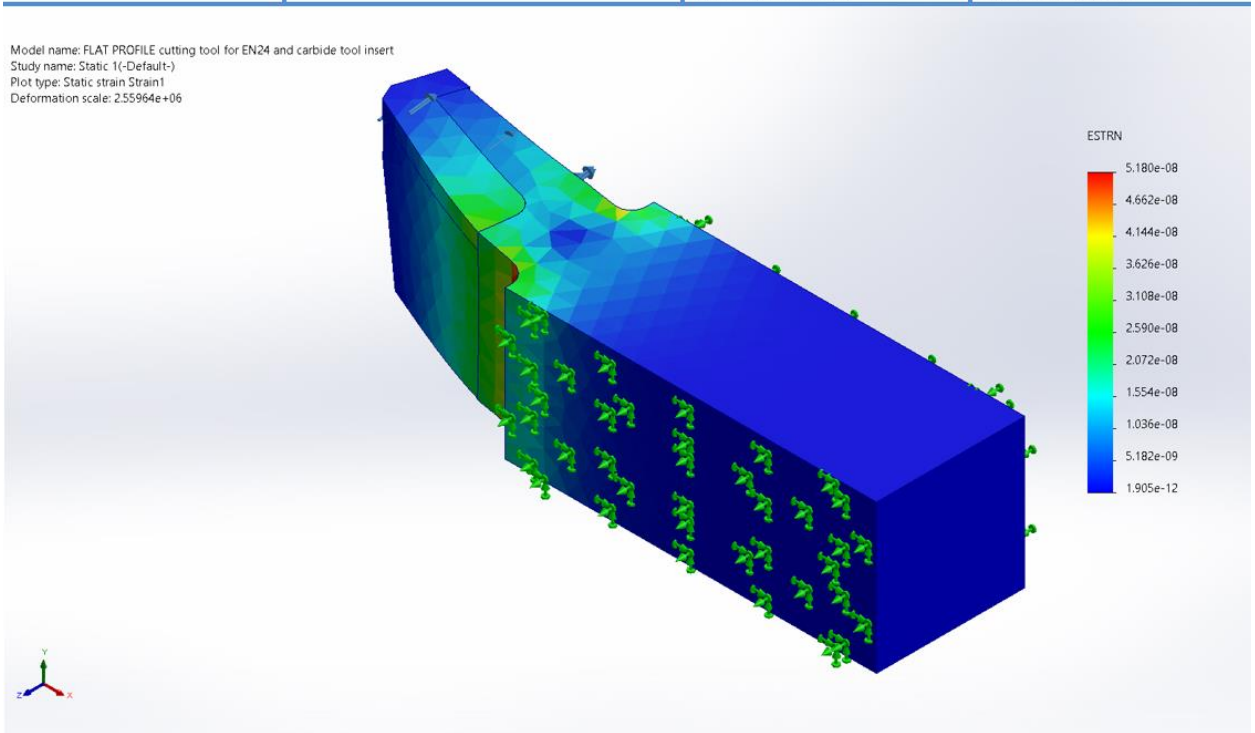

Fig 4.5 Strain (Load-1.36N)

The strain in the cutting tool is the amount of stress that the tool is subjected to during the cutting process. It is caused by the forces acting on the tool from the workpiece, such as the cutting force, friction, and vibration. The strain can be caused by the tool material being too hard or too soft, the cutting speed being too slow or too fast, the feed rate being too low or too high, and the tool being improperly sharpened or worn. This strain can lead to premature tool failure, reduced cutting performance, and poor surface finish.

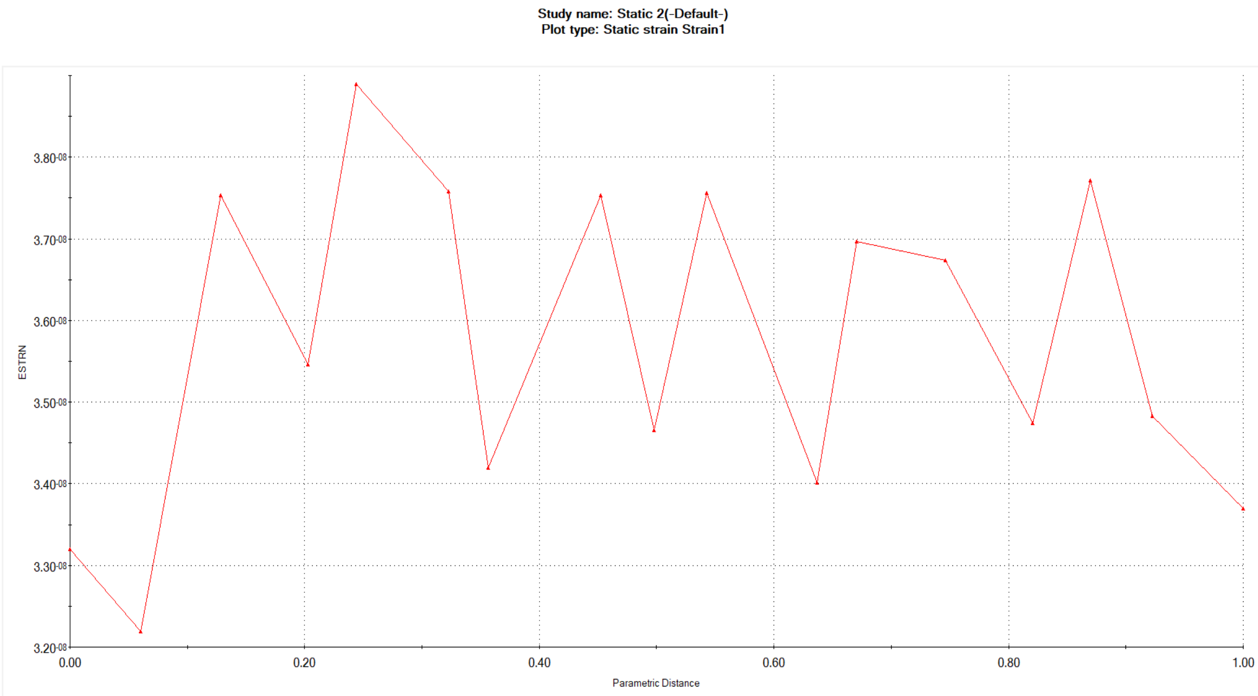

Fig 4.6 Parametric distance vs ESTRN

The graph of parametric distance vs ESTRN for strain of cutting tool shows how the amount of strain on a cutting tool increases as the parametric distance between the cutting tool and the workpiece increases. As the parametric distance increases, the strain on the cutting tool increases and reaches a peak, before decreasing as the parametric distance continues to increase. This is because the cutting tool is being pushed away from the workpiece as the parametric distance increases, leading to increased strain. The graph also shows that the strain on the cutting tool decreases as the parametric distance decreases, indicating that the cutting tool is being pulled closer to the workpiece as the parametric distance decreases.

4.2 Analysis of Stress, Displacement, Strain

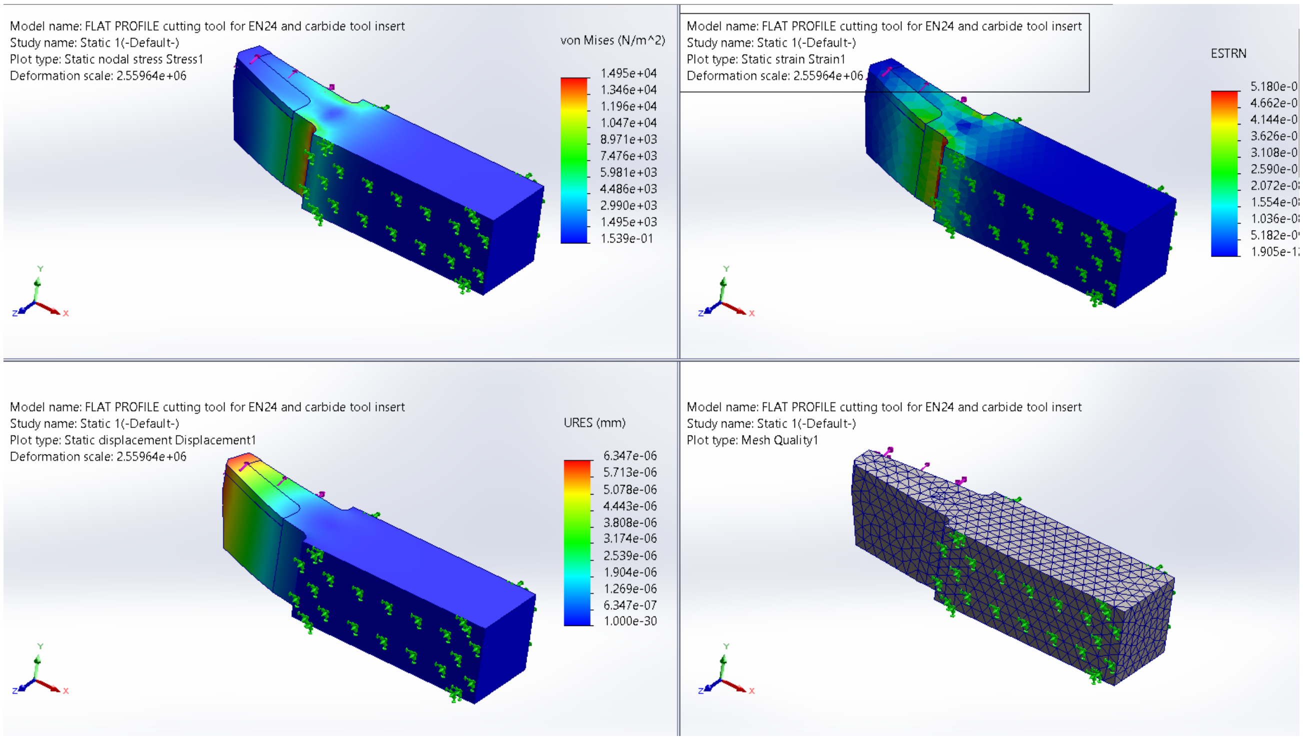

Fig 4.7 Analysis of Stress, Displacement, Strain

Stress, displacement, and strain analysis are three related but distinct types of analysis used to assess the properties of a material or structure. Stress analysis is the study of how forces affect objects and materials, and how those objects and materials respond to those forces. Displacement analysis examines how displacement occurs in a material or structure when it is subject to external loads. Finally, strain analysis is concerned with the behavior of a material or structure under the application of force, specifically how it stretches or deforms. All three analyses are used to evaluate the strength and durability of a material or structure.

4.3 Result

The design and manufacturing of cutting tools for machining profile on Inconel shell is a complex process that requires careful planning and execution. The cutting tool must be designed based on the specific parameters of the Inconel shell, such as thickness, hardness, and shape of the profile. The tool must also be designed to be able to withstand the heat generated by the cutting process. Once the design has been completed, the tool must be manufactured to exact specifications in order to ensure that it performs its intended function. The manufacturing process typically involves machining, heat treating, grinding, and polishing. The result of the design and manufacturing process is a cutting tool that is able to produce a precise profile on the Inconel shell with minimal wear. But in this cutting tool, the chip clogging occurs, and because of the clogging, the side clearance angle must be changed in another design.

4.4 Discussion

The design and manufacturing of a cutting tool for machining profiles on Inconel shells requires careful consideration and planning. The tool must be designed to be able to withstand the high temperatures and forces associated with machining Inconel. This includes considering the type of cutting tool material, the geometry of the cutting tool, the cutting speed, the feed rate, and the depth of cut. The tool must also be designed to reduce cutting forces and vibrations in order to prevent damage to the Inconel shell. Additionally, the cutting tool must be manufactured to precise tolerances in order to ensure the highest quality of machining. Finally, the tool must be tested and inspected to ensure that it meets all of the required specifications. But the cutting tool had two problems during machining, there are chip clogging and noises occurred because of chip flow interference and feed rate.

CHAPTER 5

CONCLUSION

The design and manufacturing of the cutting tool for machining the profile on the inconel shell have been completed. The cutting tool was designed based on the requirements of the machining process and the material of the shell. The cutting tool was manufactured using CNC machining techniques, and the results of the machining tests showed chip clogging in the cutting tool and noises occurring in the machine because of that side clearance angle and cutting parameters must be changed. But the cutting tool offers a long service life, good cutting performance, and a low wear rate. It is expected that the cutting tool will provide satisfactory performance in the production machining of the inconel shell.

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