DESIGN ANALYSIS OF MULTI POINT CUTTING TOOL WITH VARIOUS DEPTH PARAMETERS USING TAGUCHI METHODS

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Abstract

Multi point cutting tool is most widely used tool in several machining and metal cutting operations. The work piece material is removed or machined step by step by force which increases temperatures of both work piece and tool Itself. Where it causes in thermal damage and high tool wear rate. The tool tip may deform plastically due to high temperature which results in poor accuracy in machining. The modelling is carried out in NX 12.0 The analysis is done using ANSYS 2024 R1 (Inconel 718, SS 304, H30) to find the total deformation stress and strain to optimized Taguchi methods using different depth parameters 0.1 mm, 0.2 mm, 0.3 mm, respectively a multi stroke to be used for the cutting operation The input of the model consists of feed rate, cutting speed and depth of the cut while the output from the model. The optimization of the tool life is studied to compare the relationship of the parameters involved.

Key words: Multi point cutting tool, ANSYS 2024 R21, Taguchi methods, Inconel 718, SS 304, H30 materials

1.0 INTRODUCTION

Machining, the most widespread process for shaping metal, has become a very significant aspect of modern society and industry. The importance of the machining process is evident by the observation that nearly every device used by humanity in day-to-day life has at least one machined part or surface. From a materials viewpoint, high speed machining is a relative term, since different materials should be machined with different cutting speeds to insure acceptable tool life. Because of this difference and the fact that cutting speed determines whether a material will form continuous or segmented chips, one way to define high-speed machining is to relate it to the chip formation mechanism. Machining is a common fabrication technique where material removed from a part using a tool with a small, hard tip. Usually, the material being cut is a metal, such as aluminum or steel. In order to fabricate a part quickly, a high cutting speed desired. These higher speeds, however, lead to a faster degradation of the tool tip, which requires that the tool tip replaced more frequently. Over the history of machining, guidelines and conventions have arisen based on empirical information of trade-offs between cutting speed and tool replacement time. Machining is a term covering a large collection of manufacturing processes designed to remove material from a work piece

Multi-point cutting tool

A multi-point cutting tool is a type of cutting tool used in machining and metalworking processes. Unlike multi-point cutting tools, which have only one cutting edge, multi-point cutting tools have multiple cutting edges. These cutting edges are designed to remove material from the workpiece efficiently and accurately. Multi-point cutting tools are preferred in many metalworking applications because they can remove material faster and with higher precision compared to multi-point cutting tools. They are essential in shaping, drilling, and finishing operations in industries like manufacturing and engineering.

Advantages Of Multi Point Cutting Tool

The advantages of using multi-point cutting tools in machining and metalworking processes are as follows:

Higher Material Removal Rate: Multi-point cutting tools have multiple cutting edges, allowing them to remove material from the workpiece at a faster rate compared to multi-point cutting tools.

Improved Efficiency*: Due to the multiple cutting edges, these tools can perform machining operations more efficiently, reducing the time required to complete a task.

Enhanced Tool Life*: With multiple cutting edges sharing the cutting load, the wear on each edge is reduced, leading to a longer tool life compared to multi-point cutting tools.

Improved Surface Finish*: Multi-point cutting tools can achieve a better surface finish on the workpiece due to their ability to distribute cutting forces more evenly.

Versatility: These tools can be used for a wide range of machining operations, including milling, drilling, and shaping, making them versatile in various metalworking applications.

Cost-Effective: While initial costs may be higher than multi-point cutting tools, the increased efficiency, tool life, and quality of work produced by multi-point cutting tools often lead to cost savings in the long run.

Overall, multi-point cutting tools offer efficiency, precision, and versatility in metalworking processes, making them a preferred choice in many industrial applications.

Applications Of Multi Point Cutting Tool

Multi-point cutting tools find applications in various machining and metalworking processes across different industries. Here are some common applications of multi-point cutting tools:

- **Milling*:** Multi-point cutting tools, such as milling cutters, are widely used in milling operations to remove material from a workpiece. They are essential for tasks like face milling, profile milling, and slotting.
- **Drilling:** Drill bits are multi-point cutting tools used for creating holes in a workpiece. They come in various types, including twist drills, center drills, and indexable insert drills, to suit different drilling requirements.
- **Turning:** In turning operations, multi-point cutting tools like indexable carbide inserts are used to remove material from a rotating workpiece. They are crucial for processes like rough turning, finish turning, and threading.
- **Broaching:** Broaches are multi-point cutting tools used to shape or finish holes in a workpiece. They are commonly used in operations like keyway cutting and gear cutting.
- **Reaming*:** Reamers are multi-point cutting tools used to finish and size existing drilled holes accurately. They provide a smooth surface finish and ensure the hole meets specific dimensional requirements.
- **Gear Cutting*:** Multi-point cutting tools are essential for gear cutting processes, including hobbing and gear shaping. They help create precise gear teeth profiles and ensure proper meshing of gears.

- **Thread Cutting*:** Tap and die sets are examples of multi-point cutting tools

Objectives:

- To study the multi point cutting tool
- To design the multi point cutting tool using NX 12.0 and analyse the structural analysis using ANSYS 2024 r1
- To optimize the Taguchi methods using mini tab software various factors (Depth of cut and spindle speed, feed rate)
- To compare the results of the three materials with respect to their better performance.

2.0 LITERATURE REVIEW

The primary problem that metal-cutting companies face is the requirement to improve manufacturing quality while also lowering production costs. Other factors like as lubricants and coatings affect both the quality and the price of the finished product depending on how the cutting parameters are set up as well as the wear and tear on the tooling.

Abdullah, K.; Ulvi, S. [1] developed a turning process surface roughness prediction knowledge-based system. This project necessitated the usage of fuzzy set theory and neural networks. Set theory that is a bit fuzzy Surface roughness can be predicted using process variables. the authors constructed a rule that also predicts process variables for known surface roughness. **Abukhshim N.A., Mativenga [2]** in their research, they focus on micromachining, namely metals micro-milling and the study of micro-cutting in this context. Tools having a diameter of less than 1 mm and a resolution of 0. 05 mm are used in micro-milling. Due to manufacturing issues, these tools do not have the same complicated and sharp geometries as traditional tools. **NBV Lakshmi Kumari [3]** examined the field's prior research. It's vital to do research on how orthogonal machining affects heat generation and dissipation. Detection methods for metal-slicing temperature were also investigated. This research looked at the outcomes of high-speed cutting tests on high-strength alloys using a thermal imaging camera. At long last, the most recent findings in this field of metal machining were also investigated. They investigated temperature measurement techniques, models for forecasting cutting temperature and temperature distribution using analytical and numerical methods are also available. **G. V. R. Seshagiri Rao, M.H. Mahajan et al. [4]** both a primary heat zone (shear zone) and a secondary heat zone were investigated (tool chip interface zone). This system differs from the previous one in that it uses particle swarm optimization (PSO) to determine ideal cutting temperatures. **A. Nagarajan, T. S. Sangeetha, et al [5]** created the methods needed to get the best process parameters for predicting Al turning's surface roughness before it actually occurs. Logarithmic data transformation was used to create an empirical model using nonlinear regression. With only a few slight inaccuracies, the model produced satisfactory outcomes. According to the findings, a low feed rate was effective in reducing surface roughness, whereas a high feed rate produced high surface quality in the experimental setting. **Nitin M Mali, T. Mahender et al. [6]** has investigated silicon nitride machining in the ductile regime. It is necessary to carry out machinability tests with cut depths that range from 250 nano metres to ten micro metres. Silicon nitride's mechanical behaviour is studied using the Drucker-Prager yield criterion, which is implemented in the software Advantage. **Vijay Kumar Patel, Gopal Sahu et al [7]** For turning operations, empirical models of tool life, surface roughness, and cutting force have been developed. Cutting speed, feed, cutting depth, and nose radius were all considered when creating the mach inability model. RSM and neural networks were used to build these models, respectively (NN). **Maheshwari N Patil, et al [8]** increasing the information of the thermo-mechanical phenomena that occur in metal cutting is necessary for its progress in the future." The poor geographical and temporal resolution of standard measurement equipment makes it difficult to gather this knowledge through experimental experiments. In addition, it is unable to measure important parameters such as stresses and strains for the optimization of the processing. **S. H. Rathod, Mohd. Razik et al. [9]** Carbide cutting inserts were used in metal cutting operations to look into the relationship between tool flank wear and operational conditions. Authors made use of an empirical model and cutting mechanics simulation to forecast tool flank wear. In comparison to cutting speed, feed rate had a smaller impact on tool lifespan. **Vivek Varia, Prof. Jegadeeshwaran et al. [10]** showed how to monitor the wear on a turning tool online. Spindle-motor measurements, such as power and temperature, were selected as inputs to the monitoring system. There were two HMM methodologies used to determine tool wear: the Bar-graph Method and the Multiple Modelling Methods.

3.0 RESEARCH METHODOLOGY

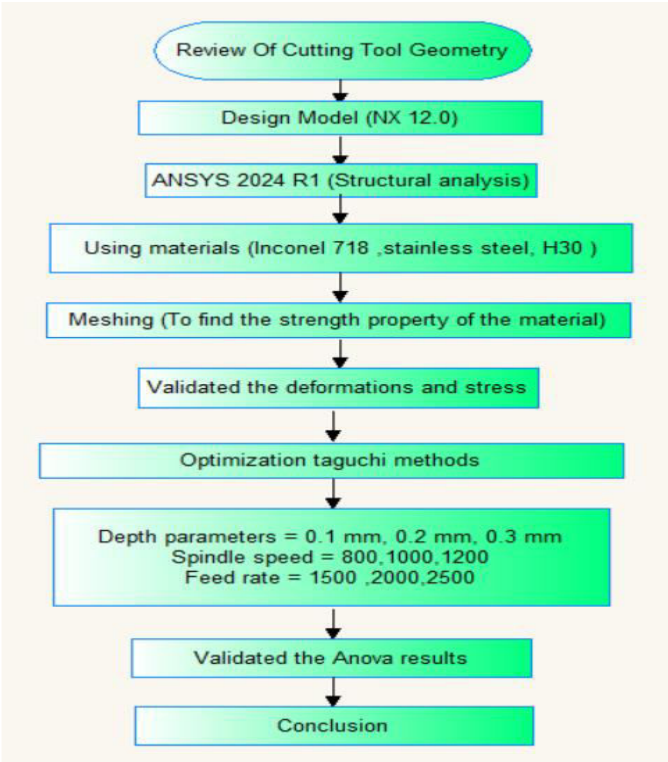


Figure: Design flow chart

Working Principal of Multi Point Cutting Tool

Milling is the process of removing extra material from the work piece with a rotating multi-point cutting tool, called milling cutter. The machine tool employed for milling is called milling machine. Milling machines are basically classified as vertical or horizontal. These machines are also classified as knee-type, ram-type, manufacturing or bed type, and planer-type. Most milling machines have self-contained electric drive motors coolant systems, variable spindle speeds, and power-operated and table feeds. The three primary factors in anybasic milling operation are speed, feed and depth of cut. Other factors such as kind of material and type of tool materials have a large influence, of course, but these three are the ones the operator can change by adjusting the controls, right at the machine.

Surface Roughness:

Surface roughness is an important measure of product quality since it greatly influences the performance of mechanical parts as well as production cost. Surface roughness has received serious attention for many years and it is a key process to assess the quality of a particular product. Surface roughness has an impact on the mechanical properties like fatigue behavior, corrosion resistance, creep life, etc.

Rotary valve turning process cutting parameters:

In turning, the speed and motion of the cutting tool is specified through several parameters. These parameters are selected for each operation based upon the work piece material, tool material, tool size, and more.

Cutting feed: The distance that the cutting tool or work piece advances during one revolution of the spindle, measured in inches per revolution (IPR). In some operations the tool feeds into the work piece and in others the work piece feeds into the tool. For a multi-point tool, the cutting feed is also equal to the feed per tooth, measured in inches per tooth (IPT), and multiplied by the number of teeth on the cutting tool.

Cutting speed: The speed of the work piece surface relative to the edge of the cutting tool during a cut, measured in surface feet per minute (SFM).

Spindle speed: The rotational speed of the spindle and the work piece in revolutions per minute (RPM). The spindle speed is equal to the cutting speed divided by the circumference of the work piece where the cut is being made. In order to maintain a constant cutting speed, the spindle speed must vary based on the diameter of the cut. If the spindle speed is held constant, then the cutting speed will vary.

Feed rate: The speed of the cutting tool's movement relative to the work piece as the tool makes a cut. The feed rate is measured in inches per minute (IPM) and is the product of the cutting feed (IPR) and the spindle speed (RPM).

Axial depth of cut: The depth of the tool along the axis of the work piece as it makes a cut, as in a facing operation. A large axial depth of cut will require a low feed rate, or else it will result in a high load on the tool and reduce the tool life. Therefore, a feature is typically machined in several passes as the tool moves to the specified axial depth of cut for each pass.

Internal operations:

Drilling - A drill enters the work piece axially through the end and cuts a hole with a diameter equal to that of the tool.

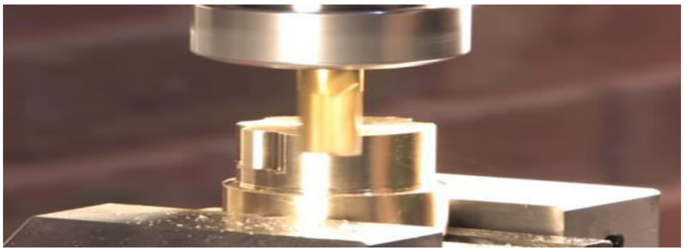


Figure: drilling process

Boring - A boring tool enters the work piece axially and cuts along an internal surface to form different features, such as steps, tapers, chamfers, and contours. The boring tool is a multi-point cutting tool, which can be set to cut the desired diameter by using an adjustable boring head. Boring is commonly performed after drilling a hole in order to enlarge the diameter or obtain more precise dimensions.

Figure: Boring process

Reaming - A reamer enters the work piece axially through the end and enlarges an existing hole to the diameter of the tool. Reaming removes a minimal amount of material and is often performed after drilling to obtain both a more accurate diameter and a smoother internal finish.

Figure: Reaming process

Tapping - A tap enters the work piece axially through the end and cuts internal threads into an existing hole. The existing hole is typically drilled by the required tap drill size that will accommodate the desired tap.

Figure: Tapping

Modeling of Multi point cutting tool:

"Unigraphics" or "Siemens NX," which is a popular computer-aided design (CAD) software used in various industries for designing, engineering, and manufacturing purposes. Siemens NX, formerly known as Unigraphics, is known for its advanced capabilities in 3D modeling, simulation, and manufacturing processes. It allows users to create complex 3D models, perform simulations to test design performance, and generate manufacturing instructions directly from the digital model.

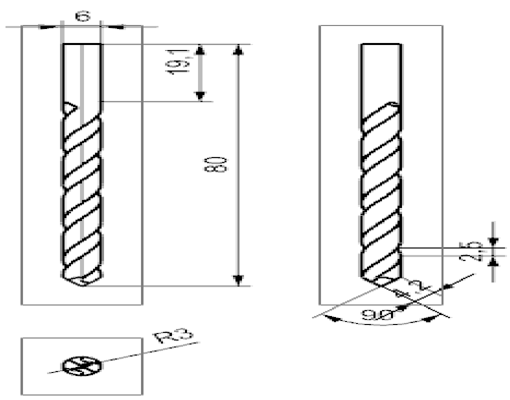


Figure: Geometry model

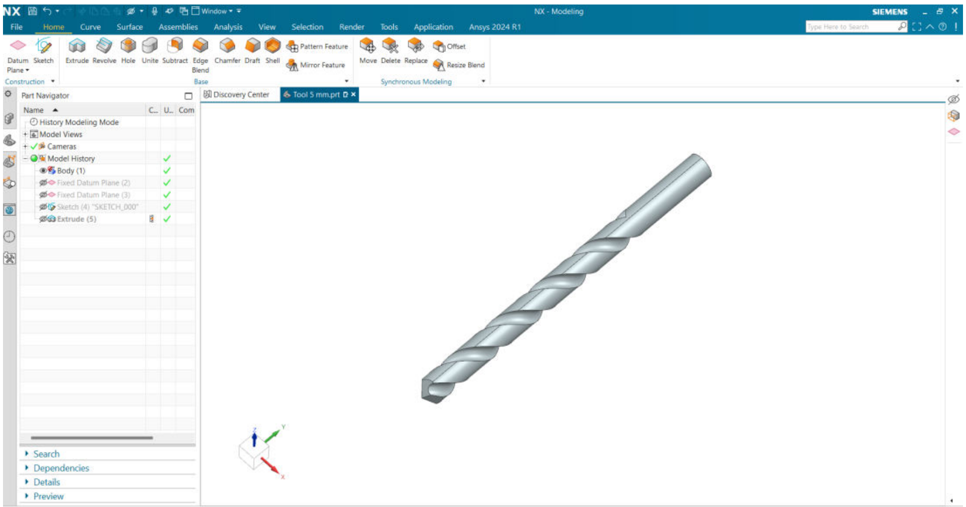


Figure: Tool design model

Load and Boundary Conditions:

It's business as usual for structural loads and boundary conditions to be used. There are four factors at play here.

Cylindrical support for work piece

Longitudinal displacement of tool (63.7 mm)

Tangential displacement of tool (0.1 mm, 0.2mm, 0.3 mm)

Speed of rotation of work piece (800 rpm, 1000 rpm, 1200 rpm)

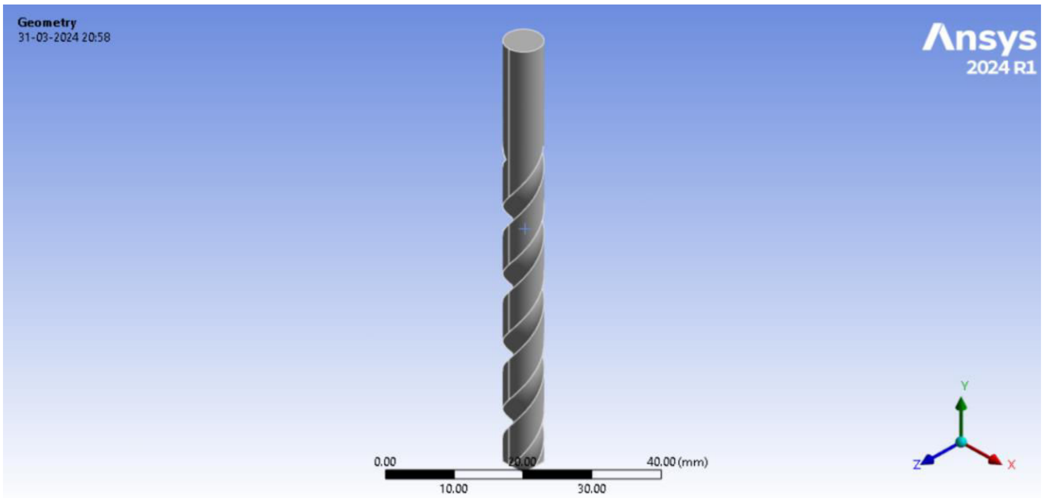


Figure: Frictional model of Multi point cutting tool

4.0 RESULTS AND DISCUSSIONS

It was decided to use a meshed model, total and directional displacements, and equivalent stress and strain as factors in the investigation. The tool under consideration was part of a device used to measure how much speed can be slowed down. Working with different materials such as Inconel 718, SS3304, and H30 Materials, Ansys Workbench 2024 R1 is well-designed software.

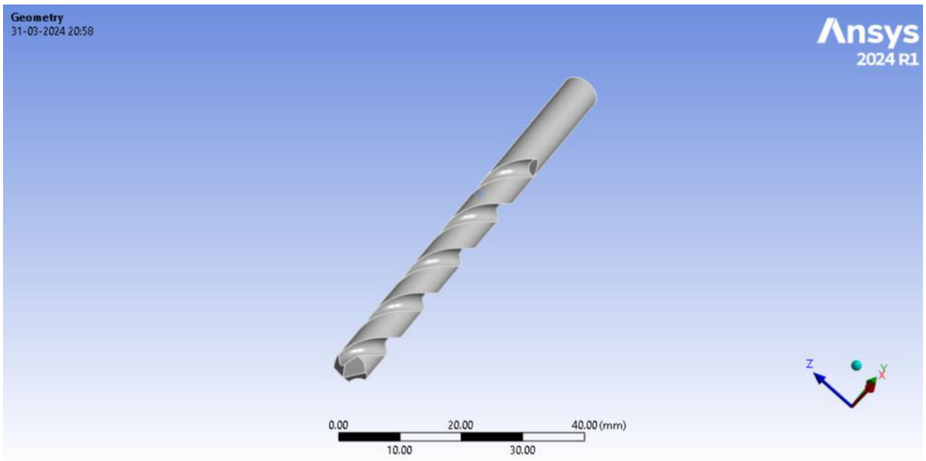


Figure: Imported model

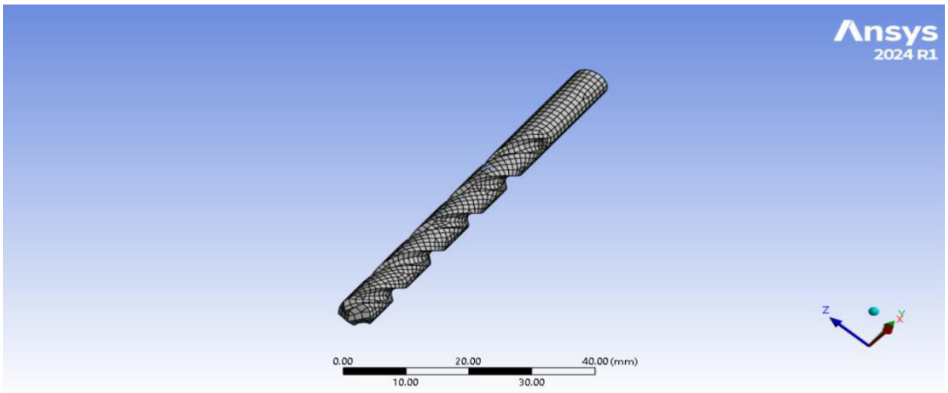


Figure: Meshed model

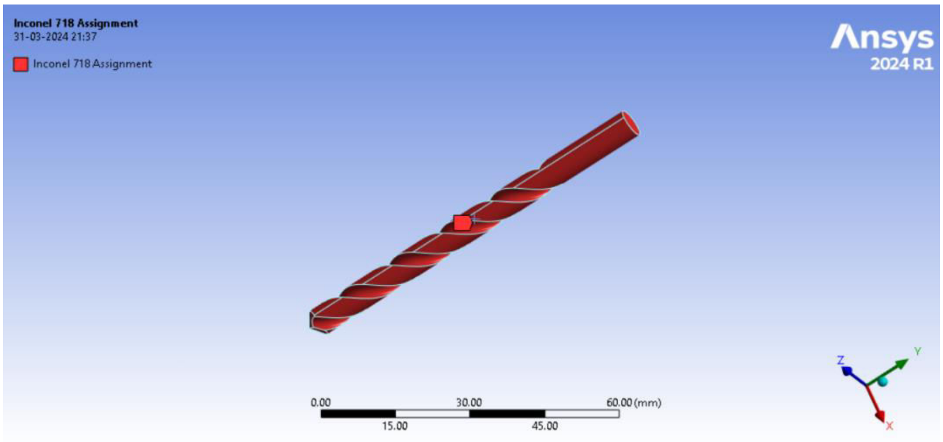


Figure: Material Assignment Inconel 718

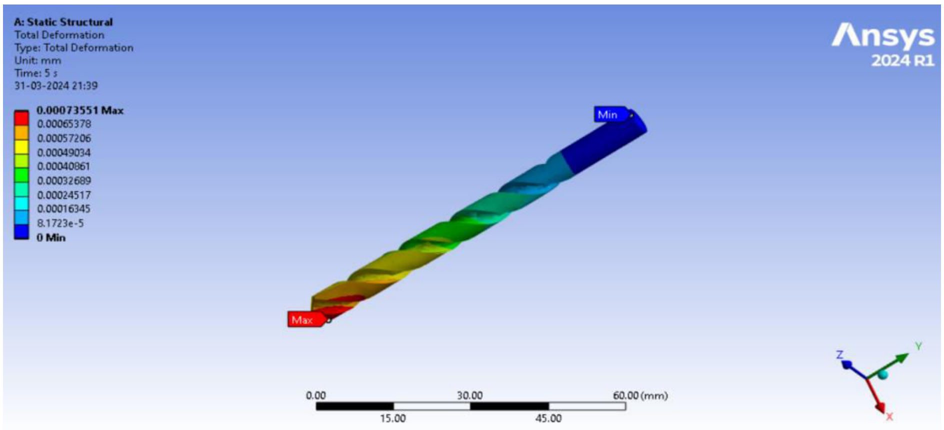


Figure: Total deformation

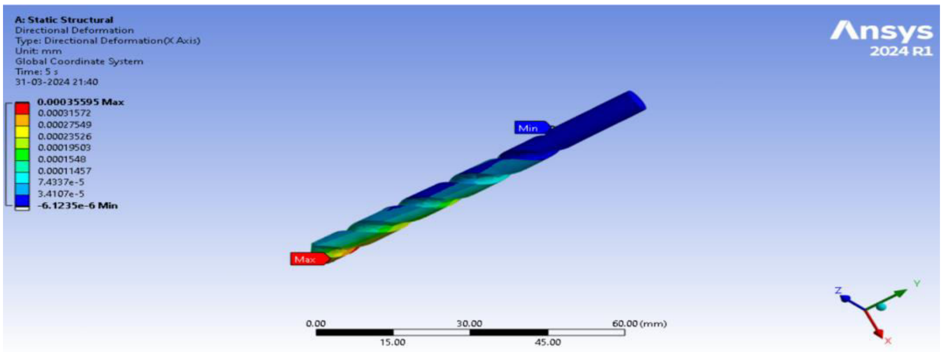


Figure: Directional deformation

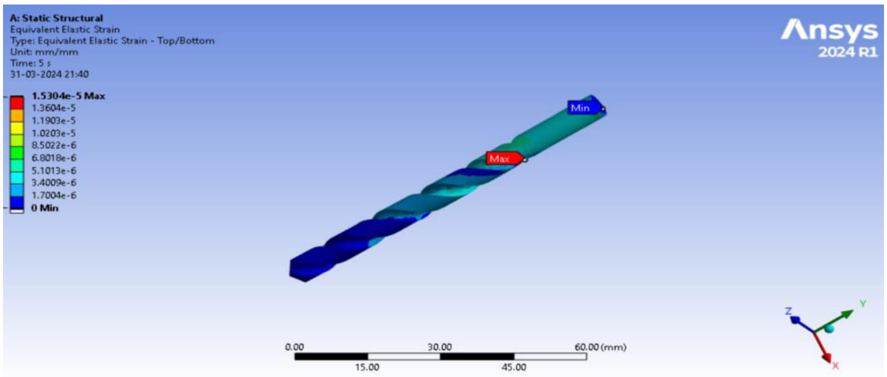


Figure: Equivalent elastic strain

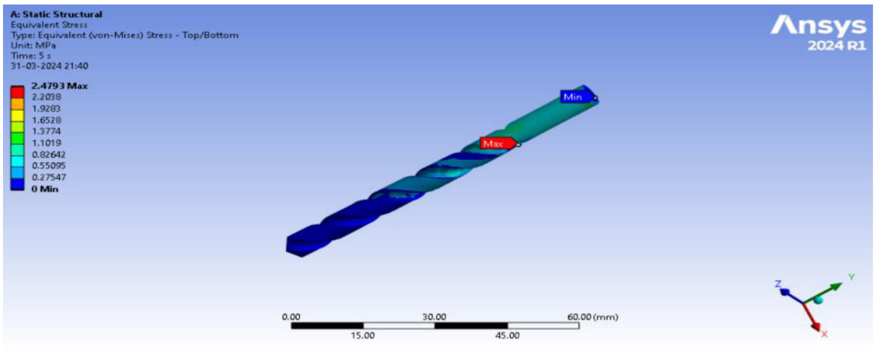
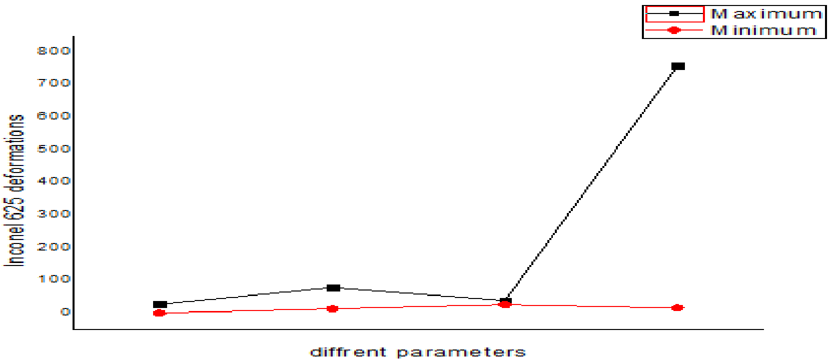


Figure: Equivalent stress

Table: Structural analysis of Multi point cutting tool using with Inconel 718 Material

Parameters	Maximum	Minimum
Total deformation	26.336	0
Directional deformation	77.617	12.567
Equivalent elastic strain	38.117	25.148
Equivalent stress	756.55	15.229



Graph: Structural analysis of Tool using with Inconel 718 Material different variations

Structural analysis of Multi point cutting tool using with SS304:

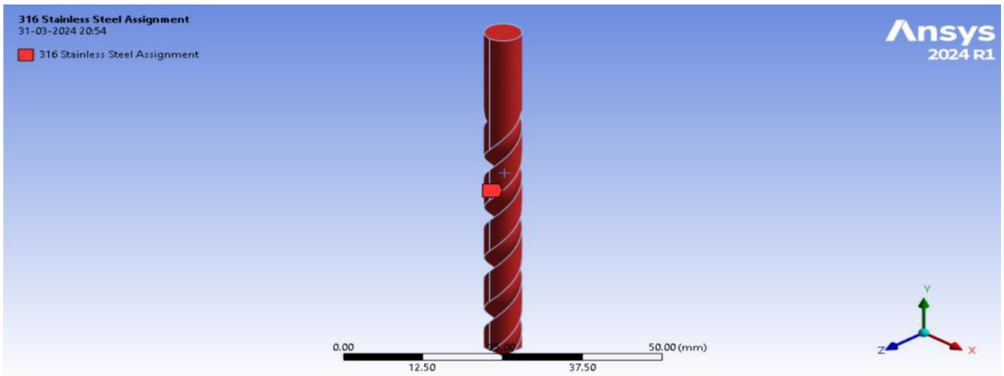


Figure: Material Assignment

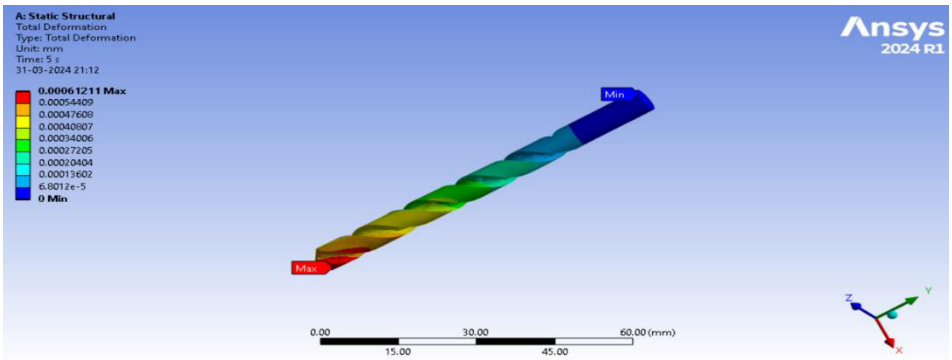


Figure: Total deformation

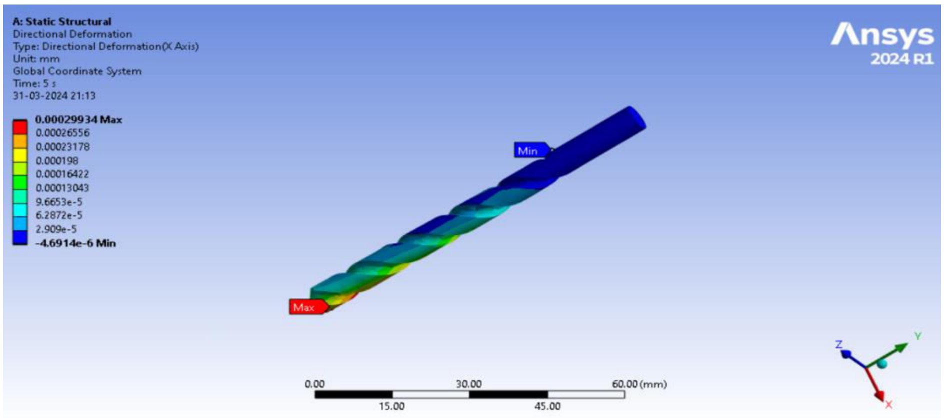


Figure: Directional deformation

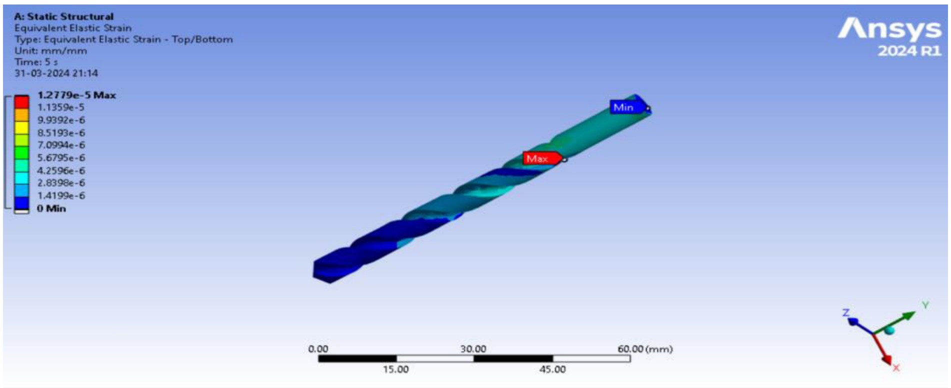


Figure: Equivalent elastic strain

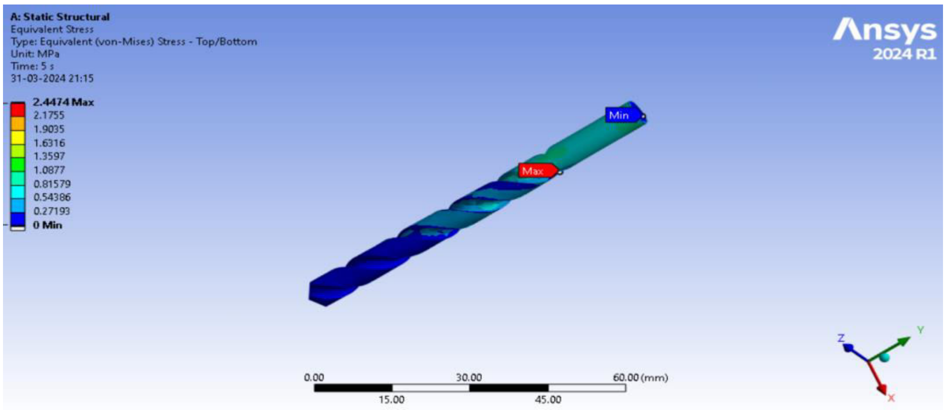
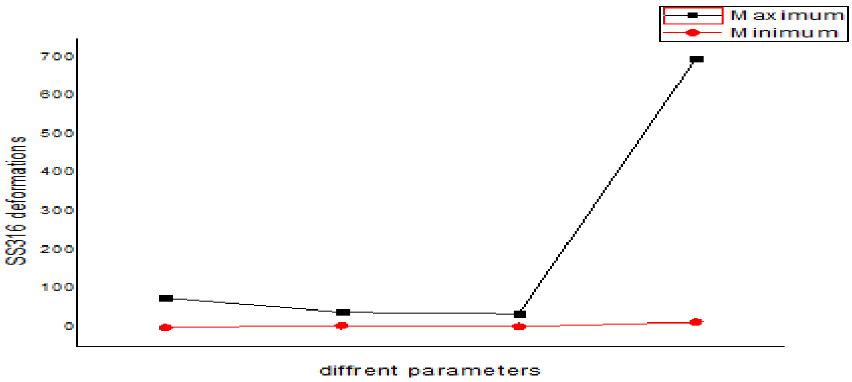


Figure: Equivalent stress

Table: Structural analysis of Tool using with stain less steel 304 Material

Parameters	Maximum	Minimum
Total deformation	152.15	0
Directional deformation	37.861	1.5196
Equivalent elastic strain	24.218	2.7546
Equivalent stress	48.281	2.7805



Graph; Structural analysis of Tool using with stain less steel 304 Material Variations

Structural analysis of Multi point cutting tool using with H30 material

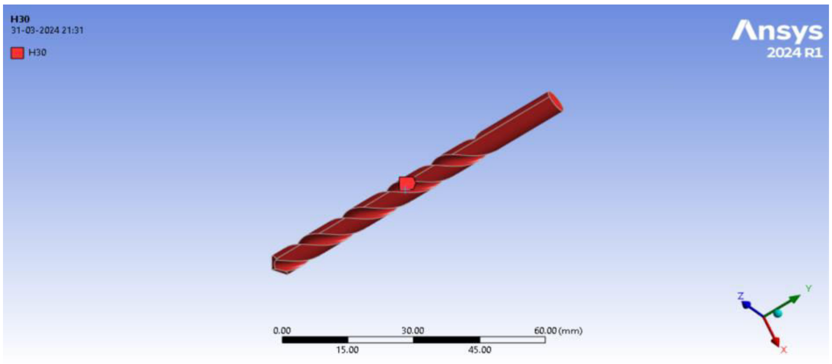


Figure: Geometrical model

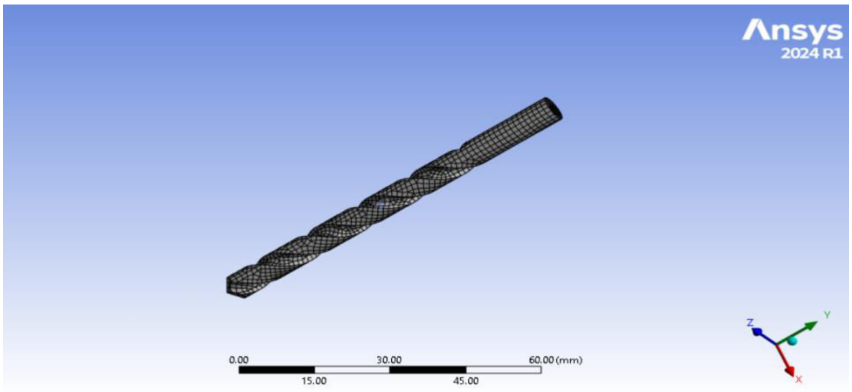


Figure: Meshed model

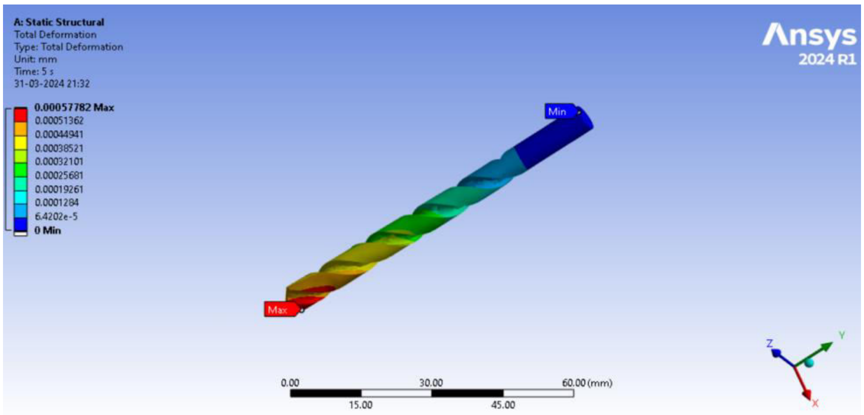


Figure: Total deformation

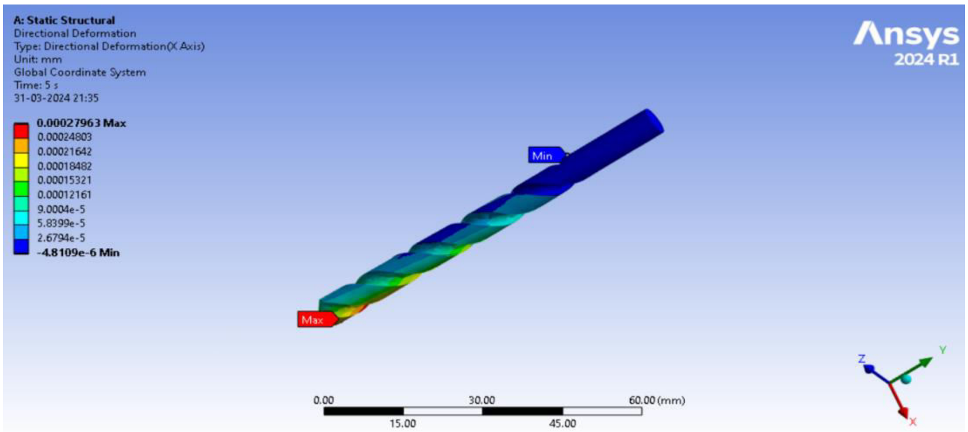


Figure: Directional Total deformation

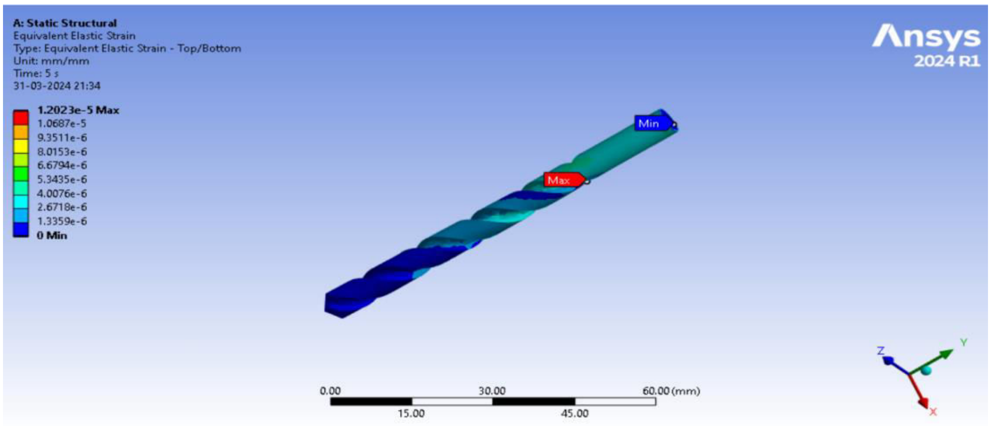


Figure: Equivalent Elastic Strain

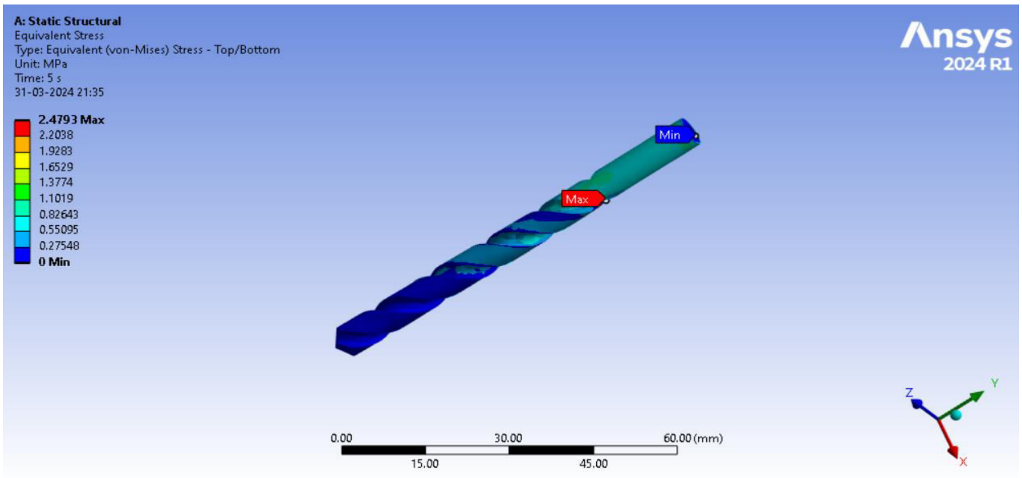
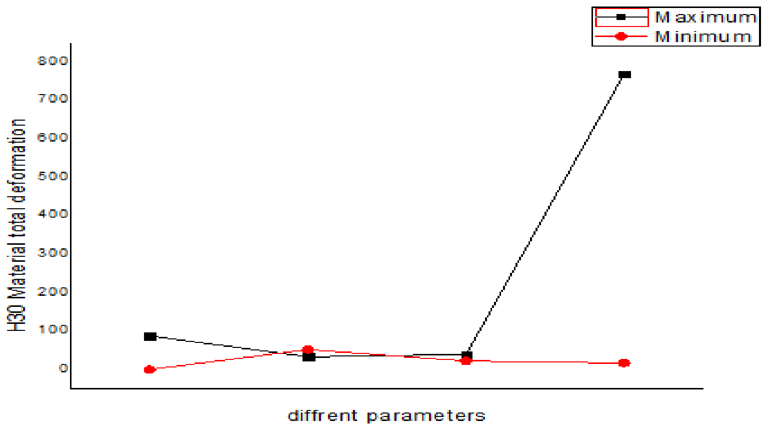


Figure: Equivalent stress

Table: Structural analysis of Tool using with H 30 alloys

Parameters	Maximum	Minimum
Total deformation	86.843	0
Directional deformation	32.813	51.215
Equivalent elastic strain	38.691	21.897
Equivalent stress	768.15	16.607



Graph: Structural analysis of Tool using with H 30 alloys variations

Taguchi's Design of Experiments

Exploratory research can be used to evaluate and improve process parameters. The most influenced process parameters on output responses are listed at different columns in an intended orthogonal array. Machine parameters such as machining speed, feed rate, and depth of cut all influence tool wear and surface roughness. It is better to use lower values when dealing with wear on the flanks or surface roughness Because of this, the preferred machining output responses are low surface roughness and cutting tool flank wear. As a result, the lower the S/N ratio, the better the results were thought to be. S/N ratio for the nominal output response can be calculated from the following characteristics.

$$\text{Smaller the better} \quad \frac{S}{N} = -10 \log\left(\frac{1}{n}\sum_{i=1}^{n} Y_i^2\right) \qquad \text{.....................} (1)$$

From S/N ratio, the actual influencing parameters and the best optimal range of selected parameters can be characterized.

Table: Taguchi parameters

	Level 1	Level 2	Level 3
Spindle Speed	800	1000	1200
Feed	1500	2000	2500
Depth of cut	0.1	0.2	0.3

Table: Taguchi L9 Orthogonal array

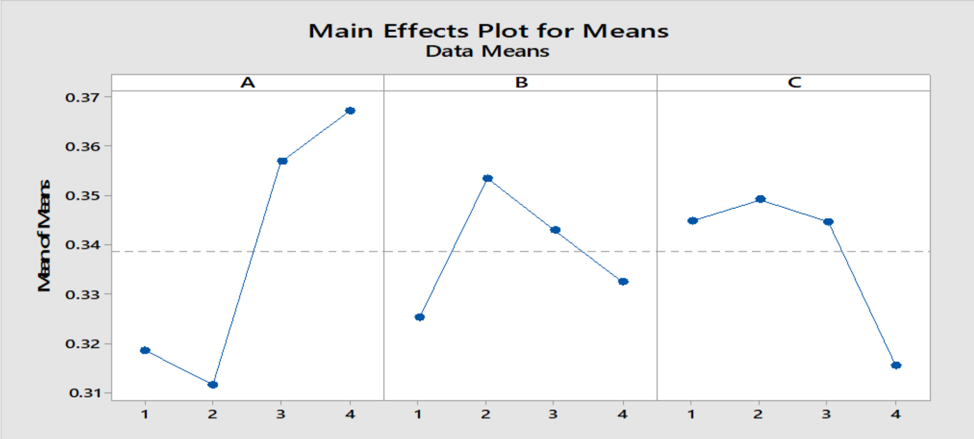
S. No	Speed	Feed	Depth of cut
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	2
9	3	3	1

ANOVA Results Multi Point Cutting Tool:

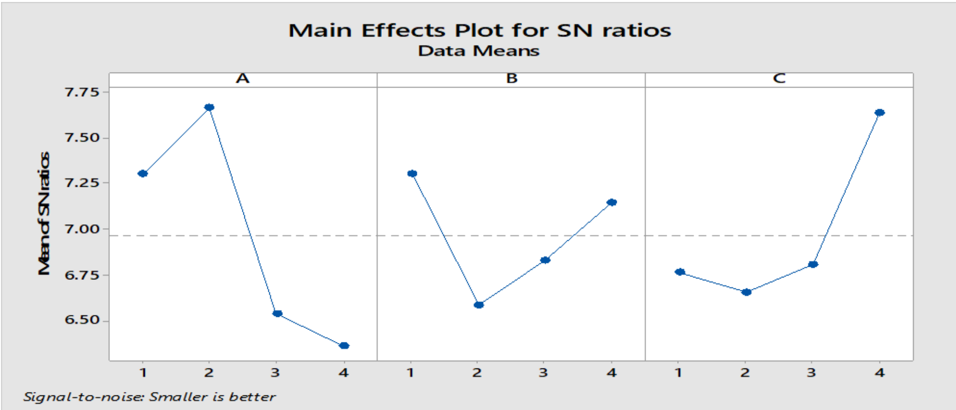
Table: L9 experimental results with Multi point cutting tool Inconel 718 material

S .no	Depth of cut	Feed rate	Spindle speed	Tool flank wear(mm)	Surface finish (µm)
1	0.1	800	1500	0.028	0.625
2	0.1	800	2000	0.024	0.639
3	0.1	800	2500	0.022	0.649
4	0.2	1000	1500	0.029	0.533
5	0.2	1000	2000	0.038	0.589
6	0.2	1000	2500	0.040	0.613
7	0.3	1200	1500	0.038	0.552
8	0.3	1200	2000	0.039	0.584
9	0.3	1200	2500	0.049	0.638

Taguchi Analysis:



Graph: Main effects plots for means



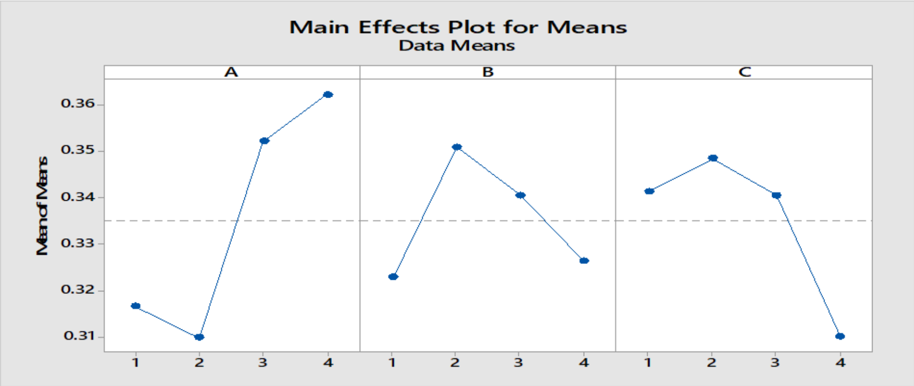
Graph: Main effects Plot for SN ratios

Graph: Main effects plot for StDevs

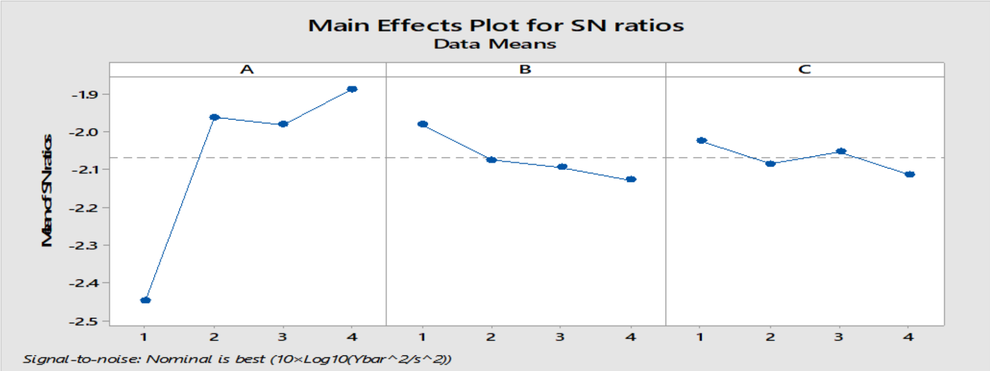
Table: **L9 experimental results with Multi point cutting tool SS 304 material**

S .no	Depth of cut	Feed rate	Spindle speed	Tool flank wear(mm)	Surface finish (µm)
1	0.1	800	1500	0.024	0.626
2	0.1	800	2000	0.023	0.642
3	0.1	800	2500	0.018	0.648
4	0.2	1000	1500	0.015	0.536

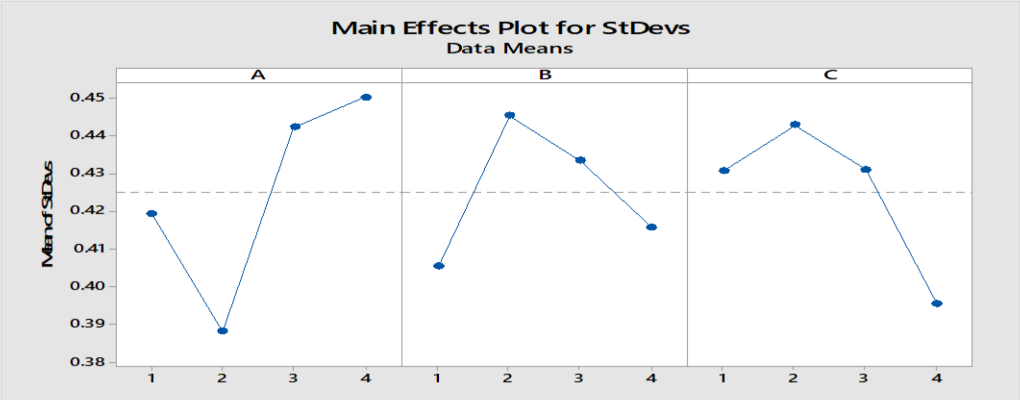
5	0.2	1000	2000	0.036	0.588
6	0.2	1000	2500	0.039	0.619
7	0.3	1200	1500	0.034	0.549
8	0.3	1200	2000	0.032	0.581
9	0.3	1200	2500	0.043	0.639



Graph: Main effect plots for means



Graph: Main effects plot for SN ratios

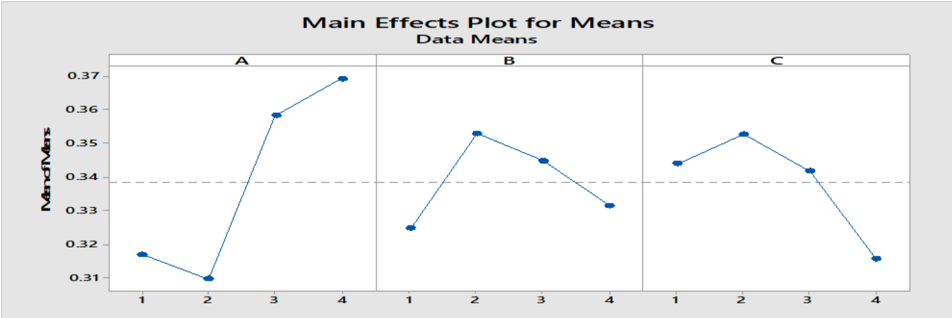


Graph: Main effects plot for StDevs

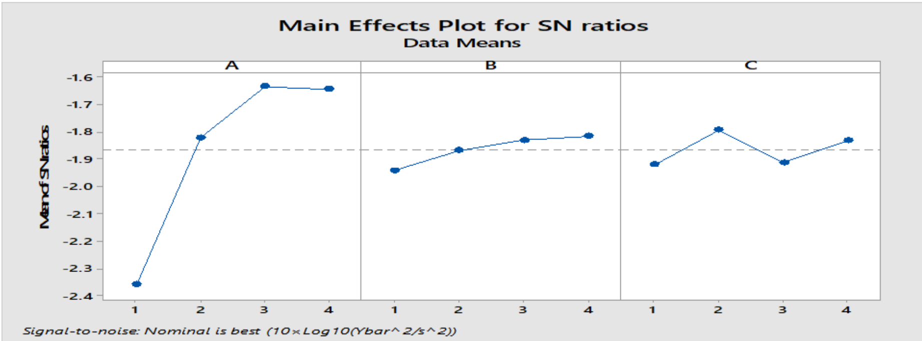
Table: L9 experimental results with Multi point cutting tool H30 Material

S no	Depth of cut	Feed rate	Spindle speed	Tool flank wear(mm)	Surface finish (µm)
1	0.1	800	1500	0.1	0.626
2	0.1	800	2000	0.1	0.639
3	0.1	800	2500	0.1	0.648

4	0.2	1000	1500	0.2	0.532
5	0.2	1000	2000	0.2	0.585
6	0.2	1000	2500	0.2	0.613
7	0.3	1200	1500	0.3	0.548
8	0.3	1200	2000	0.3	0.573
9	0.3	1200	2500	0.3	0.638

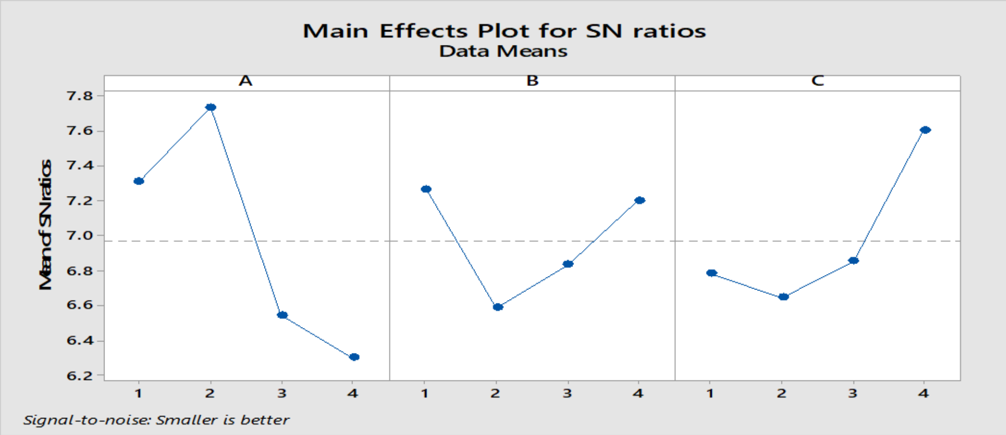


Graph: Main effects plot for Means

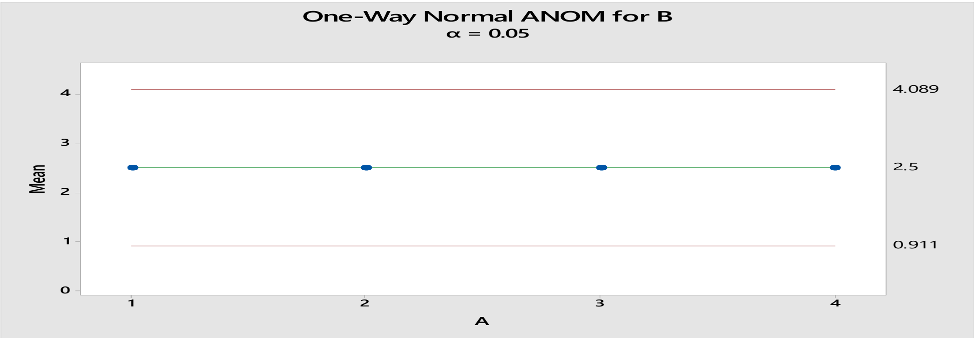


Graph: Main effects plot for SN ratios

Graph: Main effects plot for Means



Graph: Main effects plot for SN ratios



Graph: One-Way Normal ANOM for B

The novel machining process's application range is limited by the material's qualities, such as electrical and thermal conductivity, melting temperature, and electrochemical equivalent. These procedures are becoming increasingly common and unavoidable on the shop floor. Developing new machining processes for hard, high-strength, temperature-resistant alloys was motivated by the search for better ways to produce complex forms (Inconel 718, H30, SS304 and heat resisting steels etc.). Rapid advancement in the aerospace, automobile, nuclear engineering and medical fields has been made possible by using these difficult-to-machine materials.

CONCLUSION:

Finally, the concluded that structural analysis using different materials and observing the simulation results Inconel 718 has a higher tensile strength than grade 304 stainless steel H30 and does a better job of maintaining that strength at higher operating temperatures. This is because Inconel is stronger than stainless steel at high temperatures, while being more resistant to oxidation and scaling as well.

To investigated a multi characteristic response optimization model based on Taguchi Technique was developed to optimize process parameters, such as speed, feed, depth of cut, and nose radius of multi point cutting tool. Taguchi's L9 orthogonal array is selected for experimental planning. The experimental result analysis showed that the combination of higher levels of cutting speed, depth of cut and lower level of feed is essential to achieve simultaneous maximization of material removal rate and minimization of surface roughness

A L9 orthogonal array, S/N ratios and ANOVA are used to study the performance characteristics of cutting speed, feed rate and depth of cut as turning parameters with tool flank wear width as response variable. The result of the analysis show that the selected machining parameters affect significantly the tool flank wear width of Tungsten Carbide cutting tool while machining Inconel 718 and also indicate that the cutting speed is the most influencing

REFERENCES

1. Abdullah, K.; Ulvi, S. (2005): The effect of chamfer angle of polycrys-talline cubic boron nitride cutting tool on the cutting forces and the tool stresses in finishing hard turning of AISI 52100 steel. Mater. Des. 26 ISSN: 7236-1203, vol.8, no. 1, pp. 979-984.
2. Abukhshim N.A., Mativenga P.T., Sheikh M.A.,“Heat generation and temperature prediction in metal cutting: A review and implications for high speed machining”, International Journal of Machine Tools & Manufacture xx (2005) 1–19.
3. NBV Lakshmi Kumari, G. Prasana Kumar, S. Irfan Sadaq, “Analysis of multi Point Cutting Tool of a Lathe Machine using FEA”, International Journal of Engineering Trends and Technology (IJETT), Volume 20, February 2015.
4. G. V. R. Seshagiri Rao, M.H. Mahajan, “Stress Analysis at the Tip of Multi Point Cutting Tool by Varying Spindle Speed”, International Journal of Engineering, Education and Technology, Volume 3, January 2015.
5. A. Nagarajan, T. S. Sangeetha, “Analysis of coated multi point cutting tool”, International journal of Emerging Technologies in Engineering research (IJETER), Volume 2, September 2015.
6. Nitin M Mali, T. Mahender, “Wear Analysis of Multi Point Cutting Tool With and Without Coating”, International Journal of Research in Engineering and Advanced Technology, Volume 3, June, 2015.
7. Vijay Kumar Patel, Gopal Sahu, Prakash Kumar Sen, Ritesh Sharma, “To Review on Multi Point Cutting Tool and Tool Performance”, International Journal for Research in Technological Studies Volume. 2, October 2015.
8. Maheshwari N Patil, “Finite Element Analysis of Von Mises Stresses Deformation at Tip of Cutting Tool”, International journal of Innovative research in Advanced Engineering, Volume 1, April 2014.
9. S. H. Rathod, Mohd. Razik, “Finite Element Analysis of Multi Point Cutting Tool”, International journal of Modern Engineering Research, Volume 4, March 2014.
10. Vivek Varia, Prof. Jegadeeshwaran, “Finite Element Analysis of Deformation of Multi Point Cutting Tool”, International Conference on Innovations in Engineering and Technology, Volume 25, 2013.