Process Optimization of Spike Support Using CAM Software

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Abstract*- In manufacturing, the goal is to produce components that meet the design specifications. The design specification ensures the functionality aspect. Spike support is used in a fourth-generation man-portable fire-and-forget anti-tank guided missile with tandem-charged heat warhead, developed and designed by the ISRAELI company and in service with some nations. As it is a missile component, it should be light in weight at the same time strength should be more. Aluminum material is used for spike support due to its best material properties. Due to this thin wall thickness, there is more chance of rejections and reworks. Nowadays rejection is a serious problem that has been arising in every manufacturing industry. Due to this reason, the manufacturing sector is advancing into losses. There are many factors responsible for rejection and reworks, such as human errors, machine errors, process planning, material errors etc. CAD/CAM/CAE systems play a crucial role in design optimization and process optimization of any component and it is helpful in reducing the reworks and rejections. By considering the above important aspect, this project is taken up for reducing the rejections to the least values. The aim of the project is to reduce and maintain the rejection rate below six percent which was previously 9 percent and reduces and keep the rework rate below 10 percent which was previously 15%. Initially, the optimum cutting speed of the tool is evaluated by doing the harmonic analysis in the CAE system using ANSYS software. Once the cutting speeds are determined, manufacturing process plan will be developed in cam system using the NX-CAM software. Process optimization was also carried out by using the mandrel for a job holding to reduce damage to the component while machining operation is running.*

I. INTRODUCTION

1.1 COMPUTER-AIDED DESIGN (CAD)

Computer-aided design (CAD), also known as computer-aided design and drafting (CAD), is the use of computer systems to assist in the creation, modification, analysis, or optimization of the design. Computer-aided drafting explains the process of creating and developing a technical drawing with the use of specialized computer software. CAD software is used to increase the productivity of the designer, improve the quality of design and involves the improvement of communications through documentation, and helps out in the creation of the database for progressive manufacturing. CAD output is often referred in the form of electronic programmed files for print or various machining operations. CAD software takes advantage of either vector based graphics to portray the objects of traditional drafting, or to produce raster graphics showing the overall image of designed objects. CAD often involves more than just shapes. As in the manual designing and drafting of engineering drawings, the 'output of cad' must fetch information, such as materials, dimensions, and tolerances, processes, according to application-specific conventions. CAD may be used to design figures and curves in two-dimensional (2D) space, surfaces, or curves, and solids developed in three-dimensional (3D) space. 'CAD is an important industrial art' which is extensively used in many applications such as shipbuilding, including automotive, prosthetics, aerospace industries, industrial, architectural design, and much more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals. Because of its enormous economic importance and use, cad has been a major driving force for research in computational geometry, computer graphics which involve both hardware and software, and discrete differential geometry.

1.2 COMPUTER-AIDED MANUFACTURING (CAM)

Computer-aided manufacturing is the computer software used to control machine tools and related machinery in the manufacturing of work-pieces. CAM may also refer to the use of a computer to assist in all operations of a manufacturing plant, management, including planning, storage and transportation. Its main purpose is to create a faster rate of production process and components and to tool with more precise dimensions and material consistency, which in some cases, uses only the required amount of raw material, while simultaneously lower energy consumption.

1.3 COMPUTER NUMERICAL CONTROL

Computer numerical control (CNC) is a unique one, in which the motions and functions of machine tools are controlled using a prepared program containing coded alphanumeric data. CNC can control the motions of the work piece or tool, the input parameters such as speed, depth of cut, feed, and the functions such as turning the spindle on/off, turning coolant on/off.

II. LITERATURE SURVEY ON FIXTURES

POLLACK 1976 [1] - a fixture is a work-piece locating and holding device used for machine tools, inspection, welding and assembly; it does not control the position of the tool or instrument which is being used.

- Elements of the jig or fixture must also be present which support the work and items, called locators, which position the work.
- Once located and positioned, the work is clamped so that it will not move off the supports or locators.

BURLEY AND CORBETT 1998 [2]- a jig is defined as a manufacturing support that either holds a part or is itself fixed on the part and is built-in with devices to escort a cutting tool ensuring the correct position of the machining path relative to the component.

- a fixture is defined as a manufacturing support for holding and locating parts during assembly operations or machining, which does not provide definitive guidance on the cutting tools.
- tooling is used as the generic name for jigs and fixtures and also the tools set from the master gauges for calibrating jigs and fixtures.
- Hence, jig less assembly is assembly without the use of jigs; it requires that parts are manufactured to sufficient accuracy to ensure correct assembly; it is not necessarily fixtureless [or tool less] assembly.

J. C. TRAPPEY AND C. R. LIU 1990 [3]- fixture design can be classified as a part of process planning. The task is the description of process planning specifically states that "'fixture design for each work piece set-up" is an integrated planning task. However, the automation of fixture design has been overlooked in most research into automated process planning.

III. 3D MODELING

3.1 SPIKE SUPPORT 2D DRAWING

A 2D drawing is used to design a 3D model of our component using Uni-graphics NX 7.5 CAD software. Below shows the 2D drawings of the spike support with all the required dimensions for manufacturing the component without any errors.

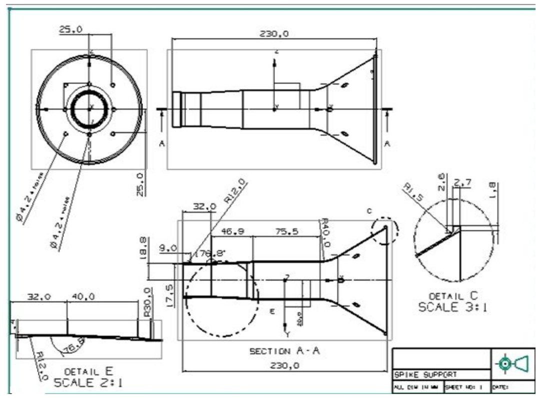


Fig: 2D input of spike support

3.2 STEPS INVOLVED IN 3D MODELLING OF SPIKE SUPPORT

3D model is designed by using NX CAD software.

SKETCHING

Below is the sketch that is required to obtain the 3D model of the spike support from the above 2D drawing. Below image shows the sketch of the spike support.

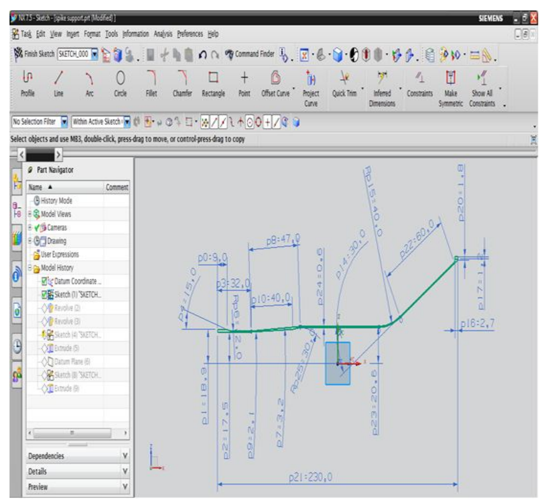


Fig: sketch of spike support

Final 3d model of spike support.

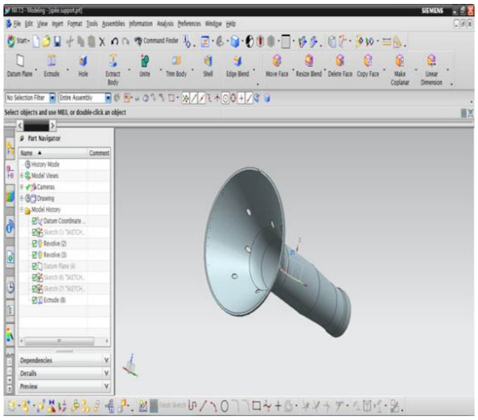


Fig: final 3d model of spike support

IV. FINITE ELEMENT ANALYSIS OF SPINDLE

4.1 HIGH-SPEED MOTORIZED SPINDLE

A high-speed spindle is an important unit which influences significantly on the dynamics of the machining process. Spindle unit has its natural frequencies, and during the machining process, the forcing frequency at which machining is done should not be the natural frequency of the spindle unit to avoid the resonance. Hence determining the natural frequency of the spindle unit is very necessary for selecting the spindle speed for machining. This analysis discusses the free vibration analysis of the spindle unit. Spindle unit is modelled, and the modal analysis is performed to determine the natural frequencies and mode shapes of the spindle.

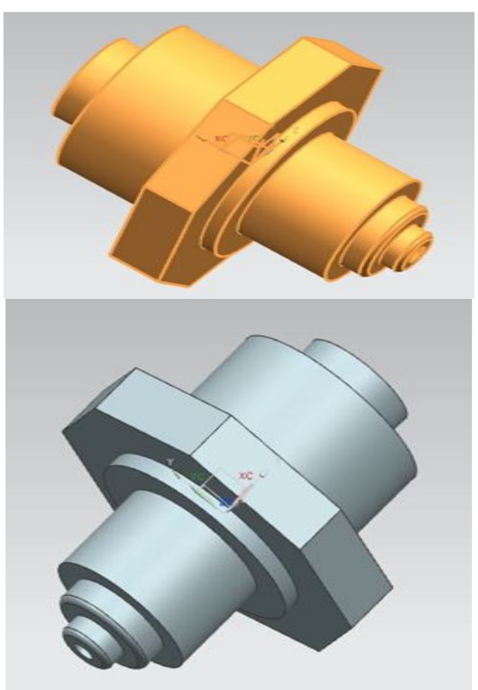


Fig: isometric view of high-speed spindle model

4.2 MODAL ANALYSIS - AN INTRODUCTION

Modal analysis is regularly used to determine the vibration characteristics such as natural frequencies and mode shapes of a structure or a machine component while it is being designed. It is noted that it can also be a starting point for another more detailed analysis such as a transient dynamic analysis, a harmonic response analysis or a spectrum analysis.

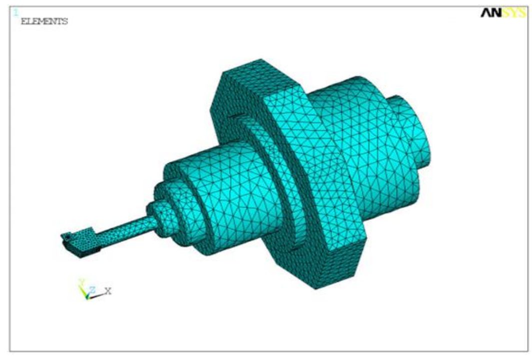
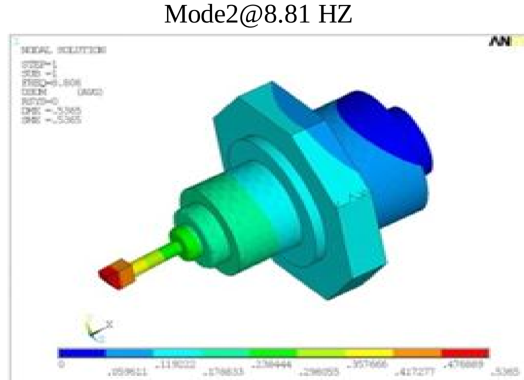


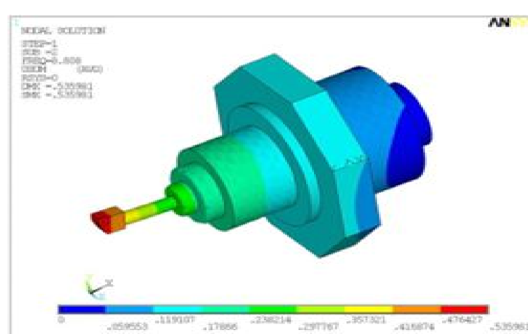
Fig: finite element meshed model of the high-speed spindle unit.

Figures below show the different mode shapes of the spindle unit.

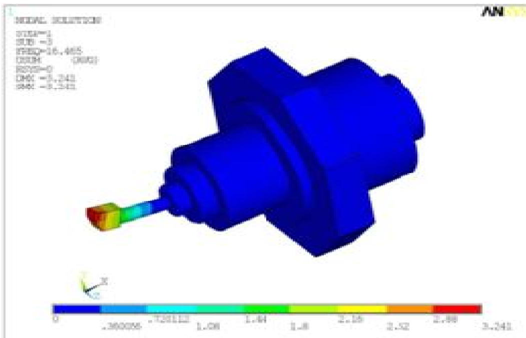
Mode1@8.8HZ

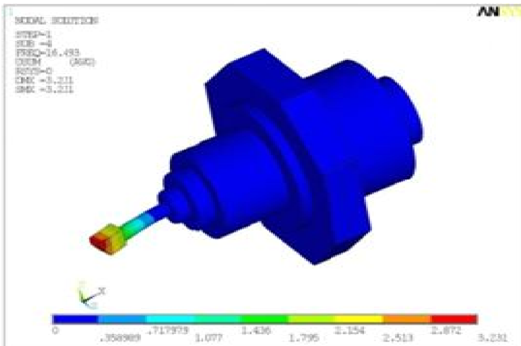
Mode2@8.81 HZ



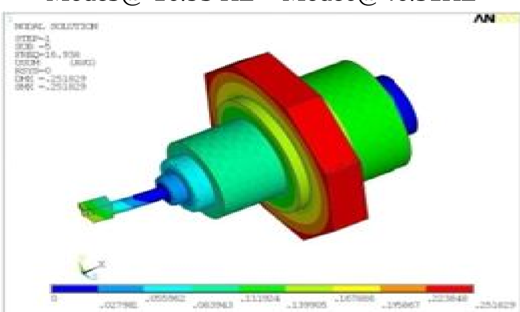


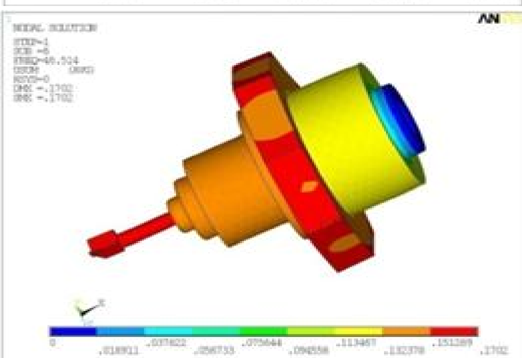
model3@16.46 HZ mode4@16.49 HZ



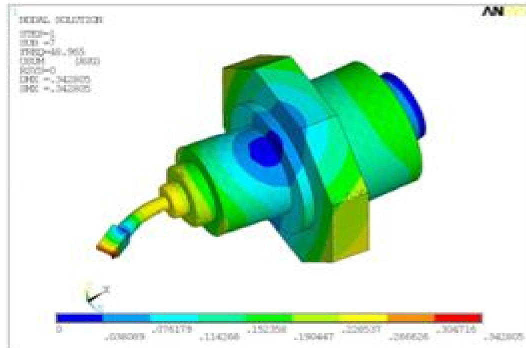


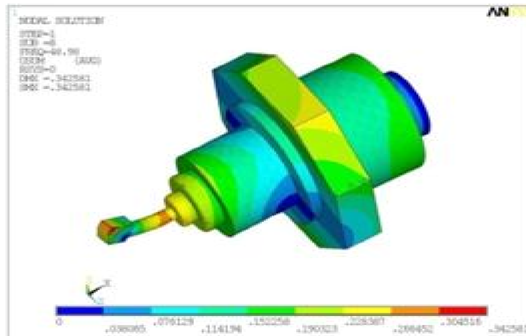
Mode5@ 16.93 HZ Mode6@46.51HZ



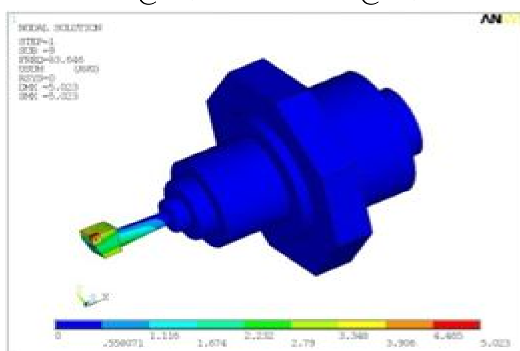


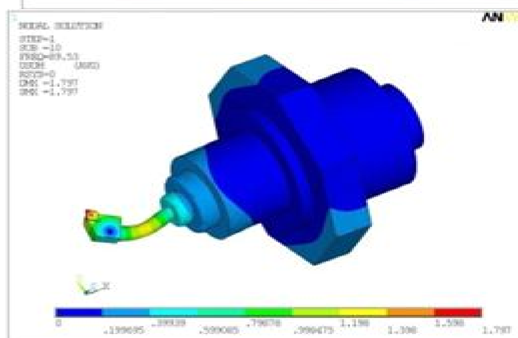
mode7@48.96 hz mode8@48.98hz





mode9@83.6 hz mode10@89.53hz





From the vibration analysis of the high-speed spindle unit, it is recommended that the frequencies listed above should be avoided during a machining process.

V. FINITE ELEMENT ANALYSIS OF SPIKE SUPPORT COMPONENT

The spike support structure having thin wall is considered here for performing harmonic analysis to predict the stable speed ranges. The spike support structure is modelled, and modal analysis has been done to find out the natural frequencies followed by harmonic analysis has been performed.

5.1 BOUNDARY CONDITIONS: Displacements are constrained parameters at the nodes where the spike is mounted on the work piece holder. Some modes to expand is given as ten so that the first ten mode shapes of the structure can be obtained.

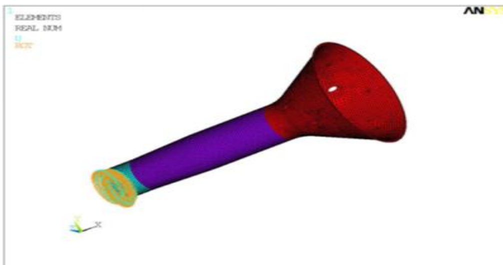
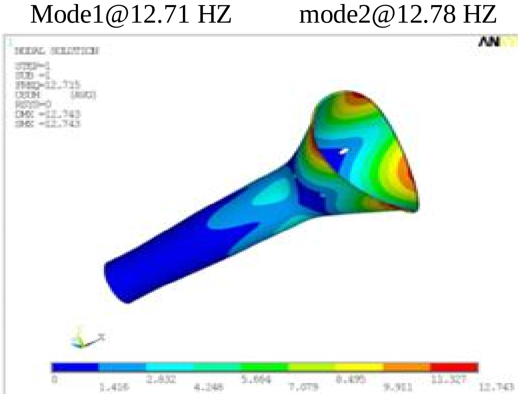
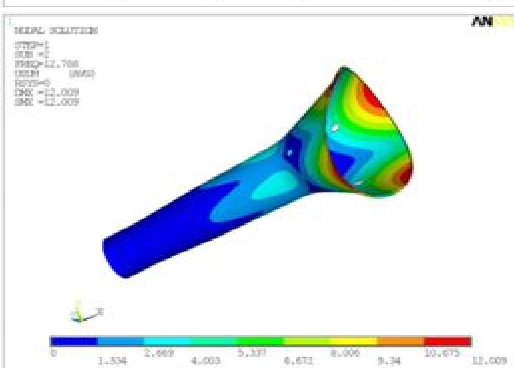


Fig: boundary conditions for modal analysis

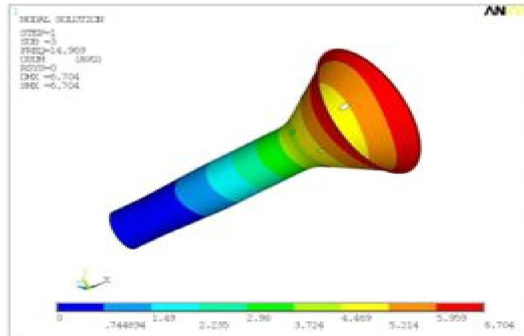
Figures below show the different mode shapes of the spindle unit.

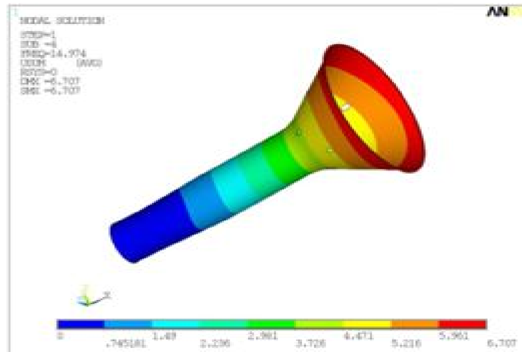
Mode1@12.71 HZ mode2@12.78 HZ



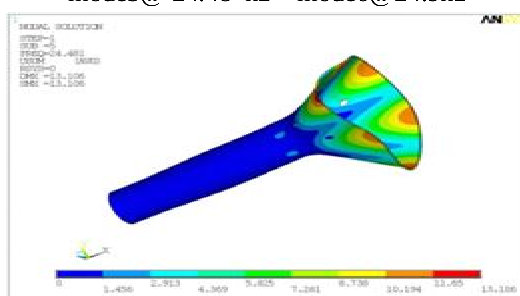


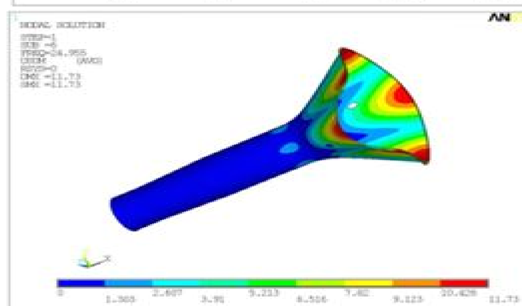
Mode3@14.96 HZ mode4@14.97 HZ



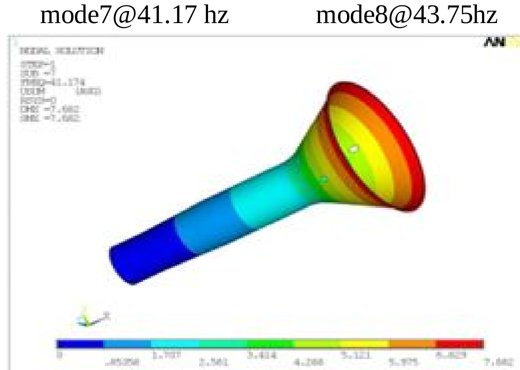


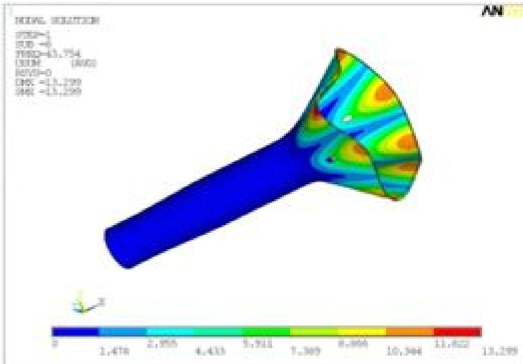
mode5@ 24.48 hz mode6@24.9hz



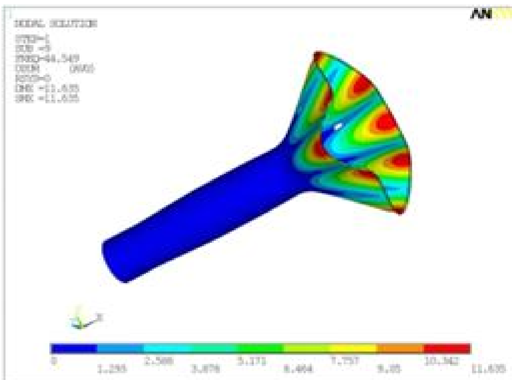


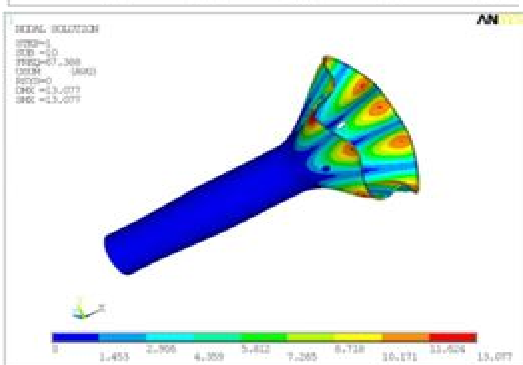
mode7@41.17 hz mode8@43.75hz





Mode9@48.96 hz mode10@83.6hz





From the vibration analysis of the spike support component, it is recommended that the frequencies listed above should be avoided during the machining process.

5.2 HARMONIC ANALYSIS OF THE SPIKE SUPPORT COMPONENT

Any sustained cyclic load will produce a sustained cyclic response (a harmonic response) in a structural system. Harmonic response analysis gives you the ability to predict the sustained dynamic behaviour of your structures, thus enabling you to verify whether or not your designs will successfully overcome resonance, fatigue, and other harmful effects of forced vibrations. "peak" responses are then identified on the graph and stress reviewed at those peak frequencies. The spike support component is segregated into three zones according to the thickness, and the loads are applied to various zones for performing harmonic analysis from which stable frequency range for each zone is predicted.

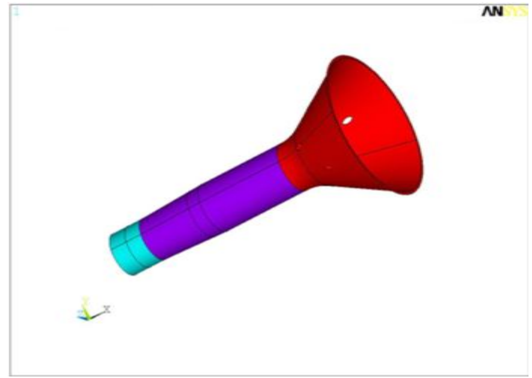


Fig: segregation of zones based on the thickness of the component

VI. COMPUTER-AIDED MANUFACTURING

From the above finite element analysis, it is concluded that the stable speed range for machining the spike support component is 10-30HZ, i.e. (600-1800 rpm). By maintaining this stable speed, spike component is prepared on CNC machine. The main objective of the project is to reduce rejection and reworks rate.

6.1 A METHODOLOGY USED IN THE MANUFACTURING OF SPIKE SUPPORT IS AS MENTIONED BELOW

- Identifying suitable machine.
- Selecting suitable tools for manufacturing the thin-walled component.
- Designing fixture/mandrel to support spike component for external operations.
- Listing down the sequence of operations performed on spike component.
- Generating tool path at specified cutting speed.
- Generating NC program using the nx-cam software.

6.2 STEPS INVOLVED IN 3D MODELLING OF MANDREL

3D model is designed and developed by using NX CAD software.

SKETCHING -below is the sketch required to obtain the 3d model of the mandrel from the above 2D drawing.

Below image shows the sketch of the mandrel.

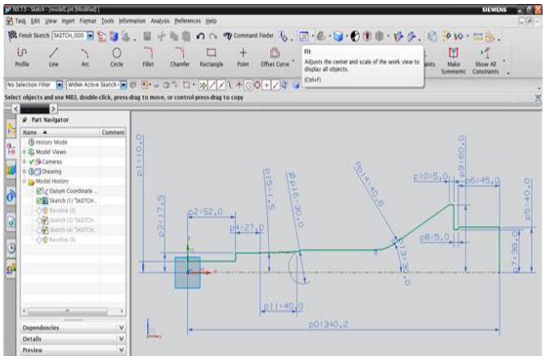


Fig: sketch of mandrel

Below image shows a final 3D model of a mandrel.

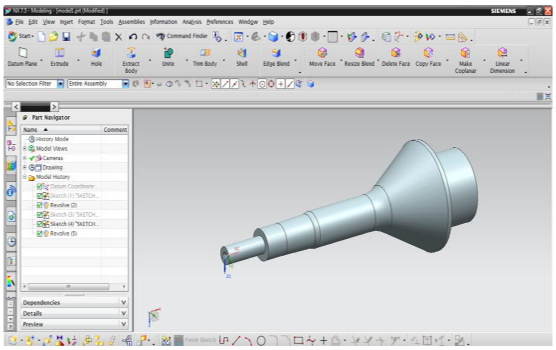


Fig: final 3D model of mandrel

6.3 CAM OPERATION IN NX-CAM
BASIC CAM SETUP

- In NX, the NC machining is referred to the setup.
- The set up for the machining jobs should be decided by looking at all the environmental information from four viewpoints: program, method, geometry, and tool.
- These four viewpoints were designed to mimic the thought process that can be used when planning the NC program.
- Each viewpoint organizes the information for the operation in a manner relevant to that particular viewpoint.

GENERATING TOOL PATH ON SPIKE SUPPORT

The series of movements made by the tip of a cutting tool. X and z codes indicate a tool path within a part program.

The path through space that the tip of a cutting tool follows on its way to producing the desired geometry of the work piece.

Set_up_1 tool path generation below image shows the creation of facing operation on spike model maintaining speed at 1200rpm and feed 0.25 mmpr.

Below image shows the creation of od_rough operation on spike model maintaining speed at 1200rpm and feed 0.25 mmpr.

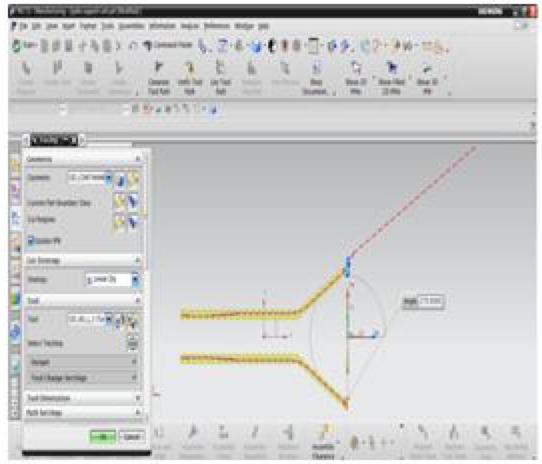


Fig: od_rough_turn operation

Below image shows the verification of drilling operation

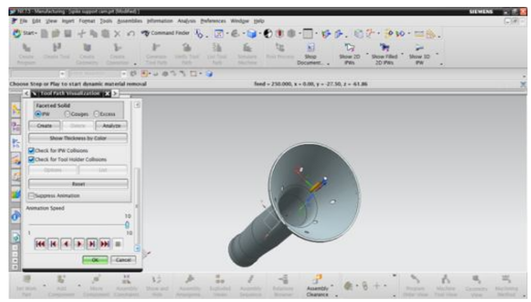


Fig: verification of drilling operation

Final model obtained after generation of tool path

FINAL COMPONENT AFTER MANUFACTURING

The above figures show surface roughness and scratch on the surface of spike support

VII. REDUCTION OF REJECTION RATE AND REWORKS RATE

Reducing rejection rate and reworks rate using 5-why (or) why-why analysis which helps in increasing production rate of the industry.

5-WHY ANALYSIS (OR) WHY-WHY ANALYSIS

- It is a method of questioning that leads to the identification of the cause(s) of a problem.
- A why-why is conducted to identify solutions to a problem that address its root cause(s). Rather than taking actions that are merely band-aids, a why-why helps to identify how to prevent the issue from happening again.
- A why-why is most effective in a team setting or with more than one person involved. Capture the input on a flipchart or a simple spreadsheet like the one below.
- First, start with the problem like to solve. Then ask, "why is x taking place?" you will end up with some answers. Jot these down.
- Repeat the process for each of the answers to the first question.
- Repeat the process for each of the answers to the second 'why' and continue until you've asked why five times.
- When you've hit the 5th why you usually have determined some root causes. Now you can identify specific action plans to address those root causes.
- Involve the right people – it helps to have those that are familiar with the process and the problem in the room, so they can answer why something happened. It is also helpful to have someone with a fresh eye participate – often they ask questions that help those involved in the problem extract the real reasons something happened.
- Avoid blaming – look for systemic problems. You are looking for systematic solutions to the problem. Blaming an individual ends up only making people feel bad. If someone didn't turn the right valve, ask the question "what could have helped the person turn the right valve?" could improvements in a procedure or labelling the valve have helped the individual?

Get creative – what systematic solutions might address the problem? Allow people to brainstorm and identify potential actions to address the issue. Later, go through the potential actions to identify the solutions that will yield the most effective results.

7.1 SEQUENCE OF OPERATIONS

MAIN CAUSES OF REJECTION RATE IN INDUSTRIES

1. Operator's negligence at work place and their poor knowledge in manufacturing.
2. Rejection rate also increased due to equipment such as component setup, assigning improper tools, fixture design problems.
3. Another cause of the increase in rejection rate is due to the procedure of machining like mistakes in the sequence of operations (turning, milling and drilling).
4. Another cause is following the norms or rules of the company in impossible conditions of machining the component.

VIII. RESULTS

Results are represented graphically to specify the quality control of spike support component.

GRAPHICAL REPRESENTATION OF HARMONIC ANALYSIS ON SPIKE SUPPORT

Zone 1-harmonic analysis has been carried out in the frequency range of 10-100hz (600-6000 rpm).from the analysis results graph of frequency vs amplitude in x,y and z directions have been plotted and shown below.

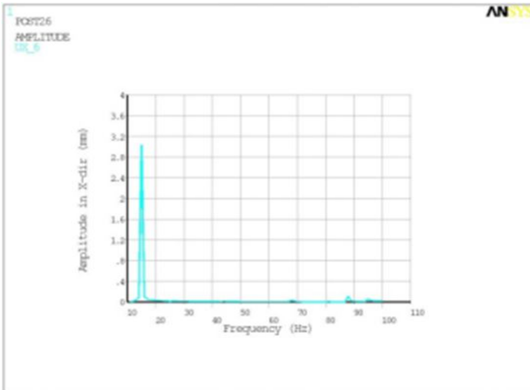


Fig: frequency vs amplitude in x-dir

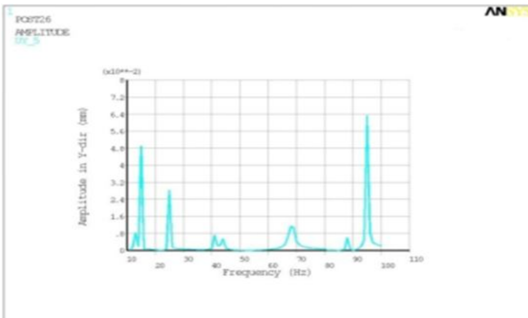


Fig: frequency vs amplitude in y-dir

Stable speed range between 20-100hz i,e (1200-6000 rpm) in x-direction and stable speed range is between 14-24hz i,e (840-1440 rpm),25-64hz i,e (1500-3840 rpm)and 70-80hz i,e (4200-4800 rpm) in y-direction respectively.

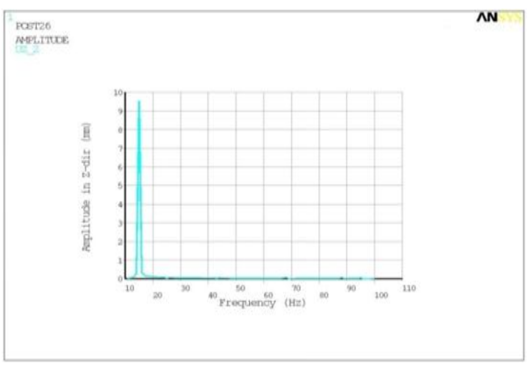


Fig: frequency vs amplitude in z-dir graph for zone1

From the above graph, it is concluded that the stable speed range is between 20-100hz i,e (1200-6000 rpm)

Zone2-harmonic analysis has been carried out in the frequency range of 10-100hz (600-6000 rpm).from the analysis results graph of frequency vs amplitude in x,y and z directions have been plotted and shown below.

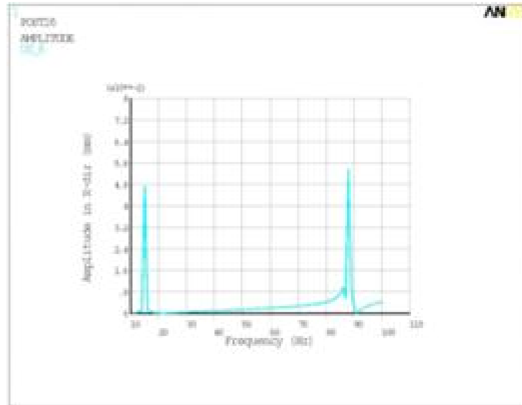


Fig: frequency vs amplitude in x-dir

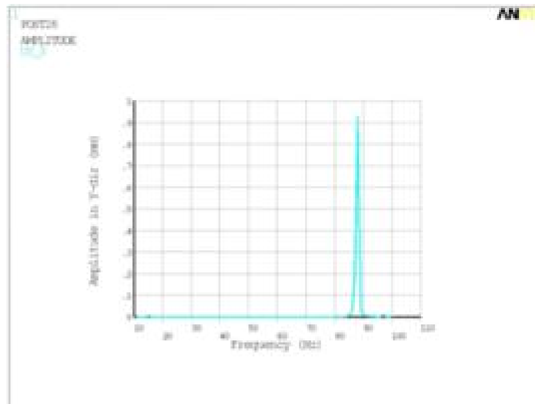


Fig: frequency vs amplitude in y-dir

Stable speed range between 20-70hz i,e (1200-4200 rpm) in x- direction and stable speed range between 10-80hz i,e (600-4800 rpm) in y-direction respectively. The component will be free of vibrations, and good surface finish can be achieved.

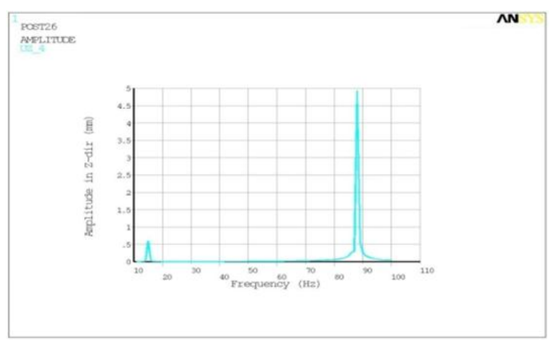


Fig: frequency vs amplitude in z-dir graph for zone2

From the above graph, it is concluded that the stable speed range is between 14-80hz i,e (840-4800 rpm)

Zone 3- harmonic analysis has been carried out in the frequency range of 10-100hz (600-6000 rpm).from the analysis results graph of frequency vs amplitude in x,y and z directions have been plotted and shown below

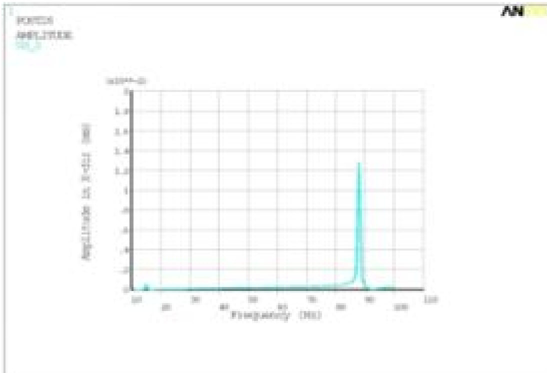


Fig: frequency vs amplitude in x-dir

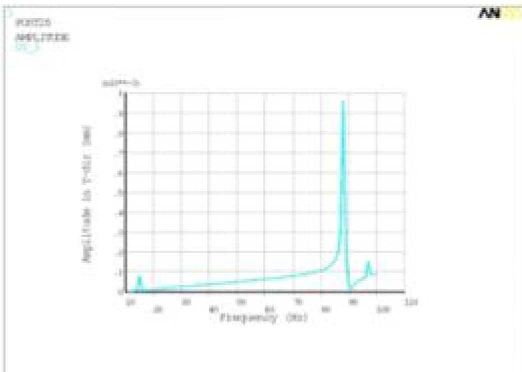


Fig: frequency vs amplitude in y-dir

Stable speed range between 10-80hz i,e (600-4800 rpm) in x-direction and stable speed range between 10-30hz i,e (600-1800 rpm) y-direction. The component will be free of vibrations, and good surface finish can be achieved.

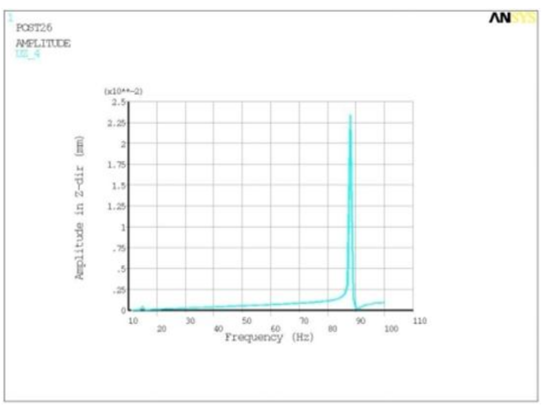


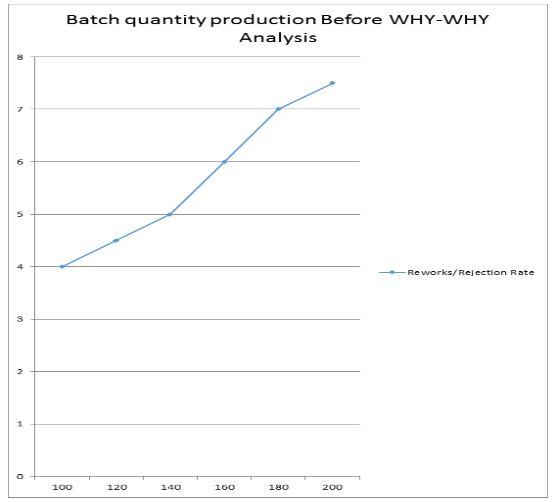
Fig: frequency vs amplitude in z-dir graph for zone3

From the above graph, it is concluded that the stable speed range is between 10-50hz i,e (600-3000 rpm)

GRAPHICAL REPRESENTATION OF REJECTION AND REWORKS RATE

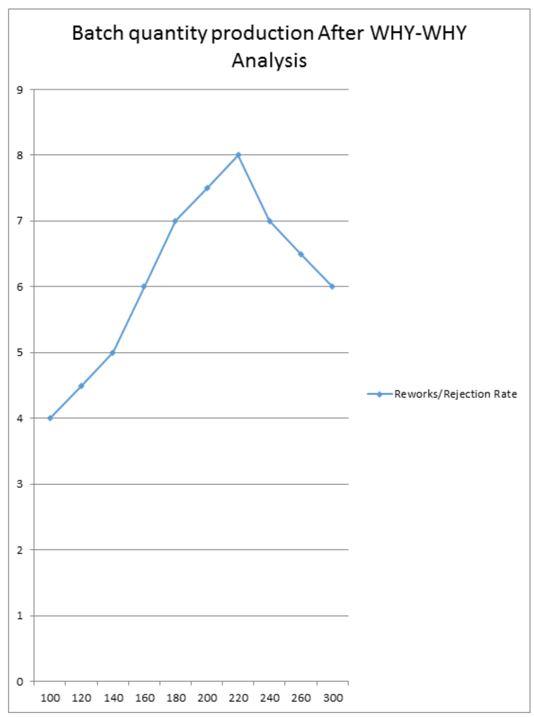
Below graphs shows the rejection and reworks rate before why-why analysis and after why-why analysis.

Results before why-why analysis



Results after why-why analysis

These four causes for rejection which are mentioned above is rectified by using why-why analysis. The following graph indicates rejection rate after why-why analysis.



From the above result graphs, it is concluded that the reworks and rejection rate is decreased from 9% to 6% after using why-why analysis.

IX. SUMMARY

- By considering 2d inputs 3d model is generated using nx-cadsoftware.
- Model analysis has been done on the spindle to find out the frequencies to be avoided while machining the

component.

- Harmonic analysis has been done on the spike support to find out the cutting speed ranges at which the component is free from vibrations.
- Tool path is generated on spike support using the nx-cam software.
- Non-expandable mandrel has been designed to support the component for external operations. By using the non-expandable mandrel, the rejection rate is more due to the gap between the mandrel and spike.
- The expandable mandrel is designed to overcome the rejection rate. Use of expandable mandrel results in less rejection compared to before mandrel.
- By using why-why analysis rejection and rework rate is reduced.
- Graphical representation of harmonic analysis on spike support is shown in results.
- Graphical representation of rejection and reworks rate before and after why-why analysis is shown in results.