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Research Paper

PARAMETRIC DESIGN AND ANALYSIS OF TWO STATION TWO SPINDLE ROUGH BORING AND FINISH BORING SPM

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The current interest in developing a manufacturing capability at the mixed scales is leading to a number of investigations concerned with the development of special purpose machine tools. Competition permanently demands the machine tool manufacturers to improve the working accuracy and the dynamical behaviour of their machines while reducing both product development time and costs. The problem with most special purpose machines is the amount of vibration that is transmitted through the spindle, which affects the quality of surface finish and the dimensional accuracy imparted to the work piece being machined. Owing to the way the spindle is mounted at the end of a cantilevered structure, low resonant frequencies can occur that are easily excited. SPM is a special purpose machine exclusively used in two wheeler automobiles. The main objective of this project is to design and perform finite element analysis of the SPM and make sure that the SPM is free from vibrations. In this thesis design calculations were done using Timoshenko beam theories for different cutting forces. Later a parametric 3D model was developed using the cad software. Both static and dynamic analyses were done using analysis software NX cad software is used for developing 3D parametric model and Ansys software is used for performing static and dynamic analysis.

Keywords: Machine tool manufacturers, Special purpose machine, Work accuracy, Design calculations

INTRODUCTION

Special purpose machines are designed and manufactured for specific jobs and as such never produced in bulk. Such machines are finding increasing use in industries. The technique for designing such machines would obviously be quiet different from those under for mass produced machines. A very keen judgment is essential for success of such machines.

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Broadly the special purpose machine tools could be classified as those in which job remains fixed in one position and those in which job moves from one station to other (transfer machines). In first case the machine may perform either only one operation or more. In the second case, the product may be either moving continuously (as in the case of spraying, polishing, sanding etc.) or intermittently (the most usual case in machining operation). Rotary intermittent motion transfer machine is very popular production machine and is described in brief below. Such a machine comprises a turret, on whose periphery several heads are mounted to receive and locate the components for working. The turret rotates intermittently about its central axis and is provided with fine and sophisticated mechanisms to control its motion so that before stopping, it is properly decelerated and desired positioning accuracy is attained. At stationary positions around the turret, usual mounted on a table, are the several tools and units which perform the machining operation. It is essential that all moments be completely synchronized in order to obtain desired product. All tools and units must have completed their operation and be withdrawn clear of the turret before it starts to index. Similarly the turret must index precisely and accurately and come to rest, before tools and units begin their work.

3D MODELING OF SPM

The two station two spindle rough boring and finish boring spm is a special purpose machine exclusively used in two wheeler automobile industry in which it is used for fine boring of combustion chamber to reduce the oil consumption of the two wheeler. The 3D model of the SPM assembly is created using UNIGRAPHICS NX software from the 2D drawings. UNIGRAPHICS NX is the world's leading 3D product development solution. This software enables designers and engineers to bring better products to the market faster. It takes care of the entire product definition to serviceability. NX delivers measurable value to manufacturing companies of all sizes and in all industries.

NX is used in a vast range of industries from manufacturing of rockets to computer peripherals. With more than 1 lakh seats installed in worldwide many cad users are exposed to NX and enjoy using NX for its power and capability.

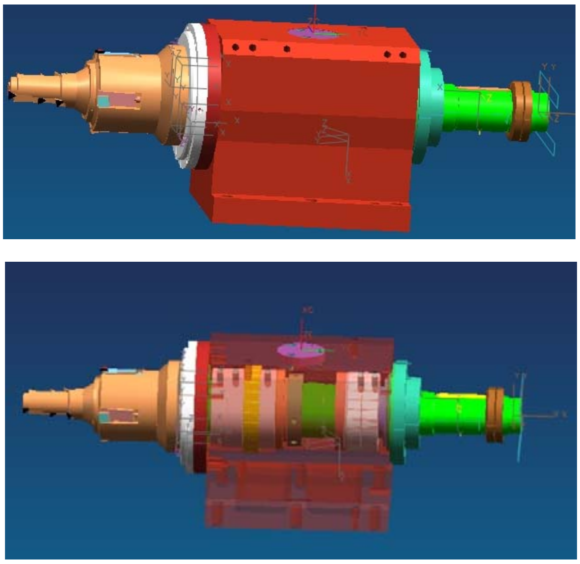
Spindle Housing

The spindle shaft and motor must be held in housing. The housing may be an integral part of the machine tool, or it may be cartridge housing. Many high speed spindle designs utilize cartridge type housing, as this is the simplest to service, and the tolerances required for high speed are easier to obtain when the housing can be produced as a cylinder.

The spindle housing is typically connected to the machine tool by means of a flange or attaching bracket. Care should be taken when handling any precision spindle. Crashes, dents, and other damage can affect the accuracy and bearing life.

SPINDLE ASSEMBLY

Figure 1: 3D Model of Spindle Assembly Developed in NX-CAD



Element Types Used

Name of the Element: SOLID 92

Number of Nodes: 10

Table 1: Material Properties

Material	Young's Modulus (Mpa)	Poisson's Ratio	Density (Kg/m^3)
High speed steel	2e5	0.3	7850

Material Properties used in the Analysis

Boundary Conditions for Case 1: In case 1 spindle with only belt loads are considered. The deflections and stresses due to belt loads are plotted.

The boundary conditions applied for the static analysis due to tensioning of belt are as follows and are shown in below figures.

- Bearing Locations arrested in all DOF as shown in the below figure.
- Spindle face is arrested in all DOF as shown in the below figure
- Load generated due to tensioning of belt is applied as cylindrical load at the belt location as shown in the below figures.

Figure 2: Bearing Locations and Face Arrested in all DoF

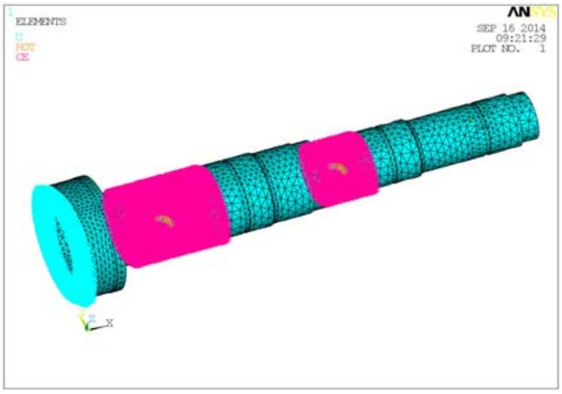
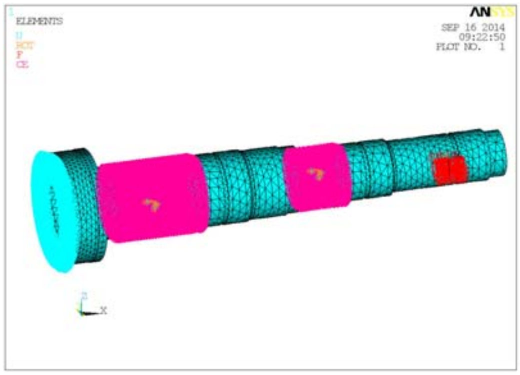


Figure 3: Belt Load Applied at the Belt Location



Results of Static Analysis: The deflections and stresses are plotted for the spindle component. The maximum displacement in X direction is observed as 0.003mm

The maximum displacement in Y direction is observed as 0.021mm

The maximum displacement in Z direction is observed as 0.01mm

Figure 4: Displacement in X-dir of Spindle Model

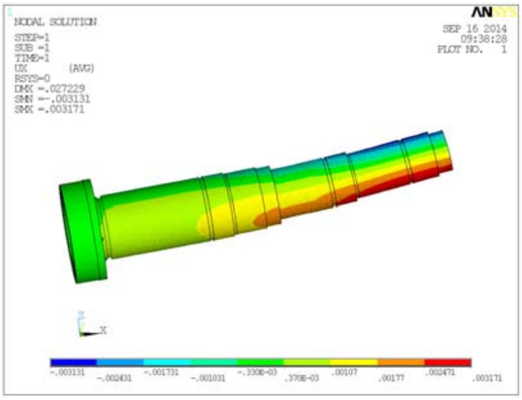


Figure 5: Displacement in Y-dir of Spindle Model

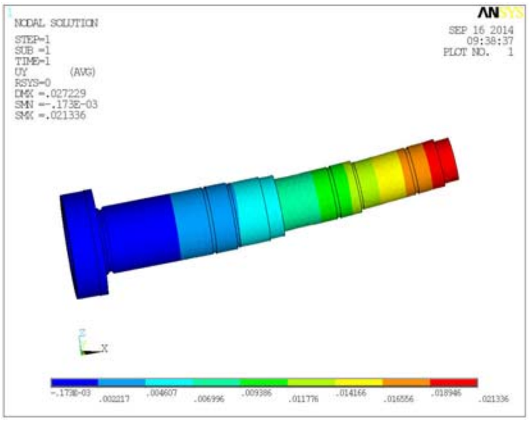


Figure 6: Displacement in Z-dir of Spindle Model

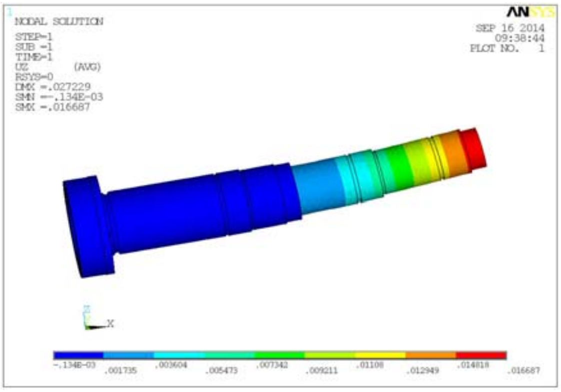


Figure 7: Resultant Displacement of Missile Piston for Case1 Model

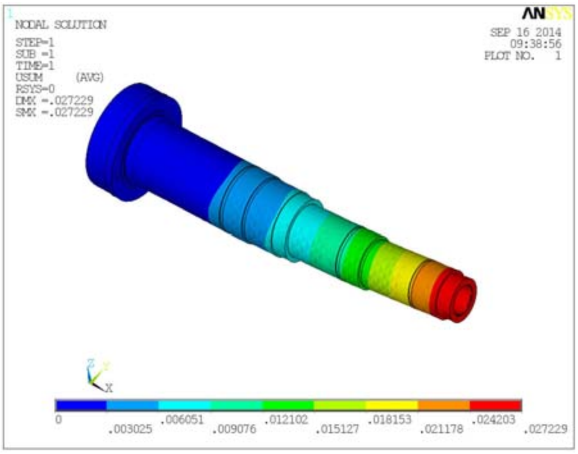
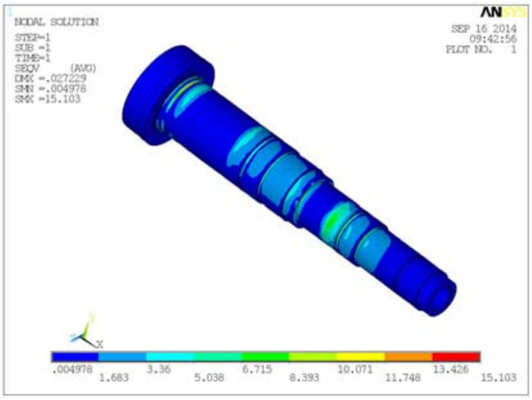


Figure 8: VonMises Stress of Spindle Model



The maximum resultant deflection in all directions is observed as 0.027mm

The maximum VonMises stress observed is 15 Mpa on the bearing location as shown in the Figure.

From the above results the maximum VonMises stress observed on the spindle is 15Mpa.The yield strength of the material is 260Mpa.The VonMises stress is less than the yield strength so the spindle component is safe for the operating loads. The Maximum deflection observed on the spindle is 0.027 mm.

Boundary Conditions for Case 2: In case 2 spindle and tool holder with belt loads and also cutting forces are considered for the analysis. The deflections and stresses due to belt loads and cutting forces are plotted. Static analysis of the spindle with tool holder is carried out by applying the belt tensions and cutting forces obtained from the calculations. Forces generated due to cutting forces are applied at the insert location as shown in the Figures.

Results of Case 2 Static Analysis: The deflections and stresses are plotted for the spindle and tool component. The maximum displacement in X direction is observed as 0.003mm

The maximum displacement in Y direction is observed as 0.02mm

The maximum displacement in Z direction is observed as 0.02mm

The maximum resultant deflection in all directions is observed as 0.026mm

Figure 9: Bearing Locations and Face Arrested in all dof for Case 2 Analysis

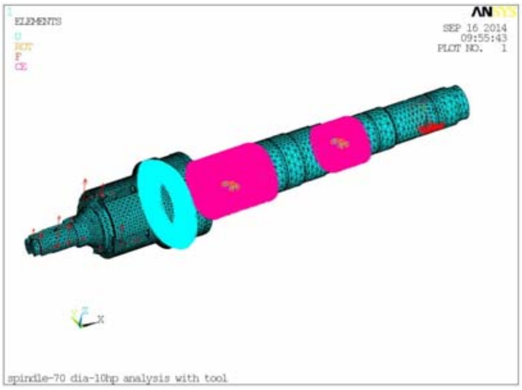


Figure 10: Belt Load Applied at the belt Location for Case 2 Analysis

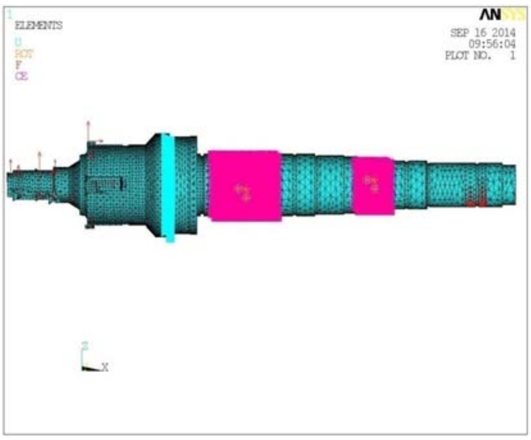


Figure 11: Cutting Forces Applied at the Insert Location for Case 2 Analysis

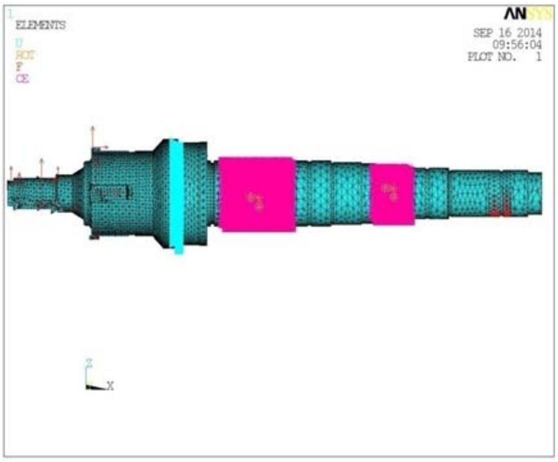


Figure 12: Displacement in X-dir of Spindle Model for Case 2 Analysis

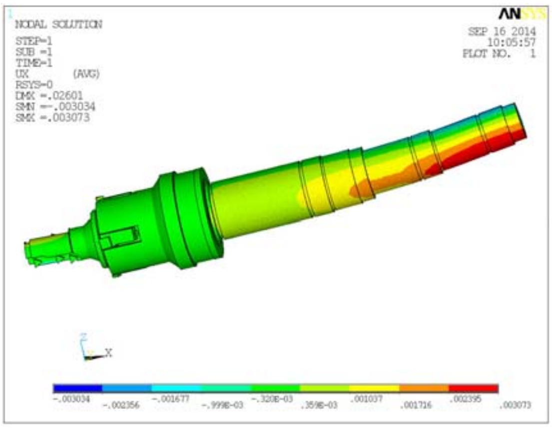
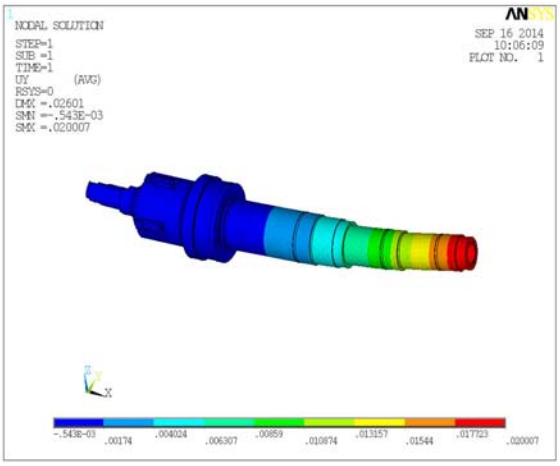


Figure 13: Displacement in Y-dir of Spindle Model for Case 2 Analysis



The maximum VonMises stress observed is 17 Mpa on the tool holder as shown in the figure.

From the above results the maximum VonMises stress observed on the spindle is 17Mpa.The yield strength of the material is 260 Mpa. The VonMises stress is less than the yield strength so the spindle component with cutting forces is safe for the operating loads. The Maximum deflection observed on the spindle is 0.026 mm.

Figure 14: Displacement in Z-dir of Spindle Model for Case 2 Analysis

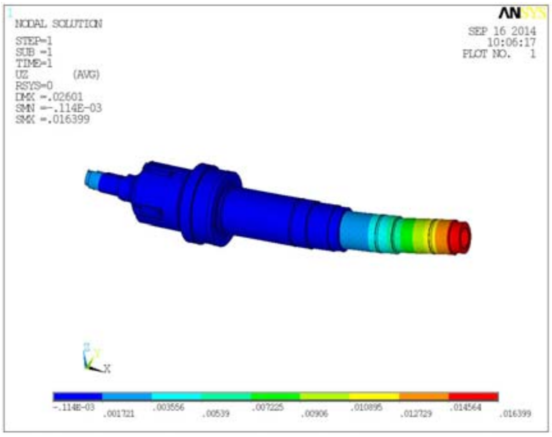


Figure 15: Resultant Displacement of Spindle for Case 2 Analysis

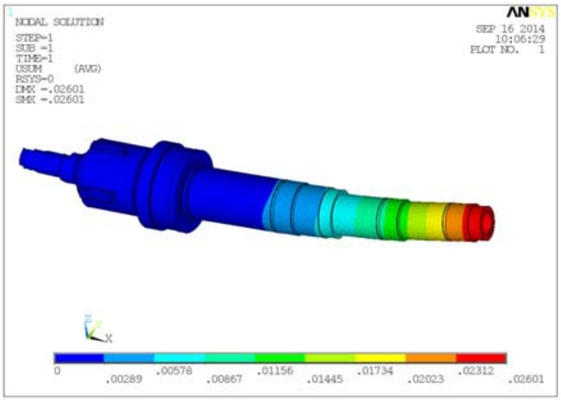


Figure 16: VonMises Stress of Spindle Model

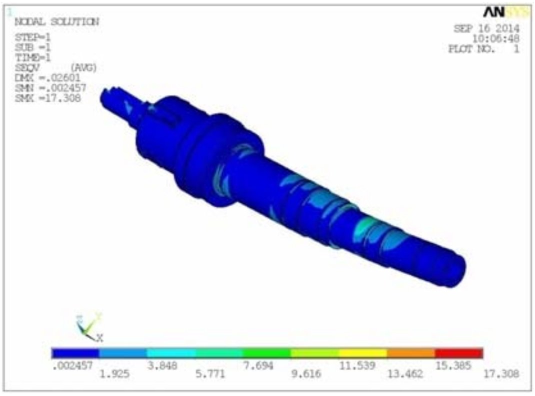
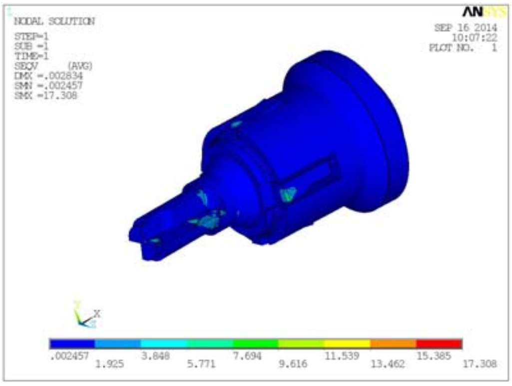


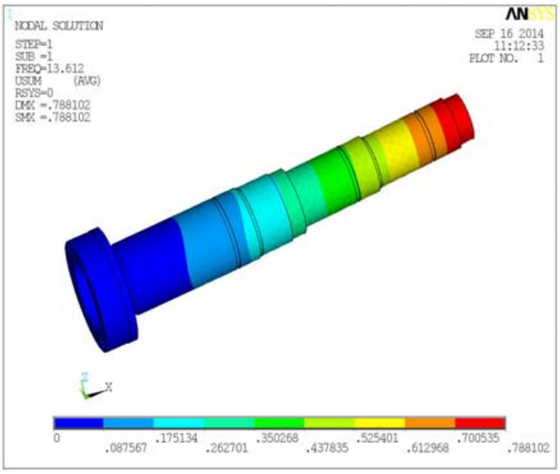
Figure 17: VonMises Stress on Spindle Model 17Mpa



The mode shape of the first 5 natural frequencies are shown below.

From the modal analysis first 10 natural frequencies are calculated. It is observed that only 1 natural frequency at 13 Hz is present in the operating range of 0-20 Hz. However harmonic analysis is carried out in the frequency range of 0 - 20 Hz, to check the structure behavior in this frequency range due to applied operating load.

Figure 18: 1st Mode Shape of the Spindle @ 13.6 Hz



Results of Harmonic analysis

From modal analysis it is observed that there exist 1 natural frequency at 13 Hz in the operating range of 0-20 Hz. So the frequency 13 Hz is critical. It is necessary to understand the structure behavior at 13 Hz due to the application of operating loads. However from the harmonic analysis we have calculated the results nearest to the natural frequency at 12 Hz and 14 Hz. The deflection at these frequencies are plotted below.

Figure 19: 2nd Mode Shape of the Spindle @ 30 Hz

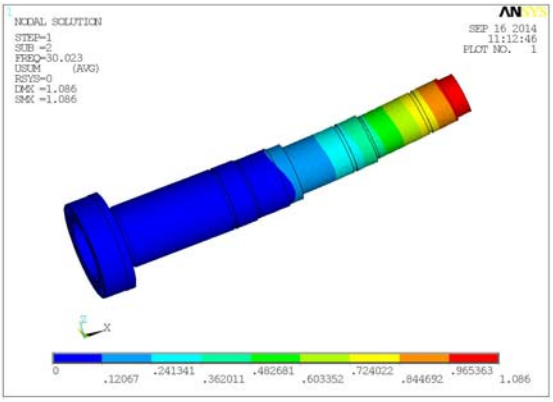


Figure 20: 3rd Mode Shape of the Spindle @ 53 Hz

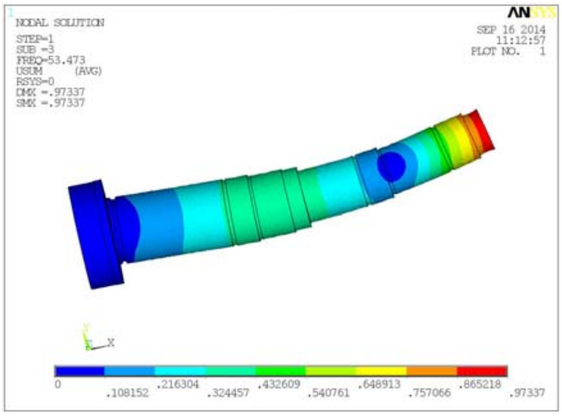


Figure 21: 4th Mode Shape of the Spindle @ 69 Hz

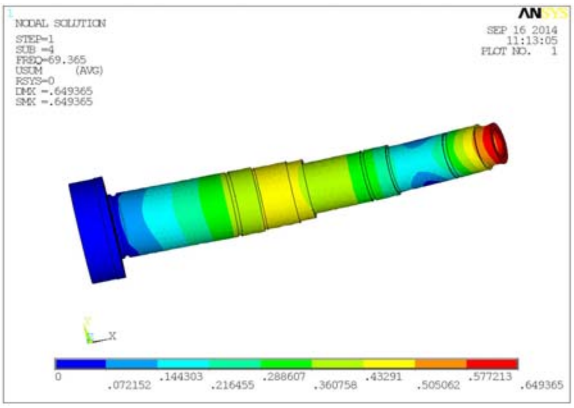


Figure 22: 5th Mode Shape of the Spindle @ 98 Hz

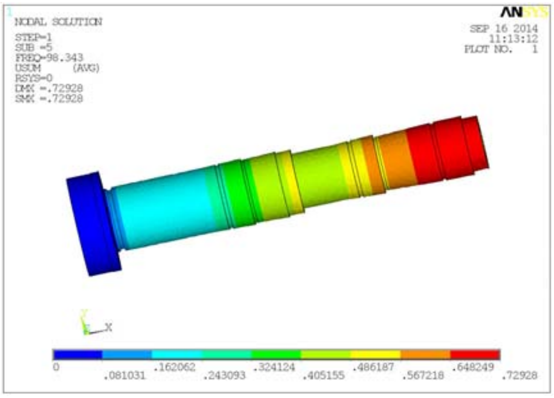
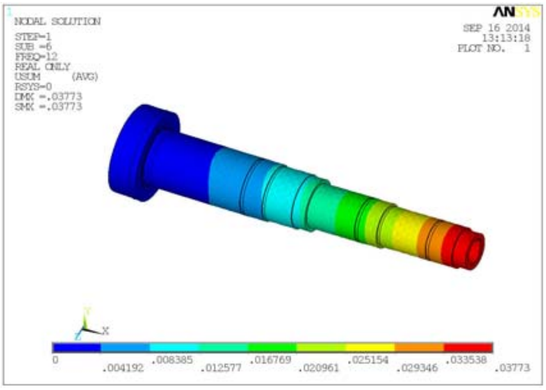


Figure 23: Maximum Deflection at 12 Hz for Harmonic Loads



RESULTS

Deflection and Stresses at 12 Hz

Maximum deflection of 0.03mm and Von Mises stress of 31.7 Mpa is observed as shown in the below figures.

Deflection and Stresses at 14 Hz

Maximum deflection of 0.16 mm and VonMises stress of 151 Mpa is observed as shown in the below figures.

Harmonic analysis has been carried out in the frequency range of 0-20Hz (0-1200 rpm).From the analysis results graph of frequency Vs amplitude in X,Y and Z directions at bearing 1, bearing 2 and spindle end locations have been plotted and shown below.

From the above harmonic analysis results, the maximum VonMises stress observed is at 14 Hz and the value is 151 Mpa. The yield strength of the material is 260 Mpa. The VonMises stress is less than the yield strength So the spindle component with cutting forces is safe for the operating loads. The Maximum deflection observed on the spindle is 0.16 mm.

Figure 24: Maximum VonMises Stress at 12 Hz for harmonic loads

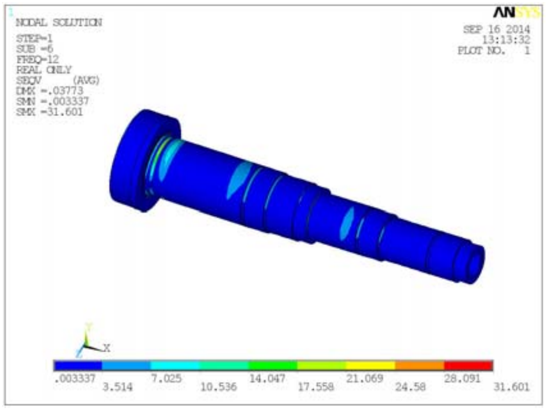


Figure 25: Maximum Deflection at 14 Hz for Harmonic Loads

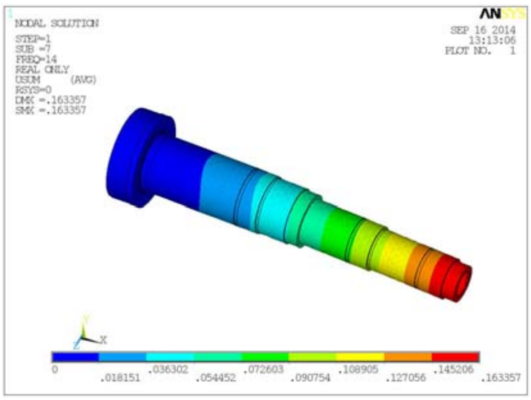


Figure 26: Maximum VonMises at 14 Hz for Harmonic Loads

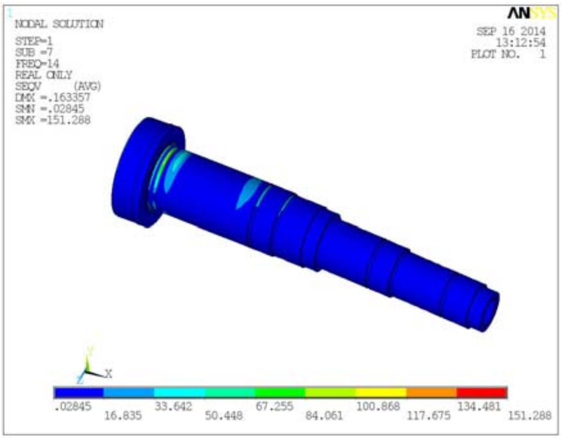


Figure 27: Frequency Vs Amplitude in X,Y and Z-dir Graph at Bearing #1

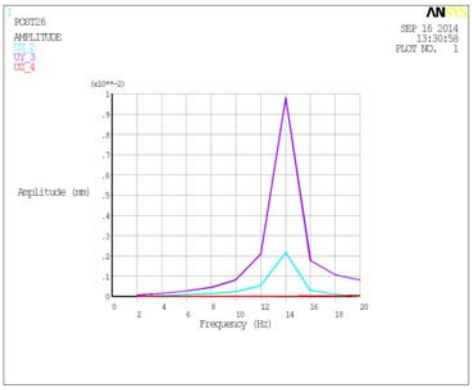


Figure 28: Frequency Vs Amplitude in X,Y and Z-dir Graph at Bearing #2

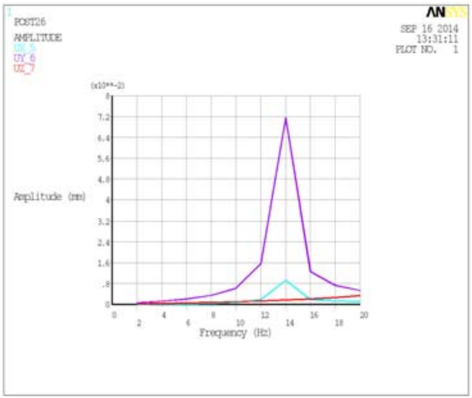


Figure 29: Frequency Vs Amplitude in X,Y and Z-dir Graph at Spindle End

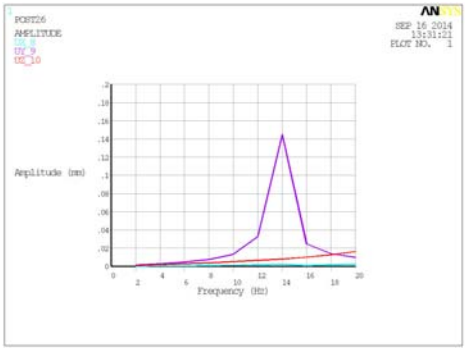
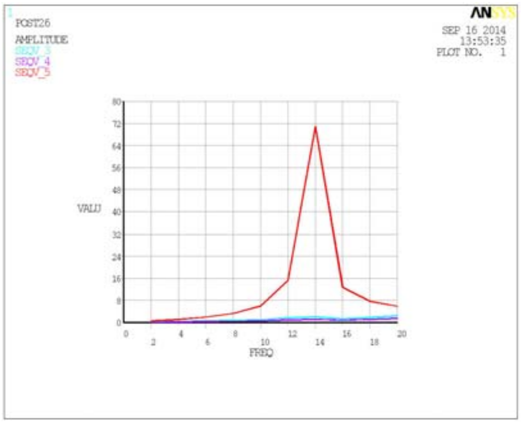


Figure 30: Frequency Vs VonMises Stress at Bearings #1 and #2 and spindle End



RESULTS AND DISCUSSION

In this project design and finite element analysis of the SPM was done and we have done dynamic analysis to make sure that the SPM is free from vibrations. In this project design calculations were done using Timoshenko beam theories for different cutting forces. Later a parametric 3D model was developed using the cad software. Both static and dynamic analyses were done using analysis software.

The spindle assembly was studied for the following conditions:

- Static Loads
- Dynamic loads

From the static analysis the results obtained are as follows:

- Analysis of spindle deflection due to tensioning of belt is 0 .027229 mm
- Analysis of spindle deflection due to axial and radial forces is 0 .026mm
- VonMises stress due to tensioning of belt is 15N/mm^2
- VonMises stress due to axial and radial forces is 17N/mm^2

From the dynamic analysis the results obtained are as follows:

- Spindle deflection at 12 Hz is 0 .03 mm
- Spindle deflection at 14 Hz is 0 .16 mm
- Von Mises stress at 12 Hz zHzH is 31.7 N/mm^2
- Von Mises stress at 14 Hz is 151 N/mm^2

CONCLUSION

3d model of the SPM assembly is done using NX-CAD and Finite element analysis is carried out using Ansys. Design calculations are performed to calculate the operating loads. Finite element analysis was done to validate the design . Based on analysis the spindle deflections and stresses have been evaluated due to tensioning of belt and cutting forces for both the static and dynamic cases. It is observed that the stresses are below the yield strength of the material which is 260N/mm2.Hence we can conclude that the spindle is safe under the given operating conditions

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