

Design and Analysis of Spindle for Oil Country Lathe

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ABSTRACT: Oil country lathe is a special type of Lathe machine in which the Spindle will have two chucks on both the ends so that it should provide the passage for job through the spindle bore and is held on either side by two chucks and various speeds of spindle is achieved by the drive controls. The main spindle will be mounted on Taper Roller Bearing on front and rear end of spindle. In the present work, the spindle arrangement for CNC Oil Country Lathe has been completely designed and developed in SOLIDWORKS Software and this model is imported to HYPERMESH through IGES format and FEA model with converged mesh is developed. Analysis has been made using finite element analysis. For this FEA model various loading conditions like static and dynamic analysis and operating conditions are applied using ANSYS to ensure that spindle is safe as per design considerations by obtaining the deflections and mode shapes considering all the forces acting on the spindle.

KEYWORDS: Oil country lathe, SOLIDWORKS, HYPERMESH, ANSYS

I. INTRODUCTION

A lathe is a machine tool that rotates the workpiece on its axis to perform various operations such as cutting, sanding, knurling, drilling, or deformation, facing, turning, with tools that are applied to the job to create an object with symmetry about an axis of rotation.

Lathes are used in woodturning, metalworking, thermal spraying, metal spinning, parts reclamation, and glass-working.. Most suitably equipped metalworking lathes can also be used to produce most solids of revolution, plane surfaces and screw threads or helices. The workpiece is usually held in place by either one or two centers, at least one of which can typically be moved horizontally to accommodate varying job lengths. Other work-holding methods include clamping the work about the axis of rotation using a chuck, or to a faceplate, using clamps.

Almost all lathes have a bed, which is (almost always) a horizontal beam (although CNC lathes commonly have an inclined or vertical beam for a bed to ensure that chips falls free of the bed). Woodturning lathes specialized for turning large bowls often have no bed or tail stock, merely a free-standing headstock and a cantilevered tool rest.

Oil Country Lathe is a popular product offering for oil and gas handling and metal industry. It is a big bore lathe of double chucks at both sides of the headstock, or it could have large swing for big workpiece. Big bore lathe is very good at threading and cutting at the two ends of long pipes or tubes.

Oil country lathe V/s Normal Lathe.

A lathe is a machine tool will have spindle and chuck to hold on single side that rotates the workpiece on its axis to perform various operations such as turning, cutting, knurling, drilling, or deformation, facing, with tools that are applied to the work piece to create an object with symmetry about an axis of rotation.

Similarly Oil Country Lathe (a) is a typical lathe machine which is specially used for threading, turning and facing of long pipes which are used in oil and gas industry. Unlike the normal Lathe machine here the spindle will have two

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

chucks on front and rear side. So that the spindle will have passage through the bore for the workpiece which are in turn held by pneumatic chucks on the spindle.



(a)

II. RELATED WORK

2.1 Design considerations of the spindle

The main functions of spindles for metal cutting machine tools are

1. Rotating the cutting tool or the workpiece with a certain precision.
2. Providing necessary power and speed to the tool or the work piece for cutting operation.
3. Resisting against the cutting forces generated during cutting operation.

2.2 Modelling of the spindle

The 3D model of the spindle was designed in SOLIDWORKS as shown. The main spindle (a) with bore $\text{Ø}210$ will have rear spindle nose (c) to hold the rear chuck. The spindle is designed for taper roller bearings at front and rear to carry the all the forces acting on it.

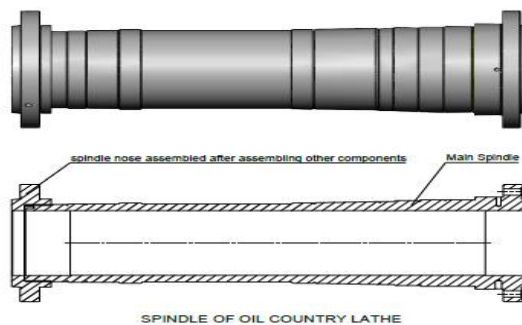
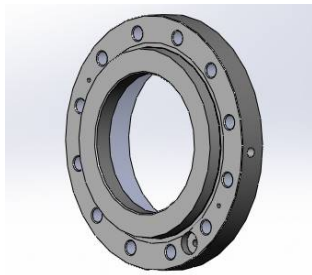


Fig -2.1: Spindle model and cross-section

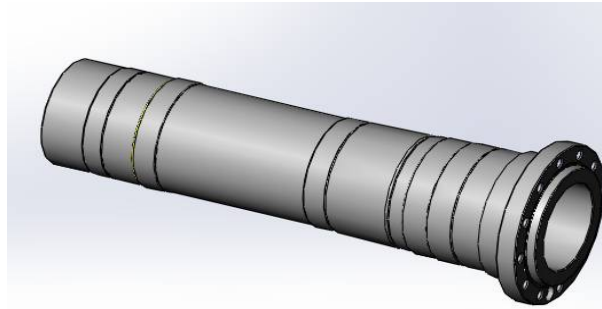
International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016



(b)



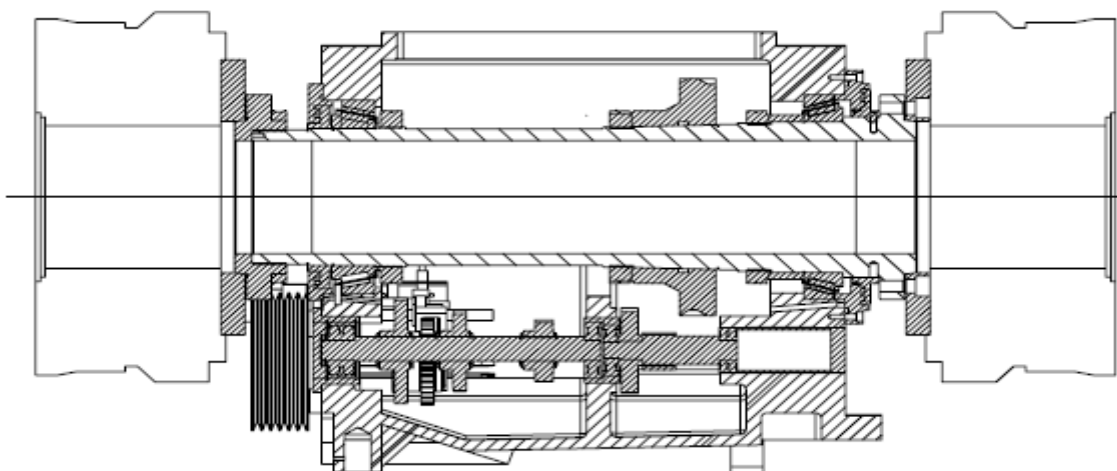
(c)

2.3 Assembly of spindle in Headstock

The spindle assembly in headstock (d) is as shown so that the spindle is mounted on Taper Roller Bearings on Front and Rear end of the headstock. The speed range of spindle is as shown in the table below. The drive will start from the motor pulley then to the headstock pulley simultaneously it will reach spindle through the shafts in sequence. Finally with the main drive controls the required range of speed is obtained.

SPEED RANGE	SPINDLE SPEED
RANGE 1	4.5-60
RANGE 2	40-105
RANGE 3	75-250
RANGE 4	175-450

Table -1: Spindle speed Range



(d)

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

2.4 Analysis

2.4.1 Engineering properties of material

Material – Forged Alloy Steel

Elastic modulus - 2.05×10^{11} N/m²

Poisson Ratio - 0.29

Shear modulus - 8×10^{10} N/m²

Mass density 7850 kg/m³

Tensile strength- 625×10^6 N/m²

Yield strength- 53×10^7 N/m²

Thermal conductivity - 49.8W/m-K

Specific heat - 486 J/kg-K

Thermal expansion - 1.15×10^{-5} /K

2.5 Permissible Load between centres.

The spindle must carry the maximum job weight of 5500kgs

Max permissible component weight between centres

Without Steady Rest – 3500 kgf

With one Steady Rest – 4500 kgf

With two Steady Rest – 5500 kgf

III. FINITE ELEMENT ANALYSIS

3.1 Basic Concept of FEA

Finite Element Analysis has now become an integral part of Computer Aided Engineering (CAE) and is being extensively used in the analysis of many tedious real time problems. The field of finite element analysis is matured and depends on rigorous mathematical foundation. Many powerful software tools and packages are available, promoting its widespread use in industries. Here the model created is converted to FEA model using HYPERMESH and the analysis is performed.

IV. PROCEDURE

For analysis, the spindle is required to be imported into any analysis software package. We used Ansys workbench and following steps are carried out for the analysis.

STATIC

DYNAMIC

V. EXPERIMENTAL RESULTS

5.1 DISPLACEMENTS USING ANSYS

The maximum deflection of the spindle obtained through ANSYS is found to be 9.061 microns as shown. As per the CMTI machine tool design handbook, the maximum deflection of shaft or spindle must not exceed 2×10^{-4} times the span between bearings. In the present work of the spindle assembly the span length between bearing support is of 800 mm for which allowable static deflection works out to be $800 \times 2 \times 10^{-4} = 160$ microns. Thus the maximum static deflection of 9.061 microns is well below the permissible value.

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(An ISO 3297: 2007 Certified Organization)

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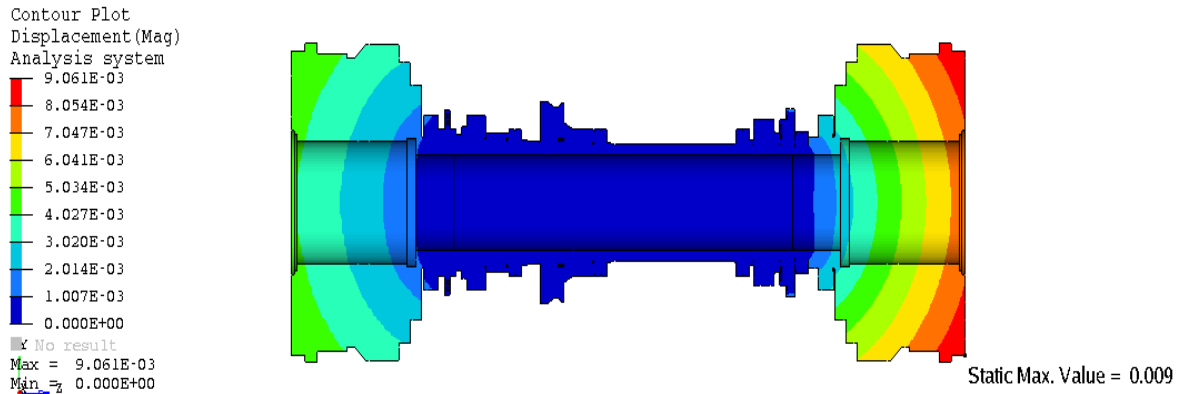


FIG 5.1: INITIALLY WHEN THE SPINDLE TENDS TO DISPLACE

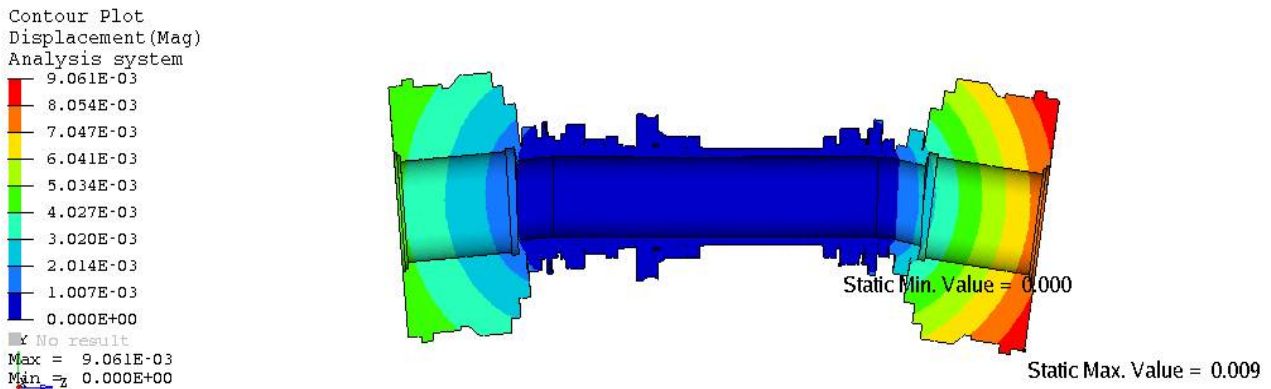


FIG 5.2: AT MAXIMUM DISPLACEMENT CONDITION

5.2 DYNAMIC ANALYSIS

Dynamic analysis can be used to determine the vibration characteristics (natural frequencies and mode shapes) of a structure or a machine component while it is being designed. It also can be starting point for another, more detailed, dynamic analysis, such as a transient analysis, a harmonic analysis, or a spectrum analysis. Dynamic analysis is the study of the dynamic properties of structures under vibration excitation. The below plot show mode shape at the required range of speed (0-10 Hz), there is no response at required range. Hence the design is safe

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

5.3.1 Modal analysis

But we have to find at what frequency the spindle gives the response. The dynamic analysis of the preliminary spindle design is also done using ANSYS Workbench. The analysis is performed with the same simplified spindle model used in the static FEM analyses. The Eigen frequencies of the spindle calculated for the first 6 modes and the results are given in Table. The mode shapes and the corresponding frequency values obtained from the analysis by expanding the modes are shown

MODE	Frequency [Hz]
1st	126.6
2nd	161.7
3rd	174.7
4th	470.77
5th	551.3
6th	672.5

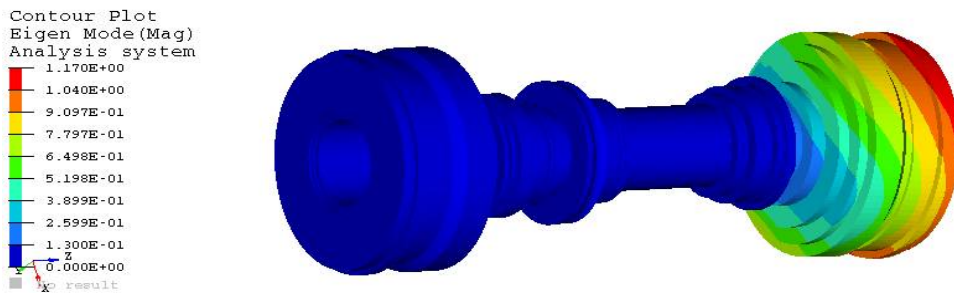


Fig 5.3: First mode at 126.6 Hz

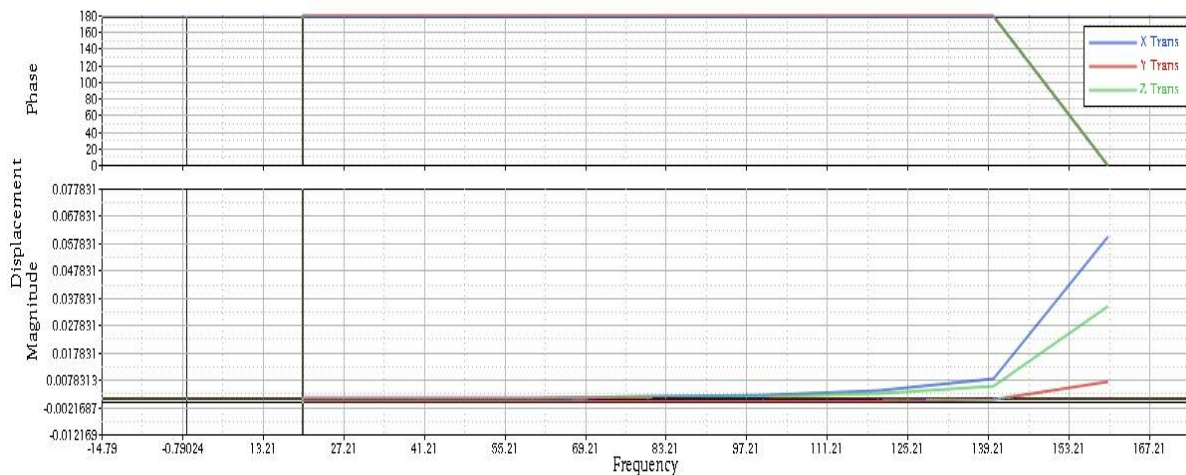


Fig 5.4: Graph for Frequency V/s Displacement

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 8, August 2016

5.3.2 MAXIMUM STRESSES:

Considering the cutting force of 10,000N and the weight of job 3000 kgf the stresses are obtained from the ANSYS result shown and it is confirmed that the maximum stress is 13.791 N/mm² considering the factor of safety also, which is in the limit of yield strength of selected alloy steel material of spindle 530 N/mm². Hence the design of the spindle is safe.

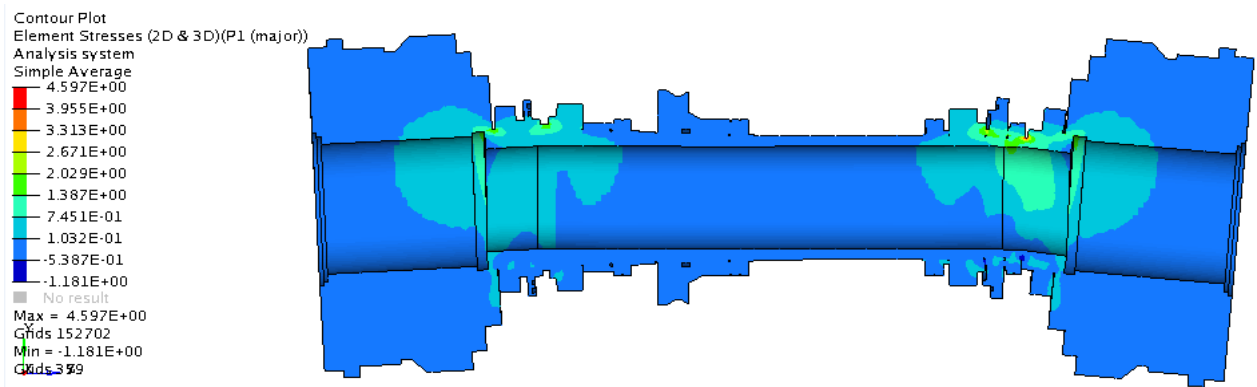


Fig 5.4: Maximum stresses in the spindle

VI. CONCLUSION

As the result of this thesis, a spindle is designed with the following specifications

1. Typical oil country lathe Spindle is designed for holding chucks on double side (front and rear).
2. it is designed to obtain the speed range from 4.5 to 450 rpm.
3. It can cut pipes with a maximum diameter of $\varnothing 210$ mm and 10m maximum length with 6 mm depth of cut at the speed of maximum 450rpm.
4. Oil country lathe and normal lathe analysis are compared and design of spindle is proved to be safe.
5. The displacement at static condition is 9.06 microns which is much lower than allowable 160microns. Hence the spindle and bearings are safe.
5. The stresses generated in the spindle shaft for the worst case loading are much lower than the yield limit 530 MPa of the shaft material, forged steel. Therefore, no plastic deformation is expected during cutting operations.
6. Its first mode frequency is 126.6 Hz which is far above the working speed range 4.5-450 rpm (10 Hz). Proves that spindle avoids any resonance during cutting.

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