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3D Design and Modeling of High-Speed Motorized Spindle using EN 8 Steel and Carbon Fiber Materials

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Abstract

In this article, high speed motorized spindle is designed and analyzed under the given load conditions. The spindle used in this thesis is that used in a milling machine. The 3D modeling of spindle is designed in CREO. The material used for spindles is Steel. In this thesis, different materials are analyzed for spindle. EN 8 steel and carbon fiber are replaced with steel. By replacing the steel with carbon fiber, the weight of the spindle decreases. Structural, and Dynamic analyses is done using ANSYS software. Modal analysis also is done to determine the frequencies.

Keywords: High speed motorized spindle, CREO, Dynamic analysis.

I.INTRODUCTION

In machine tools, a **spindle** is a rotating axis of the machine, which often has a shaft at its heart. The shaft itself is called a spindle, but also, in shop-floor practice, the word often is used metonymically to refer to the entire rotary unit, including not only the shaft itself, but its bearings and anything attached to it (chuck, etc.).A machine tool may have several spindles, such as the headstock and tailstock spindles on a bench lathe. The main spindle is usually the biggest one. References to "the spindle" without further qualification imply the main spindle. Some machine tools that specialize in high-volume mass production have a group of 4, 6, or even more main spindles. These are called **multi spindle** machines. For example, gang drills and many screw machines are multi spindle machines. Although a bench lathe has more than one spindle (counting the tailstock), it is not called a multi spindle machine; it has one main spindle.

1.1. Spindle in milling machine

Spindle is the most important part of milling machine, which is used to install the tool and drive the tool to rotate. Most of the milling machine equipment use multi-tooth cutting tools, so in the processing which will cause a sudden change in milling force, which is prone to vibration in the cutting, which requires the spindle part of a higher rigidity and vibration resistance, so the use of three-point support structure. The spindle itself is very strict processing requirements. Including materials, processing technology and technical requirements have a strict standard. This part of the content I will be in the future blog and then elaborated.

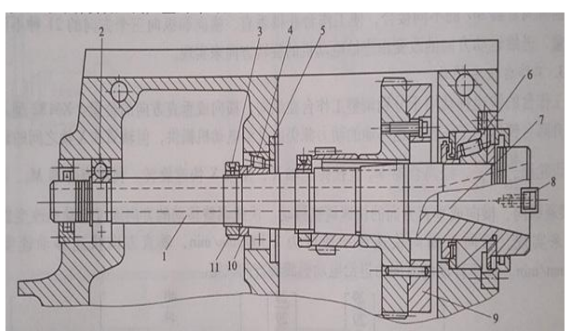

Fig. 1 schematic of spindle

1.2. Advantages of spindle

- **Perform Multiple Functions**

When one part needs to undergo several different operations, it’s simpler to use the same machine to perform these different functions. In fact, because a multi-spindle head can hold up to 24 spindles, you can machine different parts without stopping to switch heads or machines. You can even have adjustable and fixed spindles on the same head.

- **Reduced Time**

Because one head is performing multiple functions, the time it takes to drill, tap, ream, and mill a part is reduced drastically. Not only will you save time on each part, but in turn, your overall productivity will increase.

- **Disadvantages of spindle**

The main advantage of these bearings is low friction. ... The main disadvantages of these types of bearings are minimum velocity (30,000 rpm) and the cost, which is several times higher than that of a ball bearing spindle.

II. LITERATURE REVIEW

In this paper by Deping Liu, Hang Zhang, Zheng Tao and Yufeng Su[1], presents a method to investigate the characteristics of a high-speed motorized spindle system. This paper taking the high-speed milling motorized spindle of CX8075 produced by Anyang Xinsheng Machine Tool Co. Ltd. as an example, a finite element model of the high-speed motorized spindle is derived and presented. The results show that the maximum rotating speed of the motorized spindle is far smaller than the natural resonance region speed, and the static stiffness of the spindle can meet the requirements of design. The static and dynamic characteristics of the motorized spindle accord with the requirements of high-speed machining. The thermal deformation of spindle is 6.56μm, it is too small to affect the precision of the spindle. The results illustrate the rationality of the spindle structural design. In the paper by Lan Jin, Zhaoyang Yan, Liming Xie, Weidong Gou, Linhu Tang[2], a method is described in this paper for measuring t he spindle rotation error and a technique for separating the eccentric error caused by setup error of the master cylinder. The system consists of two non-contact capacitance sensors used to measure the radial displacement of the rotating master cylinder and an LMS Test.Lab used to collect the measurement data. LMS Test.Lab offers a complete engineering solution for rotating machinery. Based on our experimental research, it indicates that this system can be used to measuring the spindle rotary error at different speeds. It is also verified the feasibility of the error separation methods developed in this paper. In the paper by R. Radulescu, S. G. Kapoor and R. E. DeVor[3], a mechanistic dynamic model is used to simulate a face milling process during constant and variable speed machining. The model can be used to predict the optimum speed trajectory that can provide a low level of vibration and consequently a large productivity rate and a small surface error. The model is used to investigate the vibration of face milling processes that have one, or multiple coupled modes of vibration acting throughout the cut.

FINITE ELEMENT METHOD

Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite element method it is feasible to generate the relative results.ANSYS is an Engineering Simulation Software (computer aided Engineering). Its tools cover Thermal, Static, Dynamic, and Fatigue finite element analysis along with other tools all designed to help with the development of the product. The company was founded in 1970 by Dr. John A. Swanson as Swanson Analysis Systems, Inc. SASI. Its primary purpose was to develop and market finite element analysis software for structural physics that could simulate static (stationary), dynamic (moving) and heat transfer (thermal) problems.

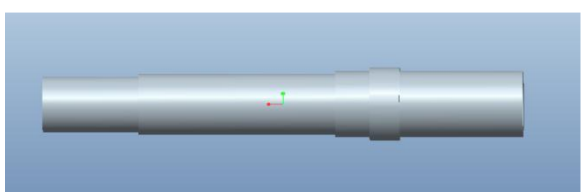

Fig. 2 3D model of spindle

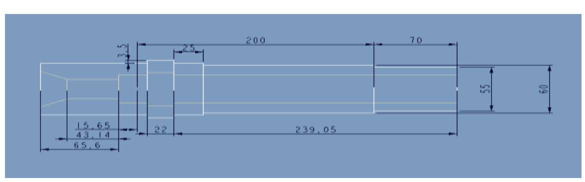

Fig. 3 2D model of spindle

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STATIC ANALYSIS OF SPINDLE

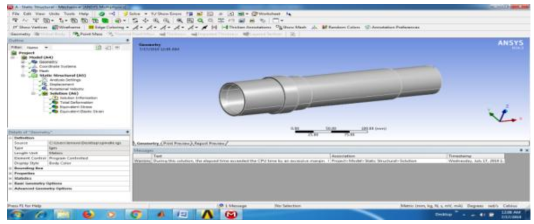


Fig. 4Imported model

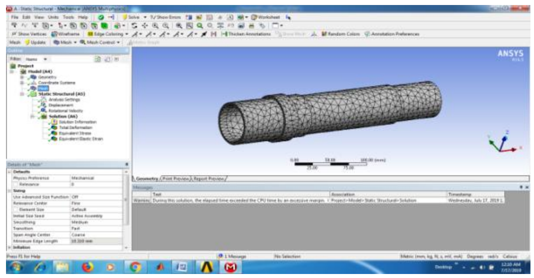
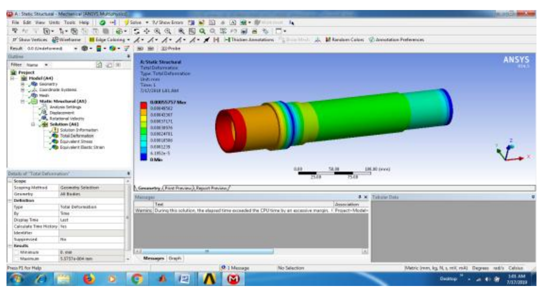


Fig. 5 Meshed model

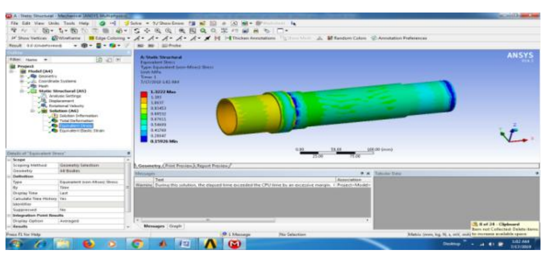
Material: carbon fiber

At speed -8000 Rpm

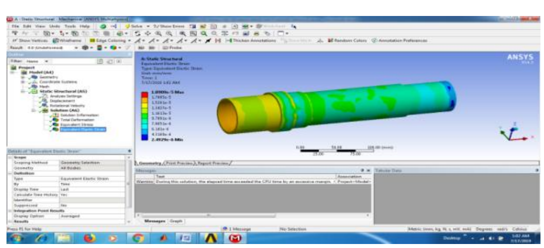
Deformation



Stress

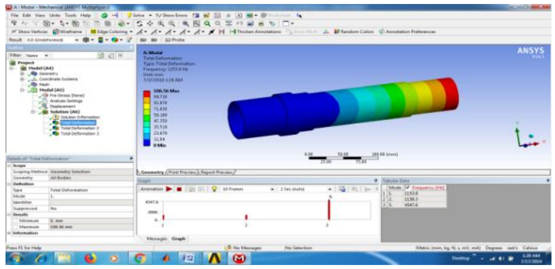


Strain

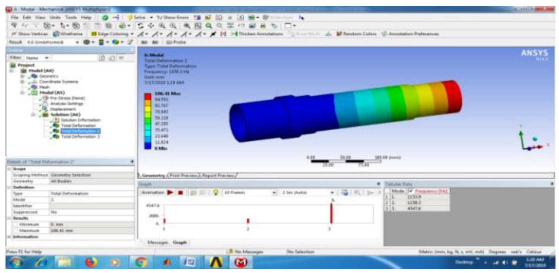


Modal analysis of spindle

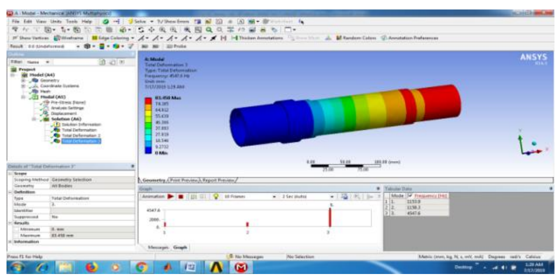
Total deformation1



Total deformation2



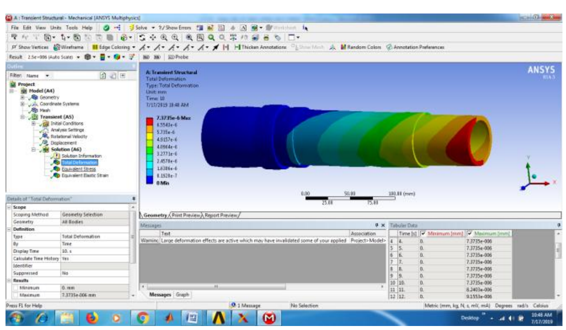
Total deformation3



Dynamic analysis of spindle

Time at-10sec

Deformation



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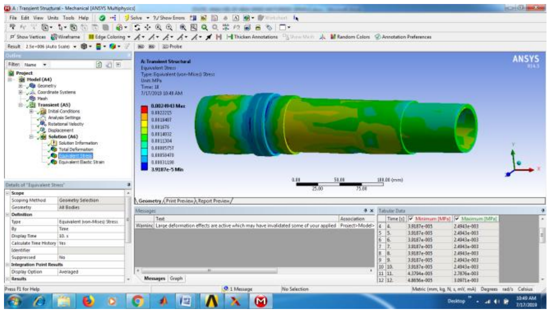
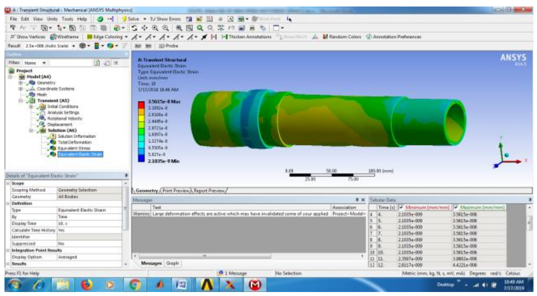
Stress



Strain



VI. RESULTS AND DISCUSSION

Static analysis results

Material	Speed	Deformation (mm)	Stress (N/mm^2)	Strain
Steel	8000	0.0009519	6.4986	3.253e-5
	12000	0.0014987	10.514	5.0828e-5
	16000	0.0021582	14.622	7.3191e-5
EN 8 steel	8000	0.0007817	5.0843	2.6511e-5
	12000	0.0012151	7.903	4.1208e-5
	16000	0.0017741	11.539	6.0166e-5
Carbon fiber	8000	0.0005575	1.3222	1.8909e-5
	12000	0.0007958	1.8873	2.69951e-5
	16000	0.0011461	2.7177	3.8868e-5

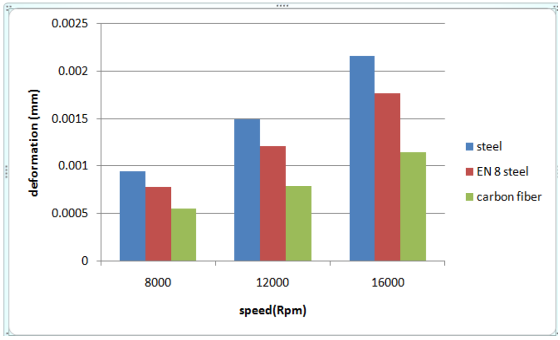
Modal analysis results

Material	Mode 1	Frequency	Mode 2	Frequency	Mode 3	Frequency
Steel	48.107	868.27	48.042	871.57	37.629	3421.8
EN 8 steel	50.232	888.3	50.164	891.67	39.343	3500.8
Carbon fiber	106.56	1153.9	106.41	1158.3	83.458	4547.6

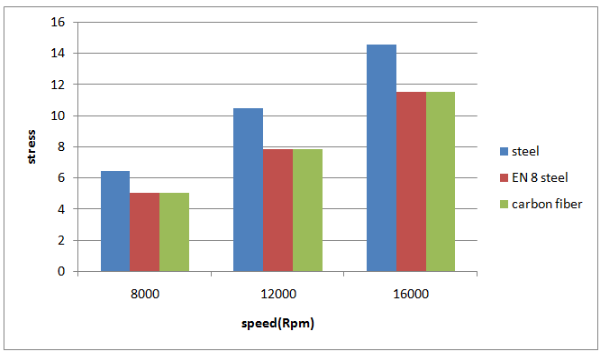
Dynamic analysis results

Material	Time (sec)	Deformation (mm)	Stress (N/mm²)	Strain
Steel	10	1.0711e-5	0.015984	8.2162e-5
	20	3.8276e-5	0.35965	1.8487e-7
	30	6.8052e-5	0.063939	3.2866e-7
EN 8 steel	10	1.472e-5	0.13229	7.08e-8
	20	3.429e-5	0.3082	1.694e-7
	30	5.463e-5	0.492	1.213e-7
Carbon fiber	10	7.3735e-6	0.0024943	3.5615e-8
	20	1.8209e-5	0.0061595	8.7948e-8
	30	3.765e-5	0.007295	9.7231e-8

Deformation



Stress



V. CONCLUSION

In this article, different materials are analyzed for spindle. EN 8 steel and carbon fiber are replaced with steel. By replacing the steel with carbon fiber , the weight of the spindle decreases. Structural and Dynamic analyses is done using Ansys software. Modal analysis also is done to determine the frequencies .By observing the static and dynamic analysis, the stress increase by increasing spindle speed and stresses decreasing for carbon fiber than carbon fiber and steel.By observing the dynamic analysis, the stress increase by increasing spindle speed and stresses decreasing for carbon fiber than carbon fiber and steel.. By observing the modal analysis, the deformation increases and frequency increasing for carbon fiber than EN 8 steel and steel.So we conclude the suitable material for high speed motorized spindle is carbon fiber

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