Design Optimization of High-Speed Motorized Spindle

K.Kiran Kumar[1], S.Sridhar [2], P.Avinash[3], Sura Sandeep[4]

[1,2,3]Asst.Professor, Dept. of Mechanical Engineering, AVN Institute of Engineering & Technology, Hyderabad, T.S., India

[4]M. Tech student, Dept of Mechanical Engineering, AVN Institute of Engineering & Technology, Hyderabad, T.S., India

***Abstract**: In today's booming industrial development, with multi-product design and production cycle reduction, high-speed manufacturing technology has been widely adopted by manufacturers. With the development of science and technology, the high frequency spindle became more and more the place of ordinary mechanical spindle, and the numerical control machine was used very much. The engineering quality of the high-precision parts depends heavily on the dynamic performance of the entire operating system, which is determined by the interrelated dynamics of the mechanical structure of the machine tool and the cutting process. This performance is of great importance in advanced manufacturing processes and high precision. The most modern in the main circulation units of the machine tools is the focus on the automatic rotary units with high speed motors and high performance. In this letter, high-speed spindle analysis is designed and tested in specific load conditions. The spindle used in this letter is used in the milling machine. 3D modelling is designed in Pro / Engineer. Materials used in steel spindle. In this message, different spindle materials are analyzed. The aluminium alloy is replaced by 6061 and 7075 steel. When replacing steel with aluminium alloys, the weight of the spindle decreases. Structural and dynamic analyzes are performed using Ansys. A conditional analysis is also performed to determine frequencies.*

Keywords : *FEA; ANSYS; Thermal Deformation; Failure;*

I. INTRODUCTION

Grinding is the process of forming using rotary cutters to remove material from the work piece that advances (or feeds) in an angle direction with the tool axis [1]. It covers a wide range of processes and several machines, ranging from small individual parts to large and heavy grinding bands. It is one of the most common processes in the machinery industry and in machinery workshops today to manufacture spare parts according to sizes and shapes.

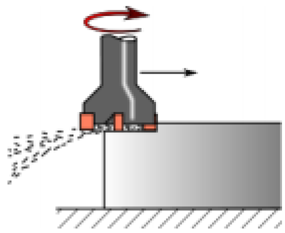


Fig 1: Face milling process (cutter rotation axis is vertical

Grinding is a cutting process using a mill to remove material from the work surface. The milling cutter is a rotary cutting tool, often with multiple cutting points. Unlike drilling, when the tool moves along its spindle, the milling cutter generally moves vertically on its axis, so that the cutting is done at the perimeter of the cutter. When the cutting tool enters the work piece, the cutting edges (grooves or teeth) are frequently cut off and shaved, shaving the work piece with each pass. The cutting action is a shear deformity. The metal is pushed out of the work in small groups that intertwine more or less (depending on the type of metal) to form the chips. This makes the metal pieces slightly different (in their mechanics) for cutting the most soft material with a blade. The grinding process removes the material by performing several small separate wounds [2][3]. This is achieved by using a cutter by many teeth, rotating the cutter at high speed or slowly extending the material through the cutter; most of the time is a combination of these three methods. The speeds and progress of the user vary with a range of variables. The speed at which the piece is made through the cutter is called speed forward or simply forward; most of the time it is measured in the physical length of each complete revolution of the cutter. The horizontal mill has the same type of x-y table, but the blades are installed on a horizontal axis (see grinding axis) through the table. Many horizontal mills also have a built-in rotary table that allows milling at different angles; this feature is called a global table. While the milling cutters and other types of tools available for the vertical milling machine can be used in the horizontal milling machine, the real advantage lies in the cutters installed on the column, called the lateral and front milling cutters, which have a cross section such as circular saw, but are usually wide and diameter In diameter. Because the cutters are well supported by the column and have a larger cross-sectional area than the end grinder, very heavy cuts can be made to allow fast material removal speeds. These are used to grind grooves and grooves. Smooth mills are used to form flat surfaces. Several breakers can be assembled on the column to grind a complex form of grooves and planes. Special cutters can also cut grooves, shapes, radius or even any required section. These specialized cut outs tend to be expensive [4]. Mini mills have spindles and two double mills. It is also easy to cut gears in a horizontal mill. Some horizontal milling machines are equipped with an electric take-off arrangement on the table. This allows synchronizing the table with a rotary device, allowing grinding of spiral features, such as hypoid gears.

II. ABOUT SPINDLE

In mechanical tools, the axis of rotation is an axis of the machine, often with a column in its heart. The same column is called a spindle, but also in the practice of the store floor, the word is often used to refer to the entire rotary unit, including not only the column itself, but also the bearings and anything connected to it. (mandrel, etc.) It contains several spindles, such as the head and the rear crow on the seat winch [5]. The main spindle is usually the largest. The reference to the "spindle" without further qualification means the main spindle. Some automated tools that specialize in mass production contain a set of 4 or 6 or even more than the main spindle. These machines are called multi-spindle. For example, many ganglion drilling machines and screw machines are multi-spindle. Although the bench winch has more than one spindle (counting the tail), it is not called a multi-spindle machine. It has a main spindle

Lathe headstock: H4 – Spindle Lathe tailstock: T5 – Spindle

III. HIGH SPEED SPINDLES

A high speed spindle that will be used in a metal cutting machine tool must be designed to provide the required performance features. The major performance features include:

- Desired Spindle Power, Peak and
- Continuous
- Maximum Spindle Load, Axial and Radial
- Maximum Spindle
- Speed Allowed
- Tooling Style, Size and Capacity for ATC
- Belt Driven or Integral Motor-Spindle

Design Although these standards may seem obvious, for the hub designer they represent a wide range of needs that are very difficult to meet and improve in design. As we will discover, many standards are contradictory to each other, and finally a commitment must be chosen to provide the best Design The tool will also provide design constraints for the spindle. The amount of available space available, cost considerations, complexity and market demands will affect the final design of the spindle [6]. The cost will have a significant impact on the design of the final spindle. The advanced and powerful spindle design will not be accepted in the low-cost machine tool. Thus, the design of the advanced machine tool can justify the higher cost of a more capable and complex spindle package. In fact, a fast and accurate machine requires a reliable high-speed spindle system. This document provides a brief description of the key components needed to understand the high-speed milling design. Emphasis will be placed on commercially available components, which are available at a reasonable cost, and which are commonly used today in existing machine tools. Future trends will also be mentioned. In addition to the high-speed system design, maintenance and reliability issues will also be addressed

IV. BELT-DRIVEN SPINDLE DESIGN

The high speed spindle of the band is somewhat similar to the traditional design of a speed spindle, with some notable variations. The spindle shaft assembly is formed by a spindle belt, which is loaded with a bearing system and rests on the spindle housing [7]. The shaft includes the tool system, which includes the conical tool, the pull rod mechanism and the tool release system. An energy saving mechanism is usually installed to provide an external uninstaller. The power and rotation of this spindle is provided by an external motor. The motor is installed near the shaft, and the torque is moved towards the shaft by a toothed belt or V. The force and speed of the torque and torque depend on the characteristics of the drive and the ratio of the belt used between the motor and spindle.

V. ADVANTAGES OF SPINDLE DESIGN

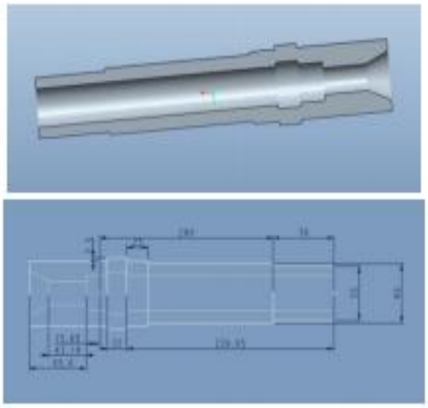
Reasonable cost: since the spindle consists of some basic parts, the cost is relatively low, compared to alternative solutions. A variety of spindle properties: Because the rotational force, torque and speed depend on the driving motor, to a large extent, the final specifications of a particular application can be modified using a different proportion of the motor or the belt. In some cases, gears are also used to provide multiple speed bands in addition to the fixed band ratio. High capacity and possible torque: the spindle motor is installed externally from the real spindle, so it is often possible to use a very large motor. The large motor, especially the large diameter, can provide very high torque and high spindle capacity. This is more difficult to design an integrated rotor for the engine, since the available space is always limited. However, there are also some limitations in the design of the belt driven rotary shaft, especially when a high speed rotary is considered.

VI. PRO-E

Engineer Pro packs in different versions to meet your needs, from the XE Pro / ENGINEER Foundation, to the advanced XE package and Enterprise XE package, the XE Enterprise Pro / ENGINEER package pool can be a broad base of functionality. From modeling powerful parts to advanced surfaces, modeling and simulation for powerful assemblies, your needs will be covered by this scalable solution. Flex3C and Flex Advantage Take advantage of this rule that provides extended functionality of your choice.

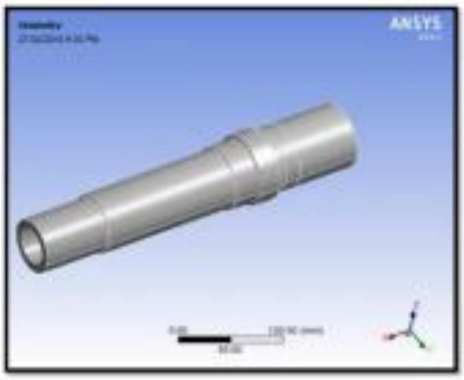
Sheet Metal

Cut section

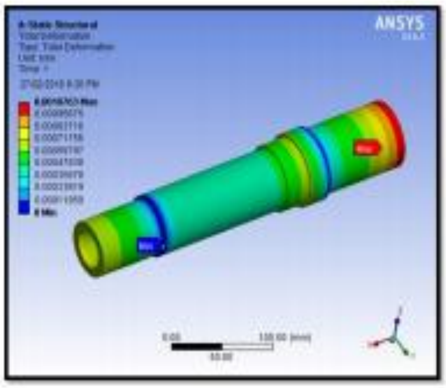


VII. STATIC ANALYSIS OF SPINDLE

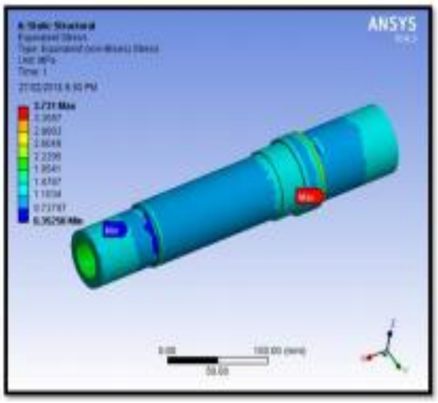
Carbon fiber material properties Young's modulus=70000Mpa Poisson's ratio=0.3 Density=0.00000160kg/mm3 Used software for this project work bench Open work bench in Ansys 14.5 Select static structural>select geometry>import IGES model>OK



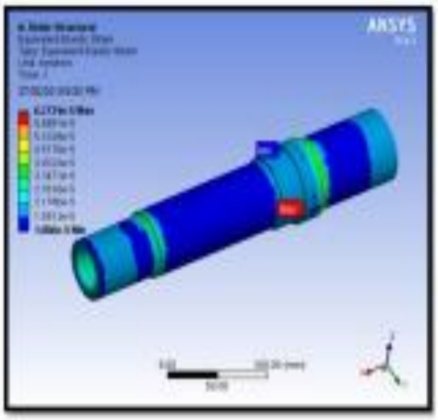
VIII. ALUMINUM ALLOY 7075 DEFORMATION



STRESS



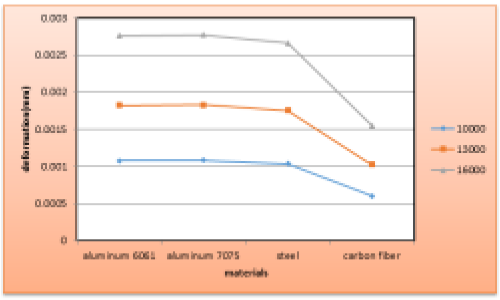
STRAIN



IX. STATIC ANALYSIS RESULT TABLE

Speed (rpm)	material	Deformation(mm)	Stress(MPa)	strain
10000	Aluminum alloy7075	0.0010763	3.731	6.2734e-5
	Aluminum alloy 6061	0.0010807	3.585	6.299e-5
	steel	0.0010379	11.146	6.518e-5
	Carbon fiber	0.00060433	2.2714	3.7951e-5
13000	Aluminum alloy 7075	0.001819	6.3056	0.00010602
	Aluminum alloy6061	0.0018265	6.0587	0.00010645
	steel	0.0017541	18.837	0.00011016
	Carbon fiber	0.0010215	3.8393	6.4149e-5
16000	Aluminum alloy 7075	0.002755	9.5516	0.0001606
	Aluminum alloy 6061	0.0027667	9.1776	0.00016126
	steel	0.0026571	28.534	0.00016686
	Carbon fiber	0.001547	5.8158	9.712e-5

Static analysis graphs



X. CONCLUSION

The engineering quality of high precision parts depends largely on the dynamic performance of the entire operating system, which is determined by the interrelated dynamics of the mechanical structure of the machine tool and the cutting process. This performance is of great importance in advanced manufacturing processes and high precision. The main units of modern gyros are focused on machine tools in rotating motor units for high speed and high performance cutting. In this letter, different materials for the spindle are analyzed. 6061 and 7075 aluminum alloys are replaced with steel. When replacing steel with aluminum alloys, the weight of the spindle decreases. Structural and dynamic analysis is performed using Ansys. Conditional analysis is also done to determine frequencies.

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