IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X
PP. 37-42
www.iosrjournals.org

Drive Mechanism Of The Spindle In A Compact Cnc Milling Machine

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Abstract:- *The machine tool industry demands high speeds, improved power density. There are greater needs for innovative spindle solutions.A spindle is, in principle, a motor driven shaft that both positions and transmits power to a tool holder or holds a work piece .Input parameters which are being used in this paper are BT 30 tool holder, Fanuc spindle motor with power 1.1kw/1.5 HP. High speed spindle is. used for mass production*
The increases stiffness,accuracy.Acceleration/deacceleration will be very low, avoids the idle time of the machine.In this design the power loss will be less. The tool is very close to the spindle.The front bearing to take up the radial and axial cutting loads without disturbing the tool geometry.It gives the better tool life.In this design bearing span and the tool holding position has kept in an optimized distance for giving better accuracy. And provide proper stiffness of the spindle.Consistence in quality will also be achieved because of Cnc system and motors..The contact angle for bearings determines the ratio of axial to radial loading possible, with radial loading being the primary benefit. Typically, contact angles of 12º, 15º, and 25º are available.It's the most economical. Belt-driven spindles will be used up to maximum rotational speed of 12,000 - 15, 000 RPM.The spindle motor is mounted externally from the actual spindle shaft, and therefore it is often possible to use a very large motor.

I. Introduction

A milling machine is a machine tool used for the shaping of metal and other solid materials. Milling machines exist in two basic forms: Horizontal and vertical, which terms refer to the orientation of the cutting tool spindle. Unlike a drill press, in which the workpiece is held stationary and the drill is37 moved Vertically to penetrate the material, milling also involves movement of the workpiece against the rotating cutter, the latter which is able to cut on its flanks as well as its tip. Workpiece and cutter movement are precisely controlled to less than 0.001 inches (0.025 millimeters), usually by means of precision ground slides and lead screws or analogous technology. Milling machines may be manually operated, mechanically automated, or digitally automated via computer numerical control (CNC)

Nomenclature
K-Material Factor
n- Revolution per minute(RPM)
Z-Number of cutting edges in contact
Cs-Cutting speed
B-Machining Exponent
T-Depth of cut in (mm)
S-Feed/Blade/Rev (mm)
F- T*S (Feed/Blade/Rev)
D-Max cutter Dia in (mm)
P_F-Feed Thrust (kgf)
P-Reaction Thrust (kgf
L_{10} = Basic rating life , Millions of revolutions ,
C = Basic dynamic load rating , N ,
C_O = Static load rating ,N,
P = Equivalent dynamic load rating , N,

P = Exponent of the life equation
(p=3 for ball bearings and 10/3 for roller bearings)
P_E = Equivalent bearing loads(combined loads of both axial and radial loads),
S = Service factor
X = Radial load factor for the bearings
Y = Axial load factor for the bearings
Fr=Actual radial bearing load , N.
F_a=Actual Radial bearing load , N.
The major components required for a high speed milling spindle design include:

- Spindle Style; Belt Driven or Integral Motor-Spindle
- Spindle Bearings; Type, Quantity, Mounting, and Lubrication Method
- Spindle Motor, Belt-Type, Motor-Spindle, Capacity, Size
- Spindle Shaft; Including Tool Retention Drawbar and Tooling System Used
- Spindle Housing; Size, Mounting Style, Capacity

Each of these components will be discussed, with emphasis on selection criteria and effectiveness for a given machine tool specificati`on. The machine tool we will assume is a modern CNC machining center with automatic tool changing ability (ATC).
To design a spindle drive mechanism for a mini cnc milling machine with a spindle motor power Of 1.1 kw and a spindle nose taper of BT 30 specifications.

BT 30 (British taper) tooling:

An improvement on CAT Tooling is BT Tooling, which looks very similar and can easily be confused with CAT tooling.BT Tooling comes in a range of sizes and uses the same NMTB body taper. However, BT tooling is symmetrical about the spindle axis.
This gives BT tooling greater stability and balance at high speeds. One other advantage is tool holder is the thread used to hold the pull stud. The thread which is used to hold the pull stud in a BT tool holder is a metric thread.
Note that this affects the pull stud only, it does not affect the tool that they can hold, this type of tooling is sold to accept metric sized tools.

PROCEDURE

We have to first justify the BT 30 spindle with power of 1.1Kw .To justify BT30 spindle with power 1.1kw we have to first specify the following :

1. The type of operation
2. The type of material.
3. The size of cutter & drill (for drilling & milling operations).

The power is calculated for different feeds & speeds for drilling and milling operations.
H.P (Horse power) : K *Z*Cs* [0.018012*(1.55F)□]
Reaction Thrust (P) : $(1.450*10^{6}*H.P)/(D*n)$
Feed Thrust (P_f) : 0.2*n

Power calculations for Drilling operations

H.P (Horse power) $=3.83*10-^{6}*k*n*z*(D^2-d^{2)*}\{ 0.147+3.937 (2*s)\}$
Reaction Thrust (P) = $35 *K*Z*(D-d)*(2*s)^{0.85}$

Type of bearings use:

According to the Fag catalogue the bearings selected are :
Angular contact ball bearings
Type : angle 15 degrees, dia 50*80*16
No:HSS7010 CT P4S DTL

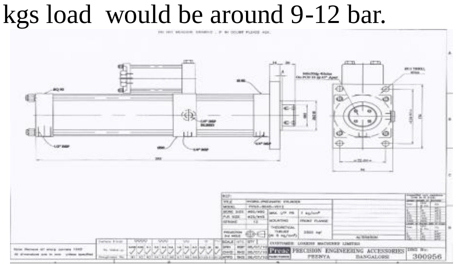
1. The angular contact spindle bearings are used to connect the housing to the spindle shaft.
2. For the rotation of the spindle the angular contact bearings are used in between the housing and shaft .The housing is connected to the motor for the spindle rotation.
3. These angular contact ball bearings are used to withstand both radial and axial loads
4. For example if we use radial bearings it cannot withstand axial loads.
5. Bearings with the greater contact angle are recommended for applications where high axial stiffness and high axial loads carrying capacity are required .They are able to support combined radial and axial loads

6. The bearings should be 1st selected according to the accommodation and then it has to be tested for life and stiffness
7. Basic rating life equation has to be calculated.
8. Precision angular contact ball bearings are used for high speeds and accuracy.

Bearing Data
T=F*R
F=T (n-mm)/R(mm)
F=T/ R (N)
P= (2ΠNT)/60
T= P*60/2ΠN Kw
Refer in annexure 1

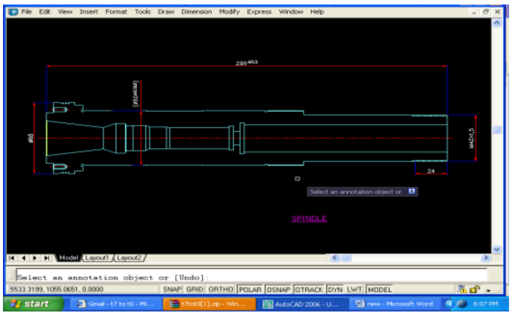
Design Of Pulley Or Power Transmission
For power Transmission we are using power Grip GT Belt 5MR here.
Power Grip Belt is:
1. Black Lash free.
2. No loss in motion.
3. No slippage.
Type of Belt : GT Belt
5MR, 169T
PL=845
W=30

Design Of Pneumatic Cylinder
Type of cylinder : Hydro pneumatic power cylinder
Model : PCS3-8045-V012
Maximum input pressure : 7kg/sq.
Stroke : 8mm
Make : orsett .pvt ltd.
Formulae:
F=230 kgs
P= 7kgs/cm^2
A =$\pi * d^2/4$
F = P * A
= $P * (\pi d^2)/4$
=7 kgs /cms × $\pi (8)^2/4$ cms
Clamping force for BT 30 of 230 kgs load would be around 4 – 7 bar.
Clamping force for BT 40 of 600 kgs load would be around 7-9 bar.
Clamping force for BT 50 of 1200 kgs load would be around 9-12 bar.

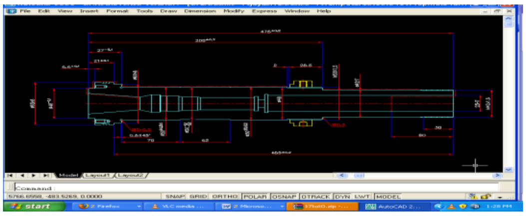


II. Results And Discussions

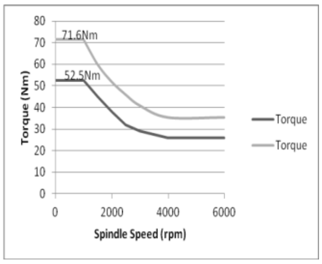
In this design both the bearing span and the tool holding position has been kept in an optimized distance for giving better accuracy and to provide proper stiffness to the spindle. The output of this design is that the bearing life has been increased. From the below drawing it is evident that the distance between the bearing span and the spacers has been reduced compared to the previous design.



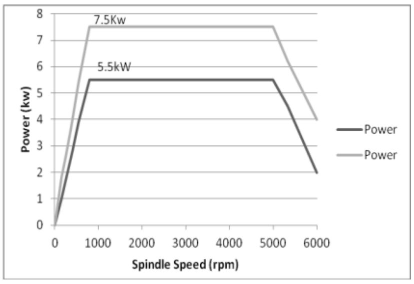
the spindle bearing span distance has been reduced compared to the below design



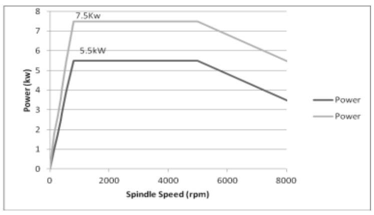
the spindle has more bearing span distance compared to the above diagram
GRAPHS:(power calculations refer annexure 1)Torque Vs Speed at 6000 RPM



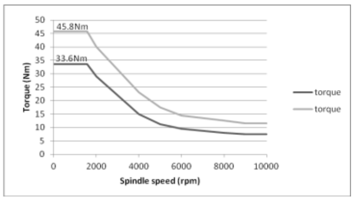
Power Vs Speed at 6000 RPM



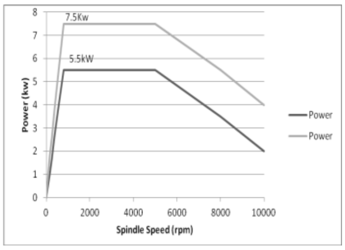
Power Vs Speed at 8000 RPM



Torque Vs Speed at 10000 RPM

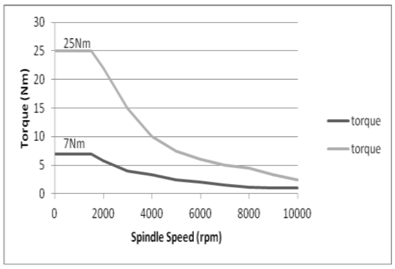


Power Vs Speed at 10000 RPM

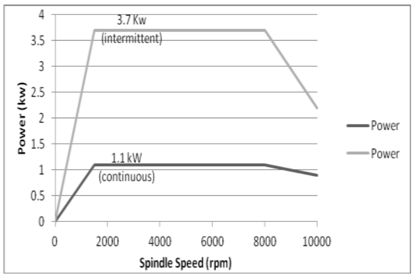


The three graphs indicate the power loss for the spindle running at high speeds (1.1000-6000 RPM, 2. 1250-8000 RPM 3.1562-10000 RPM). The power loss is more at low spindle speed. The acceleration / deaccelaration time is more for the three spindles.

Torque Vs Speed at 10000 RPM



Power Vs Speed at 10000 RPM



The output power is 0.9 kw .so from the graph it is evident that the power loss is very low at high speeds (1500-10000 RPM). By comparing the 4 graphs we can conclude that the power loss for the spindle is very low compared to the remaining three graphs. The acceleration/deaccelaration time is low for this spindle.

III. Conclusions

A high speed spindle design must take into consideration the desired end result: the required power, speed, torque, tooling system used, accuracy, and life. From this design specification, the needed components can be selected including bearings, shaft design, motor, lubrication system, tooling style, drawbar system, housing. As we have seen, bearings will impact a spindle design to the greatest degree. High speed spindle designs most often run bearings systems up to the limit, in order to be the most productive. To reach higher speeds, and maintain a reasonable life, precision bearings must be used, along with complex bearing lubrication systems. Oil jet or mist systems not only boost the speed of the bearings, they also provide cooling and cleaning functions as well. Maintenance is critical to the performance of precision bearing systems. Positive over-pressure and labyrinth air seals also should be used to protect the bearing environment.

In addition to the bearings, the spindle shaft design must be capable of providing a strong motor, suitable tooling retention system, and stiffness without developing bending problems. And, all rotating components must operate in a balanced condition.

The spindle housing must support and locate the bearings accurately, and provide the utilities needed by the spindle system. It must be stiff, as the housing transfers all forces from the spindle to the machine tool.

In general, a high speed spindle design will be the result of many compromises. Bearing size and type will dictate maximum speeds possible.

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