DESIGN METHODOLOGY AND ASSEMBLY FOR A RADIAL FEED IN A CNC GEAR HOBBING MACHINE

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Abstract - *Gear Hobbing is a special machining process for gear cutting, cutting splines, and cutting sprockets on a hobbing machine. Compared to other gear forming processes it is relatively inexpensive but still quite accurate, thus it is used for a broad range of parts and quantities. In this report we have done an extensive study over the advantages of Recirculating ball screw system over lead screw systems. The accuracy level is high by this Conventional gear hobbing machine compared to a lead screw type of system. Backlash error eradication as well as high work piece job accuracy has been achieved due to implementation of this Ball screw system. We have designed a Radial Feed drive system for a CNC P320 gear Hobbing machine as well as we have carried out various design validation processes to provide high results. On the basis of the feed system we have selected a suitable Recirculating ball screw system from the catalogue. Recirculating Ball screw system for a conventional Gear Hobbing machine in order to increase accuracy of the work piece as well as eradicate backlash error caused due to lead screw system drive.*

Key Words: **Recirculating Ball Screw system[1], backlash error[2], hobbing machine[3], shaft length[4], bearing housing[5]**

1. INTRODUCTION

Hobbing is the most widely used gear cutting process for creating spur and helical gears and more gears are cut by this way than any other process as it is relatively quick and inexpensive. Hobbing machines, also known as hobbers, are fully automated machines that come in many sizes. Each gear hobbing machine typically consists of a chuck and tailstock, to hold the workpiece or a spindle, a spindle on which the hob is mounted, and a drive motor. The hob is a cutting tool used to cut the teeth into the workpiece. It is cylindrical in shape with helical cutting teeth. These teeth have grooves that run the length of the hob, which aid in cutting and chip removal. There are also special hobs designed for special gears such as the spline and sprocket gears. The cross-sectional shape of the hob teeth are almost the same shape as teeth of a rack gear that would be used with the finished product. Hobbing machines are available as Non-CNC Type and CNC type hobbing machine.

1.1 Types of Feed in CNC Gear Hobbing Machine

The feed types in a CNC type Gear Hobbing Machines are:

- Axial Feed
- Radial Feed

Different types of axis in a CNC gear hobbing machine are:

- Spindle rotation(clockwise and anti-clockwise)
- Table rotation(clockwise and anti-clockwise)
- Axial type
- Radial type
- Hob shifting(Tangential)
- Swelling axis(angle for helical gear)

So this Study will include the modeling of radial feed drive in an Industrial CNC Gear Hobbing Machine.

1.2 Design Process for a Radial feed

The Modelling Of radial feed in machine is done in three phases:

1. Selection of Ball Screw.
2. Selection of Bearings.
3. Selection of Bearing Housing.

The Detailed Design and Modelling procedure along with suitable calculations and validations are as follows.

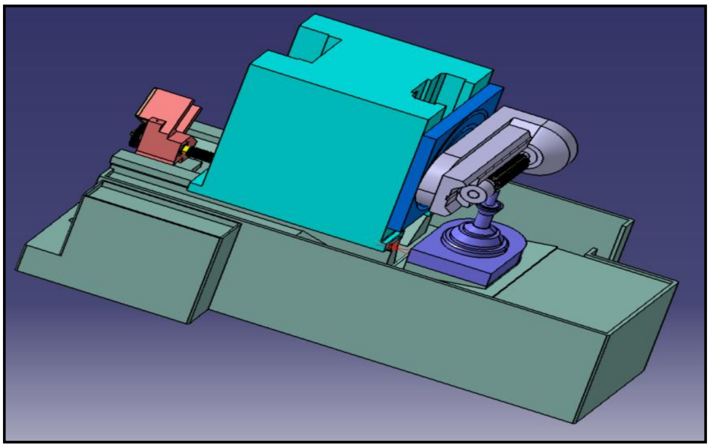

Fig -1: GEAR HOBBING MACHINE MODEL (PA320)

2. Modeling and Calculations of Various Design Parts Used In the Radial feed:

Phase 1: Selection of Ball Screw And Its Suitable Length

Maximum stroke of column: 270 mm
Minimum stroke of column: 30 mm
Total effective stroke of the column: 270 – 30 = 240 mm
Nut length: 161 + 19 = 180 mm
Clearance distance = 10 mm
Total length of Ball screw = 240 + 180 + 10 = 430 mm
Take total Safe length = 440 mm
Length of Total shaft= 440mm.

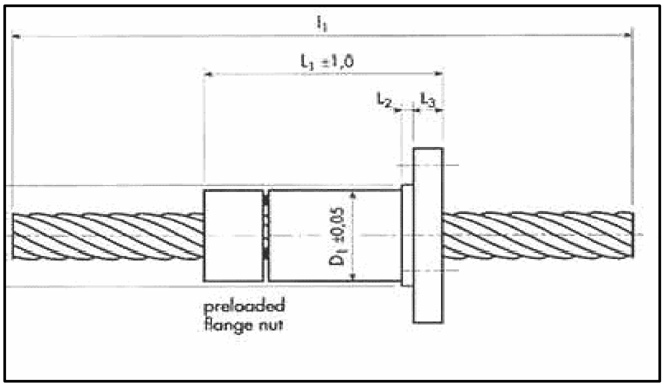

Fig -2: Layout of Shaft design

Phase 2: Validation of Selected Bearing:

The Bearing Provided By The Manufacturer Was BS40M90. Thus the Following Calculations Confirm the Suitability of Selected Bearing.

Machine Specifications Given By Manufacturer were as follows:

1).Power Transmitted : 17 KW
2).Speed of shaft : 1000 rpm
3).Shaft diameter : 40 mm
4).Type of Load : Axial and Radial.

Types of Loads Acting On Bearing:
Axial Load: Due to Column and Hob Head Weight
Radial Load: Is Almost Negligible
Fa = 2595 N.
Fr = 100 N.

Internal Diameter of Bearing: 40 mm.
Outer Diameter of Bearing: 90 mm.

THICKNESS (b) = 20 mm

Basic static Load capacity (C0) = 90000 N
Basic dynamic load capacity(C) = 59000 N
Load application factor: Ka = 1.05 for timing belt drive
(Following data is collected from IBC Bearing Chart)

CALCULATIONS:

Fa/C0 = 2595/90000 = 0.03333
Factor X = 0.56
Factor Y = 1.875

Equivalent dynamic load is:
Pe = (X*V*Fr +Y*Fa)* Ka
Pe = 5167.58 N

Rating life selection according to type of application is
L10h = 25000 hrs – For machine tool.
L10 = L10h * 60 * n / 106 Million Revolutions.
L10 = 25000 * 60 * 1000 /106
L10 = 1500 Million Revolutions.

Required dynamic load capacity (Cr):
L10 = (Cr / Pe)a where
a = 3(Ball bearing)
a = 10/3(Roller Bearing)

L10 = (Cr / Pe)a
1500 = Cr3 /5167.58 3
Cr= 58155.46 N.
If C > Cr, Then selected bearing is suitable.
If C < Cr, Then bearing of next stage is suitable.

HERE C>Cr. THUS THE BEARING SELECTED IS SUITABLE.

Phase 3: Selection of bearing Housing:

•Now the major part is to design the bearing housing according to the Shaft length and selected bearings.

•Basic background check for the housing is that we need to convert the rotary motion of the shaft to linear motion.

•Along with this we need to hold the shaft so as it does not move along with the column giving rise to any back lash error. We start various design iterations for the bearing housing keeping in mind the available column length and housing mount.

•After various design iterations, we finalized a bearing housing for PA320 type Gear hobbing machine.

DESIGN PROCESS OF HOUSING:

After assembly of the column over the bed, we inserted the screw shaft into the column. For bearing housing, the size available on the bed was 260mm.

So we started with design iterations for the housing. For supporting the shaft we selected odd combination type of support bearings.

We placed three bearings in such a way that one bearing is been adjusted using the preload cap and the other two bearings are separated from the first bearing using spacer.

For the final design we selected a 20mm thick preload cap followed a 20mm thick bearing.

After this we placed an ID OD spacer 10mm thick. Followed by the spacer we placed our second and third bearing.

An ID OD shaft was inserted and the housing was closed with another preload cap. The main function of preload cap is to restrict the gap between the bearings and spacer thus making a compact structure.

We could have selected an even type of bearing combination, but due to restricted space for the housing, we opted for an odd type bearing combination.

So for the shaft length off 150mm, we designed the inner housing of 120mm. At the shaft end a crown nut is inserted and a quarter pin is been inserted to hold the bearing as well as the crown nut strong enough so that there is no slippage.

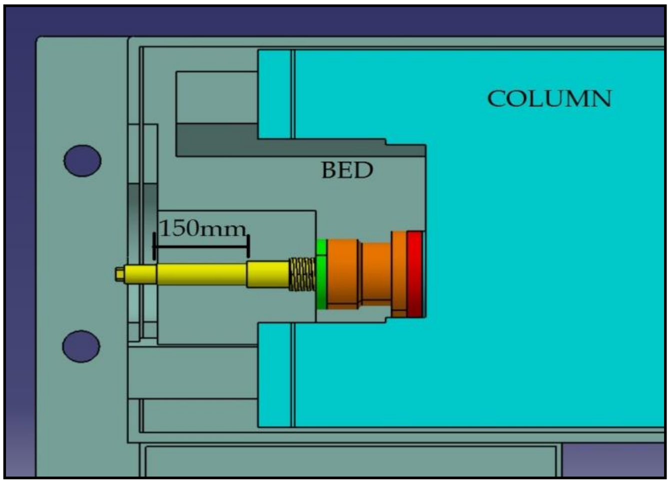

Fig -3: Top view of bed with mounted shaft

We got our Recirculating ball screw constructed from our vendor according to the machine needs. The screw shaft length was taken as 440mm and the the mounting side was taken as 150mm. The nut length as prescribed by the manufacturer's catalogue was taken as 190mm.

After this we constructed the outer Bearing housing design, considering an area of 260mm*260mm. Material used for bearing housing was FG260.

The manufacturer used EN-8 toughened from the screw shaft (56 HRC). It was case hardened for 1.2mm to 1.5mm. Later we assembled the structure and mounted the bearing housing.

We ordered our Screw type support bearings from IBC. The design for the bearing housing varies according to the CNC gear hobbing machine model. We successfully designed and mounted the radial feed for PA-300 type CNC gear hobbing machine.

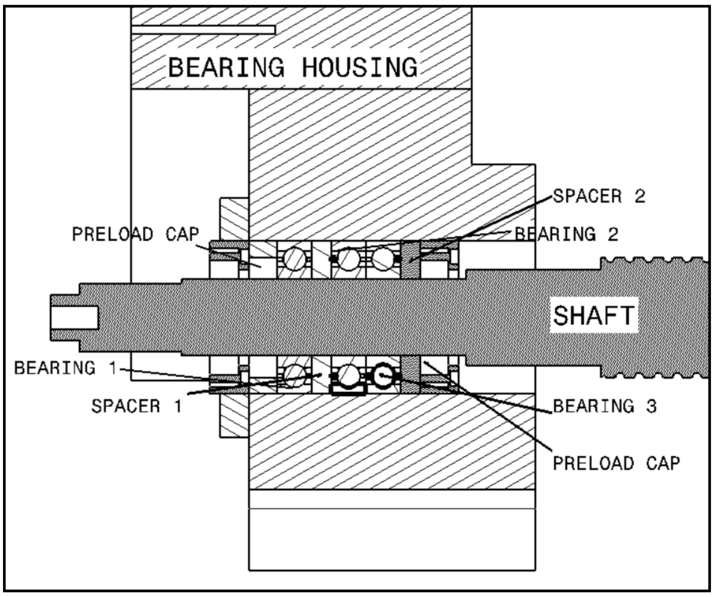

Fig -4: Inner bearing Housing structure

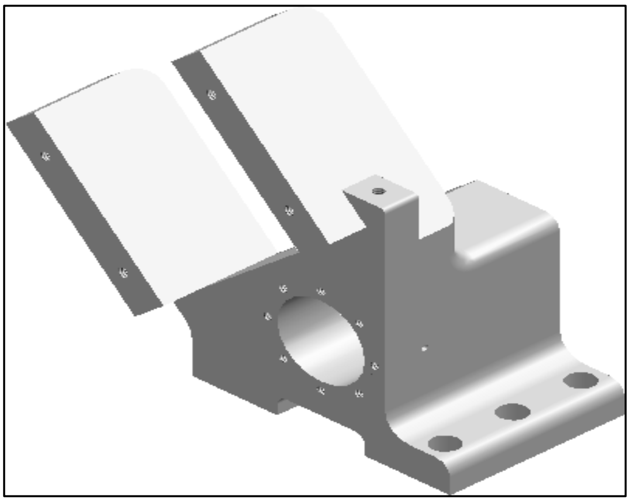

Fig -5: Final Bearing housing model

3. MACHINING PROCESS & DESIGN VALIDATION

3.1 MANUFACTURING PROCESS

- Ball screw and bearings

The ball screw and bearings were been procured from outside suppliers. We got our ball screw constructed according the needs of the bearing housing.

- Bearing housing

We used Grey Iron casting (FG260) for the housing. It was casted; stress relieved and then passed over to the final machining.

- Other parts

Other parts consist of spacer and preloading cap for which EN-8 toughened material was used. (26 HRC)

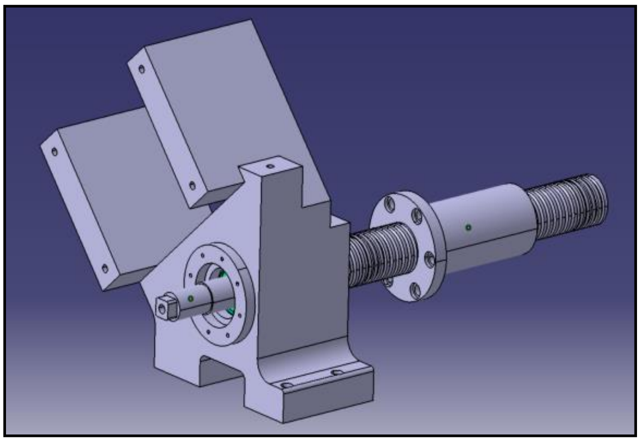

Fig -6: Radial Feed structure

3.2 PRE-ASSEMBLY AND ALIGNMENT

Pre assembly process consists of column mounting over the bed and smooth movement of ball screw system over the column.

The male guideway of the bed must match with the female guideway of the column. For this we used Scrapping and Lapping process.

- Scrapping:

The guide ways was applied with an anti-friction material (SKC-3) and was then scrapped out with the help of a chisel. These processes helped in filling up minute gaps present over the surface and provide a flat surface. This same procedure was carried out over the column strip. Later with the help of a dial indicator, we measured the flatness over the surface. This process is very important because any small gaps or inclinations could cause error over the guide ways.

- Lapping:

Lapping is a machining process in which two surfaces are rubbed together with an abrasive between them, by hand movement or using a machine. After scrapping we carried out the lapping process. This process was carried out by an outer source dealer.

After this we check the alignment for the ball screw system in the column. Firstly we place the dial indicator over the bed surface and make the column move according to the maximum and minimum stroke. The reading over the dial indicator should be less than 1micron.

Later we place the ball screw structure within the column. We place the tip of the dial indicator on the top surface of the screw system. We rotate the shaft to check for any errors. The reading should be less than 1micron for accuracy. This helps to maintain the accuracy and check the surface flatness of the bed.

3.3 FINAL ASSEMBLY

After the alignment process, we mount the bearing housing. We insert the bearings and spacer into the structure. Preloading caps are been mounted such as to preload the bearings and eradicate the back lash error. The balls in the nut structure is filled with grease and closed with a seal. Seal protects the nut and ball screw from external dust and particles.

Limit scale is used to check the accuracy of stroke and notify the user via FANUC coding.

A Limit switch is also used to determine the initial stroke length of the column.

After the housing is been mounted over, we run the machine and carry out about 60-70 jobs over. This helps us to find the accuracy of the entire machine.

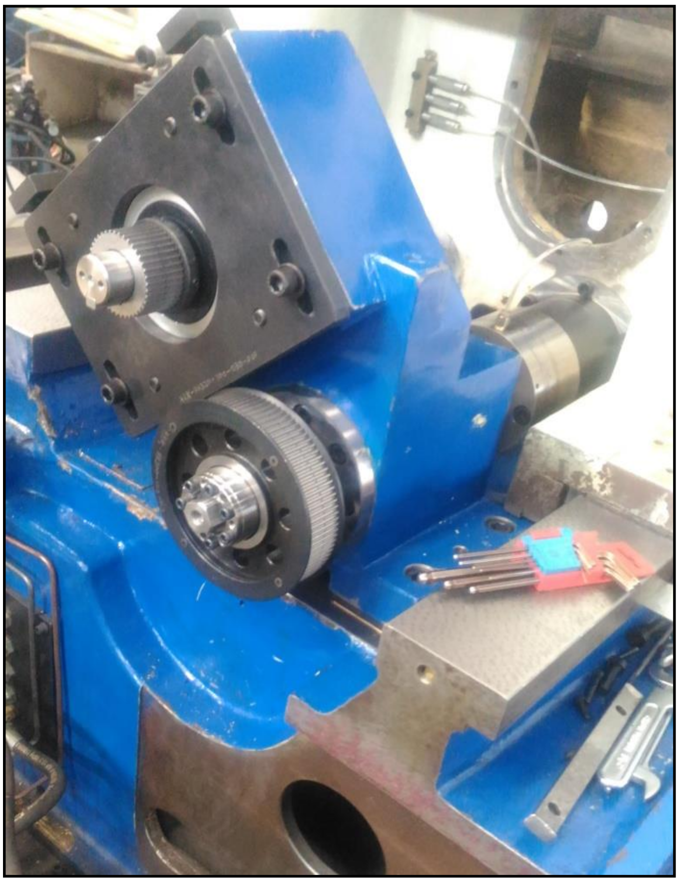

Fig -7: Final Radial Feed assembly

4. CONCLUSION

We have designed a Radial feed system for a CNC Recirculating ball screw system to convert the rotary system into a linear system. We carried various design iterations over the bearing housing in order to minimize the motor vibrations and hold the shaft. Using a lead screw causes high back lash error which was eradicated by using a Recirculating ball screw system.

We successfully reduced the back lash error from 0.5mm to 3microns.

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