PROJECT REPORT ON:

"Design, Modelling And Manufacturing Of Radial Feed For A CNC Gear Hobbing Machine"

SUBMITTED TO:

SAVITRIBAI PHULE PUNE UNIVERSITY

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BACHELOR'S OF ENGINEERING IN MECHANICAL ENGINEERING (B.E. 2017-2018)

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(An Autonomous Institute Affiliated to Savitribai Phule Pune University)

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CERTIFICATE

This is to certify that the Project Entitled

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Submitted By:

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Is A Record Of Bonafide Work Carried Out By Him, In Fulfilment Of The Requirement For The Award Of Degree Of Bachelor Of Engineering (Mechanical Engineering) Under Savitribai Phule Pune University During The Year 2017-2018

DATE:

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EXTERNAL EXAMINER

DECLARATION

We, the undersigned, hereby declare that project report entitled "DESIGN AND MANUFACTRING OF RADIAL FEED IN A CNC GEAR HOBBING MACHINE" with sponsorship from ARK MACHTEK PVT. LTD. written and submitted by us in partial requirement for B.E. Project, under the guidance of MRS. BHAVANA M.M. Is our original work and the interpretations drawn therein are based on the materials collected ourselves.

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ACKNOWLEDGEMENTS

The success and final outcome of this project required a lot of guidance and assistance from many people and we are extremely privileged to have got this all along the completion of our project. All that we have done is only due to such supervision and assistance and we would not forget to thank them.

We owe our deep gratitude to our project guide MRS. BHAVANA M.M. who took keen interest on our project work and guided us all along, till the completion of our project work by providing all the necessary information for developing a good system.

We would also thank Amit Karn Sir, of ARK MACHTEK PVT. LTD. For their encouragement and more over for their timely support and guidance till the completion of our project work.

We heartily thank our internal project guide her guidance and suggestions during this project work.

We are thankful to and fortunate enough to get constant encouragement, support and guidance from all Teaching staffs of Mechanical Department which helped us in successfully completing our project work. Also, I would like to extend our sincere esteems to all staff in laboratory for their timely support.

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 workpiece 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.

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1. INTRODUCTION

1.1 Gears:

A gear is a simple machine used to transmit motion or torque with the help of cogs or teeth. Gears can be used to produce changes in torque. Two gears, which are in mesh, always have the same teeth shape. A system of multiple gears, working in a sequence, is called a gear train.

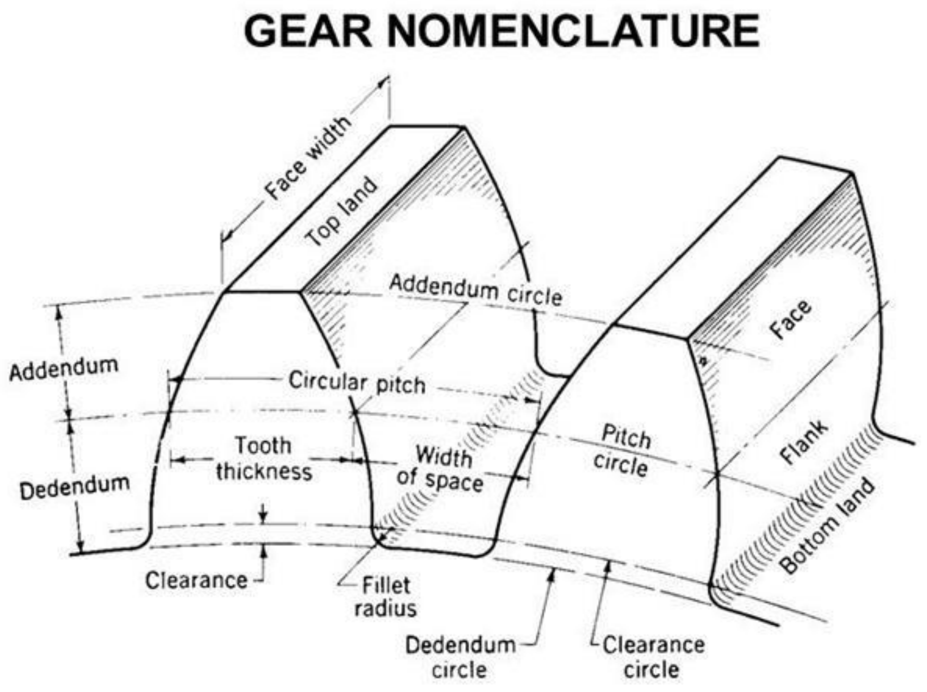
Gears transmit motion without any slip unlike belt pulley or chain sprocket, making it better suitable to reduce losses.

1.2 Basic Gear Nomenclature:

Pitch circle: An imaginary circle passing through the pitch points of the gear.

Addendum: Radial distances between pitch circle and top of gear tooth.

Dedendum: Radial distance between pitch circle and bottom of gear tooth. Dedendum of a gear is always greater than its addendum.



Gear Nomenclature

Whole depth: The total distance between the top and bottom of the gear tooth is called the whole depth.

Working depth: When two gears are in mesh, the depth of bite of the two gears is called working depth. It is equal to sum of addendums of the two gears.

Clearance: Mathematically, clearance equals the difference between whole depth and working depth.

Pitch Diameter (d): Diameter of the pitch circle from which the gear is designed. The pitch circle goes through the pitch points, which are the points of contact when two gears are in mesh.

Number of teeth (T) : Number of teeth on the circumference of the gear.

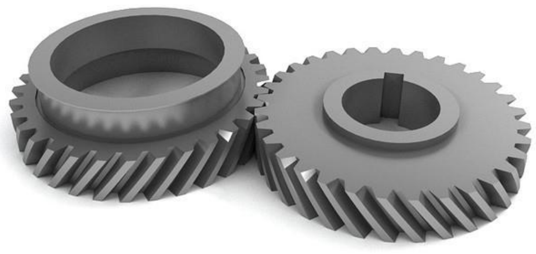
These two variables can be used to find the module of a gear, which is given by m = d/t. Module indicates its tooth size. For two gears to mesh, they should have same module.

1.3 <u>Types of Gears:</u>

Spur Gear: Simplest type of gear with teeth projected radially outward. Spur gears are used to transmit the motion across parallel axis

Spur Gear

Helical Gears: Helical gears are cylindrical gears whose teeth are not parallel to the axis of rotation. The teeth are angled and appear as a segment of a helix. Helical gears can transmit power between parallel or right angle axes.



Helical Gears

Helical gears can transmit energy between parallel or perpendicular axes through the use of helical teeth. They are designed to distribute pressure gradually along the whole tooth. Because of their tooth inclination, helical gears run smoother and quieter than other gears and are able to carry heavy loads efficiently. Due to the gradient of the teeth and the pressure applied, these gears are subject to axial thrust. This can be remedied by the use of thrust bearings and specialized lubricant.

Bevel gears: Bevel gears are gears whose shapes are conical. When two bevel gears are in mesh, their axes intersect. Hence, this makes it possible to changes the operating angle.

Bevel Gears

Spiral gear: These are bevel gears with helical teeth. The helical design helps reduce vibration and noise than a conventional spur gear. Their advantages and disadvantages are similar to those of helical gears.

Spiral Gears

Rack and pinion gear system: A rack is a toothed bar that is in connection with a spur gear. The rotational motion applied on the pinion causes the rack to move linearly with respect to the pinion. This system is used in trains to force them up steep slopes.

Rack and Pinion

Worm and Worm gear: A worm drive is a gear arrangement in which a worm (which is a gear in the form of a screw) meshes with a worm gear (which is similar in appearance to a spur gear). The two elements are also called the worm screw and worm wheel.

Like other gear arrangements, a worm drive can reduce rotational speed or transmit higher torque.

One of the major advantages of worm gear drive units are that they can transfer motion in 90 degrees.

Worm and Worm Wheel

1.4 GEAR HOBBING:

Every gear cutting process has a field of application to which it is best adapted. However, these fields overlap so that many gears can be produced satisfactorily by two or more processes. Type of gear produced is usually the major factor for the selection of the machining process. Gear production by machining can be classified as:

- Gear Hobbing
- Gear milling
- Gear shaping
- Gear broaching
- Shear cutting of gears

1.4.1 Hobbing:

It is the most widely used gear cutting process for creating spur and helical gears and more gears are cut by hobbing than any other process as it is relatively quick and inexpensive. Hobbing uses a hobbing machine with two skew spindles, one mounted with a blank workpiece and the other with the hob. The angle between the hob's spindle (axis) and the workpiece spindle varies, depending on the type of product being produced. For example, if a spur gear is being produced, then the hob is angled equal to the helix angle of the hob; if a helical gear is being produced then the angle must be increased by the same amount as the helix angle of the helical gear.

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.

Hob: 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. There are slight changes to the shape for generating purposes, such as extending the hob's tooth length to create a clearance in the gear's roots.

Hobbing machines are available in number of forms, sizes and configurations, although the principle remains the same. The most popular arrangement is the vertical type of hobbing machine where the axis of workpiece and feed motion is vertical.

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. The feed types in a CNC type Gear Hobbing Machines 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 modelling of radial feed drive in an Industrial CNC Gear Hobbing Machine. The Modelling Of radial feed in machine is done in four phases:

1. Selection Of Ball Screw.
2. Selection Of Bearings.
3. Selection Of Bearing Housing.
4. Assembly Of Gear Hobbing Machine.

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

2. REASON FOR TOPIC SELECTION:

After taking a tour of the shop floor with its various sections we chose this topic for the following:

1. It involved a variety of aspects from studying the design of the machine on CATIA V5 to the stress-strain analysis on components in the machine.

2. It was a project which would be beneficial to both the sides.

3. It would help us by expanding our existing knowledge on basic manufacturing processes as well as improving our machine designing skills. It would also help us in understanding practical limitations being faced in the industry.

3. SCOPE OF THE PROJECT

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.

4. ABOUT THE COMPANY: ARK MACHTEK PVT. LTD.

ARK Mach Tek Pvt. Ltd**.** is one of the oldest and most experienced players in the field of Automation for Gear Processing and various Grinding Machines in India. A home for many when it comes to rebuilding, reconditioning or retrofitting of old machines.

We boast of having the expertise in successfully reconditioning of more than hundreds of gear hobbing, gear shaping, gear shaving, internal grinding, pin grinding and crank shaft grinding machines of various makes like Pfauter, Libherr, Hurth, Mitsubishi, Gleason, WMW, HMT, NAXOS-UNION, LANDIS etc.

Excellent performances of machines reconditioned by us that too in very economical prices has forced the strategy makers of various companies to opt us as their reconditioning partner rather than going for those expensive new machines considering the ROI (Return on investment).

ARK was initially known as ARK ENGINEERS established in the year of 1998 and in the latter half of year 2010 the company has been incorporated as ARK MachTek Pvt. Ltd.

Anticipating the increasing demand of ventures for machine reconditioning, ARK presented itself as a complete package for machine reconditioning under the one roof.

Seeing the growth in automotive sector ARK decided to focus mainly into automation of Gear cutting / Gear processing machines which is the key element of the vehicle. More than 100’s of machine has been reconditioned till date by ARK using FANUC/SIEMENS Control.

5. LITERATURE REVIEW

1. **Recirculating ball screw – Supriya Kulkarni , Prithviraj Kajale , D.U Patil ; IJERST ISSN 2319-5991, Vol. 4, No. 2, May 2015**

   The demand for higher productivity and tight part tolerances requires machine tools to have faster and more accurate feed drive systems. As tried and tested technology, ball screw drive systems are still used in a majority of machine tools due to their low cost and high degree of stiffness. A high-speed ball screw drive system generates more heat and results in greater positioning error, adversely affecting the accuracy of machined parts.

2. **Modeling and Analyzing the Slipping of the Ball Screw - Nannan Xu , Wen Cheng Tang ; Latin American Journal of Solid and structures ; School of mechanical Engineering, Southeast University, Nanjing 211189, China.**

   This paper aims to set up the ball systematic slipping model and analyze the slipping characteristics caused by different factors for a ball screw operating at high speeds. To investigate the ball screw slipping mechanism, transformed coordinate system should be established firstly. Then it is used to set up mathematical modeling for the ball slipping caused by the three main reasons and the speed of slipping can be calculated. Later, the influence of the contact angle, helix angle and screw diameter for ball screw slipping will be analyzed according to the ball slipping model and slipping speeds equation and the slipping analysis will be obtained. Finally, curve of slipping analysis and that of mechanical efficiency of the ball screw analysis by Lin are compared, which will indirectly verify the correctness of the slipping model. The slipping model and the curve of slipping analysis established in this paper will provide theory basis for reducing slipping and improving the mechanical efficiency of a ball screw operating at high speeds.

3. **Design Calculation of Precision Ball Screw for Portable CNC Machine – Manish Patil , Prof. Hredeya Mishra ; IJIRST –International Journal for Innovative Research in Science & Technology| Volume 4 | Issue 1 | June 2017 ISSN (online): 2349-6010.**

   The demand for higher productivity and tight part tolerances requires machine tools to have faster and more accurate feed drive systems. As tried and tested technology, ball screw drive systems are still used in a majority of machine tools due to their low cost and high degree of stiffness. A high-speed ball screw drive system generates more heat and results in greater positioning error,adversely affecting the accuracy of machined parts. In this paper calculation has been done for selecting the Ball screw and there characteristics has been reviewed.

4. **Vibration analysis of High speed Ball screw drive in Machine tool feed system – Fei Zhao , Jinhua Chen , Chi Zhang , Guilin Yang ; Ningbo institute of material technology and engineering , Chinese academy of science .**

   This paper studies dynamic response of high speed ball screw drive system in machine tool feed system. In this paper , moving mass and force effect are taken into consideration synchronously and relative velocity relationship of screw and nut is studied as well. The results show that the pitch of screw , which determines relative speed of rotating beam with respect to moving excitation , have strong influence on lateral deformation .Major factors affecting the ball screw drive deformation are identified to illustrate its vibration performance.

5. **Ball screw, important components of machine tools, feed drives.**
   Stefan barbu and Laurean Bogdan

   This paper reviews the distinct position of ball screw in the structure of feed drive systems used in machine tools. Feed drive systems used in machine tools is an complex mechanism with elements like: guides, mechanical drives electrical motors and sensors. Machine tool guides designed using rolling element are reviewed, mechanical drives based on ball-screw are presented along with their compliance models, the electrical motors and sensors used in powering and measuring the motion are discussed. The paper presents experimental study of cinematic and tribologic parameters of ball screw mechanical drives actuated by a Stepper Motor and controlled by a Programmable Logic controller (PLC).

6. **Development of Gear Hobbing Fixture design for Reduction in Machine Setting Time**
   Amar Raj Singh Suri, A.P.S. Sethi

   The design of a fixture depends a lot on the designer’s expertise and experience and hence no solution is optimal or near optimal for a given workpiece. For a Gear hobbing fixture also there are multiple designs possible. This paper is about redesigning of a hobbing fixture to make it common for the other gears’ manufacturing and reduce the no of settings of the fixture on the hobbing machine. There by, reducing company’s cost & time**.** The design was checked and validated for safety under the action of cutting forces.

7. **Automation of Gear Hobbing Machine**
   Parth V Delvadiya, Thakkar Vikas, Panchal Ankit

   Now a days, gear manufacturing industry need a CNC hobbing machine for accurate gear production. If industries have conventional hobbing machine than conversion of conventional gear hobbing machine in to CNC machine with programmable logic controller and servo mechanism for better production of gear is economic and easy. By using PLC in gear hobbbing following transformations has done. In hardware transformations, to minimizes the defects of traditional gear hobbing transmission: use of more motor driving mode control process; replacement of middle transmission mechanism; direct connection of motor shaft for movement; reduce transmission error so as to improve the machining accuracy. For better control, adopted the sensors to follow movement process; use of PLC & feedback better control process. Enhancing the function of gear-hobbing after reforming, adopt MCP man-machine interface for exchange. After transformation in gear hobbing machine the test results show that computerized numerical control transformation, helps improve efficiency, accuracy, life span of old machine and minimizes complexity for the operator.

8. **Fatigue Life Analysis of Thrust Ball Bearing Using ANSYS**
   Prabhat Singh, Upendra Kumar Joshi
   This paper compares the total deformation of thrust ball bearing & contact stress b/w ball & raceways & its effect on fatigue life of thrust ball bearing. The 3-Dimensional Modeling has been done through modeling software Pro-e wildfire-5.0. The parts assembly is also done in Pro-e wildfire-5.0 & analysis has been done through ANSYS-14. An analylitical method is good, less expensive and gives the best results. Analytical results give good agreement with the experimental data. The thrust ball bearings are subjected to various, thrust & dynamic loads, which simulated easily through Pro-E software & analysis because experimentally calculation is very complicated. The general theory used for calculating the Fatigue life of Bearing is basic life rating theory. The material taken for the Bearing is AISI8720H. In this study we have used various analysis codes and got a good result through these codes.

6. STATEMENT OF OBJECTIVE

The demand for higher productivity and tight part tolerances requires machine tools to have faster and more accurate feed drive systems. As tried and tested technology, ball screw drive systems are still used in a majority of machine tools due to their low cost and high degree of stiffness. A high-speed lead screw drive system generates more heat and results in greater positioning error, adversely affecting the accuracy of machined parts. Hence we are designing 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.

7. DESIGN METHOLOGY

We have designed a radial feed system for a PA-320 gear Hobbing machine. Later we manufactured and assembled as a single part. In order to start with the design process, we must follow basic design validation rules for a good design structure. After the validation we moved on towards the designing phase which consists of three main steps such as:

- **PHASE ONE: BALL SCREW**
- **PHASE TWO: BEARINGS**
- **PHASE THREE: BEARING HOUSING**
- **PHASE FOUR: ASSEMBLY**

Later we carried out the analysis of the components to check its life and deformation.

Machining process was later carried out according to the prescribed dimensions.

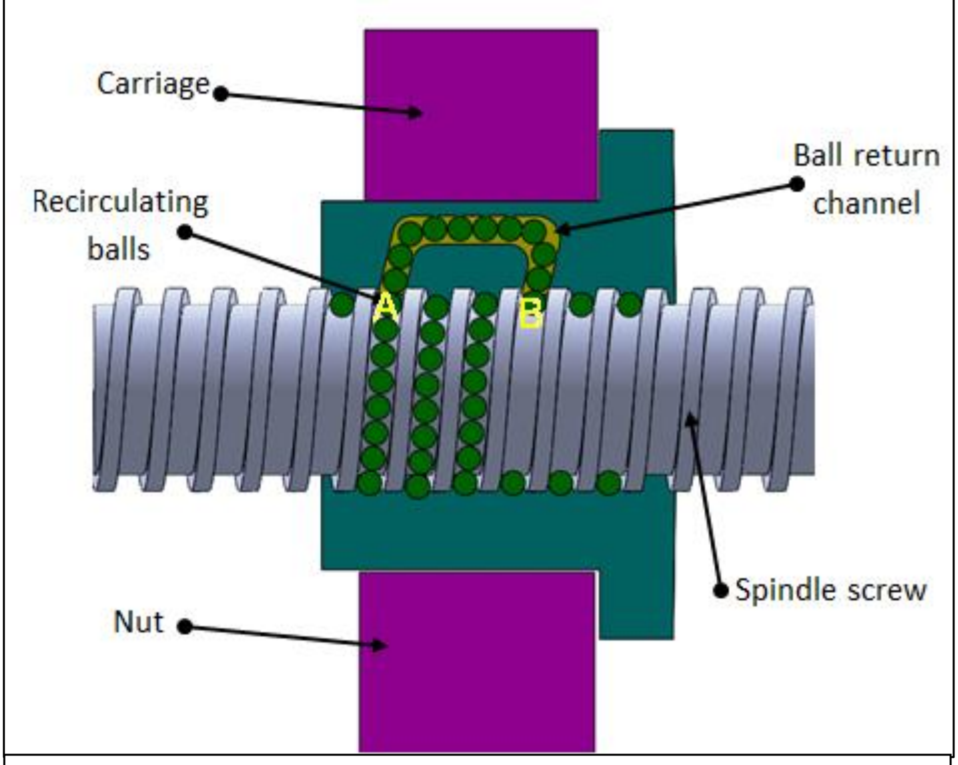
After machining we did a final design validation process and mounted the assembly.

After the complete assembly we carried out around 75-100 jobs over the machine to determine its accuracy.

Below we start with the designing phase followed by analysis and assembly.

8. PHASE ONE: BALL SCREW

The ball screw drive is an assembly that converts rotary motion to linear motion (or vice versa). It consists of a ball screw and a ball nut packaged as an assembly with recirculating ball bearings. The interface between the ball screw and the nut is made by ball bearings which roll in matching ball forms. With rolling elements, the ball screw drive has a very low friction coefficient and is typically greater than 90% efficient. The forces transmitted are distributed over a large number of ball bearings, giving a low relative load per ball comparatively. The ball nut determines the load and life of the ball screw assembly. The ratio of the number of threads in the ball nut circuit to the number of threads on the ball screw determines how much sooner the ball nut will reach fatigue failure (wear out) than the ball screw will.



1. SCHEMATIC LAYOUT OF BALL SCREW

Linear motion drives are mechanical transmission systems which are used to convert rotary motion into linear motion. The conventional thread forms like vee or square are not suitable in CNC because of their high wear and less efficiency. Therefore CNC machines generally employ ball screw for driving their workpiece carriages. These drives provide backlash free operation with low friction-wear characteristics. These are efficient and accurate in comparison with that of nut-and-screw drives. Most widely used linear motion drives are ball screws.

8.1 Applications of ball screws:

- High precision ball screws are used in steppers for semiconductor manufacturing industries for precision assembly of micro parts.
- Used in robotics application where precision positioning is needed.
- Used in medical examination equipments since they are highly accurate and provide smooth motion.
- Ball screws are employed in cutting machines, such as machining center and NC lathe where accurate positioning of the table is desired.
- Used in the equipments such as lithographic equipment or inspection apparatus where precise positioning is vital.

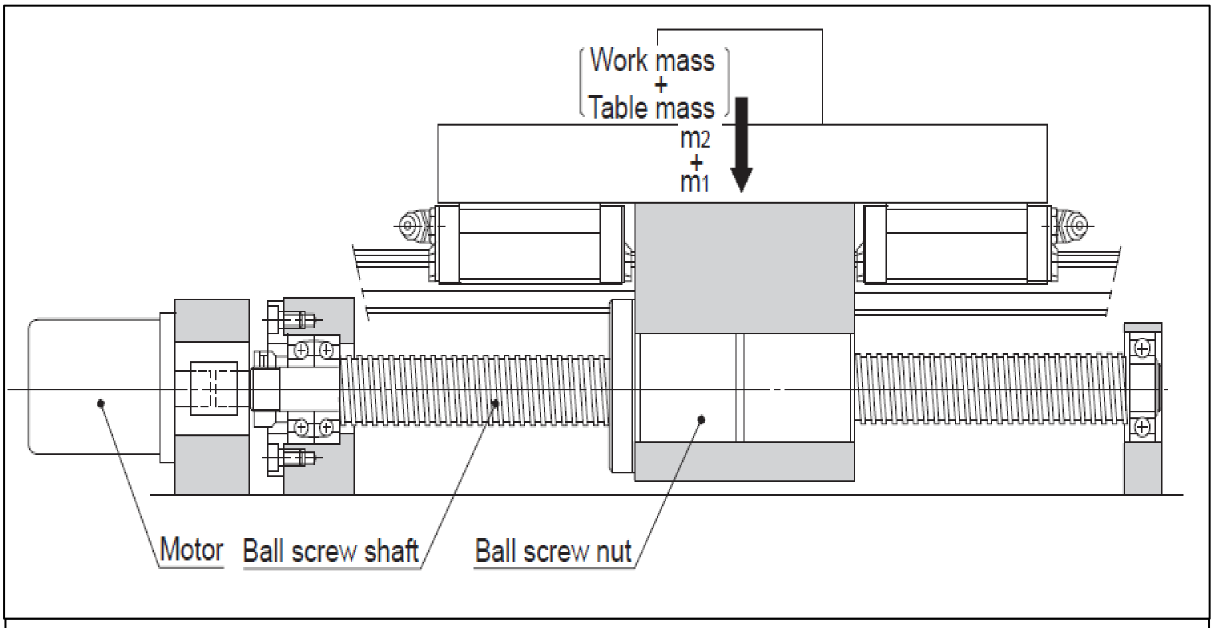
8.2 REASONS FOR USING BALL SCREW INSTEAD OF LEAD SCREW.

- High efficiency and reversibility
- Ball screws can reach efficiency as high as 90% because of the rolling contact between the screw and the nut.
- Ball screws are employed in cutting machines, such as machining center and NC lathe where accurate positioning of the table is desired.
- Therefore, the torque requirement is approximately one third of that of conventional screws Ball screws have super surface finish in the ball tracks which reduce the contact friction between the balls and the ball tracks.
- Through even contact and the rolling motion of the balls in the ball tracks, a low friction force is achieved and the efficiency of the ball screw is increased.
- High efficiency renders low drive torque during ball screw motion. Hence, less drive motor power is needed in operation resulting in lower operation cost.
- Backlash elimination and high stiffness
- Computer Numerically Controlled (CNC) machine tools require ball screws with zero axial backlash and minimal elastic deformation (high stiffness).

- Backlash is eliminated by special designed Gothic arch form ball track and preload. In order to achieve high overall stiffness and repeatable positioning in CNC machines, preloading of the ball screws is commonly used.
- However, excessive preload increases friction torque in operation. This induced friction torque will generate heat and reduce the life expectancy.
- High Lead Accuracy
- For applications where high accuracy is required, manufactures modem facilities permit the achievement of ISO, JIS and DIN standards.
- Predictable life expectancy
- Unlike the useful life of conventional screws which is governed by the wear on the contact surfaces, ball screws can usually be used till the metal fatigue.
- By careful attention to design, quality of materials, heat treatment and manufacture, ball screws have proved to be reliable and trouble free during the period of expected service life.
- Used in the equipment such as lithographic equipment or inspection apparatus where precise positioning is vital.
- The life achieved by any ball screw depends upon several factors including design, quality, maintenance, and the major factor, dynamic axial load (C).
- Low staring torque and smooth running -Due to metal to metal contact, conventional contact thread lead screws require high starting force to overcome the starting friction. However, due to rolling ball contact, ball screws need only a small starting force to overcome their starting friction.
- Quietness- High quality machine tools require low noise during fast feeding and heavy load conditions.

8.3 Steps for Selecting a Ball Screw

1. Selecting Lead Angle Accuracy
2. Selecting Axial Clearance
3. Assuming the Screw Shaft Length
4. Selecting a Lead
5. Selecting a Screw Shaft Diameter
6. Selecting a Screw Shaft Support Method
7. Studying the Permissible Axial Load(Buckling load, compressive and tensile Load)
8. Studying the Permissible Rotational Speed
9. Selecting a Nut Model Number
10. Calculating the Travel Distance
11. Nominal Life
12. Calculating the Service Life Time on the Basis of the Nominal Life



2. BALL SCREW WITH MOUNTING FORCES

8.4 Calculation for Selection Of Ball Screw And Its Suitable Length

Maximum stroke of column : 270 mm (machine spec.)

Minimum stroke of column : 30 mm (machine spec.)

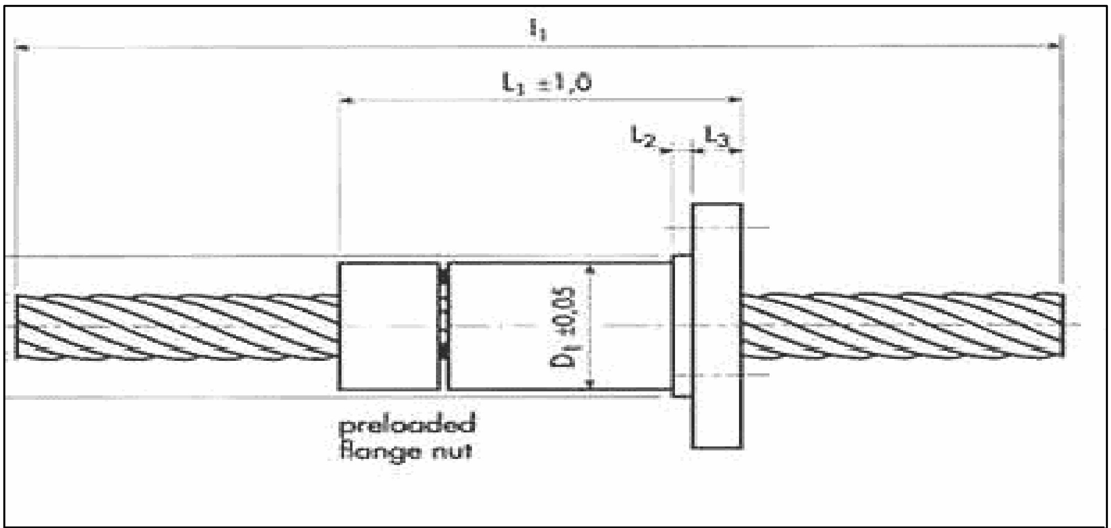
Total effective stroke of the column: 270 – 30 = 240 mm

Nut length : 161 + 19 = 180 mm (acc.to manufacturer catalogue)

Clearance distance = 10 mm

Total length of Ball screw = 240 + 180 + 10 = 430 mm

Take total Safe length = 440 mm



3. LENGTH AND DIAMETER DIAGRAM FOR BALL SCREW

After designing of the system, we move on with the designing of the ball screw system. First we calculated the total thread length according to the column length.

Total thread length= Effective length + Nut length

Total length was calculated as 470mm considering 10mm clearances on both sides. Later we studied the accuracy of Ball Screw in lead angle in accordance with JIS standards. Accuracy grades C_0 to C_5 are defined in linearity and C_7 to C_{10} in travel distance error.

		Precision Ball Screw												
												Rolled Ball Screw		
Accuracy grades		C0		C1		C2		C3		C5		C7	C8	C10
Effective thread length: Above	Or less	Representative travel distance error	Fluctuation	Representative travel distance error	Fluctuation	Representative travel distance error	Fluctuation	Representative travel distance error	Fluctuation	Representative travel distance error	Fluctuation	Travel distance error	Travel distance error	Travel distance error
—	100	3	3	3.5	5	5	7	8	8	18	18	±50/ 300mm	±100/ 300mm	±210/ 300mm
100	200	3.5	3	4.5	5	7	7	10	8	20	18			
200	315	4	3.5	6	5	8	7	12	8	23	18			
315	400	5	3.5	7	5	9	7	13	10	25	20			
400	500	6	4	8	5	10	7	15	10	27	20			
500	630	6	4	9	6	11	8	16	12	30	23			
630	800	7	5	10	7	13	9	18	13	35	25			
800	1000	8	6	11	8	15	10	21	15	40	27			
1000	1250	9	6	13	9	18	11	24	16	46	30			
1250	1600	11	7	15	10	21	13	29	18	54	35			
1600	2000	—	—	18	11	25	15	35	21	65	40			
2000	2500	—	—	22	13	30	18	41	24	77	46			
2500	3150	—	—	26	15	36	21	50	29	93	54			
3150	4000	—	—	30	18	44	25	60	35	115	65			
4000	5000	—	—	—	—	52	30	72	41	140	77			
5000	6300	—	—	—	—	65	36	90	50	170	93			
6300	8000	—	—	—	—	—	—	110	60	210	115			
8000	10000	—	—	—	—	—	—	—	—	260	140			

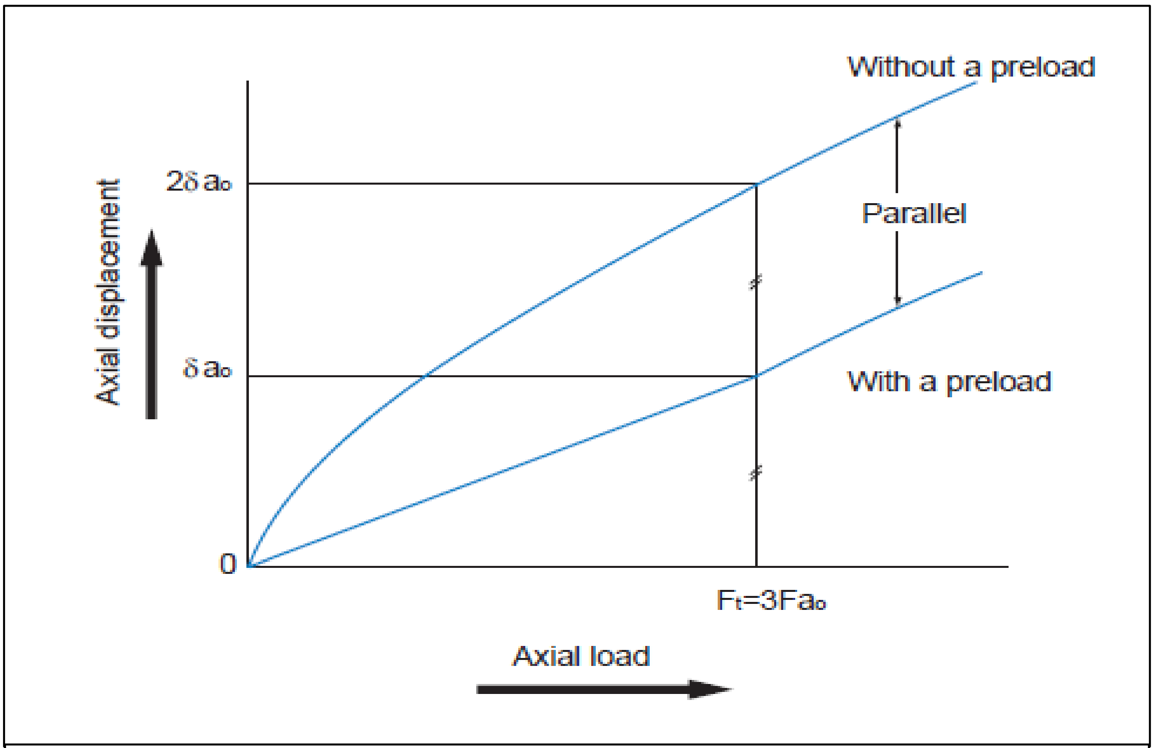
Note) Unit of effective thread length: mm

1. TRAVEL DISTANCE ERROR IN BALL SCREW

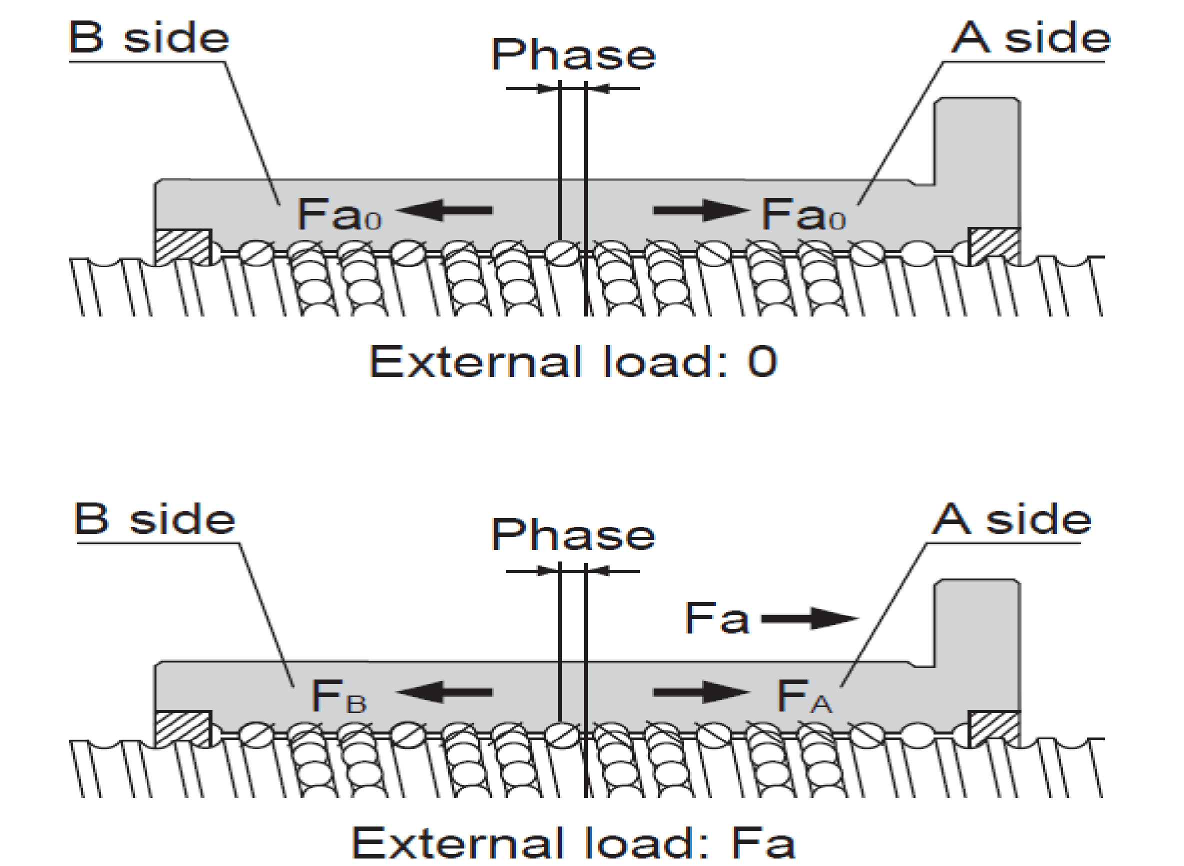
8.5 Preload methods:

Preload is to create elastic deformations (deflections) in steel balls and ball grooves in the nut and the screw shaft in advance by providing an axial load. Purpose of Preload is it eliminates axial play between a screw shaft and a ball nut. (Zero backlash). It minimizes elastic deformation caused by external force. When a preload is provided to the Ball Screw, the rigidity of the nut is increased.

There are two ways of preloading a single nut. One is called “the oversized ball preloading method”. The method is to insert balls slightly larger than the ball groove space to allow balls to contact at four points. The other way is called “the offset pitch preloading method”. This method is replaced by double nut preloading method and has the benefit of compact single nut with high stiffness via small preload force.



4. AXIAL DISPLACEMENT V/S AXIAL LOAD



5. FORCE DISTRIBUTION ON SCREW

The A and B sides are provided with preload F_{a0} by changing the groove pitch in the centre of the nut to create a phase. Because of the preload, the A and B sides are elastically displaced by δ_{a0} each. If an axial load (F_a) is applied from outside in this state, the displacement of the A and B sides is calculated as follows:

$\delta_A = \delta_{a0} + \delta_a$ $\delta_B = \delta_{a0} - \delta_a$

In other words, the loads on the A and B sides are expressed as follows:

$F_A = F_{a0} + (F_a - F_a')$ $F_B = F_{a0} - F_a'$

Therefore, under a preload, the load that the A side receives equals to F_a-F_a'. This means that since load F_a', which is applied when the A side receives no preload, is deducted from F_a, the displacement of the A side is smaller.

This effect extends to the point where the displacement caused by the preload applied on the B side reaches zero.

8.6 **Preload Torque:**

The preload torque of the Ball Screw in lead is controlled in accordance with the JIS standards. A torque required to continuously rotate the screw shaft of a Ball Screw under a given preload without an external load applied is called as dynamic preload torque. The reference torque can be calculated as:

$$T_p = 0.05\ (\tan\beta)^{-0.5}\ \frac{Fa_0 \cdot Ph}{2\pi}$$

where,

T_p : Reference torque (N-mm)

β : Lead angle

$F_{a\,0}$: Applied preload (N)

R_h : Lead (mm)

Reference torque N•mm		Effective thread length												
		4000mm or less										Above 4,000 mm and 10,000 mm or less		
		$\frac{\text{thread length}}{\text{screw shaft outer diameter}} \leqq 40$					$40 < \frac{\text{thread length}}{\text{screw shaft outer diameter}} < 60$					—		
		Accuracy grades					Accuracy grades					Accuracy grades		
Above	Or less	C0	C1	C3	C5	C7	C0	C1	C3	C5	C7	C3	C5	C7
200	400	±30%	±35%	±40%	±50%	—	±40%	±40%	±50%	±60%	—	—	—	—
400	600	±25%	±30%	±35%	±40%	—	±35%	±35%	±40%	±45%	—	—	—	—
600	1000	±20%	±25%	±30%	±35%	±40%	±30%	±30%	±35%	±40%	±45%	±40%	±45%	±50%
1000	2500	±15%	±20%	±25%	±30%	±35%	±25%	±25%	±30%	±35%	±40%	±35%	±40%	±45%
2500	6300	±10%	±15%	±20%	±25%	±30%	±20%	±20%	±25%	±30%	±35%	±30%	±35%	±40%
6300	10000	—	±15%	±15%	±20%	±30%	—	—	±20%	±25%	±35%	±25%	±30%	±35%

2. TOLERANCE CHART IN SCREW SHAFT

8.7 Permissible Axial Load

With the Ball Screw, it is necessary to select a screw shaft so that it will not buckle when the maximum compressive load is applied in the axial direction.

$$P_1 = \frac{\eta_1 \cdot \pi^2 \cdot E \cdot I}{\ell_a^{\,2}} 0.5 = \eta_2 \frac{d_1^{\,4}}{\ell_a^{\,2}} 10^4$$

P_1 : Buckling load (N)

ℓ_a : Distance between two mounting surfaces (mm)

E : Young's modulus ($2.05*10^5$ N/mm^2)

I : Minimum geometrical moment of inertia of the shaft (mm)

$ή_1$, $ή_2$ =Factor according to the mounting method

Fixed - free $ή_1$=0.25 $ή_2$ =1.3

Fixed - supported $ή_1$ =2 $ή_2$ =10

Fixed - fixed $ή_1$ =4 $ή_2$ =20

8.8 Permissible Tensile Compressive Load on the Screw Shaft

If an axial load is applied to the Ball Screw, it is necessary to take into account not only the buckling load but also the permissible tensile compressive load in relation to the yielding stress on the screw shaft.

$$P_2 = \sigma \frac{\pi}{4} d_1^{\,2} = 116 d_1^{\,2}$$

P_2 : Permissible tensile compressive load (N)

б : Permissible tensile compressive stress (147 MPa)

d_1 : Screw-shaft thread minor diameter (mm)

9. PHASE TWO: BEARINGS

A bearing is a machine element that constrains relative motion to only the desired motion, and reduces friction between moving parts. The design of the bearing may, for example, provide for free linear movement of the moving part or for free rotation around a fixed axis; or, it may prevent a motion by controlling the vectors of normal forces that bear on the moving parts. Most bearings facilitate the desired motion by minimizing friction. Bearings are classified broadly according to the type of operation, the motions allowed, or to the directions of the loads (forces) applied to the parts.

There are at least 6 common types of bearing, each of which operates on different principles:

- Plain bearing, consisting of a shaft rotating in a hole. There are several specific styles: bushing, journal bearing, sleeve bearing, rifle bearing and composite bearing.
- Rolling-element bearing, in which rolling elements placed between the turning and stationary races prevent sliding friction. There are two main types
    - Ball bearing, in which the rolling elements are spherical balls
    - Roller bearing, in which the rolling elements are cylindrical rollers
- Jewel bearing, a plain bearing in which one of the bearing surfaces is made of an ultra-hard glassy jewel material such as sapphire to reduce friction and wear
- Fluid bearing, a noncontact bearing in which the load is supported by a gas or liquid,
- Magnetic bearing, in which the load is supported by a magnetic field
- Flexure bearing, in which the motion is supported by a load element which bends.

9.1 REASONS AND ADVANTAGES OF USING BALL BEARINGS:

1. Low starting and running friction except at very high speeds.
2. Ability to withstand momentary shock loads.
3. Accuracy of shaft alignment.
4. Low cost of maintenance, as no lubrication is required while in service.
5. Small overall dimensions.
6. Reliability of service.
7. Easy to mount and erect.
8. Cleanliness.

9.2 Calculation And Validation For Selected Bearing:

The Following Calculations Were Made To Select The bearings:

9.2.1 ITERATION 1: (For BS40M72)

1. Available DATA:

Power Transmitted: 17 KW

Speed of shaft : 1000 rpm

Shaft diameter : 40 mm

Type of Load : Axial and Radial.

2. Select type of load on bearing:

Bearing selected: BS40M72

Internal Diameter: 40 mm

Outer Diameter: 72 mm

3. Select the proper type of bearing:

Select the bearing according to given conditions:

In our case select,

60` Angular Contact Bearing type.

F_r = 2595 N

F_a = 100 N

4: To find C0 and C from IBC catalogue:

C_0 = 55000 N

C = 35600 N

K_a = 1.5

5: To calculate Ratios:

F_a/C_0 = 2595/55000 = 0.04718

Factor X = 0.56

Factor Y = 1.753

6: Calculate Equivalent dynamic load:

$P_e = \{ X*V*F_r + Y*F_a \} * K_a$

$P_e = 3257$ N

7: Rating life of Bearing:

$L_{10h} = 25000$ Hrs - For M/c Tools

$L_{10} = L_{10h} * n * 60 / 10^6$

$L_{10} = 2500*1000*60 / 10^6$

$L_{10} = 1500$ Million revolution

8: Calculate value of Cr

$L_{10} = Cr^3 / Pe^3$

a = 3 -- For Ball Bearing

$C_r = 37283.34$ N

As $\mathbf{C_r > C}$, Then Selected Bearing is not suitable

Select next bearing.

9.2.2 ITERATION 2: (FOR BS40M90)

1. **Available Data:**

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

2. Select type of load on bearing:

Types Of Loads Acting On Bearing:

Axial Load: Due to Column And Hob Head Weight

Radial Load: Is Almost Negligible

F_a = 2595 N

F_r = 100 N

3. Select the bearing designation from IBC Table:

The Bearing Provided By Manufacturer Has Following Parameters:

INNER DIAMETER (d) = 40 mm

OUTER DIAMETER (D) = 90 mm

THICKNESS (b)= 20 mm

Basic static Load capacity (C_0) = 90000 N

Basic dynamic load capacity(C) = 59000 N

Load application factor: K_a = 1.05 for timing belt drive

CALCULATIONS:

F_a/C_0 = 2595/90000 = 0.03333

Factor X = 0.56

Factor Y = 1.875

4. Calculate equivalent dynamic load :

$P_e = (X*V*F_r + Y*F_a)* K_a$.

P_e = 5167.58 N

5. Rating life selection according to type of application :

L_{10h} = 25000 hrs – For machine tool.

$L_{10} = L_{10h} * 60 * n / 10^6$ Million Revolution

$L_{10} = 25000 * 60 * 1000 / 10^6$

L_{10} = 1500 Million Revolution.

6. Calculate required dynamic load capacity (C_r):

$L_{10} = (C_r / P_e)^a$

a = 3 – Ball bearing

a = 10/3 – Roller Bearing

$1500 = C_r^3 / 5167.58^3$

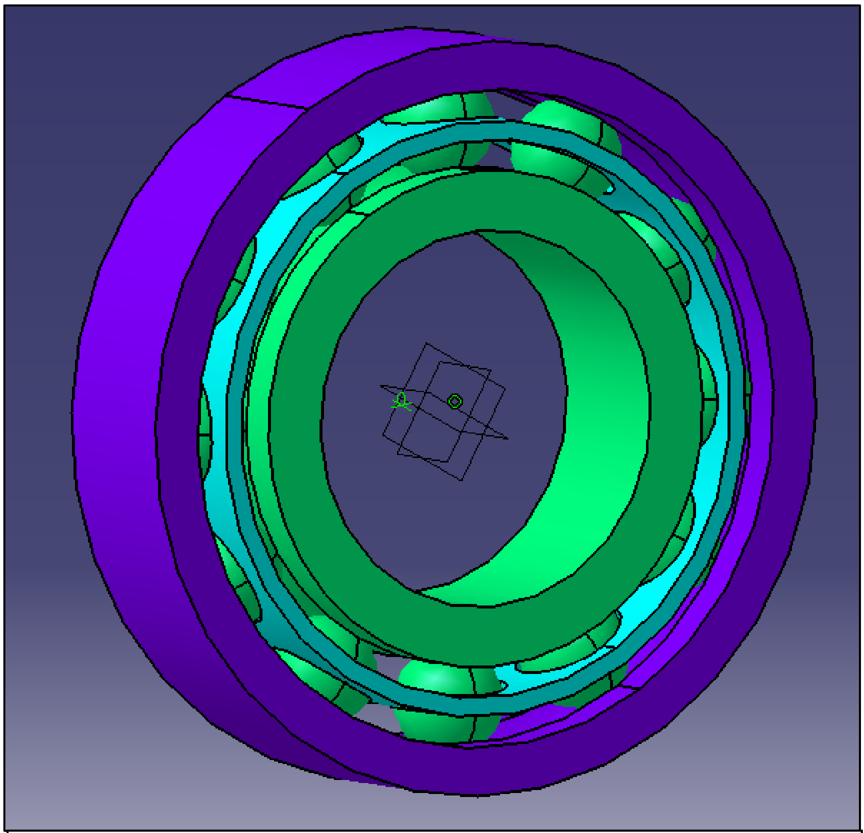
$C_r = 58155.46$ N

If $C > C_r$, Then selected bearing is suitable.

If $C < C_r$, Then bearing of next stage is suitable.

HERE $C>C_r$. THUS THE BEARING SELECTED IS SUITABLE.

Based On the Above Two Iterations , We Came To the Conclusion That BS40M90 Is The Most Suitable Bearing For Radial Feed Of Our System



6. BEARING MODEL USED IN DESIGN

Dimensions						Basic bearing no.		Abutment and fillet dimensions					Basic load ratings		Weight
d	D	B	$r_{1,2}$	r_{34}	a			r_{amax}	r_{bmax}	d_{amin}	D_{amax}	D_{bmax}	C_a	C_{oa}	
	mm		min	min	~					mm			N		kg
17	47	15	0.6	0.6	36.5	BS17M47		1.0	0.6	26	38	40	25000	32100	0.13
20	47	14	0.6	0.6	36	BS20M47/14*		1.0	0.6	28	38	40	25000	32100	0.14
20	47	15	0.6	0.6	36.5	BS20M47		1.0	0.6	28	38	40	25000	32100	0.14
25	52	15	1.0	0.6	39	BS25M52	+	1.0	0.6	34	44	45	26500	37000	0.22
25	62	15	1.0	0.6	46.5	BS25M62	+	1.0	0.6	34	52	54	29200	42800	0.27
25	62	17	1.0	0.6	47.5	BS25M62/17*	+	1.0	0.6	34	52	54	29200	42800	0.27
30	62	15	1.0	0.6	46	BS30M62	+	1.0	0.6	38	52	54	29200	42800	0.25
30	62	16	1.0	0.6	47	BS30M62/16*	+	1.0	0.6	38	52	54	29200	42800	0.25
30	72	15	1.0	0.6	56	BS30M72	+	1.0	0.6	39	63	64	35600	55000	0.32
30	72	19	1.0	0.6	58	BS30M72/19*	+	1.0	0.6	39	63	64	35600	55000	0.32
35	72	15	1.0	0.6	56	BS35M72	+	1.0	0.6	43	63	64	35600	55000	0.29
35	72	17	1.0	0.6	57	BS35M72/17*	+	1.0	0.6	43	63	64	35600	55000	0.34
35	100	20	1.0	0.6	75	BS35M100	+	1.0	0.6	47	86	89	70500	116000	1.05
40	72	15	1.0	0.6	56	BS40M72	+	1.0	0.6	48	63	64	35600	55000	0.28
40	90	20	1.0	0.6	71.5	BS40M90	+	1.0	0.6	49	80	82	59000	90000	0.64
40	90	23	1.0	0.6	73	BS40M90/23*	+	1.0	0.6	49	80	82	59000	90000	0.72
40	100	20	1.0	0.6	75	BS40M100	+	1.0	0.6	49	86	89	70500	116000	1.00
45	75	15	1.0	0.6	60	BS45M75		1.0	0.6	53	65	67	37900	61400	0.29
45	100	20	1.0	0.6	75	BS45M100	+	1.0	0.6	54	86	89	70500	116000	0.95
50	90	20	1.0	0.6	71.5	BS50M90		1.0	0.6	59	80	82	59000	90000	0.60
50	100	20	1.0	0.6	75	BS50M100	+	1.0	0.6	59	86	89	70500	116000	0.89
55	90	15	1.0	0.6	73	BS55M90	+	1.0	0.6	64	78	81	40700	74400	0.42
55	100	20	1.0	0.6	75	BS55M100		1.0	0.6	65	86	89	70500	116000	0.71
55	120	20	1.0	0.6	88	BS55M120		1.0	0.6	65	106	108	80800	137000	1.43
60	120	20	1.0	0.6	88	BS60M120		1.0	0.6	70	100	108	80800	137000	1.36
75	110	15	1.0	0.6	89	BS75M110		1.0	0.6	85	98	100	44500	93800	0.48

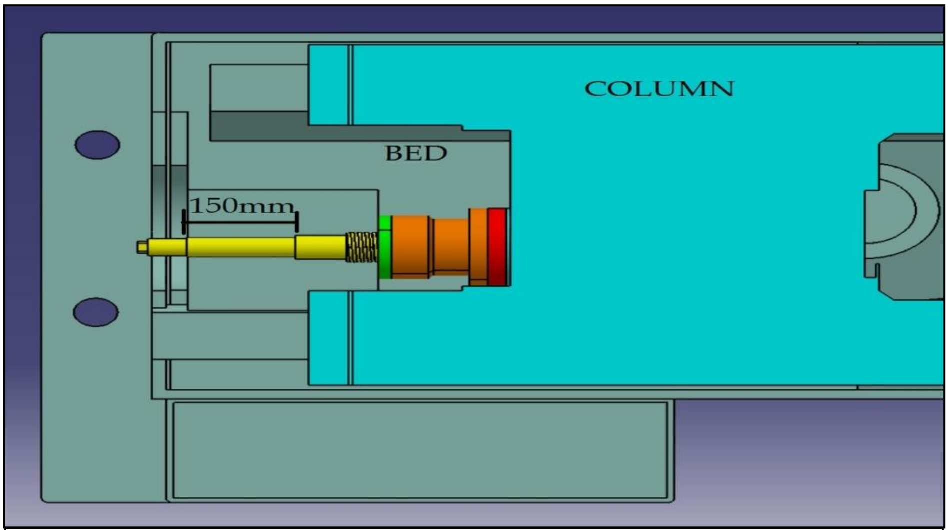
3. IBC TABLE FOR BEARINGS

10. PHASE 3: BEARING HOUSING:

- Bearing housings are modular assemblies designed to make it easy to install bearings and shafts, while protecting bearings, extending their operating life and simplifying maintenance.
- Housings are available in many sizes, and generally fall into five standard categories: split Plummer (or pillow) block housings, non-split Plummer block housings, flanged housings, take-up housings and two-bearing housings. These products can be designed to meet specific duty requirements such as load, speed and operating environmental conditions.
- Non-standard bearing housing designs can also be supplied to particular customer requirements: for example, where special shaft center heights, unusual sealing arrangements or non-standard materials of construction may be specified.
- If ease of installation and maintenance are prime considerations, then split Plummer block housings are an excellent choice as they not only accommodate pre-assembled shafts, but also simplify bearing inspections and maintenance as the shaft does not need to be disassembled.
- Grey cast iron, spheroidal graphite cast iron and cast steel are the most common materials of construction for bearing housings. Grey cast iron is most commonly used and is sufficient for the majority of applications, offering a combination of high strength, good damping and good thermal conductivity. Spheroidal graphite cast iron is more ductile and therefore provides a higher degree of strength and toughness, being capable of handling loads that are almost twice as heavy than those for grey cast iron. Where there is the threat of corrosion, bearing housings can be supplied in composite materials, in stainless steel or coated cast iron and cast steels.
- A further important task is to monitor the bearing’s performance in duty. This can be achieved through regular visual inspections or via a condition monitoring system, the latter being particularly relevant to critical installations. The most commonly monitored parameter is vibration, with the bearing condition being determined by analyzing variations in its vibration signature. Bearing temperature is another important measurement parameter, as is periodic testing of lubricant condition using a purpose-designed test kit.

10.1 Selection Of Bearing 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.

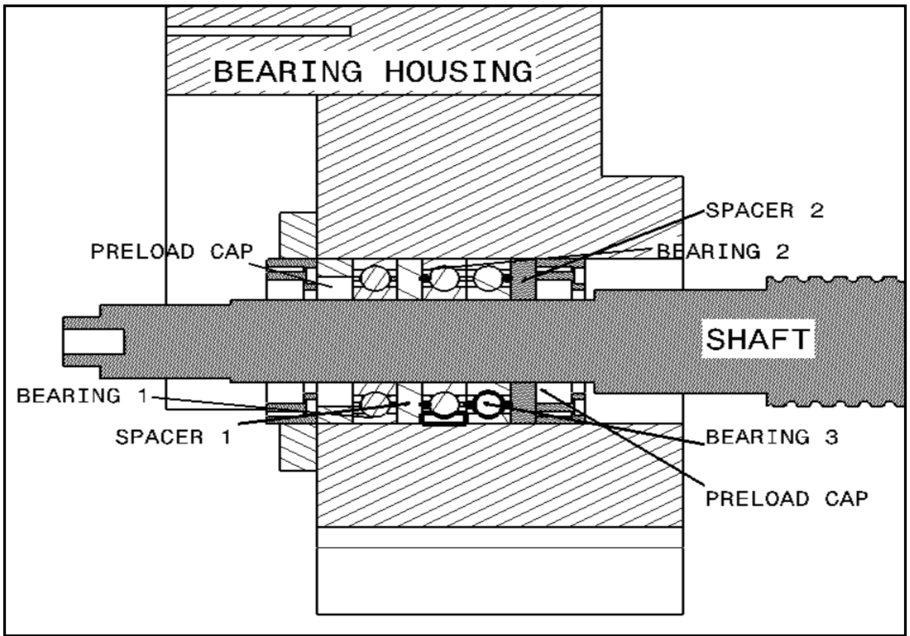


7. TOP VIEW OF BED WITH MOUNTED SHAFT

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.

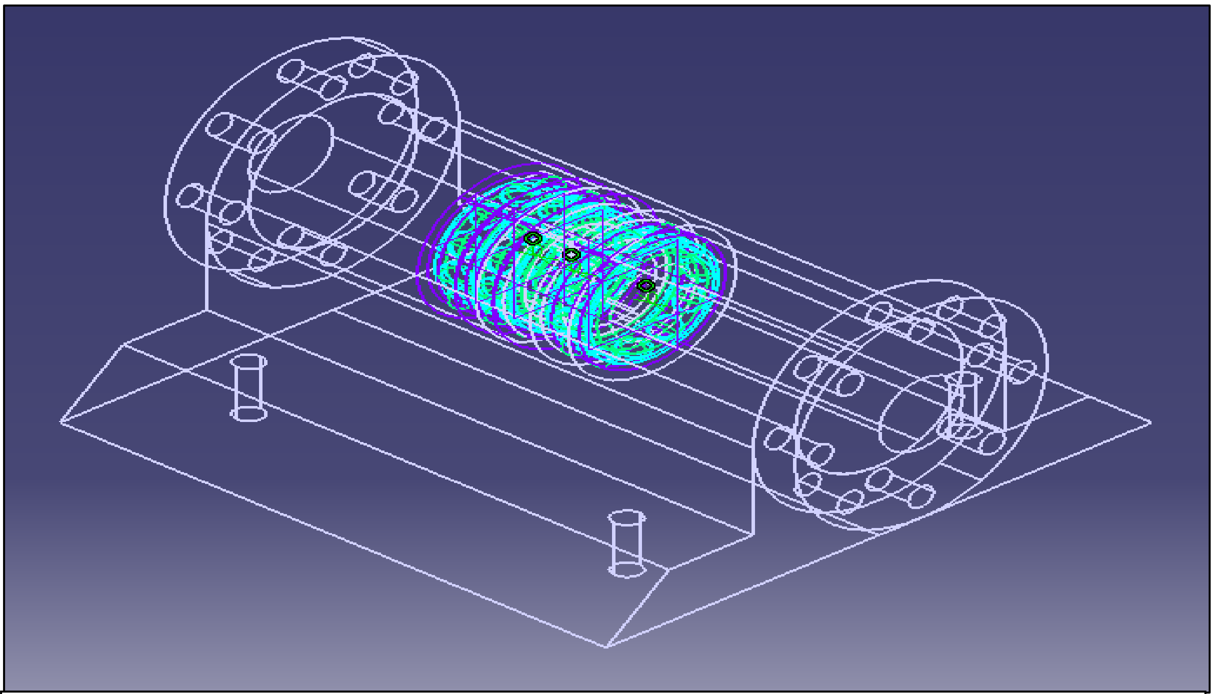
After this we constructed the outer Bearing housing design, considering an area of 260mm*260mm. Material used for bearing housing was FG260.

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.

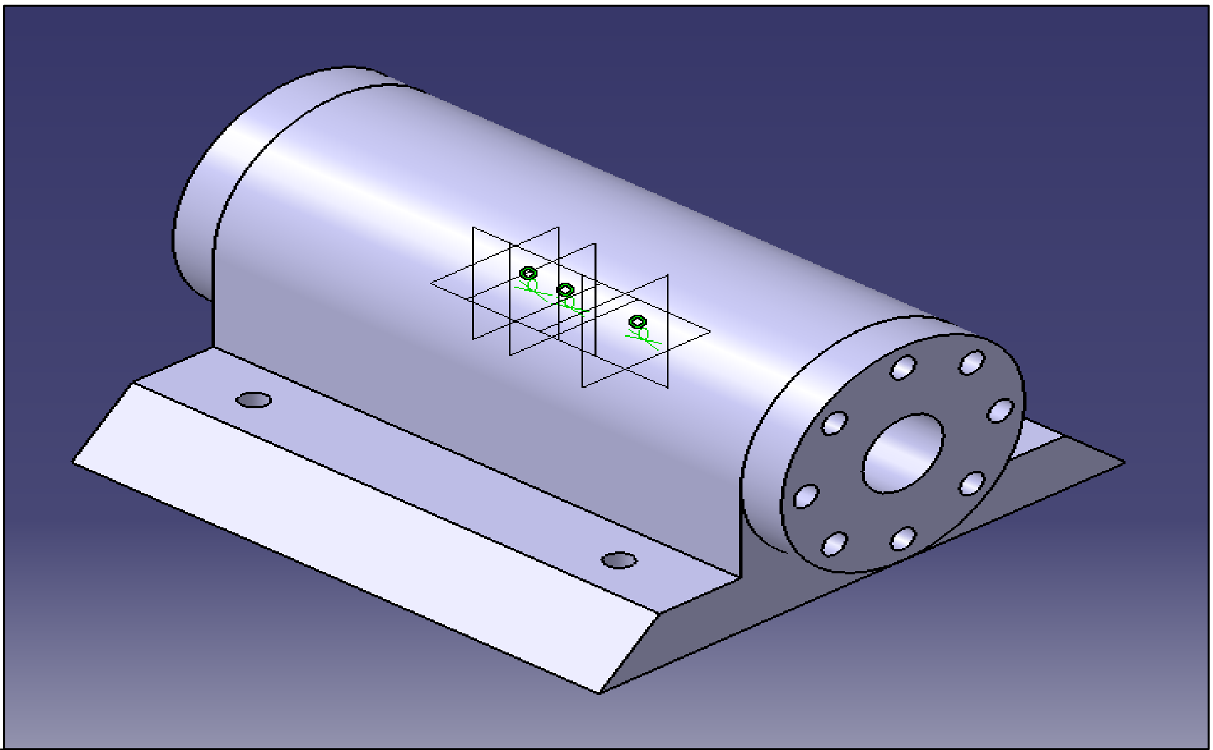


8. INNER BEARING HOUSING STRUCTURE

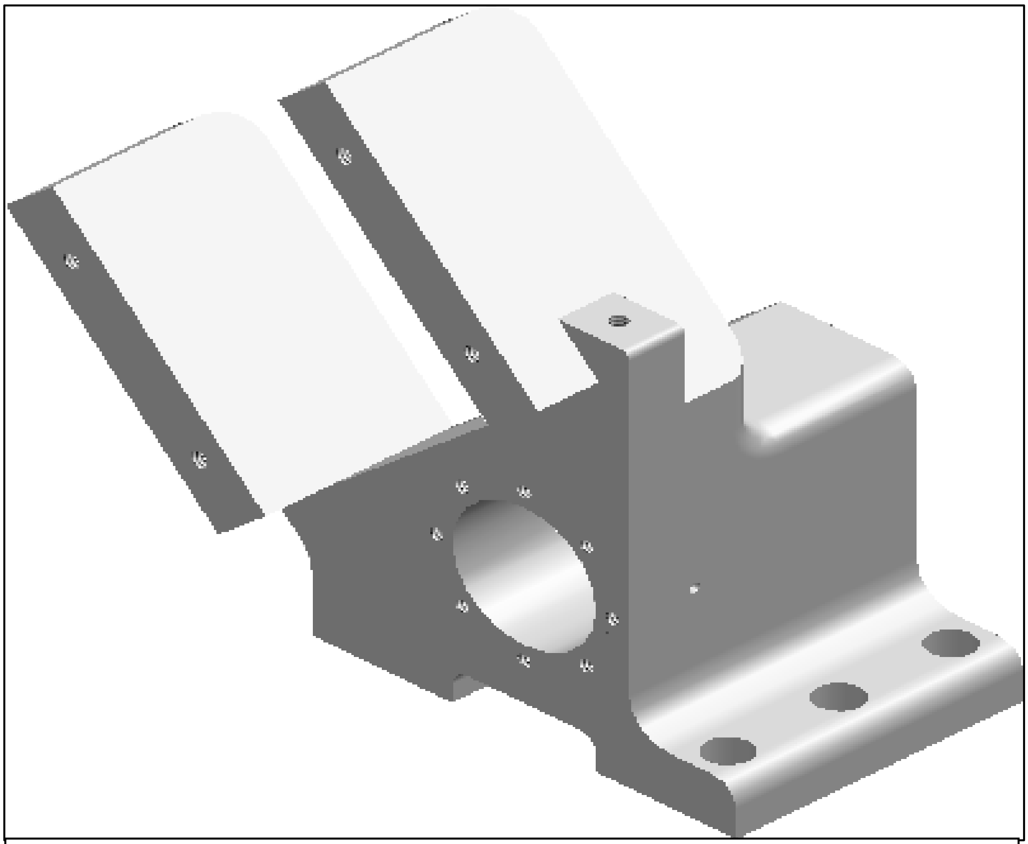
10.2 DESIGN ITERATION:



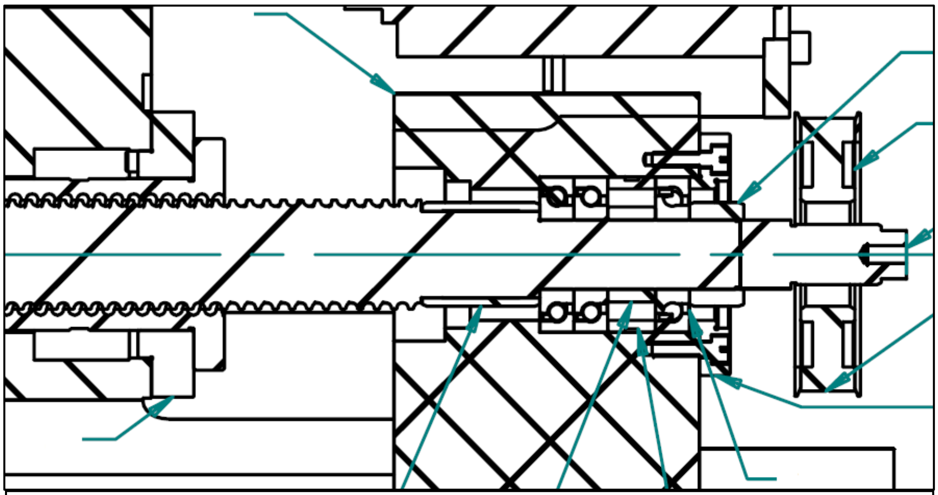
9. WIREFRAME MODEL OF BEARING HOUSING DESIGN ITERATION



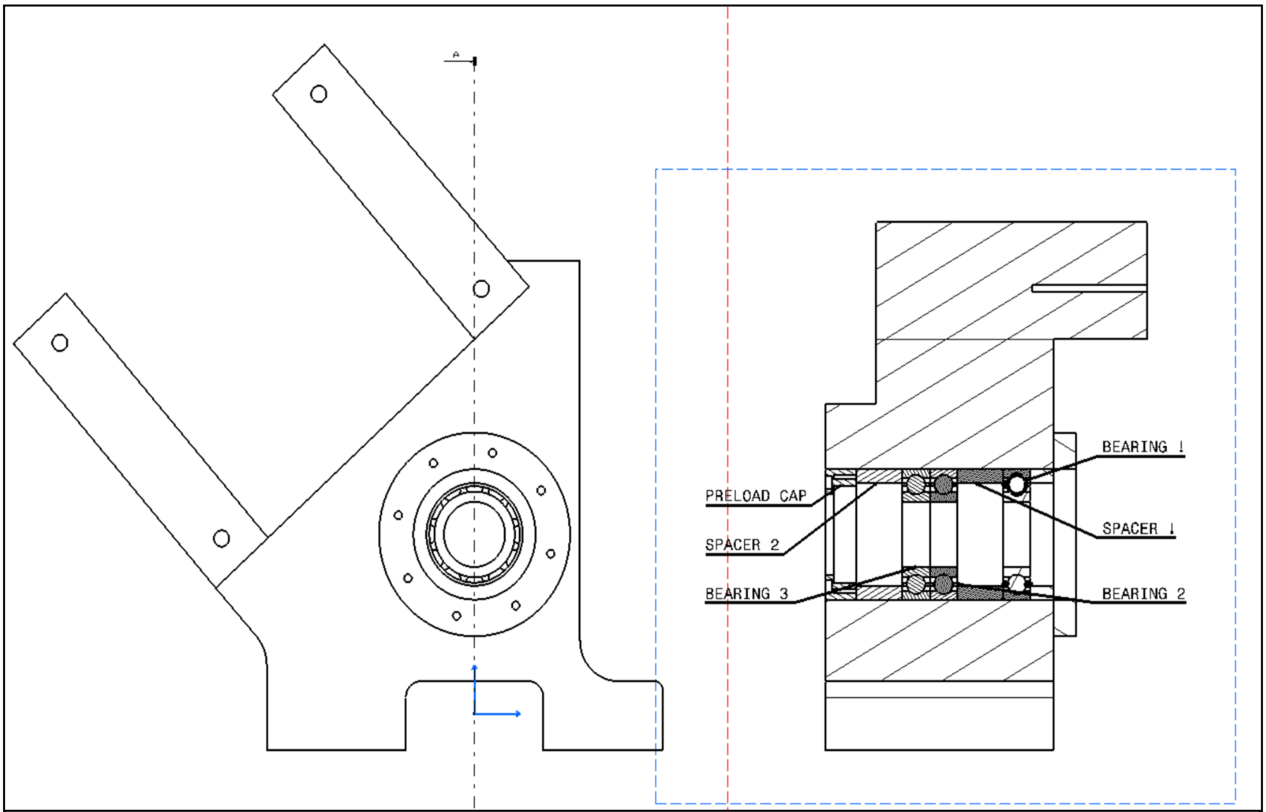
10. MODEL OF BEARING HOUSING DESIGN ITERATION



11. PROPOSED MODEL OF BEARING HOUSING DESIGN ITERATION



12. INNER BEARING HOUSING MODEL WITH BEARINGS



13. FINAL DRAFT OF BEARING HOUSING DESIGN

11. PHASE FOUR: ASSEMBLY OF GEAR HOBBING MACHINE

11.1 About P320 Pfauter Gear hobbing machine

The Pfauter P320 Vertical CNC Hobbing Machine Represents Pfauter's Most Advanced Gear Manufacturing Technology. Located in a Heavily Ribbed, Double-Wall Frame, Minimal Length Drive Trains Provide Maximum Static and Dynamic Rigidity. The Worktable Drive Comprises Two Worms and Worm Gears, Pre-Loaded Hydraulically to Guarantee Zero Backlash Throughout Machine Life. Radial, Axial, Tangential, Hob Head Swivel, and Work Table Movements are CNC Controlled. No Change Gears are used. By Means of the Features Above, the Pfauter P320 Combines Maximum Flexibility and Maximum Production Capability.

Model No. P-320 PFAUTER 6 Axis "CNC" Gear Hobbing Machine

Suitable for the hobbing of spur and helical gears, pinions, splines, sprockets, worm-gears, and other work pieces of similar profile up to 12.4" (320mm) pitch diameter, 4 DP (module 6),15.74"(400mm) face width.

11.2 SPECIFICATIONS

- GE FANUC 15-MB
- Max. Pitch Rating (Application Dependent): 4 DP or 6 MOD
- Max. Workpiece Diameter: 12.40"
- Max. Axial Travel: 15.74"
- Max. Swivel Angle: -30 Deg (LH)/+45 Deg (RH)
- Max. Hob Dimensions: 5.1" Diameter, 9" Length
- 7.9" Hob Shift Travel
- Taper in Hob Spindle: ISO 40
- Maximum Worktable Rotation: 55 RPM
- Number of Starts of Worktable Worm: 2
- Center Distance Workpiece/Hob: 1" Min., 8.85" Max.

Hob Spindle:

- Motor Power (100% Duty Cycle): 10 Hp
- Speed Range, Infinitely Variable: 72 - 720 RPM
- Rapid Traverse Rates:
- Radial: 196 IPM
- Axial:196 IPM
- Tangential: 118 IPM

Coolant:

- Tank Capacity: 178 Gallons
- Pump Flow Rate: 66 GPM
- Machine Weight (Approx.): 22,500 Lbs.
- The Model P320 Hobbing Machine is Fully Numerically Controlled, Built by American Pfauter Limited Partnership and Equipped as Follows.

Base Machine:

- Rigid Bed, Including Internal Coolant Circulation and Attached Coolant Tank.
- Main Column, Including Integral Axial Slide with Linear Guideways for Z and X Axes.
- Motorized Hob Head with Tangential Slide.
- CNC Controlled Hob Head Swivel with Automatic Hydro-Mechanical Clamping and Unclamping of Hob Head Swivel.
- Quick Hob Arbor Clamping (Mechanical Clamp, Hydraulic Release), Including Hydro-Mechanical Clamping Attachment for Outboard Bearing Support.
- Tailstock, Including Hydraulically Operated Slide. Force Adjustable from 200-350 daN (440-770 Lbs,)
- Tailstock Position Above Worktable: 14.96" Min, 30.70" Max. Worktable with Two Start, Double Worm Gear Drive.

- Complete Machine Enclosure with Sliding Door for Top Loading of workpieces and Electromagnetic Interlock of Door After Start of Work Cycle.

Electrical and Control Equipment:

- GE Series 15 MB CNC

Five Axes and One Spindle Control:

- Radial (X), Tangential (Y) , Axial (Z), CNC Hob Swivel (A), Hob Spindle (B) and Worktable (C)

GE Fanuc Series 15 MB Includes as Standard:

- Flat Operator Panel with 9.5" TFT Color Liquid Crystal Display; Custom Macro Tool Offset; and 320 Meters Part Program Storage Shared by User Menu.(Approx. 160 M Available for Customer Part Program Storage)
- GE Fanuc High Performance Digital AC Servo Drives for all Axes.
- GE Fanuc AC, Microprocessor Controlled Spindle Drive System with Serial Interface to CNC.
- Electrical Wiring for Connection to 440/460 or 480 VAC, +10%, 3 Ph, 60 Hertz and Total
- Connected Load Rating at 50 KVA. Auxiliary AC Motors for Oil Systems and Chip Removal, Etc.
- Absolute Digital Rotary Position Measurement Systems on All Axes.
- All Drive Amplifiers Equipped with Externally Mounted Heat Sinks for Dissipation of Heat Outside the Electrical Enclosure. The Machine Electrical System is Rated for Ambient Temperatures Up to 110 Deg F.

Hydraulic and Lubrication:

- Hydraulic and Recirculating Lubrication System, Including Attached Tank.

- Solenoid Valves are Manifold Mounted Forced Lubrication Recirculation of Hob Head and Worktable Progressive Guideway Lubrication System, Including Machine Mounted Tank.

Machine Controls:

- Programmable Machine Control (PMC) Via GE Fanuc CNC for Axes Motion.
- Manual and Automatic Control Modes, Safety Interlocks, Lubrication Control and Monitoring, etc. Diagnostic Messages and "Search Monitor" for Troubleshooting.

Universal Menu Parts Program:

American Pfauter Universal Menu with Data Input in Metric or Inch, of Gear, Hob Cutting, and Cycle Data; with the Following Features:

- Simultaneous Input of Up to Three (3) Different Gears and Three (3)
- Different Tools with Selectable Sequence of Execution.
- Date Tables for Axial Hobbing are Provided to Determine Feed and Speed Rates for Materials,
- Finish Requirements, and Cutting Tool Coatings, in Addition to Operator Entry of Feeds and Speeds.(All Data Tables are Passwork Protected and User Definable).
- Active Part Program Number Displayed with User Defined Comment Field.
- Can Be Used For Part Number Description. (16 Character Maximum,
- Alpha/Numeric)
- Data Entry During Cutting Cycle.
- All Input Data Can Be Saved in CNC Memory with User Definable Comment Field.(16 Character Maximum, Alpha/Numeric)
- Easy Retrieval of Previously Stored Data for Executing of Cutting Cycles.
- Menu Selectable Sequencing of Auxiliary Functions, Such As Power
- Clamping, Tailstock, Steady Rest, De-bur Tool, Robot Interface, Etc., Where Applicable.
- Fully Automatic Setup of All Axis Positions, Including Approach Calculation Overtravels, Hob Head Swivel Position, Etc.
- Radial, Axial, Radial/Axial Hobbing

- Two-Cut Cycle for Radial Cutting with Feed and Speed Selections for Each Cut.
- Two-Cut Cycles for Axial or Radial/Axial Cutting with Feed and Speed.
- Selection Including Equal or Alternating Feed Directions for Each Cut.
- Taper Hobbing (X-Z Interpolation) for the Above Combinations.
- Symmetrical or Offset Crown Hobbing for Coupling Gears, Including All
- Overtravels as Required and Crown Hobbing for Small Amounts of Crowning. Taper and
- Crown Hobbing Requires Only One Additional Input Into the Menu.
- Automatic Hob Shifting Program Including Selection of Max./Min. Hob
- Position,
- Shift Increment and Number of Parts To Be Cut Before Hob is Shifted.
- Single Indexing for Straight Gashes, Even Spacing, Single Cut, Climb,
- Conventional, Radial/Axial, Axial, Feed Rates Per Cutter Revolution.
- Tangential and Radial Tangential Hobbing.
- Special Cycle Entry Field to Define Part Program Number for User Part Programming of Special Contouring Requirements, Such as Dip, Skid, End Relief, and Combinations of the Above.

Equipped with:

- Chip Conveyor
- 220 volt/ 3 phase/ 60 cycle

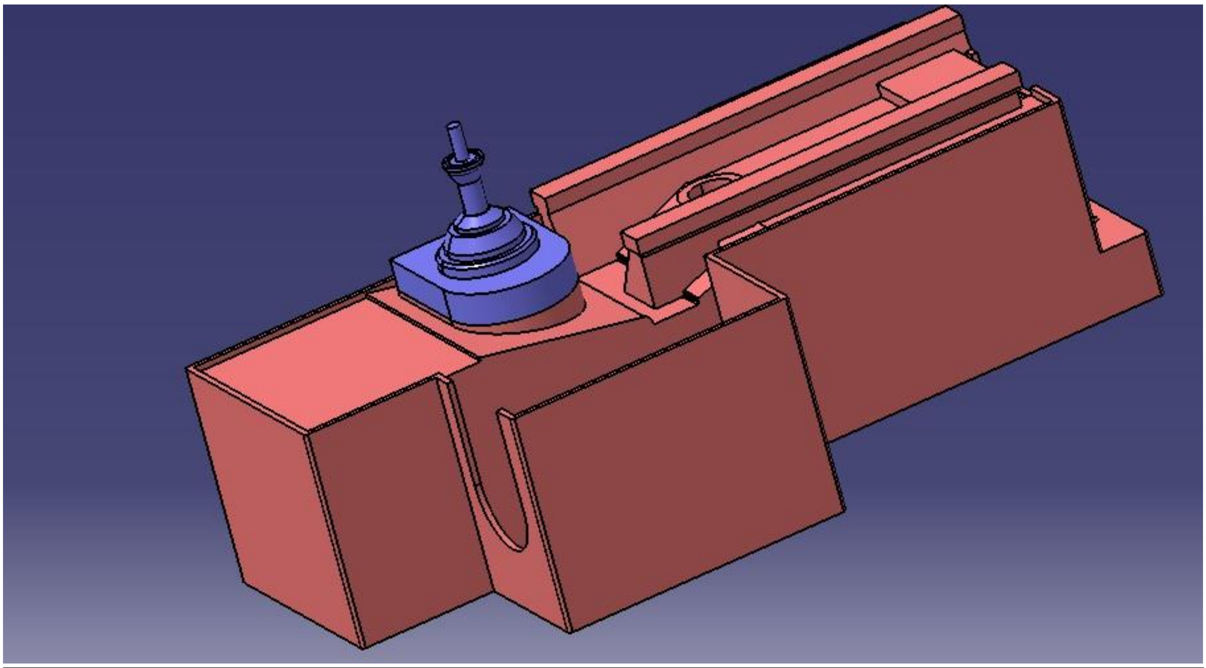
14. GEAR HOBBING MACHINE USED IN COMPANY

12. CATIA MODELLING OF CNC GEAR HOBBING MACHINE

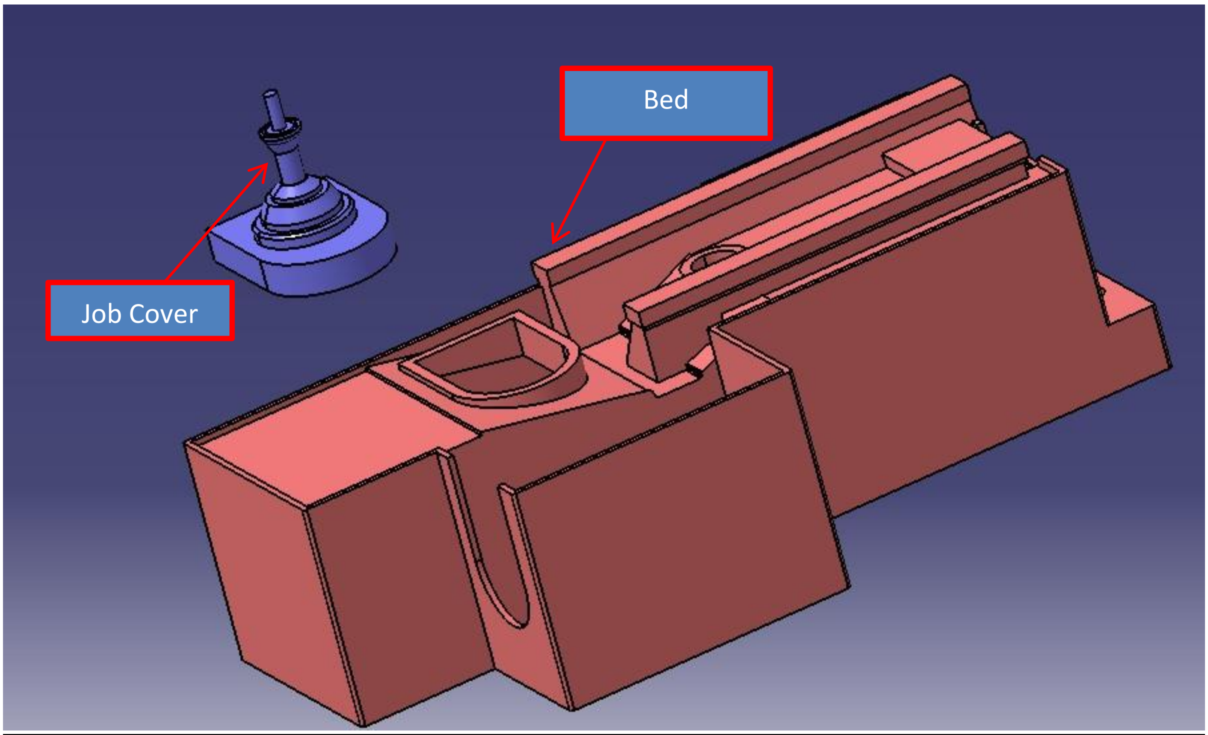
After performing various design iterations and calculations, we modelled the layout of the gear hobbing machine in CATIA V5R20. The modelling consisted of the following parts:

1. Modeling Of Machine Bed Assembly
2. Modeling Of Column Assembly
3. Modeling Of Hob Head Assembly
4. Main Assembly

12.1 BED ASSEMBLY

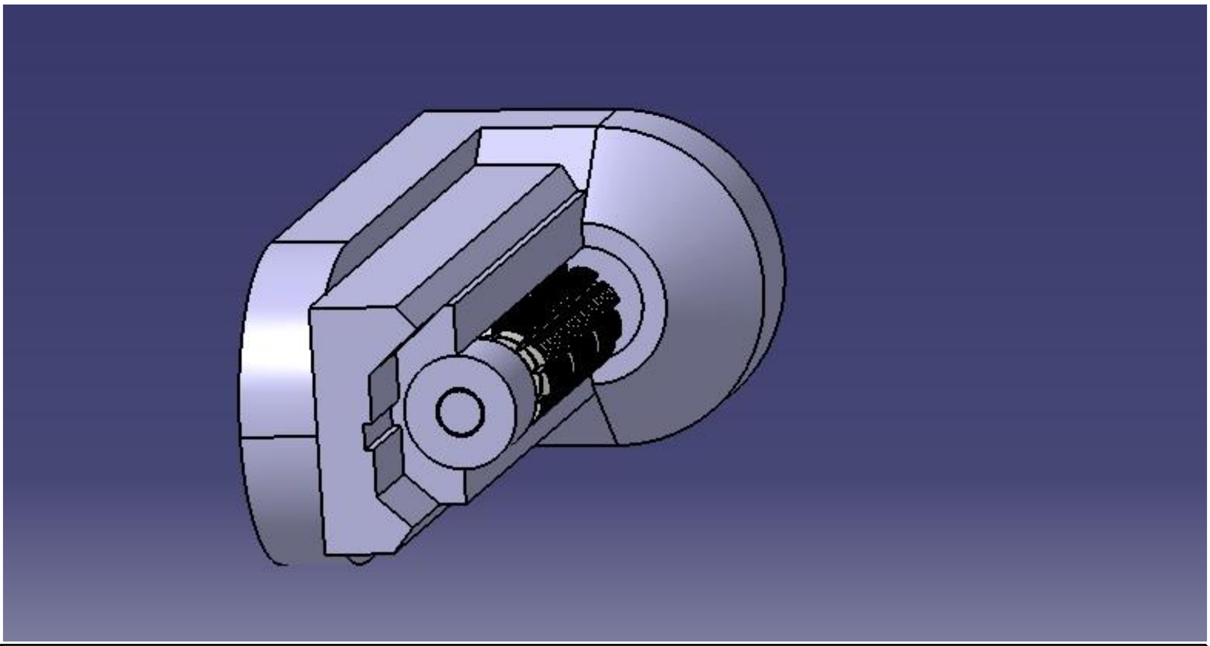


15. MODEL OF MACHINE BED

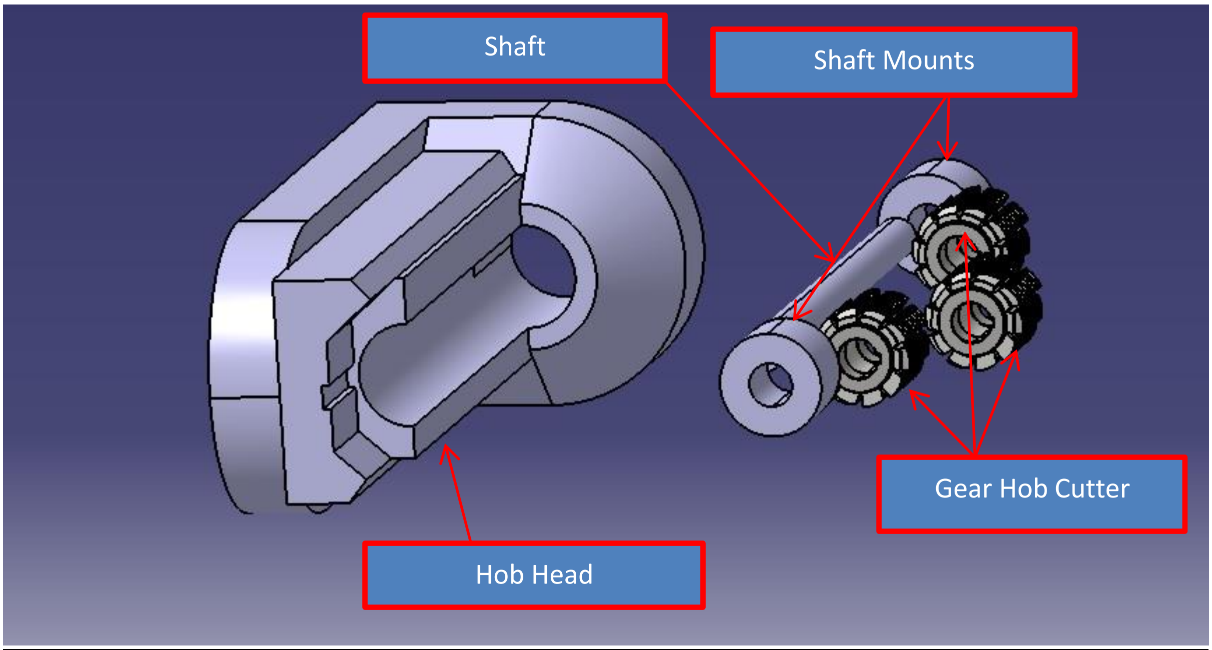


16. EXPLODED VIEW OF MACHINE BED

12.2 HOB HEAD ASSEMBLY

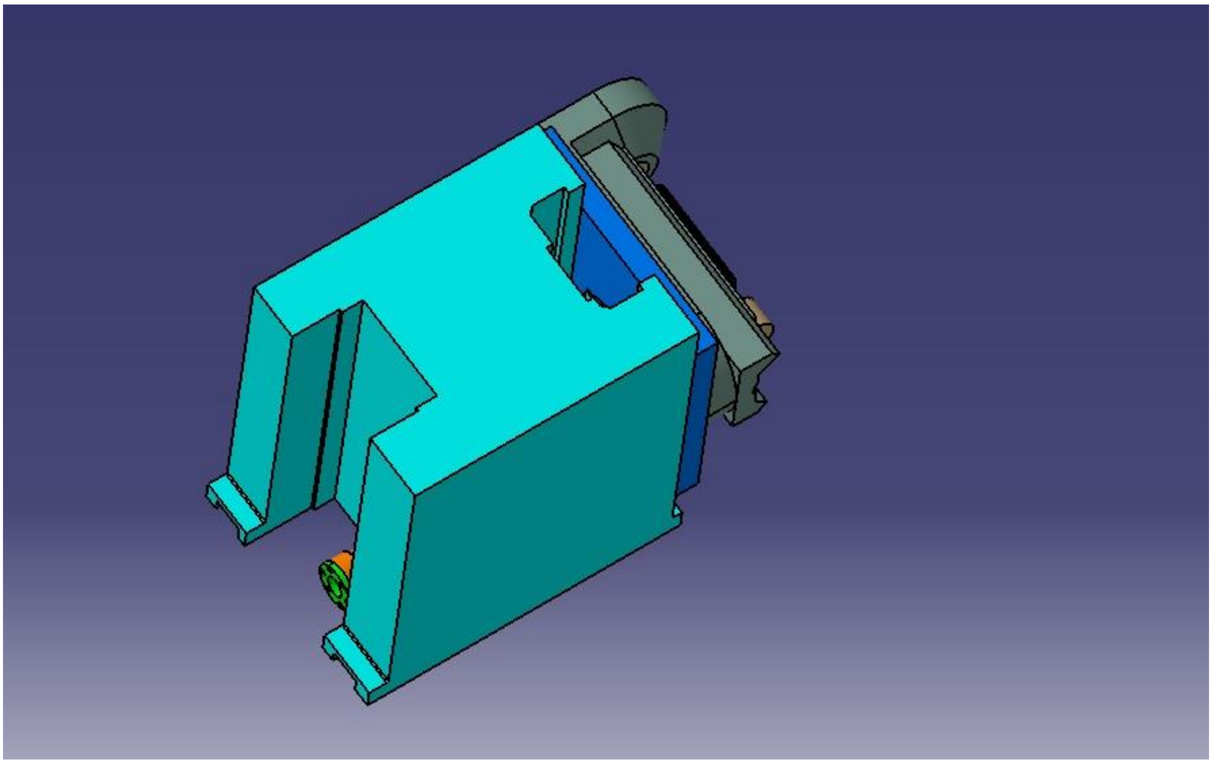


17. MODEL OF HOB HEAD ASSEMBLY

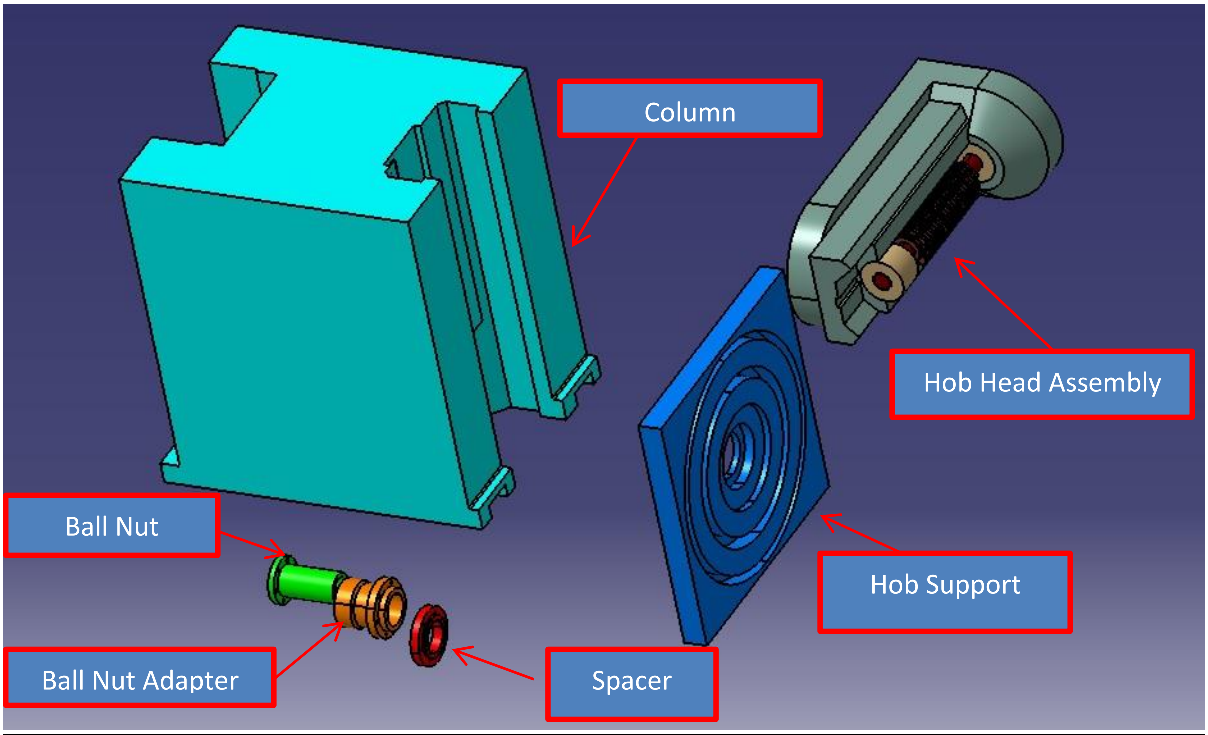


18. EXPLODED VIEW OF HOB HEAD ASSEMBLY

12.3 COLUMN ASSEMBLY

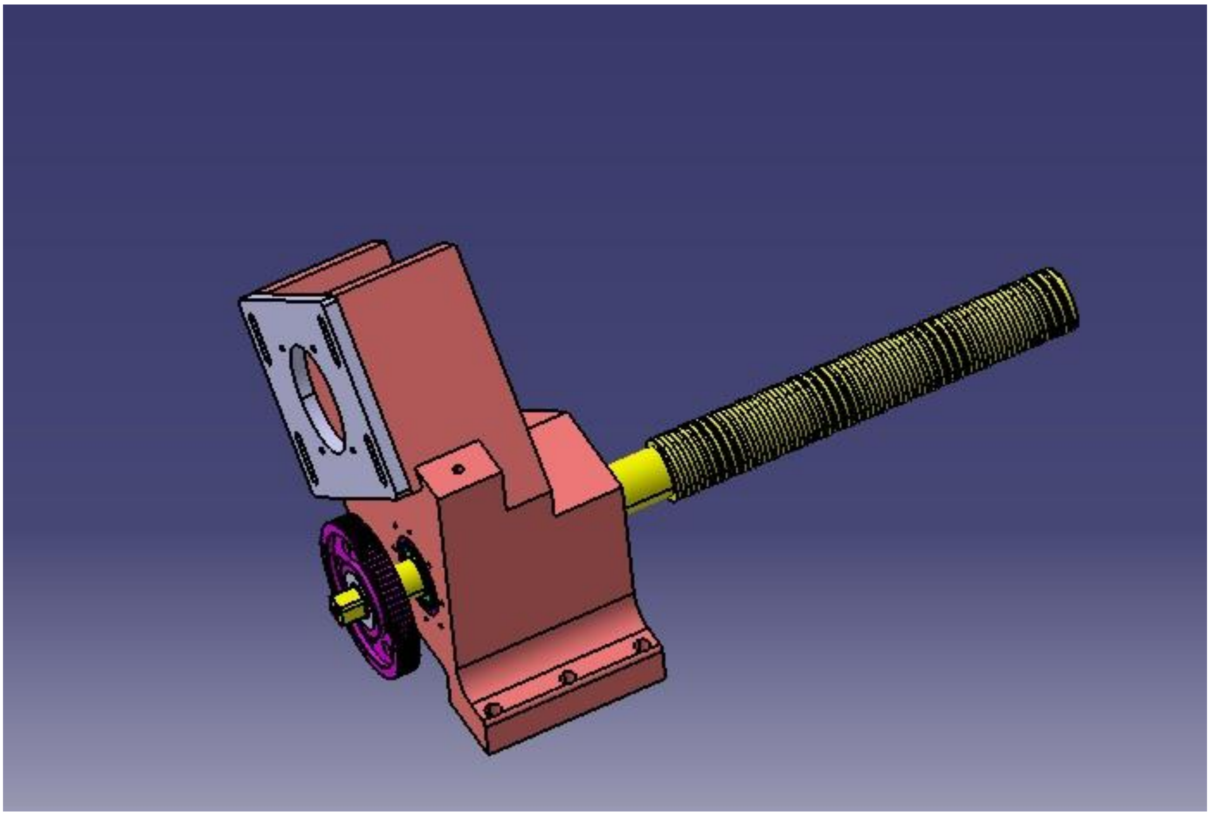


19. MODEL OF COLUMN ASSEMBLY

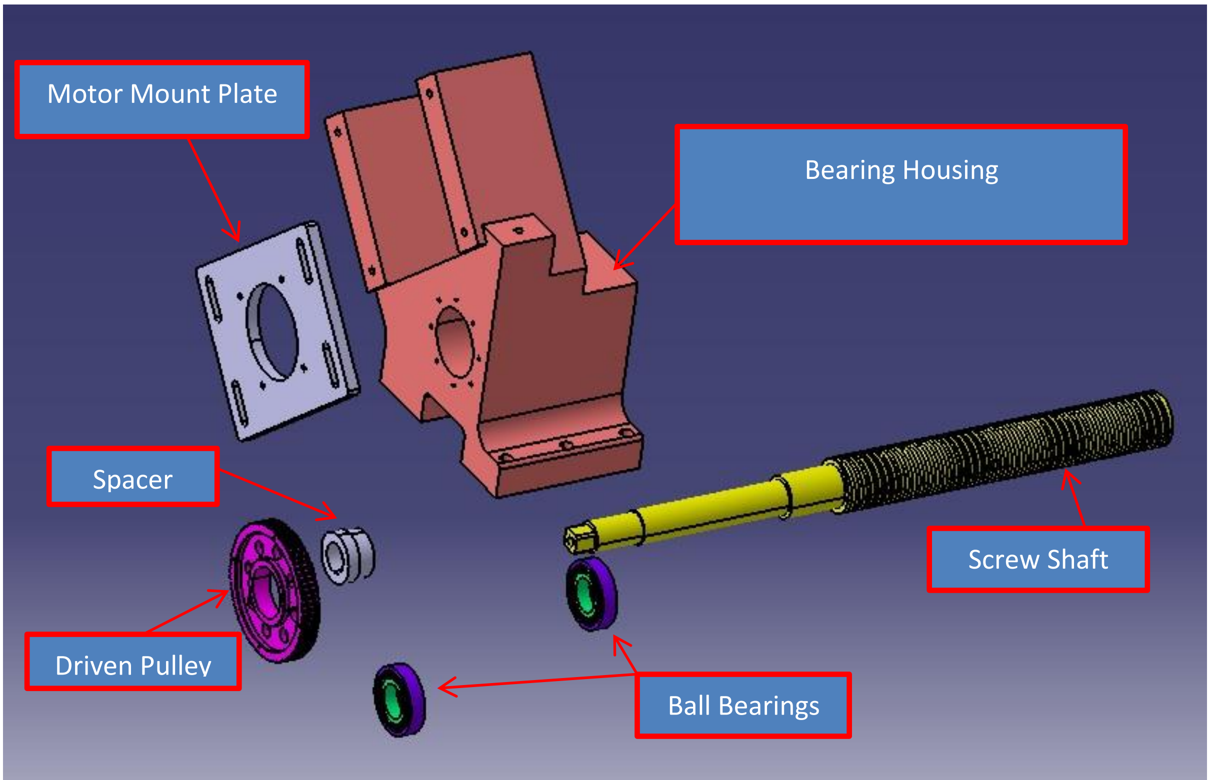


20. EXPLODED VIEW OF COLUMN ASSEMBLY

12.4 BEARING HOUSING ASSEMBLY

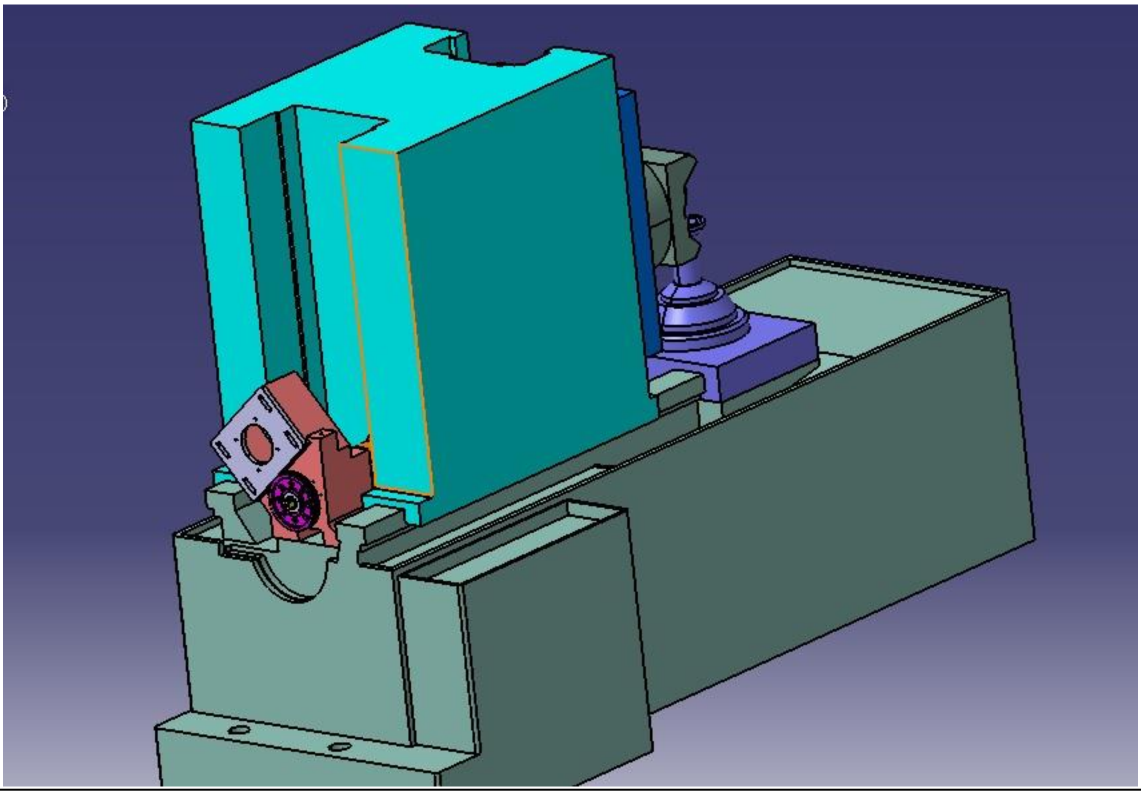


21. MODEL OF BEARING HOUSING ASSEMBLY

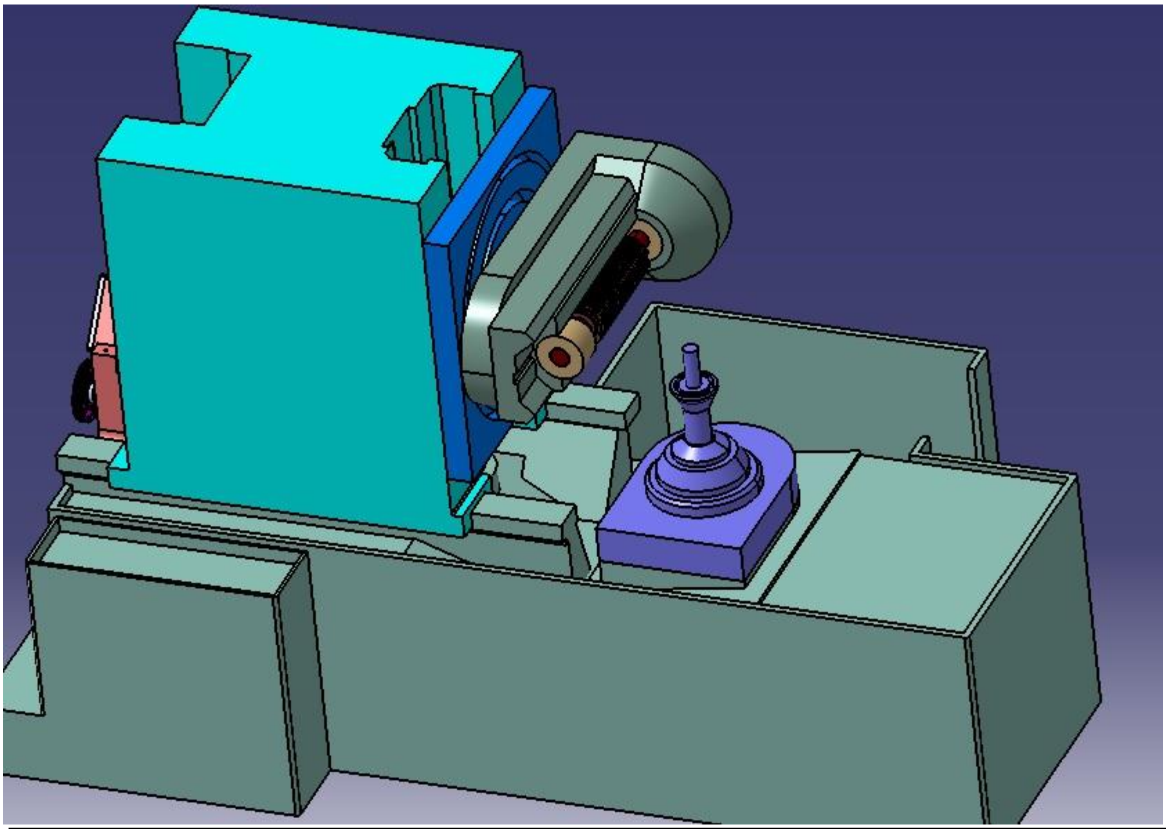


22. EXPLODED VIEW OF BEARING HOUSING ASSEMBLY

12.5 MAIN ASSEMBLY

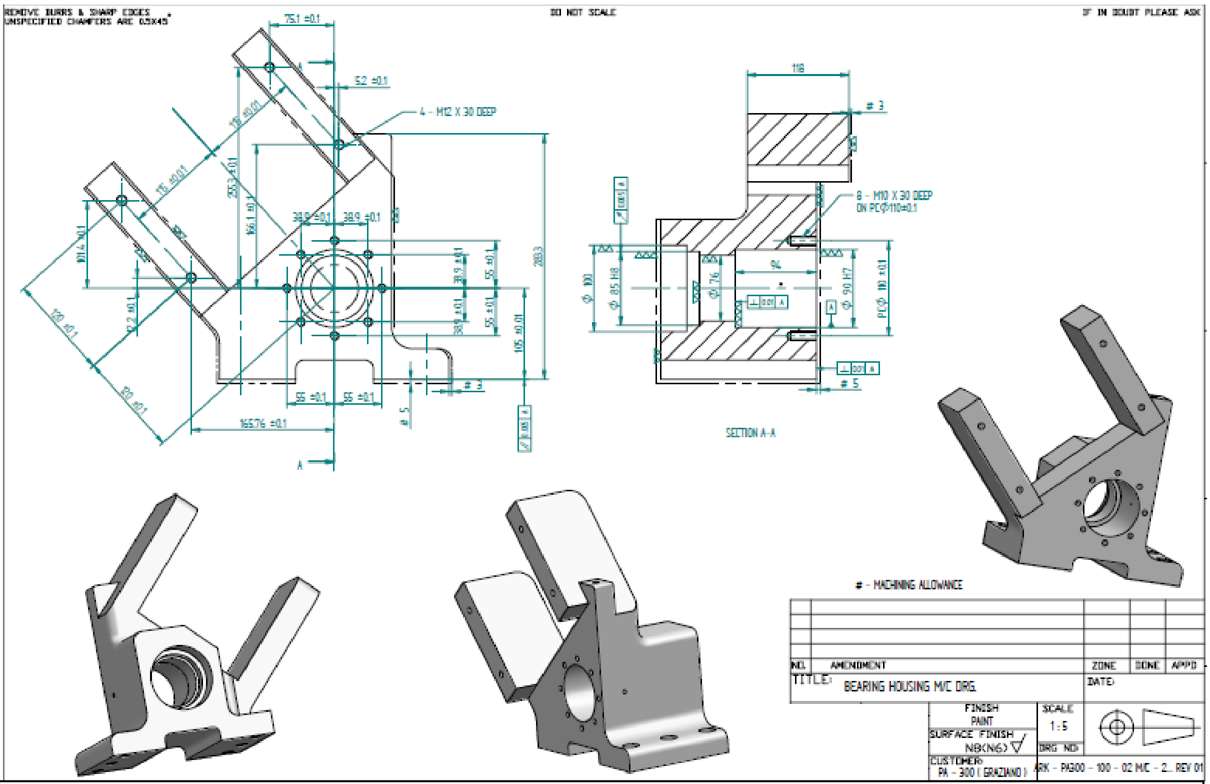


23. MODEL OF FINAL ASSEMBLY VIEW 1

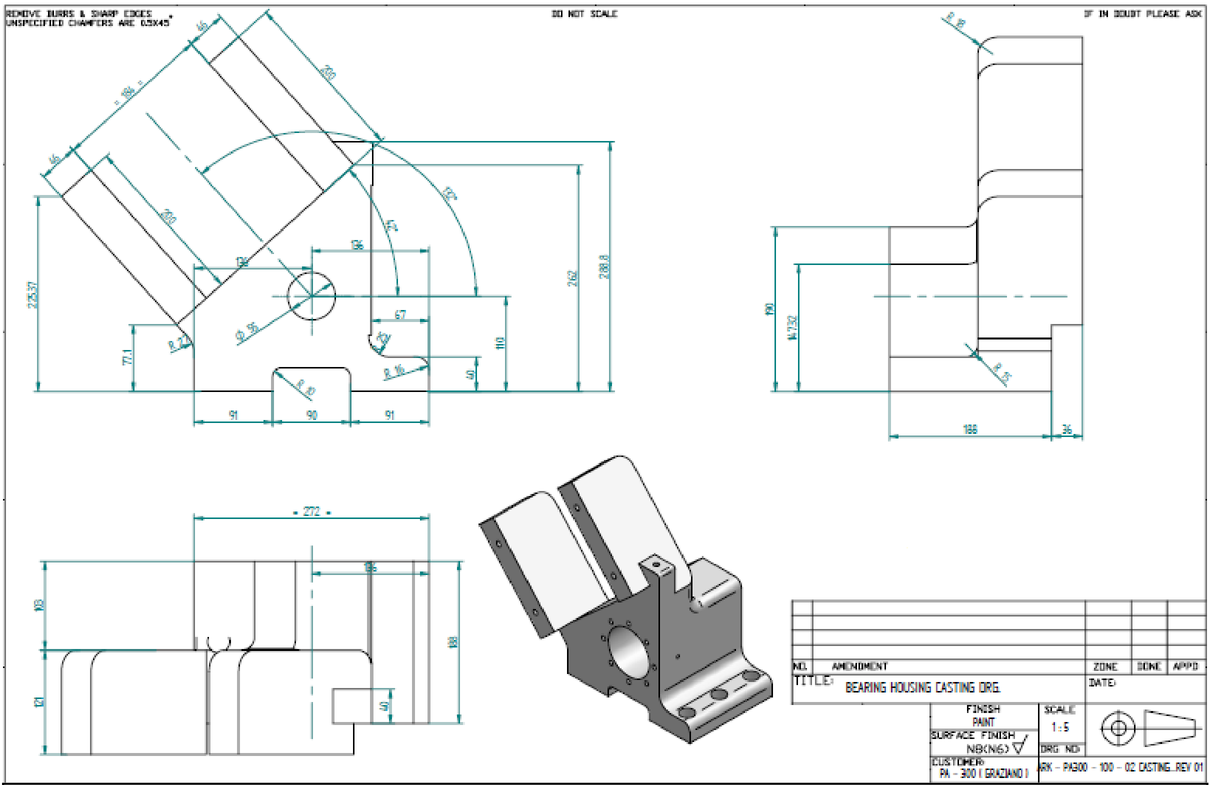


24. MODEL OF FINAL ASSEMBLY VIEW 2

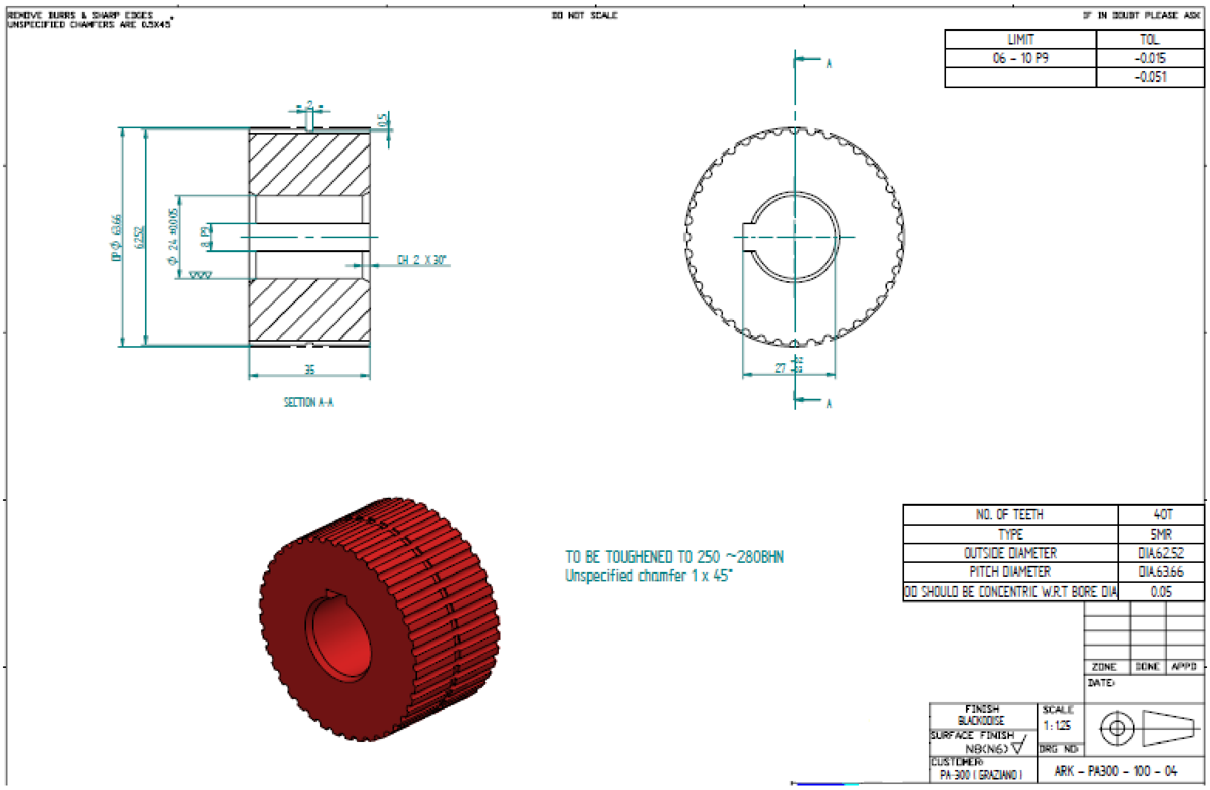
13. DESIGN DRAFTS OF PARTS:



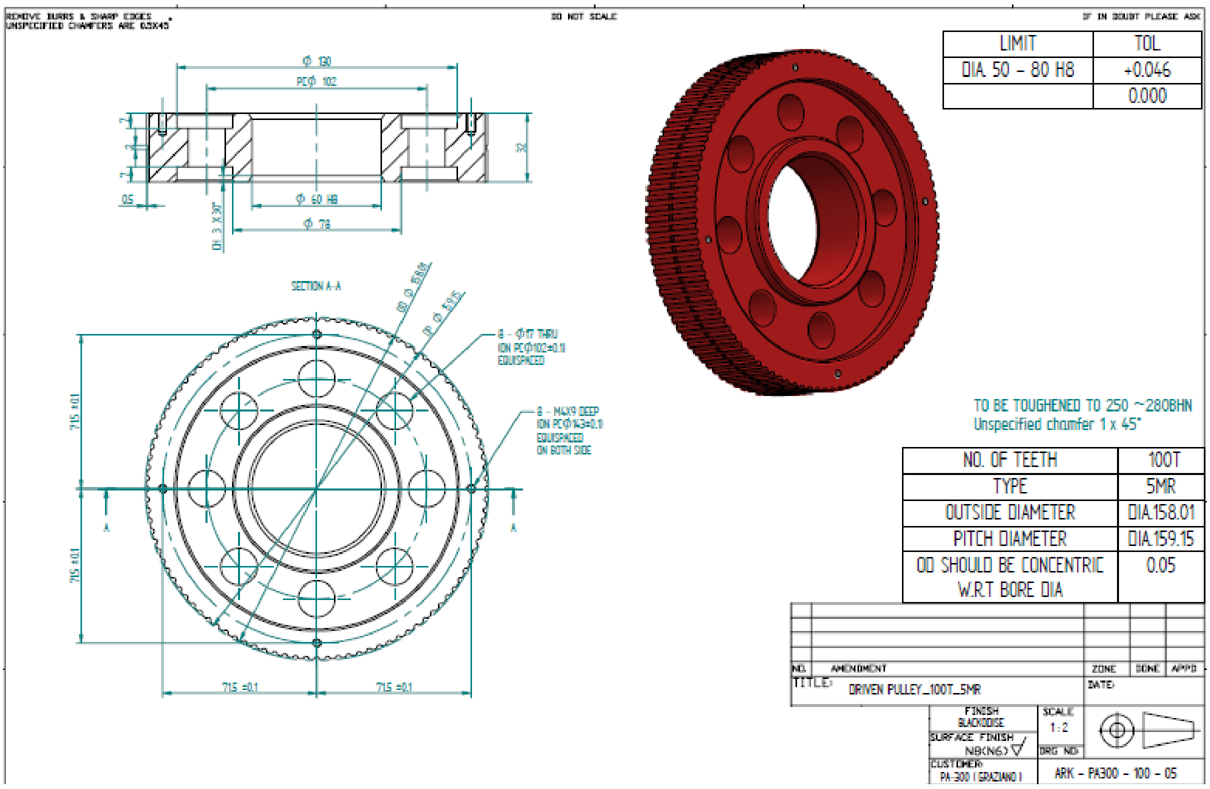
25. BEARING HOUSING VIEW 1



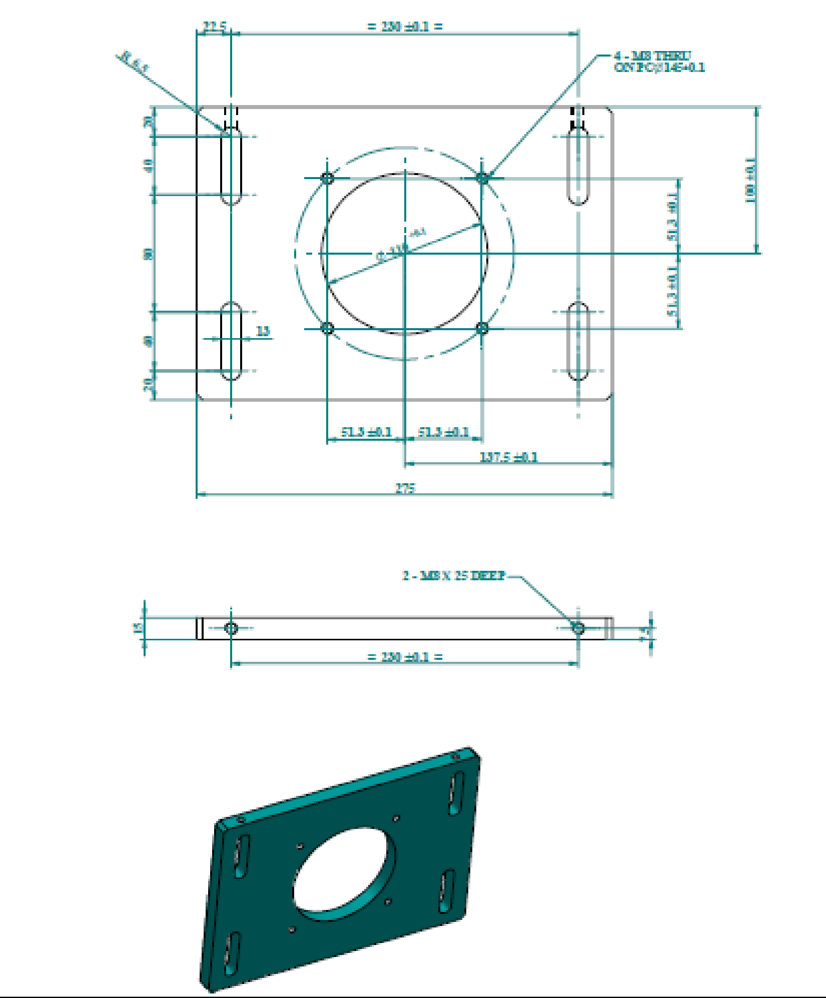
26. BEARING HOUSING VIEW 2



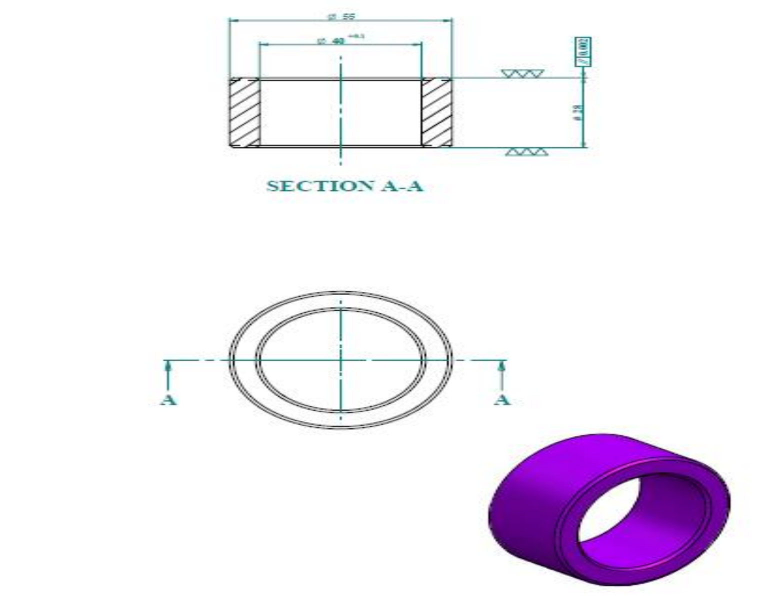
27. DRIVING PULLEY



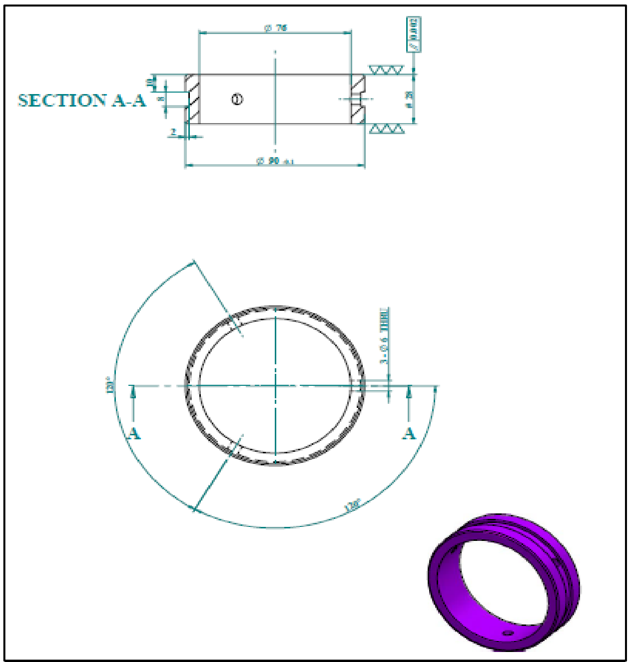
28. DRIVEN PULLEY



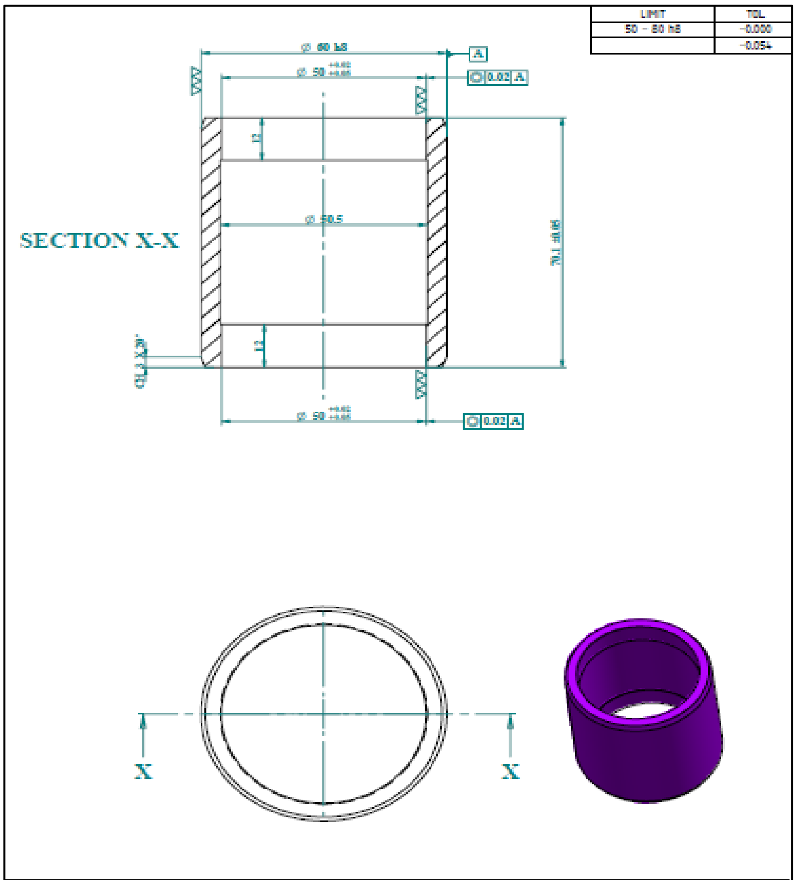
29. MOTOR MOUNT PLATE



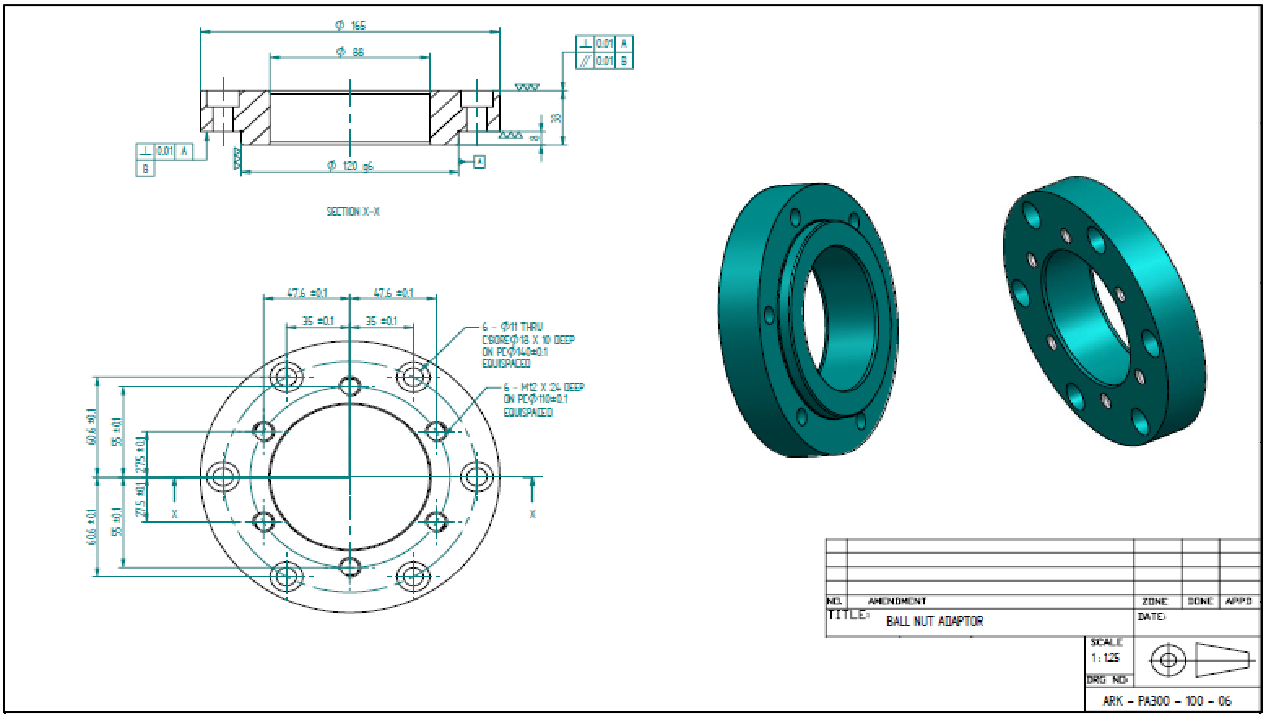
30. INNER SPACER



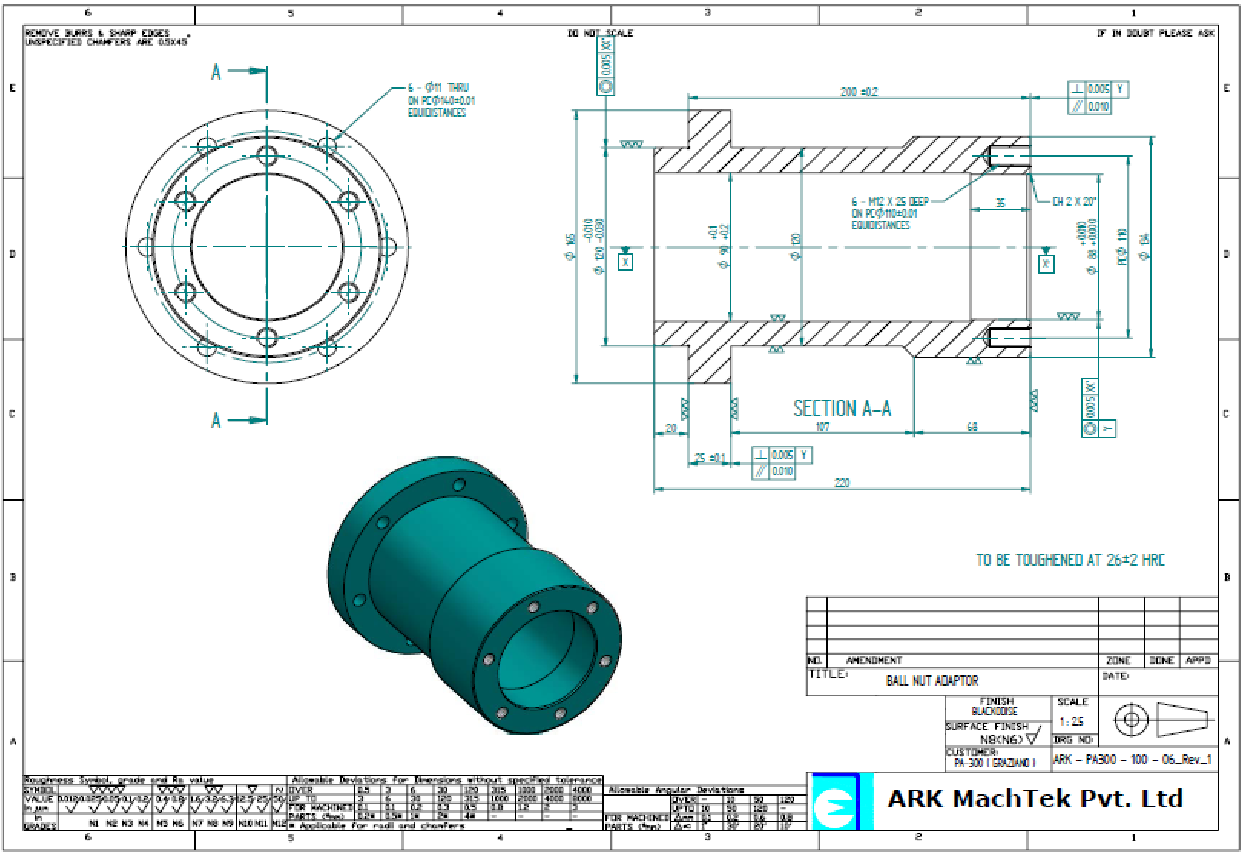
31. OUTER SPACER



32. FRONT SPACER



33. BALL NUT ADAPTER



34. ADAPTER

14. DESIGN ANALYSIS

Once we finalized the design of the bearing housing we had to carry out suitable analysis to accurately define our design. As the shaft was been outsourced, we had to carry out Modal analysis to check the Maximum frequency generated in the shaft.

14.1 Steps for calculations:

1) We have used belt type system to transmit the power from the driving pulley to the driven pulley. The driving pulley runs at 3600 rpm and transmits a rotation of 100rpm to the driven pulley. The shaft assembly is been connected with the driven pulley. Hence the entire shaft assembly rotates at 100rpm.

2) The solution provided by the software ANSYS 18.1 will be in Hertz. It provides us a range of frequency from maximum to minimum values.

So converting RPM to HZ, we get 100 rpm = 1.67Hz

3) So considering a maximum of 3000rpm, the design must be safe for a frequency of 60Hz.

Value shown in ANSYS 18.1 specifies the maximum frequency the shaft can sustain before failure.

14.2. MODAL ANALYSIS:

14.2.1 WHAT IS IT?

MODAL ANALYSIS is a simple way to calculate the natural frequencies of your system so you know which frequencies can be destructive and dangerous for it. Modal analysis calculates the natural frequencies of the system alone.

Modal is the simplest analysis and the only thing it does is telling you what are the “resonance frequencies” of your geometry. It isn’t related to a loading at this stage, only to the geometry. Resonance frequencies change due to the shape of your model and the way it is constrained only. Because generally, once you noted the dangerous natural frequencies, you actually want to know: If I excite my model at this dangerous frequency, how much deformation will I really get.

This is done use other types of analysis called Time Response Dynamic Analysis.

14.2.2 Difference between static and dynamic analysis:

- Static analysis means that we are making the assumption that the system we are simulating doesn’t depend on time.

- Whatever the time period we observe the system, it will remain always the same.

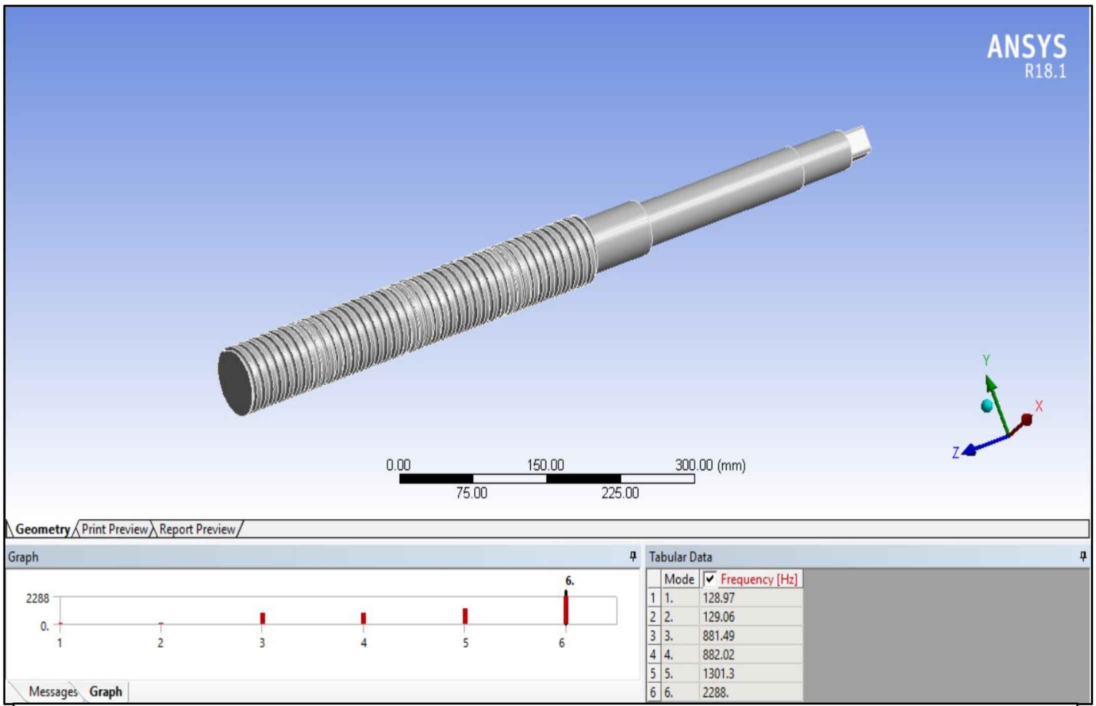
It implies of course that the loads and boundary conditions don’t depend on time either.

- In reality, this is a hypothesis, because every load has to be applied from a time t=0 sec. To take that in account, in static analysis, we just say that the load is applied infinitely slowly so there is no discontinuity during the load application.

- We can only do static analysis in certain cases where we can effectively do the assumption that the model can be considered as static.

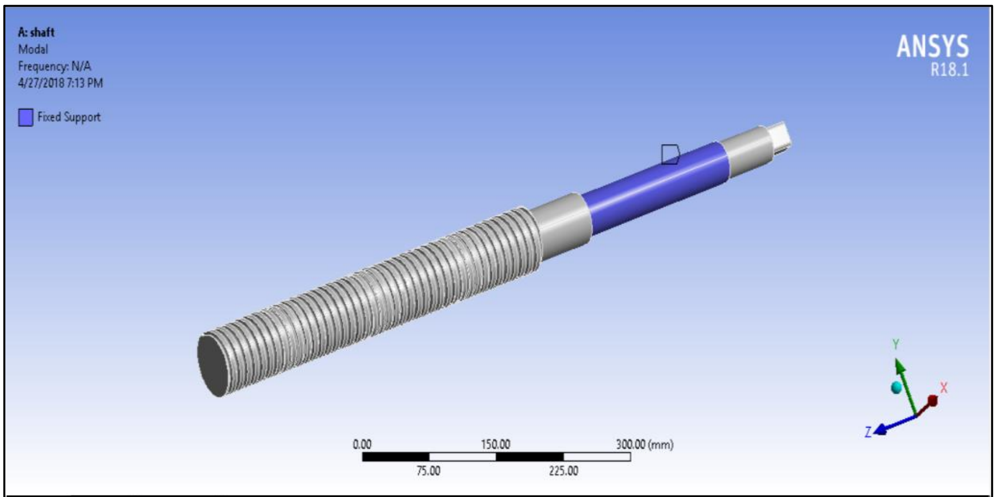
There are cases in which the loading itself (or the system) is dynamic and thus we have to perform a dynamic analysis.

14.2.3 Analysis results:



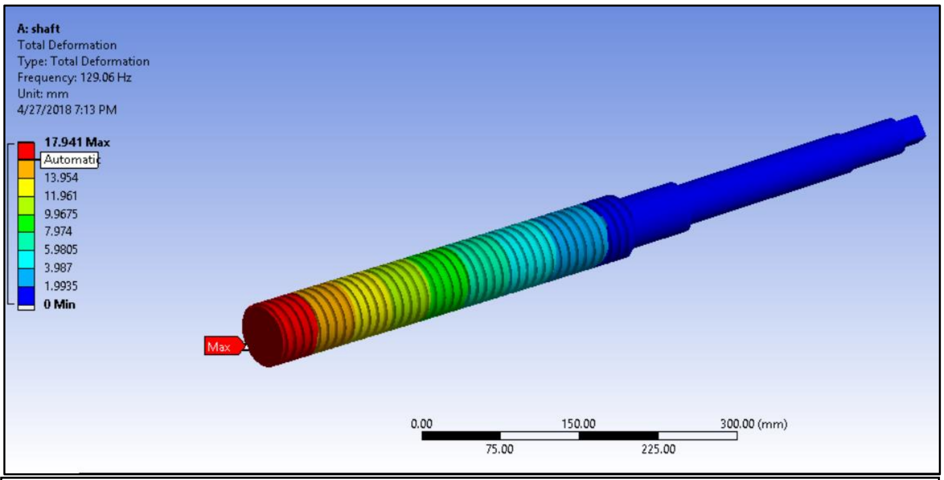
35. SCREW SHAFT GEOMETRY

After calling the geometry in ANSYS we define various boundary conditions. Here we had to define the fixed part of the shaft.

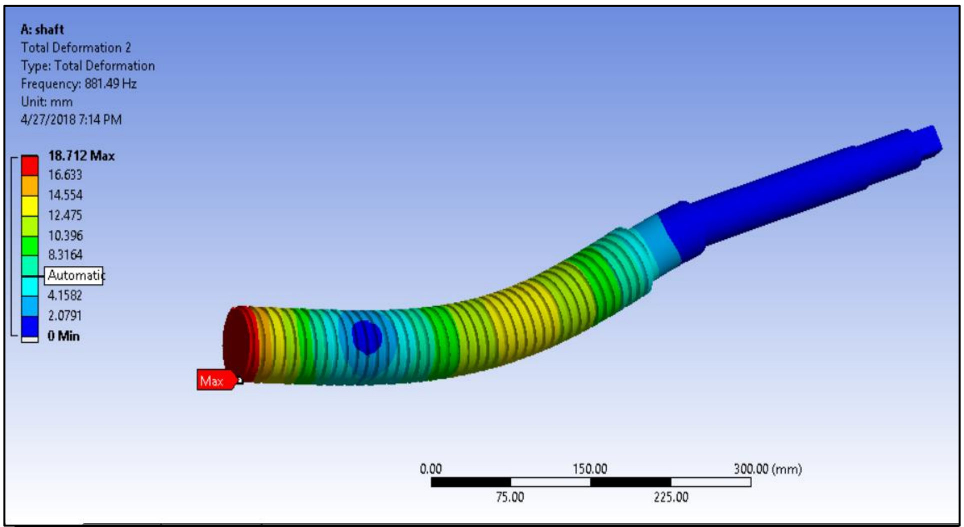


36. BOUNDARY CONDITIONS

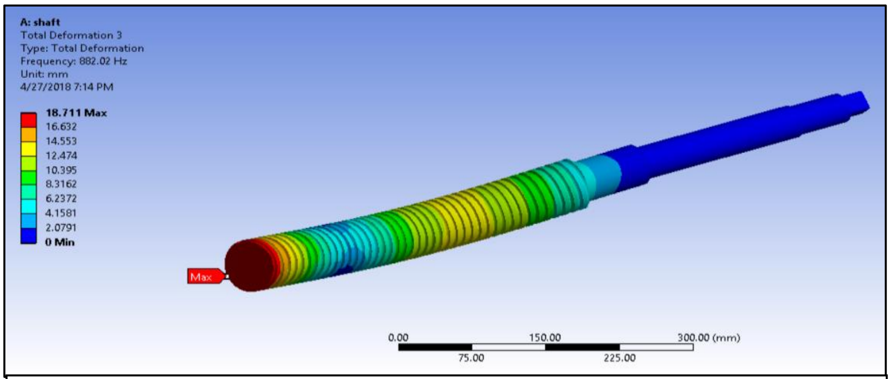
Here the highlighted portion is the fixed support. This part is been fixed into the bearing housing. Later we carried of 5 modes of frequency over the shaft design.



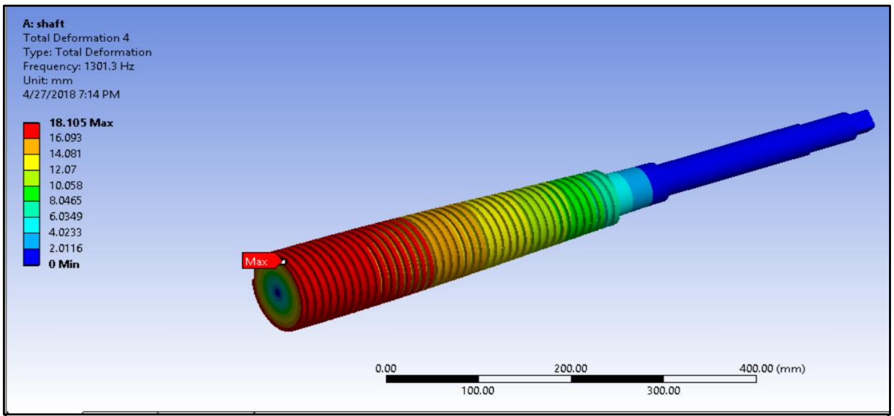
37. MODE 1



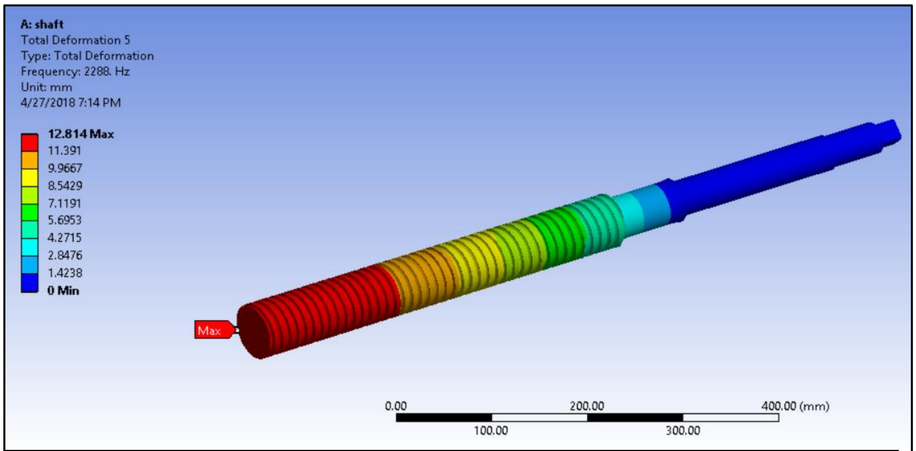
38. MODE 2



39. MODE 3



40. MODE 4



41. MODE 5

Tabular Data

	Mode	Frequency [Hz]
1	1.	128.97
2	2.	129.06
3	3.	881.49
4	4.	882.02
5	5.	1301.3
6	6.	2288.

42. FREQUENCY TABLE

The above table represents the frequency data from minimum to maximum considered. From these results we can conclude the for a speed of 100rpm the shaft is safe without maximum Deformation or stress generated.

14.3 STATIC STRUCTURAL ANALYSIS OF SHAFT ASSEMBLY

14.3.1 WHAT IS IT?

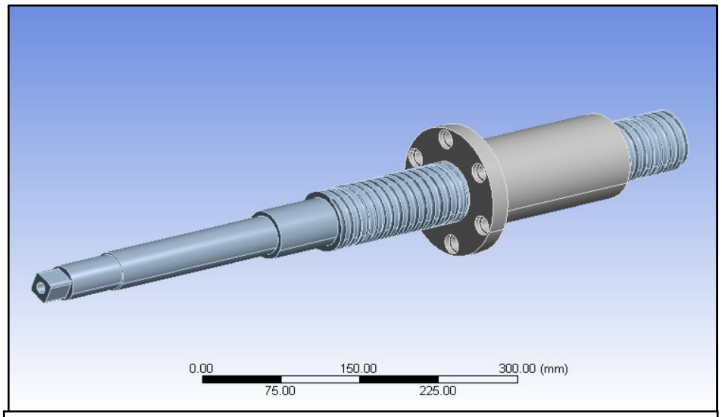
Structural analysis is mainly concerned with finding out the behavior of a physical structure when subjected to force. This action can be in the form of load due to the weight of things such as people, furniture, wind, snow, etc. or some other kind of excitation such as an earthquake, shaking of the ground due to a blast nearby, etc. In essence all these loads are dynamic, including the self-weight of the structure because at some point in time these loads were not there. The distinction is made between the dynamic and the static analysis on the basis of whether the applied action has enough acceleration in comparison to the structure's natural frequency.

A static load is one which varies very slowly. A dynamic load is one which changes with time fairly quickly in comparison to the structure's natural frequency. If it changes slowly, the structure's response may be determined with static analysis, but if it varies quickly (relative to the structure's ability to respond), the response must be determined with a dynamic analysis.

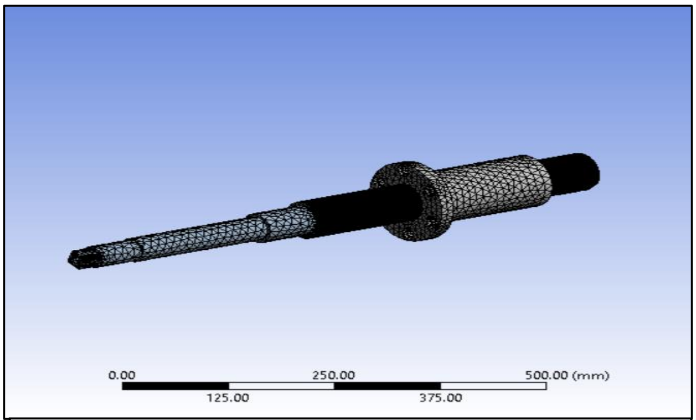
After modal analysis we decided to carry out the static analysis of the shaft assembly to determine is FOS and Life. First we calculated the forces acting over the shaft. Later we generated a suitable mesh over the Geometry. Material used was EN9 with 22 HRC(790MPa)

Allowable stress= 790MPA

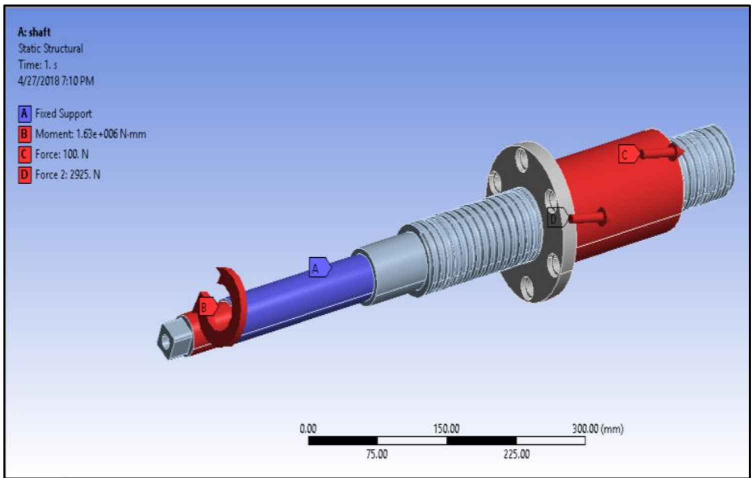
14.3.2 <u>Analysis Steps:</u>



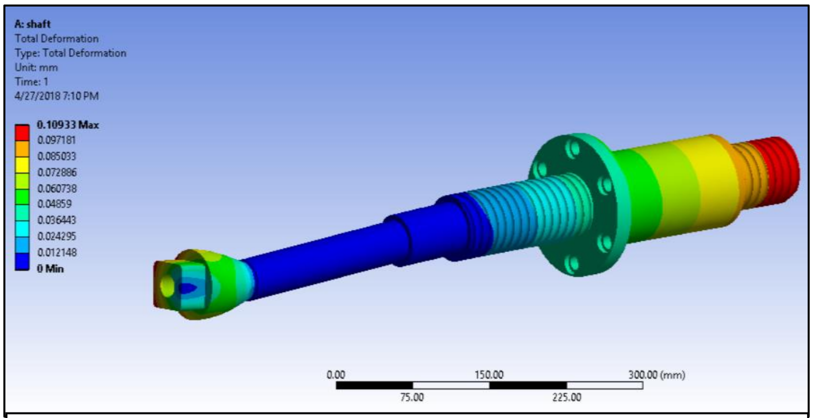
43. SHAFT-NUT ASSEMBLY MODEL



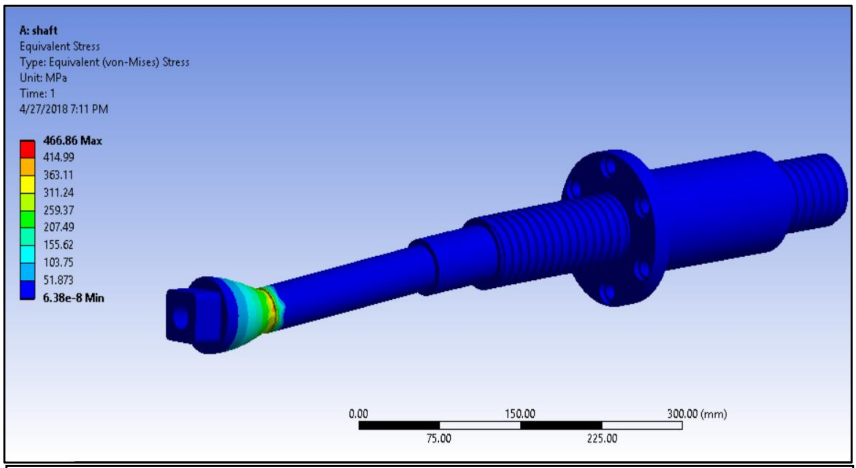
44. MESHED STRUCTURE



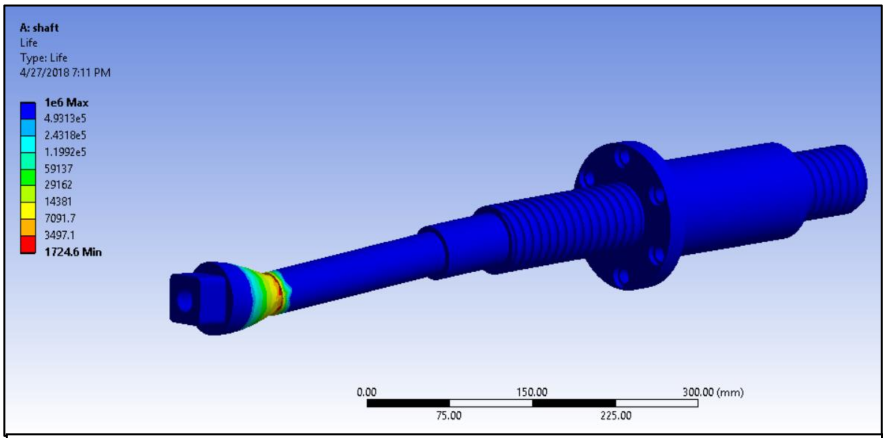
45. BOUNDARY CONDITIONS



46. DEFORMATION RESULT



47. STRESS DISTRIBUTION



48. LIFE EXPECTANCY

14.3.3 RESULTS:

Hence following results were generated from the above analysis:

Maximum Stress: 467MPa

Deformation: 0.19mm

Life: 10^6 cycles

FOS= allowable stress/maximum stress

= 790/467

=1.67

Hence our design is considered to be safe as the generated FOS is 1.67 > 1.5

15. MACHINING PROCESS & DESIGN VALIDATION

15.1 MANUFACTURING PROCESS

- Ball screw and bearings

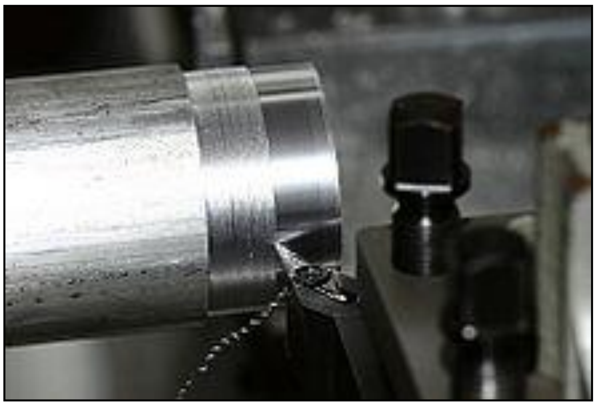
The ball screw and bearings were been procured from outside suppliers. We got our ball screw constructed according the needs of the bearing housing.

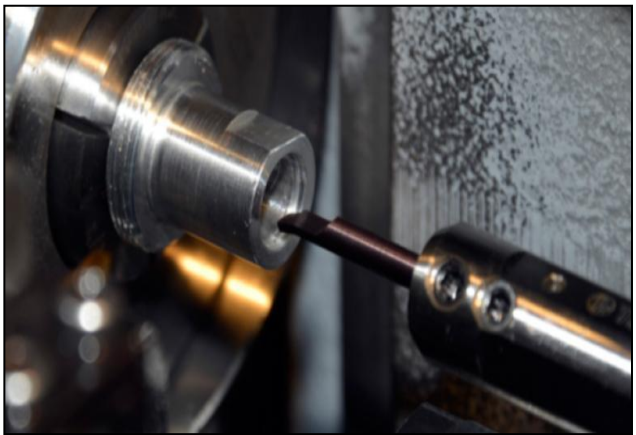
- Bearing housing

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)



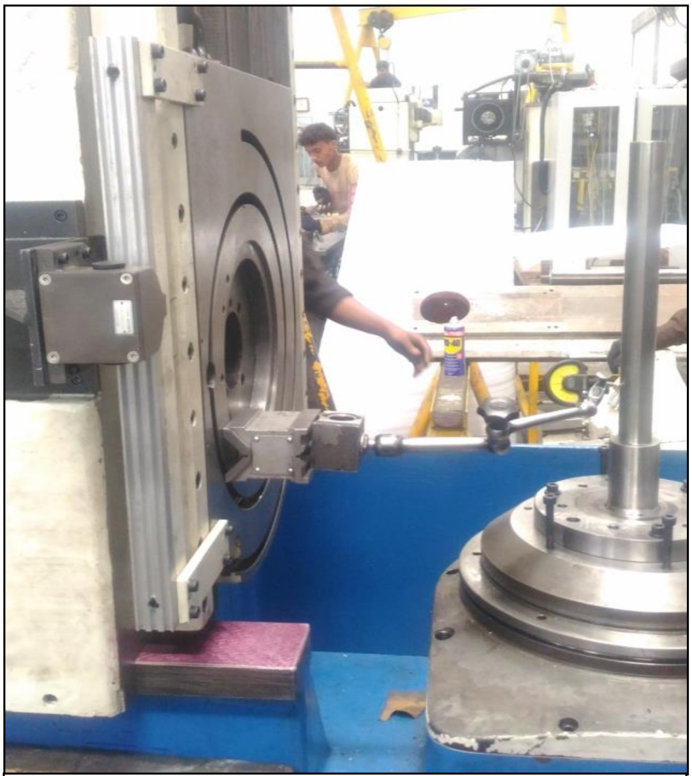


49. MACHINING OF SUB-PARTS

50. MACHINED BEARING HOUSING

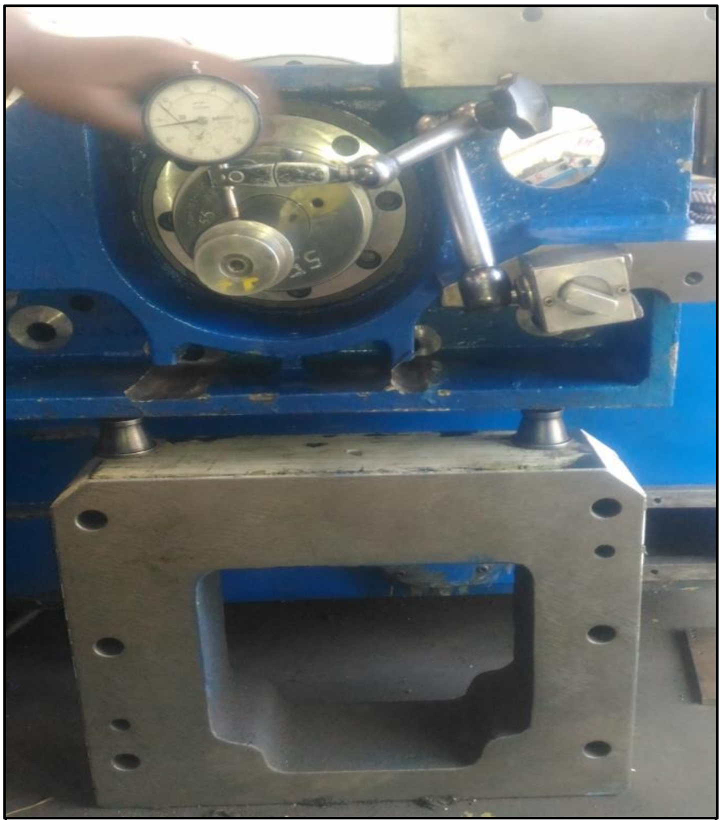
- **DESIGN VALIDATION**

51. CHECKING FOR STROKE LENGTH



52. CHECKING FOR PARALLELISM

53. SURFACE FLATNESS FOR HOB HEAD



54. CHECKING FOR SHAFT MOVEMENT

15.2 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 guide way 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:

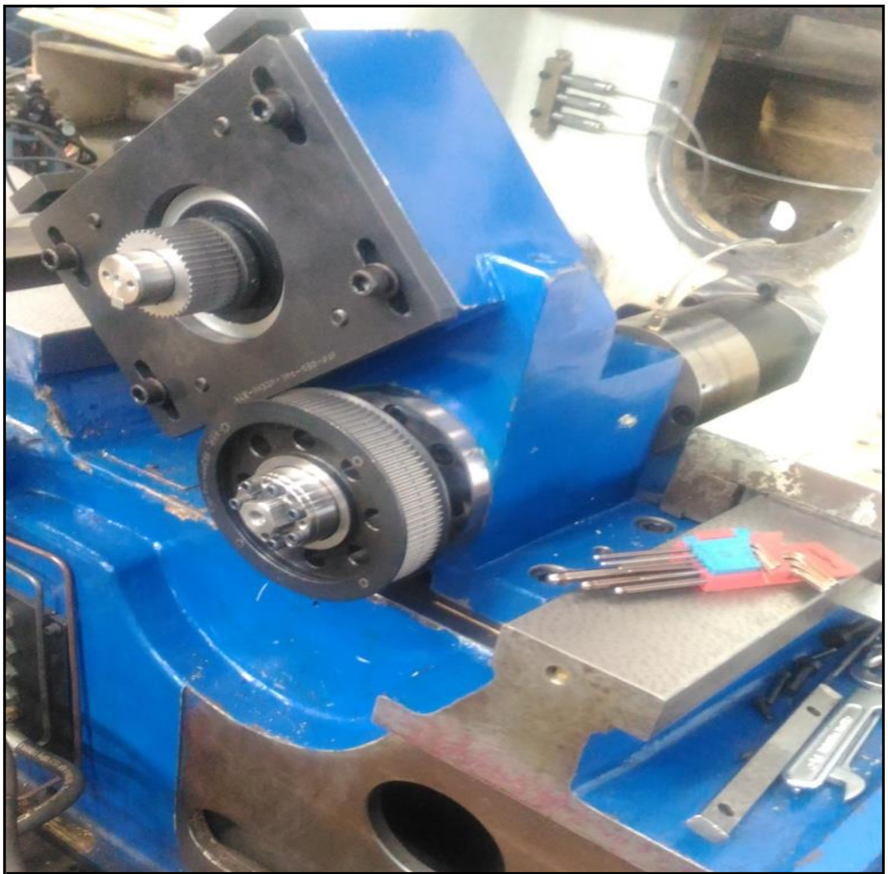
Lapping is a machining process in which two surfaces are rubbed together with an abrasive between them, by hand movement or using a machine. After scrapping we carried out the lapping process. This process was carried out by an outer source dealer.

- 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 10micron.

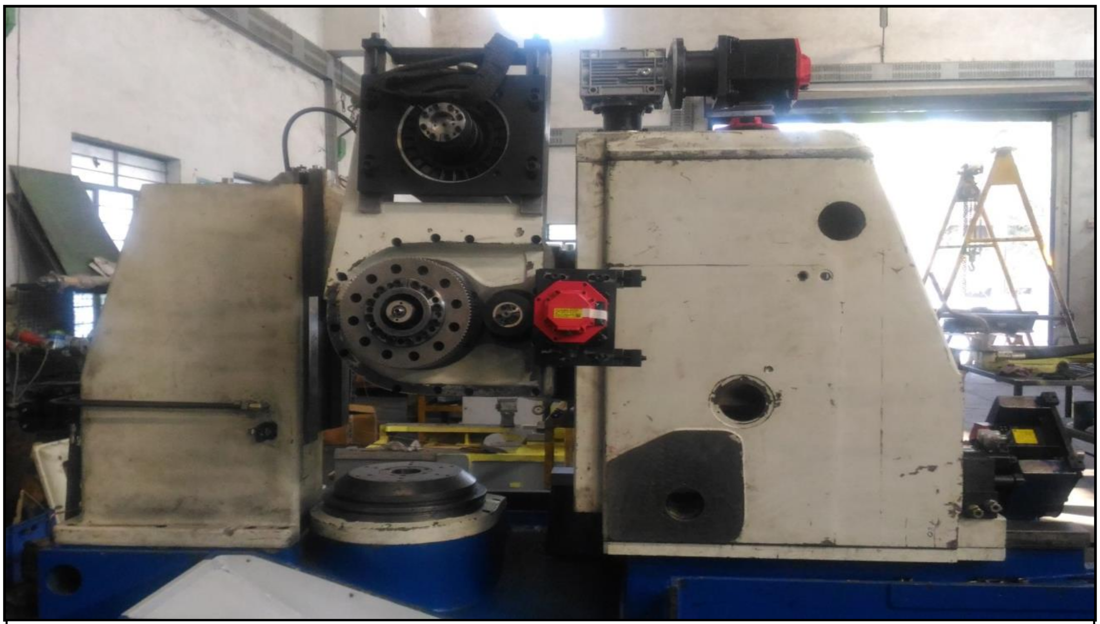
- Later we place the ball screw structure within the column. We place the tip of the dial indicator on the top surface of the screw system. We rotate the shaft to check for any errors. The reading should be less than 10micron for accuracy. This helps to maintain the accuracy and check the surface flatness of the bed.

15.3 FINAL ASSEMBLY

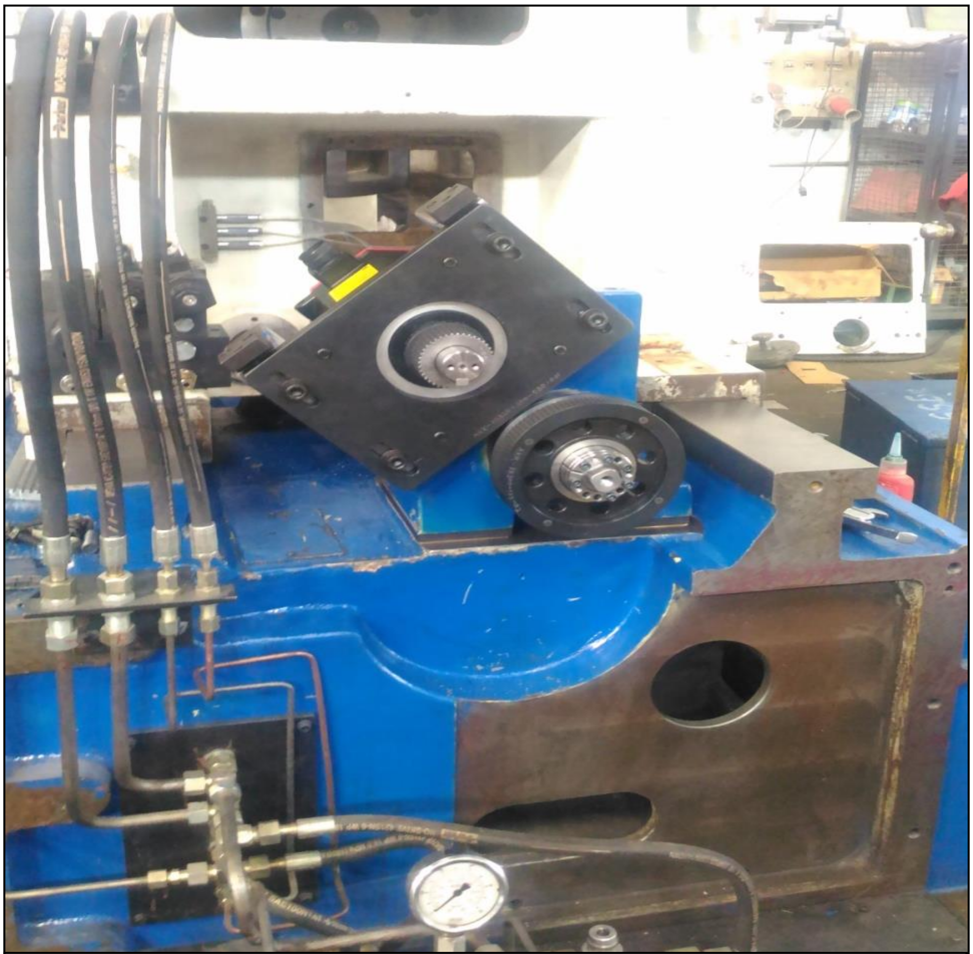
- After the alignment process, we mount the bearing housing. We insert the bearings and spacer into the structure. Preloading caps are been mounted such as to preload the bearings and eradicate the back lash error. The balls in the nut structure is filled with grease and closed with a seal. Seal protects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



55. FINAL RADIAL FEED



56. SIDE VIEW OF PA320 GEAR HOBBING MACHINE



57. FRONT VIEW OF PA320 GEAR HOBBING MACHINE

16. COST ANALYSIS

Sr. no.	Material	Cost
1)	Ball screw system	Rs. 65,000
2)	Material Cost	Rs. 10,000
3)	Manufacturing Cost	Rs. 6000
4)	Bearings	Rs. 2000
5)	Labour	Rs. 5000
6)	Misclleanous	Rs. 3000
	Total	Rs. 91,200

17. **CONCLUSION**

Thus to achieve a higher mechanical efficiency and low wear and tear, a Recirculating ball screw system is been used in a Gear hobbing Machine. We turned this conventional hobbing machine to a CNC gear hobbing machine. Hence we have achieved and successfully developed a highly optimized, backlash error free CNC hobbing machine which will provide greater accuracy as compared to the conventional system.

18. FUTURE SCOPE

We can design Radial feeds for various types of Gear hobbing machine. Conventional Gear hobbing machine can be easily converted into a CNC gear hobbing machine without any major investments. Buying a new gear hobbing machine will cost the company a fortune rather than upgrading the conventional gear hobbing machine to a CNC gear hobbing machine. The rate of work and accuracy is similar to that of a new CNC gear hobbing machine. Instead of throwing a whole bunch of machines into scrap, we can upgrade and reuse them to the fullest. There is High scope for FANUC coding and additional features to upgrade into a CNC gear hobbing machine. Use of microcontrollers and various electronic devices is greatly helping the machine to match with the accuracy found in new varients of CNC gear hobbing machine.

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