Ball Bearing

ME 338 S4 Course Project
Manufacturing Processes II
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Description

Description

A ball bearing is a rolling element that uses balls to separate the bearing rings

It serves 3 primary functions : 1) Carries radial and axial loads, 2) Reduces rotational friction and 3) Positions moving machine parts

The main principle of ball-bearing is that the rotation of the balls causes a reduced coefficient of friction compared with flat surfaces rubbing against each other.

A ball bearing consists of an inner ring (IR), an outer ring (OR), a complement of balls, and a separator to contain the balls. The outer surface of the inner ring and the inner surface of the outer ring have a groove on which the balls roll on. This groove is commonly called the pathway.

In most applications, one bearing ring is stationary and the other is attached to the rotating assembly (e.g., a hub or shaft).

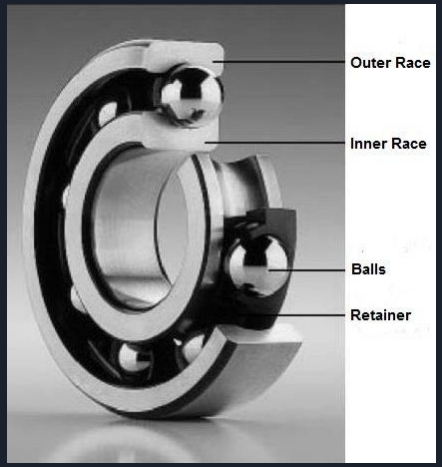


Fig 1: Ball Bearing Cross-section

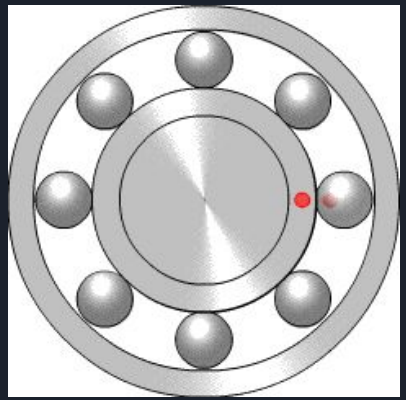


Fig 2: Ball Bearing

Applications

Applications

01: Cycle wheels

02: Automobile Transmission

From day-to-day use to the use in heavy machineries we can see huge numerous applications of ball bearings.

Primarily the ball bearings are used to support the rotating shafts in mechanical instruments.

However, it also serves to reduce the friction and thus the wear and tear caused by it.

Modified and modern bearings are also able to support a significant amount of load.

Examples of its application: Steerings, Engines, Washing machines, Sewing machines, Fans, Transmissions, Bi-cycles, etc.

Components

Components

A typical ball bearing has mainly 4 components:

- Inner and Outer Rings
- Retainer
- Balls
- Shield and seals

Rings (Inner & Outer)

Representation Image

- The bearing ring on the inside, into which the shaft is inserted, is called the inner ring.
- The one on the outside is called the outer ring and is inserted into the housing.
- The inner and outer rings support a force applied perpendicularly to the shaft and are typically made from high-purity, chrome alloy steel.
- This material has the necessary hardness and purity, essential factors for high load ratings and long service life.

Cage (Retainer)

Cage design for Deep Groove Ball Bearings

- Responsible for keeping the rolling elements separated while guiding them in motion.
- Prevents the rolling elements from falling out when a bearing ring is removed during mounting or dismounting.
- Maintains a constant spacing for optimized load distribution
- Reduces friction
- Accurately guides the rolling elements in the path during rotation

Balls, Shields and Seals

Image courtesy: Google

- Balls: A rolling elements, roll on raceways of the rings, separated and guided by the Cage and permit the bearing to rotate with minimal friction
- Shields: They are used where relatively clean operating conditions or low friction are essential because of speed or operating temperature considerations. This results in a bearing that has very low torque.
- Seals: Where contamination is moderate and where the presence of water or moisture cannot be ruled out, contact seals are typically used.

Design

Design Objectives

Fundamental idea of designing a ball bearing is to provide support to rotating shafts without bringing any hindrance to its working. The design objectives of a common ball bearings are:

- Ball bearing should sustain axial and radial load at the place of application
- It should have acceptable amount of friction
- Long bearing life
- It should not be sensitive to change in temperature (lower coefficient of thermal expansion)

These objectives can be achieved by designing and choosing proper dimensions, materials and manufacturing process. As the design not only focuses on the ball bearing but also the optimization of the process.

Design Parameters

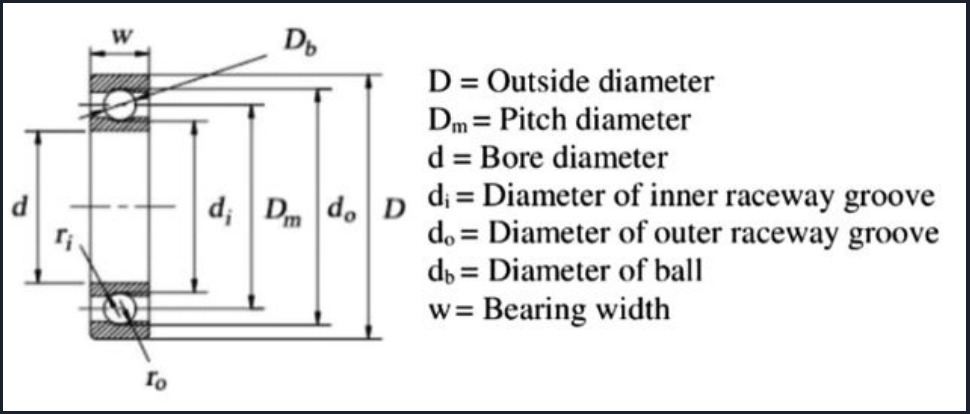


Fig 1. Design Parameters

D = **1.6535 in (42 mm)**
d = **0.7874 in (20 mm)**
do= 0.74 in (18.8 mm)
w = **0.4724 in (12 mm)**
Dm= 1.22 in (31 mm)
di = 0.49 in (12.45 mm)
db= 0.24 in (6.1 mm)
Z = **9**

Calculating Basic Load Rating:

$$C = f_c(i\cos\alpha)^{0.7} Z^{\frac{2}{3}} D^{1.8}$$

Where C = basic load rating (lbs)
i = number of rows of balls in the bearing (1 in our case)
α = nominal contact angle, degrees (0 degrees in our case)
Z = number of balls in a single row = 9
D = ball diameter (in) = 0.24
f_c = geometry factor of bearing = 4550 in

For f_c, we have to calculate $D\cos\alpha/d_m$, where d_m is the mean diameter of the inner and outer ring
$D\cos\alpha/d_m$ = 0.24/1.22047 = 0.19665
For our ball bearing, f_c = 4550 in

Putting values to get C = 1508.6 Lbf
This is an average of dynamic load capacity and static load capacity.

For our product:
Dynamic load capacity: 2,110 lb
Static load capacity: 1,140 lb
Max. RPM: 18,000 RPM

Materials

Rings (Inner & Outer)

Representation Image

- The bearing rings are subjected to repetitive high pressure with a small amount of sliding. Therefore, the materials used for rings require the following characteristics:
  - High strength against rolling contact fatigue due to large repetitive contact load
  - High hardness
  - High wear resistance
  - High dimensional stability
  - High mechanical strength
- The standard steel for bearing rings and rolling elements are AISI 52100, steel containing approximately 1% carbon and 1.5% chromium.
- Unique materials such as ceramic and plastics are also used for production. Although plastics cannot withstand extremely high temperatures, they are considerably lighter than steel, making them invaluable in the automotive industry, where every ounce matters.

Cage (Retainer)

Cage design for Deep Groove Ball Bearings

- In practice there are various materials which are used to Manufacture cages. Including both non-metals **(PTFE**, **PEEK**, or **PVDF)** and metals **(SPCC, SPHC, SPB 2).**
- In this project we have considered SPHC steel sheets.
- This choice gives us to manufacture completely metallic ball bearing.
- Other benefits of this choice is its low price and suitable material properties.

Balls, Shields and Seals



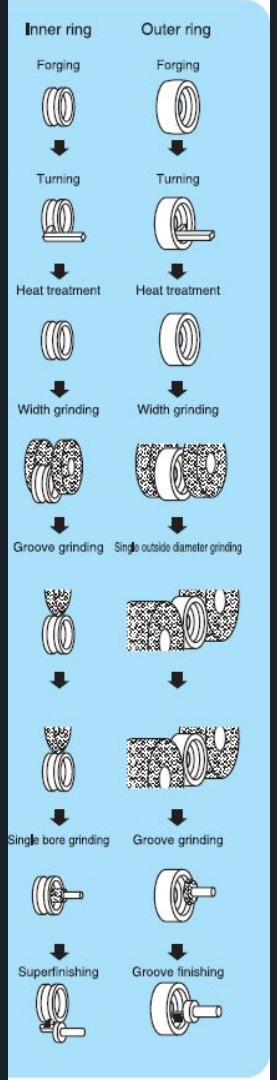
Image courtesy: Google

- Balls: Bearing Balls are also commonly manufactured from AISI 52100 steel (Same as Rings)
- Shields: Made from AISI 304 stainless steel
- Seals: The standard seal consists of nitrile/BUNA-N rubber bonded to a metal washer

Manufacturing Process & Assembly

Inner/Outer Ring Manufacturing

I. Forging: The steel bar is first heated then cut. It is then pressed by machine and molded into inner and outer ring shapes.
II. Turning: Automatic machines similar to lathes use cutting tools to cut the basic shape of the race, leaving all of the dimensions slightly too large.
III. Heat Treatment: Involves Quenching (to 800-860℃), Cooling and Tempering (1450-2000℃) to improve the hardness and wear resistance of the rings.
IV. Grinding: This makes the bearing ring be following the design requirements in quality, dimension, size and shape precision, thus qualifying it for the assembly stage. The rings are fully smoothened in this stage and cut to specific dimensions.



Cage Manufacturing

01. Firstly, a circular disk is punched out from the desirably thick steel sheet leaving holes in it. Then again, the sheet is punched around the previously punched holes. This gives us a circular ring which we have to process further.

Fig 1: Punched Sheet

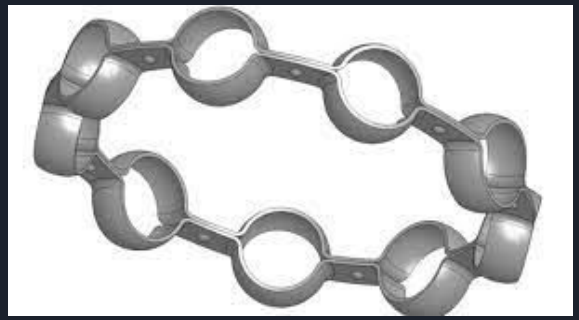
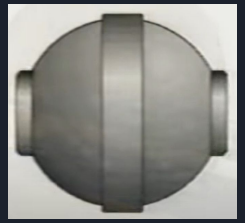
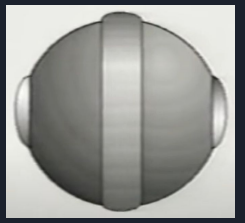


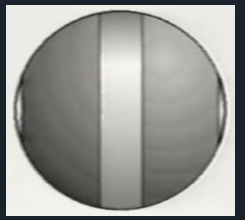
Fig 2: Forged Cage (coupled)

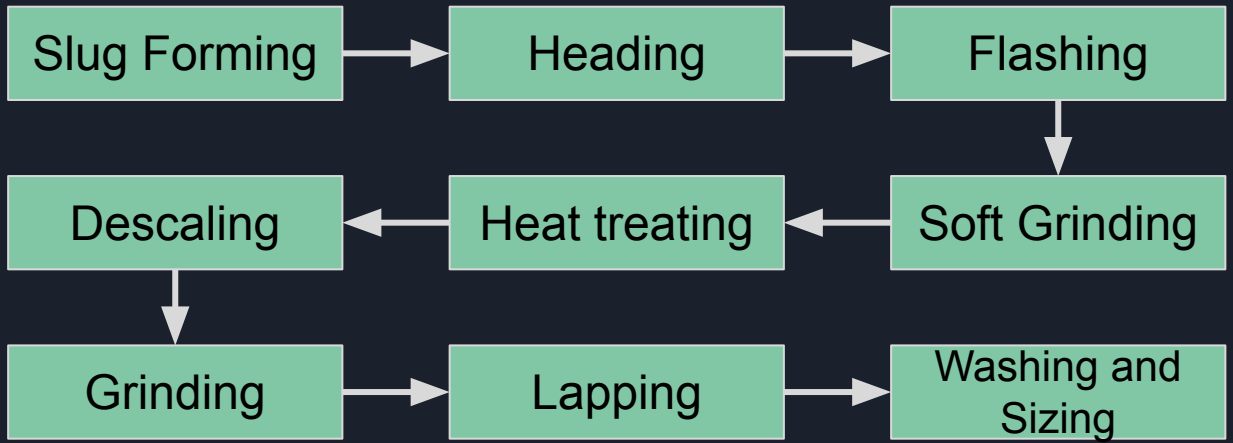
02. Then these rings are placed into the die. These die bend the ring so that it creates a semi-circular room where balls can be placed. Also, these die to make holes for the rivets. Once this is done, we have half part of the steel cage. Once a pair is ready for such parts, then it can be sent to be assembled in the ball bearings as a cage.

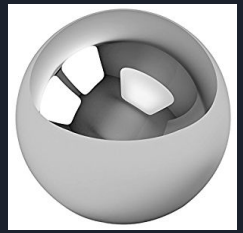
Ball Manufacturing and Finishing

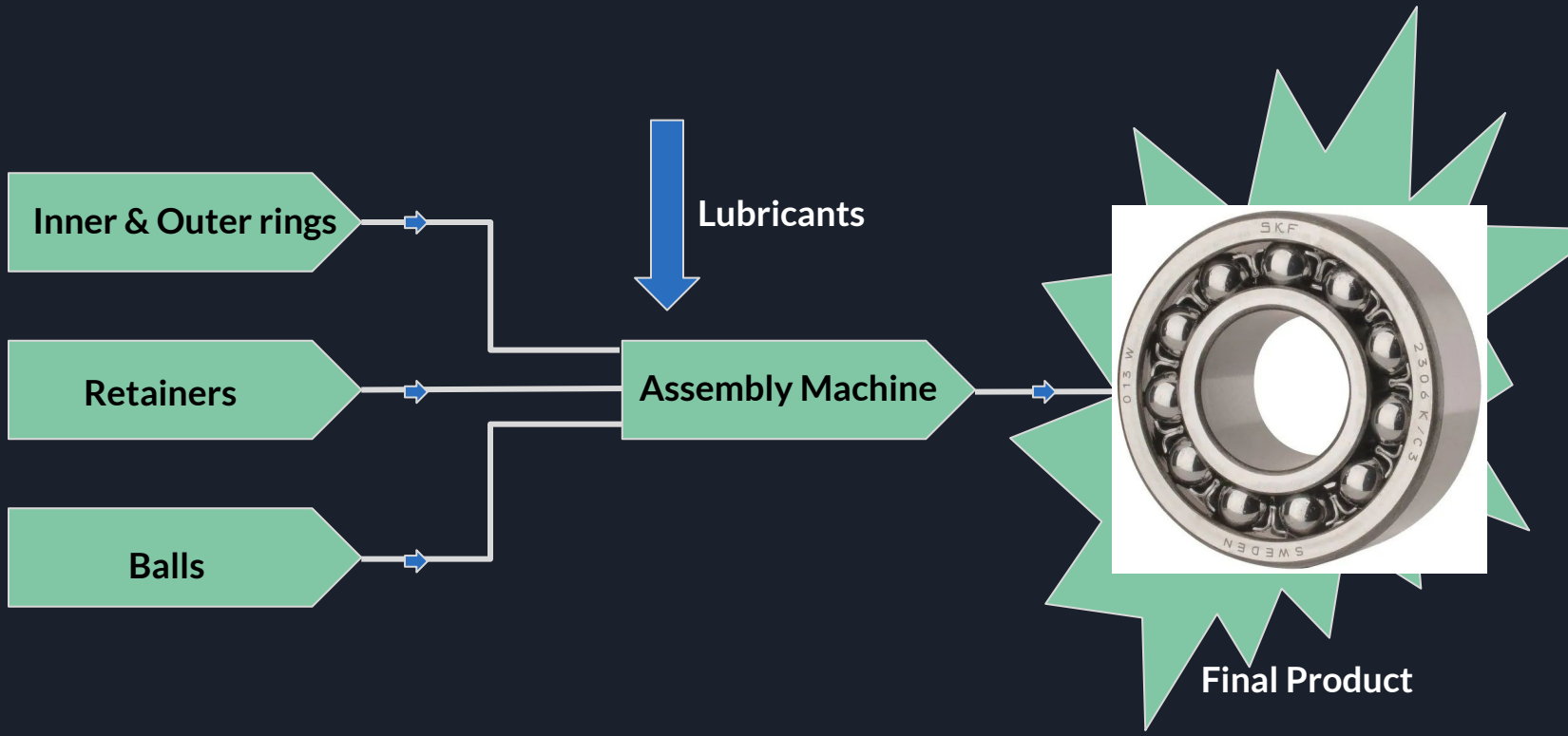
Balls start as a wire or rod slug containing the proper amount of material required in the finished ball and then it goes 9 different processes. The dimension of the rolling elements is made slightly smaller than the track on the inner and outer rings. Rolling element dimensions are controlled to very high accuracy. Surface finish and size variations are important attributes. These attributes are controlled to a micro inch level.





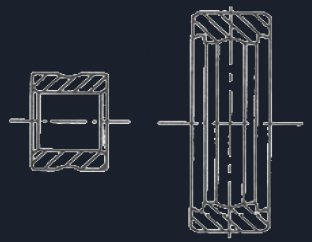



Assembly


Inner & Outer rings
Retainers
Balls
Lubricants
Assembly Machine
Final Product

Assembly operations:

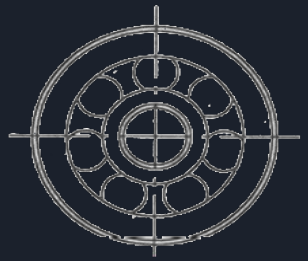
1 Pair suitable inner and outer rings



2 Assemble the balls inside the rings

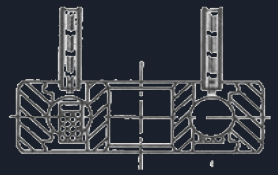
3 Recentre the inner ring

4 Spread the balls out evenly

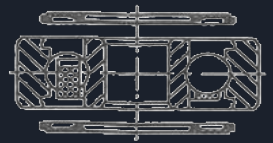


5 Assemble the cage over the balls

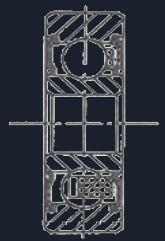
6 Add grease



7 Fit the shields or seals



8 Final quality control



Finishing & Coatings

Cleaning:

The components are cleaned in multiple process steps before coating:

- Ultrasonic cleaning
- Degreasing
- Vacuum drying
- Plasma cleaning

Lubrication:

- To reduce rolling friction and wear
- Protection of bearing surface against corrosion
- Preventing the entry and removal of foreign particles (contaminants)
- A lubricating film is preventing direct rolling contact (dry running)
- The lubricant has a significant influence on the reliability of a bearing
- Makes deep groove ball bearings maintenance-free for many applications
- Materials used: **Synthetic oils, Greases, Dry films**

Coating Materials:

Various high-purity materials are used as adhesive or functional layers depending upon the area of application:

- Silver (Ag)
- Lead (Pb)
- Gold (Au)
- Molybdenum disulfide (MoS_2)

Applying specific coatings such as silver plating, DLC and anodising, to protect metallic cages made from steel, aluminium or titanium to rolling elements and raceways can also reduce wear and friction.

Grease life in shielded/sealed ball bearing:

Grease life can be estimated by the following equation when a single-row deep groove ball bearing is filled with grease and sealed with shields or seals.

$$\log L = 6.10 - 4.40 \times 10^{-6} d_m n - 3.125\left(\frac{P_r}{C_r} - 0.04\right) - (0.021 - 1.80 \times 10^{-8} d_m n)T$$

L : grease life (hr)

d_m : $\frac{D+d}{2} = \frac{42+20}{2} = 31$ mm

where D: outside diameter; d: bore diameter (mm)

n : rotational speed (min^{-1}) (max speed = 18000 RPM)

P_r : dynamic equivalent radial load (N)

C_r : basic dynamic radial load rating (N) = 9385.7 N

T : operating temperature of bearing (°C)

Now depending on the application of ball bearing, we can know the values of P_r , n and T. So we can find the value of L.

Machines & Equipments

Punching Machine

Used in making thin rings for cages

Hot ring rolling Machine

Used in forging and rolling of inner and outer rings, forging of cage rings

Quenching and Tempering Equipment

Used for the Rings in the Quenching and Tempering process

CNC Machine

Required for the turning process in the manufacturing of Rings

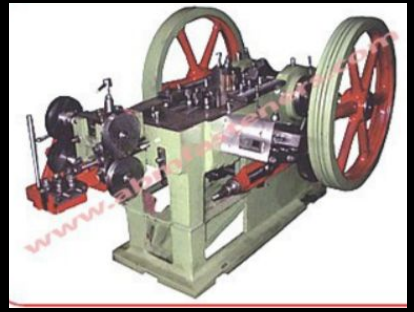
1. CNC Internal Grinder for Ring (Fig A)
2. CNC Raceway Grinder for Inner Ring (Fig B)
3. Raceway Grinder for Outer Ring (Fig C)

Finishing Machine

Used for the finishing process of rings

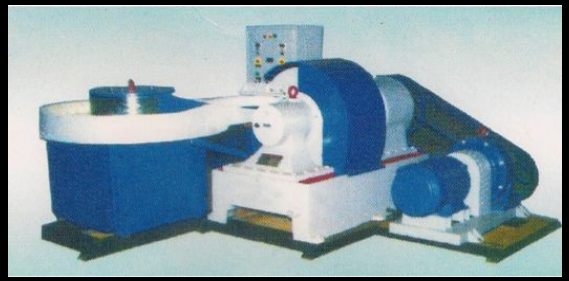
Cold Heading Machine

Used for making slug from wire



Flashing Machine

For removing flash in flashing process



Grinding Machine

For grinding of the balls in Grinding Process

Ball Lapping Machine

Used for lapping process in Ball Manufacturing

Rotary Furnace

At heating process, rotary furnace is used to heat the Balls

Assembly Machine

For doing assembly of all components

Inspection

Quality Tests for Inspection

- Bearing Life Testing
- Basic Dynamic Load Rating
- Surface Roughness Testing
- Noise Checking
- Roundness Testing
- Hardness Testing
- Profile Checking
- Crack Detection
- Chemical Analysis of Raw Materials
- Radial Clearance

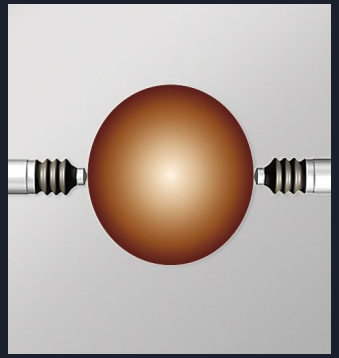


Fig 1: MSX-E3701 system used in which two sensors acquire and measure the balls.

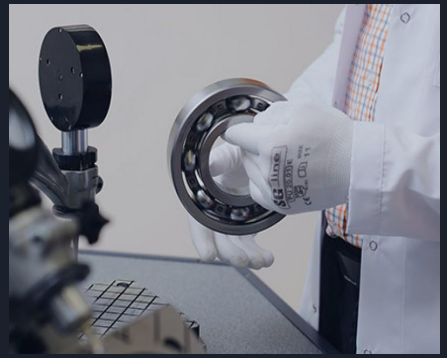


Fig 2: OPTACOM VC-10-EL machine used for characterization of surface topography.

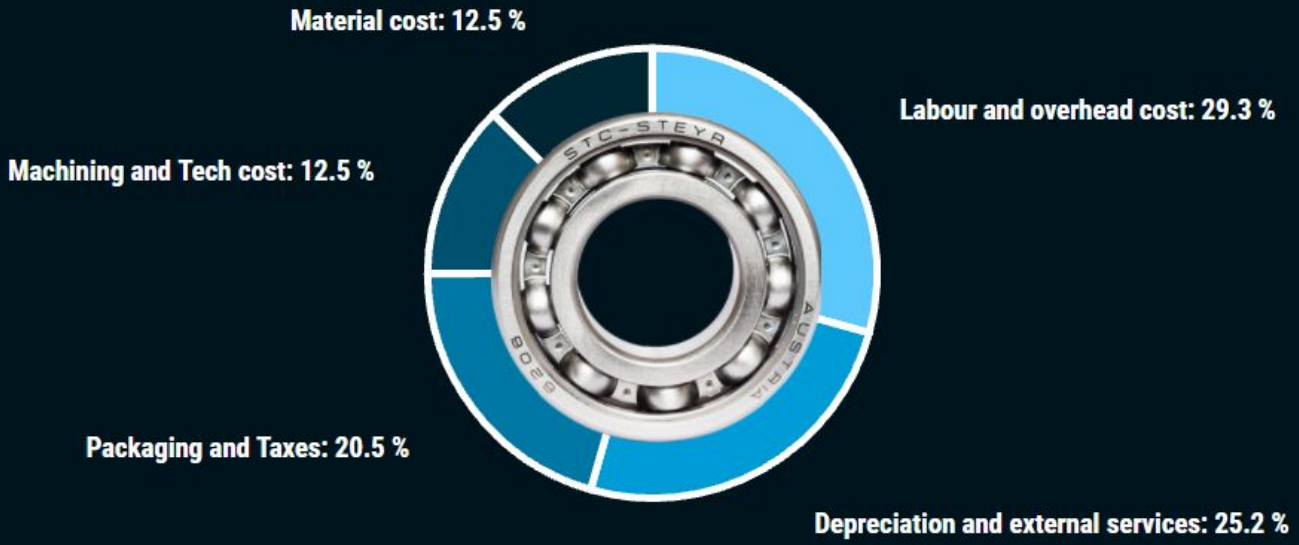
Fig 3: Noise and vibration testing using SN-X, S9912-X

Fig 4: Hardness Testing using SHR-3000

Cost Analysis

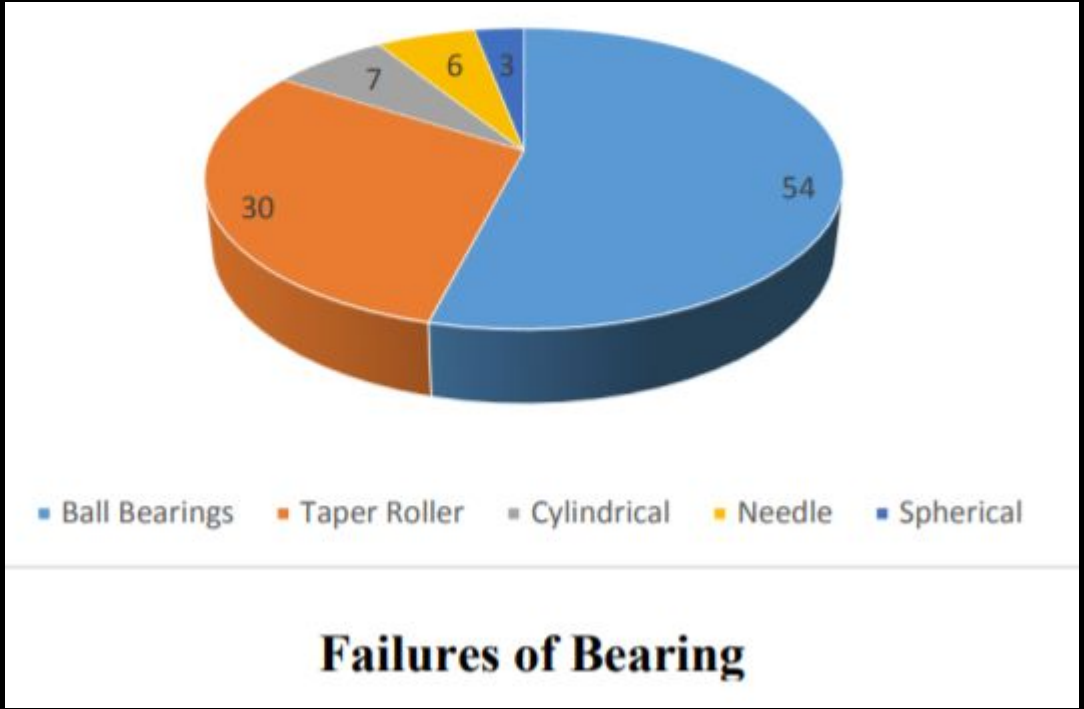
Cost per unit bearing

Total Cost adds up to INR 351.39

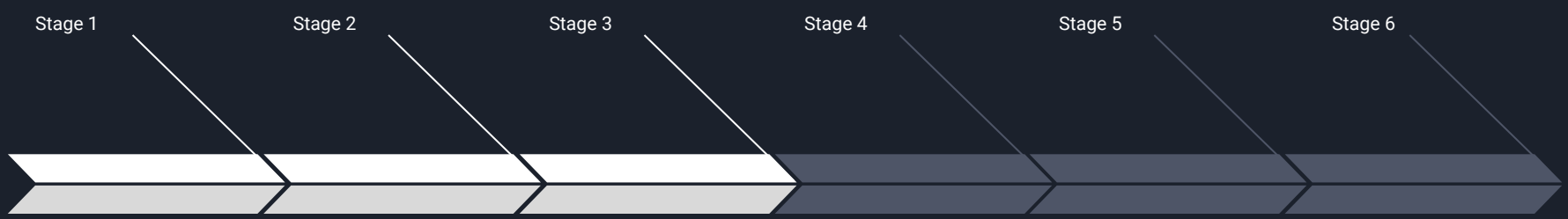


- Labour and overhead cost
- Depreciation and external services
- Packaging and Taxes
- Machining and Tech cost
- Material cost

Fun Fact: Failure of Ball Bearing is most (54 %) in compared to other types of Bearings :)



Project Contribution



Project Title: ALL

Product Description:
Shiv Modi
Product Applications:
Subodh Wankhade
Approximate Cost:
Shrey Patel

Design:
Subodh Wankhade
Shiv Modi
Components:
Shrey Patel
Engineering Drawing:
Shiv Modi

Materials + Process Selection: ALL

- Inner & Outer Rings:
Shrey Patel
- Cage (or Retainer):
Subodh Wankhade
- Balls, Shield, Seal:
Shiv Modi

Manufacturing:
ALL
Finishings, Coatings:
ALL
Machine/Equipment:
Shiv Modi
Assembly:
Subodh Wankhade
Inspection:
Shrey Patel

Cost Analysis:
ALL
Full Report:
ALL
Presentation Video:
ALL

Thank you!

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