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Modeling and Structural Analysis of A Ball Bearing

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Abstract:

The bearings provide relative positioning and rotating freedom while usually transmitting a load between shaft and housing. Ball rolling contact bearing is also call anti-friction ball bearing due to low friction generate between balls, lower and outer races. Ball bearing used for both radial and axial forces. The major issue in ball bearing application is formation of noise while be in working condition. Optimization of contact angle with proper material in ball bearing is helps to reduce the noise.

Angle of contact is defined as the angle between line joining contact points of ball and races. The contact angle of the ball bearing typically varies from 15 degrees and is measured in relative proportion to the line running perpendicular to the bearing axis.This project include about optimization of noise (less stress, deformation and frequency) in ball bearings using finite element analysis software. Analysis of ball bearing was done in Ansys software. Also different materials are used for optimization of stress, deformations and frequency, best material is suitable to ball bearing. Design of ball bearing passed through NX CAD software.

INTRODUCTION

1.1 BEARING:

Bearings are components designed to connect machine parts. Bearings transmit motion and forces. They are usually mounted on axles or shafts and inserted in housings. If a bearing transmits rotary motion, it is called a rotary bearing. Linear bearings are used for longitudinal motion. The type of friction involved distinguishes plain bearings from rolling bearings.

Plain bearings are components with a sliding layer between two parts. This sliding layer may be a solid layer that is fixed to the bearing, such as plastic or bronze layers. Otherwise, a lubricating film separates the surfaces.

Rolling bearings are bearings with two components that move in opposite directions. These parts are the inner and outer ring, and they are separated by rolling elements. The rolling elements roll between the two rings during operation. This occurs on hardened steel surfaces called raceways. The friction generated here is significantly lower compared to plain bearings. Rolling elements are the most important parts in a bearing, because they carry most of the loads. Rolling elements come in different shapes: balls, cylindrical rollers, needle rollers, tapered rollers or spherical rollers. The names of many bearing types are based on the kind of rolling element used, such as “ball bearing” or “needle roller bearing.” In modern bearings, a cage is used to provide even spacing for the rolling elements. This prevents them from contacting each other. Cages can be made from sheet steel, plastic or brass. Additional components may be sealing shields or seals. Another important part of a bearing is the lubricant. Rolling bearings are lubricated with grease or oil to extend operating life. The seal keeps the lubricant in the bearing and prevents dirt and moisture from entering.

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1.2 TYPES OF ROLLING BEARING:

Rolling bearings are classified into TWO types. 1.Ball bearings and 2. Roller bearings.

1. Ball bearing: Deep groove ball bearings, Angular contact ball bearings , Four point contact ball bearings, Self-aligning ball bearings.

2. Roller bearings: Cylindrical roller bearings Needle roller bearings Tapered roller bearings Spherical roller bearings.

1.3 BALL BEARING

A ball bearing is a type of rolling-element bearing that uses balls to maintain the separation between the bearing races.The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads. It achieves this by using at least two races to contain the balls and transmit the loads through the balls. In most applications, one race is stationary and the other is attached to the rotating assembly (e.g., a hub or shaft). As one of the bearing races rotates it causes the balls to rotate as well. Because the balls are rolling they have a much lower coefficient of friction than if two flat surfaces were sliding against each other.

Ball bearings tend to have lower load capacity for their size than other kinds of rolling-element bearings due to the smaller contact area between the balls and races. However, they can tolerate some misalignment of the inner and outer races.

1.4 CYLINDRICAL ROLLER BEARING:

Cylindrical roller bearings are used in many industrial machines and automobiles because they have a higher load carrying capacity than ball bearings and are more suited for high speed revolution. The purpose of a bearing is to provide relative positioning and rotational freedom while transmitting a load between two structures, usually a shaft and housing. The basic form and concept of the rolling element bearing are simple. If loads are to be transmitted between surfaces which are in relative motion, the action can be facilitated in the most effective manner by rolling elements when interposed between the sliding members.

The frictional resistance encountered in sliding is largely replaced by much smaller resistance associated with rolling. A commonly used bearing combination for support of a high-speed rotor is a cylindrical roller bearing. Cylindrical roller bearings have moderately high radial load capacity as well as high speed capability. Although the rolling elements are called "cylindrical", they are not true cylinders. True cylinders would produce stress concentrations at the ends of the roller-race contact, resulting in high wear and high sensitivity to misalignment. In this type of bearing, the rollers are in direct contact with each other, which causes sliding and increases friction and heat generation.

MAJOR PARTS OF CYLINDRICAL ROLLER BEARING:

1. OUTER & INNER RACES
2. CAGE(SEPARATOR)
3. CYLINDRICAL ROLLER

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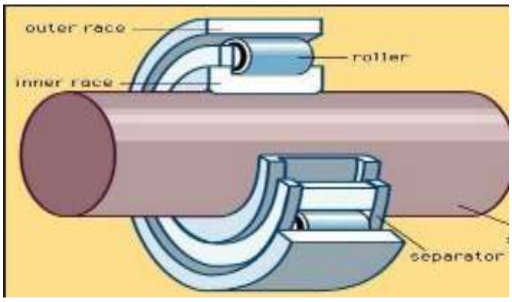


Fig: Cylindrical roller bearing

1.5 COMPOSITE MATERIALS:
A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. The biggest advantage of modern composite materials is that they are light as well as strong. By choosing an appropriate combination of matrix and reinforcement material, a new material can be made that exactly meets the requirements of a particular application. Composites also provide design flexibility because many of them can be moulded into complex shapes. The downside is often the cost. Although the resulting product is more efficient, the raw materials are often expensive. Composite material a combination of a matrix and a reinforcement, which when combined gives properties superior to the properties of the individual components. In the case of a composite, the reinforcement is the fibers and is used to fortify the matrix in terms of strength and stiffness.

The reinforcement fibers can be cut, aligned, placed in different ways to affect the properties of the resulting composite.

The matrix, normally a form of resin, keeps the reinforcement in the desired orientation. It protects the reinforcement from chemical and environmental attack, and it bonds the reinforcement so that applied loads can be effectively transferred.

TYPE OF COMPOSITES:

The term 'composite' can be used for a multitude of materials. Composites UK uses the term composite, or reinforced polymers to encompass:
1. Carbon fibre-reinforced polymers (CFRP)
2. Glass fibre-reinforced polymers (GFRP)
3. Aramid products (e.g. Kevlar)
4. Bio-derived polymers (or bio composites)

LITERATURE REVIEW
PRASANNA SUBBARAO BHAMIDIPATI: has written a title on " FEA ANALYSIS OF NOVEL DESIGN OF CYLINDRICAL ROLLER BEARING " and explained that When a bearing is properly designed, manufactured, installed, and maintained, then the natural cause of bearing failure is typically the fatigue life of its rolling elements and races. The environment within which the bearing operates also determines the bearing life. The contact stresses developed in the rolling elements and races of a typical bearing is cyclic in nature. This in turn will result in a potential fatigue failure for these elements. The fatigue life a bearing is influenced by the operating speed, load conditions, bearing material, clearance of the mating parts, contact surface geometry, and the environment in which the bearing operates.
R. J. Kleckner J. Pirvics: have published a paper on " HI GH SPEED CYLINDRICAL RO LLER BEARING ANALYS IS". This paper presents that Engine shaft speeds will be increased ,to derive greater compressor efficiency. Increased speeds, 1j.owever, accentuate centrifugal effects. Dominance in raceway loading is transformed from inner to outer rings. Failure to maintain loaded contact on the inner ring across thus spectrum of operating speeds results in the increased hazard of roller skidding, unnecessary heat generation and unstable performance. Combined with increased shaft diameters, required by system stiffnE1ss, increased speed raises questions

beyond the limits of currently available bearing design analysis.

B. Ramu, V. V. R. Murthy: have published a project entitled " Contact Analysis of Cylindrical Roller Bearing Using Different Roller Profiles". According to this, Cylindrical roller bearings are designed to carry heavy radial loads, but due to misalignment and edge loading it is affecting the life of the bearing. So in the design of cylindrical roller bearings the profile of the roller plays important roll. Stress analysis is done based on two dimensional models of the roller and raceways. The roller profiles analyzed are flat, circular and logarithmic, which is loaded against two flat raceways.

Goutam Mukhopadhyay, S. Bhattacharya: have published a journal on " Failure Analysis of a Cylindrical Roller Bearing from a Rolling Mill". According to this project, Premature failure of a cylindrical roller bearing of a gear box input shaft from a hot strip mill has been investigated. The pins of the cylindrical rollers of the bearing broke from the welded joints at their ends on the cage ring. Investigations were carried out on the failed roller pin and the welded joint. The investigation consists of visual observation, chemical analysis, characterization of macro- and microstructures, measurement of hardness profile, fractography, and energy dispersive spectroscopy (EDS). The fracture surface of the roller pins exhibits beach marks. Scanning electron microscopy (SEM) of the fracture surfaces reveals striations suggesting fatigue failure.

Mr.B.J.Jugale, Mr.M.V.Kharade: have written a paper on "A Review Paper on Failure Analysis of Cylindrical Roller Bearing". This paper represents that Cylindrical roller bearings are commonly used in aircraft power transmission, machine tools, steel industries and others due to their precision and high load carrying capacity. In present study, an experimental test rig has been developed to investigate the wear in roller bearing. The changes in micro-geometry of the bearing components have been observed through scanning electron microscope. Some major cracks have been found over the inner race surface. Solid debris particles, removed from the inner race surface, further damage the other bearing surfaces. The lubricating grease has been also failed to provide elasto hydrodynamic lubrication between the inner race and rollers.

PROBLEM DEFINITION AND METHODOLOGY

PROBLEM DEFINITION:

Ball bearing carry heavy radial loads. These are suited for low coefficient of friction and less frictional loss in high speed application. Due to this reason ball bearing generates more noise. Optimization of noise depend on materials suited for bearing. Fiber-reinforced polymer(FRP), is a composite material made of a polymer matrix reinforced with fibers. The fibers are usually glass, carbon, or aramid, although other fibers such as paper or wood or asbestos have been sometimes used. Fibers play major role in self lubrication and noise reduction in ball bearing. Optimization of contact pressure between FRP and ball bearing is used for noise reduction.

This works deals with design of ball bearing based on radial force acting on bearing. The project also includes the determination of the influence of fiber and matrix material combinations on the contact pressure distribution and contact area between the FRP and cylindrical bearings. NX CAD software is used for designing of ball bearing and Analysis was done in Ansys software.

METHODOLOGY:

1. Modeling of ball bearing will pass through NX CAD software based on radial force acting on it.
2. Designed ball bearing was imported in Ansys software.
3. Finite element analysis of ball bearing pass through Ansys software with conventional steel material and also with composite materials like E-Glass/Epoxy.
4. Results obtained from the analysis are compared and the best material is proposed based on the weight and contact pressure.

DESIGNING OF BALL BEARING UNIGRAPHICS INTRODUCTION

NX, also known as NX unigraphics or usually just u-g, is an advanced CAD/CAM/CAE software package developed by Siemens PLM software.
It is used, among other tasks, for:

- Design (parametric and direct solid/surface modelling)
- Engineering analysis (static, dynamic, electro-magnetic, thermal, using the finite element method, and fluid using the finite volume method).
- Manufacturing finished design by using included machining modules

First release of the new "next generation" version of unigraphics and i-deas, called NX. this will eventually bring the functionality and capabilities of both unigraphics and i-deas together into a single consolidated product.

Increasing complexity of products, development processes and design teams is challenging companies to find new tools and methods to deliver greater innovation and higher quality at lower cost. leading-edge technology from Siemens PLM software delivers greater power for today's design challenge. from innovative synchronous technology that unites parametric and history-free modeling, to NX active mockup for multi-cad assembly design, NX delivers breakthrough technology that sets new standards for speed, performance, and ease of use.

NX automates and simplifies design by leveraging the product and process knowledge that companies gain from experience and from industry best practices. it includes tools that designers can use to capture knowledge to automated repetitive tasks. the result is reduced cost and cycle time and improved quality.

Overview of Solid Modelling:

The Unigraphics NX Modelling application provides a solid modeling system to enable rapid conceptual design. Engineers can incorporate their requirements and design restrictions by defining mathematical relationships between different parts of the design.

Design engineers can quickly perform conceptual and detailed designs using the Modeling feature and constraint based solid modeller. They can create and edit complex, realistic, solid models interactively, and with far less effort than more traditional wire frame and solid based systems. Feature Based solid modeling and editing capabilities allow designers to change and update solid bodies by directly editing the dimensions of a solid feature and/or by using other geometric editing and construction techniques.

Advantages of Solid Modeling:

Solid Modeling raises the level of expression so that designs can be defined in terms of engineering features, rather than lower-level CAD geometry. Features are parametrically defined for dimension-driven editing based on size and position.

Features:

- Powerful built-in engineering-oriented form features-slots, holes, pads, bosses, pockets-capture design intent and increase productivity

- Patterns of feature instances-rectangular and circular arrays-with displacement of individual features; all features in the pattern are associated with the master feature.

Blending and Chamfering:

- zero radius

- Ability to chamfer any edge

- Cliff-edge blends for designs that cannot accommodate complete blend radius but still require blends

Advanced Modeling Operations:

- Profiles can be swept, extruded or revolved to form solids

- Extremely powerful hollow body command turns solids into thin-walled designs in seconds; inner wall topology will differ from the outer wall, if necessary

- Fixed and variable radius blends may overlap surrounding faces and extend to a Tapering for modeling manufactured near-net shape parts

- User-defined features for common design elements (Unigraphics NX/User-Defined Features is required to define them in advance

General Operation:
Start with a Sketch
Use the Sketcher to freehand a sketch, and dimension an "outline" of Curves. You can then sweep the sketch using Extruded Body or Revolved Body to create a solid or sheet body. You can later refine the sketch to precisely represent the object of interest by editing the dimensions and by creating relationships between geometric objects. Editing a dimension of the sketch not only modifies the geometry of the sketch, but also the body created from the sketch.
Creating and Editing Features:

Feature Modeling lets you create features such as holes, slots and grooves on a model. You can then directly edit the dimensions of the feature and locate the feature by dimensions. For example, a Hole is defined by its diameter and length. You can directly edit all of these parameters by entering new values. You can create solid bodies of any desired design that can later be defined as a form feature using User Defined Features. This lets you create your own custom library of form features.

Associativity:

Associatively is a term that is used to indicate geometric relationships between individual portions of a model. These relationships are established as the designer uses various functions for model creation. In an associative model, constraints and relationships are captured automatically as the model is developed. For example, in an associative model, a through hole is associated with the faces that the hole penetrates. If the model is later changed so that one or both of those faces moves, the hole updates automatically due to its association with the faces. See Introduction to Feature Modeling for additional details.

Positioning a Feature:

Within Modeling, you can position a feature relative to the geometry on your model using Positioning Methods, where you position dimensions. The feature is then associated with that geometry and will maintain those associations whenever you edit the model. You can also edit the position of the feature by changing the values of the positioning dimensions.

Reference Features:

You can create reference features, such as Datum Planes, Datum Axes and Datum CSYS, which you can use as reference geometry when needed, or as construction devices for other features. Any feature created using a reference feature is associated to that reference feature and retains that association during edits to the model. You can use a datum plane as a reference plane in constructing sketches, creating features, and positioning features. You can use a datum axis to create datum planes, to place items concentrically, or to create radial patterns.

Expressions:

The Expressions tool lets you incorporate your requirements and design restrictions by defining mathematical relationships between different parts of the design. For example, you can define the height of a boss as three times its diameter, so that when the diameter changes, the height changes also.

Boolean Operations:

Modeling provides the following Boolean Operations: Unite, Subtract, and Intersect. Unite combines bodies, for example, uniting two rectangular blocks to form a T-shaped solid body. Subtract removes one body from another, for example, removing a cylinder from a block to form a hole. Intersect creates a solid body from material shared by two solid bodies. These operations can also be used with free form features called sheets.

Undo:

You can return a design to a previous state any number of times using the Undo function. You do not have to take a great deal of time making sure each operation is absolutely correct, because a mistake can be easily undone. This freedom to easily change the model lets you cease worrying about getting it wrong, and frees you to explore more possibilities to get it right.

Additional Capabilities:

Other Unigraphics NX applications can operate directly on solid objects created within Modeling without any translation of the solid body. For example, you can perform drafting, engineering analysis, and NC machining functions by accessing the appropriate application. Using Modeling, you can design a complete, unambiguous, three dimensional model to describe an object. You can extract a wide range of physical properties from the solid bodies, including mass properties. Shading and hidden line capabilities help you visualize complex assemblies. You can identify interferences automatically, eliminating the need to attempt to do so manually. Hidden edge views can later be generated and placed on drawings. Fully associative dimensioned drawings can be created from solid models using the appropriate options of the Drafting application. If the solid model is edited later, the drawing and dimensions are updated automatically.

Parent/Child Relationships:

If a feature depends on another object for its existence, it is a child or dependent of that object. The object, in turn, is a parent of its child feature. For example, if a HOLLOW (1) is created in a BLOCK (0), the block is the parent and the hollow is its child. A parent can have more than one child, and a child can have more than one parent. A feature that is a child can also be a parent of other features. To see all of the parent-child relationships between the features in your work part, open the Part Navigator.

Creating a Solid Model:

Modeling provides the design engineer with intuitive and comfortable modeling techniques such as sketching, feature based modeling, and dimension driven editing. An excellent way to begin a design concept is with a sketch. When you use a sketch, a rough idea of the part becomes represented and constrained, based on the fit and function requirements of your design. In this way, your design intent is captured. This ensures that when the design is passed down to the next level of engineering, the basic requirements are not lost when the design is edited.

The strategy you use to create and edit your model to form the desired object depends on the form and complexity of the object. You will likely use several different methods during a work session. The next several figures illustrate one example of the design process, starting with a sketch and ending with a finished model. First, you can create a sketch "outline" of curves. Then you can sweep or rotate these curves to create a complex portion of your design.

Introduction to Drafting:

The Drafting application is designed to allow you to create and maintain a variety of drawings made from models generated from within the Modeling application. Drawings created in the Drafting application are fully associative to the model. Any changes made to the model are automatically reflected in the drawing. This Associativity allows you to make as many model changes as you wish. Besides the powerful Associativity functionality, Drafting contains many other useful features including the following:

- An intuitive, easy to use, graphical user interface. This allows you to create drawings quickly and easily.
- A drawing board paradigm in which you work "on a drawing." This approach is similar to the way a drafter would work on a drawing board. This method greatly increases productivity.
- Support of new assembly architecture and concurrent engineering. This allows the drafter to make drawings at the same time as the designer works on the model.
- The capability to create fully associative cross-sectional views with automatic hidden line rendering and crosshatching.
- Automatic orthographic view alignment. This allows you to quickly place views on a drawing, without having to consider their alignment.
- Automatic hidden line rendering of drawing views.
- The ability to edit most drafting objects (e.g., dimensions, symbols, etc.) from the graphics window. This allows you to create drafting objects and make changes to them immediately.
- On-screen feedback during the drafting process to reduce rework and editing.
- User controls for drawing updates, which enhance user productivity.

The manual methods include:

- The Unigraphics NX Open C and C++ Runtime function, UF_MODEL. Update all features, which logs all the features in the current work part to the Unigraphics NX update list, and then performs an update. See the Unigraphics NX Open C and C++ Runtime Reference Help for more information.

- The Playback option on the Edit Feature dialog, which recreates the model, starting at its first feature. You can step through the model as it is created one feature at a time, move forward or backward to any feature, or trigger an update that continues until a failure occurs or the model is complete.

DESIGN PROCEDURE

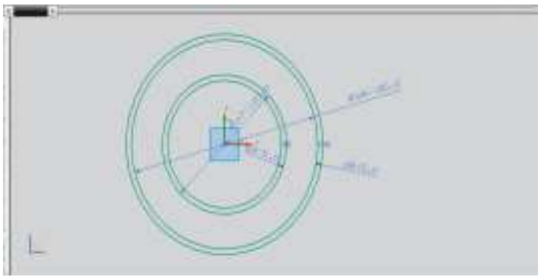


Fig.4.1 2D sketch of ball bearing

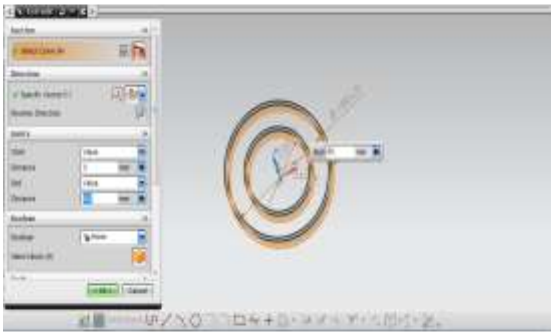


Fig.4.2 Extrude of above 2D sketch of ball bearing


Fig.4.3 Creating datum plane

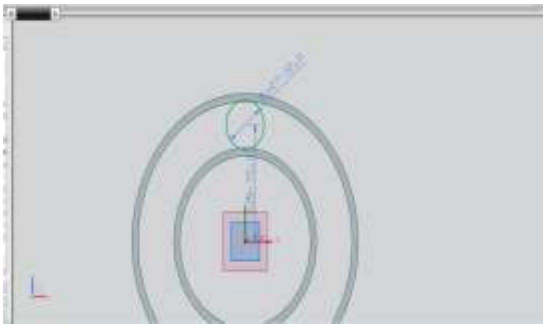


Fig.4.4 2D sketch of ball bearing

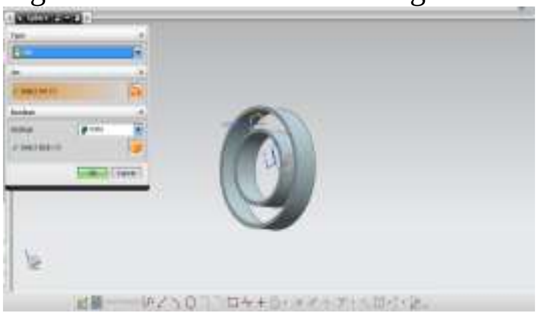


Fig.4.5 Inserting sphere between above 2D sketch of ball bearing


Fig.4.6 Circular pattern of sphere in ball bearing


Fig.4.7 Final model of ball bearing

STRUCTURAL ANALYSIS OF BALL BEARING

5.1 Finite Element Method (FEM)

The Basic concept in FEM is that the body or structure may be divided into smaller elements of finite dimensions called "Finite Elements". The original body or the structure is then considered as an assemblage of these elements connected at a finite number of joints called "Nodes" or "Nodal Points". Simple functions are chosen to approximate the displacements over each finite element. Such assumed functions are called "shape functions". This will represent the displacement within the element in terms of the displacement at the nodes of the element.

The Finite Element Method is a mathematical tool for solving ordinary and partial differential equations. Because it is a numerical tool, it has the ability to solve the complex problems that can be represented in differential equations form. The applications of FEM are limitless as regards the solution of practical design problems.

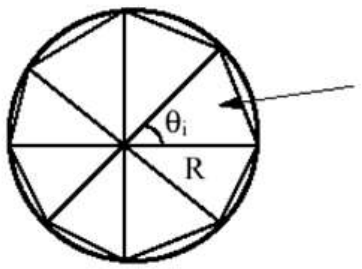
Due to high cost of computing power of years gone by, FEM has a history of being used to solve complex and cost critical problems. Classical methods alone usually cannot provide adequate information to determine the safe working limits of a major civil engineering construction or an automobile or an aircraft. In the recent years, FEM has been universally used to solve structural engineering problems. The departments, which are heavily relied on this technology, are the automotive and aerospace industry. Due to the need to meet the extreme demands for faster, stronger, efficient and lightweight automobiles and aircraft, manufacturers have to rely on this technique to stay competitive.

FEA has been used routinely in high volume production and manufacturing industries for many years, as to get a product design wrong would be detrimental. For example, if a large manufacturer had to recall one model alone due to a hand brake design fault, they would end up having to replace up to few millions of hand brakes. This will cause a heavier loss to the company.

The finite element method is a very important tool for those involved in engineering design; it is now used routinely to solve problems in the following areas.

- Structural analysis
- Thermal analysis
- Vibrations and Dynamics
- Buckling analysis
- Acoustics
- Fluid flow simulations
- Crash simulations
- Mold flow simulations

Nowadays, even the most simple of products rely on the finite element method for design evaluation. This is because contemporary design problems usually cannot be solved as accurately & cheaply using any other method that is currently available. Physical testing was the norm in the years gone by, but now it is simply too expensive and time consuming also.



Basic Concepts: The Finite Element Method is based on the idea of building a complicated object with simple blocks, or, dividing a complicated object into small and manageable pieces. Application of this simple idea can be found everywhere in everyday life as well as engineering. The philosophy of FEA can be explained with a small example such as measuring the area of a circle.

Area of one Triangle: Si = ½ * R2* Sin θI

Area of the Circle: SN = ½ * R2 * N * Sin (2 ∏ / N) → ∏ R2 as N → ∞

Where N = total number of triangles (elements)

If one needs to evaluate the area of the circle without using the conventional formula, one of the approaches could be to divide the above area into a number of equal segments. The area of each triangle multiplied by the number of such segments gives the total area of the circle.

Brief history of the fem:

Who

The reference credited is to Courant (Mathematician), Turner (air craft industry), clough (California university), Martin (air craft industry), argyris (German university),…. However, it was probably established by several pioneers independently.

When

- Initial idea in mathematical terms was put in 1940s.
- Application to simple engineering problems in 1950s.
- Implementation in large computer is 1960s.
- Development of pre and post processors in 1980s.
- Analysis of large structural problems in 1990s.

Where

Implementation and application were mainly in aircraft industry and automobile sectors (large and fast computers were available only in these industries)

What

Field problems in the form matrix methods of organizing large numbers of algebraic equations are used and matrix equations are solved. Differential equations are transformed into an algebraic form. Blocks with different geometry are hooked together for creating complex geometry of the engineering problem

Why

The advantage of doing FEM analysis is that it is fairly simple to change the geometry, material and loads recomputed stresses for modified product rather than build and test. The method can be used to solve almost any problem that can be formulated as a field problem. The entire complex problem can be cast as a larger algebraic equation by assembling the element matrices within the computer and solved.

Available Commercial FEM software packages

- ANSYS (General purpose, PC and workstations)
- SDRC/I-DEAS (Complete CAD/CAM/CAE package)
- NASTRAN (General purpose FEA on mainframes)
- LS-DYNA 3D (Crash/impact simulations)
- ABAQUS (Nonlinear dynamic analysis)
- NISA (A General purpose FEA tool)
- PATRAN (Pre/Post processor)
- HYPERMESH (Pre/post processor)

More about FEA

Finite Element Analysis was first developed for use in the aerospace and nuclear industries where the safety of the structures is critical. Today, the growth in usage of the method is directly attributable to the rapid advances in computer technology in recent years. As a result, commercial finite element packages exist that are capable of solving the most sophisticated problems, not just in structural analysis. But for a wide range of applications such as steady state and transient temperature distributions, fluid flow simulations and also simulation of manufacturing processes such as injection molding and metal forming.

FEA consists of a computer model of a material or design that is loaded and analyzed for specific results. It is used in new product design, and existing product refinement. A design engineer shall be able to verify the proposed design, which is intended to meet the customer requirements prior to the manufacturing. Things such as, modifying the design of an existing product or structure in order to qualify the product or structure for a new service condition. Can also be accomplished in case of structural failure, FEA may be used to help determine the design modifications to meet the new condition.

The Basic Steps Involved in FEA

Mathematically, the structure to be analyzed is subdivided into a mesh of finite sized elements of simple shape. Within each element, the variation of displacement is assumed to be determined by simple polynomial shape functions and nodal displacements. Equations for the strains and stresses are developed in terms of the unknown nodal displacements. From this, the equations of equilibrium are assembled in a matrix form which can be easily be programmed and solved on a computer. After applying the appropriate boundary conditions, the nodal displacements are found by solving the matrix stiffness equation. Once the nodal displacements are known, element stresses and strains can be calculated.

Basic Steps in FEA

1. Preprocess

- Create geometrical model by either hyper mesh or ansys software or any cad software.
- Import a cad model in ansys software if geometrical model was done by cad software.
- Select analysis type such as static, modal, transient dynamic, thermal analysis.
- Insert element type either 2-Dimensional(ex: Trusses, Beams) or 3-Dimensional (ex: Solid, Shell, Plate)

What is an Element?

Element is an entity, into which a system under study can be divided into. An element definition can be specified by nodes. The shape (area, length, and volume) of the element depends upon the nodes with which it is made up of.

What are Nodes?

Nodes are the corner points of the element. Nodes are independent entities in the space. These are similar to points in geometry. By moving a node in space an element shape can be changed. This is a volume element, can take the shape of a Hexahedron or a Wedge or a Tetrahedron order elements. For linear elements the edge is defined by a linear function called shape function whose degree is one. For the elements having mid side nodes on the edge quadratic function called shape function whose degree is two is used. The higher order elements when over lapped on geometry can represent complex shapes very well within few elements. Also the solution accuracy more with the higher order elements. But higher order elements will require more computational effort and time. Apply material properties (Young's modulus, Poisson ratio, Thermal conductivity, Density values) based on types of materials.

Apply meshing to FE model.

Also Apply boundary conditions and Loading conditions.

Solution

Get nodal solutions such as displacement values at each node or temperature values at each node by solving linear or non linear algebraic equations at each node.

These solutions formed based on matrix formulation for system of equations. That formula noted as

$[K]*[x] = [F]$

[K] is system stiffness matrix

[x] is displacement vector matrix, [F] is force vector

3.Postprocessing

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Postprocessor software contains sophisticated routines used for sorting, printing, and plotting selected results from a finite element solution.

ANALYSIS PROCEDURE OF BALL BEARING USING STEEL MATERIAL

Material used for ball bearing is Stainless steel alloy:
Young's Modulus: **200 GPa**
Poisson's Ratio: **0.3**
Density: **7850 Kg/m3**
Yield strength: **300 MPa**

BOUNDARY CONDITIONS:

- A radial force of 10000 N is applied on centre of ball bearing.
- The sides of cylindrical bearing are constrained in all dof.

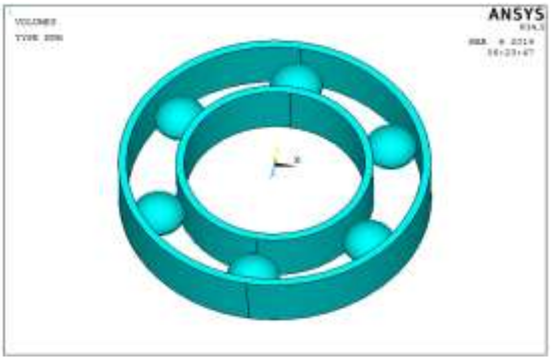

Fig.5.1 Imported ball bearing in Ansys

Fig.5.2 Created mesh on ball bearing

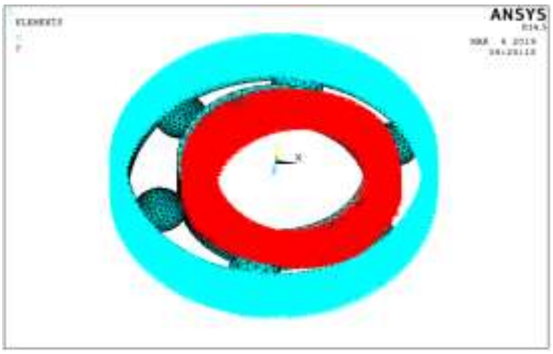

Fig.5.3 Applied load on ball bearing

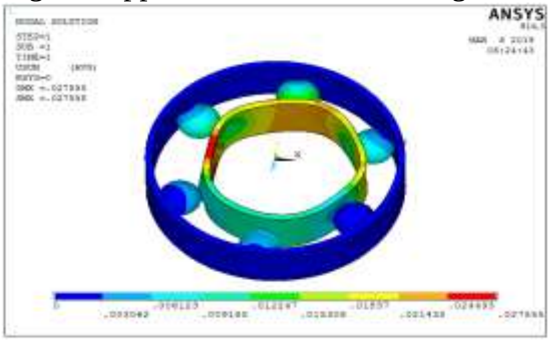

Fig.5.4 Deformation results on ball bearing

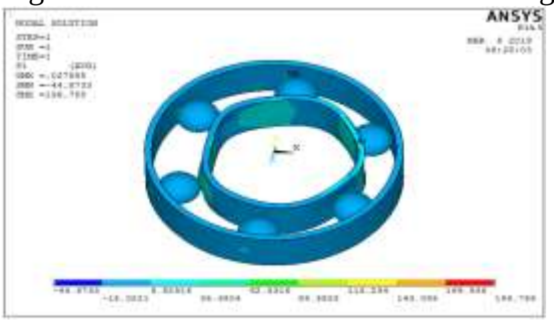

Fig.5.5 1st Principle stress results on ball bearing

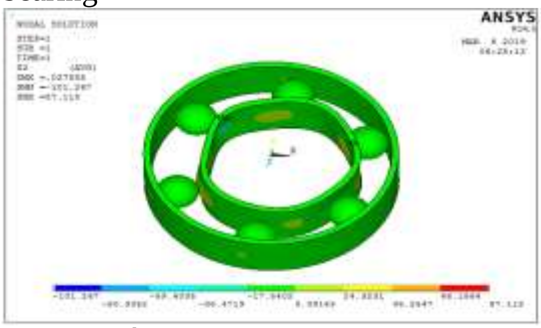

Fig.5.6 2nd Principle stress results on ball bearing

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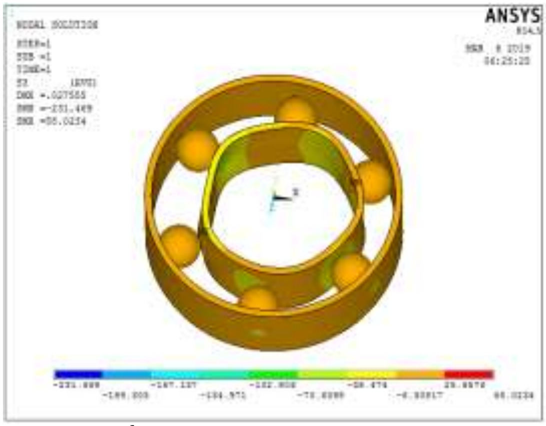

Fig.5.7 3rd Principle stress results on ball bearing

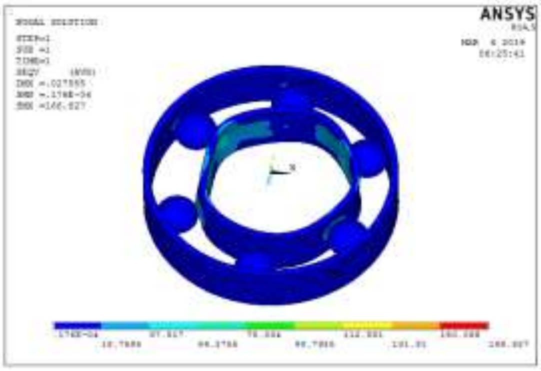

Fig.5.8 Von-misses stress results on ball bearing

From analysis results observed that, Maximum von-misses stress found on ball bearing is 168.827MPa which is less than Yield stress of stainless steel is 300MPa. The Von mises stress of ball bearing was **43.8 %** less than the yield strength of the material.

ANALYSIS PROCEDURE OF BALL BEARING USING COMPOSITE E-GLASS/EPOXY MATERIAL

Material used for bearing is composite materials (E-Glass/Epoxy):

Longitudinal Modulus (E_X): **50 GPa**

Transverse Modulus (E_Y): **12 GPa**

Shear modulus (G_{xy}): **5 .6GPa**

Shear modulus (G_{yz}): **5.6 GPa**

Shear modulus (G_{xz}): **5.6 GPa**

Poisson's Ratio: **0.33**

Density: **2000 Kg/m3**

BOUNDARY CONDITIONS:

- A radial force of 10000 N is applied on centre of cylindrical bearing.
- The sides of cylindrical bearing are constrained in all dof.

Fig.5.10 Created mesh on ball bearing

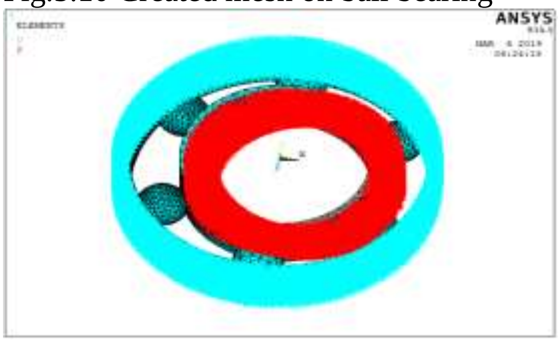

Fig.5.11 Applied load on ball bearing

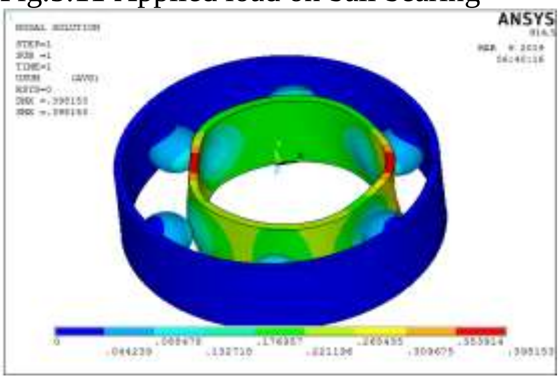

Fig.5.12 Deformation results on ball bearing

Fig.5.13 1st Principle stress results on ball bearing

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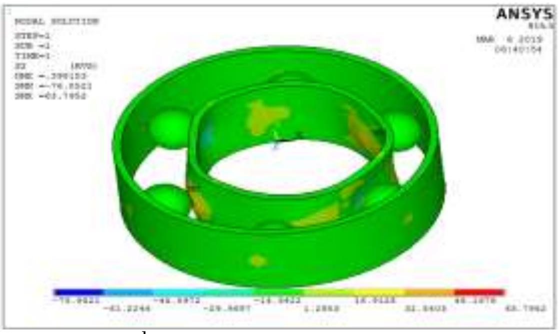

Fig.5.14 2nd Principle stress results on ball bearing

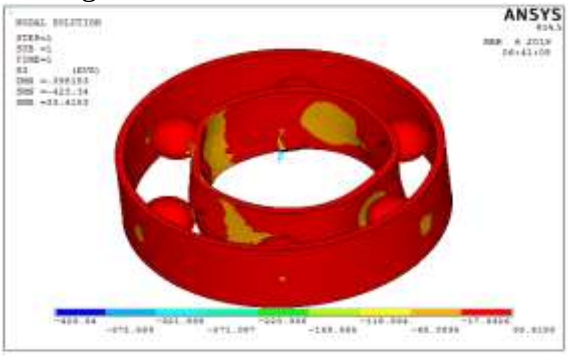

Fig.5.15 3rd Principle stress results on ball bearing

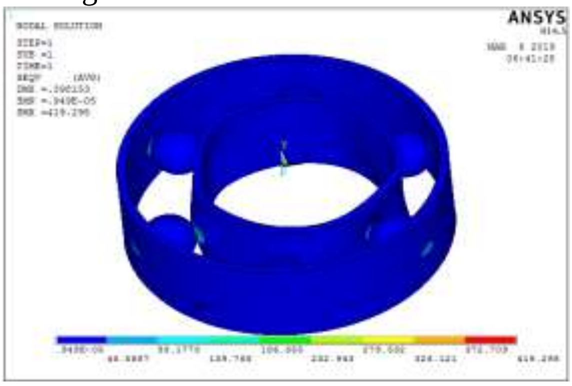

Fig.5.16 Von-misses stress results on ball bearing

From analysis results observed that, Maximum von-misses stress found on ball bearing is 419.298MPa which is less than Ultimate stress of E-Glass/Epoxy is 940MPa. The Von mises stress of ball bearing was **55.43 %** less than the yield strength of the material.

RESULTS AND CONCLUSION

Results absorbed from static analysis of ball bearing by using different materials are given below.

	STEEL MATERIAL	E-GLASS/EPOXY
Deflection	0.027 mm	0.39 mm
Von mises stress	168.82 Mpa	419.29 Mpa

From analysis of steel ball bearing results observed that, Maximum von-misses stress found on ball bearing is 168.827MPa which is less than Yield stress of stainless steel is 300MPa. The Von mises stress of cylindrical bearing was **43.8 %** less than the yield strength of the material.

From analysis of E-Glass/Epoxy ball bearing results observed that, Maximum von-misses stress found on ball bearing is 419.298MPa which is less than Ultimate stress of E-Glass/Epoxy is 940MPa. The Von mises stress of ball bearing was **55.43 %** less than the yield strength of the material.

So finally concluded that ball bearing with composite E-Glass/Epoxy material is safe for ball bearing due to high strength and low weight.

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