NONCONVENTIONAL METHOD OF SPHERICAL ROLLER BEARING DESIGN, USING FEA

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ABSTRACT. This paperwork presents the analysis of roller bearing design, in order to optimize the classical process, using the finite element method or Finite Element Analysis (FEA). First of all, it was studied theoretically modelling/simulation with finite element to understand in the best way how this works and how to obtain the best results of the study. Then it was brought a general presentation of spherical roller bearing and in the very next phase some types of spherical roller bearings were designed using the 3D software Creo Parametric, to import the geometry created in the finite element software Ansys. Next step was to initiate a study of static load conditions of spherical roller bearings and the variation of equivalent elastic strain and elastic stress, using Ansys Workbench and Ansys Mechanical Design. In the last part of the paper, using the results obtained with Ansys and the multiple-criteria decision, it was elaborated a new design version of spherical roller bearing.

KEYWORDS: design, model, finite element, Ansys, spherical roller bearings, optimization, material strain, material stress,

1. INTRODUCTION (HEADING 1)

Ordinary, modelling means that it is made a copy of an object at a certain scale. In Finite Element Analysis, modelling is a symbolic way to indicate certain aspects of a system, having the purpose to simulate its behaviour upon different conditions [1].

FEA, also called Finite Element Method (FEM), is based on the principle of simplifying a certain domain or some object with complex origin, by approximate split them in easy manipulating components. In other words, FEA has the contribution in obtaining the solution to problems within finite character by transformation and interpretation in known elements, with finite dimensions [2].

Spherical roller bearings have two rounds of spherical rollers, a common spherical raceway on outer ring and two raceways on inner ring inclined at an angle to the bearing axis. Due to the property that the spherical roller bearings are designed to fulfil some indispensables demands as low cost manufacturing, minimising maintenance, long lifecycles, resistance in hard conditions, environment sustaining, high availability on effort and technical quality support in major industry segments, it could be consider that they are efficient in any kind of industry used [3].

Behnam Ghalamchi introduced a new model of analysing the spherical roller bearings, developed as an interface between a rotational rotor and his elements of support [4].

A similar study was elaborated by Mr. Deshpande H. et al, from Department of Mechanical Engineering, Maharashtra, India which was investigated the effect of defect on Cylindrical Roller Bearing, using FEA approach, revealing that a defect size and RPM is increasing, it is a sudden increasing of the amplitude vibrations [5].

2. METHODOLOGY OF EXPERIMENTAL RESEARCH

2.1 Initial meshing

When a geometry, created in Ansys or imported from a 3D design program, is opened in Ansys Mechanical module in order to apply a static or dynamic analysis, Ansys automatically generates the discreet structures composed by finite elements, connected with nodes. This structure is called mesh and the process is called meshing.
In the same time, are automatically identified and generated the contacts between the parts of the assembly (fig. 1).

Despite of establishing the materials properties for each component previously, the mesh and contacts are generated, it is not enough to obtain the solution of the studied system. So, we need to fix the degrees of freedom by introducing proper supports and we must define the loading conditions for our spherical roller bearing. These are also called the boundary conditions (fig. 2). So it was applied a static analysis with the conditions presented beyond in Ansys to a spherical roller bearing, type MA.

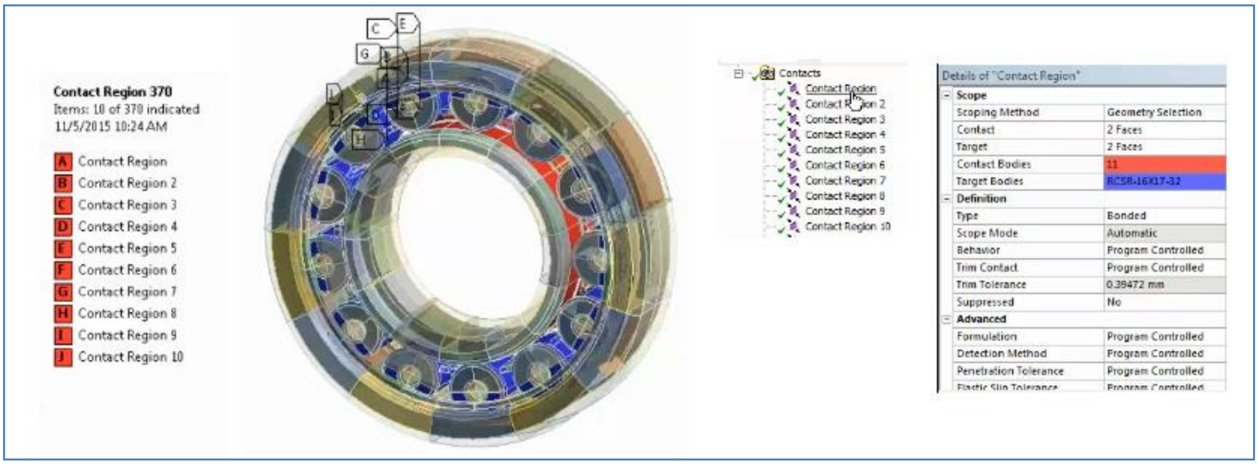

Figure 1. Automatic generation of contacts for a spherical roller bearing

First, I attached a shaft piece to the roller bearing which will facilitate simulation of its real boundary conditions. For this shaft, I fixed a contact with the inner ring, but the friction is neglected. Then I constrained its translation on x axis and I let the rotation free around the z axis.

The other degrees of freedom were constrained by two fixed supports attached on the outside surface of the outer ring. Also using the shaft piece, it was applied to the roller bearing a radial load equal to 200 KN directed to y axis.

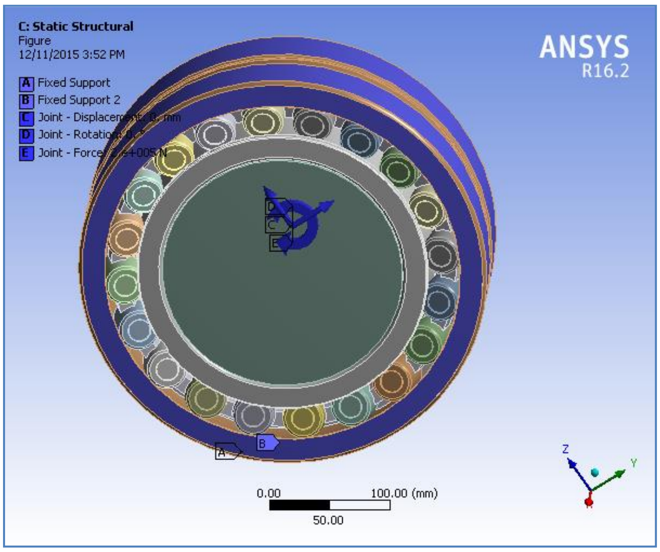

Figure 2. Boundary conditions applied to spherical roller bearing

2.2 Final meshing

The automatic generation of mesh and contacts is done in Ansys in circumstances in a way too simplified as the real ones. But, to obtain a quality analysis, the results should be controlled by the capacity of fixing the initial conditions as close as we can to the real ones.

Thus, I changed the mesh generated by the program inserting a field which aloud establishing the finite elements dimension. So, the dimension of the finite elements was fixed to 1 mm with a "hard" behaviour, which means that this condition has priority in front of other mesh conditions. (Figure 3)

Figure 3. Details of establishing dimension of finite elements

Establishing contacts is the most important factor who leads to a quality finite element analysis. For this I chose a manual setup for the types of contact within the spherical roller bearing.

These contacts are presented below.

A) Contact between the outside surface of rollers and the inside surface of inner ring, contact type being "frictional" (fig. 4)

Definition	
Type	Frictional
Friction Coefficient	5.e-002
Scope Mode	Automatic
Behavior	Asymmetric
Trim Contact	Program Controlled
Trim Tolerance	1.2343 mm
Suppressed	No
Advanced	
Formulation	Augmented Lagrange
Detection Method	Nodal-Normal From Contact
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Stabilization Damping Factor	0.
Pinball Region	Program Controlled
Time Step Controls	None
Geometric Modification	
Interface Treatment	Add Offset, Ramped Effects
Offset	0. mm
Contact Geometry Correction	None
Target Geometry Correction	None

Figure 4. Details of first "frictional" contact

B) Contact between the outside surface of rollers and the outside surface of inner ring, same type as contact A (fig. 5).

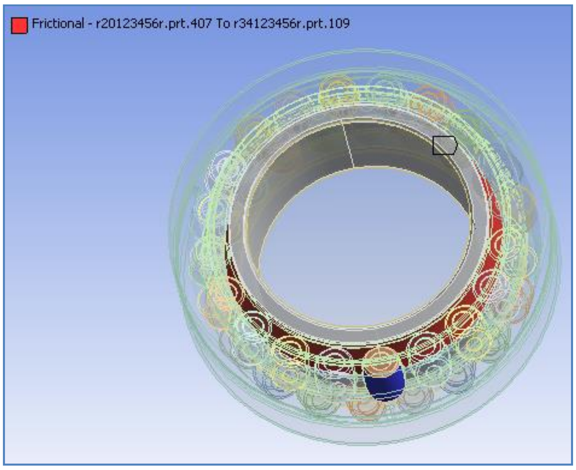

Figure 5. Second “frictional” contact

C) Contact between the outside surface of rollers and the inside surface of the cage. This type of contact is set to “bonded” (fig. 6).

Definition	
Type	Bonded
Scope Mode	Automatic
Behavior	Program Controlled
Trim Contact	Program Controlled
Trim Tolerance	1.2343 mm
Suppressed	No
Advanced	
Formulation	Program Controlled
Detection Method	Program Controlled
Penetration Tolerance	Program Controlled
Elastic Slip Tolerance	Program Controlled
Normal Stiffness	Program Controlled
Update Stiffness	Program Controlled
Pinball Region	Program Controlled
Geometric Modification	

Figure 6. Details of “bonded” contact

D) Contact between the lateral surface of rollers and the inside surface of lateral joint of inner ring, contact type being “frictionless” (fig. 7).

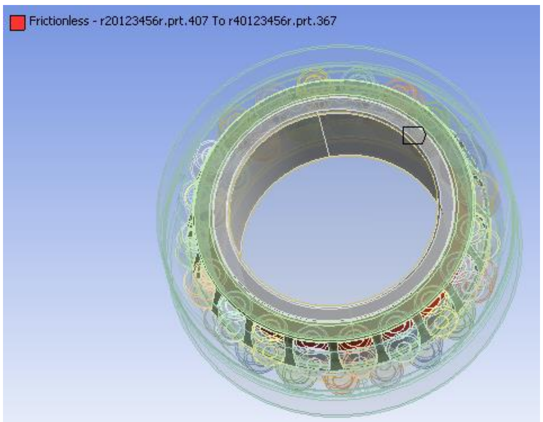

Figure 7. First “frictionless” contact.

E) Contact between the lateral surface of rollers and the inside surface of central joint of inner ring, contact type being the same, “frictionless”.

After following these steps, it was generated the system solution, results revealed in figures 8, 9, 10.

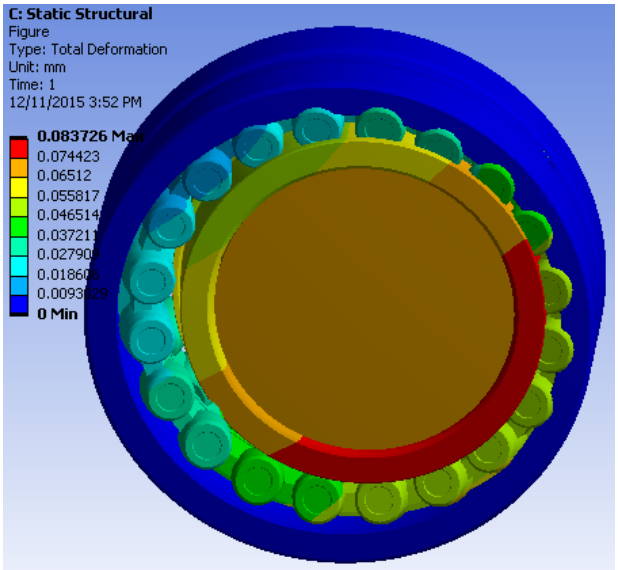

Figure 8. Total Deformation of MA spherical roller bearing

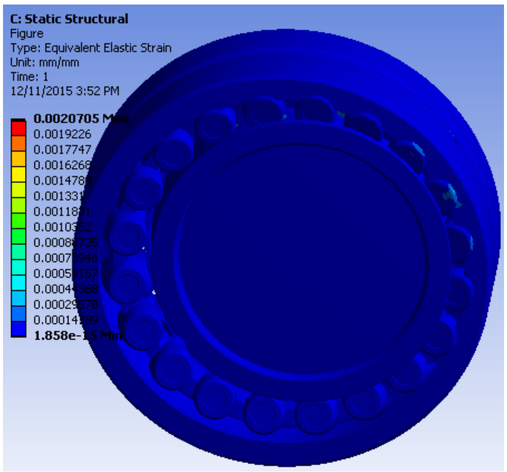

Figure 9. Equivalent elastic strain of the MA spherical roller bearing

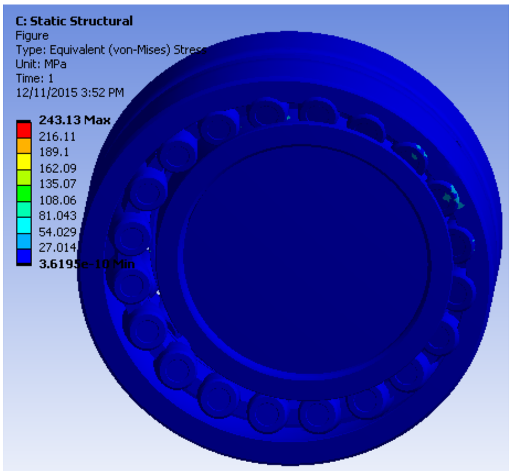

Figure 10. Equivalent stress of the MA spherical roller bearing

In the same way , it was studied other three types of spherical roller bearings, which are MB, C, CA and it was obtained specific results, that will be used later in multiple-criteria decision.

2.3 Multiple-criteria decision

First of all, it was noted the main characteristics for the four types of spherical roller bearings.

Type MA spherical roller bearing:

A1-cage guided by outer ring

A2-with lateral joints on inside ring

A3-massive cage

A4-cage formed by two pieces

A5-central joint on inner ring

A6-brass cage

Type MB spherical roller bearing:

B1- cage guided by central joint on inner ring

A2-with lateral joints on inside ring

B3-normal cage

A4-cage formed by two pieces

A5-with central joint on inner ring

A6-brass cage

Type C spherical roller bearing:

C1-cage guided by guide ring

B2-no lateral joints on inside ring

C3-special cage

A4-cage formed by two bodies

B5-with guide ring

B6-steel cage

Type CA spherical roller bearing:

D1- cage guided by inner ring

A2-with lateral joints on inside ring

A3-massive cage

B4-single-body cage

C5-no central joint on inner ring

A6-brass cage

Then it was synthesized this characteristics to observe better which are common and which are specific (fig. 11).

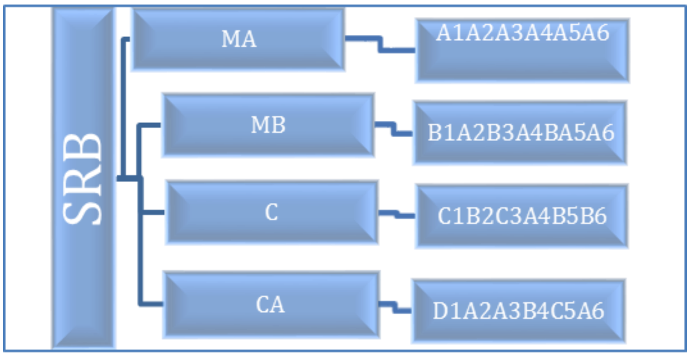

Figure 11. Spherical roller bearings synthesized scheme

The next objective is to combine these characteristics in a certain way that leads us to new and improved versions of spherical roller bearings.

So we built the so called “chart ideas”. (Figure 12)

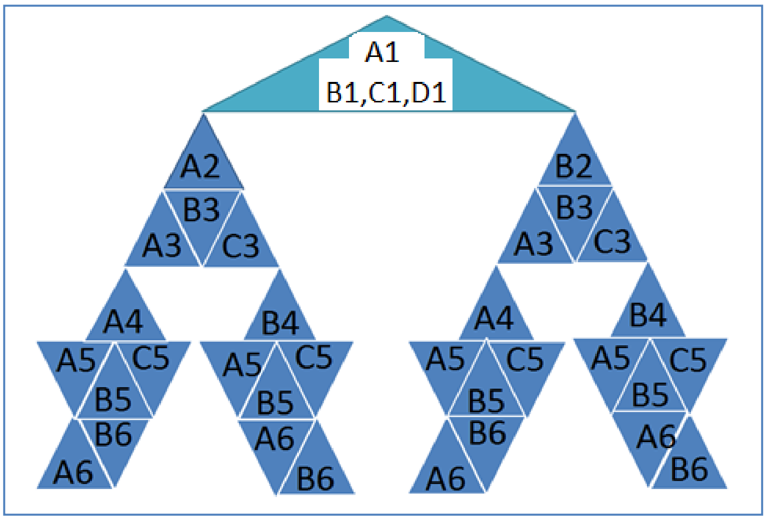

Figure 12. Chart Ideas for spherical roller bearings

Based on this chart, we can obtain 4x2x3x2x3x2=288 versions, but this number will be reduced to 40 versions after we consider some incompatibility conditions:

-guided cage on central joint needs existence of central joint to inner ring (A1≠B5≠C5)

- guided cage on outer ring also needs existence of central joint to inner ring (B1≠B5≠C5)

-guided cage on guide ring needs existence of guide ring (C1≠A5≠C5)

-the guidance of the cage is made exclusive on inner ring (D1≠A5≠B5)

-special cage cannot be used in the presence of lateral joints of inner ring (A2≠C3)

-steel cage is less massive than brass cage (A3≠B6)

-special cage cannot be single-body (B4≠C3)

-the absence of lateral joints of inner ring needs the presence of a cage formed by two bodies (B2≠B4)

Based on the results obtained in Ansys for the four types of spherical roller bearings, it was chosen ten versions of new spherical roller bearings for applying a multiple-criteria decision.

Table 1. Multiple-criteria decision

Criteria/ Type of spherical roller bearing	Resistance to high vibrations	Resistance to high speed	Resistance to high shocks	Resistance to high loads	Optimization of internal geometry	Protection against foreign corps	Resistance to wear and fatigue strength	Resistance to high temperatures	Capacity of lubrication	Feasibi--lity
I)A1A2A3 B4A5A6	0,1	0,1	0,05	0,1	0,15	0,1	0,05	0,15	0,1	0,05
II)A1A2B3 A4A5A6	0,05	0,2	0,05	0,1	0,05	0,05	0,15	0,1	0,1	0,1
III)A1A2B 3A4A5B6	0,15	0,05	0,1	0,05	0,1	0,05	0,1	0,2	0,1	0,1
IV)A1A2B 3B4A5A6	0,1	0,05	0,05	0,2	0,1	0,1	0,05	0,05	0,15	0,05
V)A1A2B 3B4A5B6	0,1	0,1	0,1	0,15	0,05	0,05	0,1	0,1	0,05	0,1
VI)A1B2A 3A4A5A6	0,05	0,15	0,1	0,05	0,1	0,15	0,1	0,05	0,1	0,05
VII)A1B2B 3A4A5A6	0,1	0,05	0,05	0,1	0,2	0,1	0,05	0,05	0,05	0,1
VIII)A1B2 B3A4A5B 6	0,05	0,1	0,15	0,05	0,1	0,1	0,05	0,15	0,1	0,05
IX)A1B2C 3A4A5A6	0,2	0,15	0,25	0,2	0,1	0,2	0,15	0,1	0,2	0,2
X)A1B2C3 A4A5B6	0,1	0,05	0,1	0,05	0,05	0,1	0,2	0,05	0,05	0,2
	1	1	1	1	1	1	1	1	1	1

According to the table, the results are:
I-0,95 , II-0,95 , III-1 , IV-0,9 , V-0,9, VI-0,9 , VII-0,85 VIII-0,9 , IX-1,75 , X-0,95
After all, the new version of spherical roller bearing that we discovered is:

A1-cage guided by outer ring

B2-no lateral joints on inside ring

C3-special cage

A4-cage formed by two bodies

A5-with central joint on inner ring

A6-brass cage

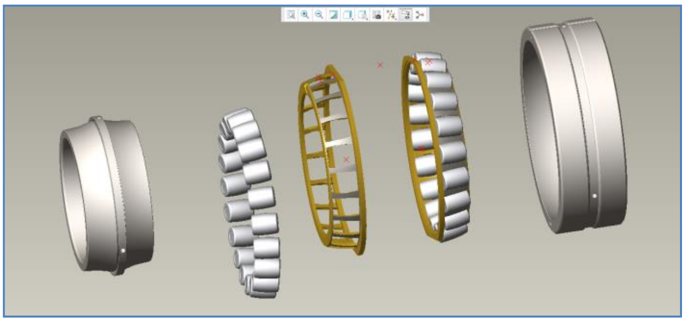

Figure 13. Exploded image of new spherical roller bearing

3. CONCLUSIONS

Even though the Finite Element Analysis can offer practical information about structures behaviour in certain situations, the results of the calculus may offer ambiguous answers to punctual problems.

This matter is meet in analysis of spherical roller bearings because they are defined by complex characteristics. So, to build a proper hypothesis and to obtain the best results, we must define correctly the geometry of the bodies, material properties, the boundary conditions, the variation of the working environment, types of finite analysis.

Also, the Finite Element Analysis simplifies more the mechanical analysis of the spherical roller bearings, comparing to other types of analysis because the software pack is extremely developed to simulate real conditions and finally to offer suitable solutions.

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