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An Analytical Study of Contact Stress and Contact Zone Analysis of Ball Bearings

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Abstract**: This paper reports Contact Stress and Contact Zone Analysis of Ball Bearings using Analytical method. The different combinations of ratios of its outer radius and inner radius i.e. (R_2, R_1) and the elasticity of the material E_1, E_2 have been considered to investigate the compressive stresses (P_0), and the contact zone (a) on the surfaces of the ball bearing. Analytical method is applied for the analysis of both spherical and cylindrical type of Ball Bearing Cavity. The results are compared between both type of bearings and final interpretation has been made.**

Keywords: Contact Stress, Contact Zone, Analytical method, Ball Bearing.

I. INTRODUCTION

In reducing the friction of rotating bodies, ball bearings and roller bearings have made an outstanding contribution. Such bearing have been brought to their present state of perfection only by many years of painstaking research and experiment. Standardization of the many different types and sizes of bearings has been most helpful to the designer. In this context it has been found that the material near the contact zone is very highly stressed , but the stress rapidly diminishes for points some distance away. This surrounding material at low stress is effective in preventing lateral expansion of the highly stressed material. The highly stressed material is thus in the state of plain strain. The ball bearing geometry consists of axial force (P_1), inner radius (R_1), outer radius (R_2), contact zone of the two bearings (a).

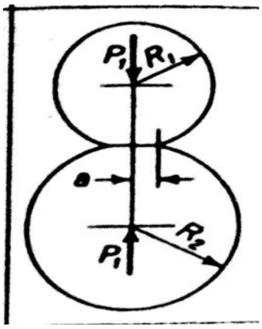

Fig. 1: Schematic diagram for the cylindrical and spherical ball bearing in dynamic condition.

II. LITERATURE REVIEW

Many researchers have carried out the stress & contact analysis , of the ball bearings. M.F.Spot[1] have framed the compressive stress and contact zone equation experimentally for cylindrical and spherical ball bearings in dynamic conditions.Nathan A. Branch [2] The governing mechanisms of fatigue spall propagation in ball bearing inner raceways are investigated through the use of elastic-plastic finite element modeling, X-ray diffraction, and the visual inspection of fatigue spall cracks.

III. PROBLEM, SCOPE & METHODOLOGY

Though the geometry of ball bearing in case of cylindrical contact or spherical contact appears to be same in 2-D structure but there is a wide variation in the amount of maximum compressive stress and contact zone when both this structures are applied in practicality. When two spheres are in contact they form a point contact and when two cylindrical bearings are in contact they form line contact. By keeping the outer radius (R_2) constant and varying the axial load (P_1) and inner radius (R_1) the maximum compressive stress and contact zone have been calculated analytically from the dynamic equation derived by M.F. spot experimentally for the cylindrical and spherical ball bearings.
The scope and methodology for the present work is as follows:

- In the Present research work an approach for the analysis of the ball bearing has been carried out under axial compressive load (axial load of 100N has been considered for analysis) and gradually it has been reduced to study the effects.
- The outer radius have been kept constant R2= 30mm
- The inner radius R1 have been varied as 8, 10, 12, 14, 16, 18, 20 mm respectively
- The values for outer compressive stress for both the spherical and cylindrical ball bearings have been compared using 2D graph and results have been analysed.
- The analytical equation for Cylindrical ball bearing are as follows:

$$P_o = 0.591\sqrt{\frac{PE_1E_2}{(E_1+E_2)}(\frac{1}{R_1}-\frac{1}{R_2})}$$

$$a = 1.076\sqrt{\frac{PR_1R_2}{(R_2-R_1)}(\frac{1}{E_1}+\frac{1}{E_2})}$$

- The analytical equation for Spherical ball bearing are as follows:

$$P_o = 0.616\sqrt[3]{P\left(\frac{1}{R_1}-\frac{1}{R_2}\right)^2\left(\frac{E_1E_2}{E_1+E_2}\right)^2}$$

$$a = 0.883\sqrt[3]{\frac{PR_1R_2}{(R_2-R_1)}\left(\frac{1}{E_1}+\frac{1}{E_2}\right)}$$

Where P_0 is the outer compressive stress and a is contact zone. Further both the types of ball bearings stresses and contact zones have been tabulated and after applying the variations the 2-D graphs are plotted to understand the phenomenon between line contact and point contact.

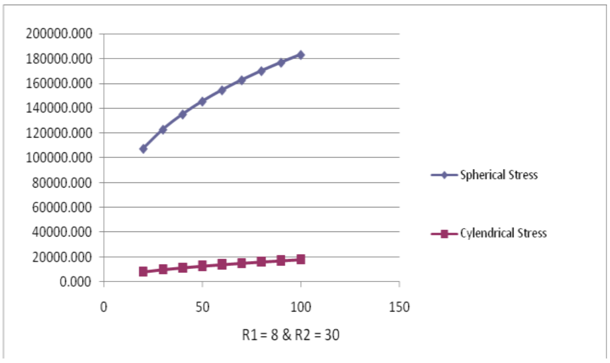

Fig 2 (a): Graph between Spherical & Cylindrical Stresses at R_1=08 & R_2=30

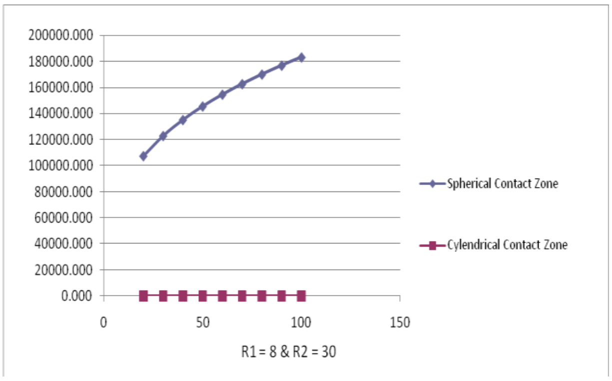

Fig 2 (b): Graph between Spherical & Cylindrical Contact Zone at R_1=08 & R_2=30

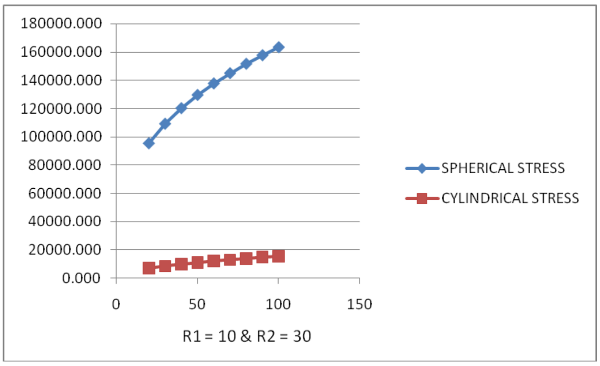

Fig 3 (a): Graph between Spherical & Cylindrical Stresses at R_1=10 & R_2=30

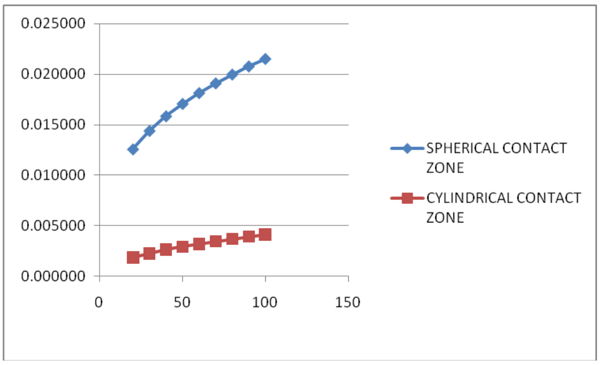

Fig 3 (b): Graph between Spherical & Cylindrical Contact Zone at R_1=10 & R_2=30

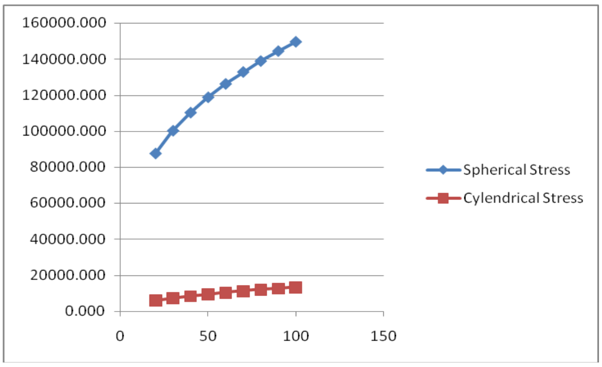

Fig 4 (a): Graph between Spherical & Cylindrical Stresses at R_1=12 & R_2=30

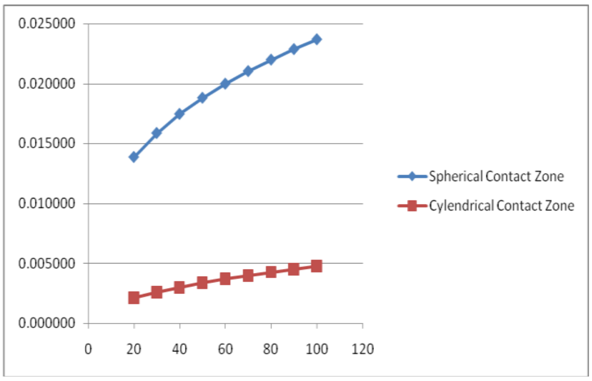

Fig 4 (b): Graph between Spherical & Cylindrical Contact Zone at R_1=12 & R_2=30

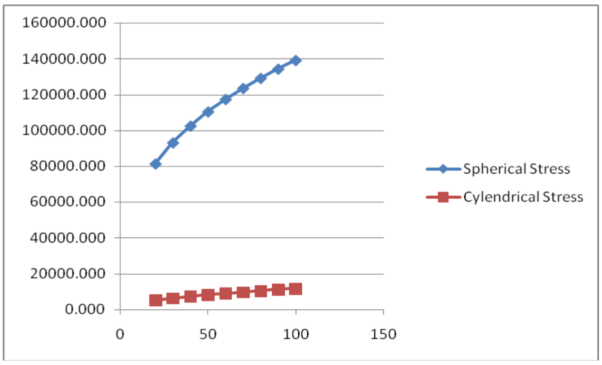

Fig 5 (a): Graph between Spherical & Cylindrical Stresses at R_1=14 & R_2=30

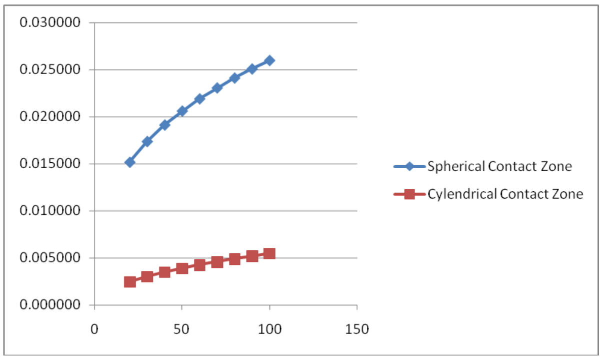

Fig 5 (b): Graph between Spherical & Cylindrical Contact Zone at R_1=14 & R_2=30

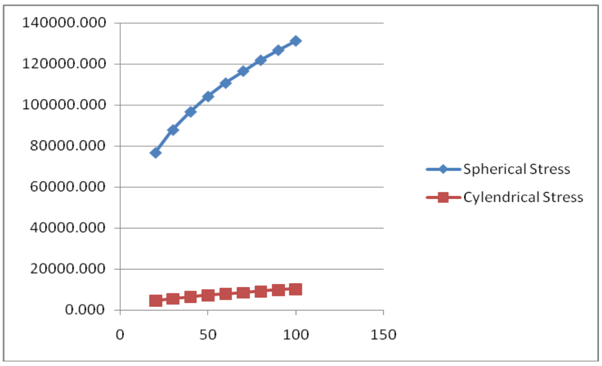

Fig 6 (a): Graph between Spherical & Cylindrical Stresses at R_1=16 & R_2=30

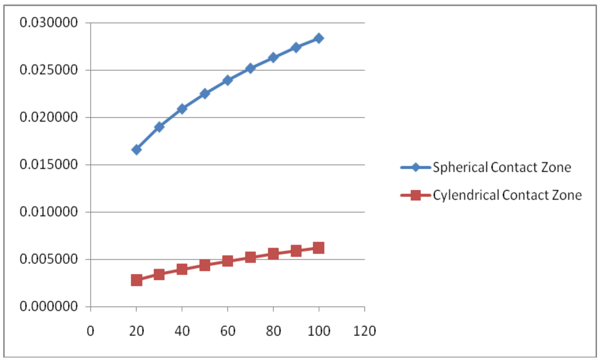

Fig 6 (b): Graph between Spherical & Cylindrical Contact Zone at R_1=16 & R_2=30

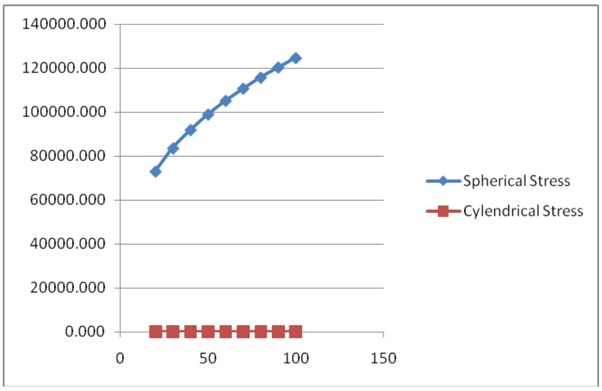

Fig 7 (a): Graph between Spherical & Cylindrical Stresses at R_1=18 & R_2=30

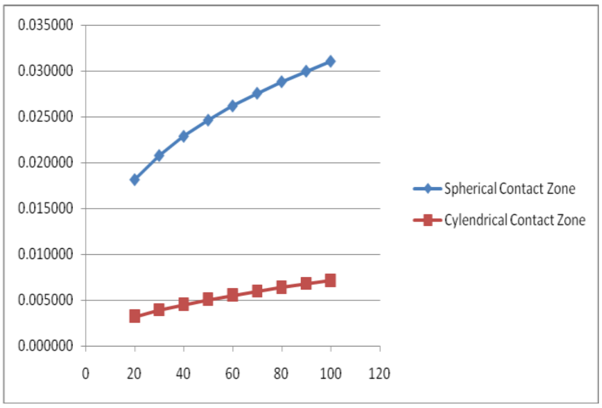

Fig 7 (b): Graph between Spherical & Cylindrical Contact Zone at R_1=18 & R_2=30

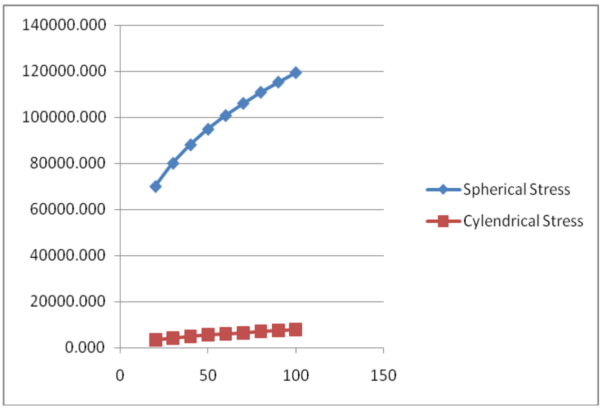

Fig 8 (a): Graph between Spherical & Cylindrical Stresses at R_1=20 & R_2=30

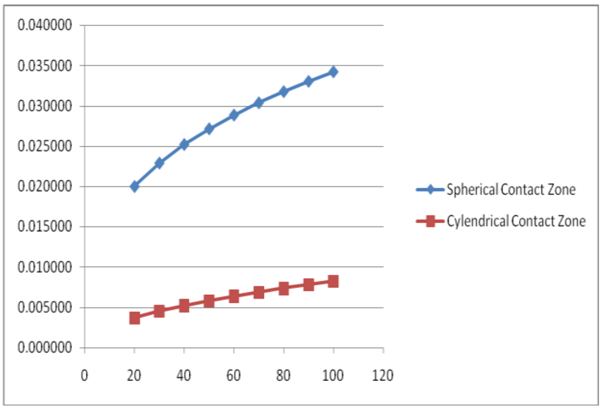

Fig 8 (b): Graph between Spherical & Cylindrical Contact Zone at R_1=20 & R_2=30

IV. RESULTS AND DISCUSSIONS

1. It is observed from figure2 (a) to figure8 (a) that the outer compressive stress for spherical surface ie. Point contact is more than cylindrical surface i.e line contact for same load.
2. It is observed from figure2 (b) to figure8 (b) that the Contact Zone for spherical surface ie. Point contact is more than cylindrical surface i.e line contact for same load.

3. It is observed from figure2 (a) to figure8 (a) that the outer compressive stress for spherical surface ie. Point contact and cylindrical surface i.e line contact can be reduced for same load by increasing the inner radius R1.
4. It is observed from figure2 (b) to figure8 (b) that the Contact Zone for spherical surface ie. Point contact and cylindrical surface i.e line contact can be reduced for same load by increasing the inner radius R1.
5. Finally it has been observed that cylindrical surface i.e line contact gives better results in comparison to spherical surface i.e point contact. So it is suggested to use line contact in case of heavy loading condition of bearing whereas in lightly loading condition of bearing point contact can be used.

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