IJRAR.ORG E-ISSN: 2348-1269, P-ISSN: 2349-5138

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYTICAL REVIEWS (IJRAR) | IJRAR.ORG

An International Open Access, Peer-reviewed, Refereed Journal

Numerical Analysis of Wear of deformation of Piston ring Seal using Bio-Fiber Composite Materials

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***Abstract*—** Positive Displacement Pumps are widely used in domestic irrigation purpose as well as industrial applications. They are considered as positive displacement pumps. This pump works on the principle of Single slider crank mechanism which consist of cylinder ad and piston. The piston slides inside the cylinder creating the pressure**.** Piston rings are widely applied to seal the clearance between the piston and cylinder in reciprocating machines such as reciprocating compressors, internal combustion engines and pumps. The wear of piston seal leads to leak of pumps. Hence in this study, the wear behaviour of piston seal material is studied. The piston seal is made of Nitrile rubber, PTFE or polymer. The alternate material of glass fiber and carbon fiber is studied. The wear test is conducted on Pin on Disc testings.

Keywords: Piston Seal, Bamboo fiber, Areca Fiber

I. INTRODUCTION

1.1 Reciprocating Pump :

Figure 1.2 Reciprocating pump [2]

Reciprocating pumps are classified according to how the water comes in contact with the piston, namely single-acting (water is in contact with one side of the piston) and double-acting (water is in contact with both sides of the piston) reciprocating pumps. Reciprocating pumps are commonly used in oil field operations in pneumatic pressure systems and in fluid storage areas where the surface pressure is more significant than atmospheric pressure.The reciprocating pump is powered by an electric motor. For completeness, the operation of the reciprocating pump depends on the crank connection movement, which rotates in a clockwise direction [3]. The Working Principle of Reciprocating Pump Is states as: During the motion of the piston from left to right (see the fig given above.) a partial vacuum is created inside the cylinder. Because of this low pressure water will rise from well through suction tube and fill the cylinder by forcing to open the suction valve. This operation is known as suction stroke. (Motion of piston from left to right) [4]

Table 1 Specifications of Pump

Parameter	Value
Suction	25 mm
Delivery	1 9 mm
Output	1730 LPH
Suction Lift	7 mtrs
Total Head	36 mtrs
Motor Required	0.375 KW
Pump Bore	40 mm
Pump stroke	40 mm
Pump Speed	250 RPM

1.2 Piston Ring Seal :

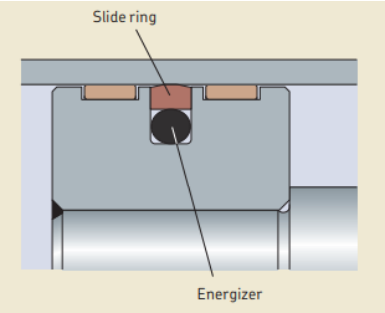

Figure 2. Arrangement of Piston Ring Seal [8]

Piston seals maintain sealing contact in sliding motion between the piston and the cylinder bore. Differential pressures acting on the piston to extend or retract the piston rod can be in excess of 400 bar (5 800 psi). The pressure acting on the piston seal increases contact forces between the piston seal and cylinder surface. Therefore, the surface properties of the sealing surfaces are critical to proper seal performance Piston seals are typically classified into single-acting (pressure acting on one side only) and double-acting (pressure acting on both sides) seals.

II MATERIALS:

2.1*PTFE :*

Figure 3. Piston Seal of PTFE Material

.PTFE materials and filled grades of PTFE, It is essential to understand that even under a heading like “carbon filled PTFE”, we have many further variables. Materials can be manipulated to offer particular property improvements over others. Even the base grade of PTFE used can display dramatic variations in physical properties and material performance.

2.2Bamboo Fiber :

Figure 3. Bamboo Plants

Bamboo is one of the fastest growing plants in the world, due to a unique rhizome dependent system. Certain species of bamboo can grow 910 mm (36 in) within a 24-hour period, at a rate of almost 40 mm (1 1⁄2 in) an hour (a growth around 1 mm every 90 seconds, or 1 inch every 40 minutes).Giant bamboos are the largest members of the grass family.It is not only used in conventional textile but also it is very useful for high performance end uses as a composite material due to high tensile strength, durability, stability.

2.3 Areca Fiber :

Figure 4.Areca Fiber

The areca husk is a hard fibrous material covering the endosperm and constitutes about 60–80% of the total weight and volume of the areca fruit. The husk fiber is composed of 55.82% cellulose, 34.28% hemicelluloses, 6.82% lignin 1.80% moisture content and 1.28% ash content. The nuts contain 8-12% of fat, which can be extracted and used for confectionery purposes. The refined fat is harder than cocoa butter and can be used for blending.The medicinal properties were described by Vagbhata (in 4th Century AD) as effective against leucoderma, leprosy, cough, fits, worms anemia, obesity.Further, arecanut also shows medicinal value in the following lines however these values are yet to be exploited for commercial

1. Methods and Finite Element Analysis :

3.1. Solid Modelling of Component :

In order to initiate for Finite Element Analysis, the component is first prepared in Creo software using all the dimensions of the component. The component model is illustrated in figure 5.

Figure 5. Software Model Bucket type piston ring

3.2. Component Imported in Ansys :

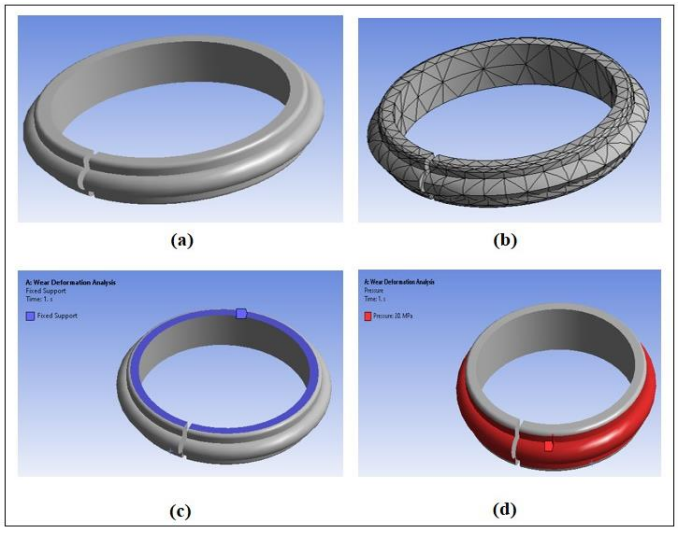

Figure 6. Finite Element Analysis Methodology

The Piston seal(figure 6a) is first modelled in the Creo software of Version 2.0. The Creo file is further saved in IGES (The Initial Graphics Exchange Specification) format which enables to export the model. Meshing of piston (as shown in figure 6b) is an integral part of the engineering simulation process where complex geometries are divided into simple elements that can be used as discrete local approximations of the larger domain. Mesh generation is the practice of creating a mesh, a subdivision of a continuous geometric space into discrete geometric and topological cells. The piston seal is resting on the bottom and upper section of the chamber, hence for analysis purpose; it is kept fixed as shown in the figure 6c. When the pump is in working condition, the piston surface faces the pressure which is developed inside the cylinder. Hence for the same, the piston seal is applied with pressure as shown in figure 6d.

3.3. Finite Element Analysis of Piston Seal Made of PTFE :

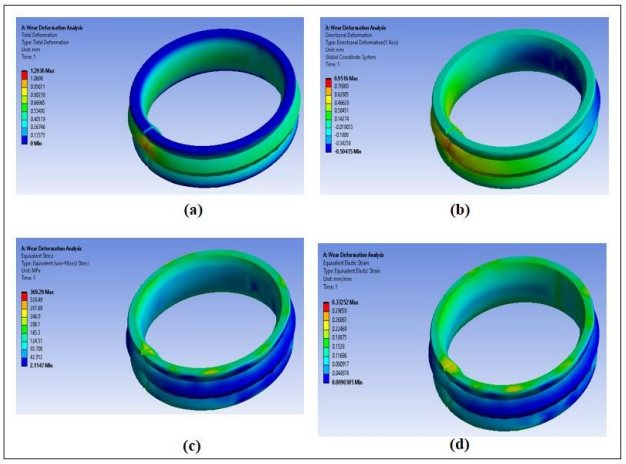

Figure 7. Finite Element Analysis of Piston Seal made of PTFE

The seal is subjected to loading of contact pressure with material properties of PTFE. The maximum deformation (Figure 7a) is obtained to be 1.20 mm with directional deformation as 0.95mm (Figure 7b) . The Eq. Stress and Strain for PTFE is obtained to be 366 MPa (Figure 7c) and 0.33 (Figure 7d) respectively.

3.4. Finite Element Analysis of Piston Seal Made of Bamboo Fiber Material :

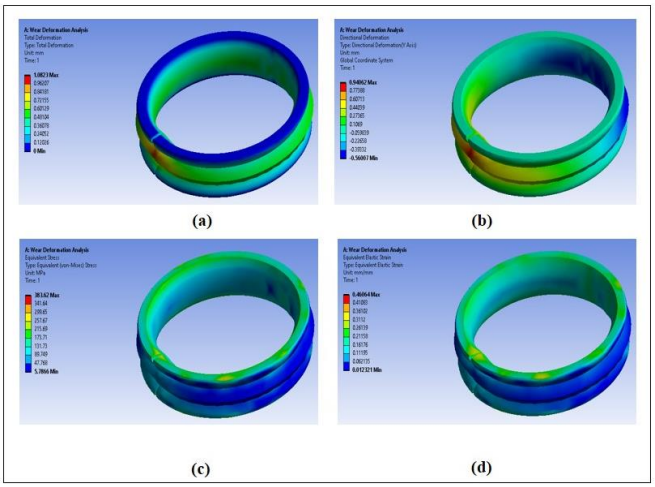

Figure 8. Finite Element Analysis of Piston Seal made of Bamboo Fiber

The seal is subjected to loading of contact pressure with material properties of Bamboo fiber. The maximum deformation is obtained to be 1.08 mm (Figure 8a) with directional deformation as 0.94mm (Figure 8b). The Eq. Stress and Strain for Bamboo is obtained to be 383 MPa (Figure 8c) and 0.46 (Figure 8d) respectively.

3.5. Finite Element Analysis of Piston Seal Made of Bamboo Fiber Material :

The maximum deformation is obtained to be 2.38 mm (Figure 9a) with directional deformation as 1.85 mm (Figure 9b) The Eq. Stress and Strain for Bamboo is obtained to be 424 MPa (figure9c) and 0.62 (figure 9d) respectively.

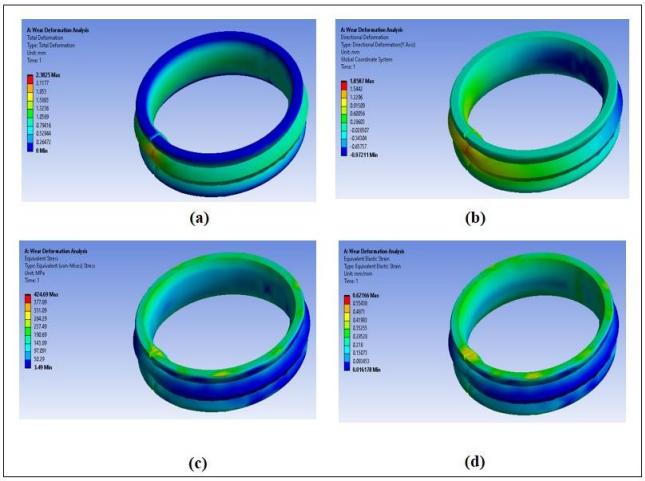

Figure 9. Finite Element Analysis of Piston Seal made of Areca Fiber

2. Result and Discussions :

4.1. Response Analysis of Total Deformation :

As explained in the figure 10 it is evident that the maximum deformation is achieved by Areca fiber of 2.38mm followed by PTFE with 1.20mm and the least is obtained by Bamboo material with 1.08mm. Hence in this criteria, the bamboo fiber proves to be slightly better than Areca and PTFE materials.

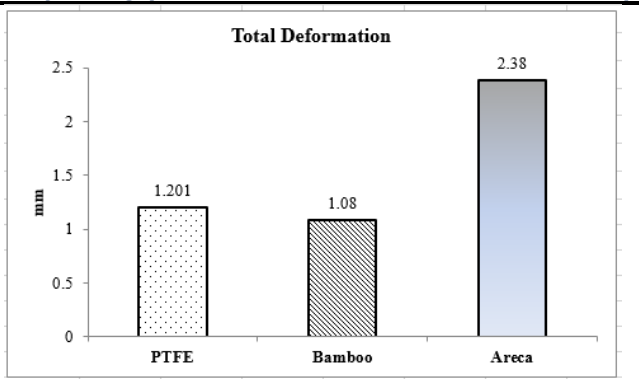

Figure 10. Comparative analysis of Total Deformation in Simulative Condition

4.2. Response Analysis of Directional Deformation :

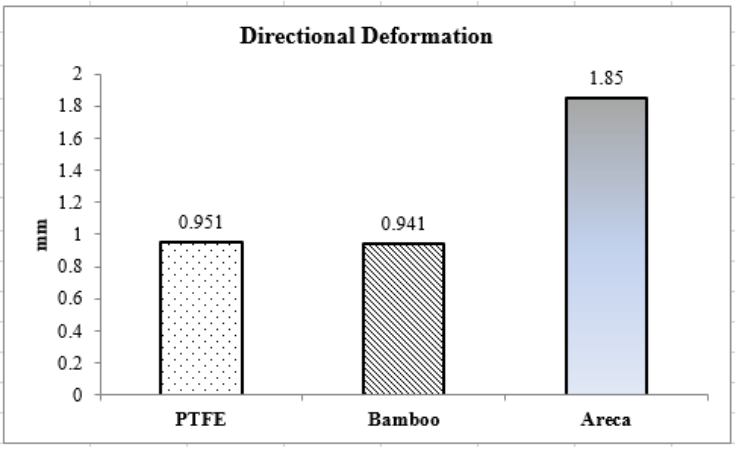

Figure 11. Comparative analysis of Directional Deformation in Simulative Condition

The deformation of material is used as wear deformation. The maximum deformation is achieved by Areca fiber of 1.85mm followed by PTFE with 0.951 mm and the least is obtained by Bamboo material with 0.941 mm. In consideration of directional deformation criteria, the bamboo fiber can sustain the wear as more as that of PTFE materials.

4.3. Equivalent Stress and Strain :

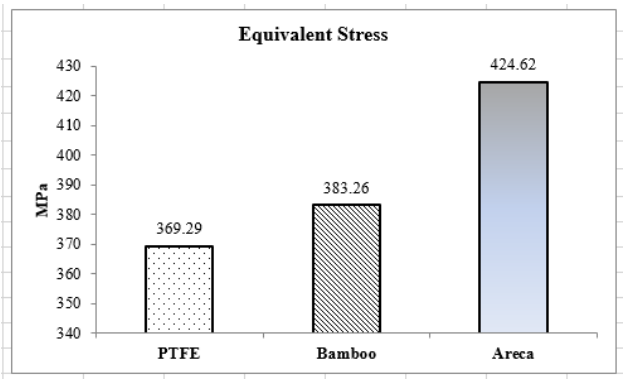

Figure 12. Comparative analysis of Equivalent Stress in Simulative Condition

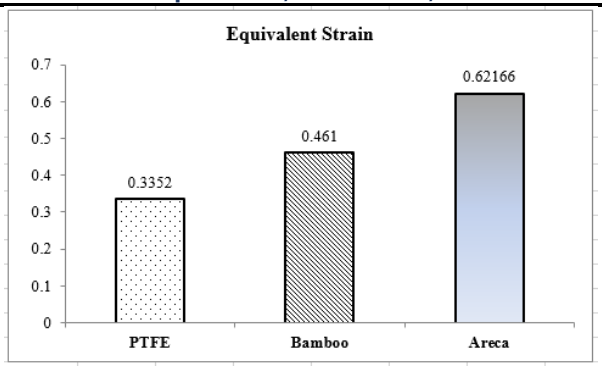

Figure 13. Comparative analysis of Equivalent Strain in Simulative Condition

For the strength criteria, the maximum stress is generated in Areca fiber composites and the least is generated in Bamboo Fiber composite. In both the criteria of stress and strain, bamboo showed better results than of PTFE.

VII. CONCLUSION

- The simulation approach is done to calculate the results in more than one approach.
- The Simulation is done for all the materials to validate the results with experimentation. The deformation is measured by simulation and the wear volume is determined with help of mathematical equations.
- In all the process, Bamboo fiber shown the best possible results amongst all.
- A Successful approach is determined for determination of Frictional resistance for Bamboo and Areca, a Natural fiber base composite material alternately for PTFE.
- The Areca fiber, if filled with fillers of Titanium oxide, Alumina Oxide or Zinc oxide, can prove to better than PTFE.
- Hence there is future scope in the research work to conduct the wear testing of the materials using the bio fibres with the fillers as mentioned above.

ACKNOWLEDGMENT

It is with a great satisfaction and euphoria that I am submitting Project report on **"Study of wear rate Investigation of Piston ring seal of Positive displacement pump using composite material".** I completed this as a part of curriculum activity. First of all i thank my guide and other who directed me to this subject and give me the opportunity to give over seminar report on it. I am also thankful to other teachers of mechanical department who gave me proper guidance. I avail this opportunity to express mine sincere gratitude towards **Prof. Thakare V.R.**,HOD in mechanical department, for permitting me to this opportunity.

I am also thankful to **Prof. Dr. Yadav D.M.**, our principal and **Prof. Thakare V.R.** ,ME Coordinator of mechanical department.

Last but not the least am also thankful to all the teacher and staff member of mechanical engineering department who directly and indirectly give their expert guidance throughout during work of seminar.

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