Alternate material for pressure cooker gasket

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Abstract. The use of Gasket or sealing ring is one of the most important and just less than a perfect method to prevent leakage of fluids both during the static and dynamic condition. Moreover, the subject of using natural or organic materials has gained prime importance amongst both designers and researchers to reduce environmental impact. This study focuses on the design and Analysis of gasket material which has a combination of Latex and Natural Fibres. Significant areas where gaskets are used have thermal and pressure force as a boundary condition, which demands the need for various sealing ring material. The model of Gaskets is prepared as per standards in SOLIDWORKS 2016 Comparison based on equivalent stress, deformation, thermal expansion, thermal stress and strain are done between Silicon rubber and natural composite materials in ANSYS workbench 18.2. The model was analysed between three materials which are Silicon rubber, Latex and Banana fibres, Latex and Coconut coir. Mathematical interpolation is used to obtain various mechanical properties of the natural Fibre using volume fraction. The critical properties considered for the Analysis are young’s modulus, the thermal expansion coefficient of the Natural Fibres

1. Introduction
A gasket is a mechanical component that is fitted between two or more components to prevent leakage of the fluids around the fitting. The word gasket is derived from the field of mechanics’ engines. Gaskets are mainly classified based on their applications; they are mostly Metals, Non-Metals, Polymers, Hybrid. They are generally made from flat material, a sheet such as a paper, rubber, Silicon metal cork, neoprene, Silicon rubber etc. Different applications of Gasket are an example of advancement in the fields of technology. However, progress is being realized in this particular domain of application; it has also brought the hazard of Non-Biodegradability of rubber gasket materials [1]. The gaskets find themselves useful for mainly thermal and pressure-based applications which have made rubber as the first choice among all other materials. Rubber has excellent mechanical properties, and if adequately vulcanized by adding certain chemicals they prove out to be stand-alone for gaskets material selection since they have resilient nature, they are intensively used in the area of compression. Since rubber is used, safety hazards are drastically reduced from the perspective of the application, but it is harmful to the environment because of its non-biodegradable property [2].

Therefore, the most important concern for researchers and industrialist is to use environmentally friendly materials without compromising the performance and quality of the product. The solution is to use biodegradable material which is obtained from natural and renewable resources. The primary reason for choosing fibrous content in composites is valid from the previous researches done, which
states that with increase in the fibre content in the composites the flexural strength also increased significantly [3,4]. The other reason to choose a natural fibres over epoxy(matrix) is that the coefficient of thermal expansion (CTE) is greater than the fibres. Therefore by increasing the fibre content the CTE is reduced considerably [5,6]. Due to these factors plant Fibres and reinforced composites are receiving more considerable attention.

1.1 Gasket
It is a component that made of elastic material which is used to provide sealing between two mating components. Figure 1 shows pressure cooker gasket model. It is circular in a section at the front view, and we can observe notch from the side view that is being fitted between two parts.

2. Problem statement
Use of gaskets has been extensive, but along with this, there comes the drawback of the material not being degradable, therefore the need to use natural fibres has gained prime importance. Therefore, an attempt to replace the non-biodegradable gasket material with natural composite materials is made in this paper

3. Methodology
Below is the procedure from the design phase to simulation for pressure cooker gasket with the help of tools like Solid works and ANSYS Workbench

3.1 Design of Gasket
The pressure cooker gasket has an outer diameter of 190mm, the internal diameter of 150mm and thickness of 3mm as shown in Figure 2. The model is converted from circular into linear for ease of embedding fibres. The length of linear model is equal to that of circumference of gasket.
3.1.1 Material properties

| Properties                  | Silicon Rubber[10] | Latex[7] | Banana Fibre[8] | Coconut Coir[9] |
|-----------------------------|--------------------|----------|-----------------|-----------------|
| Density (kg/m$^3$)          | 2300               | 950      | 1350            | 670             |
| Young’s modulus (GPa)       | 0.05               | 0.1      | 1.785           | 22              |
| Poisson ratio               | 0.49               | 0.3      | 0.28            | 0.3             |
| Thermal Conductivity (W/m-k)| 0.2                | 0.15     | 0.044           | 0.143           |

3.2 Formulas for theoretical approach

$\Delta l = \alpha \cdot \Delta T \cdot l$ (1)

Where:
- $\alpha$ = Coefficient of thermal expansion
- $\Delta l$ = Change in length
- $l$ = Total Length

$\sigma = E \cdot \alpha \cdot \Delta T$ (2)

Where:
- $E$ = Young’s modulus
- $\alpha$ = Coefficient of thermal expansion
- $\Delta T$ = Change in temperature between the room and working temperature

$\sigma_t = PD/2t$ (3)

Where:
- $P$ = Pressure
- $D$ = Diameter
- $t$ = thickness

$\varepsilon = \Delta l / l$ (4)

Where:
- $L$ = length
- $\sigma$ = hoop stress
- $\varepsilon$ = Thermal strain
4. Simulation study
The model was imported in the geometry section of Ansys workbench as shown in Figure 3.

![Geometry from ANSYS workbench](image1)

**Figure 3.** Geometry from ANSYS workbench

4.1 Type of Analysis
Static structural and thermal analysis was carried out on the gasket model to find the various results. Figures 4, 5, and 6 represent analysis system for the selected combination of materials.

![Static structural and Thermal Analysis for Silicon rubber](image2)

**Figure 4.** Static structural and Thermal Analysis for Silicon rubber
4.2 Mesh generation

Figure 5. Static structural and Thermal Analysis for Latex with Banana Fibre

Figure 6. Static structural and Thermal Analysis for Latex with Coconut Coir

Figure 7. Generated Mesh
From the above statistics as shown in Table 2, it is an evident fact that a higher number of nodes and elements are obtained at finer element sizes (29.78 mm). The results obtained are more accurate when the number of nodes and elements is more. On the other hand, it takes more computational time when the numbers of nodes are more.

To improve and check the convergence of the results, two methods were used:

a) H-type: This method refers to the change in the global element size set during the meshing process either by increasing or decreasing the element size without changing the nature of mesh used in simulations which may or may not convergence the results[11,12].

b) P-type: This method focuses on the mesh type used in the Analysis keeping the element size the same, which means the order of the elements is changed. Higher-order implies more accurate results but takes noticeably more computational time[13,14].

Considering the change in mesh size as shown in Figure 7, deformation was observed. And there was no noticeable change in deformation observed in 5 iterations over a range of 20mm to 35mm element size; hence that concludes that the results are converged.

The following types are used to infer regarding the convergence and accuracy, in this Analysis, hence the H type method of convergence is being used.

4.3 Pre-processing for simulation

a) Static structural analysis
As shown in Figure 8 for Static structural analysis, one side of gasket is fixed, and the load of 50N is applied on the other surface.

| Element size (mm) | Tetragonal |  |
|-------------------|------------|--|
|                   | Elements   | Nodes   |
| 35                | 6094       | 10282   |
| 29.78             | 4881       | 8374    |
| 20                | 5399       | 9317    |

Table 2. Statistics for the model

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a) Static structural analysis
As shown in Figure 8 for Static structural analysis, one side of gasket is fixed, and the load of 50N is applied on the other surface.
b) Thermal analysis
As shown in Figure 9 for Thermal Analysis, the convection boundary condition is applied to one surface considering the application to be boiling of water with $h=22\,^\circ\text{C}$.

![](image1.png)

**Figure 9.** Temperature boundary conditions for thermal Analysis

5. Results and discussion
As per loading and boundary conditions following results have been obtained from ANSYS workbench.

5.1 Static structural analysis
The individual Analysis was carried out on all the materials, as mentioned in Table 1.

Case 1: Stress variations observed in different selected combination of materials as shown in Figure 10.

![](image2.png)

**Figure 10.** static stress induced in material a) Silicone rubber b) Latex with banana fibre c) latex with coconut coir(20%) d) latex with coconut coir(50%)
Case 2: Strain variations observed in different selected combination of materials as shown in Figure 11

![Figure 11: static strain in material a) Silicone rubber b) Latex with banana fibre c) Latex with coconut coir(20%) d) Latex with coconut coir(50%)](image)

Case 3: Deformations observed in different selected combination of materials as shown in Figure 12

![Figure 12: Deformation in material a) Silicone rubber b) Latex with banana fibre c) Latex with coconut coir(20%) d) Latex with coconut coir(50%)](image)
5.2 Thermal analysis

Case 1: Thermal stress variation observed in different combination of materials as shown in Figure 13

Figure 13. Thermal stress induced in material a) Silicone rubber b) Latex with banana fibre c) Latex with coconut coir(20%) d) Latex with coconut coir(50%)

Case 2: Thermal strain observed in different combination of materials as shown in Figure 14

Figure 14: Thermal strain induced in material a) Silicone rubber b) Latex with banana fibre c) Latex with coconut coir(20%) d) Latex with coconut coir(50%)
Case 3: Thermal deformation observed in different combination of materials as shown in Figure 15

![Figure 15: Thermal deformation induced in material](image)

**Figure 15**: Thermal deformation induced in material a) Silicone rubber b) Latex with banana fibre c) Latex with coconut coir (20%) d) Latex with coconut coir (50%)

### 5.3 Results

| Material                                  | Static Stress in MPa | Static strain | Deformation in mm | Thermal stress in MPa | Thermal strain | Thermal deformation in mm |
|-------------------------------------------|----------------------|---------------|-------------------|------------------------|----------------|--------------------------|
| Silicon Rubber                            | 1.91                 | 0.0512        | 6.0012            | 3.677                  | 0.0750         | 0.6158                   |
| Latex with banana fibre                   | 0.3325               | 0.0019        | 0.0114            | 111.8                  | 0.0658         | 0.6043                   |
| Latex with coconut coir (20% by volume)   | 11.09                | 0.062         | 1.32              | 103.46                 | 0.1483         | 0.1832                   |
| Latex with coconut coir (50% by volume)   | 0.567                | 0.0013        | 0.0059            | 77.25                  | 0.4319         | 0.0624                   |

Table 3. ANSYS Results[15]
### Table 4. Comparison of ANSYS and Theoretical Results[16,17]

| Material                              | Thermal Stress | Thermal Deformation |                  |                  |                  |
|---------------------------------------|----------------|---------------------|------------------|------------------|------------------|
|                                       | Theoretical    | Analytical          | % error          | Theoretical      | Analytical       | % error          |
| Silicon Rubber                        | 27.9552        | 3.677               | 40.4             | 0.149            | 0.6158           | 34.23            |
| Latex with banana fibre               | 777.67         | 111.8               | 21.58            | 4.41             | 0.6043           | 27.18            |
| Latex with coconut coir (20% by volume)| 60.192        | 103.46              | 41.8             | 3.2              | 1.32             | 25.7             |
| Latex with coconut coir (50% by volume)| 49.104        | 77.25               | 35.97            | 0.00435          | 0.06249          | 31.1             |

Note: The following variation in %error, as shown in Table 4, is obtained, since the theoretical values are not calculated considering all the factors affecting during thermal boundary conditions. The theoretical values are obtained based on mathematical interpolation and regression and applied mechanics.

### 6. Conclusion

Analysis of the following natural composites are carried out to determine the static and thermal feasibility of materials. After the analysis results are obtained as shown in Table 3, the results were compared with the silicon rubber. It is found that under static conditions the material composite of latex and banana fiber and latex coconut coir (50%) shown better results than silicon rubber, but fail to withstand thermal boundary conditions. Conclusively from the result we can also state that with increase in the volume fraction of coconut coir in the composite exhibits similar trends as that of silicon rubber though not equivalent to that of silicon rubber.

Therefore with the following analysis performed, it could optimistically be concluded that replacement of silicon rubber for gasket could be possible with further treatment, property enhancement for the combination of latex and coconut coir.

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