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DESIGN AND ANALYSIS OF CYLINDER HEAD GASKET OF OIL ENGINE

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Abstract- The gas leakages from the engine can affect the overall performance of the engine during operation. The proper pre-stressing force of the bolts as well as the multi-layer head gasket design is critical factors for efficiency of engine. So to accurately calculate the stresses in Multi-Layer Steel (MLS) head gasket analysis for the normal and relative shear motions between cylinder head and gasket, gasket and block, as well as between gasket layers have to be understand in the analytical model. In this study, an analytical method was developed to effectively calculate the MLS head gasket stresses during engine operating condition. The gasket sealing between the cylinder head and the cylinder block it's totally depending on pre-stressing forces of bolts. Therefore, the applied approach of the pre-stressing force is significant for the calculation of the numerical simulation. In the analysis model, each layer of the MLS head gasket is modeled in CREO PARAMETRIC 2.0 using GASKET element, analyze by ANSYS SOFTWAR, and the GASKET element layers were stacked together according to the configuration of the head gasket. Due to the physical modeling of each gasket layer in the stacked GASKET element model, the relative shear motion between gasket layers can be analyze. Analysis, mating & meshing criterions along with comparison of results with the mathematical calculations to achieve maximum strength with minimum weight & cost.
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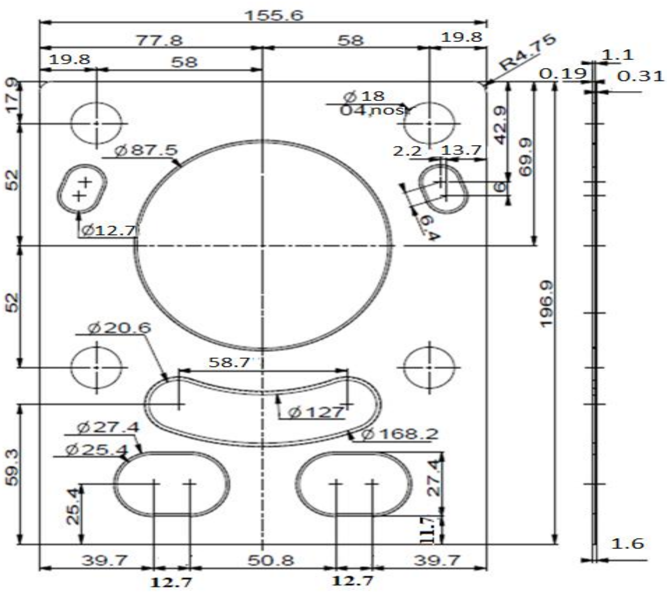
Keywords- *Gasket, Material, Engine , Modeling, Thermal Stress Analysis*

I. INTRODUCTION

Its purpose is to provide a gas tight seal between the cylinder(s), the water jackets, oil passages and the ambient air, liquids and gases. The area of the gasket around the cylinder must be robust enough to withstand the same pressures that are exerted on the pistons while ensuring that there is no leakage of coolant or combustion gases among the three volumes. It must be able to accomplish this at all engine temperature and pressures without function, as a failure of the engine gasket usually results in a failure of the full engine. The complex arrangement of components in the diesel engine is often joined together with the help of gaskets. The gaskets serve as seals to prevent the leakage of the various fluids and gases in the oil engines but these seals do wear out with constant usage of the engines. Additionally the constant heating and cooling creates expansion and contraction that is detrimental to the various seals. Leakage of gases through these seals can cause minor or very dangerous oil leak which might cause serious accidents or incident.

II. MODELING OF NEW DESIGN



New Design

Here the given model is new gasket model. In which material is change to copper – Asbestos – Copper.

2 Mathematical calculations for new design:

2.1 Material Properties for new design:-

The materials used here in the new design are copper and asbestos. Here we have three layer of gasket in which top layer-copper, Middle- Asbestos and Bottom-copper. The properties for the both are as given below.

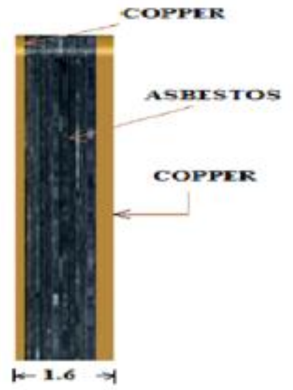


Figure: 2.1 Material-Layer of new gasket

- **Material Data:-**

The three layer gasket is used for the analysis.

1. **1st Layer- Copper-0.0122 inch**
2. **2nd Layer- Asbestos-0.0433 ± 0.004 inch**
3. **3rd Layer- Copper-0.0074 inch**

2.2 Calculation of total area of New gasket:-

New DESIGN DATA				
SR NO.	**NOMENCLATURE**	**PARTUCULARS**	**VALUE**	**UOM**
1	A1	Surface Area Top	19095.30	mm²
2	A2	Surface Area Bottom	19095.30	mm²
3	A3	Surface Area Bore	6010.16	mm²
4	A4	Surface Area Of Bolts(4)	961.63	mm²
5	A5	Surface Area Of Water Inlets	755.67	mm²
6	A6	Surface Area Of Water Inlets	720.90	mm²
7	A7	Surface area of oil inlets	146.27	mm²
		Force exerted TOTAL AREA	19095.30	mm²

Table 2.1: Area of New gasket

(1) STRESS & FORCE CALCULATION:

- By pre-stressing of the bolts **Force acting on the new gasket given by below table.**

SR	**SYMBOL**	**FORCE TYPE**	**VALUE(Kg)**	**VALUE(N)**
1	W1	Weight Of Top Layer	0.05	0.49
2	W2	Weight Of Middle Layer	0.15	1.42
3	W3	Weight Of Bottom Layer	0.01	0.11
4	M	Clamping Force	1911.31	18750.00

Table 2.2: Values of different parameters

- As here the force acting on different layer as given below.

DIFFERENT FORCE ACTING ON DIFFERENT LAYER				
SR.	**PARTICULAR**	**TYPE OF FORCE**	**VALUE**	**UOM**
1	Layer-1	Cylinder Clamping Force	75000	N
2	Layer-2	Cylinder Clamping Force+ Wight-1	75000.49	N
3	Layer-3	Cylinder Clamping Force+(Wight-1)+(Weight-2)	75000.98	N

Table 2.3: Different layer wise force

- As here the total force acting on gasket given below. In which one bolt generates 18KN force so here 4 bolts being used to tighten up the gasket so we have the below total force:

No Of Bolts	4
Total Force For Calculations	75000.00 N
Area	19095.30 mm^2

Now as know that here total three layer assembly selected in gasket element. So here are the calculations for the different layer as given below.

STRESS CALCULATION ON SAME LOAD		
Stress	3.927668	Total Stress In Gasket - N/mm^2
Stress-1	3.92766806	Stress of Layer – 1 N/mm^2
Stress-2	3.927693752	Stress of Layer – 2 N/mm^2
Stress-3	3.927719439	Stress of Layer – 3 N/mm^2

Table 2.4: Different layer wise stress

So the stress generated in the gasket element calculates by below equation.

$$\sigma = \frac{F}{A}$$

$$= \frac{75000.00}{19095.30}$$

$$= 3.92\ N/mm^2$$

Because of the pre stressing of 4 bolts of 18mm here getting the stress generated in the new gasket element is **3.92 N/mm^2**

2.3 Thermal calculation: In the case of new gasket design there is material used as copper. So in copper as the thermal stress produces due temperature condition we find in this section.

- The heat loss in the new gasket is given by below,
- **Heat loss,**

$$Q = \frac{K \times A \times \Delta T}{Dt} \quad [17]$$

Where: Q: Heat Loss (W)
A: Area of gasket element (mm^2)
t1: Max Thickness (mm)
t2: Min Thickness (mm)
T1: Outside temperature©
T2: Inside Temperature©
K: Thermal conductivity

HEAT TRANSFER BY CONDUCTION ACROSS THE BODY OF NEW GASKET				
SR.NO	**SYMBOL**	**PARTICULARS**	**VALUE**	**UOM**
1	**t1**	First layer thickness	0.31	mm
2	**t2**	Second layer thickness	1.1	mm
3	**t3**	Third Layer Thickness	0.19	mm
4	**Ri**	INSIDE RADIOUS	43.8	mm

5	**K1**	Thermal conductivity (Al)(L-1)	401	W/M.K
6	**K2**	Thermal conductivity (ASBTS)(L-2)	2.07	W/M.K
7	**K3**	Thermal conductivity (Al)(L-3)	401	W/M.K
8	**A1**	Area (L1)	$5.22*10^{-5}$	M^2
9	**A2**	Area(L2)	$3.022*10^{-5}$	M^2
10	**A3**	Area(L3)	$8.51*10^{-5}$	M^2
11	**Q**	HEAT LOSS	212.96	W/M
12	**F**	Total Force exerted	75000.00	N
13	**σ**	Stress generated	3.92	N/mm^2
14	**N**	NO OF LAYERS	3	NOS

Table 2.4: Thermal data of Gasket element

2.4 Thermal stress and strains for gasket:-

Thermal strains are strains that develop when a material is heated or cooled. The temperature distribution in the material can be obtained with appropriate boundary conditions. From the generalized Hooke's law, the strain components of the element including the thermal strains are listed as follows:

So for new material we can get the thermal stress in the new gasket as per the directions available in below figure.

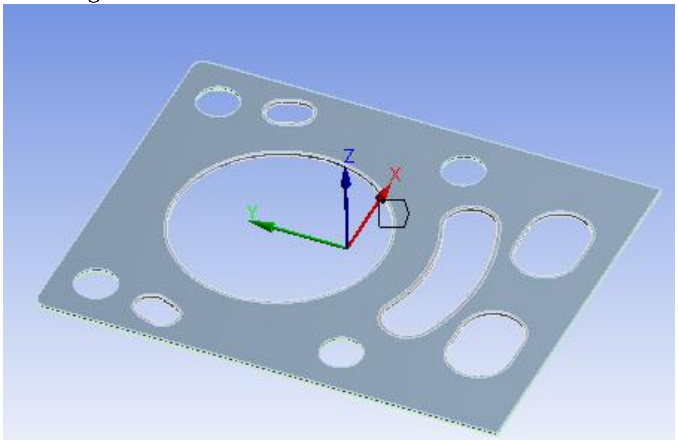


Figure 2.4: All Directions of gasket axis

- Thermal Strain equations are,

$$\varepsilon_x = [\sigma_x - v(\sigma_y + \sigma_z)]/E + \alpha\Delta T$$ [14]
$$\varepsilon_y = [\sigma_y - v(\sigma_z + \sigma_x)]/E + \alpha\Delta T$$ [14]
$$\varepsilon_z = [\sigma_z - v(\sigma_x + \sigma_y)]/E + \alpha\Delta T$$ [14]

WHERE, σ = Normal Stress
∊= **Thermal Strain**
E= Young's Modulus of Elasticity
V= Poison's Ratio
α = Co- Efficient Of Thermal Expansion
ΔT=Incremental Temperature

Here from this equation the thermal strain can be found as below.

$\sigma_x=F_x/A$	0	N/mm2
$\sigma_y = F_y/A$	0.000	N/mm2
$\sigma_z = F_z/A$	3.92	N/mm2
E=	69000	Mpa
v =	0.33	
α =	0.000018	k-1
ΔT=	1030	^0C

Table 2.5: Strain calculation data for new design

(a) Thermal strain in X-direction

$$\varepsilon_x = [\sigma_x - v(\sigma_y + \sigma_z)]/E + \alpha\Delta T$$
$$= [0 - 0.33(3.92 + 0)]/ 69000 + 0.000018*1030$$
$$= 0.018521$$

(b) Thermal strain in Y-direction

$$\varepsilon_y = [\sigma_y - v(\sigma_z + \sigma_x)]/E + \alpha\Delta T$$
$$= [0 - 0.33 (3.92 + 0)]/ 69000 + 0.000018*1030$$
$$= 0.018521$$

(c) Thermal strain in Z-direction

$$\varepsilon_z = [\sigma_z - v(\sigma_x + \sigma_y)]/E + \alpha\Delta T$$
$$= [3.92 - 0.33(0 + 0)]/ 69000 + 0.000018*1030$$
$$= 0.018483$$

From these we can get the total thermal strain produces in gasket because of temperature generated inside engine.

As the total thermal stress for new gasket,

$$б = \text{Thermal Strain} * \text{Young's Modulus Of Elasticity}$$
$$= \epsilon * E$$
$$= 0.055525693 * 69000$$
$$= 3831.273\ N/mm^2$$

III. ANSYS BASED ANALYSIS OF Gasket

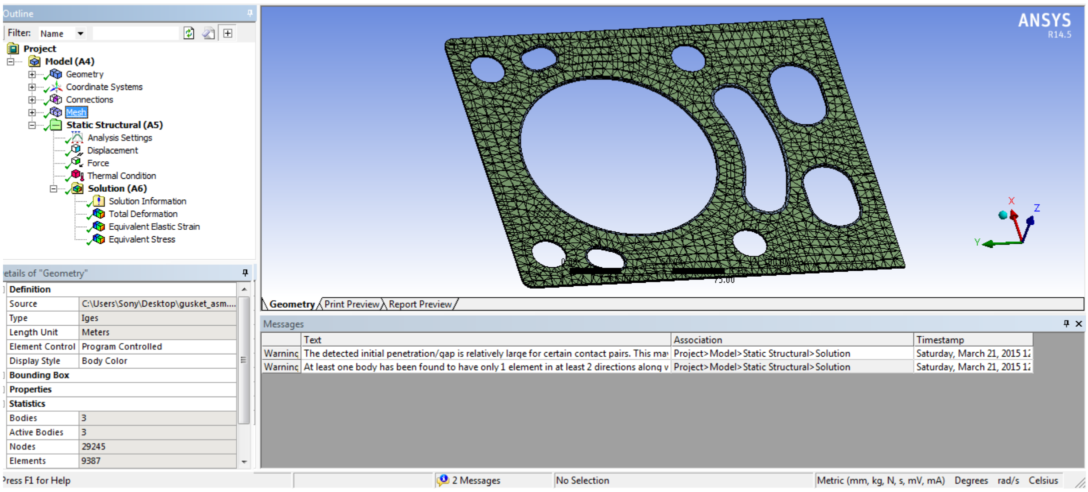


Figure 3.1: Mesh Generation in Gasket Element

3.1 Loading condition of Gasket Element

Force acting due to pre-stressed the bolt to the gasket. Here one bolt exerted the force is 18750.00 N. Total 4 bolts are used to tight the gasket. So total force exerted on gasket is 75000 N.

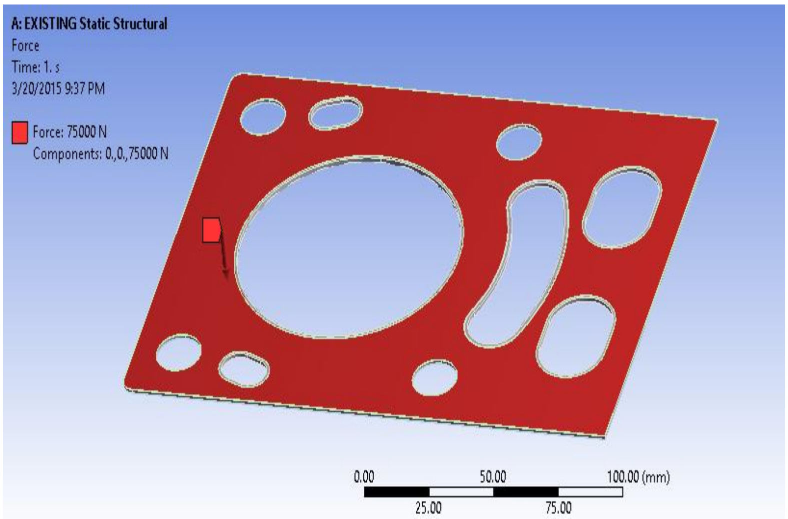


Figure 3.1: Loading conditions in Gasket element

3.2 Displacement of existing gasket design:

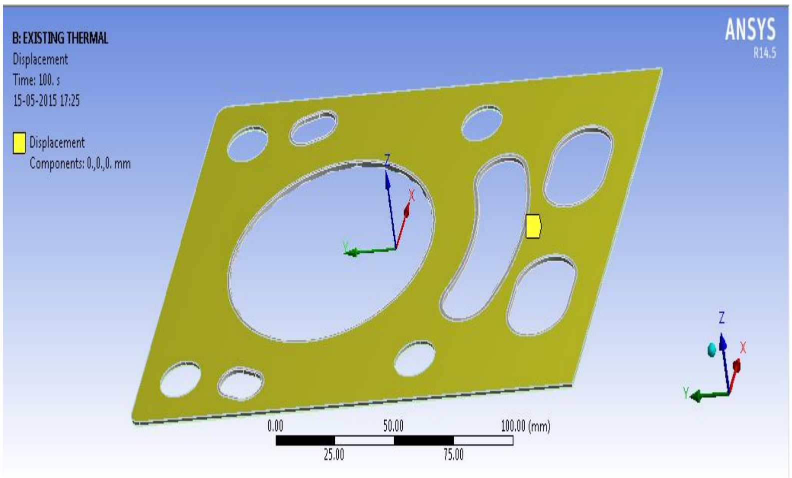


Figure 3.2: Displacement of existing gasket design

3.3 Thermal condition for existing gasket design:

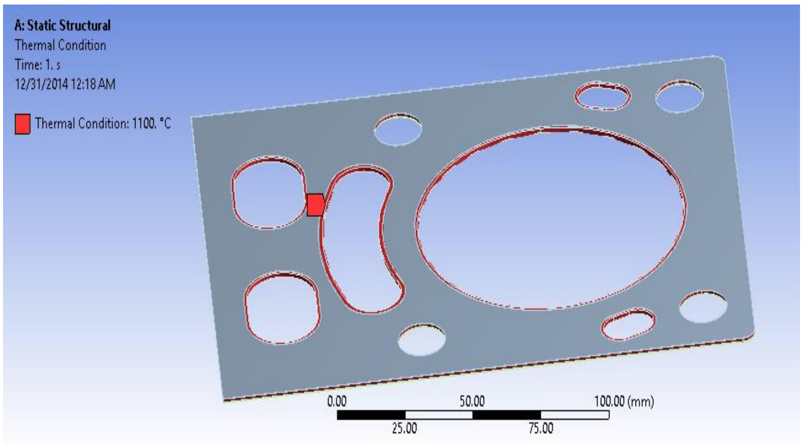


Figure 3.3: Thermal condition for gasket element

3.4 Analysis of Newgasket Model:

3.4.1 Total deformation due to loading and thermal condition:

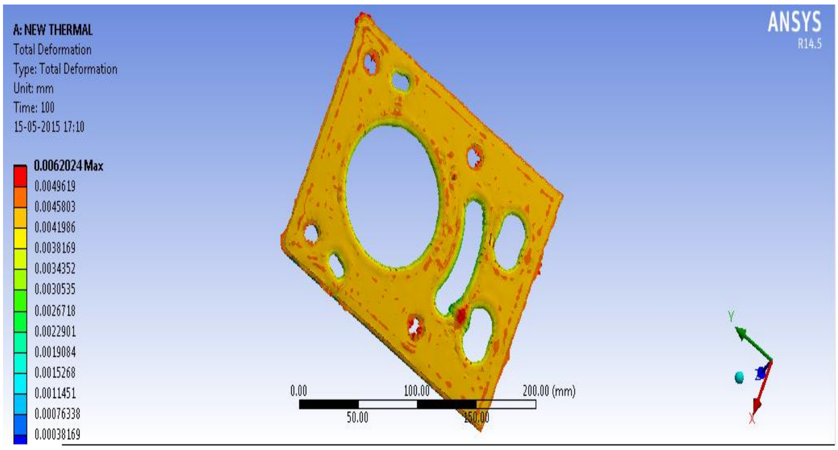


Figure 3.4.1: Total stress due to Loading and thermal

- The total deformation 0.00620 mm due to both loading and thermal condition in new design of copper.

3.4.2 Total strain due to loading and thermal condition:

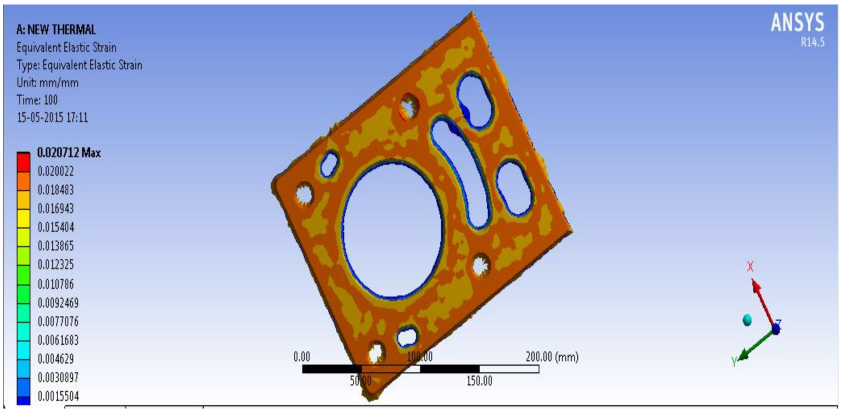


Figure 3.4.2: Total strain due to loading and thermal condition

- The Total strain due to loading and thermal condition is 0.020712.

3.4.3 Total thermal stress due to loading and thermal condition:

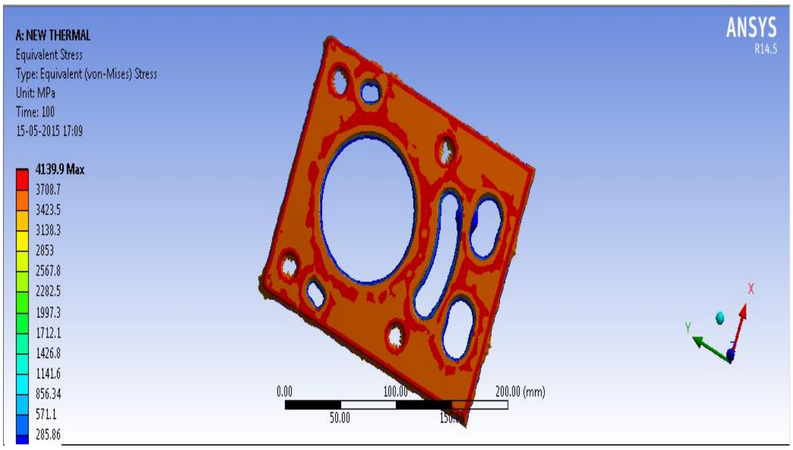


Figure 3.4.3: Total thermal stress due to loading and thermal condition

- Total thermal stress is 4139.9 N/mm^2 due to both loading and thermal condition.

IV. VALIDATION

A working model is manufactured based on the creo parametric model, during trial run for various measurements are taken and Ansys analysis is carried out to validate the assembly against basic requirement.

4.1 Results of mathematical calculations due to loading and thermal conditions both for gasket:

Here the loading is 75 KN generated on gasket element. And also the temperature is 1100^{0}C generated inside the engine.

The both conditions are crucial for gasket to withstand in assembly and increases reliability.

Because of these conditions the thermal stress generated in old and new gasket is as given below.

RESULT COMPARISON OF MATHEMATICAL CALCULATION FOR BOTH DESIGNS (N/mm^2)	
Stress Generated In Existing Design Of Gasket (Aluminium-Asbestos-Aluminium)	4684.113
Stress Generated In New Design Of Gasket (Copper-Asbestos-Copper)	3831.273

Table 4.1: Mathematical values Comparison of new and old design

Here we can see that the results obtain for Copper from the mathematical calculations of thermal stress is better than the Aluminium material.

In which the thermal stress generated in copper is 3831.273 N/mm^2. So in copper material thermal stress is reduced by 852.22 N/mm^2.

4.2 Results of Analysis due to loading and thermal conditions both for gasket:

In ANSYS work-bench 14.5 the all analysis was being performed. In ANSYS loading of 75 KN and temperature of 1100^{0}C was being applied on gasket element for both new and old design.

The results of both the designs are as given below in table.

RESULT COMPARISON OF THERMAL STRESS FOR BOTH DESIGNS (N/mm^2)	
Stress Generated In Existing Design Of Gasket (Aluminium-Asbestos-Aluminium)	4768.2
Stress Generated In New Design Of Gasket (Copper-Asbestos-Copper)	4139.8

Table 4.2: ANSYS RESULTS Comparison of new and old design

Here we can see that the results obtain for Copper from the ANSYS for thermal stress is better than the Aluminium material.

In which the thermal stress generated in copper is 4139.8 N/mm^2. So in copper material thermal stress is reduced by 628.2 N/mm^2.

4.3 Comparison of Reliability of both New and Old designs of gasket:

In the way of calculating reliability of the new gasket we can't get it without practical.

In Calculation we can see that the new gasket has less thermal stresses values than old gasket.

In which the thermal stress value of new gasket design is 4684 N/mm^2 and old design thermal stresses value is 3831 N/mm^2.

Also the temperature effect with static loading only being affected on gasket element reliability there is no such effect only because of static loading condition. Because the value of static loading 3.92 N/mm^2 is too low.

RESULT COMPARISON OF RELIABILITY FOR BOTH DESIGNS	
Existing Design Of Gasket (Aluminium-Asbestos-Aluminium)	90%
New Design Of Gasket (Copper-Asbestos-Copper)	More than 90%

Table 4.3: Reliability results Comparison of new and old design

Here we can see that the in reliability comparison the copper based new design has higher reliability than the aluminium based old design.

So now we can see say that the new gasket element is better than the older gasket and also new gasket having good reliability than the older one.

From all the comparison based on all the results we can conclude that the new design of copper material is better than the older design.

Also the Copper –Fiber-Copper material for gasket element in air cooler engine is not possible. Because there is 1100^{0}C temperature is generated and as we can see that in below table boiling point of fiber is too low.

	Aluminium	**Copper**	**Asbestos**
Appearance	Silver gray metallic	Red orange Metallic luster	Silver gray
Melting Point	933.7 K (660 ^{0}C)	1357.77 K (1084 ^{0}C)	1500^{0}C
Boiling Point	2470^{0}C	2562 ^{0}C	3500^{0}C
Density	2.70 g cm^{-2}	8.96 g cm^{-2}	-
Heat of Fusion	10.71 kJ mol^{-1}	13.26 kJ mol^{-1}	-
Heat of Vaporization	284 kJ mol^{-1}	300.4 kJ mol^{-1}	-
Strength	167 Mpa	369 Mpa	9997 Mpa

V. CONCLUSION

5.1 CONCLUSION

The main aim of this research is to switch over to the advancing design concepts based on design from the traditional approaches. This research is giving throughout analysis of proposed design for the replaced aluminum in the copper. As existing design give lots of causes and failure. And here we have new development of new design give less failure effects. Here with the application, strength criteria is analyzed with the new design by considering alternating thermal stress decent results then the previous existing material.

Cost comparison:

Material	**Cost(Rs.)**
Old Gasket(Aluminium)	**38**
New Gasket(Copper)	**42**

0

5.2 FUTURE DIRECTIONS OF RESEARCH

As a future scope, this snapping concept is used in other applications like air cooler, water cooler we can change the material by this concept and get the good reliability of new gasket materials.

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