Design and Analysis of Bimetallic Piston

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***Abstract*-The main objective is to develop a bimetallic piston, which can be used in automotive applications. In the initial study, a 3D model of bimetallic piston, was developed in solid works and in the second study, FEA (Structural and thermal) was done on bimetallic piston, considering different material combinations. Finally parameter study was done to choose the best combination of materials that is used to produce a machinable, durable bimetallic piston.**

Keywords: **Bimetallic piston, Finite element analysis, Temperature distribution.**

I. INTRODUCTION

1.1 Literature review

Maraka Veerendra Yadav et al. [1] performed analysis on two different models of bimetallic pistons considering engine operating conditions with different material combinations and analysed thermal stress distribution, thermal deformation. **Pepakayala Varaprasadet al. [2]** performed structural analysis on regular and bimetallic piston considering boundary conditions. The parameters like von misses stress and displacement were obtained from ANSYS software. **Dnyaneshwar.V.Bhandane et al. [3]** performed thermal analysis on bimetallic connecting rod with bush and analysed thermal stress distribution by altering different bushing materials. **Yenugupalli Anil Kumar et al. [4]** modelled regular, bimetallic, trimetallic piston and performed couple field analysis to determine the thermal deformation, based on this results design modifications are done to minimize the stress and deformation in bimetallic and trimetallic piston. **A. R. Bhagat et al.[5]** describes the thermal stress distribution of piston considering real engine condition during combustion process**.**

1.2 Reference Model: Yamaha Fz-16

Engine type	Air Cooled, 4 Stroke, 2 valve, single cylinder (153 cc , SOHC
Type	SI Engine
Compression Ratio	9.5:1
Maximum Power	12.81HP@ 9.61KW @8000 RPM
Maximum Torque	12.98N-M@6000
Bore	57.3mm
Stroke	57.9mm
Maximum gas pressure	8 MPa

Table no.1

II. BIMETALLIC PISTON

Bimetal refers to an object that is composed of two separate metals joined together. Instead of being a mixture of two or more metals, like alloys, bimetallic objects consist of layers of different metals. Trimetal and tetra metal refer to objects composed of three and four separate metals respectively.

Bimetal Piston refers to an automobile component that is composed of two separate metals joined together.

2.1 Methodology

- To design the bimetallic piston for a petrol engine.
- To geometrically model the bimetallic piston as per the dimensions generated from the process of design procedure followed.
- To analyse the equivalent stress due to gas pressure acting on the top surface of piston head.
- To analyse the equivalent stress using FEA approach for study.
- To analyse the temperature distribution all along the length of the piston.

2.2 Geometric modelling of piston

The bimetallic piston is designed based on empirical calculations and designed structure is to be validated by the numerical methods. In this section the modelling of bimetallic piston is done by using commercial student version modelling software and the material properties used for analytical methods are used for the same finite element modelling.

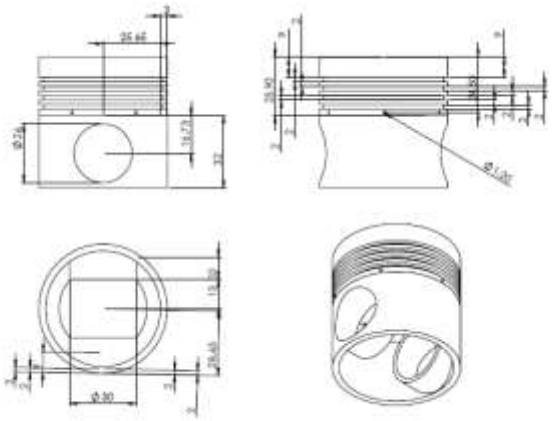

Fig.1 Bimetallic piston 2D Views

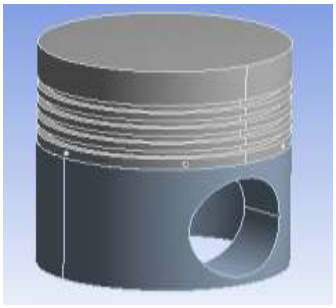

Fig.2 Bimetallic piston 3D Model (Piston Head: Cast carbon steel, Piston Skirt: Al4032- T6)

2.3 Static structural analysis of the bi-metallic piston

Static structural analysis of bimetallic was done using the finite element analysis approach. The static structural analysis of the bimetallic piston was done using ANSYS workbench to evaluate the different stresses and deformations under static loading conditions. Finite element analysis involves four main steps to solve any physics problem using ANSYS software (http://www.ANSYS.COM).

1. Preliminary decisions:

   a. Analysis type : static structural analysis

   b. CAD data : three-dimensional solid model

   c. Element type : Solid183

2. Pre-processing

   a. Define material:

      Piston Head: Cast carbon steel

      Piston Skirt: Al4032- T6

   b. Import geometry

3. Solution

   a. Apply load: load and boundary conditions applied as per engine specification

4. Post processing

   a. Total deformation

   b. Von Mises stress

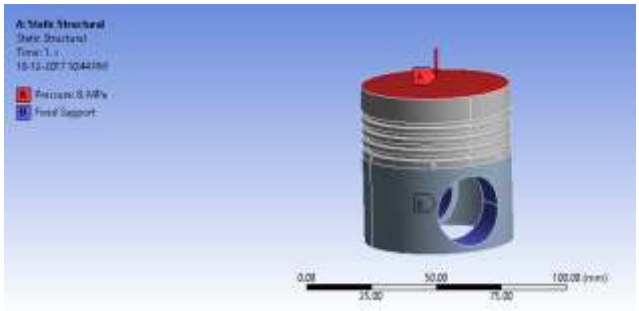

Fig.3 Boundary conditions

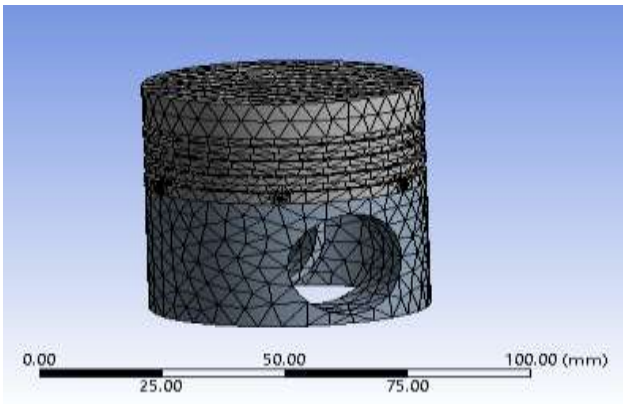

Fig.4 Geometry of mesh

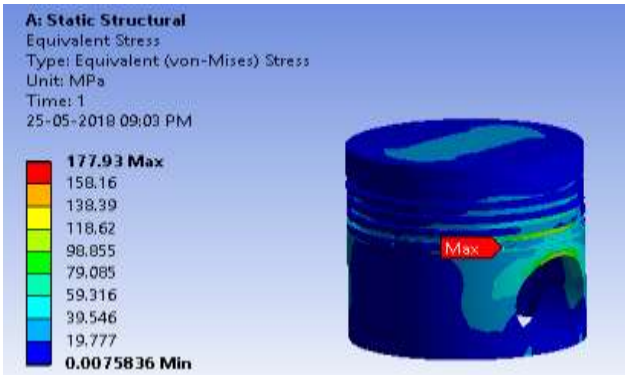

Fig.5 Equivalent stress

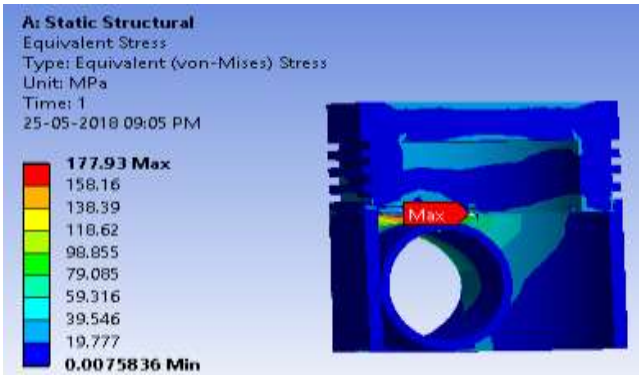

Fig.6 Equivalent stress (Cut sectional view)

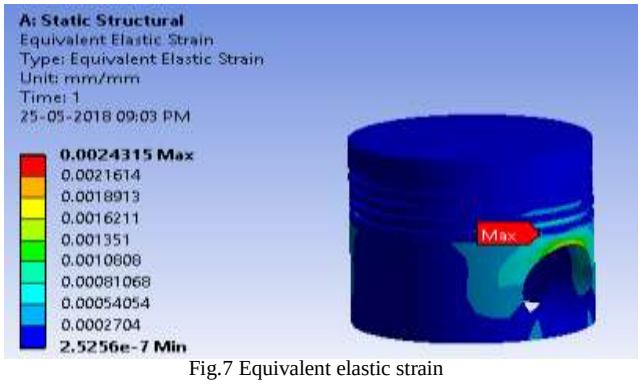

Fig.7 Equivalent elastic strain

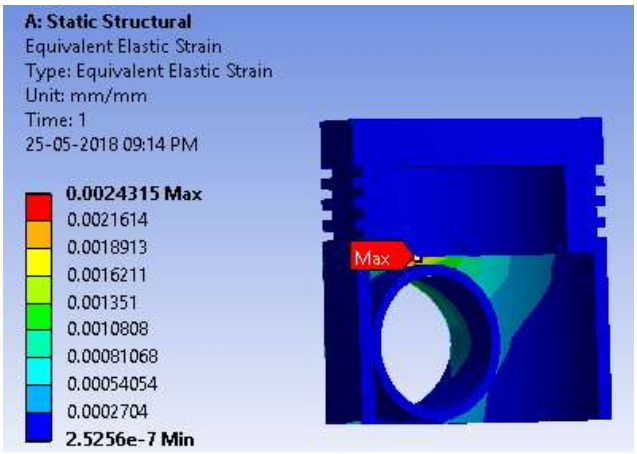

Fig.8 Equivalent elastic strain (Cut sectional view)

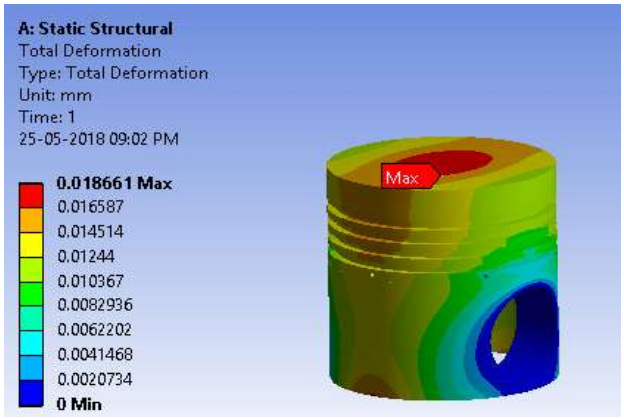

Fig.9 Total deformation

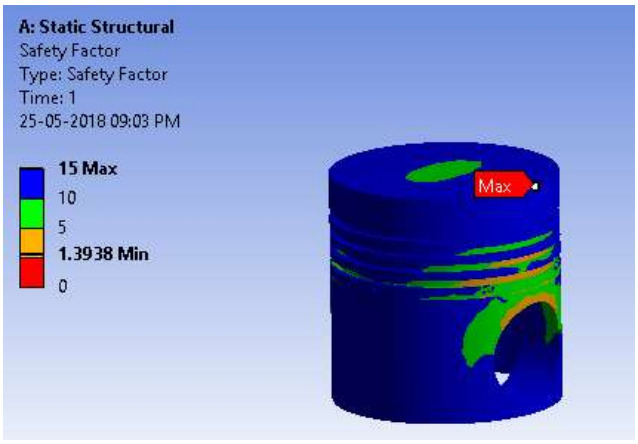

Fig.10 Safety Factor

2.4 Bimetallic piston static structural case study:

S.NO	Piston head material	Piston skirt material	Equivalent stress (Mpa)	Deformation (mm)
Case-1	Al-2219-T87	Al-2618-T61	195.22	0.03562
Case-2	Al-2219-T87	Al-4032-T6	167.61	0.036184
Case-3	Cast carbon steel	Al-4032-T6	177.93	0.018661
Case-4	Cast carbon steel	Cast alloy steel	204.48	0.012939

Table no.2: Bimetallic piston case study

2.5 Analysis of case study:

From table 2, it is found that in case 3(Piston Head: Cast carbon steel Piston Skirt: Al4032- T6) the value of equivalent stress and deformation is less when compared to remaining cases.

2.6 Thermal analysis of Bimetallic Piston:

The Bimetallic piston is divided into the areas defined by a series of grooves for sealing rings. The boundary conditions for mechanical simulation were defined as the temperature loads acting on the entire piston surface.

It is necessary to load certain data on material that refer to thermal properties. The temperature load is applied on different areas. The regions like piston head and piston ring regions are applied with large amount of heat (270 °C). The convection values on the piston wall ranges from 350 W/mK to 600 W/mK.

1. Preliminary decisions

2. Pre-processing

3. Solution

4. Post processing

1. Preliminary decisions:

a. Analysis type : Thermal analysis

b. CAD data : three-dimensional solid model

c. Element type : Solid183

2. Pre-processing

a. Define material:

Piston skirt-Aluminium alloy, Piston head - cast carbon steel

b. Import geometry

3. Solution

a. Apply load: load and boundary conditions applied as per engine specification

b. Solve: linear analysis physics problem

4. Post processing

a. Temperature

b. Total heat flux

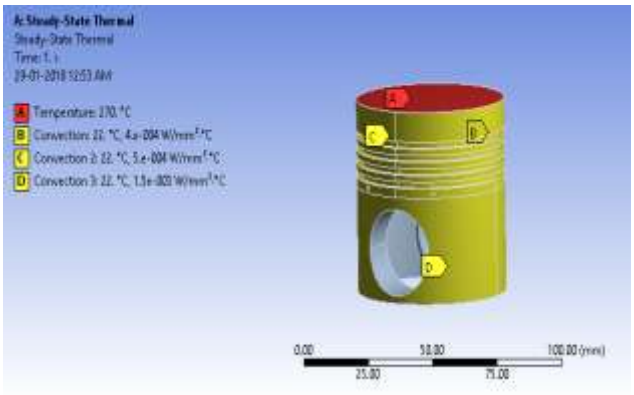

Fig.11 Thermal boundary conditions

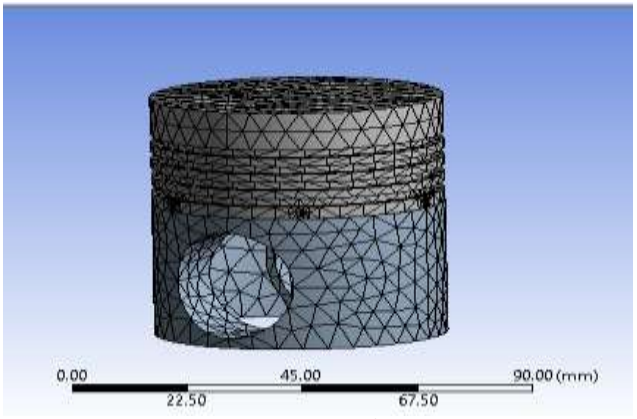

Fig.12 Geometry of mesh

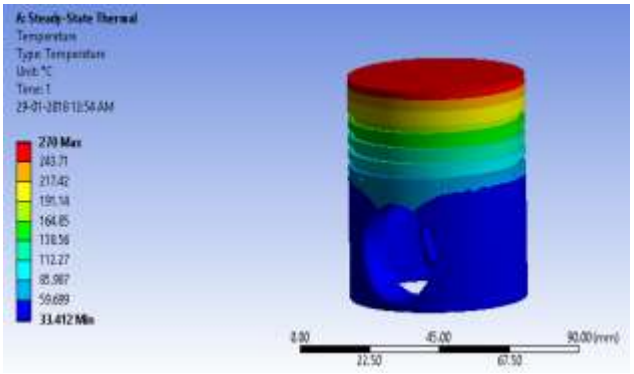

Fig.13 Temperature distribution

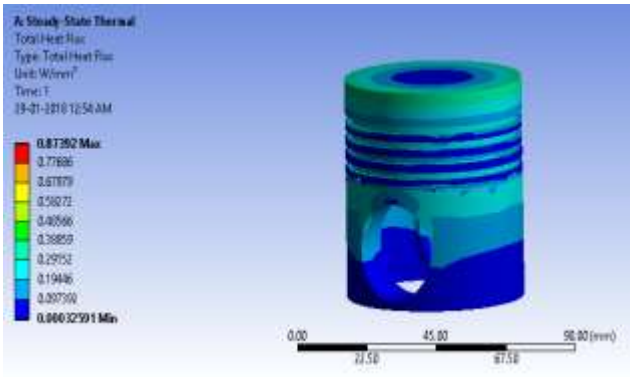

Fig.14 Total heat flux

2.7 Bimetallic piston thermal analysis case study

S.NO	Piston head material	Piston skirt material	Temperature distribution (Max-Min) °c	Total Heat flux (Max-Min) w/mm^2
Case-1	Al-2219-T87	Al-2618-T61	270-59.632	2.7922-0.001
Case-2	Al-2219-T87	Al-4032-T6	270-54.321	2.8147-0.00092
Case-3	Cast carbon steel	Al-4032-T6	270-33.412	0.87392-0.00032
Case-4	Cast carbon steel	Cast alloy steel	270-24.311	0.52465-0.000096

Table no .3: Bimetallic piston case study

2.8 Analysis of case study:

From table 3, it was found that in case 3(Piston Head: Cast carbon steel Piston Skirt: Al4032- T6) the heat dissipation capacity of bimetallic piston is more when compared to remaining cases.

III. CONCLUSION

- In the first study, In case-3(Piston Head: Cast carbon steel Piston Skirt: Al4032- T6) the value of Von-Misses Stress of Bimetallic piston was far less than was less than the remaining 3 cases and which is less than material yield stress , so our design is safe.
- In the second study, the deformation value for the case-3(Piston Head: Cast carbon steel Piston Skirt: Al4032- T6) of Bimetallic piston was far less thanthe remaining 3 cases, so our Case-3 design is safe.
- Inthe final study (Thermal analysis), in case-3 (Piston Head: Cast carbon steelPiston Skirt: Al4032-T6) the heat dissipation capacity of bimetallic piston is more when compared to remaining cases.

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