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Thermal Analysis of Plate by Using Finite Element Analysis

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Abstract: -- **In this paper two-dimensional isotropic square plate is used to investigate thermal behavior of a plate subjected to thermal loading. In this analysis, two different materials are used and obtained results are compared with each other. For finite element method formulation, ANSYS package is used. In the analysis, one boundary condition is used. Results are related to structural properties like deflection, stresses. Steady state thermal analysis and static structural analysis performed in this study.**

I. INTRODUCTION

Now days plates have become very important structural elements in construction industry. Plates are widely used in buildings, ships, aircrafts, and many other infrastructures. Plates are subjected to temperature gradients. Generally behavior of plates can be predicted using two dimensional plate theories or three dimensional elasticity theories. Based on thickness to breadth ratio, analysis of plates is classified into two types namely thick and thin plate. If the ratio is less than 0.1 and maximum deflection is less than one tenth of thickness, then the plate is classified as thin plate. In this research thin plates are used. When material properties change with temperature then it comes under thermal analysis. Finite element method is used for thermal analysis of plate. Thermal analysis plays important role in various industries related to mechanical, aerospace, civil, electronics, and instrumentation engineering. In these sectors typical requirement is measure of heat flow, weight loss, dimension change, mechanical properties as a function of temperature. Due to temperature difference within a system, or in two different systems, heat transfer phenomenon occurs. Heat generated may be transferred or dissipated to other body or to surrounding through modes of heat transfer namely conduction, convection, and radiation. In Convection, energy transfers across a system boundary due to a temperature difference by the mechanism of intermolecular interactions. In conduction, energy transfers by combined mechanisms of intermolecular interactions and bulk transport. Radiation heat transfer involves the transfer of heat by electromagnetic radiation that arises due to the temperature of the body. Thermal Analysis is carried out to determine temperature distribution, thermal gradient, heat flow and other thermal quantities. Thermal analysis can be steady state or transient. Steady state thermal analysis is less time dependent and transient thermal analysis determines temperatures and other thermal quantities that vary over time. Finite element method is very important mathematical tool in engineering applications because it can reduce a problem with infinite no of degrees to a finite degree problem with the help of discretization which is done according to the problem. To analyze a stress, FEM tool is used. Structure is discretized into finite elements which are connected through nodes. Ansys workbench is platform which can built advanced engineering simulation. Workbench has made process very simple by using drag and drop option. It has schematic view and project management tools which manages workflow.

II. REVIEW OF PREVIOUS WORK:

Hemangi K. Padate, Dr. M.A. Chakrabarti [1] have designed structure for total stress i.e. thermal and mechanical stress. They have considered different boundary conditions like simply supported and fixed, combination of both. They estimated deflection in each boundary condition. Vindhya vasiny Prasad Dubey, Raj Rajat Varma, Piyush Shankar Verma, A. K. Srivastava [2] have used ANSYS 14 to develop model of heat exchanger. They performed steady state thermal analysis by applying various thermal loading on model. Mervin Ealiyas Mathews, Shabna M. S. [3] have analyzed isotropic rectangular plate, made up of different materials and subjected to different boundary conditions by using numerical and finite element method. They used plates made up of aluminium, invar, steel. According to

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them invar plate is more suitable in thermal condition. KDufva and A A Shabana [4] used mid surface curvature which improved element accuracy and convergence properties of plate and shell. Pravin pawar, Raj Ballav and Amaresh Kumar [5] have analyzed rectangular plate with circular hole and made up of different materials. They concluded that at corners of holes maximum stress occurs. Huu-Tai Thai, Trung Kien Nguyen, Thuc P. Vo, Jaehong Lee, Taun Ngo [6] proposed new simple shear deformation theory for plates. Results are compared with various theories and ABAQUS used for FEM formulation. Mukesh Kumar Saini, Vikas Bansal, Amit Gahlaut [7] have used COSMOL computer code to estimate thermal stress of two dimensional rectangular plate. Jenny Seputro[8] used nonlinear finite element program SAFIR to analyze steel beam subjected to thermal loading.

III. METHODOLOGY

ANSYS package works in three different steps:

1. Build the model.
2. Apply loads and get solution
3. Obtain and view results

1. Build the model: In ANSYS, We use preprocessor to build model. Here we define element type, element real constants, material properties, and geometry of model. After preparing model meshing is done.
2. Apply Loads and get solution: Here boundary conditions and loads are applied. After boundary conditions and application of loading model is solved to determine required data.
3. Obtain and view results: By using post processor results can be viewed. Tabular data, charts, graphs, figures can be obtained as per requirement. Coupled Steady state thermal analysis and static structural analysis performed on square plate. Here one boundary condition is used. In this case all sides of plate are fixed

Example Analysis:

In present study, Square plate of material structural steel and aluminium have used to estimate stresses induced and produced deformations due to temperature load of 100˚C. Coupled thermal analysis and static structural analysis performed on plate. Material properties used in analysis are described in table 1.

Table 1

Properties of Materials

Structural Steel	
Coefficient of Thermal Expansion (C^-1)	1.2e-005
Thermal Conductivity (W m^-1 C^-1)	60.5
Aluminium	
Coefficient of Thermal Expansion (C^-1)	2.3e-005
Thermal Conductivity	Temperature (̊C
165 (W m^-1 C^-1)	100

Firstly steady state thermal analysis performed, boundary conditions in thermal analysis are as described in fig.1, and temperature distribution as per fig. 2.

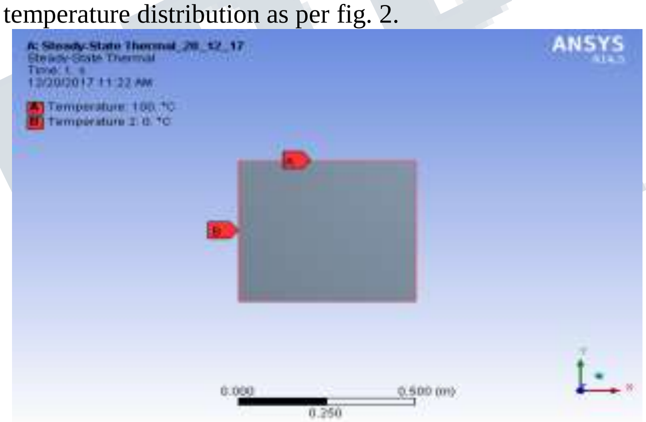

Fig 1: Boundary conditions for thermal analysis

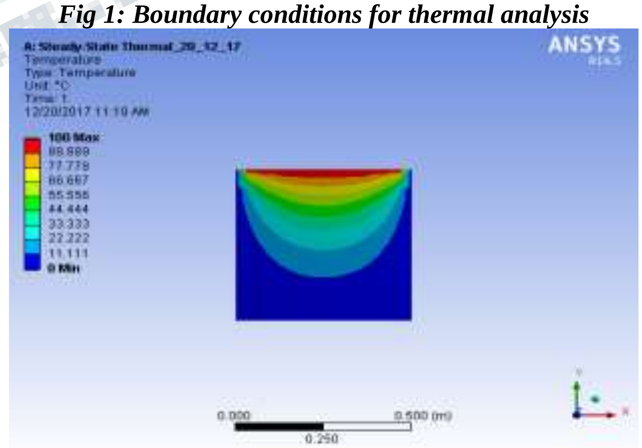

Fig.2 Temperature distribution

Then coupled static structural analysis is performed on the plate. Here one Boundary condition is used.

In this case all sides of plates are fixed as in fig 3.

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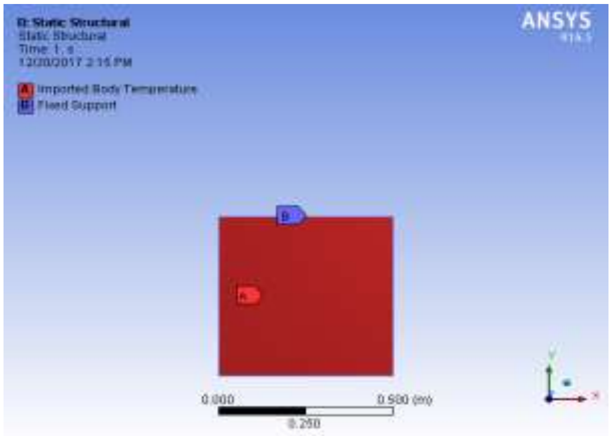

Fig 3 Boundary condition for Static structural analysis.

Then equivalent stresses, total deformation in steel and aluminium plates are estimated as per fig 4, 5, 6, 7 for this case.

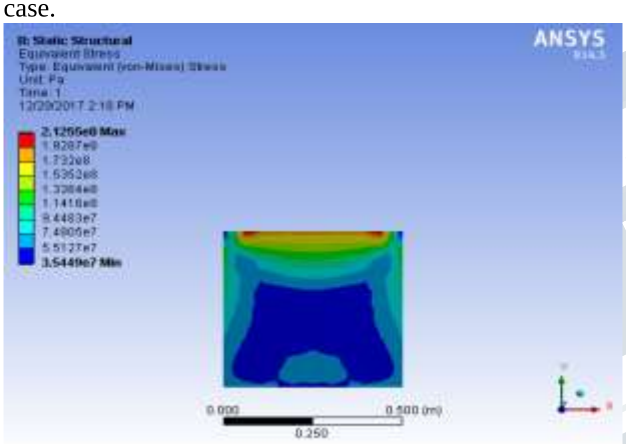

Fig. 4 Equivalent stress in steel plate

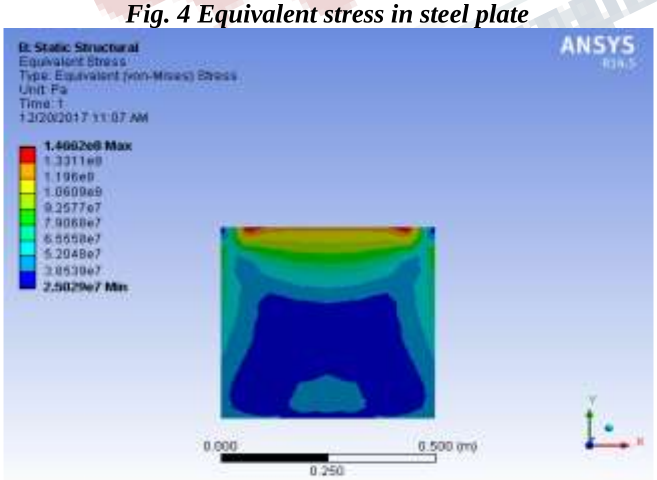

Fig. 5 Equivalent stress in aluminium plate

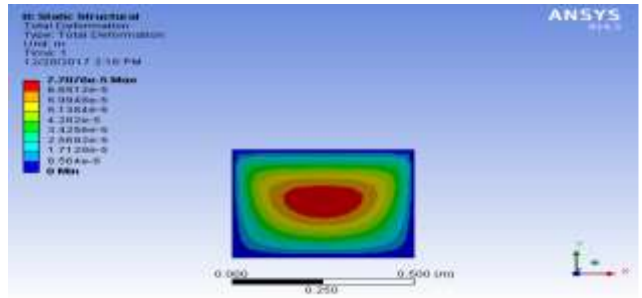

Fig. 6 Total deformation in steel plate

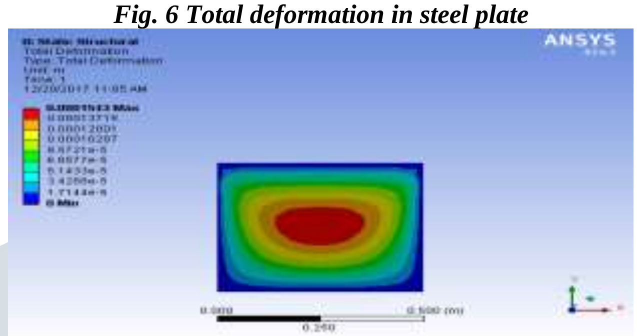

Fig. 7 Total deformation in aluminium plate

IV. RESULTS

Steady state thermal analysis performed on square plate. Temperature variation along length and width are described in table 2, 3 and fig 8, 9.

Table 2Temperature variation along Y axis (Length)

Length [m]	Aluminium [°C]	Steel [°C]
0.00	100.00	100.00
0.01	96.00	95.80
0.20	36.45	35.00
0.40	8.19	7.72
0.50	0.00	0.00

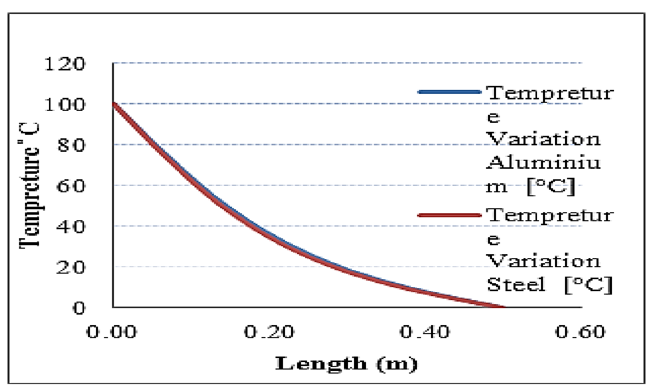

Fig.8 Temperature variation along Y axis (Length)

Table 3 Temperature variation along X axis (Width)

Length [m]	Aluminium [°C]	Steel [°C]
0.00	0.00	0.00
0.01	1.86	1.76
0.20	25.00	23.82
0.40	16.65	15.79
0.50	0.00	0.00

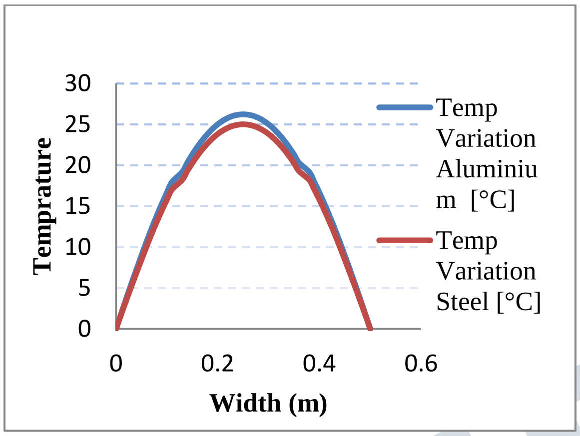

Fig. 9 Temperature variation along X axis (Width)

Then coupled static structural analysis performed on plate. In this case i.e. all sides fixed, equivalent stress and total deformation is described in table 4, 5, 6 and fig. 10, 11, 12.

Table 4 Equivalent stress along top edge (Width)

Length [m]	Steel [Mpa]	Aluminium [Mpa]
0.00	35.45	25.03
0.01	62.46	43.61
0.20	181.40	124.45
0.40	194.12	133.70
0.50	35.45	25.03

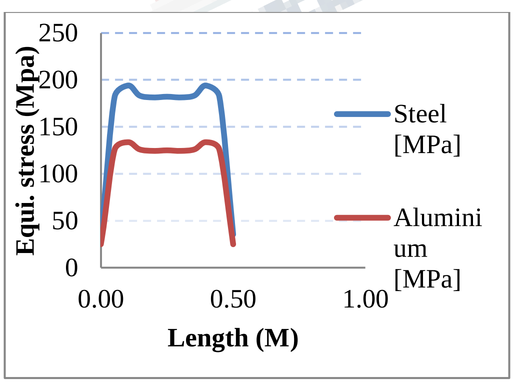

Fig.10 Equivalent Stress along top edge

Table 5 Total deformation along X axis (Width)

Length [m]	Steel [mm]	Aluminium[mm]
0.00	0.00	0.000
0.01	0.01	0.014
0.20	0.07	0.138
0.40	0.05	0.101
0.50	0.00	0.000

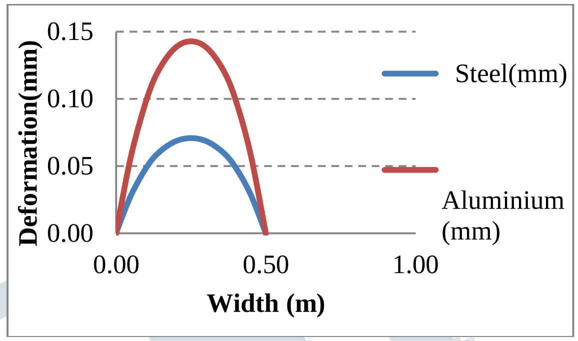

Fig.11 Total deformation Along X axis

Table 6 Total deformation along Y axis (Length)

Length [m]	Steel [mm]	Aluminium [mm]
0.00	0.000	0.000
0.01	0.010	0.019
0.20	0.077	0.154
0.40	0.035	0.070
0.50	0.000	0.000

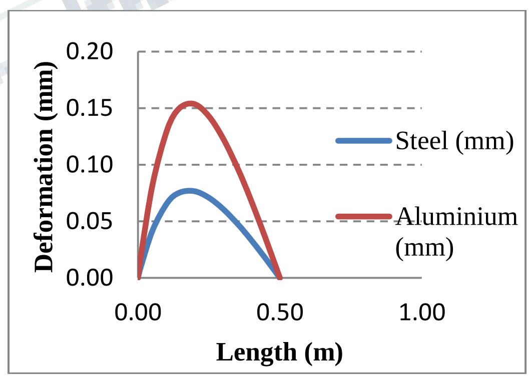

Fig.12 Total deformation Along Y axis

V. CONCLUSION

In this study, static and thermal analysis performed on plate of various materials and for one boundary condition, by using Ansys software. When same thermal load is applied on steel and aluminium plate, Structural behavior of plate is concluded as fallows,

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In all sides of plate fixed condition, Equivalent stress in steel plate is 1.5 % more than aluminium plate.
In all sides of plate fixed condition, Total Deformation in aluminium plate is 2% more than steel plate.

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