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Steady State Thermal Analysis to Investigate Total Heat Flux in a Fiber Metal Laminate for Variable Thickness

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Abstract

Fiber metal laminate (FML) belongs to metallic materials class consisting of layers of metal and fiber composite laminates which bonded together. This permits the structure to behave as very simple metal structure with affordable properties such as good resistance to corrosion, high strength to weight ratio, good resistance to fire, better fatigue properties. For the last few decades, the Fiber Metal laminates (FML) which yields high performance as a light weight material and accordingly its increasing demand in aircraft industry have a strong basement towards the development of refined fiber laminated structures. As a hybrid composites these FML's is a composition of fibers reinforced material bonded with thin metal layers. The most common types of FMLs are CARALL (carbon reinforced aluminum laminate), GLARE (glass reinforced aluminum laminate), ARALL (aramid reinforced aluminum laminate), CentrAl, that bounded by a GLARE core and layers of aluminum. These hybrid composites which have two key constituents namely aluminum metals and fiber-reinforced laminate, offer numerous advantages such as resist fatigue failure and overcome the crack growth mostly in aircraft applications.Glare composed of thin aluminium sheets that are bonded together using an epoxy adhesive film in which glass fibers are embedded. The presence of the epoxy layers causes the attention has to be given to moisture ingress, which can occur during the aircraft service life.An important parameter that might influence the material properties is the service temperature. During the day time the ambient temperature changes from - 40° to 55° C. The in-service temperature of the airplane changes from -55° C to 70°C. Especially the increased or elevated temperatures could affect the material properties of the epoxy and thus the glare properties. Hence this study mainly focused on temperature influences on glare material when the laminate thickness is considered as variable and total heat flux is calculated for the temperature differences.
Keywords: FML, hybrid composite, layers, heat flux, laminate

1. Introduction
1.1 Glare and their material properties
GLARE is a "Glass Laminate Aluminum Reinforced Epoxy" comprises of number of thin layers of aluminum metal combined with glass fiber layers, "pre-preg", surrounded with a epoxy matrix. The pre-peg layers are aligned in various directions instead of uni-direction in order to support for stress conditions to be calculated.

Moreover, the properties and the method of producing GLARE is very similar to aluminium metals. GLARE components are build using mostly classical material techniques. The advantages of GLARE over conventional aluminum metals are:[1-5].

- Better damage tolerance
- Good resistance to fire
- more impact energy.

- Specific Weight is low
- higher penetration resistance
- Good Resistance to corrosion

In 1987, Akzo Nobel got patent for first successful FML called GLARE, where Airbus A380 is the first commercial aircraft with this GLARE.

During the period of material development, the major application on the Airbus A380, partners took part in production and development such as McDonnell Douglas Boeing, US Air Force, Bombardier. GLARE laminates comprise of alternative layers of high strength aluminum alloy sheets and unidirectional glass fiber reinforced prepreg's. ARALL with advanced glass fiber is the first improvement that is developed for aeronautical applications. [6-10].

On comparison the GLARE with ARALL has a major difference in combination with glass fibers rather than aramid fibers. This range of GLARE laminates have superior properties such as strength in the fibre direction and the specific stiffness, that are improved in high strength aluminum alloy metal layers being used. This enables weight reduction in the structural components designed for tension. It has a good adhesive property in between the glass fibers when compete with ARALL.

2. Method of Approach

2.1 Steady State Thermal Analysis using ANSYS:

A steady-state thermal analysis evaluates the influence of thermal loads under steady on the specific system or a desired component. Prior to conduct a transient thermal analysis, experts may perform steady-state thermal analysis, in order to generate initial values. Even for a transient thermal analysis at the end soon after analysis carried out, the transient effects will be reduced, and hence the last step will be the steady state thermal analysis. Therefore, this steady-state thermal analysis is used to determine the thermal properties such as thermal gradients, heat flux, temperature distribution and heat flow rates which do not change with respect to time.[11-16].

 The following are the thermal loads:

- Heat flow rates
- Radiation
- Convections
- heat flow per unit area (Heat Flux)
- heat flow per unit volume (Heat generation rates)

• boundaries at Constant temperature

There are three important tasks to conduct a steady state thermal analysis in ANSYS:
- Creating Model geometry.
- Application of Loads.
- Obtaining results.

2.2 Creating Model Geometry

To create the geometrical model, the first step is to build a solid using lines, areas and volumes. predefined geometrical models are available in ANSYS library, such as rectangles, circles or thia can also done manually defining the nodes and elements for the geometry. The 2-D entities are known to be areas, and 3-D entities are known as volumes. geometry dimensions are followed by global coordinate system. The global coordinate system is Cartesian, X, Y, and Z axes by default. Instead, a different coordinate system can be selected as per the analysis.

2.3 Application of Loads (Thermal Loads)

Define the Type of analysis, apply the loads on the finite element model, set the step size options and solver, and solver for the solution.

Analysis Type setup

At this stage of analysis, the analysis type option to be given as:
- In the GUI, under menu path, click on Main Menu and opt for Solution> then click on Analysis Type> select the option New Analysis> Opt for Steady-state analysis
- STATIC, NEW, ANTYPE commands can be used if the analysis id new type
- REST, STATIC, ANTYPE, for existing analysis

2.4. Load Application on FEM (Meshed) Model

Thermal Loads to be applied on either the geometrical model namely, key points, lines, and areas or on nodes and elements said to be finite element model. Using the conventional method. Loads are to be applied on the models as single load for particular entity or the loads that are complex such as boundary conditions etc.,

Five types of thermal loads:
- Heat Flow Rate (HEAT
- Constant Temperature (TEMP)
- Heat Generation Rate (HGEN)
- Heat Flux (HFLUX)
- Convection (CONV)

Constant Temperature thermal load (TEMP)

The known temperature values and unknown temperature values to be imposed on boundaries

of the model and finally the FEA model to be constrained about specified directions. With KEYOPT(3) = 0 or 1, the elements SHELL131 and SHELL13 are constrained.

Heat Flow Rate thermal load (HEAT)

Heat Flow rates are nodal concentrated loads. these are used in line element types mostly. where it does not require to point out heat flux and convections. Therefore, the heat flow value which resembles the nodal heat flowing will be given as positive.

3 layers of FLM laminates with variable thickness 7/4/1, 5/4/3 and 6/4/2 in mm are modeled in ANSYS Mechanical APDL tool. Setting up the solver and Run the solver for the specified time steps.
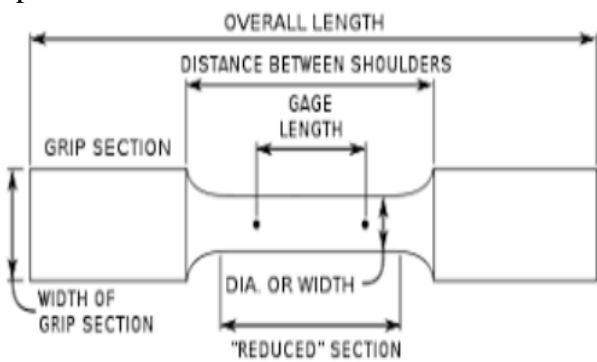

Fig.1.Model Nomenclature

3.Results and Discussions

Following are the Post processing results or contour plots captured for the composite laminate specimen with 3 numbers of layers (Aluminium/Glass/Aluminium) and varying thickness.

3.1 Contour Plots for Total heat flux
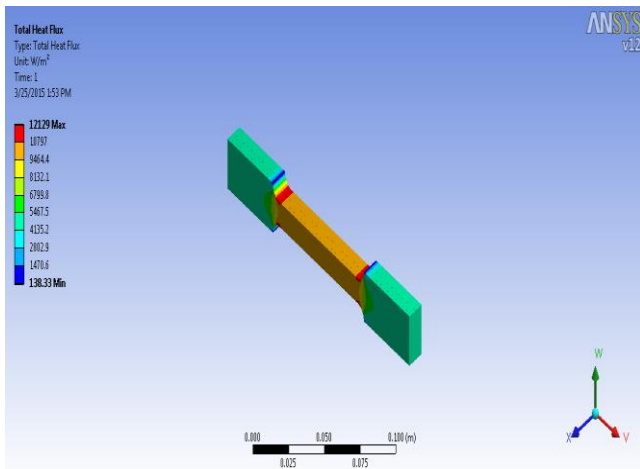
Case-1: Thickness of 3 laminates 7/4/1

Fig.2: Total Heat Flux

3.2 Contour Plots for Temperature Distribution
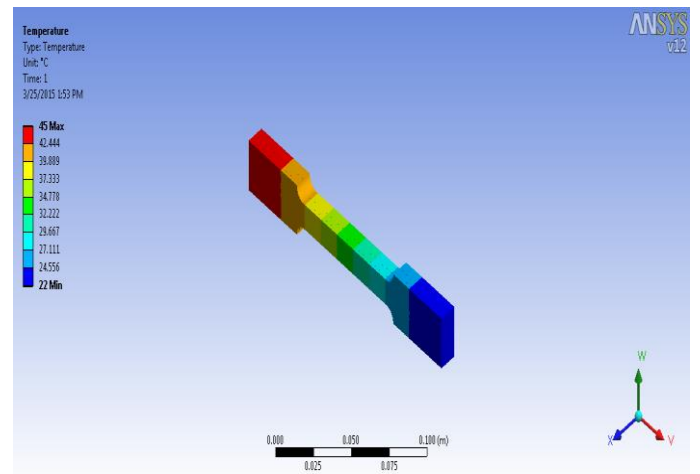
Case-1: Thickness of 3 laminates 7/4/1

Fig.3.Temperature Distribution

3.3 Contour Plots for Total heat flux
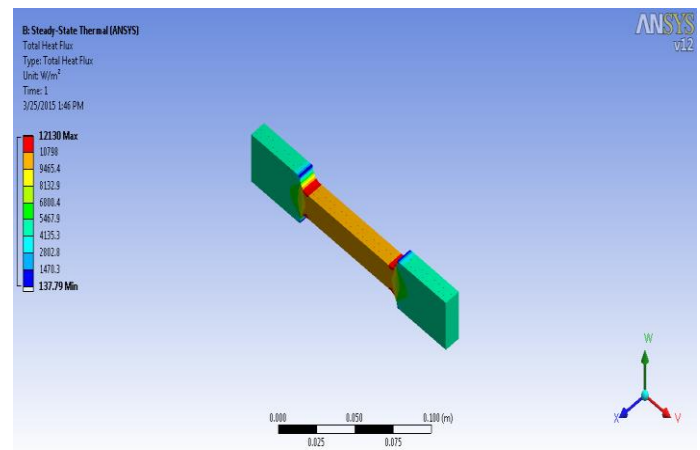
Case-2: Thickness of 3 laminates 5/4/3

Fig.4.Total Heat Flux

3.4 Contour Plots for Temperature Distribution
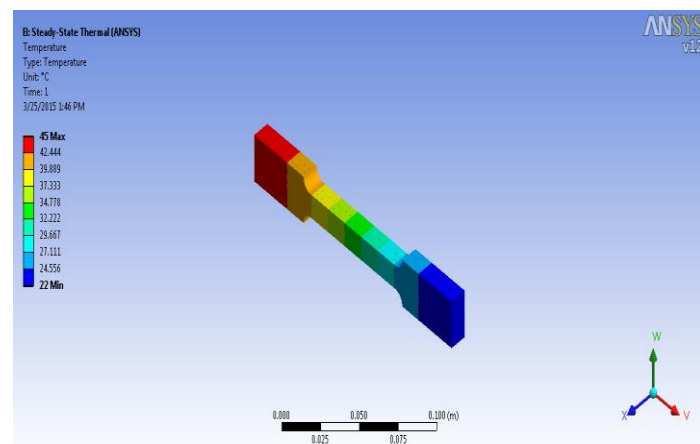
Case-2: Thickness of 3 laminates 5/4/3

Fig.5.Temperature Distribution

3.5 Contour Plots for Total heat flux
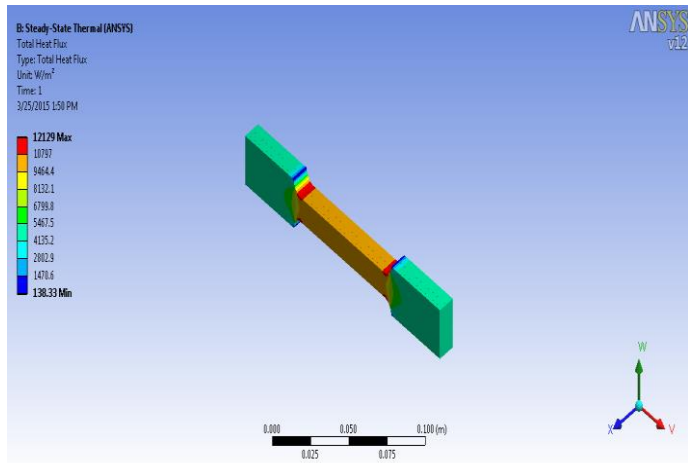Case-3: Thickness of 3 laminates 6/4/2

Fig.6: Total Heat Flux

3.6 Contour Plots for Temperature Distribution
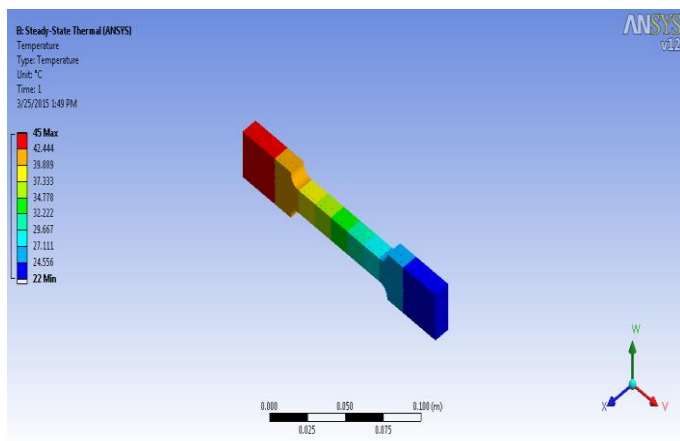Case-3: Thickness of 3 laminates 6/4/2

Fig.7: Temperature Distribution

Table-1 Comparative Thermal Analysis Results for varying laminate layer thickness in mm.

Laminate Layer thickness in mm.	Total Heat Flux		Temperature		Temperature Drop
	MAX.	MIN.	MAX.	MIN.	^{o} C
Al/Gl/Al : 7/4/1	12129	138.33	45	22	23
Al/Gl/Al : 5/4/3	12130	137.79	45	22	23
Al/Gl/Al : 6/4/2	12129	138.33	45	22	23

Conclusions

From the analysis, the following conclusions are figured out.

The thickness of the material is determinately play important role on mechanical performance.

1. It is observed from the post processing results obtained from ANSYS Steady state thermal analysis, increase in the laminate thickness of one layer of aluminum 5mm to 6mm and decrease the thickness of another layer of aluminum from 3mm to 2mm total heat flux value decreases at constant temperature value.

2. It is found that increase in the laminate thickness of one layer of aluminum 6mm to 7mm and decrease the thickness of another layer of aluminum from 2mm to 1mm total heat flux value decreases at constant temperature value.

3. From the comparative analysis on 3 models with variable thickness, it is observed that the total heat flux found maximum **12130** W/mm^2 in model with **FML 5/4/3**.

4. Maximum temperature and Minimum Temperature found uniformly distributed in all cases that is **7/4/1, 5/4/3, 6/4/2** are **45° C** and **22°** C respectively. Therefore, it is observed that there is no much influence of varying thickness in laminates both in aluminium metal and glass fiber on temperature distribution.

5. A Huge Temperature drop of about **23°C** is observed for all the cases of FML laminates. Hence the objective of this work has been attained as the proposed material thermal properties are influenced by variable thickness of FLM (Glare and aluminium) laminates

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