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Research Article

Dynamic Response of NACA 0018 for Car Spoiler using CFRP Material

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Abstract

Aerodynamics is the study of the interaction between stationary objects and moving air. The main purpose of aerofoil is to generate lift force or down force depending upon the application. National Advisory Committee For Aeronautics (NACA) is a standard board concerned with aerofoil's for all aerospace applications such as aircraft body, aircraft wing and also for automobile components such as car body design, spoiler etc. These components need to be made of materials having less density, high fatigue strength, corrosion degradation. The composites with sandwich construction are suitable for the above requirements. The present work deals with implementation of composite material for automobile rear spoiler. To design aerofoil component it require a number of coordinates and it's a challenging task. The Design Foil software provides different aerofoil profiles from which NACA 0018 is selected. As composite materials are orthotropic materials, and its properties depends upon many factors such as fiber orientation, type of matrix and fiber etc. Laminate Theory Software is used to extract the properties of composite material (under different fiber orientations. The spoiler is modeled using Solid Works software and is analyzed for the static and dynamic conditions using ANSYS software. Then results extracted from software are analyzed for its compact ability and finally best orientation of fiber is predicted.

Keywords: *NACA, Spoiler, Design Foil, Laminate Theory Software.*

1. Introduction

Spoiler is a wing like structure equipped at rear end or on top of car's trunk. They also found on the front end of car called as Air Dam. For improvement in aerodynamic conditions spoilers are installed for cars and other high performance vehicles.

Spoilers are customary for racing cars, as the racing car moves with high velocity. The pressure of air can lift up the car, there by cannot have a good contact between wheel and road. If rear spoiler is equipped to the car it pushes back of car down, so the tires can grip road better and stability of vehicle increases.

In 1960's the first car spoiler was introduced by NASCAR automobiles. In 1966, the dodge charger had a flatter nose and sloping roofline which made car unstable and lift was developed at higher speeds.

Spoiler allows air to flow over and around a moving vehicle. Due to this there is increase in turbulence which makes dispersal of air flowing over a shape there by spoiling the laminar flow.

1.1 Purpose of Spoiler

The purpose of spoiler is to affect the air flow over the car, thereby increasing aerodynamic conditions of vehicle and reducing drag effect

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Daniel Bernoulli's principle states that as the velocity of flowing fluid increases, there is a decrease in fluid pressure. This is an important principle used in aeronautical applications. The profile of an aircraft wing must be designed in such a way that air must flow slower at the bottom than at top. This makes pressure differential over and below the wing, and the net resultant force is downward force. This force is used in automobiles to maintain a good contact between tires and road for good grip.

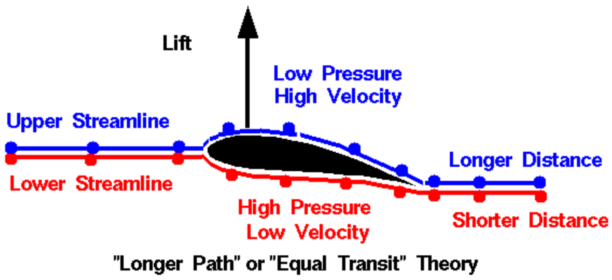

Fig.1 Basic aerofoil profile

1.2 Benefits of car spoiler

Spoilers change the airflow going over the car to increase the downward pressure, essentially pushing the car down to counter the lift. Front spoiler or air dam reduces drag by pushing the air around the car, thereby increasing the mileage of a vehicle. Another advantage of equipping rear spoiler is the added visibility. In order to have good visibility of brake lights for driver behind the car, these are sometimes mounted on rear spoiler. Most of passenger car install spoilers for stylish purpose. Equipping spoilers not only increases tractive force but they also improve braking stability making driving safer even at high speeds. They also reduce weight of vehicle.

2. Composite materials

A composite may be defined as a material system composed of two or more micro or macro constituents, which are insoluble in each other and they differ in form and chemical composition. There are wide varieties of composites available. Even wood, rock, minerals and bones are also used in composites. Modern composites consist of two phases. Matrix which is a continuous phase and other is reinforcement, which is embedded in matrix phase. The reinforcement may be in the form of fiber, flakes, or particles. Matrix which is a continuous phase binds the fiber and distributes the applied load to the fiber. The main load carrying element is fiber.

3. Problem definition

3.1 The whole work is estimated into following steps.

1. Estimation of material properties from LTS.
2. Selection of NACA 0018 from Design Foil.
3. Modeling component using solid works.
4. Finite element analysis.
5. Result analysis.

The main aim of present research work is to investigate the better orientation of carbon fiber used for car spoiler. The main requirement of automobile designers for designing car is overall weight of vehicle should be minimum. For this generally they use aluminium material even for spoiler. The present work deals with implementation of composite material in which carbon fiber embedded in epoxy matrix is considered. As composite materials are orthotropic in nature, design method used for conventional metallic materials is not suitable for composites.

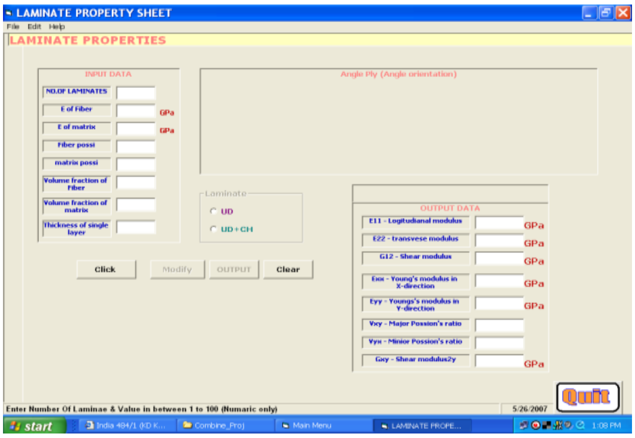

Fig. 2 A window of Laminate Theory Software

Cumbersome Classical Laminate Theory is used for predicting the properties of composites. In order to simplify the task Laminate Theory software is used for finding the properties of fiber reinforced polymer composites. For skin layer carbon fiber embedded in epoxy matrix is used keeping all the factors constant. Polyurethane foam is used inside spoiler. The fiber orientations considered for spoiler are 30º, 45º, 60º, 90º. For each fiber orientation properties are extracted from laminate theory software.

For designing aerofoil profile, large numbers of coordinates are required which is a cumbersome work. In order to simplify the task Design Foil software is used. This software provides the coordinates of different NACA aerofoils. It also helps in calculating co-efficient of lift and drag for given conditions.

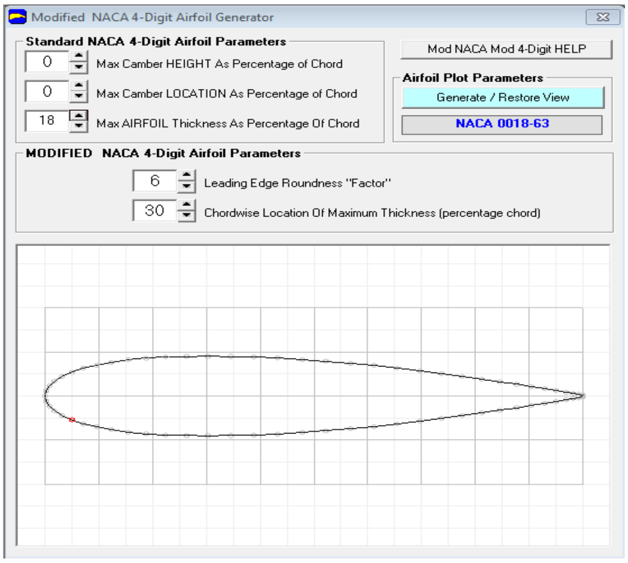

Fig. 3 selecting NACA 0018 from design foil

Based on drag and lift co-efficient, the lift force and drag force are calculated using following relations.

Lift force $L = 1/2 * \rho * v^2 * s * c_l$.

Drag force $D = 1/2 * \rho * v^2 * s * c_d$.

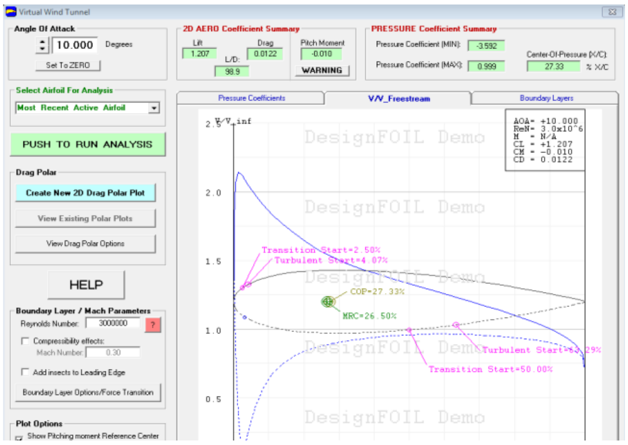

Fig. 4 Summary of lift and drag coefficients

Table 1 Calculation of lift and drag forces

Angle of attack (α)	Coefficient of lift (c_L)	Coefficient of drag (c_d)	Lift force (L) N/m	Drag force (D) N/m
20	1.100	0.0320	2012	72.4
15	1.363	0.0196	2465	43.5
10	1.207	0.0122	2132	36.7
5	0.625	0.0084	1987	32.4
0	0.000	0.0072	0	28.9
-5	-0.625	0.0084	-1987	32.4
-10	-1.243	0.0123	-2264	36.9
-15	-1.850	0.0196	-2899	43.5
-20	-2.439	0.0319	-3269	70.2

The maximum lift force was developed at -20º angle of attack. Negative sign indicates that the force acting is in downward direction. The design load is 3269 N/m.

The coordinates of NACA 0018 is exported to solid works. Then it is extruded for 1 meter length which forms polyurethane foam and the thickness of same coordinates increased up to 2 mm and extruded for 1 meter length to form skin layer of spoiler.

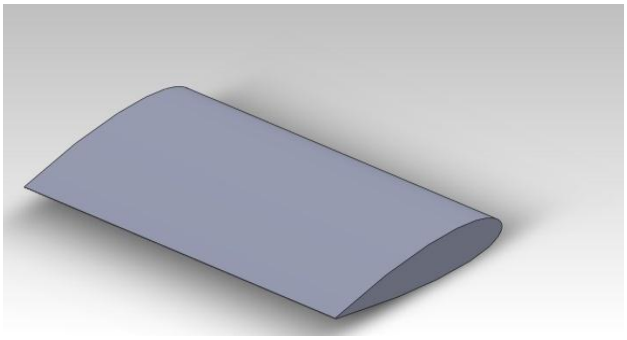

Fig. 5 spoiler modeled in solid work

The model is then imported into Ansys software. For meshing the component solid 45 element is used. Then spoiler is analyzed for its dynamic conditions. Harmonic analysis is carried out for spoiler for extracting forced frequencies and stresses from ansys software. This is done for different fiber orientations.

3.2 Load conditions

Analysis is been carried out for five cases.

Case1. A uniform load of 3269 N/m is considered for $[0°]_2$ orientation of fiber.

Case2. A uniform load of 3269 N/m is considered for $[\pm 45°]_2$ orientation of fiber.

Case3. A uniform load of 3269 N/m is considered for $[\pm 60°]_2$ orientation of fiber.

Case4. A uniform load of 3269 N/m is considered for $[\pm 90°]_2$ orientation of fiber.

Case5. A uniform load of 3269 N/m is considered for $[\pm 45°]_2$ orientation of fiber with and without foam.

4. Results

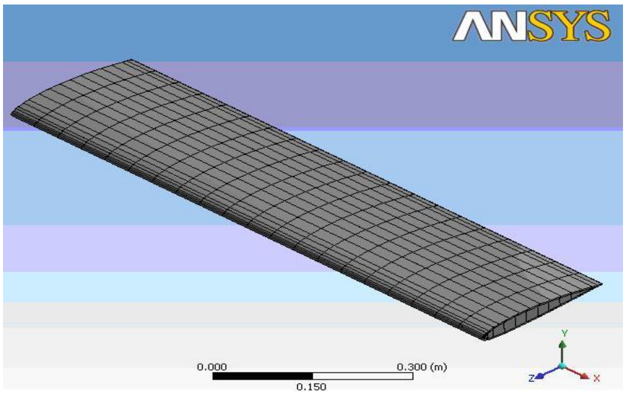

Fig.5 Meshed model of spoiler

4.1 Results for $[0°]_2$ orientation of fiber

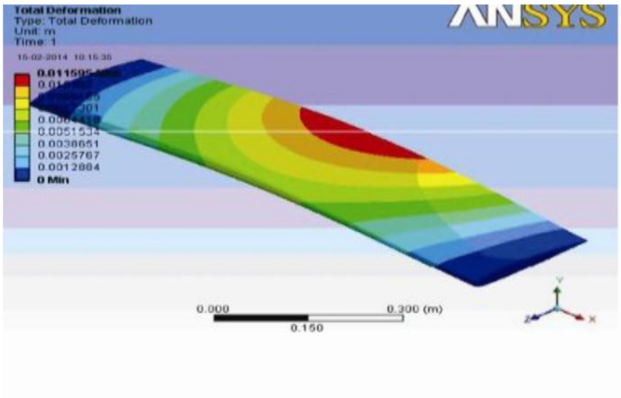

Fig.6 Deformation for $[0°]_2$ orientation of fiber.

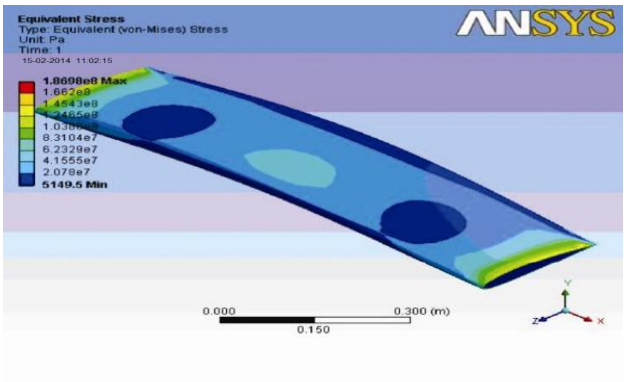

Fig.7 Stress for for $[0°]_2$ orientation of fiber.

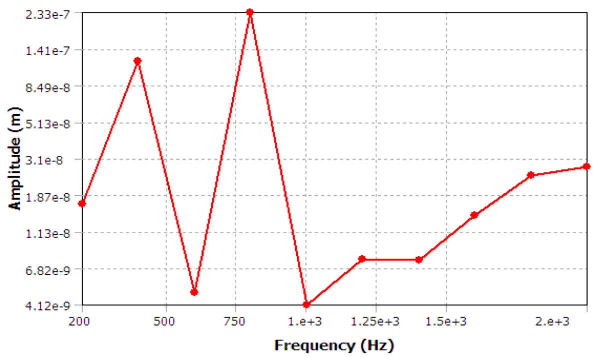

Fig.8 Frequency v/s amplitude

4.2 Results for [±45°]$_2$ orientation of fiber.

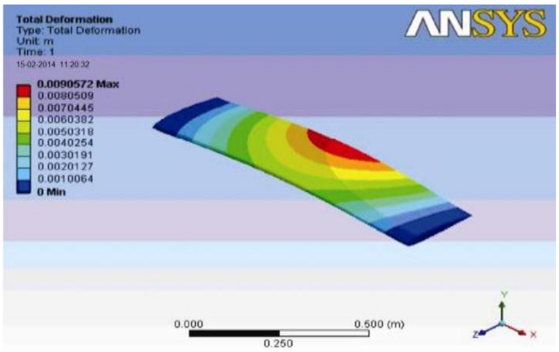

Fig.9 Deformation for [±45°]$_2$ orientation of fiber

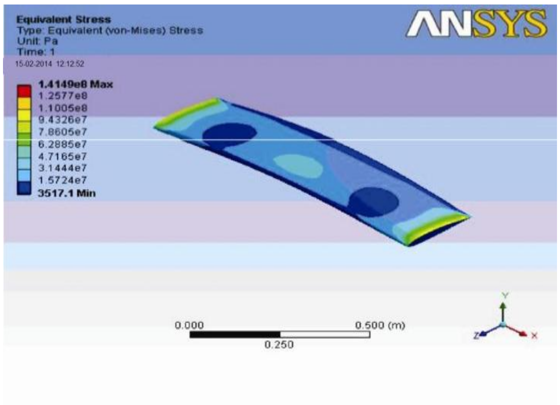

Fig.10 Stress for [±45°]$_2$ orientation of fiber

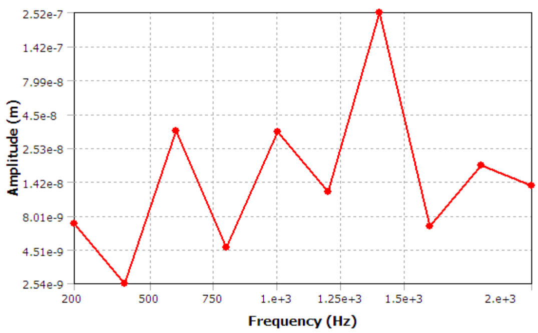

Fig.11 Frequency v/s amplitude

4.3 Results for [±60°]$_2$ orientation of fiber.

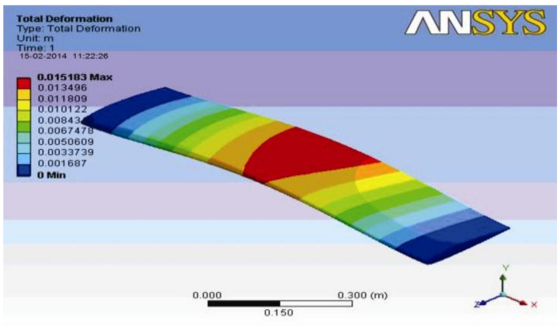

Fig. 12 Deformation for [±60°]$_2$ orientation of fiber.

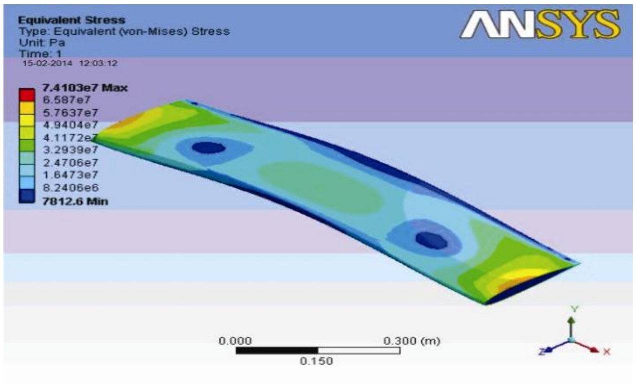

Fig. 13 Stress for [±60°]$_2$ orientation of fiber.

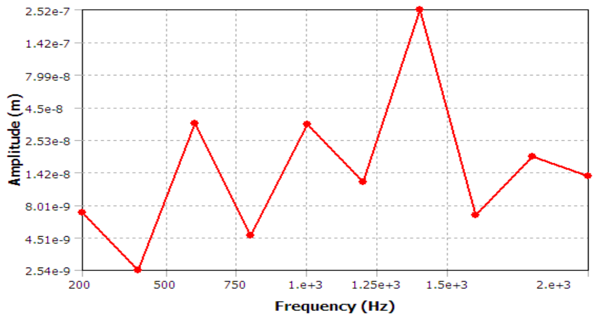

Fig.14 Frequency v/s amplitude

4.4 Results for [±90°]$_2$ orientation of fiber.

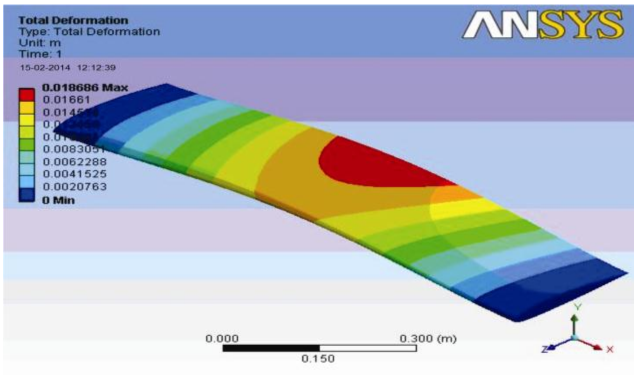

Fig.15 Deformation for [±90°]$_2$ orientation of fiber.

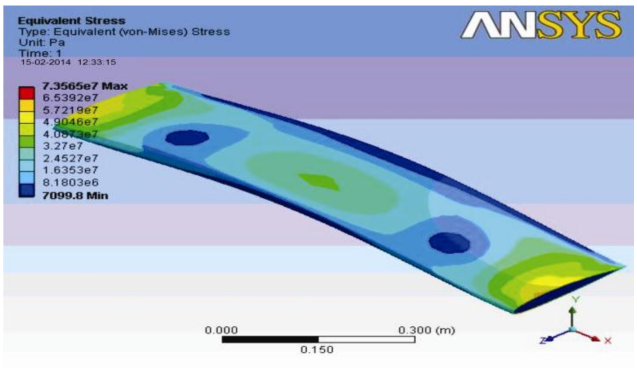

Fig. 16 stress for [±90°]$_2$ orientation of fiber.

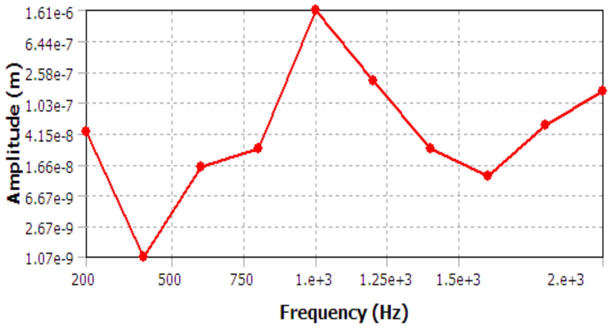

Fig.17 Frequency v/s amplitude

4.5 Results for [±45°]$_2$ orientation of fiber with and without foam

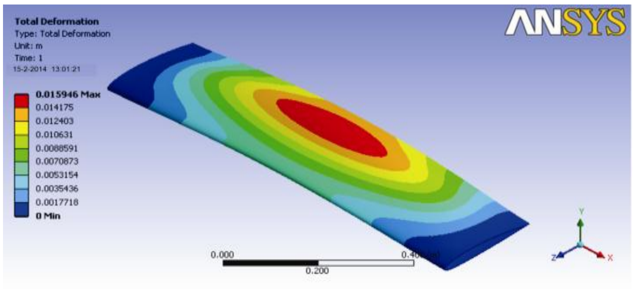

Fig.18 Deformation for [±45°]$_2$ orientation of fiber with and without foam

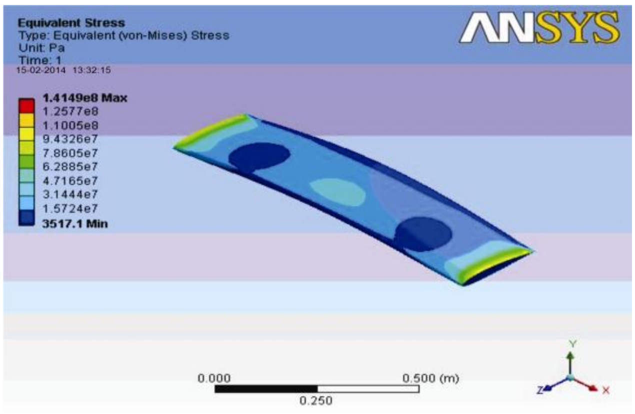

Fig. 19 stress for [±45°]$_2$ orientation of fiber with and without foam.

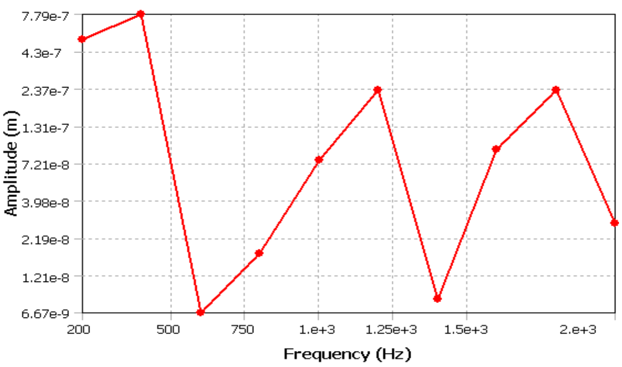

Fig.20 Frequency v/s amplitude

For various orientations of fiber the stress, deformation, and variation in amplitude are as follows:

Table 2 Stress, deformation, and variation in amplitude

S.No	Fiber orientation	Stress (N/mm^2)	Deflection (mm)	Peak frequency (Hz)
1	0^0	186.9	11.59	800
2	45^0	141.4	9.05	1400
3	60^0	741.0	15.18	800
4	90^0	735.6	18.69	1000

Table 3 Comparison of results for [±45°]$_2$ orientation of fiber with and without foam

S.No	Material	Deflection (mm)	Von-mises (N/mm2)	Peak Frequency (Hz)
1	With Foam	9.057	141.49	1400
2	Without Foam	15.946	186.98	400

Conclusions

From the above analysis following conclusions were made:

1) [±45°]$_2$ orientation of fiber with foam is better which yields minimum deformation and minimum deformation. The maximum amplitude induced at a frequency of 1400 Hz.
2) The fiber orientation for [±45°]$_2$ with foam gives best result when compared the same [±45o] orientation of the fiber without foam
3) This methodology is not only constrained for present work, but also applicable for all aerofoil components.
4) Hence with the implementation of CFRP material the weight of spoiler can be minimized without affecting the performance.

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