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Analysis Of Naca 2412 For Automobile Rear Spoiler Using Composite Material*

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ABSTRACT

The NACA 4digit series aerofoil shapes are universally accepted standard designs generally used for wind turbine blades, helicopter rotor blades and car spoilers. The Design and Simulation of these complex shapes is a challenging task for the manufacturing engineers. These components need to be made of materials having high specific strength and better fatigue properties. The composites with sandwich construction fulfill the above requirements.

The main aim of the present investigation is to select the best fiber orientation for the fabrication of automotive rear spoiler. The Design FOIL software provides different shapes of aerofoil from which NACA 2412 has been selected. The spoiler is modeled using CATIA software and is analyzed for the static deflection as well as harmonic analysis has been done by using ANSYS for various orientations of the fiber. The designed model has been compared with the values obtained from the simulation values. This confirms the design feasibility and software adoptability for the design of sandwich aerofoil shapes.

Keywords : Design-Foil Software, CATIA, ANSYS.

1.0 INTRODUCTION

A car spoiler is a wing like accessory that is usually attached to the rear end of the cars, or normally mounted on top of a car's trunk or positioned under the front bumper. While the rear spoiler is sometimes called 'wing', the frontal car spoilers are also called 'air dam'. Car spoiler dynamically improves the external beauty of the car making the car stand out in a crowd, making it more trendy and sporty. In automobile parlance, a spoiler is an aerodynamic device that is attached to an automobile. The intended function of this device is to 'spoil' unfavorable air movement across a body of vehicle of some kind in motion.

It is customary for racing and other high performance sports cars to be fitted with spoilers. Nowadays-even passenger vehicles use spoiler very commonly. To put it more succinctly, a car spoiler improves the performance of the car and even sometimes stimulates its resale value of the car.

1.1 Basic function of spoiler

The main function of a spoiler is diffusing the airflow passing over and around a moving vehicle as it passes over the vehicle. This diffusion is accomplished by increasing amounts of turbulence flowing over the shape, “spoiling “the laminar flow and providing a cushion for the laminar boundary layer often spoilers are added solely for appearance with no thought towards practical purpose**.**

The shape of an aircraft wing causes the air to flow faster over the top surface than the bottom one. Bernoulli’s principle says that this means there is a lower pressure on the top surface compared to the bottom surface and so this creates lift. However if the wing were turned upside down then the resultant force would be downwards, this is called down force and is useful in car design as it pushes the tires onto the road giving more grip.

1.2 Composite Materials

A composite is a structural material that consists of two or more combined constituents that are combined at a macroscopic level and are not soluble in each other. One constituent is called reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase material may be in the form of fibers, particles, or flakes. The matrix phase materials are generally continuous. In this form, both fibers and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone. In general, fibers are the principal load carrying members, while the surrounding matrix keeps them, and protects them from environmental damages due to elevated temperatures and humidity.

2.0 HEADINGS

2.1 Reasons Why Sandwich (Polyurethane Foam) is Selected For Certain Applications:

Sandwich structures have been widely used for many years in applications such as aircraft panels, marine-craft hulls, racing car bodies and spacecraft solar arrays. The combination of high strength-to-weight and high stiffness-to-weight ratios, which are extremely important design parameters in many applications, makes the use of sandwich structures a highly competitive design option that provides for very high structural performance, which is often paired with multifunctional capabilities. Examples of areas where sandwich structures are being used for high-performance purposes include aerospace, automotive, marine, wind turbine and many other industries.

The evolution of a composite sandwich structure with lightweight, high strength core material and with good holding capacity for mechanical connections provides an opportunity to develop this material for structural beam applications.

2.2 BRIEF DESCRIPTION OF THE PRESENT WORK:

In the present work a NACA 2412 spoiler made of glass/epoxy sandwich constructed model is fabricated after a selection of the better orientation of fiber from the simulation results obtained from the FEA. Then the static deflection test is carried out to validate the simulation results.

The whole work can be divided in to the following steps:

Estimation of material properties.
Geometrical modeling.
FEA analysis.
Theoretical Calculations.
Fabrication

A software Classical Laminate Theory has been found to find out the material properties of glass/polyester composite skin. The material properties are estimated for the glass/polyester composite skin based on classical laminate theory. The geometric model is prepared in CATIA V5 plat form. For this the required coordinates of the spoiler are imported from DESIGN – FOIL SOFTWARE, Then the model is meshed and analysed statically and dynamically.

2.3 Description of Design FOIL workshop

Design FOIL is the preferred professional airfoil development system used to design and analyze the airfoil shapes. It has the following features:
The Built-In Airfoil Generation Workshops Airfoils one can generate with Design FOIL:

NACA 4-Digit
NACA 4-Digit Modified
NACA 5-Digit
NACA 6-Digit
NACA 7-Series
NACA 8-Series
Airfoil Archive Viewer (In Archive Tools Menu)

Design FOIL alone contains a wealth of airfoil solutions. One way to add to its usefulness was to include the almost 1,200 airfoils contained in the UIUC archive. Using this special feature allows you to quickly look at many famous and infamous airfoils.

2.4 STEPS IN ANALYSIS

Processor

Input to the problem depends upon the number of materials in the model and as in the present work two materials Foam and composite Skin are used. Foam is an isotropic material so it requires at least two properties to be defined. density, youngs modulus and poisons ratio is given as input for Foam. As composite skin is made up of anisotropic material it requires is at least four properties to be defined.Density, youngs modulus in x-direction, youngs modulus in y-direction, major poissons ratio and minor poisons ratio and shear modulus are input to the skin. Creation of the Finite Element Model is carried out in the solution.

Solution:

A uniformly distributed Load is applied along the length of the spoiler all degrees of freedom is constrained at both ends of spoiler that of in fixed beam.

Postprocessor:

In post processor the required results are obtained
Resultant deformations
Stress distribution, von-misses stresses
Deformation in static and dynamic load direction

2.5 Terms related with harmonic analysis

Period of cycle or time period : it is the time interval after which the motion is repeated itself. The period of vibration is usually expressed in seconds.
Cycle: it is the motion completed during one time period
Frequency : it is the number of cycles described in one second.

3.0 INDENTATIONS AND EQUATIONS

3.1 Elastic properties of unidirectional continuous fiber lamina are calculated from the following equations.

Longitudinal modulus is
$E_{11}=E_fV_f+E_mV_m$
And major Poisson’s ratio:
$\upsilon_{12}=V_f\upsilon_f+V_m\upsilon_m$
The transverse modulus is:
$E_{22}=(E_f/E_m)/(E_fv_m+E_mV_f)$
And minor Poisson’s ratio:
$\upsilon_{21}=E_{22}/E_{11}\upsilon_{12}$
Shear modulus is
$G_{12}=(G_fV_m+G_mV_f)$

3.2 Calculation of lift and drag Forces

In the present work the Design FOIL workshop is used to export the coordinates for geometric molding and to estimated the lift and drag coefficients. Based on the lift and drag coefficients the lift and drag forces are calculated based on the below mentioned formulae:

Lift force $L=\frac{1}{2}\rho*V^2*S*C_l$
Drag force $D=\frac{1}{2}\rho*V^2*S*C_d$

Where L and D are lift and drag forces respectively,
ρ is the density of air 1.01 kg/m^3
V is the velocity of air, in this case it is assume that the vehicle is at rest and the air is moving with a velocity about 118.056 m/sec.
S is the chord length, which is equal to 0.253 mm.
C_l and C_d are the coefficients of lift and drag.

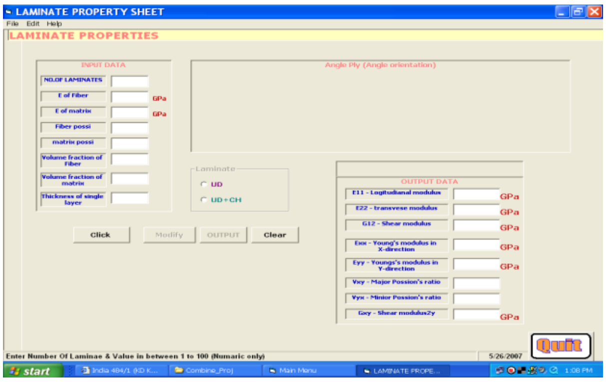
3.3 The governing equation for static analysis is

$$[K]\,[Q] = [F]$$

Where,
[K] = Structural stiffness matrix
[Q] = Nodal displacement vector
[F] = Loads applied include concentric, thermal etc.

4.0 FIGURES AND TABLES

4.1 Formation of classical Laminate Theory



Enter Number Of Laminae & Value in between 1 to 100 (Numaric only)
5/26/2007

Fig 1: Laminate software front end generated using VB software

4.2 DESIGN FOIL

Typical Aerofoil shapes have been found in a defferent NACA series from that a NACA 2412 four digit model has been taken for the simulation.

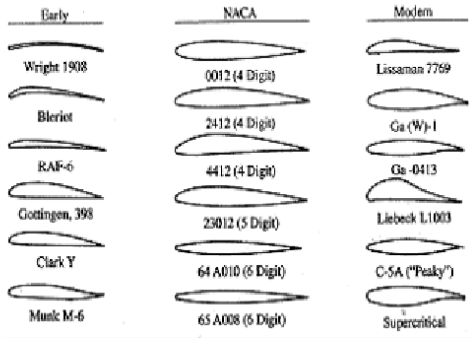
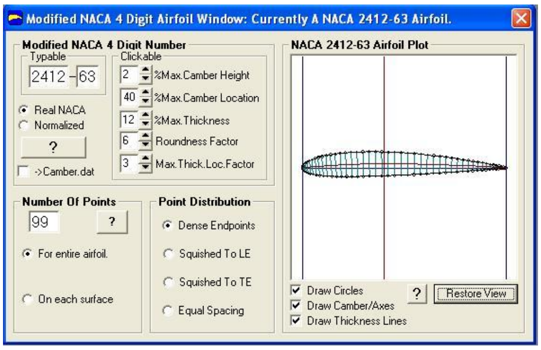


Fig 2: Typical Aerofoil shape


Modified NACA 4 Digit Airfoil Window: Currently A NACA 2412-63 Airfoil.

2412 - 63
2 %Max.Camber Height
40 %Max.Camber Location
12 %Max.Thickness
6 Roundness Factor
3 Max.Thick.Loc.Factor
● Real NACA
○ Normalized
☐ ->Camber.dat

Number Of Points: 99
● For entire airfoil.
○ On each surface

Point Distribution
● Dense Endpoints
○ Squished To LE
○ Squished To TE
○ Equal Spacing

☑ Draw Circles
☑ Draw Camber/Axes
☑ Draw Thickness Lines

Fig.3: Basic aerofoil structure

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	1.409	0.0368	2511.96	65.6
15	1.495	0.0228	2665.28	40.64
10	1.309	0.0135	2333.68	24.06
5	0.857	0.0089	1527.86	15.86
0	0.263	0.0088	468.87	15.68
-5	-0.332	0.0089	-591.89	15.86
-10	-0.923	0.0128	-1647.52	22.81
-15	-1.503	0.0204	-2679.55	36.37
-20	0	0.0357	0	63.64

Table.1 : Calculation of Lift and Drag Forces

From the above table maximum lift force occurs at an angle of -15^{o} and is equal to 2679.55 N/m acting down wards, so the design load is 2679.55 N/m.

4.3 Preparation of CAD Model:

The coordinates obtained form the Design FOIL workshop software are fed into CATIA sketcher and then extruded up to one meter, this gives the foam part and then the same coordinates are used to form the skin by giving thickness as 3mm and then extruding up to 1m.

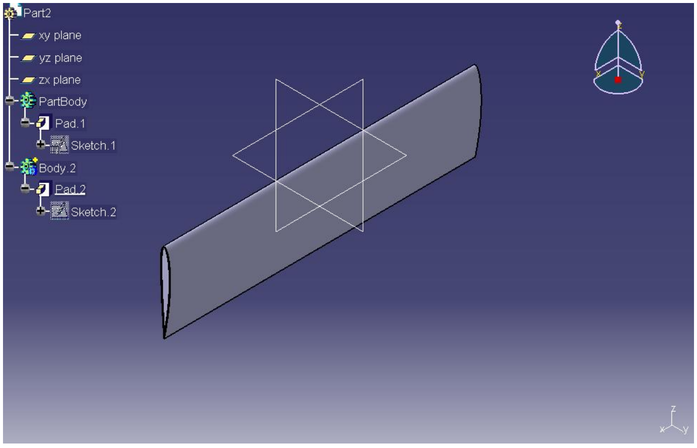


Fig 4 : Assembled Aerofoil Model

5.0 RESULTS

5.1 ALUMINIUM MATERIAL

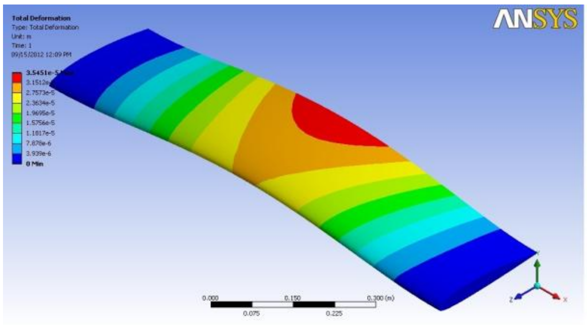


Fig. 5. Deflection For Aluminium

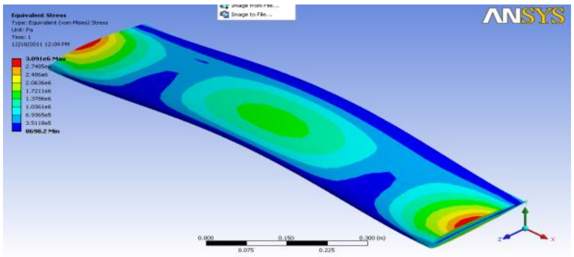


Fig.6: Equivalent stress For Aluminium

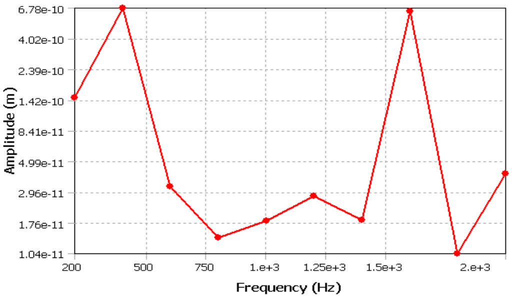


Fig.7 : Frequency Vs Amplitude for aluminium

5.2 RESULTS FOR 45^0 ORIENTATION

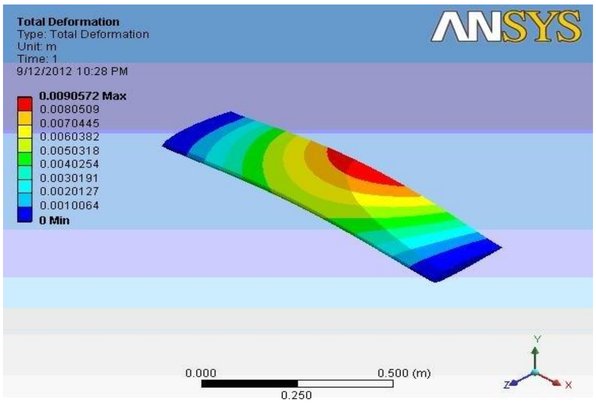


Fig.8 : Deflection at 45^o orientation

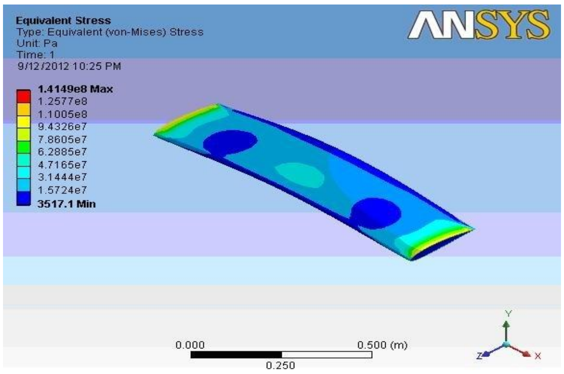


Fig.9 : Equivalent stress at 45^o orientation

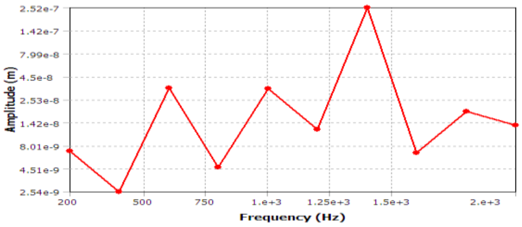


Fig.10 : Frequency Vs Amplitude (45^0)

Minimum Frequency	0. Hz
Maximum Frequency	2000. Hz
Display	Bode
Results	
Maximum Amplitude	2.5232e-007 m
Frequency	1400. Hz
Real	2.5232e-007 m
Imaginary	0. m

Table.2. Results for Harmonic analysis(45°)

5.3 (±45^0)RESULTS FOR WITHOUT FOAM

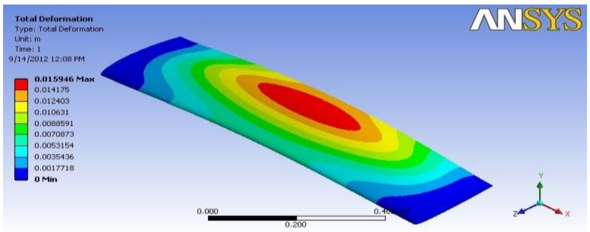


Fig.11 : Deflection at 45^0 orienatation without foam

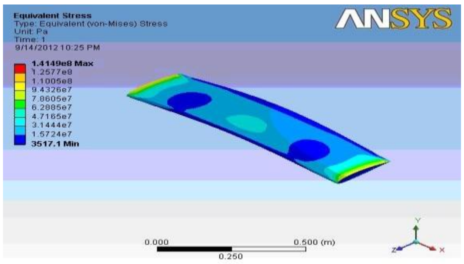


Fig.12 : Equivalent stress at 45^{0}orienatation withoutfoam

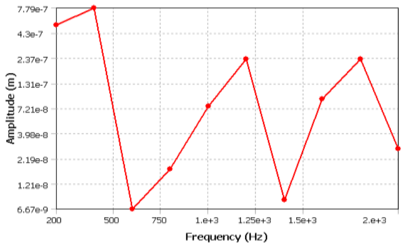


Fig. 13 : Frequency Vs Amplitude at 45^0 orienatation without foam

Minimum Frequency	0. Hz
Maximum Frequency	2000. Hz
Display	Bode
Results	
Maximum Amplitude	7.7927E-007m
Frequency	400 Hz
Real	-707927e-007 m
Imaginary	0. m

Table.3. Results for Harmonic analysis

12. CONCLUSION

i) The simulation results are that [±45^o] orientation of the fiber is the best orientation for the fabrication of the spoiler.
ii) [±45^o] orientation of the fiber with foam gives best result when compared the same [±45^o] orientation of the fiber without foam
iii) The fabrication of the spoiler has been done with sandwich construction..
iv) The theoretical calculation and the simulation results differ i.e., due to localized buckling effect in the sandwich construction.

Acknowledgment

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