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Vibration and CFD Analysis of Air Craft Composite Wing in Subsonic Air Flow

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Abstract: A wing is a type of fin with a surface that produces aerodynamic force for flight or propulsion through the atmosphere, or through another gaseous or liquid fluid. As such, wings have an airfoil shape, a streamlined cross-sectional shape producing lift. A wing's aerodynamic quality is expressed as its lift-to-drag ratio. The lift a wing generates at a given speed and angle of attack can be one to two orders of magnitude greater than the total drag on the wing. A high lift-to-drag ratio requires a significantly smaller thrust to propel the wings through the air at sufficient lift. The requirements for the aircraft wing are High stiffness, High strength, High toughness and Low weight. In this thesis, an aircraft wing will be designed and modeled in 3D modeling software Pro/Engineer. The materials used for aircraft wings are mostly metallic alloys. In this thesis, the materials are replaced by composite materials Fiber Glass, Boron Fiber and Ceramic Fiber. Static analysis and buckling analysis on the wing will be done to determine the stresses produced by applying loads. Vibration analysis will be done on the aircraft wing to determine the frequencies. CFD analysis will be done on the wing to determine the lift and drag forces by changing angle of attacks. Analysis will be done in Ansys.

Keywords: Glass fiber, Epoxy resin, Flyash, Hand lay-up method, FFT analyzer.

I. INTRODUCTION

Composite materials at those that are formed by the combination of two or more materials to achieve properties those are superior to that of its constituents. Generally composite material is composed of reinforcement embedded in a matrix. When designed properly the new combined material exhibits better strength than would each individual material.

In recent years most of the manufacturing plants like aerospace, automotive industries are using glass fiber reinforced composites as they offer a high strength and modulus compared to other metallic materials.

The main advantage of these composite materials is their excellent surface finish, high strength to weight ratio, low density and fatigue damage tolerance. Hence, fiber reinforced composites are emerging as the substitution for other commercially available metals in preparing most of the components in automotive and aerospace industries where weight of the component is the critical factor.

Because of their higher impact strengths, high strength to weight ratios, glass fibers are widely used in many industrial applications. In order to improve the tensile properties of glass fiber reinforced components, a method a was proposed to mix the flyash powder whose particle size ranging from 53 to 78μm to epoxy resin[1].Since flyash possess a good damping properties, the addition of flyash also improves damping qualities in situations where components are subjected to dynamic loading.

II. LITERATURE REVIEW

The following works are done by some authors on aircraft composite wing:
The work done by Sudhir Reddy Konayapalli M. Tech (Production Engineering & Engineering Design) [1], Weight is estimated based on the sketch and a chosen design mission profile. A more refined method is conducted based on calculated performance parameters to achieve a more accurate weight estimate which is used to acquire the external geometry of the airplane. A three-dimensional layout of the airplane is created using RDS software based on conic lofting, then placed in a simulation environment in Matlab which proved the designs adherence to the design goals. In addition, static stress analysis is also performed for wing design purposes.

In the work done by G Sai Rahul[2], Dissimilar thickness of the airfoil and layer directions were almost taken to study the result of bending-torsion. These laminated features are usually designed using the different layers, sequence of stacking, geometrical and mechanical properties. Finite number of layers can be integrated to form many laminates, The wing loading was due to its self-weight and weight of other propulsion systems or due to acceleration due to gravity was deliberated and the deflection over here can be found, this actually studied by aero elasticity. In the work done by Beulah Saripalli[3].

The purpose of the current research is to assess the strength, durability and thermo mechanical behavior of a hybrid composite-aluminum wing structure by testing and

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analysis. The work performed in this paper focuses on the analysis part of the research and is divided into two parts. In the work done by J.Arun[4], Metal composite possesses considerably improved properties together with high durability, toughness, hardness and less density compared to other two different materials. Wings area unit is the foremost vital elements in aircraft. The potency of the craft will increase, once the weight of the aircraft reduces.

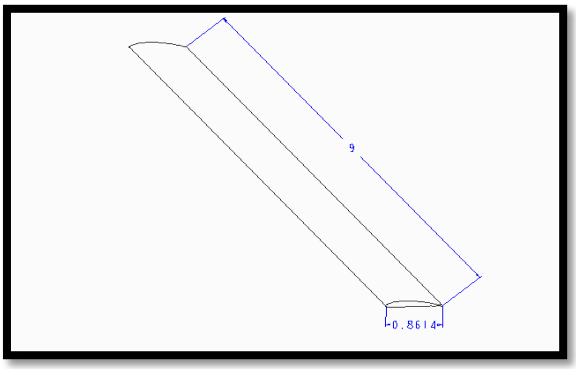
In the work done by Toshihiro Ikeda[5] The purpose of this research is to assess the aerodynamic efficiency of a BWB aircraft with respect to a conventional configuration, and to identify design issues that determine the effectiveness of BWB performance as a function of aircraft payload capacity.

III. MODELING OF WING

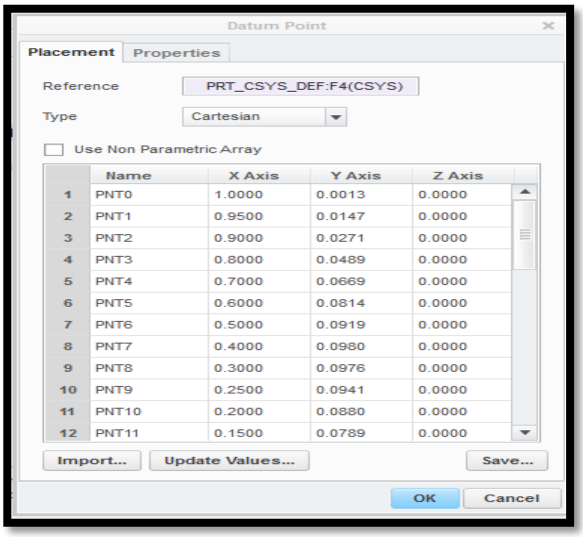
Point's data of NACA 4412

X	Y	X	Y
1	0.0013	0.0125	-0.0143
0.95	0.0147	0.025	-0.0195
0.9	0.0271	0.05	-0.0249
0.8	0.0489	0.075	-0.0274
0.7	0.0669	0.1	-0.0286
0.6	0.0814	0.15	-0.0288
0.5	0.0919	0.2	-0.0274
0.4	0.098	0.25	-0.025
0.3	0.0976	0.3	-0.0226
0.25	0.0941	0.4	-0.018
0.2	0.088	0.5	-0.014
0.15	0.0789	0.6	-0.01
0.1	0.0659	0.7	-0.0065
0.075	0.0576	0.8	-0.0039
0.05	0.0473	0.9	-0.0022
0.025	0.0339	0.95	-0.0016
0.0125	0.0244	1	-0.0013

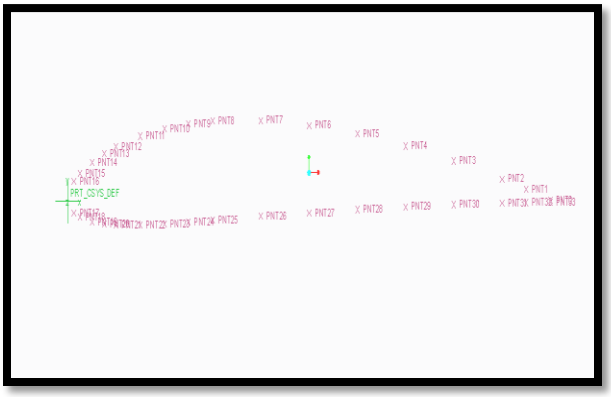
3D model of wing – original model



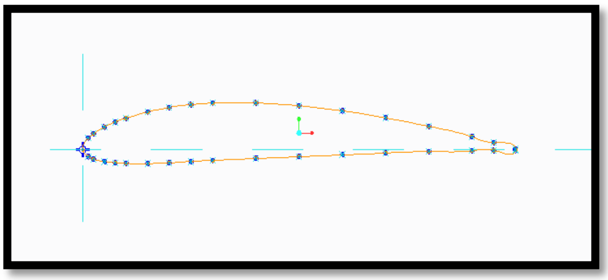
Edit points



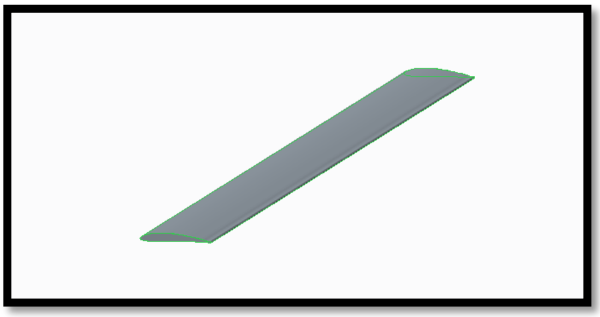
Import points



Sketch



Modified model



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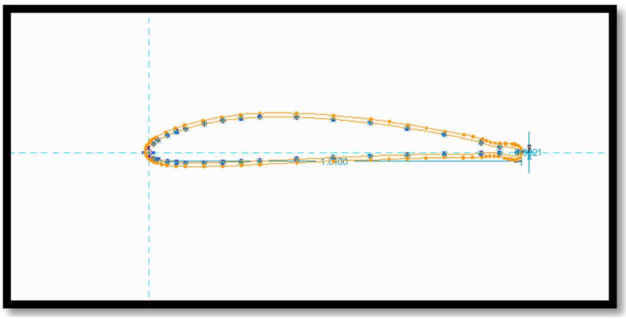
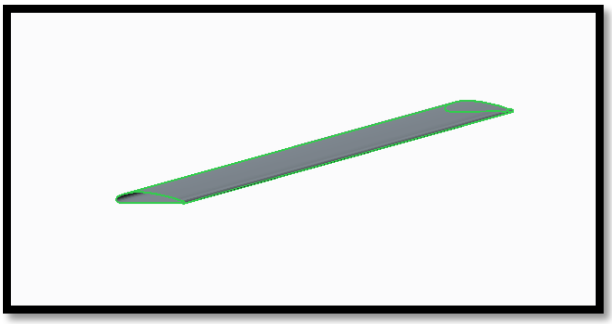
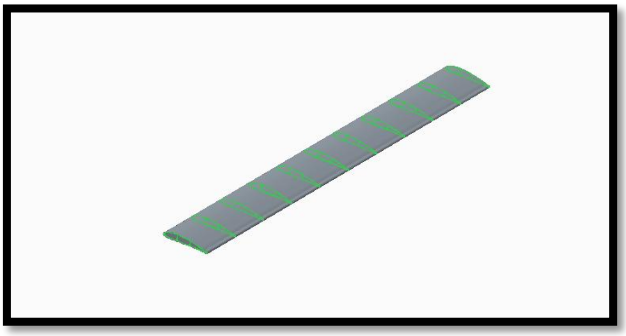
3D Model



Adding ribs to the wing

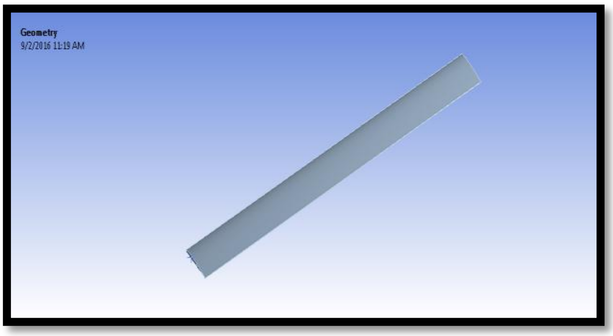




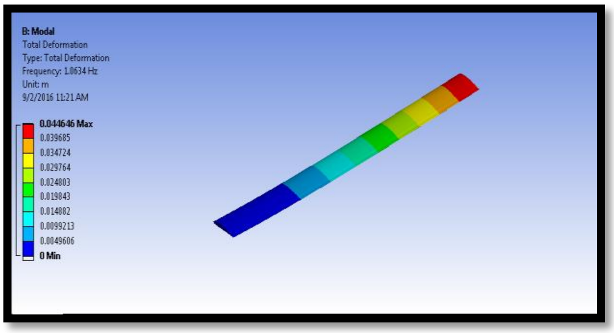
IV. ANALYSIS OF AIR CRAFT WING

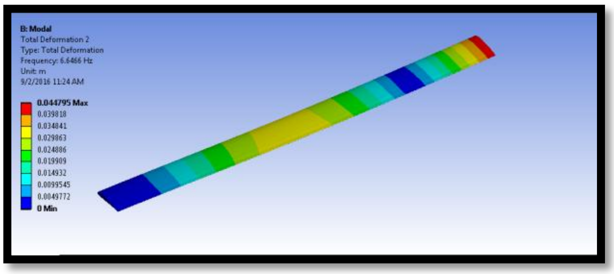
1. Vibrational analysis original wing

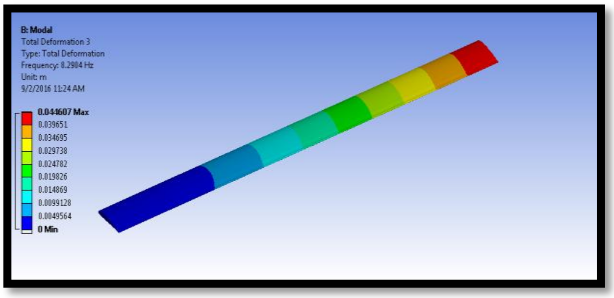
i. Aluminium alloy T6061



Density : 2700 kg/m^3
Young's modulus : 689000Mpa
Poisson's ratio : 0.33

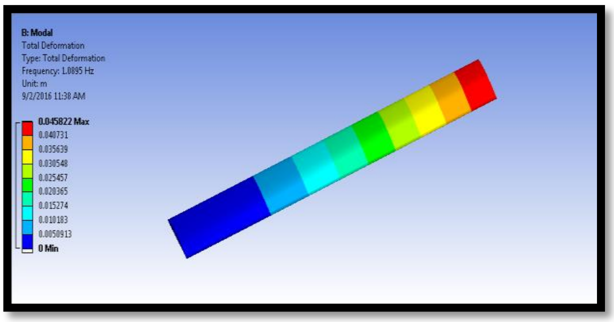


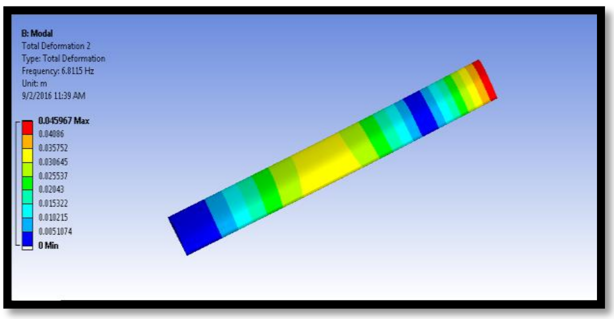




ii. C-fiber glass

Density : 2560 kg/m^3
Young's modulus : 4830 MPa
Poisson's ratio : 0.23





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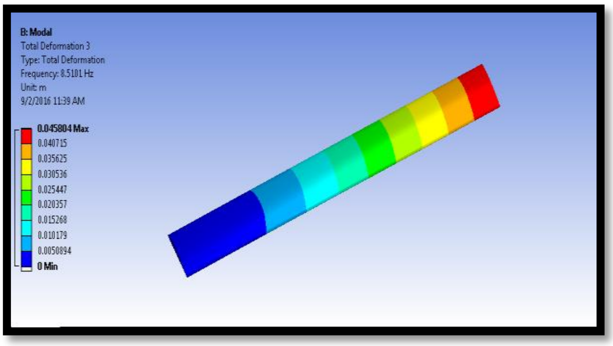
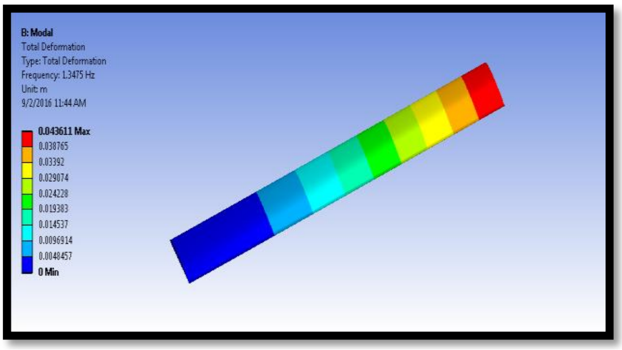
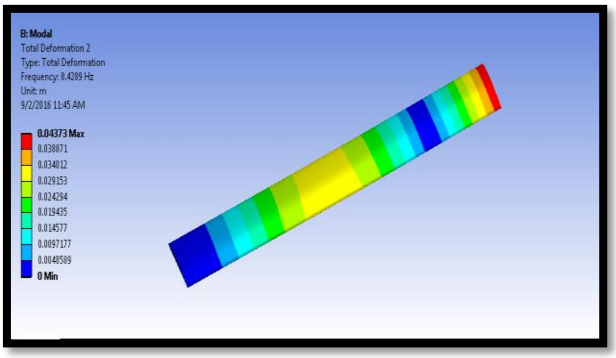
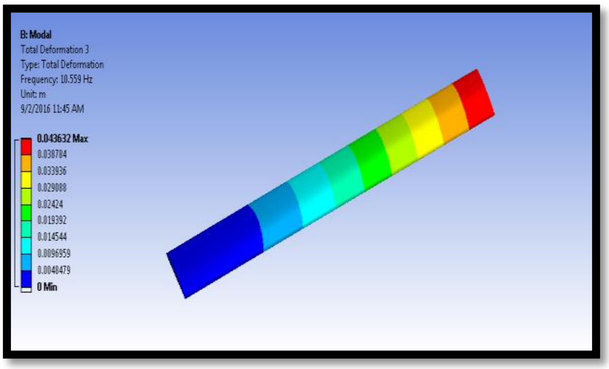


iii. Boron fiber

Density : 2820 kg/m^3
Young's modulus : 117000 Mpa
Poisson's ratio : 0.13

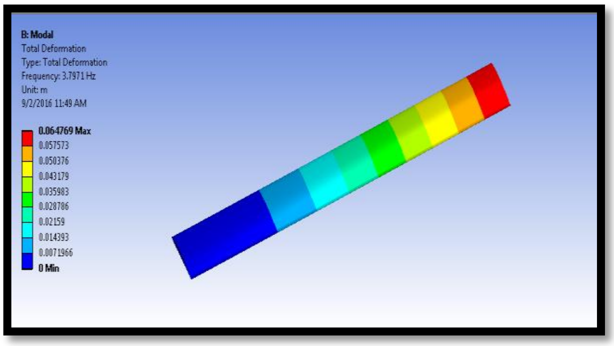


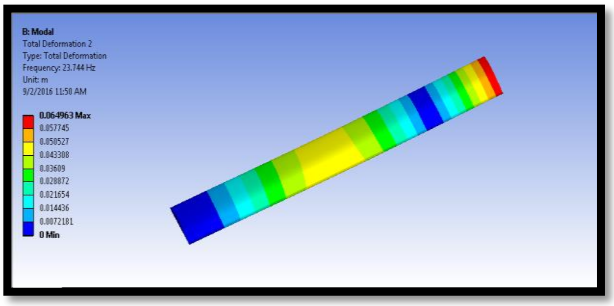


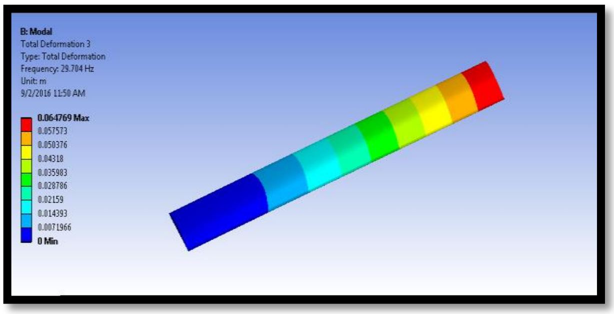


iv. Ceramic fiber

Density : 1280 kg/m^3
Young's modulus : 420000 MPa
Poisson's ratio : 0.22

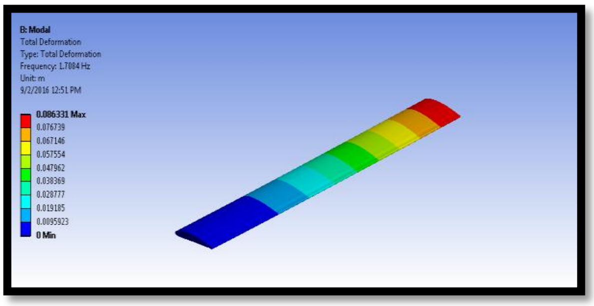


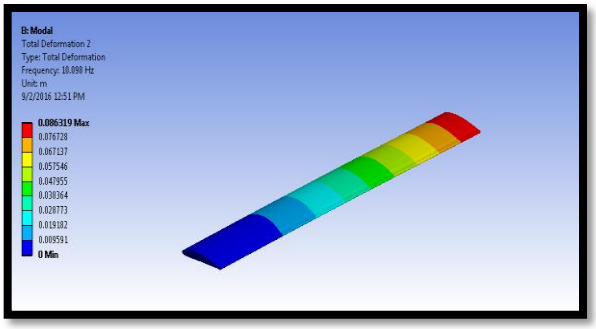




2. Vibrational analsis of modified wing

i. Aluminium and boron fiber





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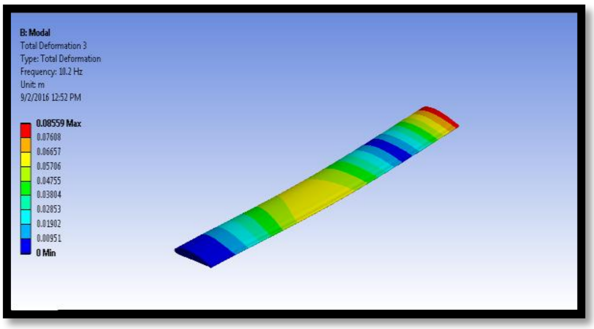
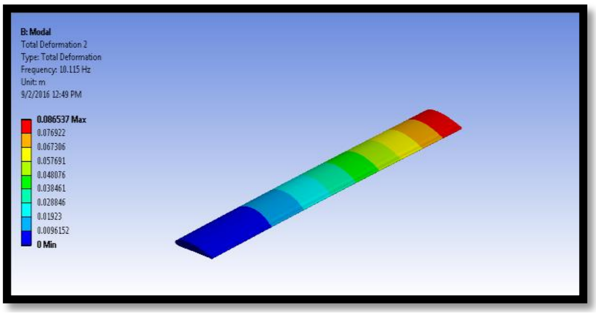
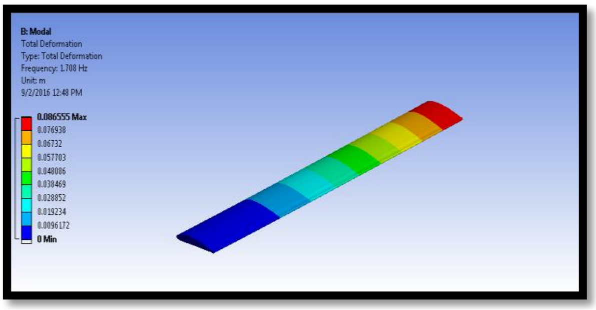
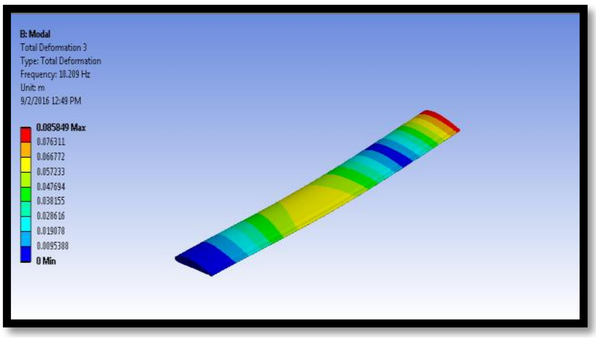


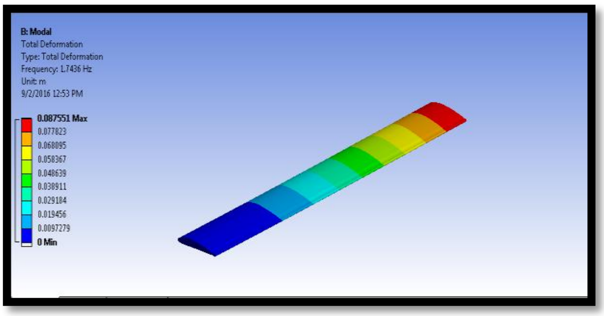
ii. Aluminium and fiber glass

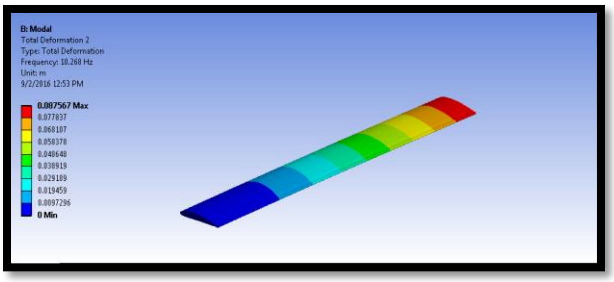


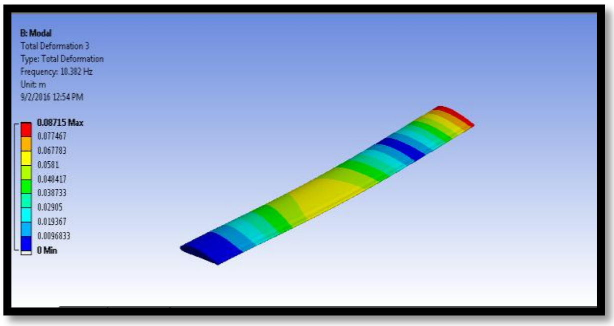




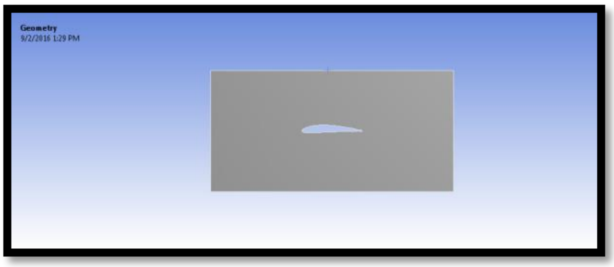
iii. Aluminium and ceramic fiber

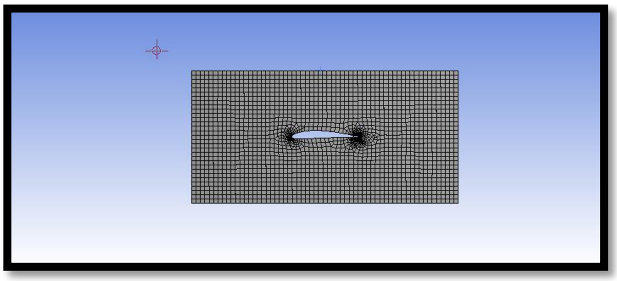


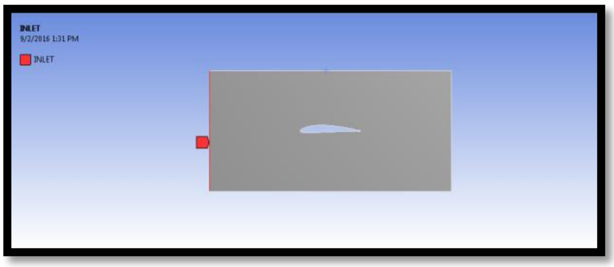


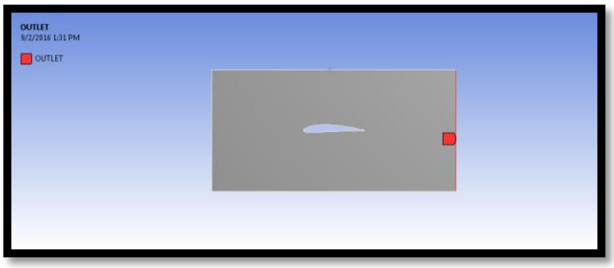


iv. CFD analysis of NACA 4412









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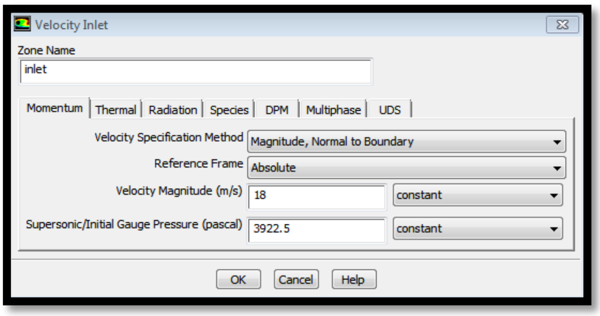
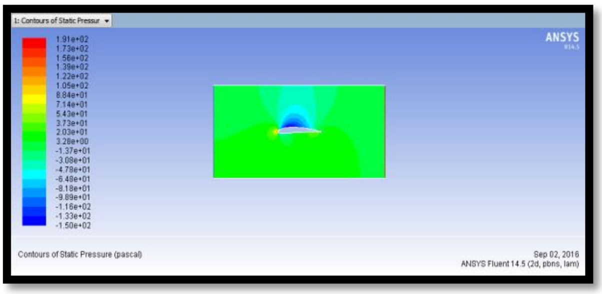
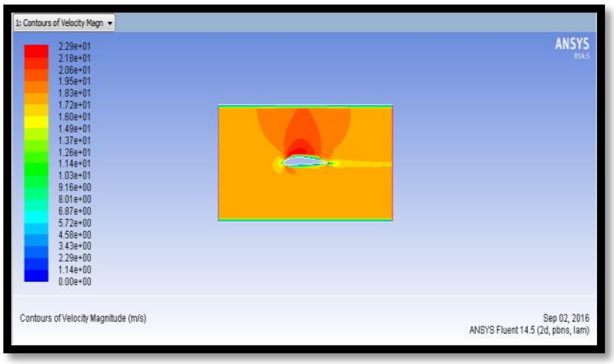
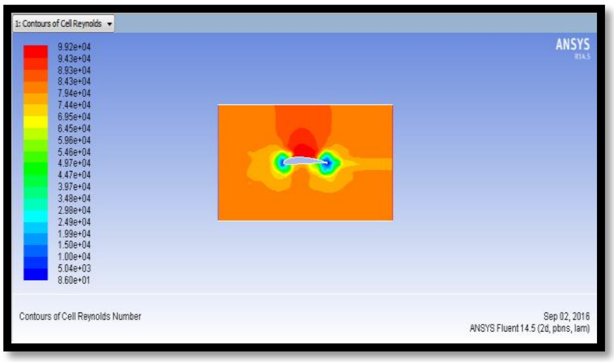
Boundary conditions
Velocity: 18 m/s
Pressure: 3922.5 Pa









V. RESULTS

1. Model analysis of original model

	MODE 1		MODE 2		MODE 3	
	DEF (m)	FRQ (Hz)	DEF (m)	FRQ (Hz)	DEF (m)	FRQ (Hz)
AL T6061	0.044646	1.0634	0.044795	6.6466	0.044607	8.2904
C-FIBER GLASS	0.045822	1.0895	0.045967	6.8115	0.045804	8.5101
BORON FIBER	0.043611	1.3475	0.04373	8.4289	0.043632	10.559
CERAMIC FIBER	0.064769	3.7971	0.064963	23.744	0.064769	29.704

2. Model analysis of modified model

	MODE 1		MODE 2		MODE 3	
	DEF (m)	FRQ (Hz)	DEF (m)	FRQ (Hz)	DEF (m)	FRQ (Hz)
ALUMINIUM & C-FIBER GLASS	0.086331	1.7084	0.086319	10.098	0.08559	10.2
ALUMINIUM & BORAN FIBER	0.086555	1.708	0.086537	10.115	0.085849	10.209
ALUMINIUM & CERAMIC FIBER	0.0875551	1.7436	0.087567	10.268	0.08715	10.382

3. CFD analysis results

	Pressure (Pa)	Velocity (m/s)	Reynolds number	Lift force (N)	Drag force (N)
Naca4412	1.91e+02	2.29e+01	9.92e+04	8.1180359	5.1227907

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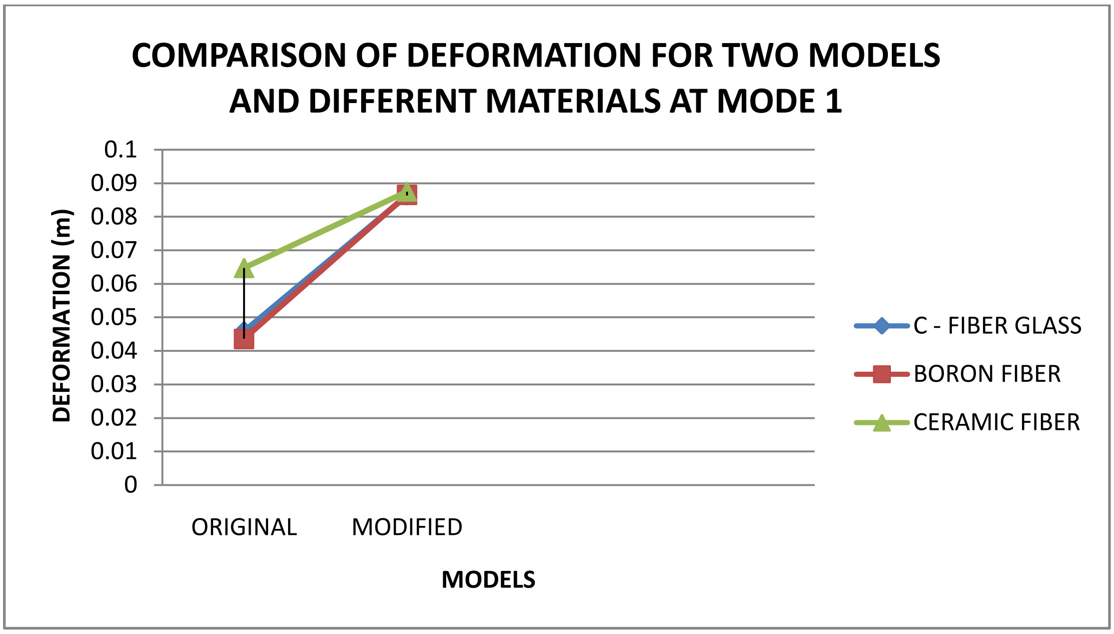
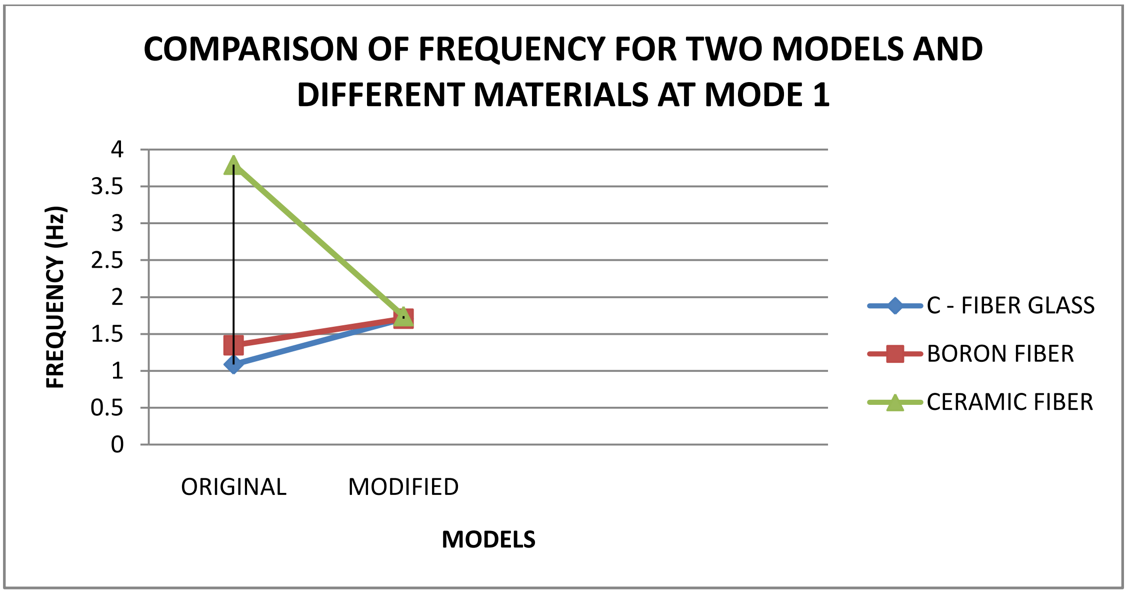
VI. GRAPHS





VI.CONCLUSION

In this thesis, an aircraft wing of NACA 4412 is designed and modeled in 3D modeling software Creo 2.0. The wing is modified by adding ribs. The materials used for aircraft wings are mostly metallic alloys. In this thesis, the material is replaced by composite materials C – Fiber Glass, Boron Fiber and Ceramic Fiber. The advantage of using composite materials is their high strength to weight ratio. For the original model, the materials compared are Aluminum alloy, C – Fiber Glass, Boron Fiber and Ceramic Fiber. For the modified model, the wing material is Aluminum alloy and material of inner ribs are varied C – Fiber Glass, Boron Fiber and Ceramic Fiber.

Static analysis is done on the wing by applying air pressure for all materials. By observing the analysis results, the deformation and stresses are more for wing with ribs than compared with that of original wing. When compared the results between materials, the stresses are less for Ceramic Fiber.

Vibration analysis is done on the aircraft wing to determine the frequencies. By observing the results, the frequencies are less for modified model for Ceramic fiber but deformations are less. So the vibrations are less for modified model.

CFD analysis is done on the aerofoil to determine pressure, velocity, mass flow rate. By observing the CFD results, the pressure is more at the tip of the bigger end of the aerofoil and decreasing towards the rear end. The velocity is more on the surface of the aerofoil and decreasing near the tips of the both ends.

By observing the buckling analysis results, the load multiplier is less for modified model than original model (i.e), the modified model buckles when the present applied load is multiplied with that of load multiplier. The material Ceramic Fiber is better.

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