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DESIGN AND ANALYSIS OF ULTRA LIGHT WING STRUCTURE BY USING ADVANCED COMPOSITE MATERIAL

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Abstract

An aircraft is a machine that is able to fly by gaining support from the air. It counters the force of gravity by using either static lift or by using the dynamic lift of an airfoil, or in a few cases the downward thrust from jet engines. A wing is a type of fin that produces lift, while moving through air or some other fluid. As such, wings have streamlined cross-sections that are subject to aerodynamic forces and act as an airfoils. A wing's aerodynamic efficiency is expressed as its lift-to-drag ratio. In this project wing structure of the ultra light aircraft was developed by using cad tool (CATIA) and analyzed with CAE TOOL.

Our aim of the project is to reduce the stresses on the wing structure to increase its strength to weight ratio. To do this here two wing structures were developed (NACA 0012 &0016) analyzing with existing material (al-7075) and Kevlar composite materials. From the results we can say which wing structure and which combination of material would be better for ultra light aircraft model.

Key Words: CAE Tool, CATIA, Ultra Light, Kevlar composition.

1. INTRODUCTION

1.1 INTRODUCTION

Ultra light aviation (called micro light aviation in some countries) is the flying of lightweight, 1 or 2 seat fixed-wing aircraft. Some countries differentiate between weight-shift control and conventional 3-axis control aircraft with ailerons, elevator and rudder, calling the former "micro light" and the latter "ultra light".

Kevlar is the registered trademark for a para-aramid synthetic fiber, related to other aramids such as Nomex and Technora. Developed by Stephanie Kwolek at DuPont in

1965, this high-strength material was first commercially used in the early 1970s as a replacement for steel in racing tires. Typically it is spun into ropes or fabric sheets that can be used as such or as an ingredient in composite material components. Currently, Kevlar has many applications, ranging from bicycle tires and racing sails to body armor, because of its high tensile strength-to-weight ratio; by this measure it is 5 times stronger than steel. It is also used to make modern drumheads that withstand high impact. When used as a woven material, it is suitable for mooring lines and other underwater applications. A similar fiber called Twaron with roughly the same chemical structure was developed by Akzo in the 1970s; commercial production started in 1986, and Twaron is now manufactured by Teijin

Kevlar Properties

1. Para-aramid fibers such as Kevlar® and Twaron®, which are slightly different, have outstanding strength-to-weight properties, and have high tenacity which makes it difficult to cut or fray.
2. High Rigidity Young's modulus (stiffness): 130-179 GPa compared to carbon Fiber 300 GPa and glass 81 GPa, low elongation to Break (does not stretch much).
3. Resistant to organic solvents, but sensitive to Chlorine, Some Acids and Bases.
4. Good resistance to abrasion and cutting
5. Tensile Strength is Slightly less than E glass fiber
6. No melting point. Resistant to thermal degradation. Low flammability
7. Good fabric integrity at elevated temperatures
8. Nonconductive under regular conditions, but can absorb water and salt water.
9. Sensitive to degradation from ultraviolet radiation
10. Sensitive to shock load. Can fail unexpectedly if subject to shock.
11. Relatively low compression strength compared to Carbon fiber.

2. LITURATURE REVIEW

T.V. Baughn and P.F. Packman [1] in 1986, conducted a finite element analysis to determine the structural integrity of a high-wing cable-supported ultralight aircraft. A simple, symmetrical, half-structure macro-model was analyzed and subjected to level flight loading and two-wheel-landing loading conditions. Flexural and bending stiffness for the supported and unsupported wing were also determined. A preliminary damage tolerance analysis was conducted in which selected cable elements and wing compression struts were removed, the redistributed loads calculated, and possible aircraft flight configurations examined. The model can generate all cable loads, displacement of each structural node (for each loading condition), generate displacement plots, and locate potential highly stressed regions.

Baughn, T. and Johnson, D. [2] in the same year of 1986, proposed a design change from high-wing cable-supported to strut supported aircraft. One of the most common designs is the high wing cable supported ultralight. Because of its simple shape and method of construction owners like to modify the structure and aerodynamic surfaces to attempt to improve the performance of the aircraft. One of the more common modification requests is for the conversion from a cable supported to a strut supported aircraft. The objective of the modification is to reduce the drag and improve the performance of the ultralight. The purpose of their study is to determine the structural performance of the cable supported aircraft and compare it to the structural performance of a strut supported version of the same aircraft and to provide an estimate of the change in drag associated with the conversion from cable supported to strut supported.

Girish S. Kulkarni [3] in 1987, with the help of all the design guidelines provided by Baughn, T along with considering critical condition in un-accelerated flight, done a Finite element method based structural design to analyze the behaviour of an airplane under Aerodynamic loading

3. DESCRIPTION

3.1 CAD DESIGN TOOL (CATIA)

CATIA is a suite of programs that are used in the design, analysis, and manufacturing of a virtually unlimited range of product. CATIA is a parametric, feature-based solid modelling system, **“Feature based”** means that you can create part and assembly by defining feature like pad, rib, slots, holes, rounds, and so on, instead of specifying low-level geometry like lines, arcs, and circle& features are specifying by setting values and attributes of element such as reference planes or surfaces direction of creation, pattern parameters, shape, dimensions and others.**“Parametric”** means that the physical shape of the part or assembly is driven by the values assigned to the attributes (primarily dimensions) of its features. Parametric may define or modify a feature's dimensions or other attributes at any time.

DESIGN OF WING RIB

To create the airfoil shape NACA0016 here we are using DESIGN FOIL software which is useful to create that shape

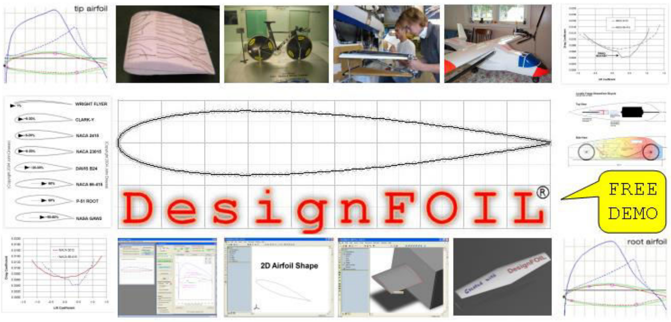
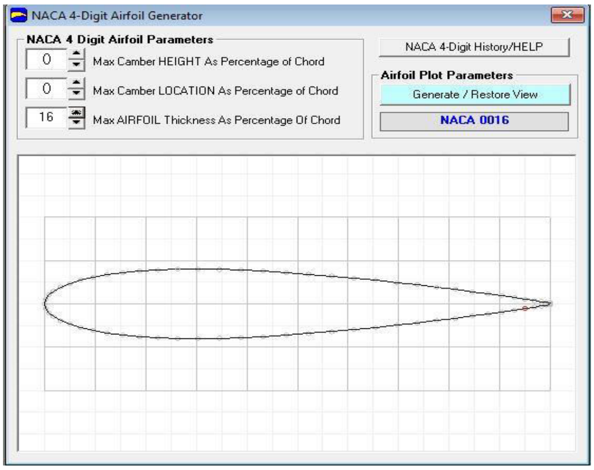


Fig 3.1.1 DESIGN FOIL



NACA 4 Digit Airfoil Parameters

0 Max Camber HEIGHT As Percentage of Chord
0 Max Camber LOCATION As Percentage of Chord
16 Max AIRFOIL Thickness As Percentage Of Chord

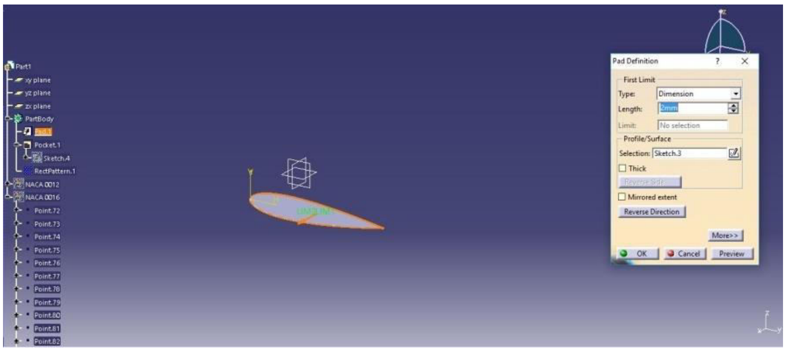
Airfoil Plot Parameters

NACA 0016

Fig 3.1.2 NACA 0016 SHAPE

NACA 0016			INDEX	X_Coord	Y_Coord			
INDEX	X_Coord	Y_Coord	24	0.263066	0.079593	INDEX	X_Coord	Y_Coord
1	1.000000	0.001680	25	0.224551	0.078104	49	0.303487	-0.080019
2	0.997987	0.002056	26	0.188255	0.075527	50	0.345492	-0.079433
3	0.991965	0.003176	27	0.154469	0.071861	51	0.388739	-0.077907
4	0.981981	0.005014	28	0.123464	0.067135	52	0.432883	-0.075528
5	0.968117	0.007529	29	0.095492	0.061399	53	0.477568	-0.072399
6	0.950484	0.010669	30	0.070776	0.054724	54	0.522432	-0.068628
7	0.929224	0.014367	31	0.049516	0.047199	55	0.567117	-0.064324
8	0.904509	0.018552	32	0.031883	0.038918	56	0.611260	-0.059597
9	0.876536	0.023146	33	0.018019	0.029977	57	0.654508	-0.054557
10	0.845531	0.028066	34	0.008035	0.020463	58	0.696513	-0.049303
11	0.811745	0.033228	35	0.002013	0.010452	59	0.736934	-0.043936
12	0.775448	0.038547	36	0.000000	0.000000	60	0.775448	-0.038547
13	0.736934	0.043936	37	0.002013	-0.010452	61	0.811745	-0.033228
14	0.696513	0.049303	38	0.008035	-0.020463	62	0.845531	-0.028066
15	0.654508	0.054557	39	0.018019	-0.029977	63	0.876536	-0.023146
16	0.611260	0.059597	40	0.031883	-0.038918	64	0.904509	-0.018552
17	0.567117	0.064324	41	0.049516	-0.047199	65	0.929224	-0.014367
18	0.522432	0.068628	42	0.070776	-0.054724	66	0.950484	-0.010669
19	0.477568	0.072399	43	0.095492	-0.061399	67	0.968117	-0.007529
20	0.432883	0.075528	44	0.123464	-0.067135	68	0.981981	-0.005014
21	0.388739	0.077907	45	0.154469	-0.071861	69	0.991965	-0.003176
22	0.345492	0.079433	46	0.188255	-0.075527	70	0.997987151	-0.002056095
23	0.303487	0.080019	47	0.224551	-0.078104	71	1	-0.00168

Fig 3.1.3 NACA 0016 key points

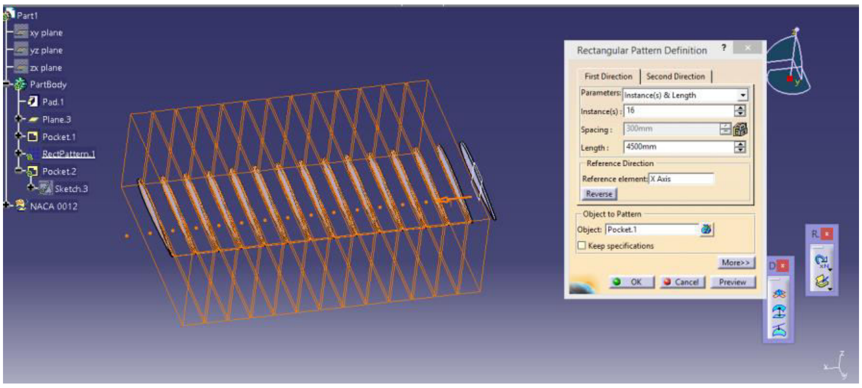


Pad Definition

First Limit
Type: Dimension
Length: 2mm
Limit: No selection
Profile/Surface
Selection: Sketch.3
☐ Thick
Reverse Side
☐ Mirrored extent
Reverse Direction

Fig 3.1.4 wing rib

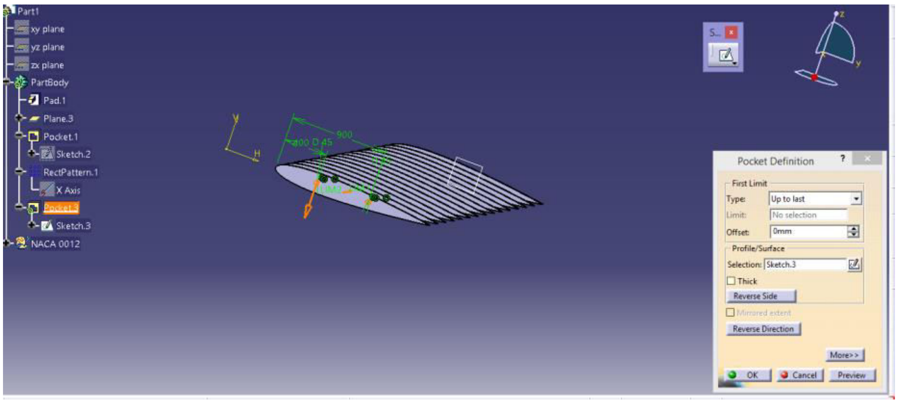
Here we are going to create 15 no of wing ribs with the span distance of 4500mm by using pattern. To insert stringers we also made holes by using pocket option



Rectangular Pattern Definition

First Direction | Second Direction
Parameters: Instance(s) & Length
Instance(s) : 16
Spacing : 300mm
Length : 4500mm
Reference Direction
Reference element: X Axis
Reverse
Object to Pattern
Object: Pocket.1
☐ Keep specifications

Fig 3.1.5: Creating 15 no of wing ribs with the span distance of 4500mm



Pocket Definition

First Limit
Type: Up to last
Limit: No selection
Offset: 0mm
Profile/Surface
Selection: Sketch.3
☐ Thick
Reverse Side
☐ Mirrored extent
Reverse Direction

Fig 3.1.6: Making holes for wing ribs

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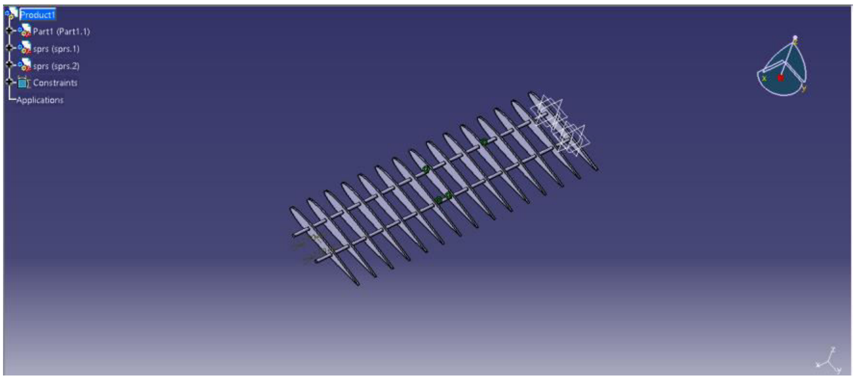
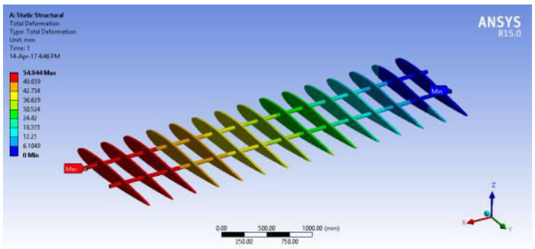


Fig 3.1.7: Inserting stringers in wing ribs

3.2 ANSYS ANALYTICAL SYSTEM

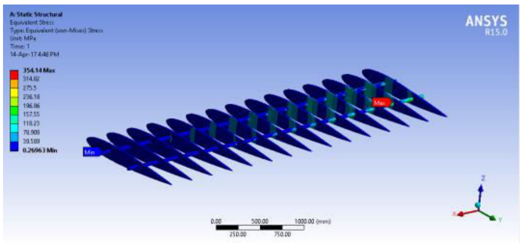
For all engineers and students coming to finite element analysis or to ANSYS software for the first time, this powerful hands-on guide develops a detailed and confident understanding of using ANSYS's powerful engineering analysis tools. The best way to learn complex systems is by means of hands-on experience.

NACA 0012 wing structure:



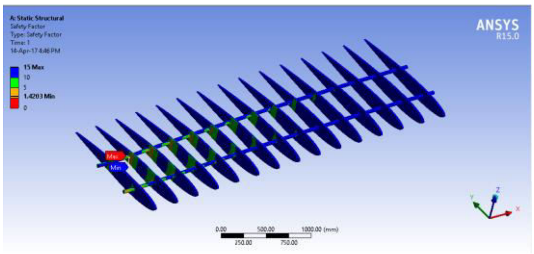
A: Static Structural
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1
14-Apr-17 4:46 PM

Fig 3.2.1: deformation of al-7075



A: Static Structural
Equivalent Stress
Type: Equivalent (von-Mises) Stress
Unit: MPa
Time: 1
14-Apr-17 4:46 PM

Fig 3.2.2: stress of al-7075



A: Static Structural
Safety Factor
Type: Safety Factor
Time: 1
14-Apr-17 4:46 PM

Fig 3.2.3: safety factor of al-7075

From the above results here we got maximum stress value is 354.14Mpa and safety factor value is 1.4203 and generally we cannot eliminate complete stresses on the body but we can reduce it by changing design and material properties values. Here we took al-7075 material for both ribs and stringers. To decrease the stress and increase the strength to weight ratio here we changing materials, i.e we took another two materials those are CFRP and KEVLAR materials

KEVLAR:

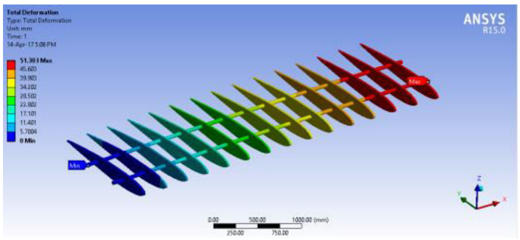


Fig 3.2.4: deformation of Kevlar

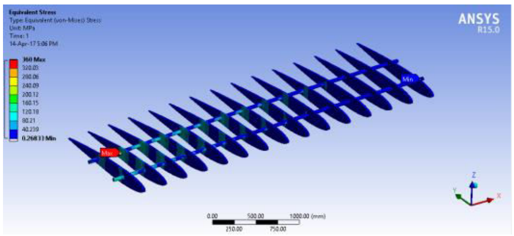


Fig 3.2.5: stress of Kevlar

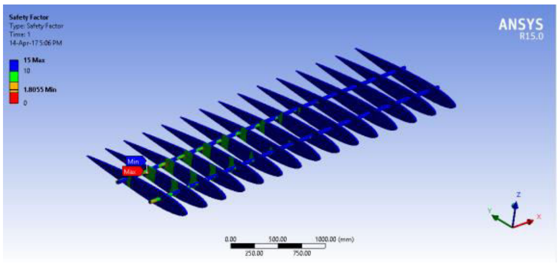


Fig 3.2.6: safety factor of Kevlar

NACA 0016 wing structure:

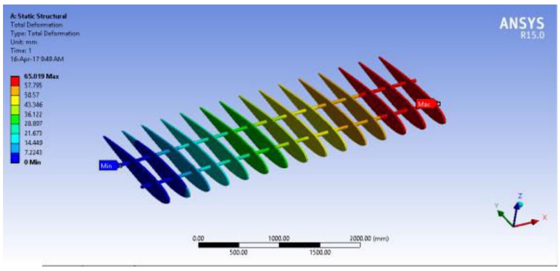


Fig 3.2.7: deformation of NACA 0016

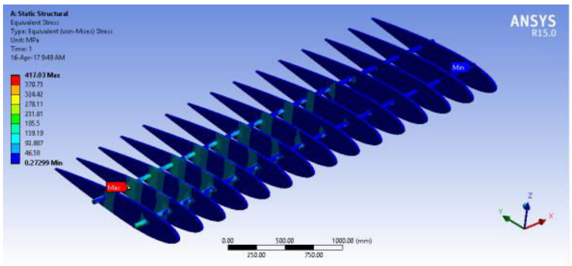


Fig 3.2.8: Stress of NACA 0016

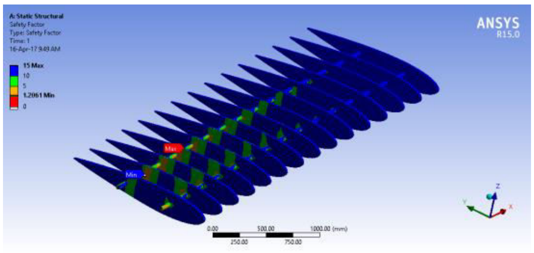


Fig 3.2.9: Safety factor of NACA 0016

From the above results here we got maximum stress value is 417.03Mpa and safety factor value is 1.2061 and generally we cannot eliminate complete stresses on the body but we can reduce it by changing design and material properties values. Here we took al-7075 material for both ribs and stringers. To decrease the stress and increase the strength to weight ratio here we changing materials, i.e we took another two materials those are CFRP and KEVLAR materials

Kevlar

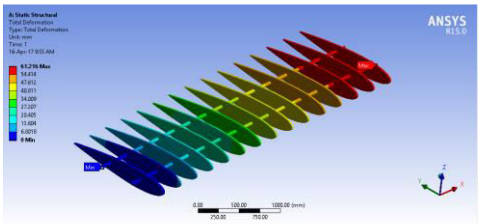


Fig 3.2.10: Deformation of Kevlar

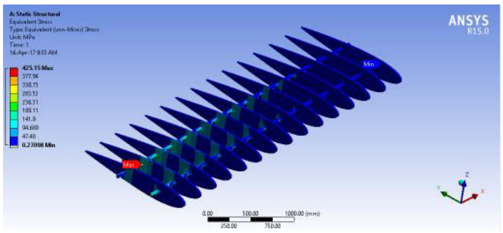


Fig 3.2.11: Stress of Kevlar

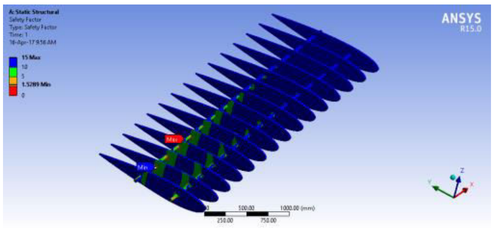


Fig 3.2.12: Safety factor of Kevlar

4. RESULT

Here we consider al-7075 material as existing material for both structures and applied 14Mpa pressure on ribs and calculated results like deformation, stress, safety factor values. In this case

NACA 0016 has huge stress (417.03Mpa) compared with NACA 0012 (354.14Mpa) structure. The results are illustrated in the following tables.

Table 4.1: Results of various materials

	Deformation(mm)	**Stress(Mpa)**	**Safety factor**
Al-7075	65.019	417.03	1.2061
Cfrp (stringers) &al-7075 (ribs)	86.797	434.27	1.1583
Cfrp (ribs) &al-7075 (stringers)	85.716	439.07	1.0796
Kevlar (stringers)&al-7075 (ribs)	60.447	409.77	1.2275
Kevlar (ribs) &al-7075 (stringers)	61.216	425.15	1.5289

Table 4.2: Results of various materials

	Deformation(mm)	**Stress(Mpa)**	**Safety factor**
Al-7075	54.944	354.14	1.4203
Cfrp (stringers) &al-7075 (ribs)	71.549	362.63	1.3871
Cfrp (ribs) &al-7075 (stringers)	73.663	367.52	1.2897
Kevlar (stringers)&al-7075 (ribs)	51.436	347.85	1.446
Kevlar (ribs) &al-7075 (stringers)	51.303	360	1.8055

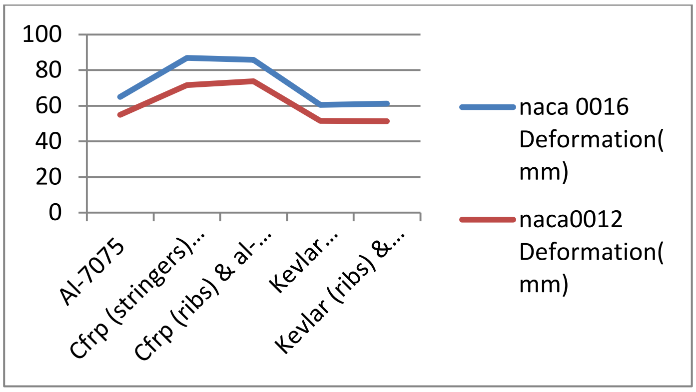


Fig 4.1: Deformation of materials NACA 0012 and NACA 0016

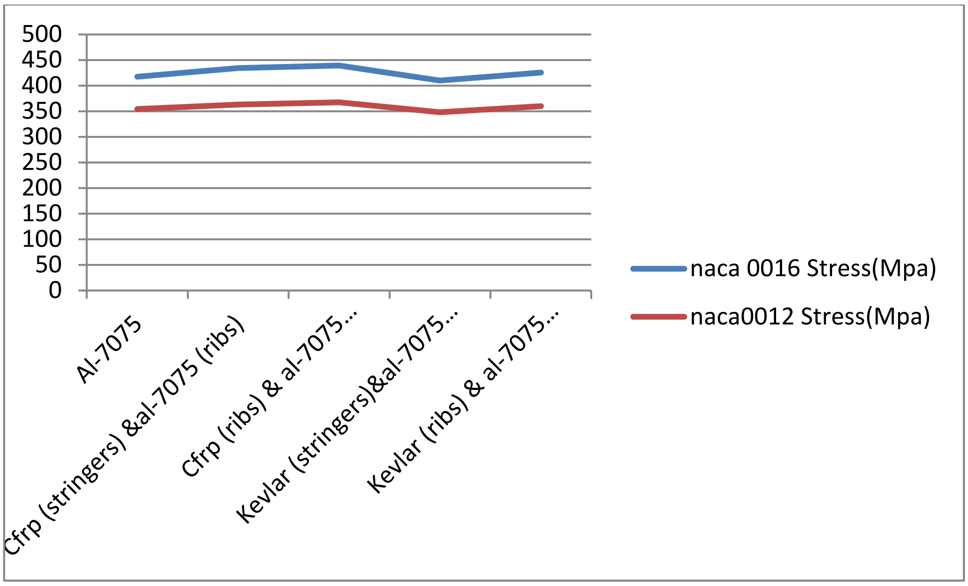


Fig 4.2: Stress of materials NACA 0012 and NACA 0016

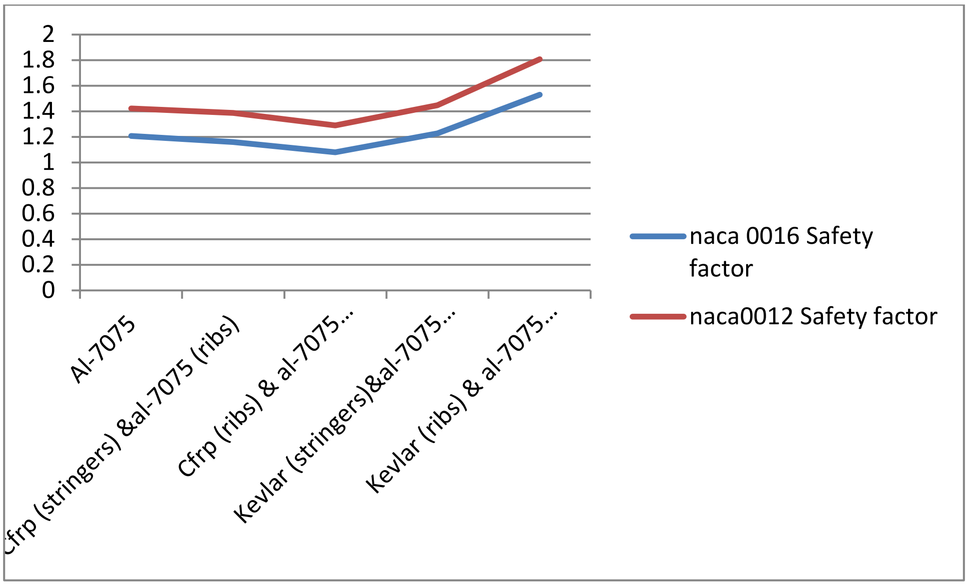


Fig 4.3: Safety factor of materials NACA 0012 and NACA 0016

From the above results here we got maximum stress value is 354.14Mpa and safety factor value is 1.4203 and generally we cannot eliminate complete stresses on the body but we can reduce it by changing design and material properties values.

5. CONCLUSION

In this project ultra light aircraft wing structure was developed by using CAD TOOL (CATIA) and analyzed with CAE TOOL (ANSYS WORK BENCH) , in this project we took different wing structuresthose are NACA 0012 and NACA 0016 and calculated their maximum strength values. Here we consider al-7075 material as existing material for both structures and applied 14Mpa pressure on ribs and calculated results like deformation, stress, safety factor values. In this case NACA 0016 has huge stress (417.03Mpa) compared with NACA 0012 (354.14Mpa) structure. It means by using NACA 0012 wing structure we can reduce 63Mpa amount of stress it means the strength will increases.

To get more efficient wing structure here we using composite materials also those are CFRP and KEVLAR. In this process first we apply CFRP to stringers and ribs (al-7075) then next CFRP (ribs) &al-7075 (stringers), and we repeat same process for Kevlar &al-7075 materials for both structures. From the results NACA 0012 wing structure has high strength to weight ratio in all these conditions, finally we can conclude that NACA 0012 wing structure with ribs (Kevlar) stringers (al-7075) materials will increase the strength of the wing structure compare to existing material.

6. REFERENCES

[1] T.V. Baughn and P.F. Packman."Finite element analysis of an ultralight aircraft", Journal of Aircraft, Vol. 23, No. 1(1986), pp.82-86.

[2] Baughn, T. and Johnson, D., "Structural Design Considerations for Ultralight Aircraft," SAE Technical Paper 861388, 1986,doi:10.4271/861388.

[3] Girish S. Kulkarni, A thesis of „Structural Design and Analysis of an Ultralight Airplane‟, IIT Kanpur, 1987.

[4] ZdobyslawGoraj, „Ultralight wing structure for high altitude long endurance UAV‟, ICAS 2000 Congress.

[5] William Zimmerman and Howard W. Smith, „Report on test set-up for the structural testing of air mass sunburst in Ultralight aircraft‟ 2001

[6] L. Pascale, F. Nicolosi, "Design and Aerodynamic analysis of a light twin-engine propeller aircraft" ICAS 2008.

[7] HuiwenHu and Huaien Kao, "Model Validation of an Ultralight Aircraft Using Experimental Modal Analysis" Journal of Aeronautics,Astronautics and Aviation, Series A, Vol.41, No.4 pp.271 - 282 (2009).

[8] Kesavulu A, F.AnandRaju& Dr. M.L.S. Deva Kumar, "Properties of Aluminium Fly Ash Metal Matrix Composite" Vol. 3, Issue 11,November 2014, ISSN: 2319-8753.

[9] William L. KO, Dryden Flight Research Center, Edwards, California "Mechanical- and Thermal-Buckling Behaviour of Rectangular Plates with Different Central Cutouts", NASA/TM-1998-206542, March 1998.

[10] R.C. Batra, Z. Wei, "Dynamic buckling of a thin thermoviscoplastic rectangular plate", Department of Engineering Science and Mechanics, Virginia Polytechnic Institute and State University,MC 0219, Blacksburg, VA 24061, USA, November 2004.

[11]J. Purbolaksono, M.H. Aliabadi."Application of DRBEM for Evaluating Buckling Problems of Perforated Thin Plates" European Journal of Scientific Research ISSN 1450-216X Vol.31 No.3 (2009), pp.398-408