International Journal For Advanced Research In Science & Technology
A peer reviewed international journal www.ijarst.in
ISSN: 2457-0362

DESIGN AND ANALYSIS OF AIRCRAFT WING WITH DIFFERENT WINGLET ANGLES

[1]B. Anil Kumar Reddy, [2]Ms. D Anitha, [3]Dr. D Govardhan

[1]M-Tech Scholar, [2]Asst Professor, [3]Professor &HOD

*Department of Aeronautical Engineering Institute of Aeronautical Engineering Dundigal Road, Dundigal, Hyderabad, Telangana 500043

ABSTRACT: A wing structure of a flying machine which is able to fly with assistance of air foil profile that produces lift by the vehicle's forward velocity. Fixed-wing air ship pursues the cantilever pillar structure in which the one end is fixed to the fuselage and another is set to be the free end. In this proposal, venture definite structure of coach flying machine wing with winglet made by utilizing CREO. At that point pressure examination of the wing structure is done to process the worries at wing structure. The anxieties are evaluating by utilizing the limited component approach with the assistance of ANSYS to discover the security factor of the wing with winglets. Life forecast requires a model for exhaustion harm aggregation, steady plentifulness S-N (stress life) information for different pressure proportions and neighbourhood stress history at the pressure focus. In this proposition, the mentor flying machine wing with winglets with points (45^0 and 25^0) is thinking about for the itemized investigation. Static and weakness investigation of the entire wing area is done to figure the burdens and life at various winglet points (25^0 and 45^0) because of the applying weight load.

Key words: aircraft wing, winglets, CFD analysis, drag force structural analysis, strength.

Introduction

Many of us who fly regularly have most probably seen a so-called winglet or wingtip device at the end of the wing of an airliner at least once. It is showing up more and more often on more and more types of aircraft, thus we felt it’s time to give an overview to our readers about these sometimes funny, sometimes cool and stylish looking aircraft parts.

Fig 1.1 Winglet on Virgin Atlantic A340-600 - c by Dan Valentine on Airliners.net

Airliners to use raked wingtips: Boeing 747-8, Boeing 767-400ER, Boeing 777(-200LR; -300ER; and freighter versions) plus the new Boeing 787 Dreamliner and the Airbus A350. The 747-8, the 787 and the A350 will have special, new kind of wings, which do not have a separate winglet, but have raked, and blended wingtips integrated – without a sharp angle between the wing and the winglet.

Fig 1.7 Raked Wingtips on the new Boeing 787 and Airbus A350

Aviation Partners, for its part, continues to test the most extreme interpretation of a winglet yet, the closed Spiroid (above), chasing the promise of a 10% cruise fuel-burn reduction.

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal www.ijarst.in
ISSN: 2457-0362

And it doesn't stop there, as these recent US patents show.

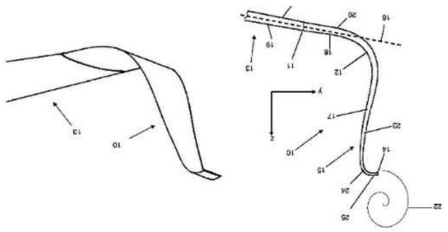

fig 1.14 Graphic: USPTO

6 advantages of aircraft winglet

Since the 1970s, when the price of aviation fuel began spiralling upward, airlines and aircraft manufacturers have looked at many ways to improve the operating efficiency of their aircraft.

Winglets have become one of the industry's most visible fuelsaving technologies and their use continues to expand. Winglets increase an aircraft's operating efficiency by reducing what is called induced drag at the tips of the wings.

An aircraft's wing is shaped to generate negative pressure on the upper surface and positive pressure on the lower surface as the aircraft moves forward. This unequal pressure creates lift across the upper surface and the aircraft is able to leave the ground and fly.

Unequal pressure, however, also causes air at each wingtip to flow outward along the lower surface, around the tip, and inboard along the upper surface producing a whirlwind of air called a wingtip vortex.

7 Dis-advantages of aircraft winglet

It has been shown in Chapter 5 that the most effective method of reducing vortex drag is by increasing the aspect ratio, i. e. increasing the wing span for a given total area. It follows that whatever the gain from using winglets, a similar improvement could be achieved by an increase in aspect ratio. This could be done by fitting a simple wing extension. Such a span extension would, of course, increase the bending loads on the mainplane and would add weight, so the best solution is again decided by economics rather than aerodynamics. Nonetheless, whereas winglets require considerable research and, usually, wind tunnel testing to ensure they are of the most favourable shape and set at the best angle, to lengthen the wing is comparatively simple. Moreover, stretching a wing in this way is guaranteed to reduce vortex drag at all airspeeds. A longer wing is more prone to flutter problems and slower in roll than a short wing, but adding winglets to a short wing also increases the danger of flutter and the additional mass at the tip creates more rolling inertia.

II. LITERATURE REVIEW

DESIGN AND ANALYSIS OF WINGLET

The project is focused on the modeling and analysis of winglet of aircraft. In aerodynamic engineering, drag reduction is a big challenge. To reduce drag a device called winglet which is placed vertically at set of angle on the end of aircraft wing. Winglet design will reduce the fuel consuming by reducing the aircraft drag and makes the aircraft more stable during flight, also it will give the aircraft engine longer life by reducing the load on the engine thrust. The aim is to design and simulate a model of winglet fo used to construct the winglet models and ANSYS is used to test and simulate the winglet model. With wing angles, results are compared and aircraft because it lowers the amount of drag and increases the fuel efficiency by using less energy by reducing wing improving the aircraft performance.

Design and Analysis of Spiroid Winglet by W.GiftonKoil Raj1 , T.AmalSeba Thomas2 Wingtip vortices are strongly associated with induced drag for a three-dimensional wing. So it is important to neglect the wingtip vortices in order to

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
www.ijarst.in
IJARST
ISSN: 2457-0362

reduce the induced drag. The drag breakdown of a typical transport aircraft shows that the lift-induced drag can amount to as much as 40% of the total drag at cruise conditions and 80– 90% of the total drag in take-off configuration. One way of reducing lift-induced drag is by using wingtip devices. By applying biomimetic abstraction of the principle behind a bird's wingtip feathers, we study spiroid wingtips, which look like an extended blended wingtip that bends upward by 360 degrees to form a large rigid ribbon.In this paper a configuration of different winglets are studied. A model composed of wing of boeing-737 is designed using CATIA and also the spiroid winglet are designed and attached with a boeing 737 wing using CATIA. Then the modelled wing is meshed using ICEM-CFD. The meshed model will be analysed using ANSYS FLUENT. Finally the percentage decrement of wingtip vortices is calculated using the analysis results.

III. MATERIALS AND METHODOLOGY

Material properties

Material	Density (g/cc)	Youngs modulus (MPa)	Poisson's ratio
Kevlar-49	1.44	112000	0.36
S2 glass	2.48	85500	0.21
Boron fiber	2.61	428000	0.13

The methodology in this by adopts the CATIVA V5R20 for designing of UCAV wing and winglet. Meshing and analysis are done by ANSYS V18.1. Here CFD flow analysis is carried out for both UCAV wing with and without winglet.

A. Design parameters for wing and winglets are as follows: Wing is designed by using asymmetric air foil of NACA 6 series i.e., NACA 64A210. This NACA 64A210 air foil have lower drag at higher speeds compared to winglet angles 25° and 45° angle.
B. Static analysis results comparing to materials Kevlar- 49, s2 glass and boron fiber

Aircraft wing with winglet 25° angle and 45° angle designed in CATIA v5 parametric software. The aircraft wing shape created with NACA 64A210 points.

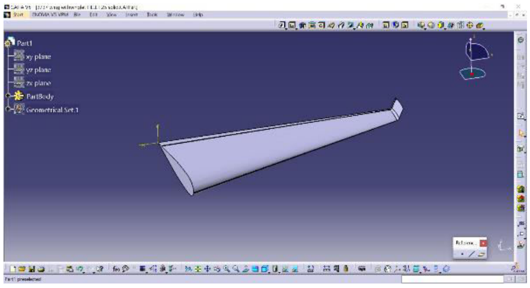

Fig 4.3 Winglet with 25 angle

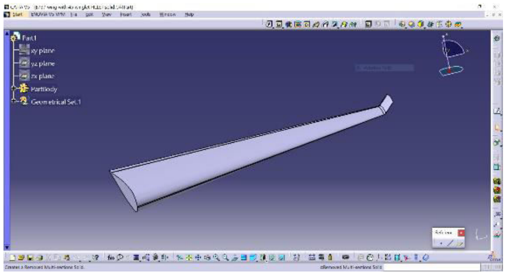

Fig 4.4 Winglet with 45 angle

CFD ANALYSIS OF AIRCRAFT WING

5.3.1 CASE 1 WITHOUT WINGLET

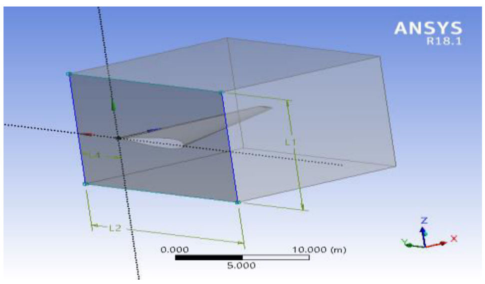

Fig 5.3.1 Imported model

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
www.ijarst.in
ISSN: 2457-0362

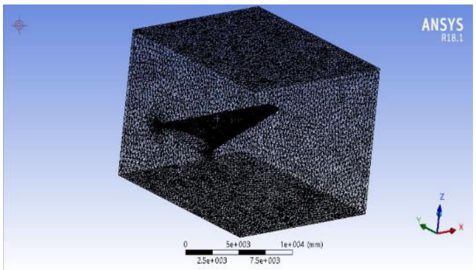

Fig 5.3.2 Meshed model

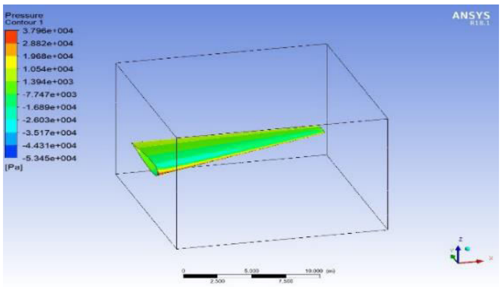

Fig 5.3.5 Pressure

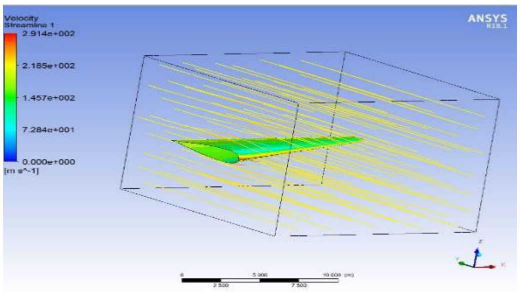

Fig 5.3.6 Velocity

Forces

Zone	Forces (n) Pressure	Viscous
wall-solid	(-259.33987 85.742767 -73.708801)	(0.53292763 6.1969323 -1.7712427)
wingsurface	(17203.711 4997.7207 144795.48)	(-41.645023 2175.2244 -22.331369)
wall	(-421123.03 6.0725476e-08 1.0089012e-08)	(0 2645.1055 -5.7984939)
Net	(-404178.66 5083.4635 144721.78)	(-41.112096 4826.5268 -29.901106)

Forces - Direction Vector (0 1 0)

	Forces (n)			Coefficients		
Zone	Pressure	Viscous	Total	Pressure	Viscous	Total
wall-solid	85.742767	6.1969323	91.9397	139.98819	10.117441	150.10563
wingsurface	4997.7207	2175.2244	7172.9451	8159.544	3551.3867	11710.931
wall	6.0725476e-08	2645.1055	2645.1055	9.9143635e-08	4318.5395	4318.5395
Net	5083.4635	4826.5268	9909.9902	8299.5322	7880.0437	16179.576

Fig 5.3.7 Drag force

Forces

Zone	Forces (n) Pressure	Viscous
wall-solid	(-259.33987 85.742767 -73.708801)	(0.53292763 6.1969323 -1.7712427)
wingsurface	(17203.711 4997.7207 144795.48)	(-41.645023 2175.2244 -22.331369)
wall	(-421123.03 6.0725476e-08 1.0089012e-08)	(0 2645.1055 -5.7984939)
Net	(-404178.66 5083.4635 144721.78)	(-41.112096 4826.5268 -29.901106)

Forces - Direction Vector (0 0 1)

	Forces (n)			Coefficients		
Zone	Pressure	Viscous	Total	Pressure	Viscous	Total
wall-solid	-73.708801	-1.7712427	-75.480044	-120.3409	-2.8918249	-123.23272
wingsurface	144795.48	-22.331369	144773.15	236400.79	-36.459379	236364.33
wall	1.0089012e-08	-5.7984939	-5.7984939	1.6471857e-08	-9.4669288	-9.4669287
Net	144721.78	-29.901106	144691.87	236280.45	-48.818132	236231.63

Fig 5.3.8 Lift force

CASE 3 WINGLET WITH 45 ANGLES

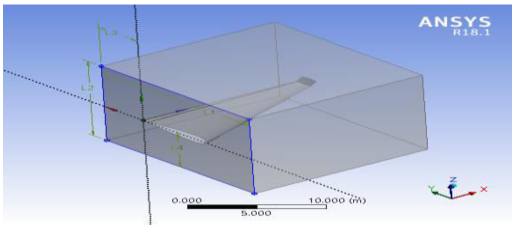

Fig 5.5.1 Imported model

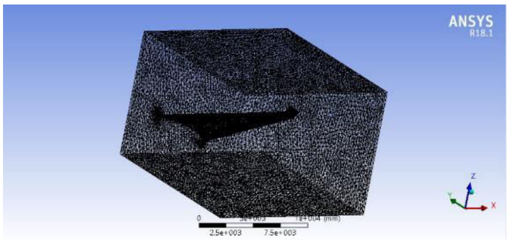

Fig 5.5.2 Meshed model

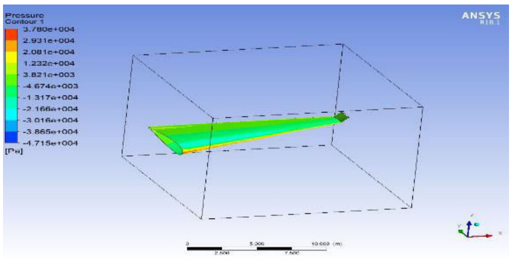

Fig 5.5.5 Pressure

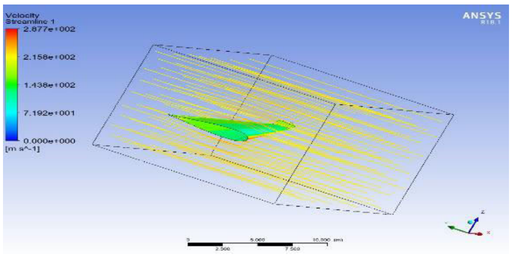

Fig 5.5.6 Velocity

Forces

Zone	Forces (n) Pressure	Viscous
wall-solid	(-2577.4409 -833.20306 2788.8015)	(-0.91422105 48.015495 -1.0199521)
wingaircontact	(12554.095 15654.943 112533.32)	(-48.418495 2669.4973 -15.428761)
wall	(-417978.47 -6.7996681e-14 2.7911129e-13)	(0 3302.1406 -6.4173694)
Net	(-408001.81 14821.74 115322.12)	(-49.332716 6019.6534 -22.866082)

Forces - Direction Vector (0 1 0)

	Forces (n)			Coefficients		
Zone	Pressure	Viscous	Total	Pressure	Viscous	Total
wall-solid	-833.20306	48.015495	-785.18757	-1360.3315	78.392645	-1281.9389
wingaircontact	15654.943	2669.4973	18324.441	25559.091	4358.363	29917.454
wall	-6.7996681e-14	3302.1406	3302.1406	-1.1101499e-13	5391.25	5391.25
Net	14821.74	6019.6534	20841.394	24198.76	9828.0056	34026.765

Fig 5.5.8 Drag force

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal
www.ijarst.in
ISSN: 2457-0362

```
Forces
                         Forces (n)
Zone                     Pressure                                    Viscous
wall-solid               (-2577.4409 -833.20306 2788.8015)           (-0.91422105 48.015495 -1.0199521)
wingaircontact           (12554.095 15654.943 112533.32)             (-48.418495 2669.4973 -15.428761)
wall                     (-417978.47 -6.7996681e-14 2.7911129e-13)   (0 3302.1406 -6.4173694)
------------------------ -------------------------------------------- --------------------------------------------
Net                      (-408001.81 14821.74 115322.12)             (-49.332716 6019.6534 -22.866082)

Forces - Direction Vector (0 0 1)
                         Forces (n)                                  Coefficients
Zone                     Pressure        Viscous       Total          Pressure        Viscous       Total
wall-solid               2788.8015       -1.0199521    2787.7816      4553.1453       -1.6652279    4551.4801
wingaircontact           112533.32       -15.428761    112517.89      183727.87       -25.189813    183702.68
wall                     2.7911129e-13   -6.4173694    -6.4173694     4.556919e-13    -10.477338    -10.477338
------------------------ --------------- ------------- -------------- --------------- ------------- -------------
Net                      115322.12       -22.866082    115299.26      188281.02       -37.332379    188243.68
```

Fig 5.5.8 Lift force

Material- s2 glass

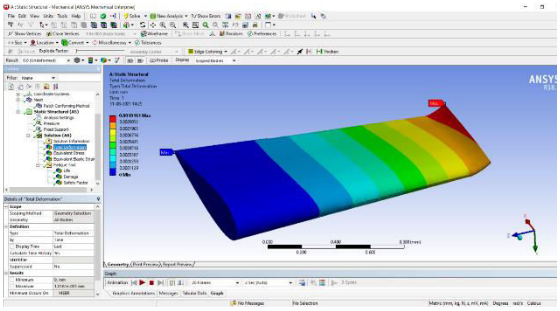

Fig 5.6.2.1 Deformation **for winglet angle 25⁰**

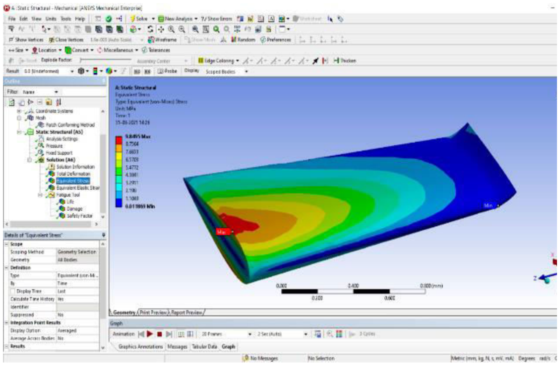

Fig 5.6.2.2 stress **for winglet angle 25⁰**

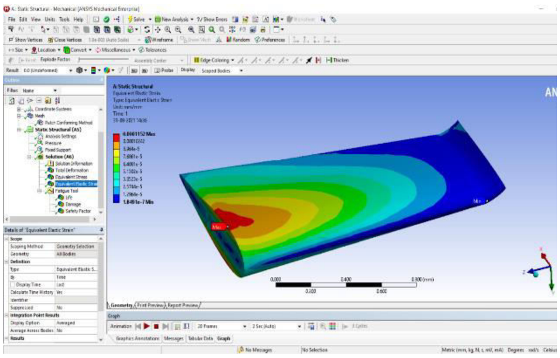

Fig 5.6.2.3 strain **for winglet angle 25⁰**

Material- s2 glass

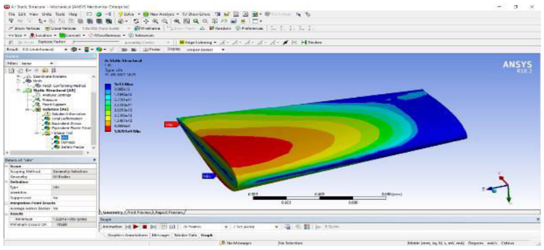

Fig 5.7.2.1 life for no winglet

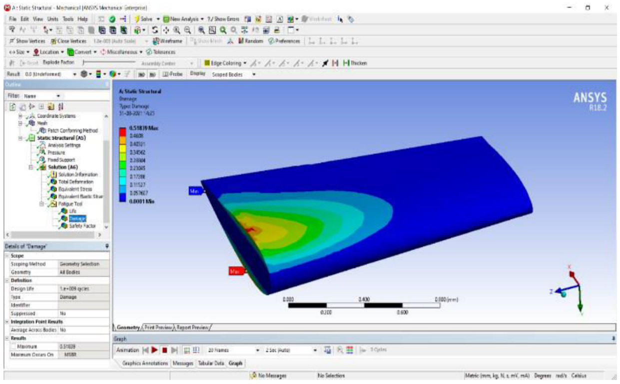

Fig 5.7.2.2 damage for no winglet

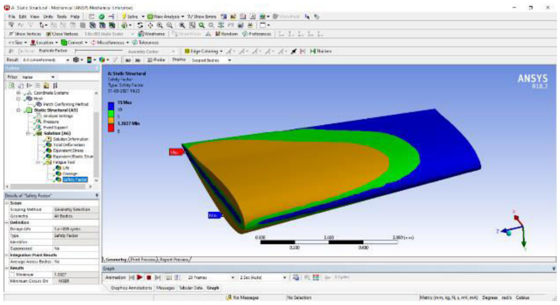

Fig 5.7.2.3 safety factor for no winglet

Material- s2 glass

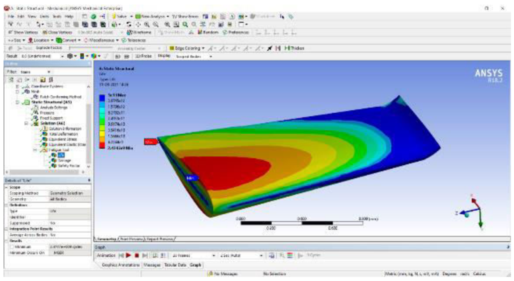

Fig 5.7.3.1 life for winglet angle 25⁰

International Journal For Advanced Research In Science & Technology
A peer reviewed international journal www.ijarst.in
IJARST
ISSN: 2457-0362

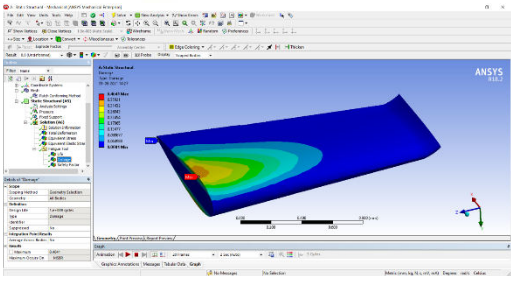

Fig 5.7.3.2 damage for winglet angle 25^0

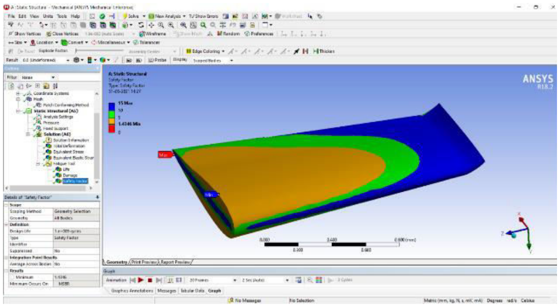

Fig 5.7.3.3 safety factor for winglet angle 25^0

Material- s2 glass

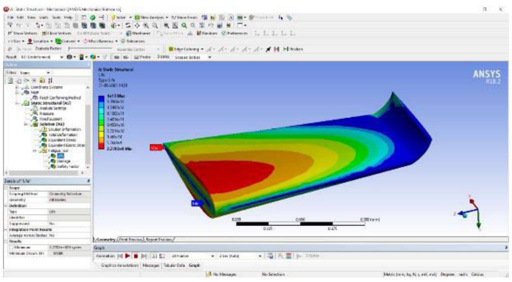

Fig 5.7.4.1 life for winglet angle 45^0

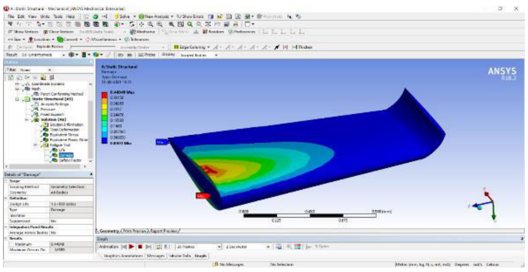

Fig 5.7.4.2 damage for winglet angle 45^0

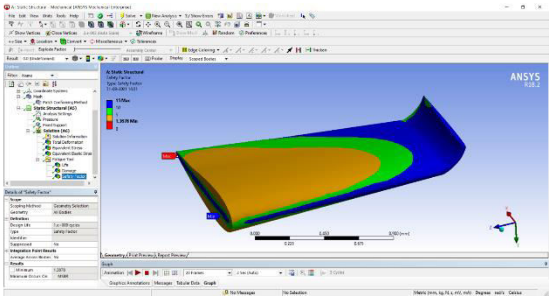

Fig 5.7.4.3 safety factor for winglet angle 45^0

5.7.5 Material- boron fiber

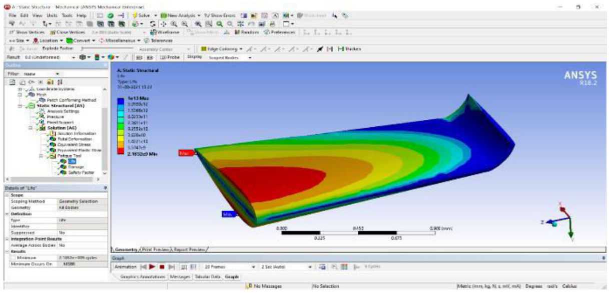

Fig 5.7.5.1 life for winglet angle 45^0

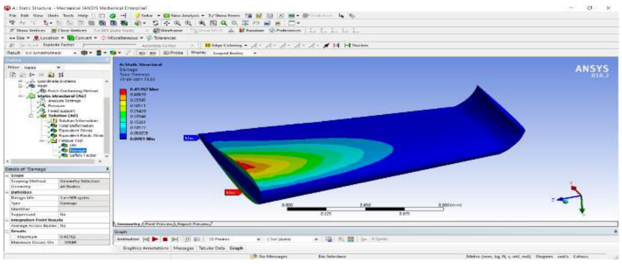

Fig 5.7.5.2 damage for winglet angle 45^0

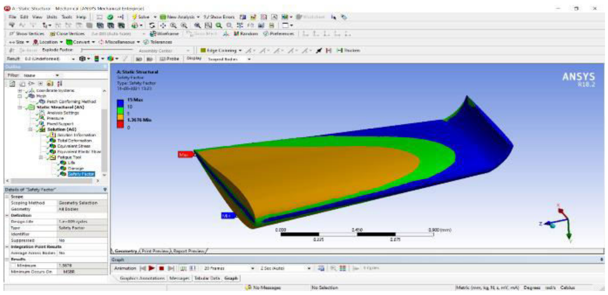

Fig 5.7.5.3 safety factor for winglet angle 45^0

RESULTS AND DISCUSSIONS

Table 6.1 CFD ANALYSIS RESULTS TABLE

Models	Pressure (Pa)	Velocity (m/s)	Drag force (N)	Lift force (N)
No winglet	3.796e+004	2.914e+002	16179.576	236231.63
25^0	4.290 e+004	2.892 e+002	19334.211	231802.32

45^0	3.780 e+004	2.877 e+002	34026.765	188243.68

Table 6.2 Static analysis results table

Models	Materials	Deformation (mm)	Stress (MPa)	Strain
No winglet	Kevlar -49	0.00070386	10.85	9.7267e-5
	S2 glass	0.00094648	10.847	0.00012686
	Boron fiber	0.00019033	10.977	2.5647e-5
	Aluminium alloy	0.0011179	10.701	0.00015127
25^0	Kevlar -49	0.00075719	9.9006	8.8571e-5
	S2 glass	0.0010161	9.8495	0.0001152
	Boron fiber	0.0002042	9.9455	2.3241e-5
	Aluminium alloy	0.001202	9.8378	0.00013856
45^0	Kevlar -49	0.00085116	10.727	9.6302e-5
	S2 glass	0.0011404	10.182	0.00011936
	Boron fiber	0.00022901	10.332	2.414e-5
	Aluminium alloy	0.0013507	10.562	0.0001495

Fatigue analysis results table

Models	Materials	Life	Damage	Safety factor
No winglet	Kevlar -49	1×e13	0.51885	1.3022
	S2 glass	1×e13	0.51839	1.3027
	Boron fiber	1×e13	0.53403	1.2872
	Aluminium alloy	1×e13	0.50133	1.3204
25^0	Kevlar -49	1×e13	0.40957	1.4272
	S2 glass	1×e13	0.4041	1.4346
	Boron fiber	1×e13	0.41442	1.4207
	Aluminium alloy	1×e13	0.40285	1.4363
45^0	Kevlar -49	1×e13	0.50432	1.3172
	S2 glass	1×e13	0.44049	1.3878
	Boron fiber	1×e13	0.45762	1.3676
	Aluminium alloy	1×e13	0.48459	1.3378

CONCLUSION

The main purpose of this project is learning and analysed the aerodynamics performance of Wing and different types of winglets with wings. The aerofoil's NACA 64A210 designed in CREO and gone through flow simulated in ANSYS.

Here introducing the composite materials Kevlar -49 , s2 glass and boron fiber. Present material is aluminium alloy materials for wing, this aluminium alloy material replaced with composite materials.

The simulated of a winglet and after three angles (0°, 25° & 45° angles) wing models with different winglets was carried out pressure, velocity, drag force and lift force at different winglet angles.

Design parameters for wing and winglets are as follows: Wing is designed by using asymmetric air foil of NACA 6 series i.e., NACA 64A210. This NACA 64A210 air foil have lower drag at higher speeds compared to winglet angles 25° and 45° angle.

By observing the CFD analysis results the drag force decrease by decreasing the NACA series. Drag force value reduced at 25° angle NACA 64A210 series.

So, it can be concluded the NACA 64A210 at 25° angle of winglet is the better model. When we compared the material s2 glass material has less stress than Kevlar-49, boron fiber and aluminium alloy .

By observing the fatigue analysis results the safety factor value more at wing with winglet 25° angle and s2 glass material has more safety factor. so it can be concluded the s2 glass material is the best material for winglet.

REFERENCES

[1] Yates,J. E. , and Donaldson, C., "Fundamental Study of Drag and an Assessment of Conventional Drag-Due-To-Lift Reduction Devices", NASA Contract Rep 4004, 1986

[2] Whitcomb, R. T., "A Design Approach and Selected Wind-Tunnel Results at High Subsonic Speeds for Wing-Tip Mounted Winglets", NASA N D-8260, 1976

[3] Whitcomb, R. T., "Methods for Reducing Aerodynamic Drag", NASA Conference Publication 2211, Proceedings of Dryden Symposium, California 1981

[4] Maughmer, M. D., Timothy, S. S., and Willits, S. M., "The Design and Testing of a Winglet Airfoil for Low-Speed Aircraft", AIAA Paper 2001-2478, 2001

[5] McLean, D., "Wingtip Devices: What They Do and How They Do It" presented at the Boeing Performance and Flight Operations Engineering Conference, 2005.

[6] Lambert, D., "Numerical Investigation of Blended Winglet Effects on Wing Performances, report" Liege University; 2007.

[7]http://www.boeing.com/commercial/757family/pf/pf_facts.html.

[8] http://www.winggrid.ch/2014

[9] Smith, M. J., Komerath N., Ames, R., and Wong, O., "Performance Analysis OF A Wing with Multiple Winglets" American Institute of Aeronautics and Astronautics (AIAA-2407), 2001.

[10] Versteeg, H., and Malalasekera, W. "An Introduction to Computational Fluid Dynamics: The Finite Volume Method" Longman, 1995.