International Journal For Technological Research In Engineering
Volume 5, Issue 11, July-2018 *ISSN (Online): 2347 - 4718*

COMPARATIVE ANALYSIS OF AIRCRAFT WING FUSELAGE LUG ATTACHMENT BRACKET

Sumanth M H[1], Ayyappa T[2]
[1]Post Graduate Student, [2]Assistant Professor
Department of Mechanical Engineering, DayanandaSagar College of Engineering, Bangalore.

Abstract: Aircraft is a complex man made machine or structure that is able to fly in the sky and is used to transport the passengers and goods from one place to another. A fighter aircraft is a type of aircraft that need to execute complicate maneuvers and turns while fighting with enemies. Complicate maneuvers implies instant change in direction, acceleration and roll which induce high magnitude loads on the aircraft structural components. Although there are wide variety of aircrafts most have the same major components like fuselage, empennage, wings , landing gears, and the power plant, among which the fuselage and the wings are important structural components. The wing are connected to the fuselage by means of wing fuselage lug attachment bracket. This paper deals with the modelling and simulation of static behaviour of wing fuselage lug attachment bracket in the fighter airframe structure, using finite element method to ensure the static load carrying capability. The Fatigue cracks will appear at high tensile stress locations, so as to foresee the Fatigue Life of the wing fuselage lug attachment bracket, fatigue life calculations is carried out analytically for the given load spectrum on the bracket using constant amplitude fatigue diagrams for various stress ratios and local stress for different materials. And also attempt is made to reduce the weight of the lug bracket by using better materials with lower density, and their behaviour in static and fatigue analysis is studied and results are compared.

I. INTRODUCTION

An aircraft is a machine that is able to f1y by gaining the support from the air. It is used to transport the passengers from one place to the other. Since from the mytho1ogy many attempted to f1y a machine in the sky and many were unsuccessful in f1ying their machines, and have lost the 1ives during the experiment. But eventually in 1910 Wright Brothers were able to bui1d a machine which was ab1e to fly for 59 seconds, that is a short duration of time, it was a first milestone for deve1opment of the aviation. Later many researches were made for transporting the goods and passengers. Then it was brought to business for the purpose of transportation . And also used in mi1itary for air support, hence forth many fighter p1anes are developed. Although the airplanes are designed for different purposes, most of the components will be similar. Most of the airoplane structures include fuselage, wings , empennage , landing gears and power plant and the control surfaces.

II. FIGHTER AIRCRAFT

Fighter or the Attack aircrafts are the most exciting machines in the military sphere because of the design, speed and weaponry installed in the aircrafts. A fighter aircraft is a typical military aircraft which is primarily designed for the purpose of air to air combat against other aircrafts and also with the mission to attack the targets on the ground. The main characteristics of these aircrafts is maneuverabi1ity, speed and the small size . The fighter aircrafts were developed at the time of First World War to gain supremacy in the battle over sky. A typical fighter aircraft with main parts is shown in below figure 1.

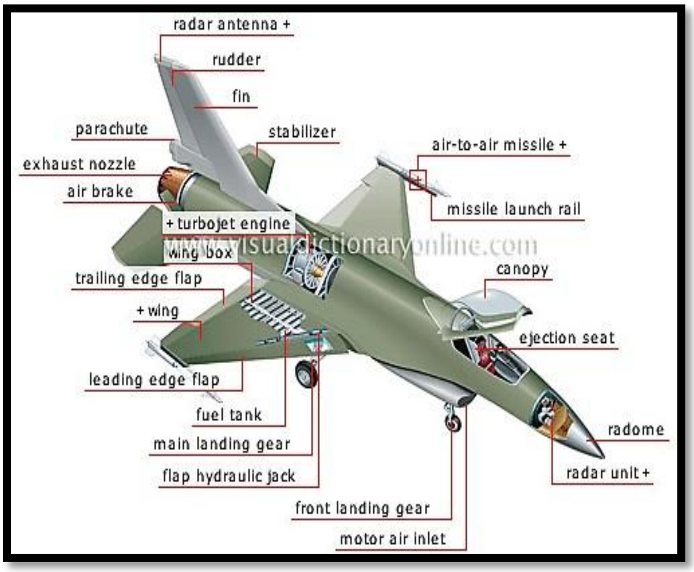

Fig. 1 Typical fighter aircraft with parts

BACKGROUND

The wings and the fuselage of the aircraft are the important key structural parts of an aircraft. Each of which have important roles to play in flight of the aircraft. Wings are subjected to different loads, so in all the cases the wings have to be rigidly attached to the fuselage, failure of which may lead to severe consequences. Several methods are being used in joining the wings of the aircraft to the main body or the fuselage, some of them are as follows,

- Spliced plates:widely used because of its 1ight weight,it is more reliable and inherent fai1 safe feature in it.
- Tension bolts: Easy to assemble or dissemble..
- Lugs: Require less manufactural fitness. Easy to assemble and remove and are widely used in mi1itary aircrafts and more economic.
- Combination of splice plates and tension bolts

:More reliable and have fail safe feature in them.
Lugsare the type of structural connector elements that are widely used in airframe for pin connection of the components in airframe structure. Some of the key parts that use lugs include engines pylon support fittings, wing fuselage attachments, and landing gear links are the typical applications of this type.
Normally heavy concentrated loads are received through 1ug joints. Failure of lug joints will lead to fatal fai1ure of the whole structure. So Finite element analysis study and experimental data's will help the designer to safeguard the structure from fatal failures. Attachment lugs are one among the most fracture critica1 components in aircraft structure. Henceforth, it is significant to establish the design criteria and analysis methods to ensure the damage tolerance of aircraft lug attachments. In the ongoing work an attempt has been made to design and analyse a wing fuselage lug attachment bracket for a typical fighter aircraft, aircraft design practices are used. The design provides safety against failure of the lug against static loading, and also Fatigue life to crack initiation at high stress locations will be estimated by using the Miner's rule with the help of standard constant life SN diagrams for different materials used in the lugs.

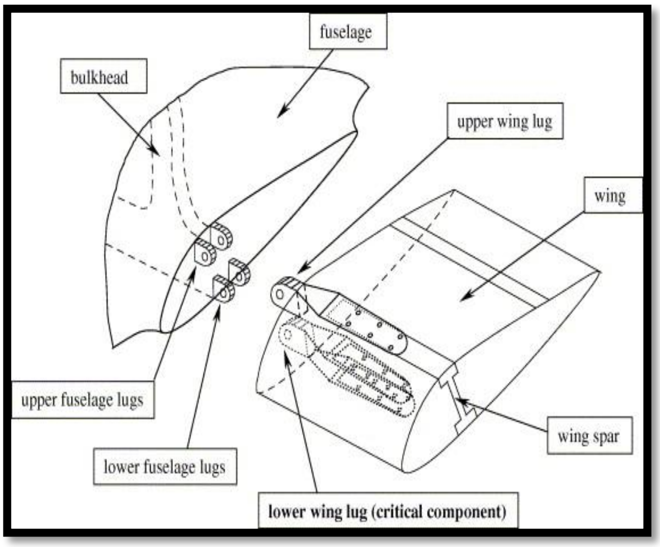

Fig. 2 components of typical wing fuselage connector

With this background, some of the Literature Survey carried out can be discussed. Shashikumar.C, Nagesh.N, Ganesh [1] carried out design and analysis of wing fuselage bracket for fighter aircraft, to predict fatigue life. Fatigue cracks will appear at location of high stress. B.K. Sriranga, Dr.C.N. Chandrappa, R. Kumar and Dr.P.K. Dash[3] used civil transport aircraft for analysis of wing fuselage lug attachment bracket. Wings and fuselage are attached through wing fuselage brackets. At the time of flight wings will undergo highest bending due to maximum lift. Bending load joints are used for analysis.Md. Abdul Wajeed, BabuReddy[4] carried out fatigue damage estimation for 4-seater aircraft (ROBIN DR400 DAUPHIN) using Miner's rule using constant amplitude SN diagrams.

OBJECTIVES OF THE WORK:

- To design a typical aircraft wing fuselage lug attachment bracket, for "6g" loading condition, andto carry out linear static analysis and fatigue damage estimation of the lug bracket for typical flight load spectrum.
- Modelling of the aircraft wing fuselage lug attachment bracket taking the geometric specifications from the standard journal paper using NX cad software, and use of finite element method for analysing the lug bracket of for two different cases of materials
- To analyze the behaviour of the lug bracket using steel alloy AlSl 4340 and aluminium alloy Al 2024T351 as one case of materials for '6g' load condition. And to carryout fatigue damage estimation, to study the behaviour on repeated cyclic loading in locations with maximum stress for the lug bracket
- To analyze the behaviour of the lug bracket using Titanium alloy Ti- 6Al -4v and Aluminium alloy 7075 T6 as another case of materials for '6g' load condition. And to carryout fatigue damage estimation, to study the behaviour on repeated cyclic loading in locations with maximum stress for the lug bracket
- Comparison of the results for the two case of materials used in wing attachment bracketII.

III. PROPOSED METHODOLOGY

This project work is focused on the modelling and the stress analysis of aircraft wing fuselage attachment bracket using different sets of materials for the bracket and fatigue damage estimation is carried to study the behaviour of bracket for repeated cyclic loading. And then results are compared. The Methodology and work flow carried in the present workis as shown in the below figure 3.

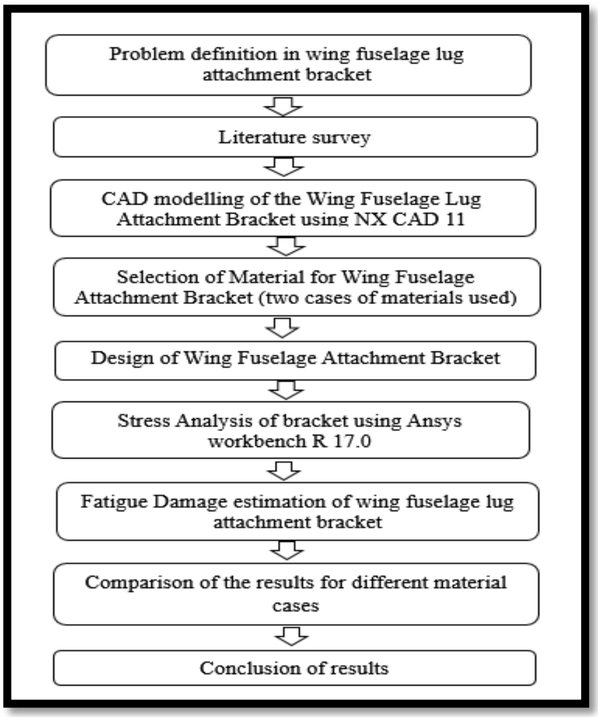

Fig. 3 Workflow chart

IV. CAD MODELLING

CAD Modelling of wing fuselage lug attachment bracket considered for a typical fighter aircraft is as shown in the below figure 4. The attachment bracket consists of lug and a portion of spar connected to each other by several rivets. The lug consists of two pin holes with integrated bottom and top flanges which is used to connect the I spar. The pin holes in lug helps in connecting bracket to the fuselage frame by pin joints. The geometrical specifications of lug bracket for the "6g" design, considered for analysis is taken from a standard journal source.

The different structural parts wing fuselage lug attachment bracket are

- Lug – a part with pin holes for connecting with fuselage.
- I-spar – It is principal structural member of wings, an I section in the wing on which the wing surfacing is done.
- Top and bottom flanges – these flanges are integral parts of lug through which the lug and I spar are connected by riveting .

Rivets – the rivets are cylindrical structures used for connecting or joining purpose.

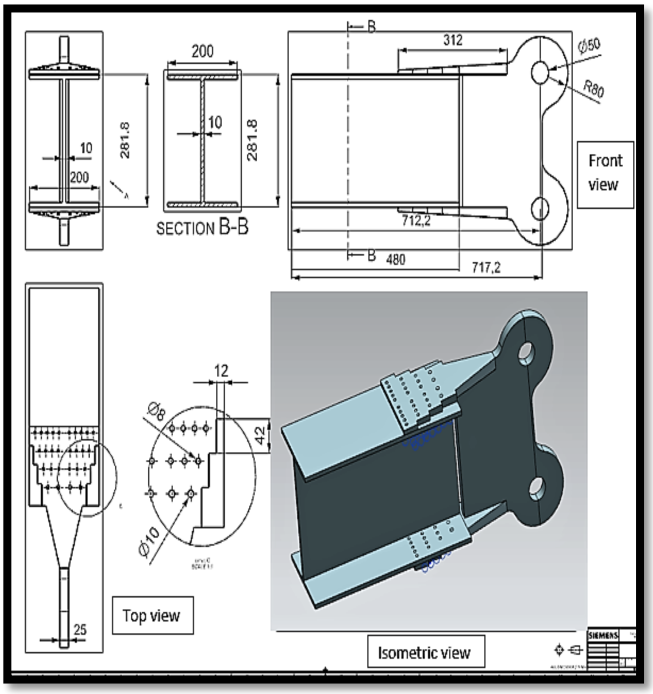

Fig. 4 Cad modeling

V. MATERIAL SELECTION FOR THE WING ATTACHMENT BRACKET

In aeronautica1 applications, strength allied to lightness is most important in material selection. In many situations, trials and errors can be very expensive and good project and design is important. For this reason the material properties to be considered for structural applications as,

- Yield stress
- Ultimate stress
- Temperature 1imits
- Stiffness
- Fatigue resistance
- Corrosion resistance
- Fracture toughness
- Fragi1ity at 1ow temperatures
- Crack growth resistance
- Ductility
- And re1iablity

CASE 1

MATERIALS USED

The materials considered for wing fuselage lug attachment bracket for studying their behaviour in case 1 are as follows

- The material used for the lug portion in wing attachment bracket is heat treated steel alloy AISI 4340, It is used at a variety of strength levels and at each level possesses remarkable ductility and toughness and strength. It also has good fatigue property in it. Their main uses are in powertransmission gears and shafts, aircraft landing gears and other structural parts in aircraft.
- The material used for I sectional spar and rivets in the wing attachment bracket is A1uminium alloy 2024 T351,The main characteristics of 2024 alloy is good machinability and surface finish capability. It has high strength and light in weight.

Table 1 Material Properties for case1

S1.NO	PARAMETERS	Al–2024-T351	AISI-4340
1	Young's Modulus(Mpa)	72400	203000
2	Poison's Ratio	0.33	0.32
3	Ultimate Tensile Strength (Mpa)	503.7	1835
4	Yield Stress, бy (Mpa)	472.6	1550
5	Density (ρ) (kg/m^3)	2800	7850

VI. FINITE ELEMENT ANALYSIS

The finite element analysis is implementation of FEM to solve a certain type of problems that are complicated by analytical methods. The finite element method (FEM) is numerical technique for solving problems that are described by partia1 differential equations or could be formulated as functional minimization. A domain of interest is represented as assembly of finite elements, approximating functions in finite e1ements are determined in terms of nodal values. A continuous physical problem is transformed into a discretized finite element problem with unknown noda1 values.

In the present work the analysis of wing fuselage attachment bracket is carried out using Ansys Workbench 17.0. A new material set is created in engineering material set for steel alloy AlSl 4340 and aluminium alloy 2024 T351. These materials are used in linear static analysis. The bracket modelled in NX Cad is imported into Ansys in .IGES or .STEP format. The contacts between different solids are created automatically.

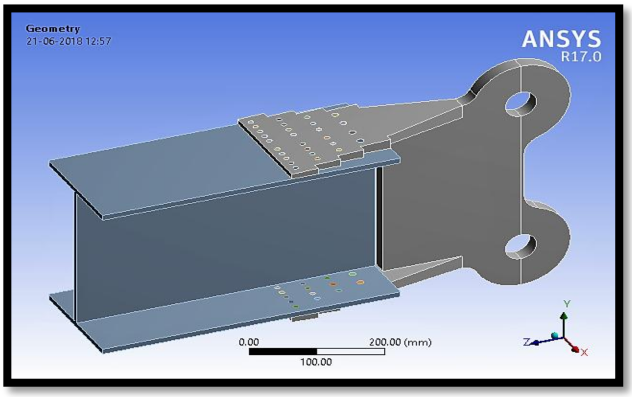

Fig. 4 Geometric model of lug bracket

VII. MESHING OF BRACKET

Meshing is discretization technique. To analyse the structural domain, the domain could be sub divided into smaller domains or element and each sub domain or element is called mesh, and the process of doing this is called meshing.. The element has shape specified by the nodes. There are several types of element shapes which are further divided into various classes depending on their use. A volume element has the shape of hexahedron-8 nodes, wedge-6 nodes, pyramid-5 nodes and tetrahedron-4 nodes.

All the solid parts in the component geometry is meshed using Tetrahedron type meshing. Fine meshing is accomplished in locations with stress concentration and coarse meshing at other regions of the component. Therefore from meshing 61438 nodes and 33702 elements are developed. The meshed model of bracket is as shown below figure 5.

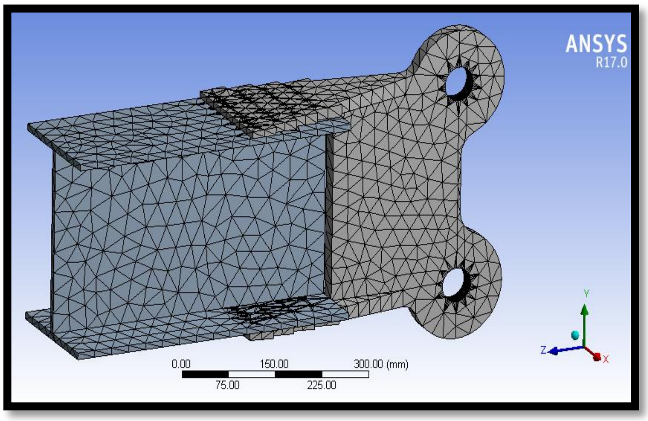

Fig. 5 Meshed model of lug bracket

VIII. LOADS AND BOUNDARY CONDITIONS

The loads and boundary conditions applied on wing fuselage lug attachment bracket is as shown in the figure6.The bending load acting at the root of the bracket is calculated for '6g' load factor with FOS 1.5 which creates a load of 90584.62 N. It is introduced at one end of the spar beam in upward direction as maximum lift is generated in the wings during take-off. This load will essentially create the required bending moment at the root of the bracket where wing and fuselage will be attached.

The top and bottom lug holes of the wing fuselage Lug attachment bracket are constrained with all six degrees of freedom at the semi-circular circumferential region.

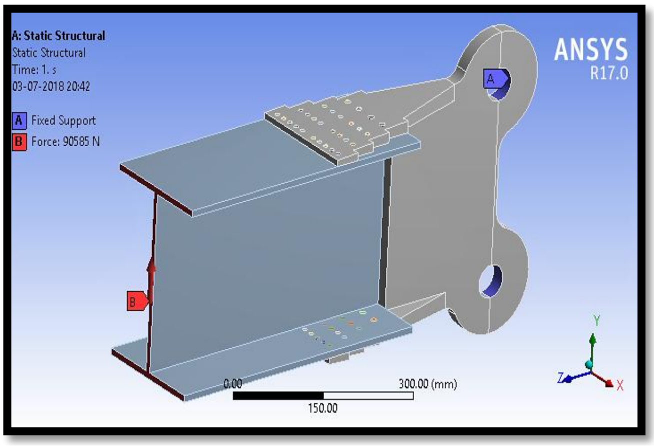

Fig. 6 Load and BC on bracket

IX. STRESS ANALYSIS IN WING FUSELAGE ATTACHMENT BRACKET

After applying loads and boundary conditions the analysis setup is solved. A maximum stress value of 940 mpa is observed at one of the lug holes and while hiding the lug portion a maximum stress value of 431 mpa is observed in the I spar. And a total deformation of 4.43 mm is observed in the I spar. The stress values and the deformation contour is as shown in figure 7 &8.

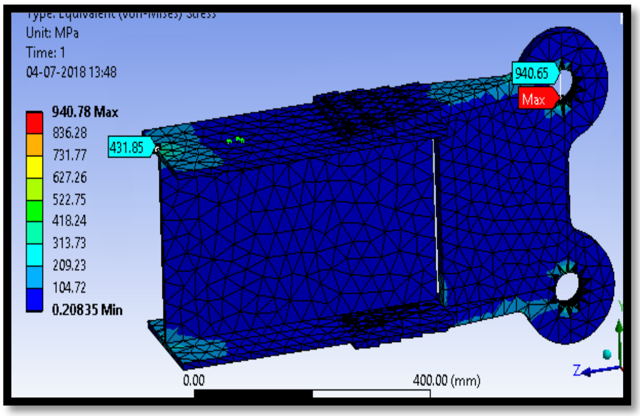

Fig. 7 Stress contour

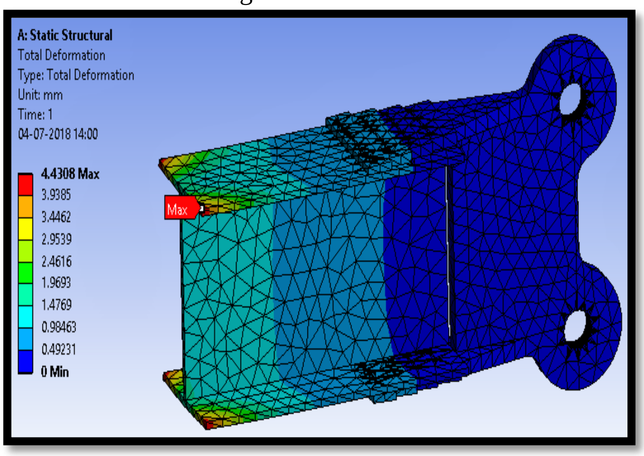

Fig. 8 total deformation contour

Load case	Name of the structures	Material used	Yield Stress, бy Mpa	Maximum stress by FEAMpa
6g	Lug portion of the attachment bracket	AISI-4340	1550	940
6g	I-sectional spar	Alloy – 2024-351	472.6	431

Table 2 stress analysis results for case1

From the table2 the maximum stress from analysis in both the materials is less than the yield strength for 6g loading condition therefore the design of lug attachment considered in the study is safe.

The location of maximum stress is the possible location for crack initiation in the structure, due to repeated fatigue loading in the structure. So this maximum stress is used as input for the fatigue life estimation of the wing attachment bracket.

X. FATIGUE DAMAGE ESTIMATION

Fatigue or the metal fatigue is the failure of a structure or component due to the cyclic stress caused by repetitive loading and unloading condition. The failure mainly occurs in three phases i.e. crack initiation, crack propagation and catastrophic over1oad failure.

A damage tolerant design criterion and stress- life approach is been adopted for conducting fatigue estimation. For performing fatigue calculations constant amplitude loading is preferred. In the problem variable amplitude loads will be acting but by converting them to groups of constant amplitude loading in their respective frequency. If loading is constant amplitude, then it represents the numbers of cycles until the part will failure due to fatigue. Calculation of fatigue life to crack initiation is carried out by using Palmgren-Miner`s Rule. According to Miner’s rule,

when D = $\sum \frac{ni}{Nf} = C$

Where D = damage

ni = applied number of cycles

Nf = number of cycles to failure

C = constant equal to 1

For different stress amplitudes the number of cycles to failure is obtained from the typical constant life SN data, fatigue diagram for various stress ratio for fatigue behaviour, of the materials.

XI. FATIGUE CALCULATIONS

As the component is subjected to cyclic loading a fatigue crack will always initiate from the location of maximum tensile stress. From stress analysis of wing fuselage lug bracket, the maximum stress location is found at one of the lug holes in lug part made of AlSl 4340. The damage accumulation is calculated using the load spectrum of the typical flight. The fatigue load spectrum, along with maximum stress for various constant amplitude load factors ‘g’ is tabulated in below table 3.

Cycles Applied (Ni)	Range of 'g'	Stresses in lug portion (AISI 4340)	
		Stress min.(Mpa)	stress max.(Mpa)
45000	0.5 - 1.0	76	153
55000	1.0 - 1.5	153	229
38000	1.5 - 2.0	229	305
20000	2.0 - 2.5	305	381
12000	2.5 - 3.0	381	458
15000	3.0 - 3.5	458	534
5000	3.5 - 4.0	534	610
550	4.0 - 4.5	610	686
450	4.5 - 5.0	686	763
300	5.0 - 5.5	763	838
250	5.5 - 6.0	838	940

Table 3Load spectrum and corresponding stress

Typical graph of constant life (SN) fatigue diagram for various stress ratios for Steel alloy AlSl 4340 is as shown in below figure 9.

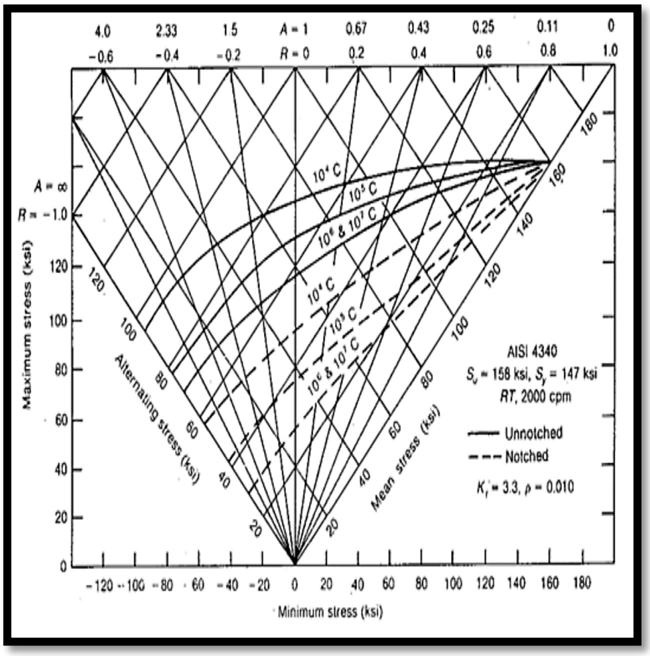

Fig. 9 Typical constant life SN diagram for AlSl 4340

XII. TABULATION OF FATIGUE DAMAGE RESULTS

In static analysis of wing fuselage lug bracket, the maximum value of stress found is 940 mpa in one of the lug holes. The damage calculated at different g range with reference from constant amplitude S-N data for steel alloy AISI 4340, is tabulated in the table4

Table 4 Fatigue damage results

Failure no. cycles (Nf)	Amplitude stress(Mpa)	Mean stress(Mpa)	Stress Ratio R	Damage Accumulated -miner rule D ($D = \frac{ni}{Nf}$)
$>10^7$	38.5	114.5	0.5	0.004500
$>10^7$	38	191	0.7	0.005500
$>10^7$	38	267	0.8	0.003800
$>10^7$	38	343	0.8	0.002000
$>10^7$	38.5	419.5	0.8	0.001200
$>10^7$	38	496	0.9	0.001500
$>10^7$	38	572	0.9	0.000500
$>10^7$	38	648	0.9	0.000055
$>10^7$	38.5	724.5	0.9	0.000045
$>10^7$	37.5	800.5	0.9	0.000030
>10	51	889	0.9	0.000025
				$\sum =$ 0.019155

For each block or group of constant amplitude load spectrum the structure has infinite life from constant amplitude SN diagrams so safe life design. The total damage accumulated in structure is found to be in the 0.019155 <1. According to Palmgren-Miner 1inear damage rule when the damage fraction is less than unity the material is safe, often satisfactorily for failure is predicted. The damage at which failure is expected to occurs when the damage fraction is equal to 1. So for all the given fatigue load spectrum the wing fuselage lug bracket is safe and no crack initiation takes place.

CASE 2

MATERIALS USED

- The material used for the lug portion in wing attachment bracket is Titanium alloy Ti 6Al 4V, This type of alloy is common1y used in aircraft industries. The titanium alloys are made strong as compared to aluminium and stee1 due to their higher toughness, rigidity, corrosion resistance and better thermal properties. Titanium alloys can sustain heat upto 4000°C, because of this temperature 1imit, it is widely used in aerospace industry, marine industry and power generation industries. These type of a1loys is used to make blades, rings, discs, airframes, fastener components and aircraft structural components.
- The material used for I sectional spar and rivets in the wing attachment bracket is A1uminium alloy 7075 T6, It is strong, with strength comparable to steels and has good fatigue strength and machinability. It is re1atively high cost compared to other alloys Aluminium 7075 alloy is main1y used in manufacturing aircraft and other aerospace applications. Due to their high strength to density ratio 7075 alloys are used in transport, marine and automotive and aviation industries.

S.NO	PARAMETERS	Al 7075 T6	Ti- 6Al -4v
1	Young's Modulus(Mpa)	71700	113800
2	Poison's Ratio	0.33	0.34
3	Ultimate Tensile Strength (Mpa)	572	950
4	Yield Stress, бy (Mpa)	503	880
5	Density (ρ) (kg/m³)	2810	4430

Table 5Material Properties for case2

FINITE ELEMENT ANALYSIS

The FE analysis and fatigue damage estimation is carried same as in previous section.

A new material set is created in engineering material set for titanium alloy Ti 6Al 4V and aluminum 7075 T6. These materials are used in linear static analysis.

MESHING OF BRACKET

All the solid parts in the component geometry is meshed using Tetrahedron type meshing. From meshing 59231 nodes and 31058 elements are developed. The meshed model of bracket is as shown below figure10.

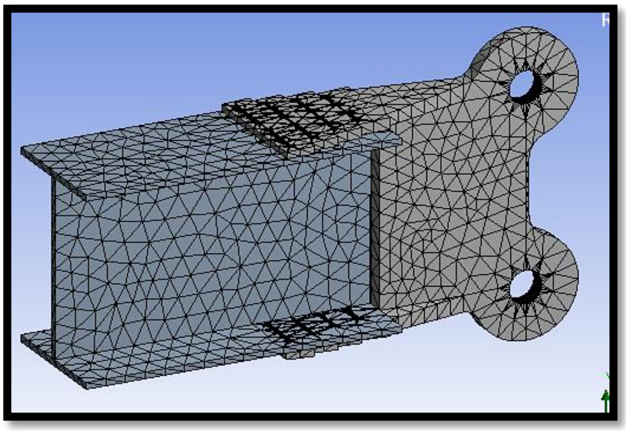

Fig. 10Meshed model of lug bracket

LOADS AND BOUNDARY CONDITIONS

The loads and boundary conditions is same as in previous section.

STRESS ANALYSIS IN WING FUSELAGE ATTACHMENT BRACKET

A maximum stress value of 818mpa is observed at one of the lug holes and while hiding the lug portion a maximum stress value of 441mpa is observed in the I spar. And a total deformation of 5.02 mm is observed in the I spar. The stress values and the deformation contour is as shown in figure 11 &12.

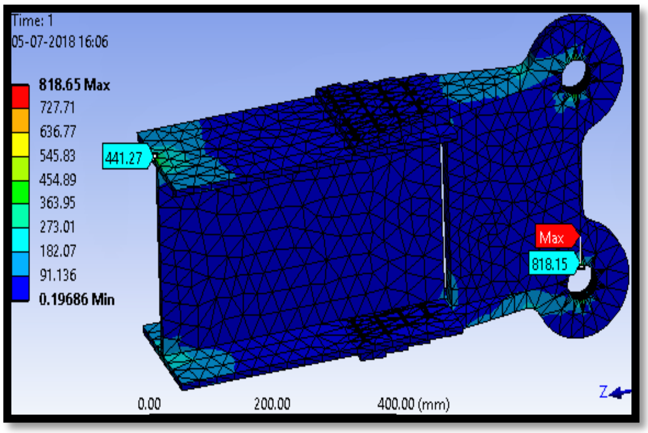

Fig. 10 Stress contour

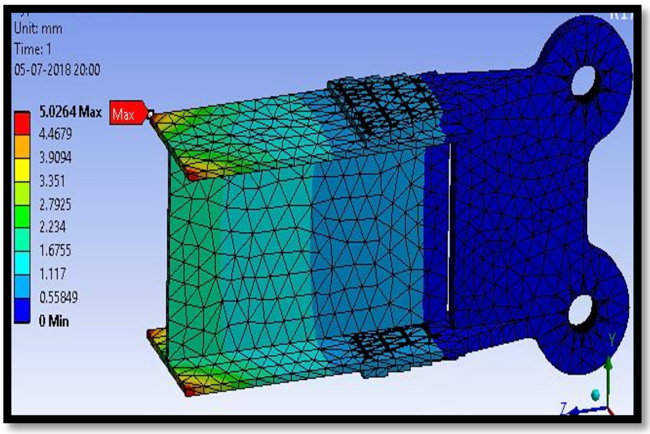

Fig. 12 total deformation contour

Load case	Name of the structures	Material used	Yield Stress, бy Mpa	Maximum stress by FEAMpa
6g	Lug portion	Ti- 6Al -4v	880	818
6g	I-sectional spar	Al 7075 T6	503	441

Table 6 stress analysis results for case2

From the table6 the maximum stress from analysis in both the materials is less than the yield strength for 6g loading condition therefore the design of lug attachment considered in the study is safe. Due to repeated fatigue loading in the structure. So this maximum stress is used as input for the fatigue life estimation of the wing attachment bracket.

XIII. FATIGUE CALCULATIONS

From stress analysis of wing fuselage lug bracket, the maximum stress location is found at one of the lug holes in lug part made of titanium alloy Ti 6Al 4V. The fatigue load spectrum, along with maximum stress for various constant amplitude load factors 'g' is tabulated in below table 7.

Table 7Load spectrum and corresponding stress

Cycles Applied (Ni)	Range of 'g'	Stresses in lug portion (Ti- 6Al -4v)	
		Stress min.(Mpa)	stress max.(Mpa)
45000	0.5 - 1.0	66	133
55000	1.0 - 1.5	133	199
38000	1.5 - 2.0	199	265
20000	2.0 - 2.5	265	331
12000	2.5 - 3.0	331	398
15000	3.0 - 3.5	398	464
5000	3.5 - 4.0	464	530
550	4.0 - 4.5	530	596
450	4.5 - 5.0	596	663
300	5.0 - 5.5	663	729
250	5.5 - 6.0	729	818

Typical graph of constant life (SN) fatigue diagram for various stress ratios for Steel alloy Ti- 6Al -4v is as shown in below figure

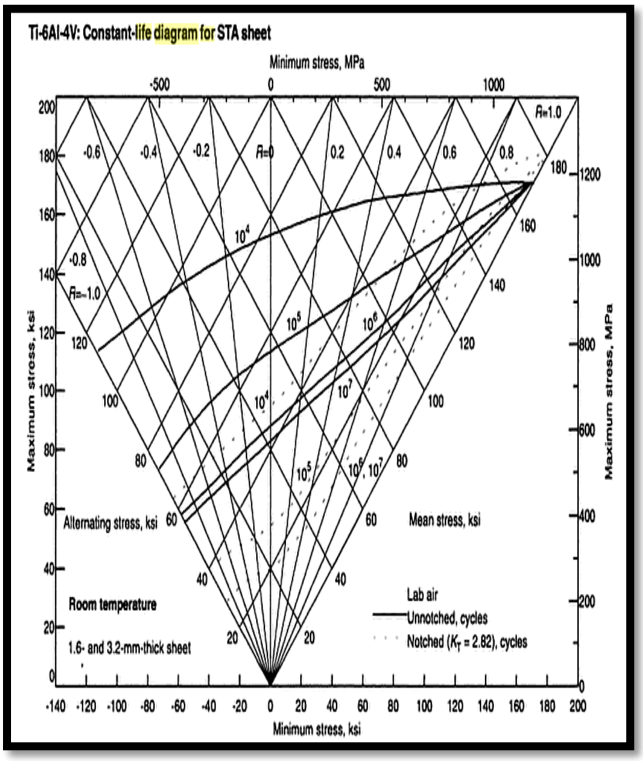

Fig. 13 Typical constant life SN diagram for Ti 6 Al 4V

XIV. TABULATION OF FATIGUE DAMAGE RESULTS

In static analysis of wing fuselage lug bracket, the maximum value of stress found is 818mpa in one ofthe lug holes. The damage calculated at different g range with reference from constant amplitude S-N data for titanium alloy 6 Al 4v, is tabulated in the table 8.

Table 8. Fatigue damage results

Failure no. cycles (Nf)	Amplitude stress(Mpa)	Mean stress (Mpa)	Stress Ratio R	Damage Accumulated By Palmgren-miner rule D ($D = \frac{ni}{Nf}$)
$>10^7$	33.5	99.5	0.5	0.004500
$>10^7$	33	166	0.7	0.005500
$>10^7$	33	232	0.8	0.003800
$>10^7$	33	298	0.8	0.002000
$>10^7$	33.5	364.5	0.8	0.001200
$>10^7$	33	431	0.9	0.001500
$>10^7$	33	497	0.9	0.000500
$>10^7$	33	563	0.9	0.000055
$>10^7$	33.5	629.5	0.9	0.000045
$>10^7$	33	696	0.9	0.000030
>10	44.5	773.5	0.9	0.000025
				$\sum =$ 0.019155

For each block or group of constant amplitude load spectrum the structure has infinite life from constant amplitude SN diagrams so safe life design. The total damage accumulated in structure is found to be in the 0.019155 <1. According to Palmgren-Miner 1inear damage rule when the damage fraction is less than unity the material is safe. So for all the given fatigue load spectrum the wing fuselage lug bracket is safe and no crack initiation takes place.

XV. CONCLUSION

- Finite element approach is used for the analysis of wing fuselage lug attachment bracket.
- Analysis is carried in 2 cases. In case1 steel alloy AlSl 4340 and aluminium alloy 2024 T351 is used and in case2 Titanium alloy Ti 6Al 4V and Aluminium alloy 7075 T6. Several iterations are carried out for mesh independent value for maximum stress result.
- From the static analysis, the maximum stress in 2 cases of materials was less than the yield strength so bracket configuration design is safe.
- Fatigue damage estimation of the aircraft wing fuselage lug attachment bracket is carried for the2 cases of materials. A damage tolerant design criterion and stress- life approach is been adopted for conducting fatigue estimation. For the given load spectrum damage factor is less than unity.so safe life design and no crack initiation takes place.
- The properties of the materials used in case2 has better values compared to the one used in the case1 in aircraft industry and while comparing the total weight of the brackets, using case1 materials bracket weight is 36.187 kg and that for case2 materials is 24.435 kg which is a huge thing in aircraft industry, so we can say that case2 materials are better compared to case 1 for the bracket and could be used for bracket fabrication.

FUTURE WORK

- The shape optimization of the lug attachment bracket can be done.
- Use of composite material may further reduce the weight & strength can be improved.
- The test set up could be build & analysis can be performed on bracket unit.
- Dynamic analysis of the bracket can be carried out.
- Modal analysis of the bracket can be carried out.

REFERANCES

[1] Shashikumar.C, Nagesh.N, Ganesh “Design and Analysis of Wing fuselage attachment bracket for fighter aircraft” International Journal of Engineering Research and General Science Volume 4, Issue 1, January-February, 2016.

[2] Harish E.R.M, Mahesha.K, Sartaj Patel “Stress Analysis for Wing Attachment Bracket of a six seater Transport Airframe Structure” International Journal of Innovative Research in Science, Engineering and Technology. Vol. 2, Issue 7, July 2013.

[3] B.K. Sriranga, Dr.C.N. Chandrappa, R. Kumar and Dr.P.K. Dash “Stress Analysis of Wing-Fuselage Lug Attachment Bracket of a Transport Aircraft” International Conference on Challenges and Opportunities in Mechanical Engineering, Industrial Engineering and Management Studies, 11-13 July, 2012.

[4] Md. Abdul Wajeed, Babu Reddy “Stress Analysis of Fuselage Frame With Wing Attachment Beam And Fatigue Damage Estimation” International Journal of Engineering Research And Technology (IJERT). Volume : 4, Issue: 11, November 2015.

[5] J. Precilla, Dr. P. Maniiarasan, A.T.SamRajan “Simulation of Wing Fuselage Attachment Using Fem” International Journal of Modern Trends In Engineering And Science. Volume: 2, Issue: 10, 2015.

[6] Tarun Kumar B.Jain, Boopathi Raja .G, MeenakshiSundaram “Stress Analysis of Wing Attachment Brackets” International Journal of Engineering Research And Technology (IJERT). Volume : 5, Issue: 05, May 2016.

[7] Chetan B S, NarayanaSwamy G, K E Girish “FATIGUE LIFE ESTIMATION OF REAR FUSELAGE STRUCTURE OF AN AIRCRAFT” International Journal of Research in Engineering and Technology. Volume: 04 Issue: 07 | July-2015.

