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Material Replacement and Failure Analysis of Nose Landing Gear's Fork for Skyranger Swift 912S(1)

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***Abstract* - Landing gear is most significant part in an aircraft system during ground and take off operations. Generally, a landing gear should bear serious compressive load, drag load and side load. This paper present structural analysis of a Nose Landing Gear failure. The developed study comes following an accident occurred in which the nose of the landing gear's fork of a light sport aircraft, Skyranger Swift 912S(1) had failed during landing. The Fork is the connecting member between the shock strut and the axle containing the wheel-brake assembly. As the fork and axle are subjected to shock loads while landing, the strength of these components is very much essential to withstand the dynamic loads. The main objective here is to determine the stress behavior and the displacement of a nose landing gear fork of an aircraft for different materials during landing using structural finite element analysis. Some modifications to the fork material have been proposed with the goal of improving its performance during service.**

Index Terms – Nose Landing Gear (NLG), Skyranger Swift, Fork, Composite Material, Structural Analysis, Ansys Workbench

I. INTRODUCTION

Aircraft landing gear is a most essential support of an aircraft for landing and ground operations. It is hooked up with primary structural members of an aircraft. As the landing gear is the interface of airplane and ground, so that all the ground loads are transmitted by it to the aircraft frame. The main functions of the landing gear are energy absorption at landing, braking and taxi control. Without that the energy cannot be dissipated and would impact the airframe and damaging it with time.

The need to design with minimum weight and volume, reduced life cycle cost and high performance poses many challenges to landing gear designers. The layout of the landing gear system determines the load transfer to the structure, ground stability and control. It is often made as retractable to decrease the aerodynamic drag on aircraft while flying [1].

The aircraft under study here is Skyranger Swift 912S(1) which is high-wing, two seat light sport aircraft. It was certified in the United Kingdom to the requirements of British Civil Airworthiness Requirements (BCAR) Section S Issue 2 [3]. Crashed Skyranger was built in 2007 and had accumulated 422 hours of flight at the last maintenance check, which occurred on 21 August 2019 [4]. It uses Leaf-Type Spring Strut which is a cantilevered spring steel strut connecting the main wheels to the fuselage. It consists of spats. These structures are covers for gaps and spaces between parts of an aircraft to reduce drag, and to improve appearance.

The aircraft's nose landing gear failed during a normal landing roll, causing the aircraft to pitch over and come to rest inverted. The nose wheel fairing would have made it difficult for a pilot to fully inspect the area where the failure occurred during the pre-flight inspection. The aircraft came to rest approximately 170m along Runway 22. Witness marks made by the aircraft on the runway were consistent with a progressive collapse of the nose landing gear fork during the landing roll. There was no evidence of the nose landing gear having struck an object and there were no significant holes or depressions in the runway surface. A small quantity of fuel had leaked from the aircraft's left wing fuel tank whilst the aircraft was inverted [4].

II. OBJECTIVES AND METHODOLOGY

The following objectives are formulated for present work:

- To design and model NLG's fork by using software like CATIA.
- The NLG's Fork made of different alloys will be doing static structural analysis in ANSYS.
- To propose new material for NLG's fork with the goal of improving its performance during service.

The analysis of landing gear will be done for different Titanium alloys. The landing gear with different alloys will be tested by applying a force during the landing under static structural analysis in ANSYS 19.2. Then the total deformation, maximum principal stress and strain were calculated for different alloys after applying the boundary conditions and load.

III. MATERIAL SELECTION

Table 1 refers to materials that can be used for the design of NLG's Fork are Titanium (Ti) alloys, Aluminum alloys, Steel and Magnesium alloys.

Table 1: Different types of material and their properties

Property	Density (g/cc)	Young's Modulus (Gpa)	Yield Strength (Mpa)	Tensile Ultimate Strength (Mpa)
Material				
Aluminum 5182	2.65	69.6	130	275
Aluminum 7075 T6	2.81	71.7	480	572
Ti7Al4Mo	4.51	119	860	1200
TIMETAL 834	4.55	120	930	1050
Titanium 6AL-4V	4.43	113	1100	1170
Titanium 6AL-6V- 2Sn	4.54	117	1210	1280
Titanium 10Al-2Fe-3V	4.65	110	900	970
ASM AE81	1.82	44	232	352
ASM WE54	1.84	44	213	298
ASM ZE62	1.84	45	303	350
ASM AE70	1.82	43	216	322
Alloys Steel 4340	7.85	210	470	745

IV. COMPUTATIONAL INVESTIGATION

A. Geometry

The modelling of NLG's fork is done using CATIA V5. Then the model is imported into ANSYS.

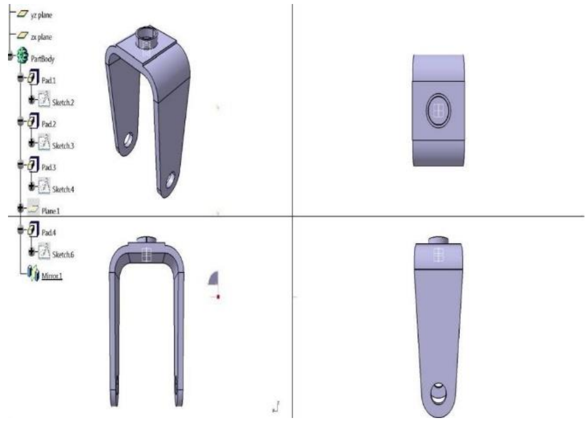

Fig 1: Isometric View of Fork

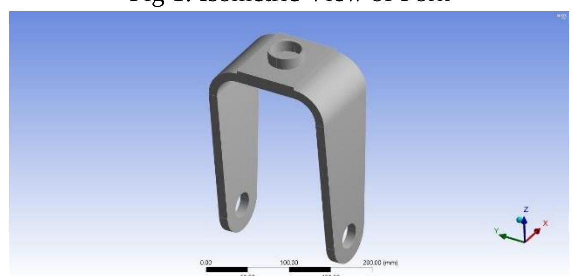

Fig 2: Geometry of Fork

B. Grid Generation

In order to get accurate results, it is required to have smaller aspect ratios and hence tetrahedron meshing is used for meshing as it provides aspect ratio close to unity. Element size is of 0.8mm.

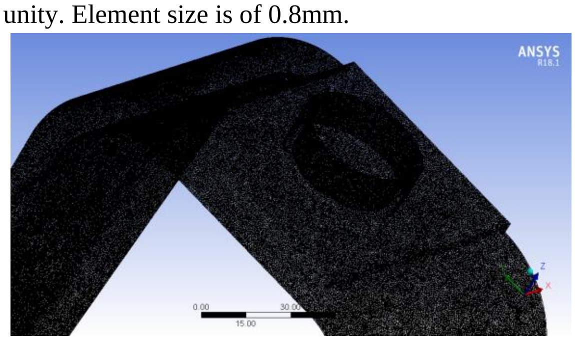

Fig 3: Tetrahedron meshing for NLG's Fork with 0.8mm element size

C. Boundary Conditions

Two boundary conditions are applied. Fixed boundary condition is given to the axle hole. Force is applied on the upper part of the fork of magnitude 4636.6 N in the downward direction.

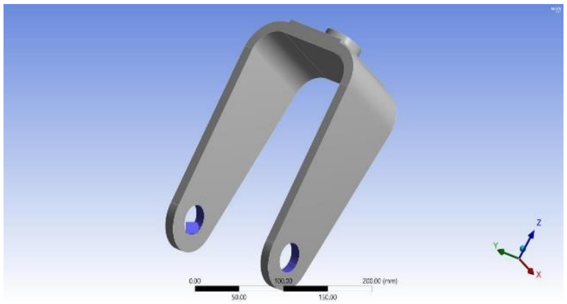

Fig 4: Fixed boundary condition

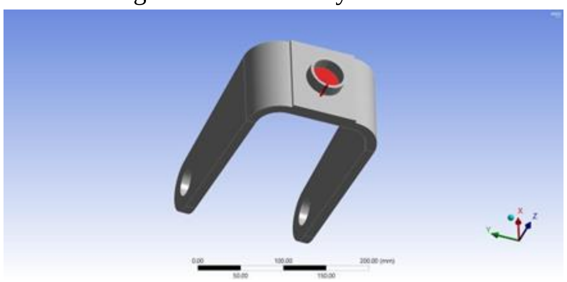

Fig 5: Application of Force

D. Grid Analysis

Grid Independent analysis begins with a coarse mesh and it is refined to finer mesh or it can begin with a fine mesh and refined to a coarse mesh. For each run it is done until the results do not change significantly. To check the quality of the mesh various runs has been carried out on the basis of the element size for the conventional material Aluminum Alloy 5182.

Table 2: Gird Independent Study for Aluminum Alloy 5182

Sl. No.	Element Size (mm)	Number of Elements	Equivalent Maximum Stress (Gpa)
1.	5	44416	0.019379
2.	3	184868	0.025379
3.	1.5	1067683	0.035885
4.	1.2	1834376	0.035974
5.	1	2784839	0.039276
6.	0.9	3571336	0.039776
7.	0.8	4710042	0.040354
8.	0.7	6362109	0.042044

After several iterations the best mesh was the one with 4710042 elements which is selected for the further stimulation.

V. RESULTS AND DISCUSSION

The structural behavior of NLG's Fork has been studied for different materials and the results are tabulated and compared.

A. Case-1: Aluminum Alloy 5182

The maximum equivalent stress acting is equal to 40.354MPa and the total deformation acting is equal to 0.097776mm.

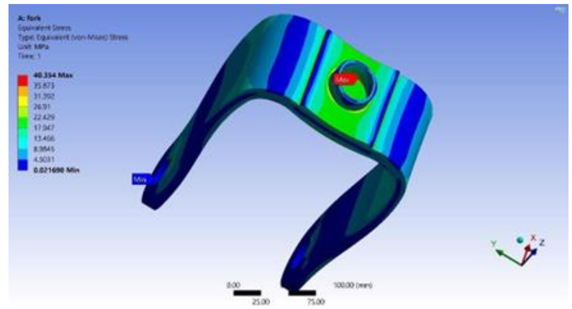

Fig 6: Maximum equivalent stress for Aluminum Alloy 5182

B. Case-2: Aluminum Alloy 7075 T6

The maximum equivalent stress acting is equal to 40.354MPa and the total deformation acting is equal to 0.094912mm.

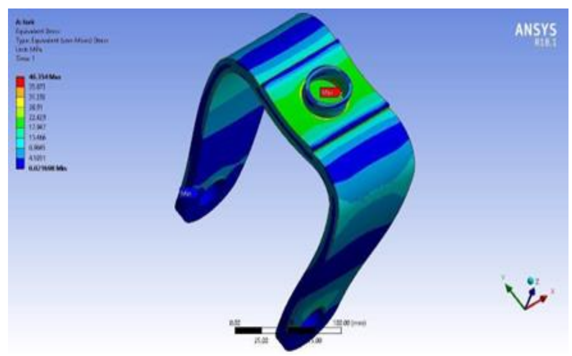

Fig 7: Maximum equivalent stress for Aluminum Alloy 7075 T6

C. Case-3: Ti7Al4Mo

The maximum equivalent stress acting is equal to 38.219MPa. The total deformation acting is equal to 0.056218mm.

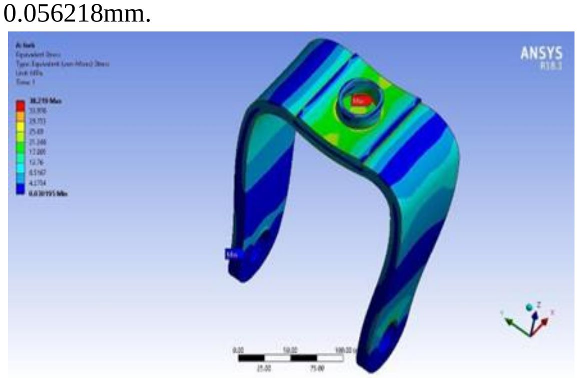

Fig 8: Maximum equivalent stress for Ti7Al4Mo

D. Case-4: TIMETAL 834

The maximum equivalent stress acting is equal to 40.881Mpa and the total deformation acting is equal to 0.056935mm.

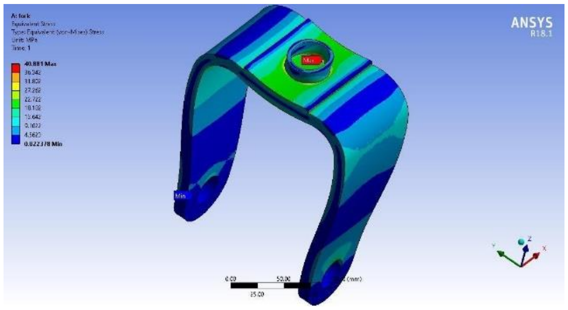

Fig 9: Maximum equivalent stress for TIMETAL 834

E. Case-5: Titanium 6AL-4V

The maximum equivalent stress acting is equal to 38.219MPa and the total deformation acting is equal to 0.059203mm.

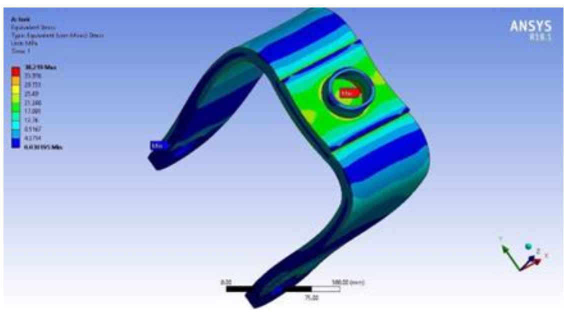

Fig 10: Maximum equivalent stress for Titanium 6AL-4V

F. Case-6: Titanium 6AL-6V-2Sn

The maximum equivalent stress acting is equal to 40.881MP and the total deformation acting is equal to 0.058395mm.

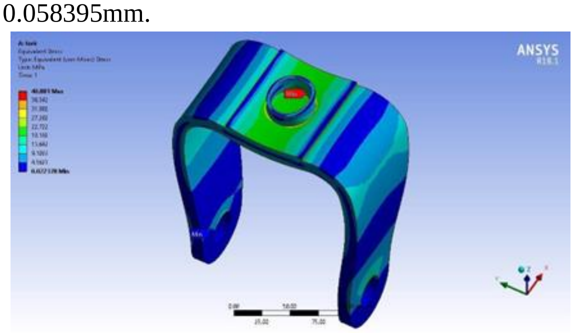

Fig 11: Maximum equivalent stress for Titanium 6AL-6V-2Sn

G. Case-7: Titanium 10Al-2Fe-3V

The maximum equivalent stress acting is equal to 40.354MP and the total deformation acting is equal to 0.061865mm.

H. Case-8: ASM AE81

The maximum equivalent stress acting is equal to 41.092MPa and the total deformation acting is equal to 0.15552mm.

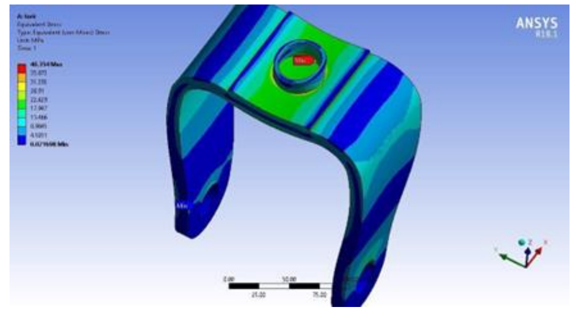

Fig 12: Maximum equivalent stress for Titanium 10Al-2Fe-3V

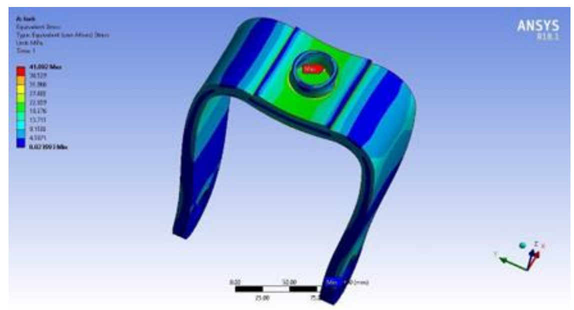

Fig 13: Maximum equivalent stress for ASM AE81

I. Case-9: ASM WE54

The maximum equivalent stress acting is equal to 41.092MPa and the total deformation acting is equal to 0.15552mm.

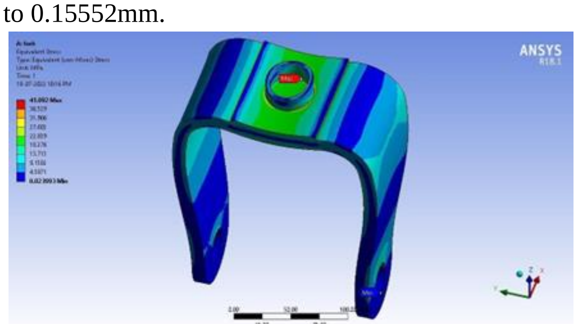

Fig 14: Maximum equivalent stress for ASM WE54

J. Case-10: ASM ZE62

The maximum equivalent stress acting is equal to 41.092MPa and the total deformation acting is equal to 0.15206mm.

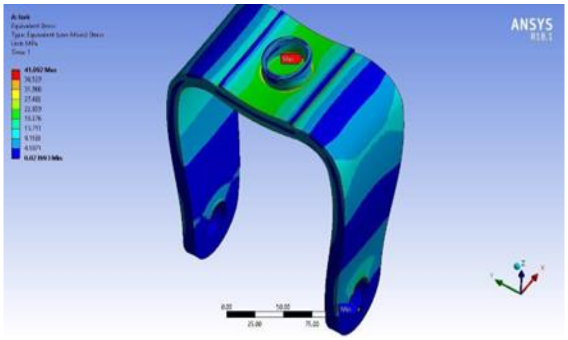

Fig 15: Maximum equivalent stress for ASM ZE62

K. Case-11: ASM AE70

The maximum equivalent stress acting is equal to 41.092MPa and the total deformation acting is equal to 0.15913mm.

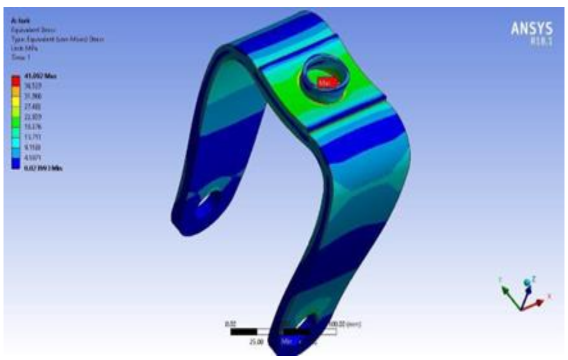

Fig 16: Maximum equivalent stress for AE70

The Table 3 shows the comparison of total deformation and maximum principal stress for different materials. For the given boundary conditions as stated above, Ti7Al4Mo and Titanium 6AL-4V shows least values of total deformation and maximum equivalent stress. Hence, Ti7Al4Mo and Titanium 6AL-4V holds good performance.

Table 3: Comparison of total deformation and maximum principal stress for different materials

Material	Equivalent Maximum Stress (MPa)	Total Deformation (mm)
Aluminum 5182 Alloy	40.354	0.097776
Aluminum Alloy 7075 T6	40.354	0.094912
Ti7Al4Mo	38.219	0.056218
TIMETAL 834	40.881	0.056935
Titanium 6AL-4V	38.219	0.059203
Titanium 6AL-6V- 2Sn	40.881	0.058395
Titanium 10Al-2Fe- 3V	40.354	0.061865
ASM AE81	41.092	0.15552
ASM WE54	41.144	0.15552
ASM ZE62	41.144	0.15206
ASM AE70	41.092	0.15913

VI. CONCLUSION

For modelling CATIA V5R was used. Before doing the structural analysis, the material had to be identified and that the selected material may not correspond exactly to the real one and, therefore, the obtained results do not correspond exactly to the reality.

For Structural analysis ANSYS WORKBENCH was used. A tetrahedron mesh has been used to ensure accurate solution. After meshing the boundary conditions were applied to the model and the force was applied in the downward direction. Equivalent maximum stress was analyzed for different materials.

Material Titanium 6AL-4V and Ti7Al4Mo shows lesser total deformation and maximum equivalent stress than other materials under similar conditions. So, application of Titanium 6AL-4V and Ti7Al4Mo will help improve the life of the NLG's fork and avoid landing gear damage.

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