Static Analysis of Helicopter Skid Landing Gear made of Composite Materials

Mandeep Chetry [*], Han Dong [**]

**College of Aerospace Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China*
*** College of Aerospace Engineering, Nanjing University of Aeronautics and Astronautics, Nanjing 210016, China*

DOI: 10.29322/IJSRP.9.09.2019.p9378
http://dx.doi.org/10.29322/IJSRP.9.09.2019.p9378

Abstract- A helicopter is an aircraft that can take off and land vertically. A helicopter is also called a rotary aircraft. It can hover and rotate in the air and can move sideways and backwards while aloft. Nowadays, many parts of helicopters are built of composite materials. Composites are made of two or more materials, combined together to obtain a new matter with properties that are superior to those of individual components. It is quite obvious that mechanical properties of composites depend mainly on the choice of material components used for the composite but they are also considerably influenced by the applied fabrication technique.
Helicopters use skid landing gears mainly because they weigh less than wheels. Simulation results of both cases where helicopter skid landing gear is made up of Aluminum alloy and composite materials are presented in this paper. Finite Element Analysis is done to simulate the loads and boundary conditions for both the cases. Then tensile stress, shear stress and deformation are compared for both the cases. Change in the material from Al alloy to composite material significantly reduced deformation of the landing gear.

Index Terms- Analysis, Cavity air injection panels, Computational Fluid Dynamics, Ultra-Compact Combustor

I. Introduction

Composites are being increasingly used for structural components for aircraft and space applications because of their superior specific strength and stiffness properties in comparison aluminum and steel. The weight savings that were realized by applying composites used to be one of the main drivers to apply these materials. However, nowadays a reduction in fabrication cost is becoming important as well. The objective therefore is to combine new cost effective fabrication methods with lightweight structural concepts in order bring the exploitation of composite materials to a higher level. [1]

Skid landing gear comprises pivotable cross beams and skids, skids being each disposed in an essentially longitudinal direction laterally on a respective side of the helicopter's landing gear. At least one discrete damper is provided for at least one pivotable cross beam, discrete damper being connected with one end to the pivotable cross beam and with another end to the fuselage. The pivotable cross beam is of the cantilever type. Fixed bearings and floating bearings are provided at the fuselage. Torsion bar springs are mounted to fixed bearings and floating bearings, respective inner end of at least one pivotable cantilever cross beam being attached to torsion bar spring at the floating bearing in such a manner that moments are transferred from the respective inner end of each pivotable cantilever cross beam via torsion bar spring to the fuselage at said fixed bearing.

The design process began with an identified rotorcraft configuration with available specifications from NASA TM 84281. [2] An AH-1S Cobra Helicopter was used for the analysis. Skid landing gear dimensions were based off partially available data for the AH-1S Cobra and the dimensions listed in the work done by Airoldi and Janszen [3] and Monterrubio and Scharf. The landing gear was modeled in CATIA and ABAQUSTM was used for static explicit FEA, conducted under limit loads first.

Figure 1: AH-1S Cobra Rotorcraft

II. BACKGROUND

Helicopter landing gear must be designed to secure helicopter fuselage, several electronic equipment and passengers under ultimate design dynamic landing conditions. In order to survive high- energy impacts, the skid landing gear must be designed conditions. In order to survive high- energy impacts, the skid landing gear must be designed to provide adequate energy absorptions. The design landing conditions, which applies to the helicopters basic structural design gross weight, requires rotor lift equal the aircraft's weight during the landing conditions. Normally in this modern world of rotorcraft two types of landing gear systems are used. The complex and heavy type of landing gears are wheeled type. The wheeled type design includes the features like tires, wheel, braking devices, oleo struts and other hydraulic equipment. The break and shock absorbers act as an energy absorber. The main attraction of this type of landing gear is they have retracting mechanisms which more complicates the design. Another type which is commonly used is the skid landing gear. The positive aspects of the skid landing gears are it offers simplicity in design and reduction in empty weight (WE). It is usually made from light metal alloys. They also give an excellent i fatigue performance and they have no concerns associated with corrosion which metals have. [4]

There are various types' materials been used for skid landing gear such as aluminum 7075 [4], glass fibers, titanium metal matrix composite (MMC) [5], and sandwich composites structures.
The main advantages of composite materials are they have high mechanical properties, ease of fabrication, they have flexibility of design options and also light weight, they are corrosion resistant, the impact resistant is very high, and they have excellent fatigue strength. [6]

The landing gear has significant importance in the design of a helicopter for the functional aspect is that the structural changes it needs to secure the ground and absorb the landing impact. The landing gear is a unique and important component. It should bear extreme and varying loads when an aircraft maneuvers on the ground or alights, yet it should be lightweight and compact because it is stowed and unused during most of flight hours. The stresses to which it shall be given a landing gear are significant and therefore the design of its structural parts requires a very thorough study of the forms to meet the requirements of weight, strength and rigidity. The materials in this type of composite structures, as it appears, would find their natural application if it were not for the technological difficulties encountered in implementing the structures of complex shapes that characterize, as mentioned, the landing gear [7]. Composite has many excellent features such as high strength to weight ratio, flexibly designed and manufactured, easily structure-function integrated [8].

Finite element analysis of solid plate and sandwich composite plates can be performed using ABAQUS. Analysis can also be performed to compare the effect of unidirectional, cross-ply and angle-ply laminate configurations on the bending deflection of the sandwich plate. There are numerous analysis and optimization can be done on a skid landing gear design using multi body analysis and genetic algorithm [5]. The methodology involves the load factor developed during limit loads under multiple landing scenarios.

A drop test simulation is very expensive and difficult to implement numerically if the complete material history involved in all designs and manufacturing phase is to be accounted for. For that reason, some researchers have decided to use the rigid/flexible multi body dynamic code such as ADAMS to simulate the drop test of a skid landing gear. An assembly of rigid elements was used in the simulations which were compared to the elastic finite element analysis. They showed that the flexible body model presents good results but the behavior law of the landing gear has to stay within the elastic domain. Other researchers decided to investigate on reducing the computational time using a hollow rectangular beam element with Ls-Dyna. This used element appeared to be time effective and relatively accurate compared to experimental results. However, it does not provide enough integration point through the thickness and hence not enough precision. However, it can be developed by complete methodology to simulate drop tests and to compare them with experimental results.[9][10].

Some researchers carried out finite element computation using ANSYS software. The finite-element meshes of these models were generated using eight node brick solid 45 element and Beam188 [11].

III. COMPUTATIONAL METHODS

The material parameters and constraints for modeling were selected from Shrotri [4]. The model was modified in CATIA. The top view of the landing gear is in figure 2.

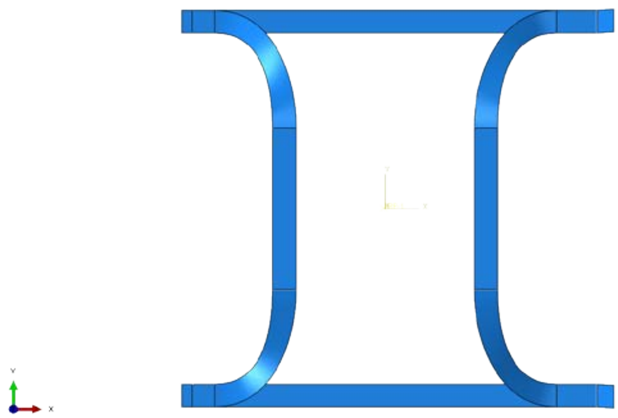

Figure 2: Top view of modeled landing gear

The material properties of the composite materials are also derived from the paper [4]. The values are then input in ABAQUS.

Property	**Value**
E_1(GPa)	191
E_2(GPa)	9.5
v_{12}	0.24
G_{12}(GPa)	5.3
ρ(kg/m^3)	1621.7

Table 1: Material properties of the composite made model

Material properties are assigned to each part of the landing gear model and layered, as shown in the figure 3 below.

Layer	Material	Thickness (m)	Angle (°)
(+Z)			
9	Epoxy Carbon UD (230 GPa) Prepreg	0.002	-45
8	Epoxy Carbon UD (230 GPa) Prepreg	0.002	0
7	Epoxy Carbon UD (230 GPa) Prepreg	0.002	90
6	Epoxy Carbon UD (230 GPa) Prepreg	0.002	45
5	Honeycomb	0.01	0
4	Epoxy Carbon UD (230 GPa) Prepreg	0.002	45
3	Epoxy Carbon UD (230 GPa) Prepreg	0.002	90
2	Epoxy Carbon UD (230 GPa) Prepreg	0.002	0
1	Epoxy Carbon UD (230 GPa) Prepreg	0.002	-45
(-Z)			

Figure 3: Material properties assigned layer by layer

The layers are presented in figure 4.

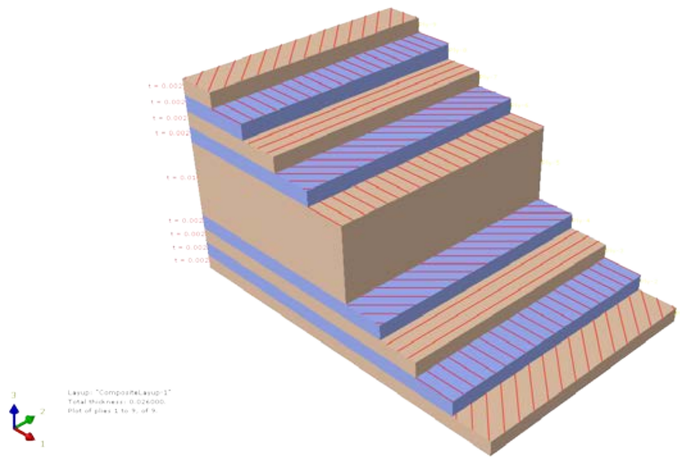

Figure 4: 3D view layer by layer

After meshing the model in ABAQUS, the “Tie Function” is used to bind different parts.

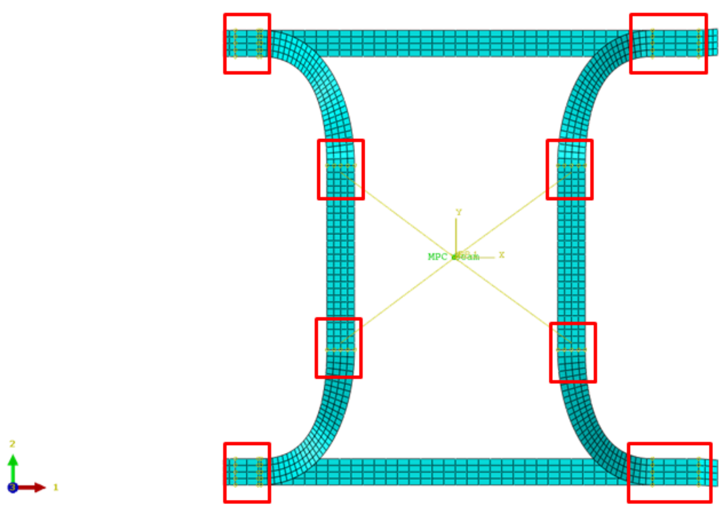

Figure 5: Different parts bound together

Then, a rigid reference point is created at (0,0,500) that imparts mass to the reference point and establishes a rigid beam connection with the landing gear via the MPC function. Parameters are taken from references. Point mass of 3636.36 kg is modeled.

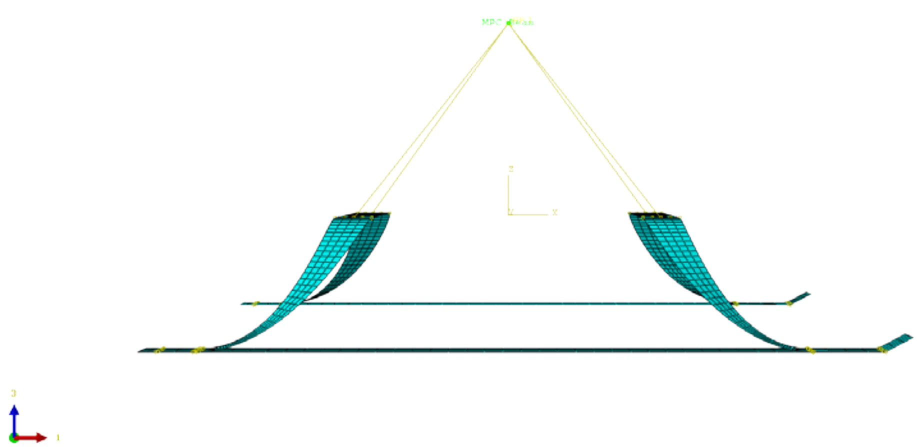

Figure 6: Mass modeled as MPC function

Loads and Boundary conditions are then applied to the model. Load of 15190N and constraints in all the four bases are applied as shown in figure 7.

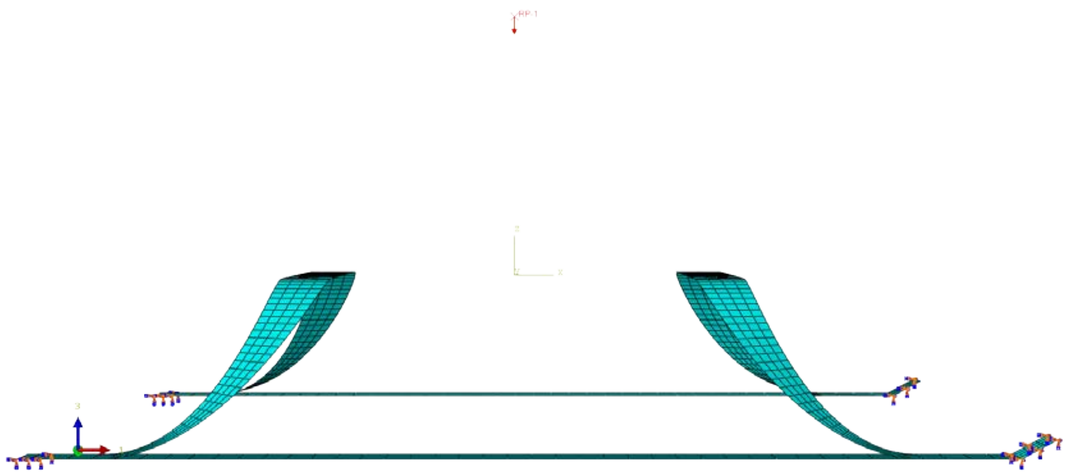

Figure 7: Loads and Boundary Conditions applied to the model

Finally, Static Analysis is performed in ABAQUS for both composite built landing gear and Aluminum alloy built landing gear. Then, Static Analysis was performed using ABAQUS under the same boundary conditions. The aluminum alloy material was then compared to the composite model. . The parameters of the aluminum alloy material are as follows: Elastic Modulus 69 GPa, Poisson's ratio 0.32, Density 2700 kg/m^3.

IV. Calculation Results and Analysis

After analysis was performed, many parameters were considered in order to compare the two different cases. The following figures describe the parameters and their values.

A. Tensile Stress

- S_{max}

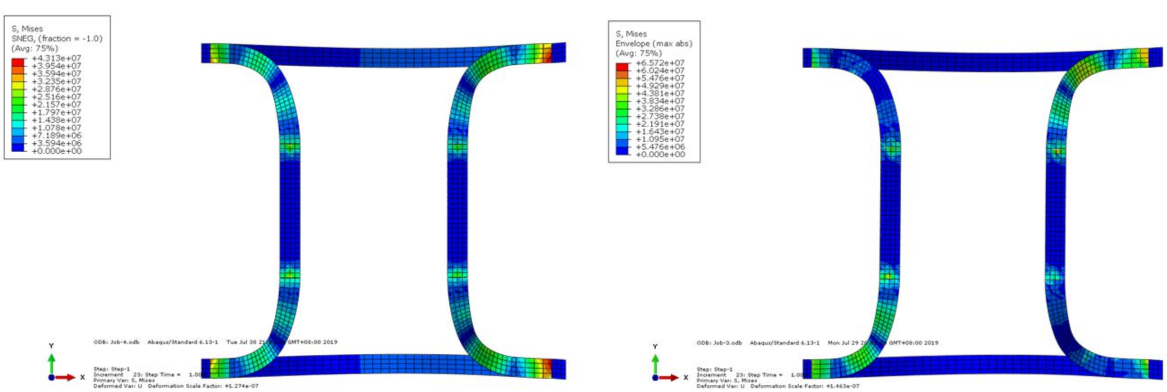

Figure 8: S_{max} of Al-alloy material and composite material respectively

- S_{11}

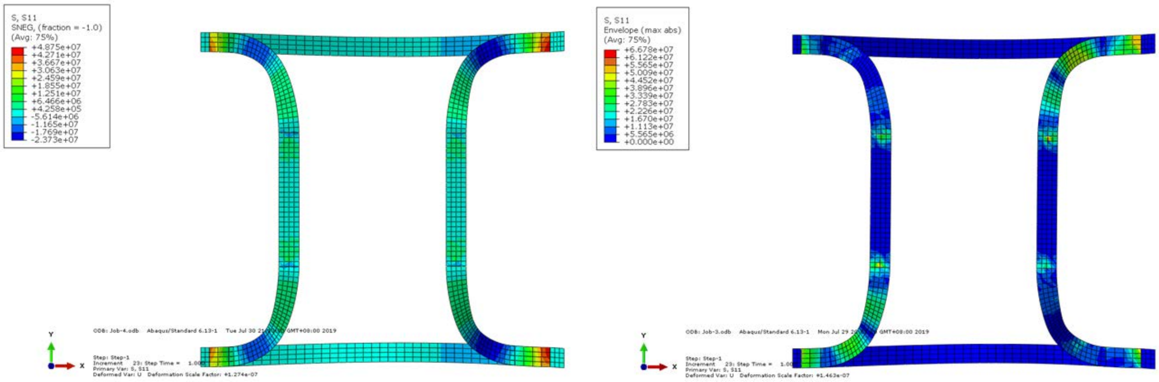

Figure 9: S_{11} of Al-alloy material and composite material respectively

- S_{22}

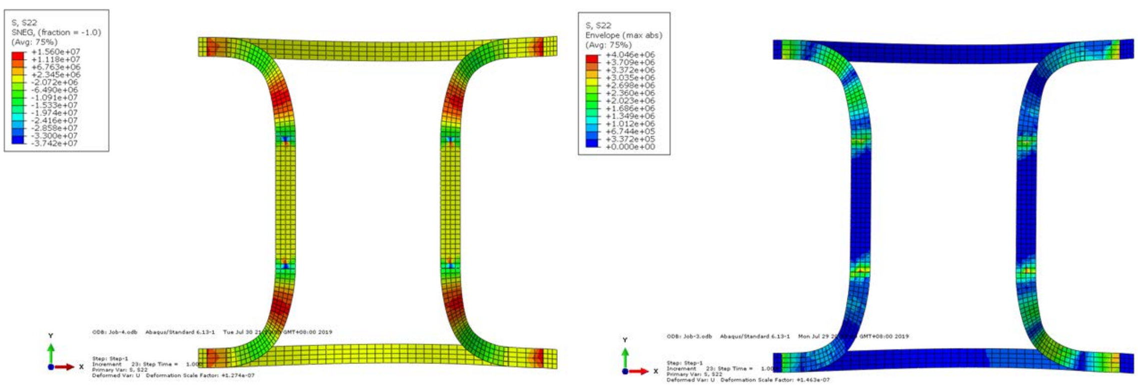

Figure 10: S_{22} of Al-alloy material and composite material respectively

B. Shear Stress (S_{12})

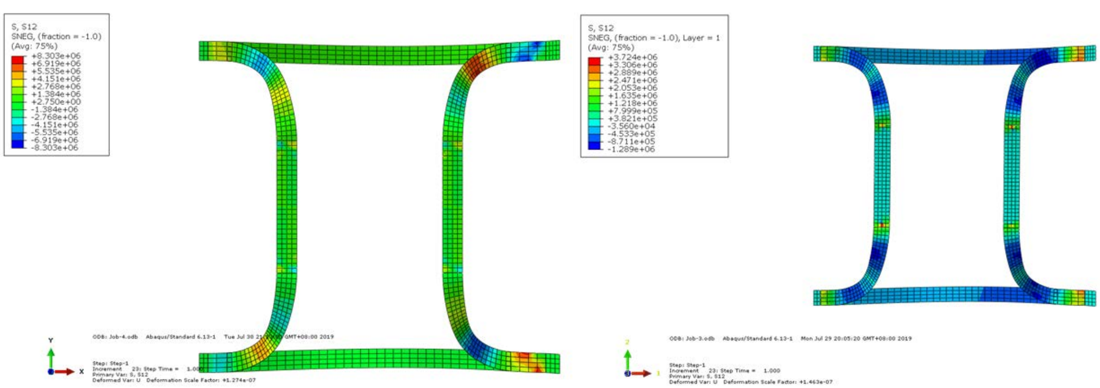

Figure 11: Shear force of Al-alloy material and composite material respectively

C. Deformation

- U_{max}
-

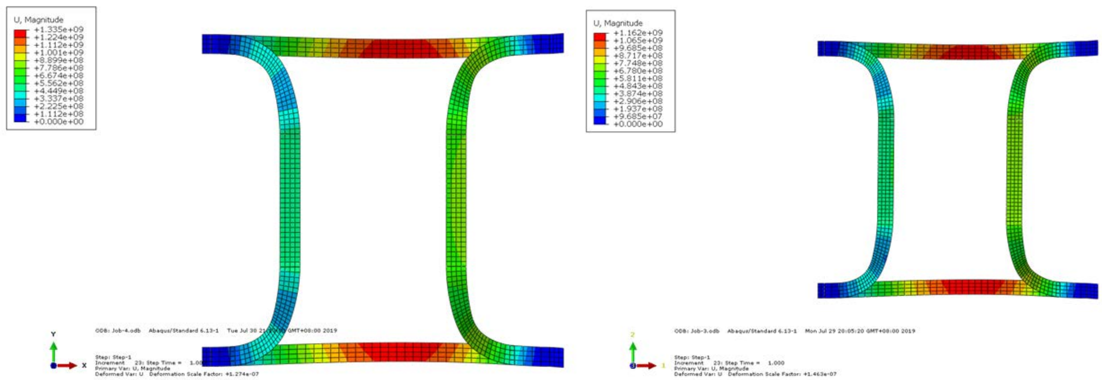

Figure 12: U_{max} of Al-alloy material and composite material respectively

- U_1

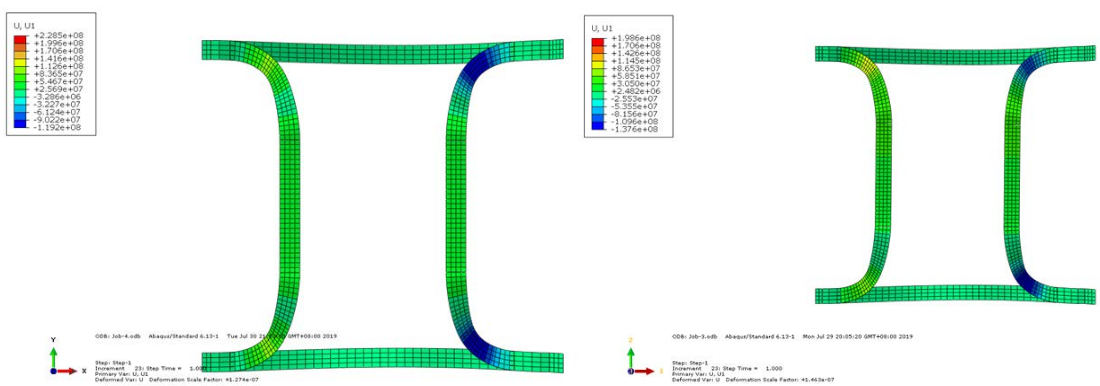

Figure 13: U_1 of Al-alloy material and composite material respectively

- U_2

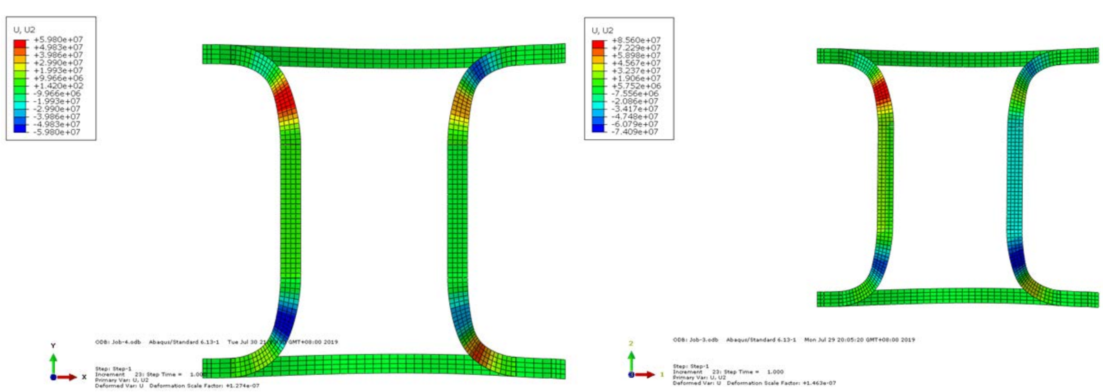

Figure 14: U_2 of Al-alloy material and composite material respectively

- U_3

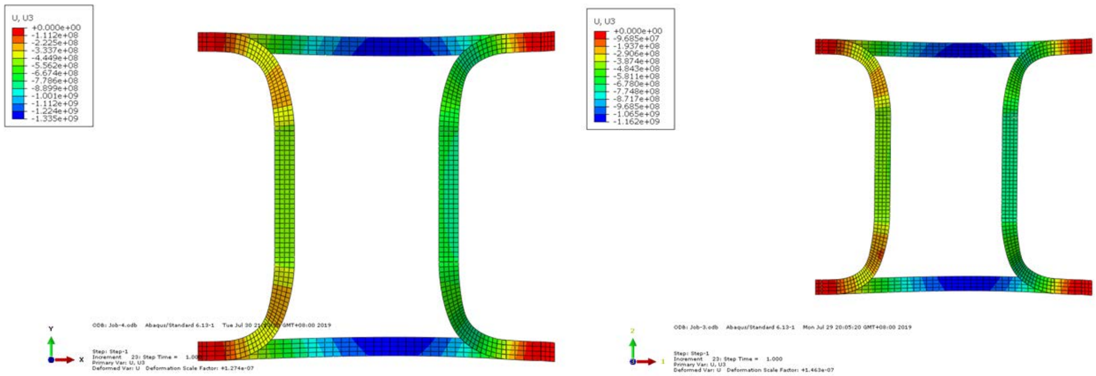

Figure 15: U_3 of Al-alloy material and composite material respectively

All the results presented in the figures above are described in the table below.

	Stress/MPa			**Shear /MPa**	**Deformation/mm**				**Weight**
	S_{max}	**S_{11max}**	**S_{22max}**	**S_{12max}**	**U_{max}**	**U_{1max}**	**U_{2max}**	**U_{3max}**	
Composite Material	6.572e7	6.678e7	4.046e6	3.724e6	1.162e9	1.986e8	8.560e7	1.162e9	**Composite material is 40% that of Al Alloy**
Al Alloy	4.313e7	4.875e7	3.742e7	8.303e6	1.335e9	2.285e8	5.980e7	1.335e9	

Table 2: Results

It can be seen from table 2, that composite made landing gear has less deformation compared to that of Al alloy made landing gear. Comparing the data in the table 2, it can be seen that under the same conditions, the stress level of the composite landing gear is higher than that of the aluminum alloy landing gear, and the deformation result is better than that of the aluminum alloy landing gear, and the effect of weight reduction is 40%.

V. CONCLUSION

This paper presents numerical simulations to both the cases where helicopter skid landing gear is made up of Aluminum alloy and composite materials. Comparing the stress and deformation results, composite made landing gears are better than the Aluminum alloy made landing gear. However, the composite made landing gear can be more optimized using different types of composite materials such as honeycomb structure. It can be followed up for the researches in future.

ACKNOWLEDGMENT

I'm grateful to my supervisor Mr Han Dong and my senior mate for guiding me throughout my research works. I also would like to thank Chinese Government for providing me with postgraduate studies scholarship.

REFERENCES

[1] H. Thuis, "The development of composite landing gear components for aerospace applications," 2004.

[2] I. Sharf and L. Monterrubio, "Influence of landing gear design on helicopter ground resonance," in Modeling and Simulation Technologies Conference and Exhibit, 1999.

[3] A. Airoldi, L. L.-5th W. C. on Multidisciplinary 2003, "Design and Optimization of Helicopter Skid Landing Gear with Multibody Analyses," re.public.polimi.it.

[4] K. Shrotri and D. Schrage, "Composite Skid Landing Gear Design Feasibility," J. Am. Helicopter Soc., vol. 54, no. 4, p. 042004, 2009.

[5] C. Caprille, A. Airoldi, P. Biaggi, and P. Mandelli, "Multi-body simulation of a helicopter landing with skid landing gear in various attitude and soil conditions," 1999.

[6] S. Mukherjee and P. C. Chandra, "Design optimization for sandwich composite plate," September, pp. 0–6, 2017.

[7] M. Guida, F. Marulo, B. Montesarchio, and M. Bruno, "Innovative Anti Crash Absorber for a Crashworthy Landing Gear," Appl. Compos. Mater., vol. 21, no. 3, pp. 483–494, Jun. 2014.

[8] X. Y. Zhu and J. W. Lu, "Stress and Buckling Analysis of a Certain Type of All-Composite Landing Gear," Adv. Mater. Res., vol. 663, pp. 692–697, Feb. 2013.

[9] C.-H. Tho, C. E. Sparks, A. K. Sareen, M. R. Smith, and C. Johnson, "Efficient Helicopter Skid Landing Gear Dynamic Drop Simulation Using LS-DYNA," J. Am. Helicopter Soc., vol. 49, no. 4, pp. 483–492, Oct. 2004.

[10] S. N. Kumar, "Design and Structural Analysis of Skid Landing Gear," Int. J. Curr. Eng. Technol., vol. 2, no. 2, pp. 635–642, 2013.

[11] B. Derisi, Suong Hoa, Duosheng Xu, M. Hojjati, and R. Fews, "Composite Tube Exhibiting Large Deformation under Bending," J. Compos. Mater., vol. 44, no. 16, pp. 2005–2020, Aug. 2010.

AUTHORS

First Author – Mandeep Chetry, Postgraduate Student, Nanjing University of Aeronautics and Astronautics, mandeep.chetry007@outlook.com
Second Author – Han Dong, Professor, Nanjing University of Aeronautics and Astronautics, donghan@nuaa.edu.cn