Numerical Analysis of an Aircraft Wing

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Abstract
A wing is a structural component of aircraft which is used to produce lift during the flight. Wing structure contains skin, ribs and spars sections. Wings are the most prominent lift producing component of the aircraft. The selection and design of the profile do depend on the type of the aircraft and its purpose. Testing the wing structures experimentally is very expensive and time consuming. In the present study a standard NACA profile considered is modeled in SOLID WORKS and structural analysis is carried out using ANSYS workbench. The stress analysis is carried out to examine the stresses along the length of the wing. Wing with and without spar and ribs are taken for analysis. Aluminum 2024-T3, steel and balsa wood are considered for the study. The purpose of the present study is to correlate and validate the finite element model against the modal test for further complex analysis. The deformation pattern and the associated stress fields are predicted accurately using the proposed finite element analysis.

Key words: aircraft wing, spar, deformation.

1. INTRODUCTION

A wing of an aeroplane structure is capable of flying with help of airfoil profile that generates the lift by the vehicle's forward air speed which in turn generates pressure difference at the top and bottom surfaces. The wing forms a primary structural component of which is used to produce lift force during flight and researchers have paid attention with regard to parametric design and optimization [**1, 2**]. When the engine is started air is sucked into the compressor through the inlet increasing pressure ratio at the exit of the compressor. Then air and fuel is mixed inside combustion chamber and burnt. When high pressure, high temperature gases is accelerated through the nozzle, thrust force is produced which propels the aircraft in forward motion. Due to this forward motion, air flows over the wing which is aerodynamic in shape. Due to the aerodynamic shape of the wing along with Bernoulli's principle the velocity of flow is less at bottom of the wing and high at top of wing. Due to this pressure difference is created between top and bottom surface of wing and thus lift is generated [**3**]. Wing must have high strength to weight ratio, high fatigue life since it is subjected to alternate repeated loadings during flight. The main aim of the paper is to find the deformation and stress distribution in a wing made up of three different materials. The structural steel, AL2024T3 and balsa wood are considered**.** Finite element analysis is performed on the generated wing structure using SOLID WORKS and ANSYS software. The results presented here have shown that the properly design aircraft wing can perform better when focused on the dimensions of the wing. The cross section of wing is called airfoil which is made aerodynamic in shape to reduce drag [**4**]. The aerodynamic efficiency of wing is expressed in terms of lift/drag ratio. Fuselage and empennage are other structural components of aircraft. Fuselage houses passengers, crew, and cargo etc. while as empennage provides stability to the aircraft during flight. Aluminium is widely used material for aircraft structure. About 80% of the structure is made up aluminium and aluminium alloys [**5**].

2. METHODOLOGY

The geometric data for the chosen NACA profile is chosen from NACA website **[6]**. The wing profile is created in xz plane and extruded along z axis as shown in **fig 1** Using Solid works software [**7**]. Different part files are created each for the wing, spar and rib and are finally assembled in the workspace giving appropriate constraints. The **fig 2** gives the details of the wing structure in sectional view.

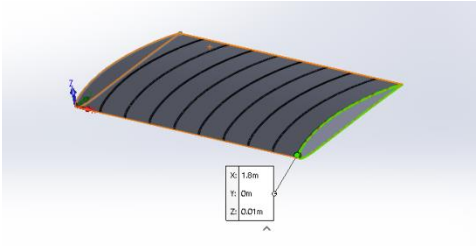

Fig 1. Geometrical model of the wing with spar and ribs.

The model is imported to the ANSYS workbench **[8]** to carry out the structural analysis. The appropriate boundary conditions are imposed to simulate the static structural analysis of a wing.

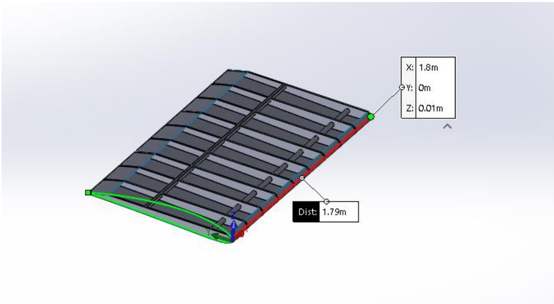

Fig 2: Sectional view of the wing with ribs and spars

One end of the wing is fixed in all DOF and the pressure load is applied on the skin surface. The properties of the materials for the analysis are as shown in **Table 1.**

Table1: Material Properties

Material	**Balsa wood**	**AL2024T3**	**Structural Steel**
E (GPa)	0.9	73.1	200
μ	0.31	0.33	0.3
G (GPa)	0.3435	26.6	76.923
ρ(kg/m^3)	225	2770	7850

3. Results and discussions

3.1. Wing with spar and ribs

Firstly the analysis is carried out on the wing with spar and ribs. The finite element mesh generated in ANSYS work bench is as shown in **fig [3].** The number of nodes and elements generated are 195904 and 108445 respectively. The pressure load of 500Pa is applied to the wing structure as shown in fig 4. The body force is applied in terms of standard earth gravity of 9.8066 m/s^2.

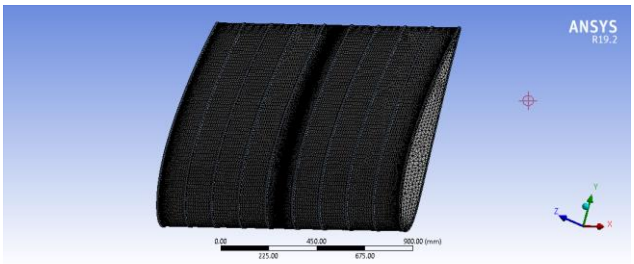

Fig 3. Finite element mesh on wing structure

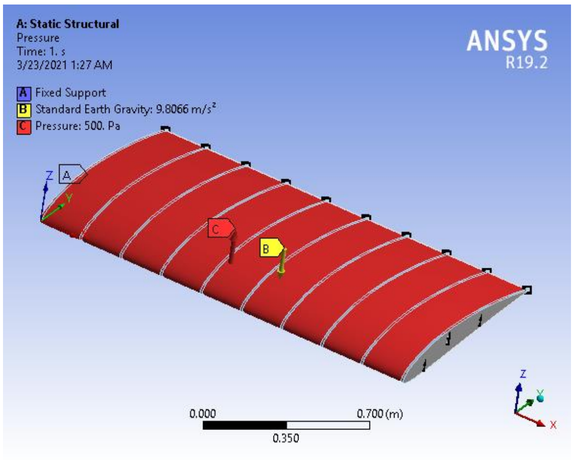

Fig 4. Finite element mesh on wing structure

The total deformation as evidenced for the balsa wood is shown in fig 5. The maximum deformation is obtained as 3.9818mm. The maximum von-Mises stress is predicted as 0.762MPa as shown in fig 6.

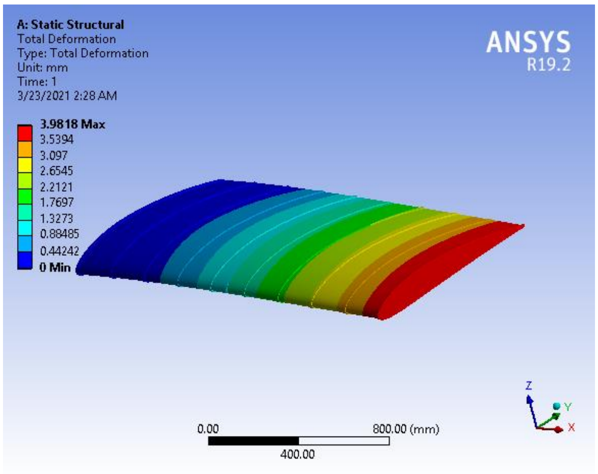

Fig 5: Total deformation in balsa wood wing

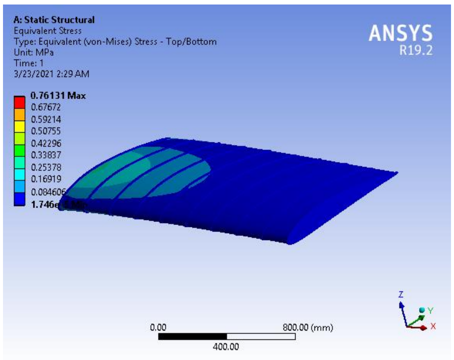

Fig 6. Von-Mises stress distribution on balsa wood wing.

Similarly analysis is carried out as did for balsa wood. The results of the aluminium T2024T3 and the structural steel are presented in Fig [7-10].

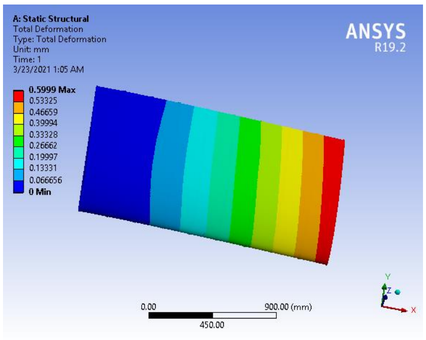

Fig 7: Total deformation in Aluminium wing

The total deformation for the aluminium is predicted as 0.6mm as shown in Fig7. The von-Mises stress is shown in Fig 8, from which maximum value is 9.40Mpa.

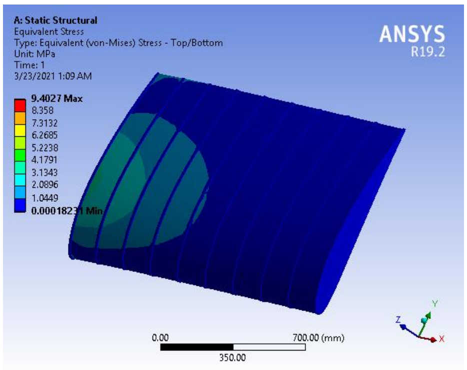

Fig 8. Von_Mises sress distribution on Aluminium.

Fig [9, 10] shows the total deformation and equivalent stress distribution on Structural steel.

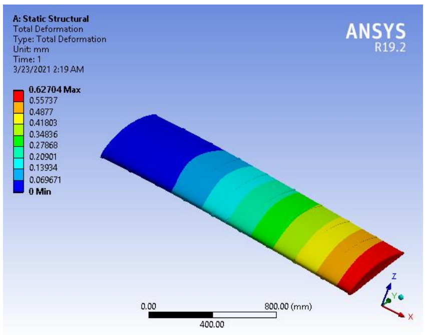

Fig 9: Total deformation in structural steel wing

3.2 Case II: wing without spar and ribs.

Equally analysis is done on the wing made of balsa wood without spar and ribs treating it as a solid. The deformation pattern and the corresponding equivalent stress distribution is as shown in fig 10 and fig 11 respectively.

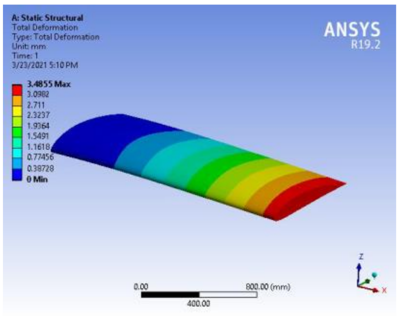

Fig 10. Deformation pattern in balsa wood without ribs and spars

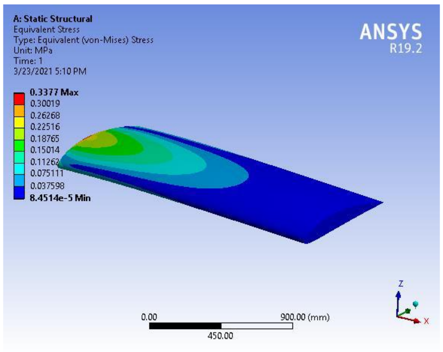

Fig 11. VonMises stress distribution in balsawood wing without ribs and spars.

Similarly analysis is performed on Aluminium and structural steel as shown in Fig 12-15.

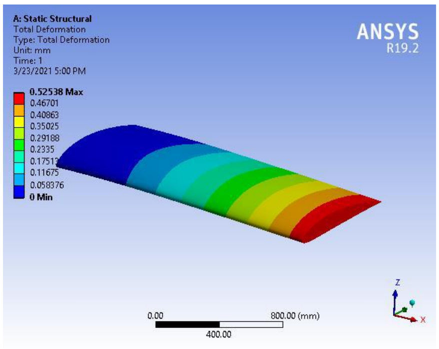

Fig 12. Deformation pattern in Aluminium wing without ribs and spars

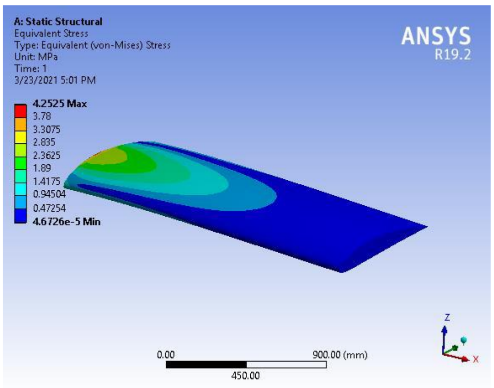

Fig 13. VonMises stress distribution in Aluminium wing without ribs and spars

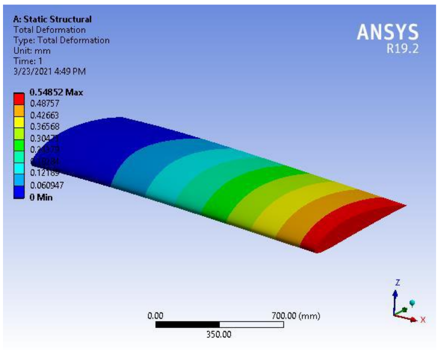

Fig 14. Deformation pattern in structural steel wing without ribs and spars

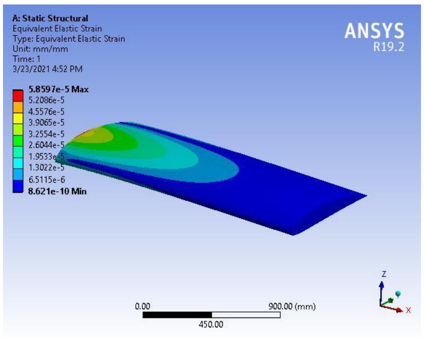

Fig 15. VonMises stress distribution in structural steel wing without ribs and spars

The results obtained for case-I and case-II are compared in a Table 2.

Table 2: Comparison of results

Material	**Total Deformation (mm)**		**Equivalent Stress (MPa)**	
	Wing with ribs and spars	Wing without ribs and spars	Wing with ribs and spars	Wing without ribs and spars
Balsa Wood	3.9818	3.4855	0.76131	0.3377
AL2024T3	0.5999	0.52538	9.4027	4.2525
Structural Steel	0.627	0.54852	26.79	11.719

The variation of maximum deformation and VonMises stress in wing with and without ribs is compared in Fig 16 to Fig 17. The drastic reduction in weight accompanied with increased stiffness is evidenced in wings with ribs and spars. The established procedure can be used to evaluate the performance of wings using finite element analysis before they are taken to manufacturing.

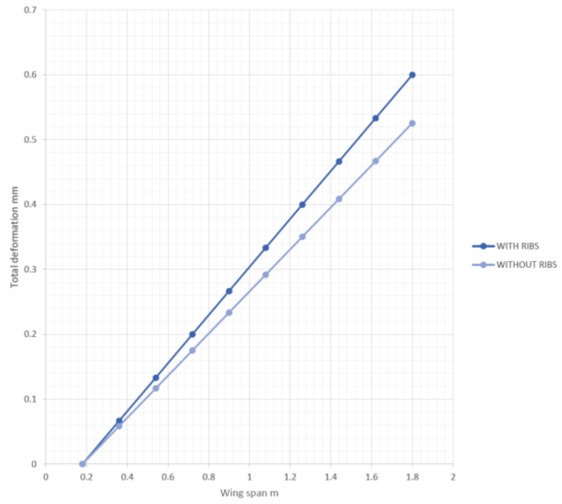

Fig 16. Comparison between wing with ribs and without ribs in Aluminium.

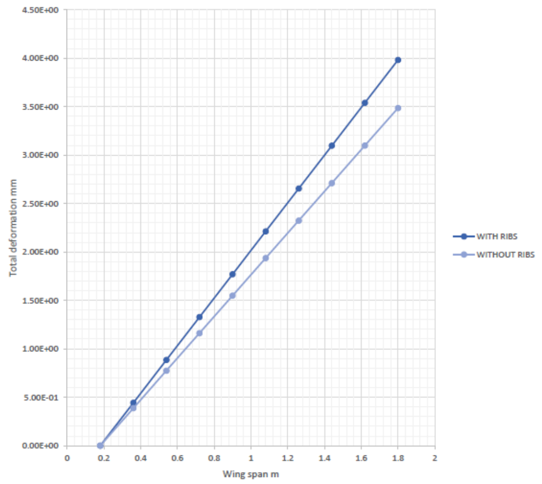

Fig 17. Comparison between wing with ribs and without ribs in Balsawood

4. CONCLUSIONS

The structural analysis of an aeroplane wing using NACA profile is carried out with three diffferent materials using SOLID WORKS and ANSYS Workbench softewares. The proposed method can model and anlyse the wing so that the experimentation cost and associated time is saved for product developement. The wing configuration further need to be modified so as to bring down the weight and to increase the stifffness by adopting suitable sections for different components of an aeroplane wing.

5. REFERENCES

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