IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 1, January 2016.
www.ijiset.com
ISSN 2348 – 7968

Experimental and Numerical Investigation of Numerical and Thermal analysis of a Trapezoidal wing

Santhosh SA[1], S. Kalyan Yadav[2], S S Mahesh Reddy[3]

[1] Student, Department of Mechanical Engineering, East Point College of Engineering & Technology, Bangalore, India-560049,

[2,3] Assistant Professor, Department of Mechanical Engineering, East Point College of Engineering & Technology, Bangalore -560049,

Abstract

Aircraft is a machine that is used to transport people and cargo from one place to another. It is one of the fastest means of transportation we see as on today. To manufacture aircraft we would require more than 1 lakh components. Each component is made to its precision and a lot of considerations are made to ensure that the flight operates in the correct manner and all safety precautions are undertaken while manufacturing and during flight. Wing is one of the important components of the aircraft. The wings are designed such that they retain the aerodynamic shape when they are under stress. The main purpose of the wing is to generate lift and control the airflow while flying. The wings are designed to reduce drag at the leading edge, generate lift by its crescent and manage airflow with the help of rear edge. In this project we perform the Modal and thermal analysis for a trapezoidal wing (Prototype) on a reduced scale. Frequencies and mode shapes are determined in the Modal analysis part and temperature distribution is determined in the thermal analysis part. The project is carried out both experimentally and numerically. CAD, CAE and CFD software tools are used to perform the numerical part.

1. Introduction

Aircraft is an assembly of many components. Some of the important parts of an aircraft are:

- Fuselage **–** This is the main part which holds the crew, passengers and cargo and all other components are attached to it.
- Wings – This is a supporting part which helps create lift in air.
- Empennage **–** These are the tail structures that control the airplane by maintaining stability.
- Propulsion system - The propulsion system holds the engines that provide thrust to the airplane.
- Undercarriage **–** Undercarriage refers to parts attached to the lower side which includes struts, wheels and brakes

The materials that are used to manufacture the aircraft components include both ferrous and nonferrous metals. Aircraft materials are selected depending upon the location, type of loading and the application it serves.

The components are subjected to various tests and the behavior of each of the component is studied. Modal Analysis is one such step where we look into the dynamic behavior of the Structure.

It is important to determine the dynamic response of a structure. In my study I have performed the modal analysis of a trapezoidal wing to understand the dynamic behavior of the wing. It is necessary that the engineers design a structure such that the resonance does not occur. In the event of resonance, the destruction begins unless it is designed to withstand the stress.

In my study we also determined the temperature distribution over a wing due to the heat source, placed at the longer edge of the wing.

2. Literature Survey

The Literature review before and during the Project gave us the right approach to conduct the project. The papers presented here are some of more relevant pertaining to the project. The accompanying creators distributed papers are as per the following:

E.G.Tulapurkara, Yashkumar and A.Venkattraman [1] have made a study on the drag polar and the stability derivatives for Boeing 747 airplane, for the flight Mach number of 0.8 and altitude of 140,000 feet (approximately 12000 meters). In their study they considered the trapezoidal wing to perform the drag polar and stability derivatives. It was found that the estimated derivatives are within 10% of the values for the flexible airplane.

T. Krishnamurthy [2] the paper presents the concept of equivalent plate. This concept was introduced in order to overcome the expensive FEA approach in the early stages of the design. In this method, the parameters like load, deformation and stiffness of the equivalent plate is matched to the actual wing by defining the factors geometric and dynamic scale factor. The analysis showed that the concept can be used to perform and predict the frequency response and flutter analysis successfully.

ISSN 2348 – 7968

Dana C Gould [3] in his paper presents the results of “thermal analysis for a conceptual level High Speed Civil Transport (HSCT) wing using the p-version finite elements”. In this p-version type of the finite element method (FEM), the triangulation is kept fixed and the degree p, of the piecewise polynomial approximation, is gradually increased until some anticipated level of precision is reached. The work showed the importance of heat transfer due to Radiation throughout the structure. Their study also showed that the decrease in the mesh size leads to very high or unacceptable execution times. The mesh size was decreased to study the temperature distribution over the internal structures more accurately. Further, use of P-version type of finite element method showed an improvement in the computation process for such analysis.

3. Tables, Figures and Equations

Material	Properties				
	E (GPa)	Specific Gravity(v)	Tensile Ultimate Stress(MPa)	Tensile Yield Stress(MPa)	Density (g/cm^3)
Aluminium					
2024-T3	72	0.33	449	324	2.78
7075-T6	71	0.33	538	490	2.78

Table 1: Properties of the Aluminum material

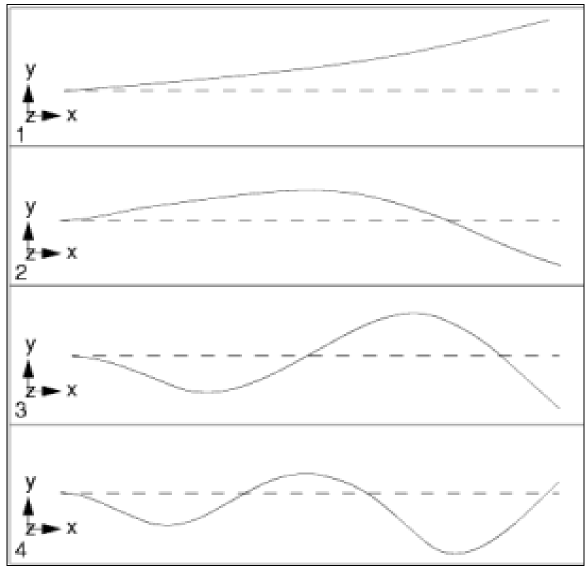


Figure 1: First four mode shapes of a Cantilever Beam

Equations:

$([K_c] + [H]) \{T\} = \{p\}$ …… (a)

Where $[K_c]$ is the conductivity matrix,

[H] is the boundary convection matrix due to free convection,

{T} is an unknown nodal temperature and

{P} is the thermal loading vector.

The system of linear equations is solved to find the nodal temperature {T}.

Thermal load vector can be expressed as:

$\{P\} = \{PB\} + \{PH\} + \{PQ\}$… (b)

Where {PB} is the power due to heat flux at boundary, {PH} is the boundary convection vector and {PQ} is the power vector due to internal heat generation.

The matrix on the left hand side (LHS) of equation (a) is singular unless temperature boundary conditions are specified. The equilibrium equation is solved simultaneously using a Gauss Elimination method to determine the unknown temperatures. After the unknown temperatures at the nodal points of the elements are determined, the temperature gradient $\{\nabla T\}$ can be calculated according to element shape functions. Element fluxes can be calculated by using:

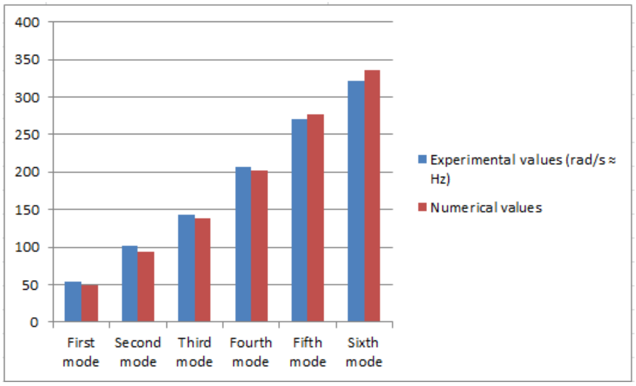
$\{f\} = [k] \{\nabla T\}$ …………….. (c)

Where, [k] represents the conductivity of the material.

ISSN 2348 – 7968

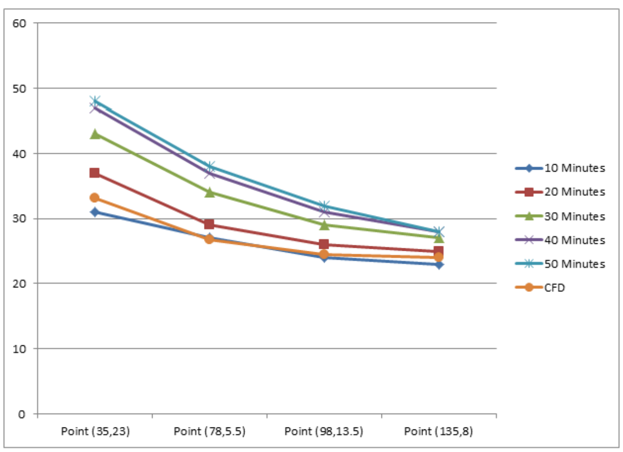
4. Results and Discussions

Graph 1: Modal analysis results



The graph gives the plot of the experimental values in comparison with the numerical values. The numerical values are approximately within 12 Percentage of the Experimental values.

Graph 2: Thermal analysis results



The nature of the graph gives an indication that the plots from the experimental data and the numerical data exhibit similar behavior.

References

[1] E G Tulapurkara,Yashkumar and Venkattraman, "Drag Polar, Stability derivatives and Characteristic roots of a jet airplane, April 2007

[2] Thiagarajan Krishnamurthy, "Frequencies and flutter speed estimation for damaged aircraft wing using scaled equivalent plate analysis", April 2010

[3] Dana C Gould, "Thermal analysis of a High Speed Aircraft Wing using p-version finite elements", January 2001

[4] Tang Jiapeng, Xi Ping, Zhang Baoyuan, Hu Bifu, "A finite element parametric modeling technique of aircraft wing structures", January 2013

[5] "Mechanics of Aircraft Structures, 2nd Edition" book by C T Sun