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Flutter Analysis of Typical Aircraft Wing using Doublet Lattice Method

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Abstract: Flutter is a dynamic instability. Flutter occurs at a velocity when the aerodynamic forces balances the elastic forces, beyond which the exciting forces exceed the restoring forces and the amplitude of disturbance will grow without limit. Thus flutter is a self-excited vibration. Wing flutter is the one that is most often encountered and the most important, among the types of flutter categorized as lifting surface flutter. In the simplest kind of example of binary flutter, known as flexure-torsion flutter, the only motion of importance are bending and twisting of the wing, wherein it is sufficient to take one generalized co-ordinate for flexure and one for torsion. The objective of the present work is to find on set of dynamic instability in particular, flutter for a typical wing structure using commercial code doublet lattice method in MSC/NASTRAN. And also studying the parametric sweep angles of wing and their flutter characteristics. The FE Modeling will be done in HYPERMESH and the flight load module of the MSC/PATRAN will be used for aero mesh generation. The flutter module of the MSC/NASTRAN is used as the solver.
Keywords: Flutter, HYPERMESH, NASTRAN, Double Lattice Method

I. INTRODUCTION

Aeroelasticity can be defined as a branch of aeromechanics that deals with the interaction among inertial, aerodynamic and structural stiffness effects in air vehicle. The study of aeroelasticity classified into two fields: static aeroelasticity, which deals with the steady response of an elastic body to a fluid flow; and dynamic aeroelasticity, which deals with the body's dynamic response. Static aeroelastic classified into divergence, control reversal. Dynamic aeroelasticity defined as the interactions among the aerodynamic, inertial and elastic forces. It is classified into flutter, Buffeting, transonic aeroelsticity. A wing is a type of fin with a surface that produces aerodynamic forces facilitating movement through air and other gases, or water and other liquids. As such, wings have an airfoil shape, a streamlined cross-sectional shape producing lift. Many aircrafts were crashed due to flutter acting on horizontal tail, wing, and vertical tail etc on various parts of the aircraft. In this paper wing flutter is encountered on the optimized structural wing designed. The material used in this design is Aluminium. In an aircraft, as the speed of the wind increases, there may be a point at which structural damping is insufficient to damp out the motions which are increasing due to aerodynamic energy being added to the structure. This vibration can cause structural failure and therefore considering flutter characteristics is an essential part of designing an aircraft. It is initiated by rotation of airfoil. Flutter is a dangerous phenomenon encountered in flexible structures subjected to aerodynamic forces. It considered as one of the most dangerous aeroelastic phenomenon. It occur when damping is tending to zero. It occurs as a result of interactions between aerodynamic, inertial and stiffness forces actin on the structure. A swept wing is a wing which angles either forward or backward from its root rather than straight sideways direction. It has an effect of reducing shock waves. Flutter is caused by coalescence of two structural modes i.e. pitch and wing bending motion.

II. OBJECTIVE

A. The Objective Of This Paper Is To Find Out The

1) Computing Eigen values and Eigen vectors corresponding to mode shapes and frequencies.
2) Computing damping and stiffness
3) Plot V-g and V-f graphs to identify the flutter velocities and the flutter behavior.
4) study of sweep angle of wings

B. Specifications of Wing Structure

The wing is designed in HYPERMESH. It consists of 9 ribs in transverse direction and three spars in longitudinal direction for half wing. The thickness of the wing is continuously varying between the two of each ribs.Engine made of RB2 in hypermesh is mounted on either side of the full wing (supporting two ribs on either side of wing) carrying mass of 1000 kg.total mass of full wing is 24,016 kg, remaining mass is distributed on fuel tank as generally at root 60 percent and 40 percent on other side of root.

Root chord	3030 mm
Tip chord	1515 mm
Length	9000 mm
Aspect ratio	3.9
Taper ratio	0.49
Aerofoil	NACA 2410
Rear spars	70% of chord from leading edge
Front spars	30% of chord from trailing edge
Mass	24016 kg
Surface area	1.043e8 mm

Table 1 design parameters

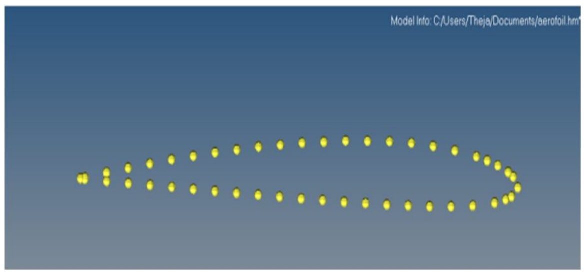

Fig1 Aerofoil NACA 2410

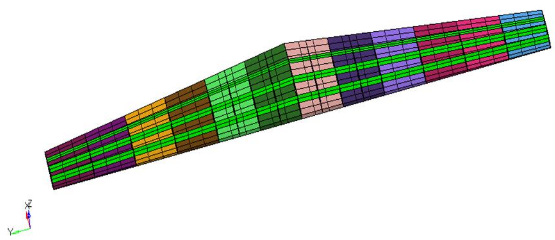

Fig2 bottom skin

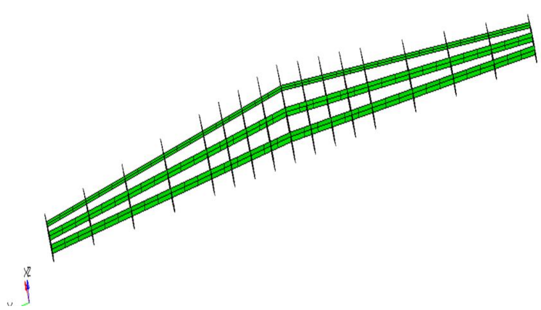

Fig3 ribs and spars

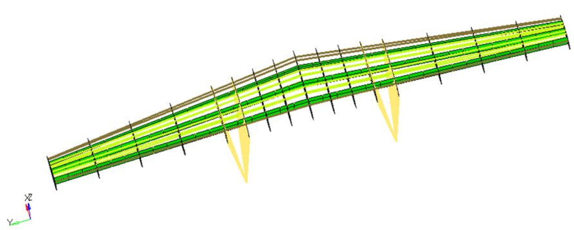

Fig4 stringers and engine on wing

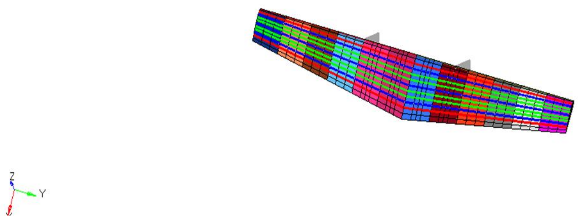

Fig5 Full wing model

III. LITERATURE REVIEW

These are the various papers similar to my analysis which are considered

[1]T.S.Vinoth Kumar, A.Waseem Basha "Static & Dynamic analysis of a typical aircraft wing structure using MSC NASTRAN" The main objective is to fix an appropriate structure within the given envelope and to estimate the Gross take-off weight, wing loading, Stress distribution, low frequency vibrational modes, take-off distance and stall velocity. The detailed wing structure is modeled using CATIA V5. Then stress analysis of the wing structure is carried out by using the finite element approach with the help of MSC NASTRAN/PATRAN to find out the safety factor of the structure. [2]N.G. Vijaya Vittala, A.C.Pankaj "Dynamic and Aeroelastic analysis of a transport aircraft" The dynamic and Aeroelastic characteristic of a transport aircraft has been established using MSC/NASTRAN. The doublet lattice method has been used to estimate the appropriate unsteady air loads generated on the lifting surfaces of the aircraft Flutter analysis of the complete aircraft has been carried out by both PK and KE methods and the critical flutter velocities have been evaluated. [3]Nur Azam and Erwin Sulaeman "Aeroelastic flutter analysis of supersonic wing with multiple external stores" The analysis of simulation of a supersonic wing equipped with external missiles loaded on the wing is presented. The structural mode shapes at each generated frequency are also presented. The analysis is carried out using MSC NASTRAN FEM software. The wing flutter with the external stores was simulated at different altitudes. The result shows that the flutter velocity is sensitive to the flight altitude. [4]Alfonso Pagani, Marco Petrolo "Flutter analysis by refined 1D dynamic stiffness elements and doublet lattice method" An exact dynamic stiffness matrix is then developed by relating the amplitudes of harmonically varying loads to those of the responses. g-method is used to conduct flutter analyses of both isotropic and laminated composite lifting surfaces. The obtained results match those from 1D and 2D finite elements with experimental analyses. It can be stated that refined beam models are compulsory to deal with the flutter analysis of wing models.

IV. METHODOLOGY

A. Finite Element modeling

This first step involves the modeling of a typical aircraft wing done in HYPERMESH.

B. Dynamic Characterization of the space vehicle components

Structural equations of motion for the finite-element model of the wing are of the form,

$$[M]\{A(t)\}+[D]\{A(t)\}+[K]\{A(t)\} = 0$$

Where M= mass modal matrix

D = damping matrix

K= stiffness matrix

A(t) = principal coordinates

Then structural dynamic analysis is carried out to study the behavior of the structure and the first five flexible modes and its frequencies are considered to be the predominant modes.

C. Unsteady Aerodynamics

This is the third step involves an aerodynamic model that represents the forces acting on a structure is required for conditions where aeroelastic effects flutter is present

D. Flutter Solution

In this step user has to specify the flight speed, reduced frequency, velocities, and number of modes to be extracted, according to the method. The flutter analysis is carried out using the Doublet lattice method for subsonic regime of Mach numbers (0.5-1.2) for

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supersonic regime of Mach numbers (1.2-1.9) and piston theory for hypersonic Mach numbers (2.0-8.0). In this paper, analysis done from 0.3 to 0.8. PK method is used to find flutter with user specified velocities.

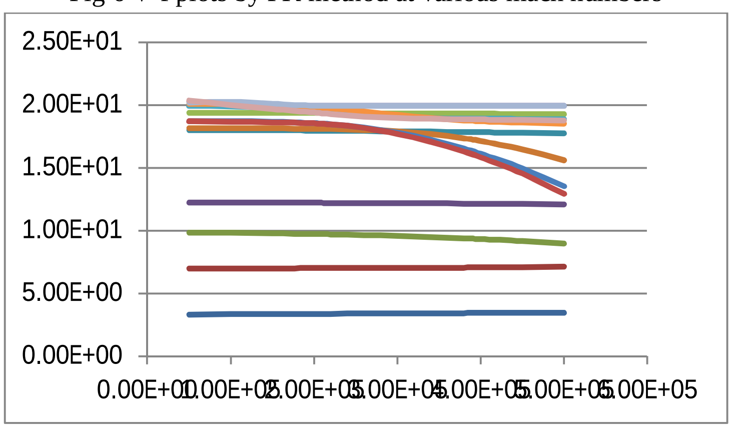
V. ANALYSIS AND MESHING

In this project MSC PATRAN is used as a preprocessor and post processor and it is used for the aero mesh generation. The wing MSC NASTRAN is used as a solver. Quad and Tria elements (mesh) is used in this wing structure. There are four solution methods to find out flutter. They are PK method, in which user have to specify velocities,PKNL method, in which flutter points method, in which user specified reduced frequencies,KE method, in which neglecting viscous damping. In this paper analysis is done by using PK method in subsonic region of mach number from 0.3 to 0.8.special care has to be taken on meshing on corners and check the entire model, nodes are in connectivity. Top and bottom was meshed with Quad element with element density 10. Spars also meshed with Quad element. Ribs were meshed with combination of Quad and Tria elements. I section is used in stringers.

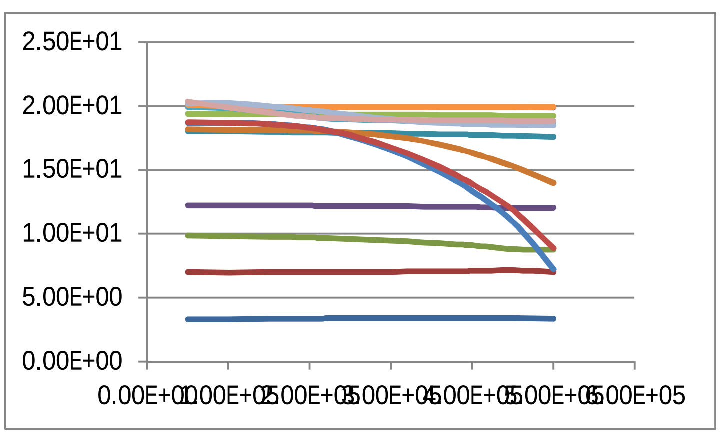
VI. RESULTS AND DISCUSSION

Modal analysis is defined as the study of the dynamic properties of structures under vibration excitation. It is the field of measuring and analyzing the dynamic response of structures and or fluids during excitation. It is mainly to determine the natural mode shapes and frequencies of an object or structure during free vibration. The physical interpretation of
the eigenvalues and eigenvectors which come from solving the system are that they represent the frequencies and corresponding mode shapes. Sometimes, the only desired modes are the lowest frequencies because they can be the most prominent modes at which the object will vibrate, dominating all the higher frequency modes.In this paper analysis carried for 20 modes and their frequencies and damping values were determined by giving set of velocity values ranging from
50,100,150,200,220,240,260,280,300,320,340,360,380,400,420, 440,460,480,500 m/s respectively. In this paper, velocity versus frequency, velocity versus damping values were plotted as shown below

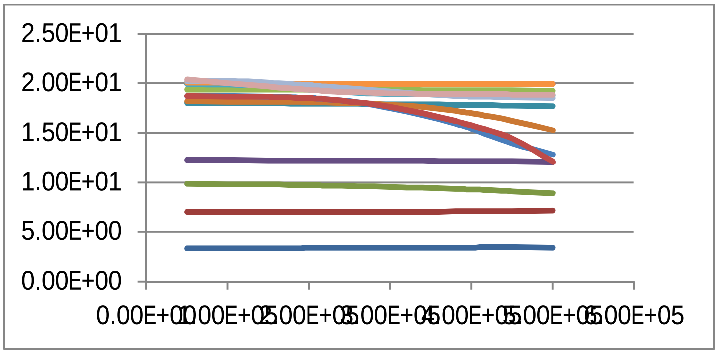
Fig 6 V-f plots by PK method at various mach numbers



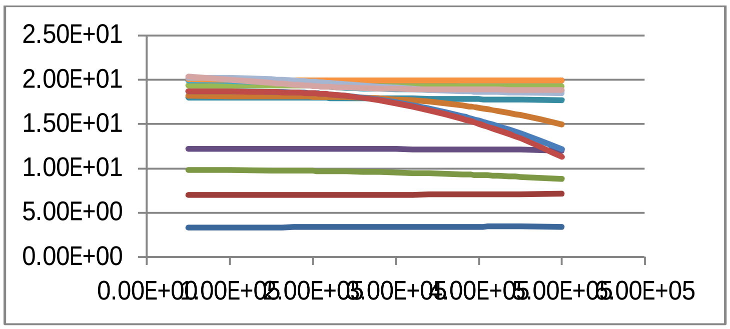
M=0.3



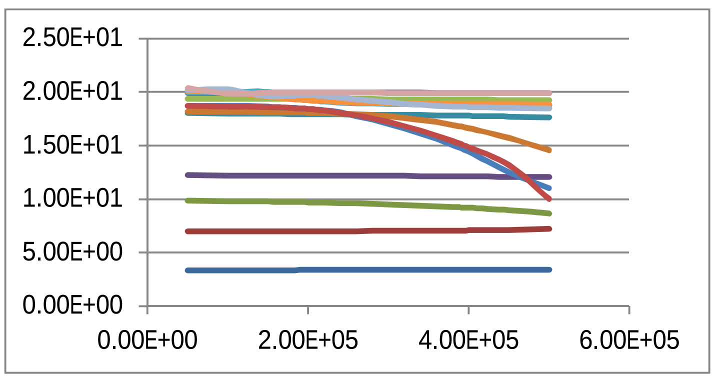
M=0.4



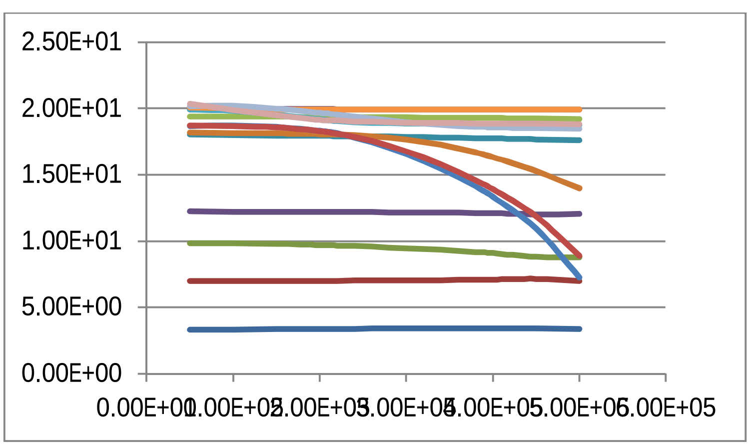
M=0.5



M=0.6

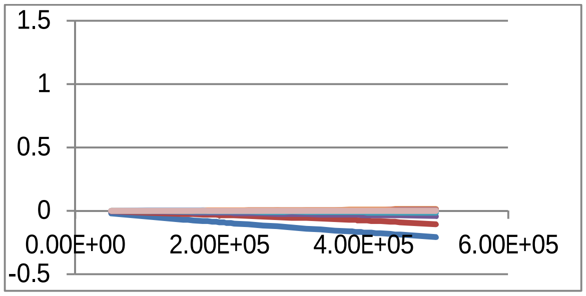


M=0.7

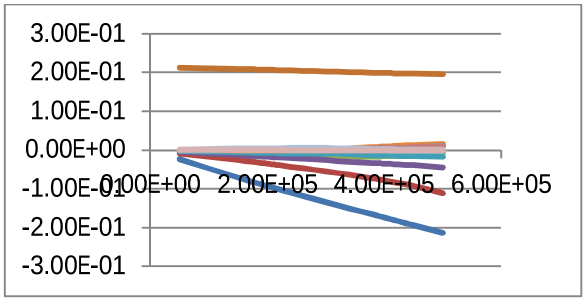


M=0.8

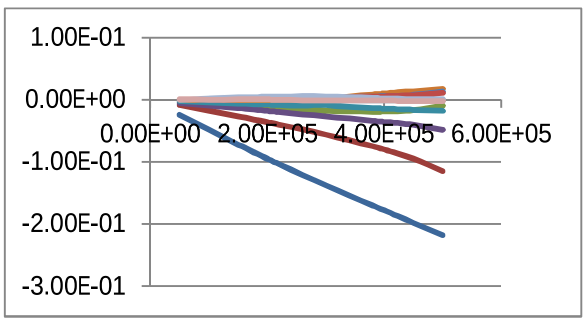
Fig 7 V-g plots by PK method at various mach numbers



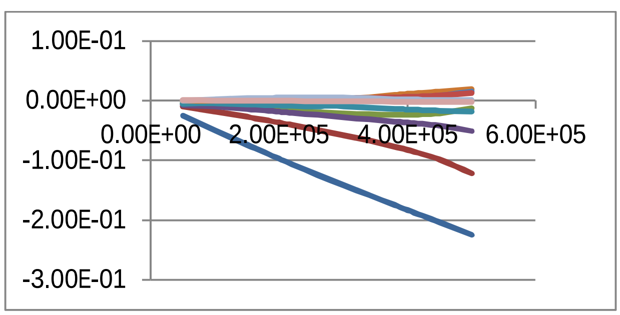
M=0.3



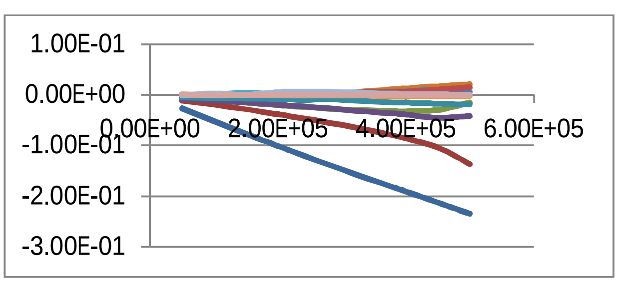
M=0.4



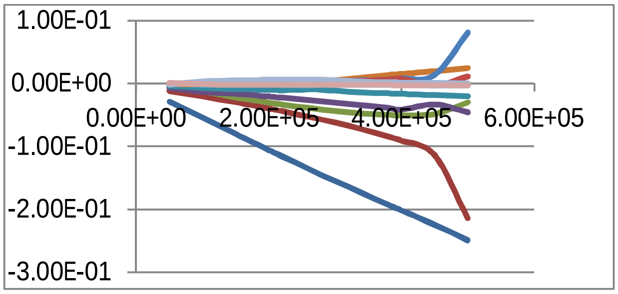
M=0.5



M=0.6



M=0.7



M=0.8

VII. CONCLUSION

Aircraft wing model is done by using HYPERMESH and it is subjected to various set of velocity values wit density ratio one. The above graphs showing the flutter points at which crosses other one and decreasing the point corresponding to velocity and frequency, damping is the flutter frequency, flutter velocity.

VIII. FUTURE SCOPE

Further by putting forward and backward sweep angles, can study the flutter characteristics and it can be modeling and analyzed by any software in future

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[11]