Estimate Flutter Speed Half Wing Model of N219 using MSC NASTRAN

[1]MIRNA SARI, [2]MUCHAMAD BAYU SAKTI PRATAMA, [3]HARUS L.G

[1]Student of Mechanical Engineering Departement, Intitut Teknologi Sepuluh Nopember, Surabaya, INDONESIA
[2]Muchamad Bayu Sakti Pratama, Supervisor of Aeroelasticity Indonesian Aerospace, Bandung, INDONESIA
[3]Harus L.G., Advisor Thesis in Institut Teknologi Sepuluh Nopember, Surabaya INDONESIA

Abstract: Flutter occurs when the aerodynamic forces associated with motion in two modes of vibration cause the modes to couple in an unfavourable manner. A half wing model was used to simplify the analysis and obtain its frequency and damping on a given speed range. This paper presents the prediction of flutter speed on half wing model N219 aircraft. This study covers two parameter variations, altitude (sea level, 5000 ft, 10000 ft) and Mach number (0.1; 0.2; 0.3). The model consists of three mass configurations: zero fuel, minimum fuel, and maximum fuel. The tools for flutter analysis in this research is MSC NASTRAN software. The most critical flutter speed occurred at 165 m/s, outside of flutter clearance envelope.

Key-words: Half wing, N219 aircraft, Flutter, MSC Nastran.

1. Introduction

Indonesia is an archipelagic country that 2/3 of its territory comprising waters that connecting more or less 13.000 dispersed big and small, and also inhabited and uninhabited islands [1]. Indonesia has mode of air transport into two type. There are commercial aircraft and pioneer aircraft [2]. PT. Dirgantara Indonesia (Indonesian Aerospace) is the first and the biggest manufacturer and assemblier of aircraft in Indonesia [3].

N219 Aircraft is one of a producted by PT. Dirgantara Indonesia [4]. It has capacity to carry 19 passengers and cargos and entried into service in year 2017 [5]. Flutter is a rapid self-feeding motion which is caused by the interaction of aerodynamics, structuural and inertial forces. Flutter can cause major damage on aircraft structure which can lead to fatal accident in aviation [6].

In other paper presented the study of a flexible wing so the flutter suppression using piezoelectric (PZT) can be investigated further [7]. Instead of the passive suppession will increase the mass of aircraft. The result of the test is to measure of flexible wing designwhich is suppressed on materials choice. PZT transduction is used by active and passive flutter suppressions for highly flexible wing [8]. By properly place the piezoelectric actuators and energy harvester. It was possible to stabilize the wing, while extracting a certain amount energy, both of which would contribute to improving the performance of wing and aircraft. Furthermore, the methods of flutter analysis of aeroelastic system includes modelling uncertainties is more efficient. Both of structural and aerodynamic uncertainties can have notable effect on the damping of the flutter modes. The method shows that main advantage is the ability to analyse the combine effect of structural and aerodynamic uncertainties [9].

There are several methods to estimate the flutter speed based on frequency matching such as the K method and the PK method [10]. This paper presents the flutter speed results using PK method. Based on [11], the PK method is used to determine the aerodynamic stiffness and damping matrices as a function of reduced frequency. MSC Nastran has The SOL 103 module to used to simulate the normal modes of each frequency. The SOL 145 module is developed to obtain the damping and reduced frequency variations as a function od velocity. The flutter speed can be determined when the graph of velocity versus damping factor is plotted. This paper presents the first 3 fundamental normal modes of SOL 103 which is affects to critical flutter speed of this subsonic wing with three mass configurations and considering the variation of altitude and mach number.

In this paper consists of 4 parts. Part 1 present scope of study, objectives as introduction. Part 2 briefly describes procedure of the Finite Element Method (FEM) analysis result. Part 3 presents the result of the analysis FEM results. Finally, part 4 describes the conclusions of estimating flutter speed half Wing model of N219 using MSC NASTRAN.

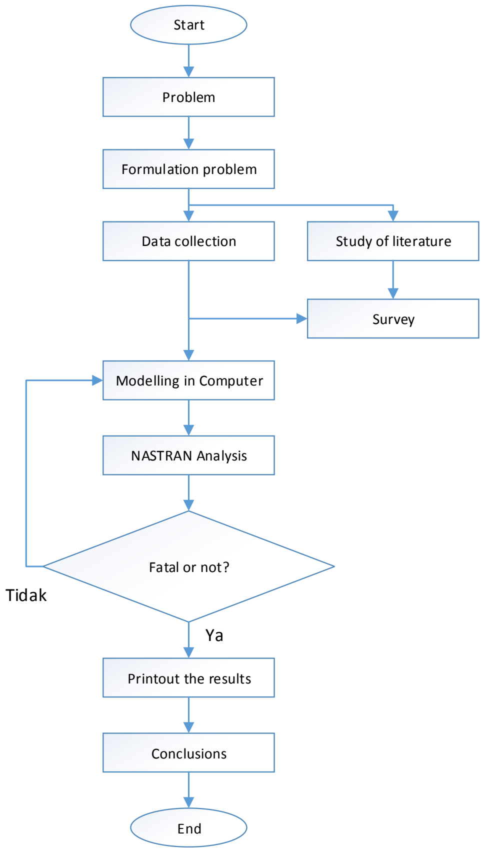
2. Methodology

The research method used is descriptive analysis research method. research methods to make a factual and accurate description of a situation or event and its analysis.

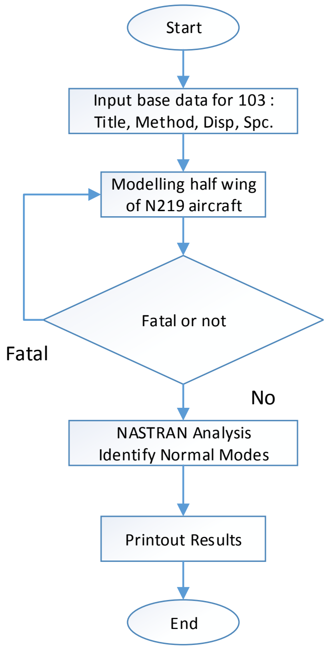
In fulfilling the data needed to analyze and predict flutter on the N219 half-wing model aircraft, the authors carry out the following data collection methods:

1. Interview techniques: asking questions that lead to business data retrieval to those who are competent in their fields
2. Literature study: study the theories - books from reference books that can support the analysis that the author did.

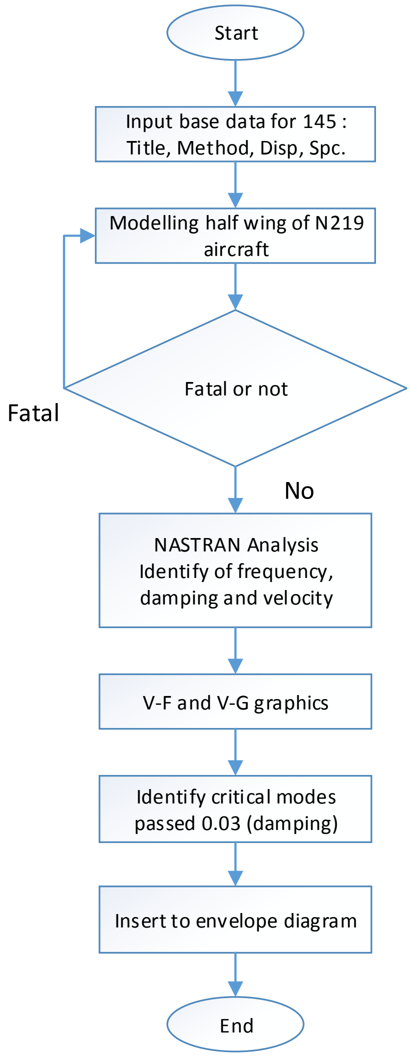
Flow chart research :



Flow chart of Normal Modes analysis (103 method)



Flow chart of flutter analysis



3. Structural Analysis

3.1 Characteristic of Supersonic Wing Aircraft

The aircraft wing shape could be outlined in several ways. The references trapezoidal wing is the base line geometry used to begin the wing layout. Figure below illustrates the most important angles and parameters used to describe it [12].

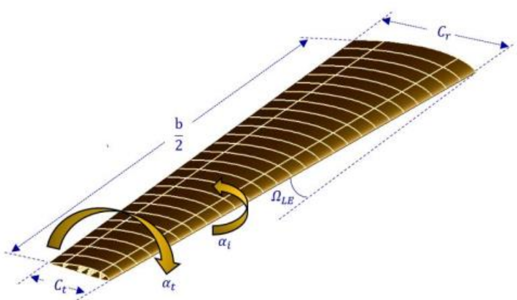


Fig 1. Geometric Properties for subsonic wing of aircraft

Where :

S : Wing area

b : wing span (the distance from wing tip to wing up)

C : Chord length of an airfoil

Cr : Chord length at the wing root

Ct : Chord length at the winφ

ΩLE : Wing sweep angle at leading edge

αt : angle of twist

αI : angle of incidance

Based on the above, further wing characterizing parameter are defined as follow :

Aspect ratio :

$$A = \frac{b^2}{S}$$

The aspect ratio is the primary ruling factor of the wing lift-to-drag ratio. Increasing the aspect ratio will decrease the wing drag and vice versa. On the other hand, the increase in aspect ratio will cause an increase in the wing span, this will overload the wing structure. It is clear that the selection of the aspect ratio compromises between the lift to drag ratio and the wing structural weight, a pertinent value must be selected to obtain the best results for these two conflicting imports.

3.2 Geometry of Half Wing Model

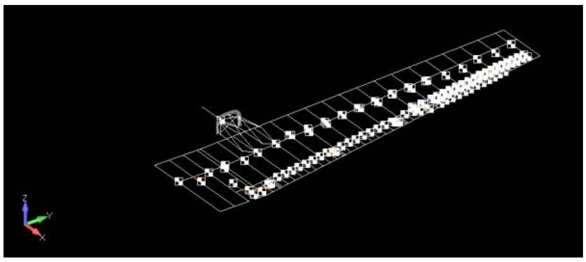


Fig 2. Half wing model

4. Unsteady Aerodynamics

For flutter prediction, unsteady aerodynamics on the wing surface, which is oscillating according to the structural dynamic mode shapes, is estimated using the boundary element method. For the subsonic region, the unsteady aerodynamic loads are calculated using the Doublet Lattice Method (DLM). The wing is modeled as a flat lifting surface and is discretized into a number of trapezoidal elements.

Based on [10], a set of aerodynamic influence coefficients in the form of a matrix equation is generated. The basic relationships between the lifting pressure and the dimensionless normal velocity induced by the inclination of the surface to the air stream can be formulated as below,

$$\{w_j\} = [A_{jj}]\left\{\frac{f_j}{q}\right\}$$

Where,

w : the normal wash velocity

f : the aerodynamic pressure

q : the dynamic pressure

A : the aerodynamic influence coefficient matrix

The substantial differentiation matrix of the structural deflection to obtain the downwash is given by equation below,

$$\{w_j\} = [D_{jk}^1 + ik\, D_{jk}^2]\{u_k\} + \{w_j^g\}$$

Where,

k : the reduced frequency

The integration of the pressure to obtain forces and moments yields,

$$\{P_k\} = [S_{kj}]\{f_f\}$$

The three equation can be combined to give the aerodynamic influence coefficient matrix in this equation,

$$[Q_{kk}] = [S_{kj}][A_{jj}]^{-1}[D_{jk}^1 + ikD_{jk}^2]$$

The DLM theories compute A matrix. Then, the marix decomposition forward and backward substitutions are used in computation of the Q matrix. Subsonic region will be used DLM for Nastran Software. The Nastran coding development in view of aerodynamics will consider the outer part of the wing box structure including the control surface of the wing.

5. Pk Method Of Flutter Solution

Following [10] the PK equation for modal flutter analysis can be formulated as this equation

$$\left[M_{hh}p^2 + \left(B_{hh} - \frac{\frac{1}{4}\rho c V Q_{hh}^I}{k}\right)p + \left(k_{hh} - \frac{1}{2}\rho V^2 Q_{hh}^R\right)\right]\{u_h\} = 0$$

Where the circular frequency ω and the reduced frequency k are related to p as

$$k = \frac{\omega c}{2V}$$

$$p = \omega(2g + i)$$

The flutter solution is rewritten in the state space form as in equation below where A is complex number.

$$[A - p\, I]\{u_h\} = 0$$

The eigen solution of that equation is in the form of a complex eigen value p for each mode, which in turn will give the structural damping g for the real part and frequency ω for the imaginary part. Note that the result is computed for each velocity which is embedded in the damping and stiffness matrix termsof equations.

6. Simulations Results And Discussion

6.1 Normal Modes Analysis - SOL 103 – MSC Nastran

For the FEM data, the boundary condition at the wing root is rigidly fixed, no deflection and no rotation in the x, y, and z direction at the front, middle and rear spars of the wing box. The first 15 normal modes of the wing structure are shown in Tabel below. Note that the rigid body mode is not included in the list. The frequency and its associated shape are recorded in Table 1.

Table 1. Normal Modes Results of SOL 103

No	Name shape	Frequency (Hz)	Deformation
1	Aileron vertical bending	3.246	0.58
2	Wing vertical bending	4.426	0.142
3	Engine vertical bending	7.979	0.0774
4	Wing vertical bending	8.859	0.752
5	Wing vertical bending	11.373	0.0754

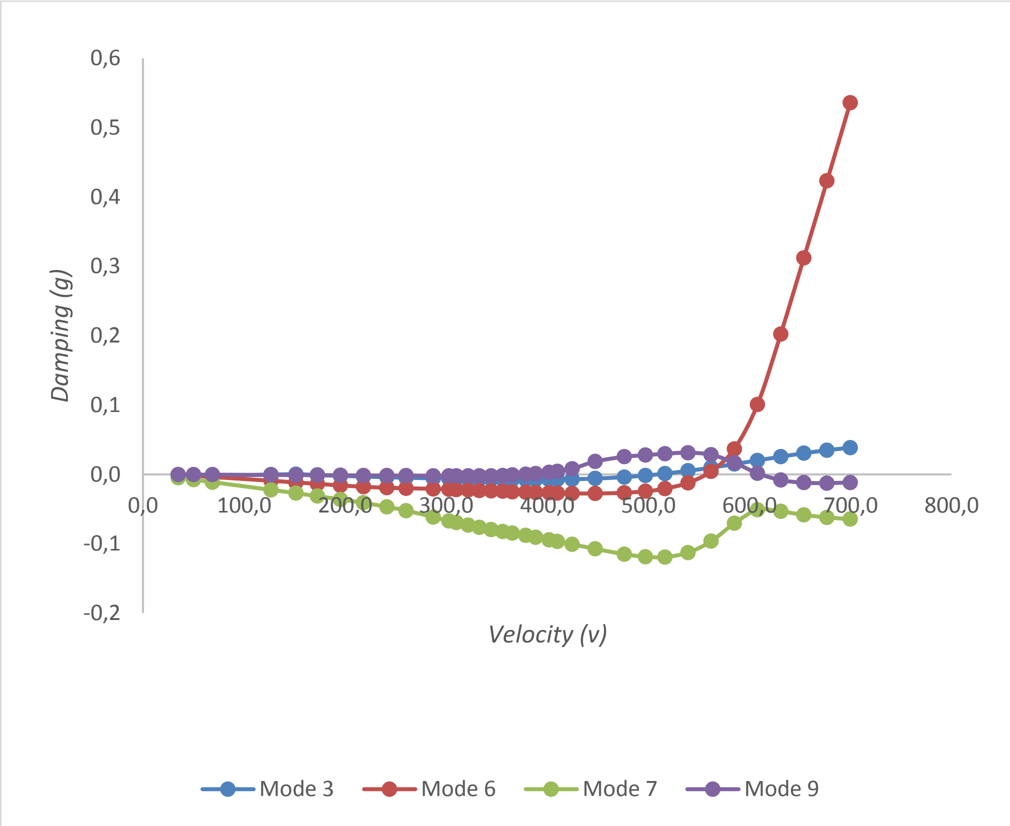
6	Wing torsion	14.875	0.0781
7	Wing lateral bending	17.631	0.111
8	Engine torsion	18.287	0.0534
9	Wing lateral bending	21.860	0.0656
10	Wing torsion	26.211	0.149
11	Wing lateral bending	30.219	0.098
12	Wing vertical bending	39.429	0.182
13	Wing torsion	43.131	0.192
14	Flap vertical bending	45.049	0.185
15	Wing vertical bending	47.149	0.0756

6.2 Flutter Solution – SOL 145 of MSC Nastran

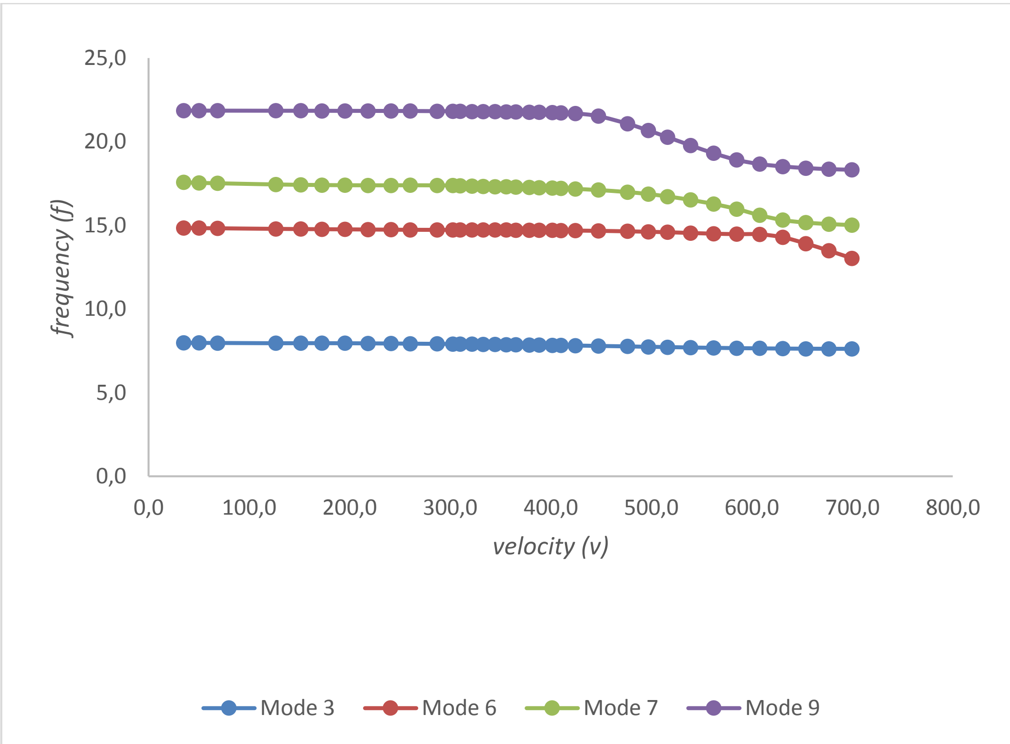
SOL 145 simulation is further carried out at different Mach number to find the match point velocity at 0 ft (sea level), 5000 ft, and 10000 ft. The graph of structural damping versus velocity and damping versus frequency of every mode at 0 ft is plotted in **Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**. The flutter dominant mode most lilely occurs at mode 3, 6,7 and 9 like data in Table 2. The several modes that has value of damping more than 0.03.

Table 2. Half wing natural frequencies for the first three modes

ZERO FUEL (Mach Number 0.1)						
Modus Number	Altitude					
	sealevel		5000 ft		10000 ft	
	Freq	Speed	Freq	Speed	Freq	Speed
3	7.68	603.12	7.68	631.25	7.68	651.11
6	14.71	564.71	14.66	606.07	14.64	633.13
7	17.53	598.67	17.37	645.92	17.29	676.13
MINIMUM FUEL (Mach Number 0.2)						
Modus Number	Altitude					
	sealevel		5000 ft		10000 ft	
	Freq	Speed	Freq	Speed	Freq	Speed
3	7.63	651.62	7.63	676.65	7.64	695.63
6	14.48	580.35	14.42	620.2	14.39	647.52
9	20.2	519.47	-	-	-	-
MAXIMUM FUEL (Mach Number 0.3)						
Modus Number	Altitude					
	sealevel		5000 ft		10000 ft	
	Freq	Speed	Freq	Speed	Freq	Speed
7	14.23	564.15	14.2	604.82	14.17	631.9

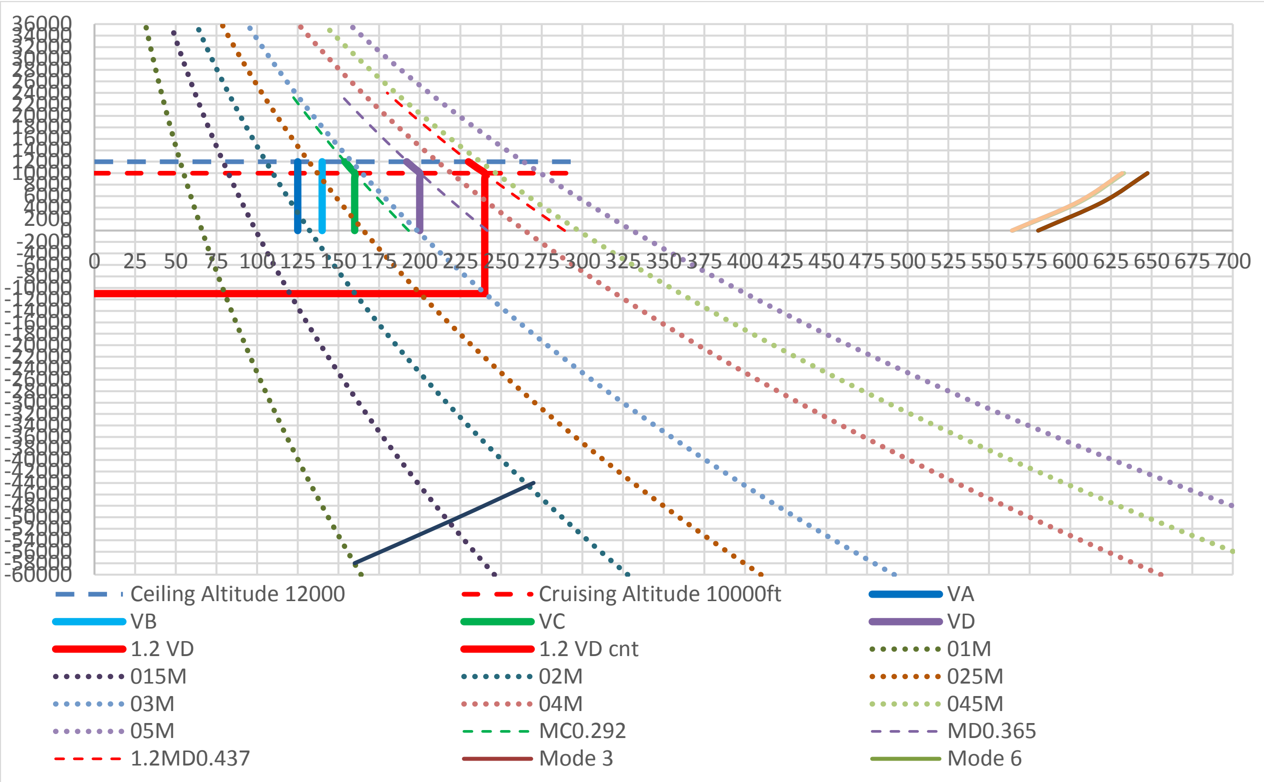


(a)



(b)

The flutter velocity and flutter mach number for this variation can be shown in Table 2. The result shows that the wing flutter is sensitive to altitude. For this reason, the calculation is performed also for a negatitive altitude where h_{neg} = -58000 ft. This negative altitude is derived analytically in [14] for transport aircraft and military UAV (Unmanned Air Vehicle) [15] as the result of all combinations of altitudes and speeds encompassed by the V_{dive} or M_{dive} versus altitude envelope enlarged at all points by an increase of 15 percent in equivalent airspeed at both constant Mach number and constant altitude.



7. Conclusion

In accordance with CASR Part 23 regulations, that passenger aircraft must meet these regulations. The flutter analysis results occur in the envelope area (safe flight condition). There are normal modes that give effect flutter speed. That is occurred when 165 m/s, while flutter in altitude far below the sea level (-58000 ft).So with the existing parameters, the aircraft is estimated to be safe in this conditions. So, for estimating critical flutter will be occur on minimum fuel, mach number 0.1 and altitude 0 ft.

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