Flutter velocity

Science

FLUTTER VELO Flutter is a dynamic instability of an elastic body (wing or fin) in an airstream and like divergence the only forces necessary to produce flutter are those due to the deflection of an elastic structure from its initially un-deformed state.

2. The flutter velocity or critical speed UF and frequency 'F are defined respectively as the lowest airspeed and corresponding circular frequency at which an elastic body flying at a given atmospheric pressure and temperature will exhibit sustained harmonic oscillation.

3. When there is no flow and the rocket's fin is disturbed, say, by a poke with a rod, oscillation or vibration occurs, which is damped (reduction of amplitude caused by structural resistance) gradually over successive vibration cycles.

4. When the speed of flow is gradually increased, the rate of damping of the oscillation of the disturbed fin increases at first.

5. With further increase in rocket velocity, however, a point is reached at which the damping rapidly decreases.

6. At the critical flutter velocity, an oscillation can just maintain itself with steady amplitude.

7. At speeds above this critical condition (UF), any small accidental disturbance of the fin from a gust of wind can serve as a trigger to initiate an oscillation of great violence that will rip the fin right off the rocket causing an unstable flight condition.

8. Rocket fins should be designed so the flutter velocity is never exceeded.

9. Please note that no flutter velocity exists for center of gravity positions (Xcg) forward of the elastic axis (Xea) of the fin/wing.

10. Please note the two equations presented here are an approximation

based on steady flow flutter assumptions and are only valid for ''/'h > 1 and mass ratio (') < 10. Where, ''/'h is the ratio of the natural torsion frequency to the natural bending frequency.

11. For a more precise analyses of the critical flutter velocity use either the Theodorsen method or U-g method.

Where,

U = Flutter velocity

'' = Uncoupled torsion frequency

b = Average fin half-chord

m = Fin mass

S = Fin surface area

r' = Fin radius of gyration, e = Xea - Xac

'CL/'' = Fin lift slope = CL' (2'' for 2-D fins), x' = Xcg - Xea.

Note: This equation is an approximation for subsonic flutter velocity.

TORSION-FLEXURE (2-D) UNSTEADY FLUTTER ANALYSIS

The discussion in the previous section of the Pines' flutter velocity approximation (used on the main screen) is based on quasi-steady aerodynamic assumptions. Therefore, as stated in An Introduction to the Theory of Elasticity, the Pines' approximation is practical for determining flutter velocity of low speed aircraft and model rockets. However, high speed aircraft and model rockets require the linearized aerodynamic theory represented by Theodoren's function, F(k) + i G(k) and implemented on the new Torsion-Flexure (2-D) Unsteady Flutter analysis screen in FinSim 4. Simply stated, the aerodynamic forces of the linearized theory are coupled with the assumption of a two-dimensional standard airfoil, that is an airfoil having two degrees of freedom: a bending or flexure degree of freedom, h measured around the elastic axis and a pitching or torsion degree of freedom, ' measured around the elastic axis of the airfoil.

INPUT VARIABLES FOR TORSION-FLEXURE (2-D) UNSTEADY FLUTTER

g = Structural damping coefficient, usually having a value between 0. 005 and 0. 05 for metalic structures

' = mass ratio = m/(' ' b2) = (4/') ('m/'air) (t/c) = Ratio of the mass of the wing to the mass of a cylinder of air of a diameter equal to the chord of the wing.

ah = Axis of rotation (elastic axis) location from the wing/fin center-chord = 2 Xea - 1

x' = C. G. location aft of the axis of rotation (ah) location = (2 Xcg - 1) - ah

r' = Radius of gyration about the elastic axis = SQR[I''/ (m b2)]

'' = Natural angular frequency of torsional vibration around 'a' in vacuum (rad/sec)

'h = Natural angular frequency of wing in flexure (bending) in vacuum (rad/sec)

b = Half chord, used as a reference unit length (inches)

Where:

Xcg = Center of gravity location measured from the airfoil leading edge divided by the chord length (c).

Xea = Elastic axis location measured from the airfoil leading edge divided by the chord length (c).

and r' (radius of gyration) is made non-dimensional by dividing by b (half chord), c = chord length and t = thickness.

k = '' b / U = Reduced frequency or Strouhal number represents the ratio of the characteristic length of the body (b) to the wave length of the disturbance. Where U is the mean speed of the flow and '''is the fundamental frequency of the wing in torsional oscillation in still air (rad/sec).