Proceedings International Conference on Mathematical Problems in Aerospace, Engineering and Sciences
Sao Jose dos Campos - SP, Brazil, June 30 – July 3, 2010.

THE INFLUENCE OF STARTING TRANSIENTS, AERODYNAMIC DEFINITION AND BOUNDARY CONDITIONS ON ELASTIC AND VISCOELASTIC PANEL AND WING FLUTTER

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ABSTRACT: In past and present elastic and viscoelastic analyses, the starting transient contributions of the deformations remain unresolved. Their important influence is due to the inherent memory and energy dissipation associated viscoelastic material behavior. While mathematically acceptable, physically simple harmonic motion (SHM), or any other function, cannot suddenly appear in its pristine state at the proverbial $t = 0$, nor can the flight velocity instantaneously reach a finite value. The SHM is achieved in the deflection solution $w(\widetilde{x}, t) \sim \exp(\widetilde{d} + \imath\,\omega)$ when the flutter velocities and frequencies reach eigenvalues at $\widetilde{d} = 0$.

The SHM deflections must be preceded by a build-up during a preferably short time interval $0 \leq t \leq t_1$ where $t_1 < t_0$, $\widehat{d} < 0$ and $V < V_f$. The time t_0 is the time when the modulus $E(t_0)$ begins to relax. Thus the buildup and possible short time resultant transient responses are contained in the elastic portion of the relaxation modulus curve at $0 \leq t \leq t_0$ (see Fig. 1a) and no additional memory effects will be imposed on the SHM portion, provided any transient responses die out before t_0 is reached. The ICs then become

$$w(\widehat{x}, 0) \;=\; \frac{\partial w(\widehat{x}, 0)}{\partial t} \;=\; \frac{\partial w(\widehat{x}, t_1)}{\partial t} \;=\; 0 \quad \text{and} \quad w(\widehat{x}, t_1) \;=\; w^{SHM}_{max}(\widehat{x}) \tag{1}$$

where $w^{SHM}_{max}(\widehat{x})$ is the largest SHM deflection (see Fig. 1b). In essence, it is the aerodynamic pressure (lift) that experiences the buildup or startup due to a velocity buildup from 0 to V_f or from a cruising velocity to a larger V_f. The velocity then can be characterized by

$$V(t) \;=\; \begin{cases} F(t) \;=\; \underbrace{\dfrac{V_f}{2}\left[1 - \cos\dfrac{\pi\,t}{t_1}\right]}_{\text{a sample function}} & 0 \leq t \leq t \leq t_1 \quad \text{buildup phase} \\[2ex] V_f\,H(t - t_1) & t \geq t_1 \qquad \text{steady state condition} \end{cases} \tag{2}$$

with

$$F(0) \;=\; \frac{\partial F(0)}{\partial t} \;=\; \frac{\partial F(t_1)}{\partial t} \;=\; 0 \quad \text{and} \quad V(t_1) \;=\; V_f \tag{3}$$

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where $t = 0$ represents the relative time when the velocity change is initiated.

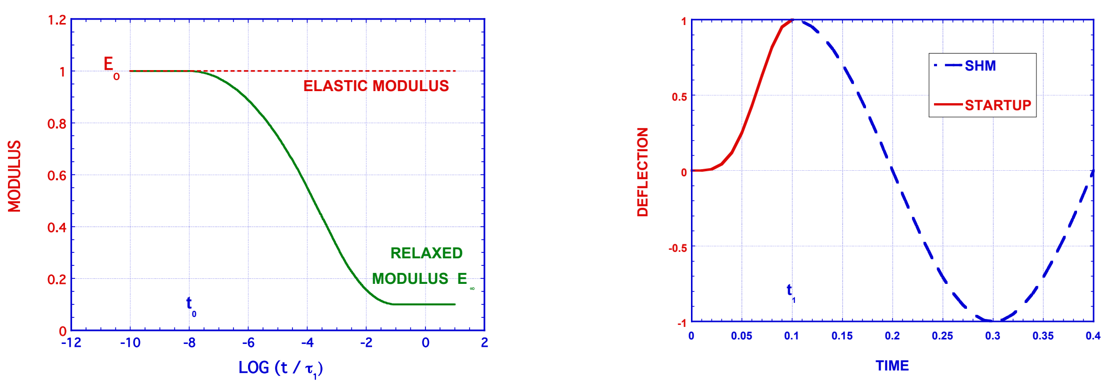
This approach consis of specifying the velocity growth function that will satisfy the ICs of Eq. (1) but may produce transient start up oscillations in $w(\widehat{x}, t)$ prior to $t = t_1$. Alternately, one may impose a smooth non-oscillatory deformation function for $w(\widehat{x}, t)$ prior to t_1, determine the necessary aerodynamic plate pressure history and spatial distribution and calculate the needed velocity time function. This second approach is physically considerably more difficult to execute since it is relatively easy to control the velocity time function in flight. While this is a well defined problem and eliminates transient oscillations, it represents a physically unrealistic approach since the aerodynamic pressure is determined by the airfoil and wing characteristics and is not subject to prescriptions designed to eliminate transient oscillations.

A typical elastic flutter frequency has a high end value of some 50 Hz. If the startup time t_1 is say 0.01 secs[3] and the beginning relaxation time t_0 is 0.1 secs, then the initial elastic SHM may undergo some 5 cycles or less. Generally in that short time frame the deflections would not develop large destructive w amplitudes even if $\widehat{d}$ were slightly positive, since high flutter frequencies would be required. After $t > t_0$ the viscoelastic effects take over and the flutter velocity V_f will adjust itself accordingly to acquire a value distinct from the elastic V_f^E, such that $V_f \gtreqless V_f^E$.

Preliminary results indicate that the inclusion of starting transients in the flutter analyses produces significant alterations in the flutter eigenvalues.

ACKNOWLEDGEMENT: Support by grants from from the Natural Sciences and Engineering Research Council of Canada (NSERC) and the Private Sector of Program Division of the National Center for Supercomputing Applications (NCSA) at the University of Illinois at Urbana-Champaign (UIUC) are gratefully acknowledged. The authors also acknowledge with thanks and appreciation the most useful and incisive comments furnished to them by Professor Earl H. Dowell of Duke University.

[1] Craig G. Merrett and Harry H. Hilton (2010) "Flutter of elastic and viscoelastic panels in incompressible, subsonic and supersonic flows," *Proceedings Tenth International Conference on Recent Advances in Structural Dynamics, Paper No. 007*, Southampton, UK.



(a) Elastic and Viscoelatic Moduli

(b) Startup and SHM with $\boldsymbol{t_1 = .1}$

Figure 1: Relaxation and Startup Times

[3]This implies that in such short time intervals, the elastic terms predominate over the viscoelastic ones.