with increasing panel length to width ratio The occurrence of single degree of freedom flutter, its experimental definition and theoretical prediction, remains one of the important problems in panel flutter A detailed discussion is not possible here, but the reader is referred to Refs 8–11 for the literature on the subject

References

[1] Hedgepeth, J M , "Flutter of rectangular simply supported panels at high supersonic speeds," J Aeronaut Sci **24,** 563–573 (1957)

[2] Voss, H M , "The effect of an external supersonic flow on the vibration characteristics of thin cylindrical shells," J Aerospace Sci **28,** 945–956, 961 (1961)

[3] Eisley, J G and Luessen, G , "The flutter of thin plates under combined shear and normal edge forces including the effects of varying sweepback," AIAA J **1,** 620–627 (1963)

[4] Kordes, E E and Noll, R B , "Theoretical flutter analysis of flat rectangular panels in uniform coplanar flow with arbitrary direction," NASA TN-1156 (January 1962)

[5] Voss, H M , "The effect of some practical complications on the flutter of rectangular panels," AIA Symposium on Structural Dynamics of High Speed Flight (April 1961)

[6] Movchan, A A , "On vibrations of a plate moving in a gas," Prikl Mat Mek **20,** 2 (1961)

[7] Houbolt, J C , "A study of several aerothermoelastic problems of aircraft structures," Doctoral Thesis, Eidgenössischen Technischen Hochschule, Zurich (1958)

[8] Lock, M H and Fung, Y C , "Comparative experimental and theoretical studies on the flutter of flat panels in a low supersonic flow," Air Force Office Sci Res TN 670 (May 1961)

[9] Cunningham, H J , "Analysis of the flutter of flat rectangular panels on the basis of exact three dimensional linearized supersonic potential flow," IAS Paper 63-22 (January 21–23 1963)

[10] McClure, J D , "On perturbed boundary layer flows," Mass Inst Tech Fluid Dynamics Res Lab Rept 62 2 (June 1962)

[11] Dowell, E H and Voss, H M , "Experimental and theoretical panel flutter studies in the Mach number range 1 0 to 5 0" (rept confidential, title unclassified), Aeronaut Systems Div ASD-TDR-63-449 (June 1963)

Optical-Acoustic Effects in Solid Films

Arthur V Houghton*
University of New Mexico, Albuquerque, N Mex

AND

Russell U Acton†
Sandia Corporation, Albuquerque, N Mex

Acoustics effects of light radiation on solid film are noted, and a measurement method is described Acetylene soot, camphor soot, flat black paper, glass, white paper, aluminum, and blackbody cavities were investigated Proposed uses are noted

OPTICAL-ACOUSTIC effects were noted in gases in 1881 Recently, several Soviet investigators were concerned with different spectral regions and measurement methods in gases [2–6] In some of our studies on diffusivity, similar optical-acoustic effects have been found in solid films In the system used in this investigation (Fig 1) the specimens were irradiated with a xenon gas phototube which puts out 1 megalumen for 1 msec The acoustic pickup was a microphone with a flat response from 60 to 13,000 cps

Received September 24, 1963
* Associate Professor of Mechanical Engineering
† Staff Member

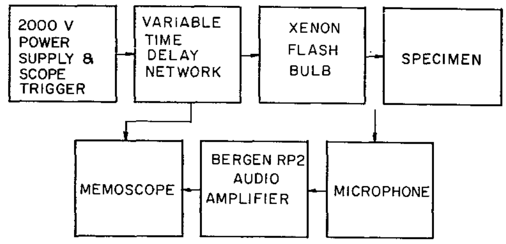

Fig 1 Flash and audio system

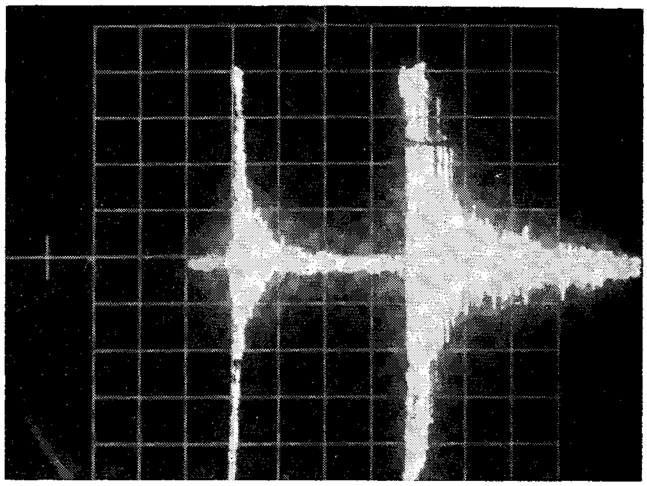

Fig 2 Photograph of scope trace

Very sharp audible pulses were noted from acetylene soot covering on both electrical conductors and nonconductors Less sharp reports were obtained from camphor soot and a very small noise from the flat black paper White paper and various transparent plastics gave no report at all The report given off by the black materials apparently is due to air motion following energy absorption

In the use of uncoated aluminum sheet, no effect was noted for plates over 1 cm in thickness Very thin aluminum sheets gave out a high pitched tone when irradiated This effect appears to be due to light radiation pressure Figure 2 shows the scope trace for acetylene soot The left-hand pulse is relay noise obtained by closing the relay when the speciemen is not irradiated, and the right-hand grouping is due to the combination of this same relay and the audible report due to energy absorption This is a second sweep obtained when the horizontal sweep is moved and the specimen is irradiated The sweep speed was 20 msec per division, and the vertical scale was 1 v per division Reversing the acetylene coated glass so that the uncoated side is to the light stops the noise, thus indicating that the effect is beyond 2 7 μ because the glass is not transparent beyond that point

In this case, the light pressure or the formation of gas between the glass and the coating was sufficient to blow the coating off of the glass Measurements from force transducers behind the specimen were inconclusive since several types of transducers appeared to be sensitive to the electrical transients in the circuit Measurements of blackbody cavities gave results similar to the acetylene soot

It is proposed that the order of magnitude of thermal absorptivity of nearly black specimens may be evaluated by a comparison of the magnitude of the acoustic energy released upon irradiation with the flash bulb Extensive study would appear to be required if high accuracy were to be obtained

References

[1] Tyndall, J , "Action of an intermittent beam of radiant heat upon gaseous matter," Nature **23,** 374–377 (1881)

[2] Gerlovin, Ya I , "Optico acoustic effects in the ultra violet region of the spectrum," Optics Spectroscopy **8,** 352 (1959)

[3] Bresler, P I and Ruzin, B N, 'Optical acoustic effect in mercury vapor,' Optics Spectroscopy **8**, 387 (1960)
[4] Veingerov, M L and Sivkov, A A, A single beam optical-acoustic gas analyzer,' Optics Spectroscopy **8**, 388 (1960)
[5] Bresler, P I and Ruzin B N, 'An optico acoustic phenomenon in the visual and ultra violet spectral regions and its relations to photoelectrical processes in gases, Optics Spectroscopy **9**, 11–13 (1960)
[6] Pankratov, N A, Non selective optico acoustic radiation detractors with electrodynamic microphone,' Optics Spectroscopy **11**, 366–367 (1961)

Turbulent Wake Characteristics with Different Eddy Viscosity Coefficients

Koon Sang Wan*
General Electric Company, Philadelphia, Pa

In the studies of turbulent hypersonic wakes, the viscosity coefficient for laminar wake is generally replaced by an eddy viscosity coefficient The forms of the eddy viscosity coefficient assumed in various theories[1–5] may be classified into three general types They are

$$\mu_{\epsilon_1} = K_1\delta(\rho_e u_e - \rho u) \tag{1}$$

$$\mu_{\epsilon_2} = K_2\delta\rho (u - u) \tag{2}$$

$$\mu_{\epsilon_3} = K_3\delta\rho (u - u) \tag{3}$$

where the K's are constants to be assumed All these three forms of the eddy viscosity coefficients reduce to the same expression generally used in the incompressible turbulent free-mixing problem, i e, $K_i\rho_i\delta_i(u_i - u_i)$

This note gives and compares some numerical results of the equilibrium turbulent-wake characteristics obtained by using these three different forms of the eddy viscosity coefficients with the governing equations, method of calculations, and initial and boundary conditions being the same for all three cases

To simplify the analysis, the usual wake equations of the boundary-layer type approximation are further reduced by assuming the Lewis number and the Prandtl number equal to one, and the axial pressure gradient as negligible The governing equations are, then, in axisymmetric coordinates

$$\frac{\partial(\rho u)}{\partial x} + \frac{1}{r}\frac{\partial(\rho v r)}{\partial r} = 0 \tag{4}$$

$$\rho u \frac{\partial u}{\partial x} + \rho v \frac{\partial u}{\partial r} = \frac{1}{r}\frac{\partial}{\partial r}\left(r\mu_\epsilon \frac{\partial u}{\partial r}\right) \tag{5}$$

$$\rho u \frac{\partial h}{\partial x} + \rho v \frac{\partial h}{\partial r} = \mu_\epsilon \left(\frac{\partial u}{\partial r}\right)^2 + \frac{1}{r}\frac{\partial}{\partial r}\left(r\mu_\epsilon \frac{\partial h}{\partial r}\right) \tag{5a}$$

It is well known that the following relation holds in this case, i e,

$$h + (u^2/2) = A + Bu \tag{6}$$

where A and B are constants If the initial condition also satisfies (6), then this relation between the enthalpy and the velocity is valid for the whole viscous flow regime It remains now to solve Eq (5)

To do this, the integral method is employed The integration of Eq (5) from $r = 0$ to $r = \delta$ gives

$$\frac{d}{dx}\left[\rho u^2\delta^2 \int_0^1 \frac{\rho u}{\rho u}\left(\frac{u}{u} - 1\right)\frac{r}{\delta}\, d\left(\frac{r}{\delta}\right)\right] = 0 \tag{7}$$

Received September 24, 1963

* Research Engineer, Space Sciences Laboratory, Missile and Space Division Member AIAA

where Eq (4) and assumption $du/dx \cong 0$ have been used, and the boundary conditions $\partial u/\partial r = 0$ at $r = 0$ and $r = \delta$ have been enforced Equation (7) can then be rewritten as

$$\rho u^2\delta^2\theta = \text{const} \tag{7a}$$

where

$$\theta = \int_0^1 \frac{\rho u}{\rho u}\left(\frac{u}{u} - 1\right)\frac{r}{\delta}\, d\left(\frac{r}{\delta}\right) = \int_0^1 \frac{\rho u}{\rho u}\left(\frac{u}{u_e} - 1\right)\eta d\eta$$

The momentum balance along the axis gives another condition as

$$\left[\rho u\left(\frac{\partial u}{\partial x}\right)\right]_{=0} = \left(2\mu_\epsilon \frac{\partial^2 u}{\partial r^2}\right)_{=0}$$

It can be shown that this is equivalent (see Ref 6), in nondimensional form, to

$$\left(\bar\rho\bar u \frac{\partial \bar\rho\bar u}{\partial \bar x}\right)_{\eta=0} = \left(\frac{\mu_e}{\rho u \delta_0}\frac{2\bar\mu_\epsilon}{\bar\delta^2}\frac{\partial^2\bar\rho\bar u}{\partial\eta^2}\right)_{\eta=0} \tag{8}$$

where $\bar\rho = \rho/\rho$, $\bar u = u/u$, $\bar\mu_\epsilon = \mu_\epsilon/\mu$, $\bar x = x/\delta_0$, $\bar\delta = \delta/\delta_0$ and δ_0 is the initial viscous wake radius

Now, the following profile for $\bar\rho\bar u$ is assumed,

$$\bar\rho\bar u = F(\eta) + a[1 - F(\eta)] \tag{9}$$

where $F(\eta)$ is the given initial profile for $\bar\rho\bar u$ at $x = 0$ Substituting (9) into (8) results in

$$\frac{da}{d\bar x} = \frac{\mu_e}{\rho u \delta_0}\frac{2\bar\mu_\epsilon}{\bar\delta^2}\frac{F_0''(1 - a)}{(1 - F_0)[F_0 + a(1 - F_0)]} \tag{10}$$

where $F_0 = F(0)$ and $F_0'' = (\partial^2F/\partial\eta^2)_{\eta=0}$ The solution of Eqs (10) and (7a) yields $\bar\delta$ and a as functions of $\bar x$ and hence the distribution of $\bar\rho\bar u$ With the thermodynamic relation $\rho = f_1(h,p)$ or $h = f_2(p,\rho)$ and relation (6), $\bar h$ and $\bar u$ can be calculated The wake characteristics in the whole field can then be obtained

To study the effect of the different eddy viscosity coefficients given in (1–3) on the wake characteristics, it remains to substitute these coefficients into (10) in turn, and obtain the solution for the individual case using the same initial and boundary conditions

This has been applied to the case of a slender cone at altitude = 150,000 ft and M_∞ = 19 52 The external inviscid flow conditions were assumed uniform The initial flow profiles used in the calculations are shown in Fig 1 It is noted that the peak enthalpy is located off the axis for the initial profiles so assumed The results of the variations of the centerline enthalpy $\bar h$ with $2K\bar x$ for the three cases are shown in Fig 2, and those of the centerline velocity $\bar u$ and the eddy viscosity coefficient $\bar\mu_\epsilon'$ in Fig 3

From Fig 2, it is seen that the distance which the off-axis peak enthalpy takes to reach the axis differs significantly

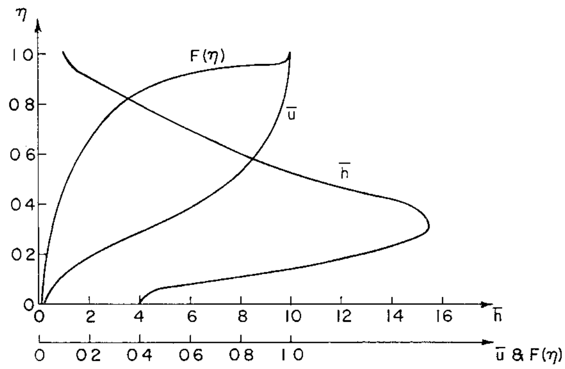

Fig 1 The initial profiles; slender cone, altitude = 150,000 ft, M_∞ = 19 52