flowfield while Rusanov's method shows considerable difference in density and temperature in the shock layer. This may be a result of allowing the viscosity to vary.

The addition of heat-transfer terms to the flow equations had little effect on their convergence at $M = 10$; however, at $M = 30$, only the modified Lax method converged even after α was corrected as described in the section on radiation.

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Influence of Splitter Plate on Galloping Response of an Angle Section

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Nomenclature

a_1 = coefficient of polynomial curve fit, coefficient 'A' in Ref. 4
h = maximum width of the angle model
k_y = plunging stiffness of the system
ℓ = length of the model
m = mass of the oscillating system
η_y = dimensionless mass parameter, ρh^2 $(2m)$
r_y = viscous damping coefficient in plunging
t = real time
x, y = downstream and transverse co-ordinates, respectively
$\bar{y}$ = amplitude of lateral displacement
U_{0y} = dimensionless critical velocity, $2\beta_y/\eta_y a_1$
$\bar{Y}$ = dimensionless amplitude of the plunging motion
$\bar{Y}^*$ = $\bar{Y}/U_{0y}$
$\bar{Y}_0$ = dimensionless initial amplitude of lateral motion
$\bar{Y}_0^*$ = $\bar{Y}_0/U_0{}^y$
α_0 = mean angle of attack of oscillating system
β_y = dimensionless damping parameter for plunging system, $r_y/2m\omega_{ny}$
ρ = density of fluid
τ = dimensionless time for oscillating system, ω_{nyt}
τ^* = reduced dimensionless times for oscillating system, $\beta_y \tau$
ω_{ny} = natural circular frequency in plunging, $(k_y/m)^{1/2}$

Introduction

The vortex excited oscillations of aerodynamically bluff bodies, when exposed to a fluid stream, have been a subject of considerable study. To engineers, the prevention of aeroelastic vibrations of smoke stacks, transmission lines, suspension bridges, buildings, etc., is of particular interest. Angle section members used in open engineering structures, have been known to experience large amplitude oscillations when exposed to normal atmospheric winds, and in a few instances failure has been reported. The bluff geometry together with low natural frequency make these members susceptible to aeroelastic vibrations of vortex resonant or galloping nature. The character of the aerodynamic forces and the resulting instabilities have been discussed by the authors in the two recent papers.[1,2]

Often, as is the case with a structural angle beam, the instability at a given fluid stream velocity and angle of attack may be the combined effect of both vortex resonance and galloping. To permit the study of the individual forms of excitation, a judicious choice of either damping, angle section size or natural frequency is required to separate the two phenomena. At certain orientations of the angle section, it appeared that the vortex formation had some influence on the starting wind velocity, displacement amplitude and build-up time of the galloping instability. The present study explores the role of vortex formation during the galloping instability by isolating the former through the use of a splitter plate.

Experimental Set-Up and Discussion

Shown in Fig. 1 is a cross section of the angle model oriented at the angle of attack (α_0) of 45°, and the location of the splitter plate in the wake. Flow lines indicate typical instantaneous positions of the separated shear layers and the formation of shedded vortices if the splitter plate were absent. As reported by Arie and Rouse,[3] the formation of alternating vortices in the wake of a 3-in. flat plate located transverse to the freestream could be suppressed using a splitter plate 30 in. deep. Therefore, during the experimental tests with the 1-in. angle section, a 10-in. splitter plate was mounted at the downstream edge of the model causing the flow to reattach on the plate after initial separation at the corners of the model.

The experimental program was conducted in a low-speed, low-turbulence, return-type wind tunnel with a test section of $36 \times 27 \times 96$ in. A schematic of the model support system is shown in Fig. 2. The $1 \times 1 \times \frac{1}{4}$ in. angle section was mounted vertically on a system of journal bearings located on a frame encircling the tunnel test section. This gave the model a plunging degree of freedom lateral to the flow direction with structural and mean aerodynamic conditions essentially two-dimensional. Variable stiffness and damping were introduced through coil springs and electromagnetic eddy current dampers, respectively. The plunging displacement of the model was monitored using a variable inductance type of transducer.

A comparison of the representative gallping data, with and without the splitter plate, are summarized in Fig. 3 for the angle section at $\alpha_0 = 45°$. The results are expressed in terms of the non-dimensional displacement amplitude and build-up time vs the velocity parameter. Theoretical curves derived from a quasi-steady analysis[4] have been included to substantiate the validity of such an approach.

The results in absence of the splitter plate indicate that the influence of the vortex formation is to partially reduce the displacement amplitude and increase the time for build-up from rest at least over the initial velocity range conducive to galloping.

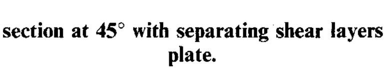

Fig 1 Angle section at 45° with separating shear layers and a splitter plate.

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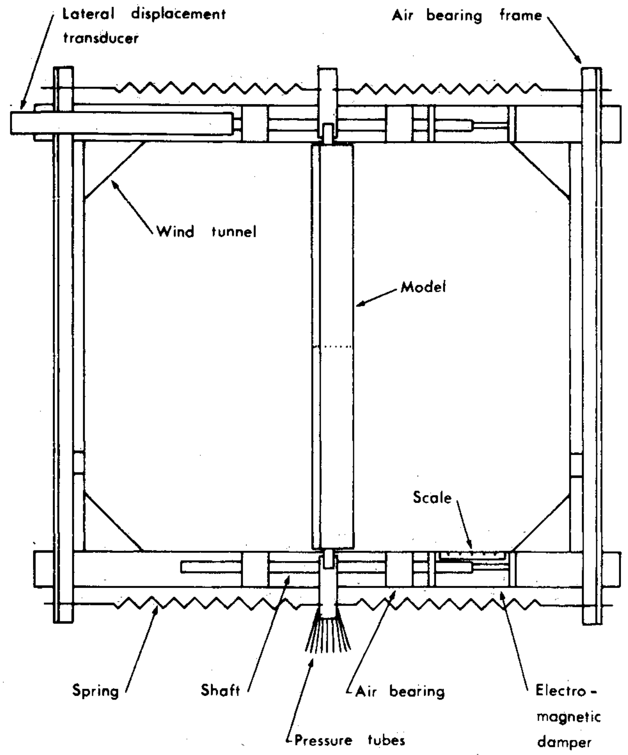

Fig. 2 Details of model support system permitting plunging degree of freedom.

For higher wind speeds, say $U^* > 4$, the frequency of vortex shedding has becomes sufficiently well separated from the cylinder frequency so as to have no influence on the galloping instability.

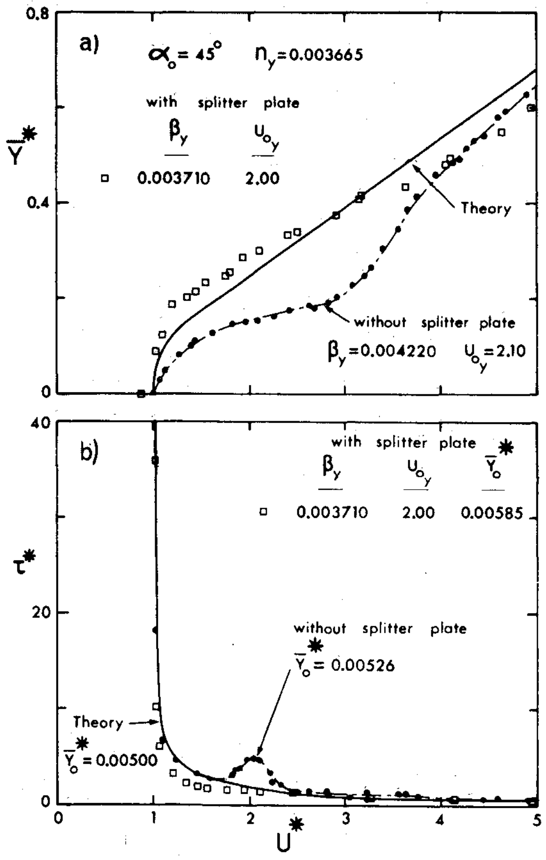

Fig. 3 Dimensionless plots of galloping amplitude and build-up time vs velocity showing the effect of vortex suppression through the use of a splitter plate.

The lower amplitude motion exhibited by the angle section for $U^* < 4$ in absence of the splitter plate may represent partial asynchronous quenching[5] of the galloping oscillations by the vortex induced fluctuating forces. Parkinson and Santosham[6] have extended the quasi-steady galloping theory to include the effects of the wake vortices and predicted asynchronous quenching for a square section in water.

It should be mentioned that the change in slope of the asymptote for the oscillating angle section with the splitter plate is not too significant because only small amplitude measurements can be obtained with the plate held stationary. Large relative motions between model and plate would create a different flowfield and consequently a variation in the resulting aerodynamic forces.

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Shock Wave Shaping

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Introduction

RECENT work[1,2] has brought attention to the shaping of strong shock waves by suitable wall shaping. The motivation for this is primarily the use of area changes in a duct to produce stronger shocks, and hence high enthalpy gas which may then be expanded in the nozzle of a short duration hypersonic tunnel. The above two references describe attempts to generate a shaped collapsing wave front to achieve this purpose. Both methods use Whitham's approximate theory[3] for strong shocks to establish the wall profile. In the first case the characteristic wave is centred and in the second the wall shape is arranged to result in a cylindrical wave. In neither case is a comparison made between the experimental and theoretical shock profiles. This Note describes some work which uses similar methods but, since weaker shocks are involved, employs the more general solution to Whitham's theory.

Theoretical Considerations

Whitham's theory for determining shock profiles employs the method of characteristics and ignores any effect of the flowfield behind the shock on the shock itself. It assumes that the shock propagates along ray-tubes within which there is a differential relationship between the shock Mach number and ray-tube area.

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