Conclusion

This form of solution has also been evaluated for five and seven stringer panels and, here again, the comparison with finite element solutions is good. Thus, by allowing the skin in a stiffened panel to carry some of its direct stress capacity, a more accurate distribution of the internal stress system can be obtained. For the panel tested, the shear stress distribution gives a value of stress in the skin, adjacent to the load application point, which is 120% greater than that predicted by the simple lumping Scheme 3. Since the analysis technique used herein gives a better approximation to the internal stress system in the panel, failure of the panel by shear buckling can now be more accurately predicted.

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Technical Comments

Comment on "Wind Effects on Electrostatic Autopilots"

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SULLIVAN[1] recently described some wind-tunnel experiments designed to simulate the current generated by ionizers used in Electric Field Stabilizers. As originally demonstrated by Hill,[2] the vertical fair-weather atmospheric electric field can be used as a reference for aircraft stabilization. The experiments described by Sullivan measure the output currents generated by two radioactive sources placed at the ends of a mounting board and placed in a wind tunnel so that the ends of the board could be rotated in a plane perpendicular to the air flow. An electric field across the tunnel simulated the earth's vertical electric field. The output current was then measured as a function of wind velocity and angle of orientation of the mounting board with respect to the direction of the electric field. The entire system simulates an aircraft with ionizers on the wing tip at various speeds and angles of bank. The experiment is a valid one and does demonstrate the dependence of the output current on velocity and angle of bank. However, we believe that the analysis given in the paper to describe the velocity dependence is based on an erroneous physical picture of the current generating mechanism. The basic difference between our understanding of the radioactive probe and the analysis given by Sullivan is as follows.

1) Sullivan's analysis implies that a major source of current originates downstream from the ionizer and that the ions flow back to the body along the field lines. Mathematically this is evidenced in both the expression for the "ionized pair density," ρ, which is calculated for the region downstream where the ionization rate q is zero and also in the limits of integration of Eq. (10) in Sullivan's paper. We maintain that the current originates primarily by the action of the electric field on the highly ionized region just above the ionizing probe. Ionic velocities resulting from the mobility of an ion in the atmospheric electric field are less than a few meters per second thus preventing the return of ions to the aircraft for speeds above a few meters per second. Furthermore, the radioactive sources on aircraft are insulated so that only current which originates at the ionizer flows through the amplifier.

2) The velocity dependence in Sullivan's analysis, Eq. (11), arises from the decay of ion densities downstream by recombination. We propose that the ion density downstream of the probe is irrelevant and that the velocity dependence arises from the removal of the "shielding charge" which develops at the outer boundary of the region of high ionization. If the velocity is very low, one polarity of ion will be drawn out of the highly ionized layer and the other polarity ion will be repelled to the probe. This results in a very low field in the highly ionized region with a highly charged shielding layer existing at the outer

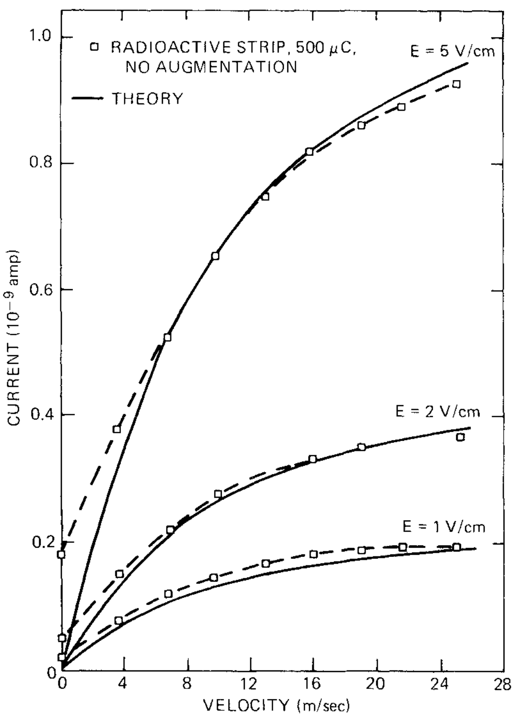

Fig. 1 Current as a function of velocity for electric field values of 1, 2, and 5 v per cm. Solid lines are calculated from Eq. (1).

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boundary of the high conducting layer. As the velocity increases this charged layer is partly removed by the wind so that the electric field can penetrate the highly ionized region and increase the effectiveness of charge separation. The charge in the shielding layer is carried away by the wind and an equal and opposite charge is carried to the ionizer by the action of the field on ions in the ionized layer.

An analysis for the physical model just described which calculates the current generated by the removal of the shielding layer charge as a function of wind velocity and externally imposed field has been worked out (Hill and Hoppel[3]) and will be presented at the Fifth International Conference on Atmospheric Electricity as part of a paper[4] on radioactive collectors. Here we cite only the equation for the current per unit width without derivation.

$$\frac{i}{w} = \epsilon \frac{\Delta\lambda}{\lambda(z_o)} V_x E \left[\exp\left(-\frac{\lambda(z_o)x}{\epsilon V_x}\right) - 1 \right]$$

where

$$E = E(\infty) \exp\left\{ 0.34 \frac{\Delta\lambda}{\lambda(z_o)} \left[\exp\left(-\frac{\lambda(z_o)x}{\epsilon V_x}\right) - 1 \right] \right\}$$

where

- V_x is the velocity aspirating the ionizer,
- $E(\infty)$ is the perpendicular component of the electric field far enough from the collector to be uninfluenced by the shielding charge,
- $\Delta\lambda$ is the change in conductivity across the boundary of the highly ionized layer and is determined from the ionization rate and recombination coefficient.
- $\lambda(z_o)$ is the conductivity at the boundary and here taken to be half of $\Delta\lambda$.
- x is the length of the ionizer.
- ϵ is the permittivity of free space.

Equation (1) has been verified experimentally as shown in Fig. 1 which compares currents generated by an ionizer in a wind tunnel as a function of velocity with those predicted by Eq. (1) for different values of electric field.

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Reply by Author to M. L. Hill and W. A. Hoppel

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I WOULD like to thank Messrs. Hill and Hoppel for their comments on my paper and also for providing me with a more detailed version of their theory which was of assistance in preparing this response.

In reply to the comment that the ionizers are insulated, I would like to state that, within the context of the model, the electric field pattern is as shown in my Fig. 4 until charge begins to flow. When this charge begins to build up on the insulated region between the ionizers, however, the electric field lines will then terminate on the ionizers only. Thus, the "number" of field lines serving as charge paths to the amplifier is essentially unchanged. I chose not to elaborate on this point in the interest of simplicity.

The first comment, however, concerning the ion mobilities is a valid one and does raise a serious objection to the model as proposed. I feel that their model presents a picture of this phenomenon which is much closer to reality.

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Comment on "A Criterion for Assessing Wind-Tunnel Wall Interference at Mach 1"

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GOODMAN[1] proposes a criterion for determining conditions for negligible wall interference in a sonic stream. The criterion that the tunnel similarity parameter G must be order one or greater for negligible interference is mathematically and physically unrealistic. The analysis contains several oversimplifications which are commented on here. Equation numbers and notation are those used in Goodman's Note.

Goodman's analysis adopts the transonic small disturbance equation for $M_\infty = 1$. The local linearization approximation is used to reduce the non-linear mixed elliptic-hyperbolic equation to a linear parabolic equation. This simplification results by assuming that the local flow acceleration $(\gamma + 1)\, U_X/U_\infty$ is a positive number λ throughout the flowfield. The flow problem is then likened to a one-dimensional heat conduction problem with the streamwise direction x becoming the time-like variable and the lateral direction z the space-like variable. The semi-infinite problem $0 \leq z \leq \infty$ corresponding to unbounded flow past an airfoil is considered. Body boundary conditions are applied at $z = 0$, and all disturbances are assumed to vanish at $z = \infty$.

The analysis is oversimplified in at least two respects. First, the assumption that the acceleration λ is positive throughout the flow field is erroneous. In fact λ may be positive, zero, or negative. The heat conduction problem as stated is ill-posed since the diffusity "constant" λ^{-1} changes sign. Thus, the relation following Eq. (4), $z \geq O\,(x/\lambda)^{1/2}$ which forms the basis for the criterion is impractical. Second, the wind-tunnel wall boundary condition is not considered in the analysis. The tunnel case corresponds to a heat conduction problem in a bounded domain $0 \leq z \leq H$ with appropriate conditions specified at both boundaries. As such, a solid wall would correspond to zero heat transfer ($\phi_z = 0$), a freejet to a constant temperature boundary (ϕ = constant), and ventilated walls to

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