Reply by Author to U. H. Kurzweg

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THE author wishes to thank Prof. Kurzweg for pointing out the work which he has done concerning the stability of inviscid heterogeneous swirling flows subjected to disturbances of arbitrary asymmetry.[1] His work was unknown to the author at the time of publication of Ref. 2 and his contribution to the literature should be acknowledged. However, a number of points should be discussed regarding the choice between a viscous and nonviscous model.

It is clear from observation of the rapid dissipation of the velocity profile given in Fig. 3 of Ref. 2 for the *stable* flow that viscous effects indeed play a major role in the transient flow structure, with a considerable amount of momentum exchange occurring during the first second after the flow has been established. This occurs in such a fashion as to reduce $d/dr(r^2)$ which is stabilizing. Under these circumstances one must conclude that viscous dissipation is an important factor in the characterization of the instability phenomenon. This motivated the use of Yih's criterion. However, the author did not claim that the dissipative effect of thermal diffusivity was a factor in the onset of the instability.

Kurzweg establishes his sufficiency condition for stability in Eq. (1) of Ref. 1. In using this sufficiency condition to interpret the instability, he assumes that the disturbance in the axial direction is single mode ($k = 0$). Otherwise the stabilizing contribution of $(k/m)^2 d/dr[\rho(r^2\Omega)^2]$ is unknown. Gas injection in the experiment reported in Ref. 2 was accomplished through a single orifice having a $\frac{1}{16}$-in.-diam. located at the midplane of a cylindrical vessel having a length and diameter equal to 6 in. As a result, it was not possible to ensure that the rotating flow was two-dimensional. Had the jet issued from a slit extending the length of the vessel, a very nearly two-dimensional flow would have resulted. Thus, there is no way of knowing whether the axial wave number, k, was equal to or greater than zero. It is not clear whether Kurzweg's sufficiency condition would be violated for cases other than the $k = 0$ case which he assumed.

Although both linear models of Refs. 1 and 3 can give a clue to the instability, neither can correctly interpret the phenomenon without considering the finite amplitude momentum exchange. As is evident in Fig. 2 of Ref. 2, the instability occurs in a violent manner. In order to be successful in analyzing the nature of its occurrence, one would have to use a viscous nonlinear model with nonaxisymmetric disturbances. A linear model may not correctly predict the onset of the instability in the presence of large amplitude disturbances such as those observed. The choice between the inviscid nonaxisymmetric sufficiency condition proposed by Kurzweg or the viscous symmetric sufficiency condition proposed by Yih[3] is mute, since both of these models neglect the nonlinearities which appear to occur in the observed instability. It was the author's intention to use Yih's criterion only to give a basic phenomenological interpretation of the instability.

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Index categories: Jets, Wakes, and Viscid-Inviscid Flow Interactions; Nonsteady Aerodynamics.

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References

[1] Kurzweg, U. H., "Comment on Stability of Rotating Stratified Fluids," *AIAA Journal*, Vol. 12, No. 3, March 1974, p. 415.

[2] Johnston, S. C., "Stability of Rotating Stratified Fluids," *AIAA Journal*, Vol. 10, No. 10, Oct. 1972, p. 1372.

[3] Yih, C. S., "Dual Role of Viscosity in the Instability of Revolving Fluids of Variable Density," *The Physics of Fluids*, Vol. 4, No. 7, July 1961, pp. 806–811.

Errata

Sonic Boom of Hypersonic Vehicles

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EQUATION (7) should read

$$\left(\frac{\Delta p}{p_0}\right)_s = 0.242\left(\frac{MC_D{}^{1/2}}{r_s/d}\right)^{1/2}\left[\left(\frac{r_s/d}{MC_D{}^{1/2}}\right)^{1/2} - 0.721\right]^{-1/2} \tag{7}$$

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Index category: Supersonic and Hypersonic Flow.