$$\frac{dF}{dU} = \begin{bmatrix} u & \rho & 0 & 0 \\ u^2 & 2\rho u & 0 & 1 \\ uv & \rho v & \rho u & 0 \\ \frac{u}{2}(u^2+v^2) & \frac{\gamma}{\gamma-1}p + \frac{\rho}{2}(3u^2+v^2) & \rho uv & \frac{\gamma}{\gamma-1}u \end{bmatrix}$$

$$\frac{d^2F_1}{dU^2} = \begin{bmatrix} 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad \frac{d^2F_2}{dU^2} = \begin{bmatrix} 0 & 2u & 0 & 0 \\ 2u & 2\rho & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad \frac{d^2F_3}{dU^2} = \begin{bmatrix} 0 & v & u & 0 \\ v & 0 & \rho & 0 \\ u & \rho & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$\frac{d^2F_4}{dU^2} = \begin{bmatrix} 0 & \left(u^2 + \frac{u^2+v^2}{2}\right) & uv & 0 \\ \left(u^2 + \frac{u^2+v^2}{2}\right) & 3\rho u & \rho v & \frac{\gamma}{\gamma-1} \\ uv & \rho v & 0 & 0 \\ 0 & \frac{\gamma}{\gamma-1} & 0 & 0 \end{bmatrix}$$

$$\frac{dS}{dU_p} = \begin{bmatrix} u(s-c_p) \\ \rho \\ 0 \\ \frac{\mathrm{M}_x c_p}{a} \end{bmatrix}^T \quad \frac{d^2S}{dU_p^2} = \begin{bmatrix} -\frac{uc_p}{\rho} & (s-c_p) & 0 & \frac{\mathrm{M}_x c_p}{\rho a} \\ (s-c_p) & 0 & 0 & \frac{c_p}{a^2} \\ 0 & 0 & 0 & 0 \\ \frac{\mathrm{M}_x c_p}{\rho a} & \frac{c_p}{a^{a}} & 0 & -\frac{\mathrm{M}_x c_p}{ap} \end{bmatrix}$$

DISCUSSION

L. H. Smith, Jr.[1]

The authors are to be congratulated for treating a very complex phenomenon in a comprehensible fashion and distinguishing the effects of the several sources of unsteadiness.

It seems to be implied, although not actually stated, that the mixing loss (entropy rise) from stator exit nonuniformities that is calculated at the interface plane is largely inevitable regardless of what the downstream rotor does to the flow. I have always thought that a rotor could partially flatten a stator vane viscous wake through a reversible energy exchange process, thereby avoiding some of the entropy rise that would occur if the wake were flattened entirely by mixing. In a recent article (Smith, 1993), it is pointed out that the propulsive efficiency of a self-propelled craft can be increased by placing the propulsor in the wake of the craft. It can be shown that the energy thereby saved is just equal to the reduction of wake mixing loss, the wake having been flattened by reversible energy addition rather than by viscous dissipation. This case can be related to the subject of the present paper by thinking of the propelled craft as a giant stator vane and the propulsor as an idealized rotor.

The amount of mixing loss that can be avoided in an actual turbine or compressor by this mechanism is probably not large, but it has been speculated that this may explain part of the gain in efficiency that is usually observed when the stages of a multistage compressor are spaced together more closely.

References

Smith, L. H., Jr., 1993, "Wake Ingestion Propulsion Benefit," *Journal of Propulsion and Power*, Vol. 9, No. 1, pp. 74–82.

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[1] GE Aircraft Engines, Cincinnati, OH 45215.