Technical Comments

Comments on the "Increase of Boundary-Layer Heat Transfer by Mass Injection"

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A RECENT Note by Gersten and Gross[1] states that an "anomalous behavior between heat transfer and surface mass transfer exists" for nearly adiabatic wall, laminar boundary layers. The relationship is interpreted as anomalous because contrary to "the general rule" in this region "surface injection increases heat transfer at the wall and suction decreases heat transfer." It is the purpose of this Comment to show that when a consistent definition of heat transfer is used and an adequate range of variables is examined using accurate solutions, then no anomalous relationship is found. The "extraordinary situation" referred to in Ref. 1 is a logical consequence of the regular behavior of solutions in this region.

The consistent and logical relationship between heat and mass is illustrated in Fig. 1, which summarizes a parametric study performed using the exact numerical solution of Ref. 2. Here $q_s = Cg_s'/Pr$ and f_o is the standard stream function at the surface. The particular flow considered was that with $E = u_e^2/2H_e = 0.5$, $Pr = 0.740$, and gas viscosity proportional to static enthalpy raised to the power of ω. For this situation the zero injection adiabatic wall enthalpy ratio $g_s = 0.927$ (Ref. 2). The predictable increase of q_s with suction and decrease with blowing is shown for a slightly cooled wall ($g_s = 0.92$) and a slightly heated wall ($g_s = 0.93$). The curve fit of Ref. 1 limits their consideration to a narrow region around $f_o = 0$ where no anomaly can be detected if a consistent sign convention is adhered to.

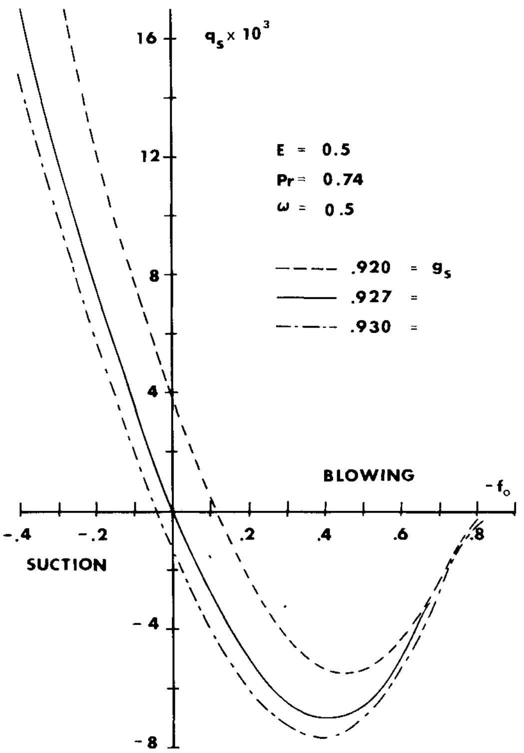

Fig. 1 Variation of heat transfer with mass transfer.

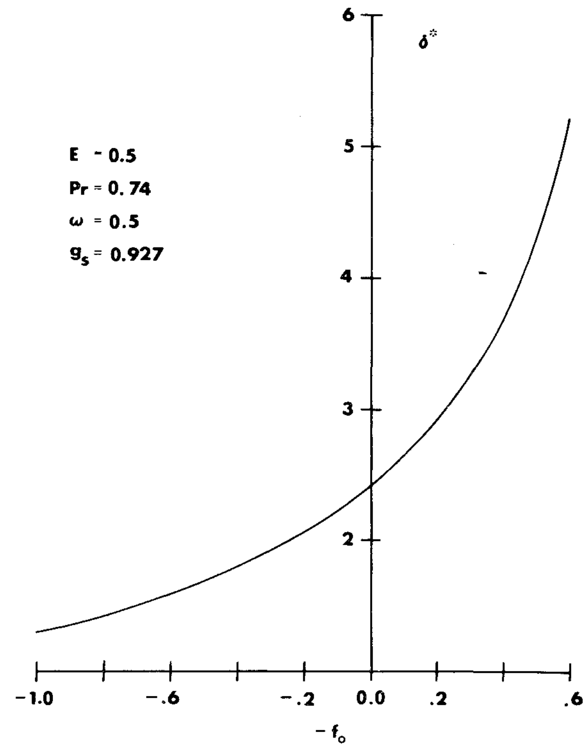

Fig. 2 Variation of the displacement thickness with mass transfer.

The observation made by Ref. 1 that the situation is reversed when their "universal point A" is reached corresponds to the minima in the curves of Fig. 1. These minima are displaced towards $f_o = 0$ as T_w is increased so that eventually, for high enough T_w, the minimum is located at $f_o = 0$ and point A of Ref. 1 is reached.

The observed phenomena are explained in Ref. 1 in terms of changes in boundary-layer thickness. However, Fig. 2 shows that near $f_o = 0$ the changes in displacement thickness δ^* are rather small. The changes in q_s for small f_o are due to the changes in T_{aw} with blowing.[3] Rapid thickening is observed for $(-f_o) \approx 0.4$ when the boundary layer begins to be blown off. Then the boundary-layer thickening effect dominates. This occurs for values of f_o well beyond the range of validity of the relation of Ref. 1.

References

[1] Gersten, K. and Gross, J. F., "Increase of Boundary-Layer Heat Transfer by Mass Injection," *AIAA Journal*, Vol. 11, No. 5, May 1973, pp. 738–739.

[2] Wortman, A., "Mass Transfer in Self-Similar Laminar Boundary-Layer Flows," Doctoral dissertation, Aug. 1969, University of California at Los Angeles, Los Angeles, Calif.

[3] Wortman, A., Mills, A. F., and Soo-Hoo, G., "The Effects of Mass Transfer on Recovery Factors in Laminar Boundary-Layer Flows," *International Journal of Heat and Mass Transfer*, Vol. 15, No. 3, March 1972, pp. 443–456.

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