and cases 1-3 in Ref. 2. One can speculate that for the case of supersonic flow over a blunt fin,[4] at least in the region ahead of the blunt fin, the flow is strongly dominated by the geometry and other inviscid mechanisms. The strength of the primary vortex was closely predicted; hence so were the main features. For the case of supersonic flow over a swept corner,[2] the mechanism for generating the primary vortex was probably not correctly simulated; hence so were not the strength of the vortex and its associated features.

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Reply by Author to C.-M. Hung

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THE claim made by Hung[1] that the separated flow phenomenon on a highly swept wedge, discussed in Ref. 2, is similar to that for a blunt fin at zero sweep, analyzed by him,[3] is based solely on the similarity in the measured pressure distributions (compare Figs. 1 and 2 of Ref. 1). This is where the similarity ends. It is well-documented that the separated flow structures are very different, as different at least as those for blunted and sharp fins.[4] Thus, it is true that the dominant mechanism is inviscid for the blunt fin in Ref. 1, as demonstrated by the insignificant effect of a factor of four difference in the thickness of the approaching turbulent boundary layer (compare Figs. 2 and 4 in Ref. 1). This contrasts sharply with the large effect of Reynolds number exhibited by the experimental swept-wedge pressure distributions (compare Fig. 1 of Ref. 1 with the following Fig. 1).

Another demonstration of the fact that the separated flow structures causing apparently similar separated flow effects (Figs. 1 and 2 of Ref. 1) are very different, is the large effect of sweep angle in the case of the swept wedge.[5,6] When the sweep was decreased from 60 to 40 deg, the large effect of Reynolds number on the correlation between predicted and experimental pressure distributions essentially disappeared (compare Fig. 1 of Ref. 1 with the following Fig. 2). It is suggested in Ref. 2 that, as in the case of delta wings, the sweep has to be increased beyond 50 deg before a strong vortical structure develops which contains a secondary vortex of significant size and strength, as in the low Reynolds number case shown in Fig. 1 of Ref. 1.

Hung's colleague, Horstman, found that his Navier-Stokes calculations could detect a secondary seapration in the case of a highly swept sharp fin, provided the grid was refined enough.[7] However, the secondary vortex structure was of insignificant size and could not explain the upstream influence observed experimentally, and "the reasons for this discrepancy remain a mystery." In his plans to solve this mystery through improving the computational method, Horstman does not discuss any efforts to improve the prediction of the primary vortex structure, which Hung thought "was probably not cor-

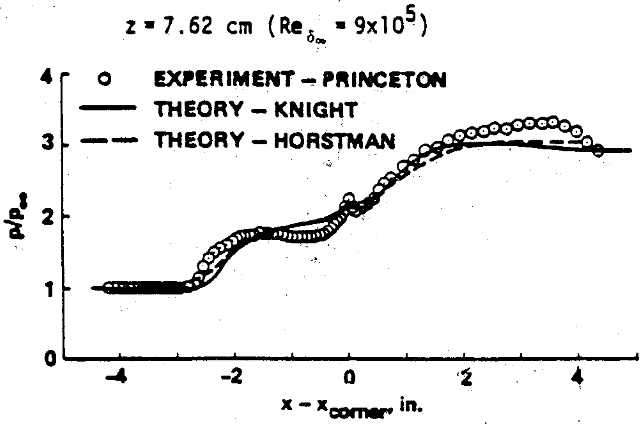

Fig. 1 Pressure distribution for the 60-deg swept 23-deg compression corner at $M_\infty = 3$ and high Reynolds number.[5]

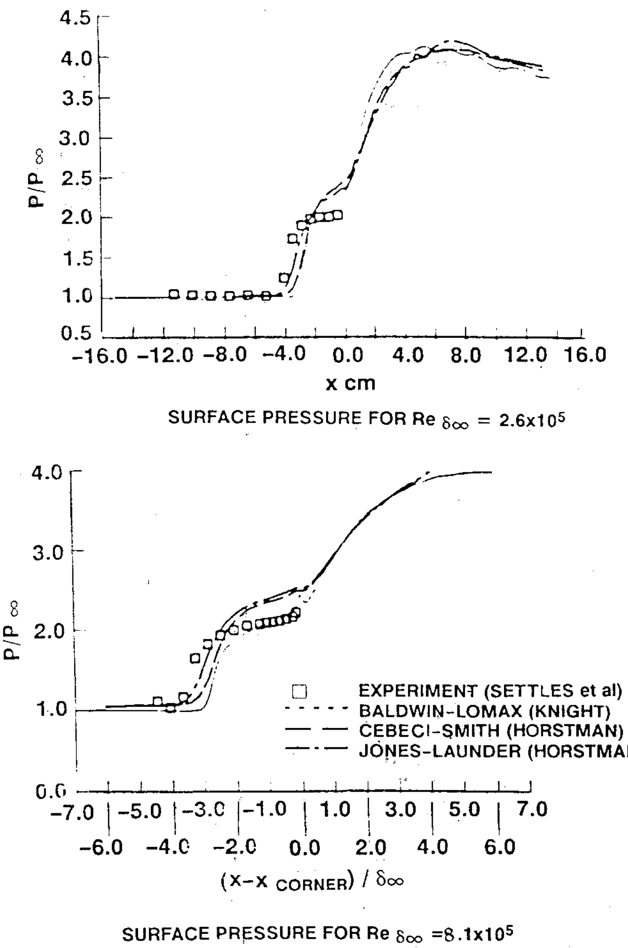

Fig. 2 Supersonic turbulent flow past 40-deg swept compression corner at $M_\infty = 3$.[6]

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rectly simulated," thereby explaining the poor correlation between prediction and experiment in Fig. 1 of Ref. 1. The only concensus appears to be that more research is needed, research in which close cooperation between theoreticians and experimentalists, of the type discussed in Ref. 8, will be sorely needed.

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Comment on "New Eddy Viscosity Model for Computation of Swirling Turbulent Flows"

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IN recent comments on Kim and Chung's[1] new eddy viscosity model by Gessner[2] and Leschziner[3] and a reply by Kim and Chung,[4] the determinations of modeling constants and the value of the turbulent kinetic energy production to dissipation ratio were argued. Kim and Chung implemented the k–ϵ model by deriving an algebraic equation for eddy viscosity based on the algebraic Reynolds stress model proposed by Rodi.[5] In Rodi's model, the equation is

$$\frac{\overline{u_i u_j}}{k} = \phi_1 + \frac{P_{ij}}{\epsilon} + \phi_2 \delta_{ij} \tag{1}$$

where

$$\phi_1 = \frac{1 - C_2}{(P_r/\epsilon) + C_1 - 1} \tag{2}$$

$$\phi_2 = \frac{2}{3} \frac{C_2(P_r/\epsilon) + C_1 - 1}{(P_r/\epsilon) + C_1 - 1} = \frac{2}{3}\left[1 - \frac{P_r}{\epsilon}\phi_1\right] \tag{3}$$

δ_{ij} is a Kronecker delta, P_{ij} the production tensor of the Reynolds stresses $\overline{u_i u_j}$, P_r the production of the turbulent kinetic energy k, ϵ the isotropic dissipation rate, C_1 the inertial return-to-isotropy constant, and C_2 the forced return-to-isotropy constant.

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After some elaborate manipulation, Kim and Chung obtained an expression for the eddy viscosity ν_t:

$$\nu_t = \frac{\alpha}{1 + \beta R_i} \frac{k^2}{\epsilon} \tag{4}$$

where

$$R_i = \frac{k^2}{\epsilon^2} \frac{W}{r} \frac{\partial W}{\partial r} \tag{5}$$

$$\beta = 4\phi_1^2 \tag{6}$$

$$\alpha = \phi_1 \phi_2 = \frac{2}{3}\phi_1\left(1 - \frac{P_r}{\epsilon}\phi_1\right) \tag{7}$$

For the flow without swirl, R_i is equal to zero, and then the constant α can be determined by matching with $C_\mu(= 0.09)$. Gessner argued about matching α with $C_\mu = 0.09$ for a flow in local equilibrium ($P_r/\epsilon = 1$), which is true for the presence of wall but not necessary for swirling free jet flows. In Gessner's comment, a systematic analysis was shown to decide the values of ϕ_1 and ϕ_2 (and so the modeling constants C_1, C_2) as $P_r/\epsilon = 1$. Kim and Chung, however, replied with a good argument that it is not necessary to let $P_r/\epsilon = 1$ in the process of determining the value of β. Kim and Chung may be able to choose β literally in order to fit the experimental data, but the ratio of P_r/ϵ obtained from choosing $\beta = 0.25$ is not equal to the one shown in their reply.

From Eq. (6), we know that $\phi_1 = 0.25$ if $\beta = 0.25$ is chosen, and so P_r/ϵ is computed to be 1.84 from Eq. (7) according to Kim and Chung's matching α with $C_\mu(= 0.09)$. Surprisingly, in Kim and Chung's reply, a statement was made: "Our model constant $\beta = 0.25$ implicitly assumes that P_r/ϵ is about 0.8 for $C_1 = 1.8$ and $C_2 = 0.6$ or $C_1 = 3$ and $C_2 = 0.3$. And if $C_1 = 2.2$ and $C_2 = 0.55$, $\beta = 0.25$ implies that $P_r/\epsilon = 0.6$."[4] It is obvious that the value of P_r/ϵ is fixed according to Eqs. (6) and (7) if α and β are selected. Simple algebra shows that with three unknowns (C_1, C_2, and P_r/ϵ; or ϕ_1, ϕ_2, and P_r/ϵ) only three equations are required. Several combinations, therefore, can be used to solve the problem. In Kim and Chung's statement, the prescribed C_1, C_2, and β along with $\alpha = C_\mu = 0.09$ is definitely overspecified; the value of P_r/ϵ is not matched, unless they do not require $\alpha = C_\mu = 0.09$ proposed in their original paper.[1]

If we assume that Kim and Chung want to maintain $\alpha = 0.09$, then the following exercise will demonstrate the inconsistency of their statement. From Eqs. (2), (3), (7), and (8), for $C_1 = 1.8$ and $C_2 = 0.6$,[6] $P_r/\epsilon = 1.41$ and $\beta = 0.131$ are obtained; for $C_1 = 3$ and $C_2 = 0.3$,[7] $P_r/\epsilon = 1.58$ and $\beta = 0.153$ are obtained; for $C_1 = 2.2$ and $C_2 = 0.55$,[8] $P_r/\epsilon = 1.34$ and $\beta = 0.126$ are obtained. These results show that $P_r/\epsilon > 1$, which violates $0 < P_r/\epsilon \leq 1$ in the flowfield protested by Kim and Chung. The argument in Kim and Chung's reply can be valid only when $\alpha = C_\mu \neq 0.09$, which is inconsistent with their original approach.[1] The selection of $\beta = 0.25$ along with $C_1 = 1.8$ and $C_2 = 0.6$[6] or $C_1 = 3$ and $C_2 = 0.3$[7] implies that $P_r/\epsilon = 0.8$ and $\alpha = C_\mu = 0.133$, whereas $P_r/\epsilon = 0.6$ and $\alpha = C_\mu = 0.142$ are obtained by the specified $\beta = 0.25$ with $C_1 = 2.2$ and $C_2 = 0.55$.[8] If this is the case, then the good agreement of the result from the new eddy viscosity with experimental data cannot imply that the success is due to the inclusion of Richardson's number or the ad hoc change of the modeling constant C_μ.

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