# Reply by the Authors to F. Motallebi

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MOTALLEBI rightly pointed out the misprints in Eqs. (8) and (10) (Ref. 1). In addition to these errors, introduced in printing, there are others that have been reported in the Errata that appeared in *AIAA Journal*, Vol. 32, No. 11, 1993, p. 2192. These errors do not change our results and conclusions since our program and analysis are correct.

The horizontal axis of Fig. 1a is labeled correctly, although in step 2 of the skin-friction algorithm it is referred to as $Re_{\delta_2}$. When discussing Fig. 1, we considered only incompressible flows, and hence the parameter $Re_\theta$ was used. However, as we extended the algorithm from incompressible flows to compressible flows, an important step was to change the parameter in the $\Pi$ correlation from $Re_\theta$ (viscosity evaluated in the freestream) to $Re_{\delta_2}$ (viscosity evaluated at the wall) following Fernholz and Finley [see the discussion following Eq. (8)]. This change was stated clearly in the beginning of Sec. II.

We disagree with Motallebi's statement that the algorithm is limited to "hypersonic" flows. The current method can be considered as an extension of Coles' method, which was proposed mainly for low-speed flows. For $M = 0$, the method reproduces the Kármán-Schoenherr skin-friction formula. In the published paper,[1] we gave examples only for high Mach number flows because this is where the model is most likely to break down. Supersonic flows are less severe test cases, and the model works well. Figure 1 shows an example, where the comparison of the present algorithm with the data of Moore and Harkness[2] was made for a flow over an almost insulated surface with a freestream Mach number of 2.8 and a very high Reynolds number, $Re_\theta = 4 \times 10^5$. As can be seen from the figure, the comparison is excellent.

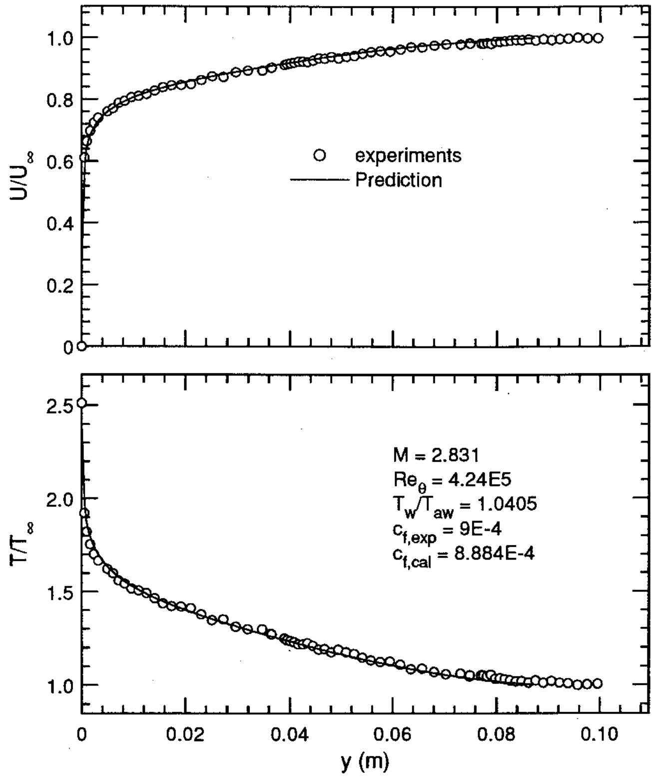


**Fig. 1 Comparison with Moore and Harkness data; $M_e = 2.83$, $T_w/T_{aw} = 1.04$, and $Re_\theta = 4.24 \times 10^5$.**

Motallebi's query regarding the iteration process can be explained by referring to Eq. (8) in the text, which represents the final universal equation for velocity. It contains only two unknowns, $\delta$ and $\Pi$. The correlation between $Re_\theta$ (or $Re_{\delta_2}$) and $\Pi$ can be found in Fig. 1a, which is provided in the form of a table in our computer program. Since $\theta$ (or $\delta^*$) is specified in our algorithm, an iteration procedure is required to find the value of $\delta$ corresponding to the desired value of $\theta$ (or $\delta^*$). Finally, $U_\delta^+ (= U_\delta/u_\tau)$ is obtained by substituting $U_{c,\delta}^+ (= U_{c,\delta}/u_\tau)$ directly into Eq. (6). This step is straightforward, but inevitably the notation is complicated.

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## References

[1]Huang, P. G., Bradshaw, P., and Coakley, T. J., "Skin Friction and Velocity Profile Family for Compressible Turbulent Boundary Layers," *AIAA Journal*, Vol. 31, No. 9, 1993, pp. 1600–1604.

[2]Moore, D. R., and Harkness, J., "Experimental Investigation of the Compressible Turbulent Boundary Layer at High Reynolds Numbers," *AIAA Journal*, Vol. 3, No. 5, 1965, pp. 631–638.