Technical Comments

Comments on "A Study of Penetration of a Liquid Injectant into a Supersonic Flow"

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THIS Note is in response to a recent paper by Kolpin, Horn, and Reichenbach[1] concerning the penetration of liquid jets. It should be noted that only a portion of the data surveyed in Ref. 2 was compared with their new data.

Reference 2 develops theories that apply for two regimes, an acceleration wave regime and a capillary wave regime. Most of the experimental data available happens to fall in the acceleration regime. There is one set,[3] however, which is in the capillary wave regime and, as expected, does not correlate with the data in the acceleration wave regime. All the data considered in Ref. 1 was in the acceleration wave regime.

References

[1] Kolpin, M. A., Horn, K. P., and Reichenbach, R. E., "Study of Penetration of a Liquid Injectant into a Supersonic Flow," *AIAA Journal*, Vol. 6, No. 5, May 1968, pp. 853–858.

[2] Adelberg, M., "Breakup Rate and Penetration of a Liquid Jet in a Gas Stream," *AIAA Journal*, Vol. 5, No. 8, Aug. 1967, pp. 1408–1415. (Errata for this Ref. is in Ref. 4.)

[3] Fenn, D. B., "Correlation of Isothermal Contours Formed by Penetration of Jet of Liquid Ammonia Directed Normal to an Airstream," RM E53J08, Feb. 3, 1954, NACA.

[4] Adelberg, M., "Mean Drop Size Resulting from the Injection of a Liquid Jet into a High-Speed Gas Stream," *AIAA Journal*, Vol. 6, No. 6, June 1968, pp. 1143–1147.

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Reply by Authors to M. Adelberg

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AS is evident from the title of our article,[1] we were concerned only with liquid injection into a supersonic flow, whereas the data referred to by Adelberg are for injection into a subsonic flow.[2] The data are therefore irrelevant to our study, in which the correlation for penetration height was demonstrated for liquid injection with large Weber numbers into supersonic streams.

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[1] Kolpin, M. A., Horn, K. P., and Reichenbach, R. E., "Study of Penetration of a Liquid Injectant into a Supersonic Flow," *AIAA Journal*, Vol. 6, No. 5, May 1968, pp. 853–858.

[2] Fenn, D. B., "Correlation of Isothermal Contours Formed by Penetration of Jet of Liquid Ammonia Directed Normal to an Air Stream," RM E53J08, Feb. 3, 1954, NACA.

Comment on "An Investigation of the Effect of Suction on Hypersonic Laminar Boundary-Layer Separation"

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Nomenclature

c = width of flat plate
h = height of step
M_0 = inviscid Mach number of flow on surface upstream of ramp
M_∞ = freestream Mach number
P_w = surface pressure
P_∞ = freestream static pressure
Re_0 = inviscid-flow unit Reynolds number on surface upstream of ramp, in.$^{-1}$
Re_{x_0} = $Re_0 x_0$
x = distance from leading edge along surface, in.
x_0 = distance from the leading edge to the beginning of separation interaction, in.
θ = ramp deflection angle, deg

BALL and Korkegi[1] presented experimental pressure distributions for separated regions created by a slender wedge with various base-ramp compression angles at $M_\infty = 12.3$. They made the following statement in this paper; "The results of this investigation for the plateau pressure and no corner suction, as shown in Fig. 3, appear to indicate that the separations are not of the free interaction type. However, similarity scaling as suggested by Curle[23] of the streamwise coordinate x, reduces the pressure data into a similarity plot in excellent agreement with the data of Lewis.[22]" However, Lewis, Kubota, and Lees[2] concluded that such a correlation ($M_0 = 4$ and 6, Fig. 6 of Ref. 2) indicated that free interaction existed for their surface pressure data.

Lewis, Kubota, and Lees[2] correlation is, in fact, substantial evidence of free interaction. The correlation variables contain only local pressure, distance from the beginning of interaction, flow properties at the beginning of interaction, and wall-to-freestream temperature ratio. No reattachment conditions appear. Thus, the surface pressures and, hence, the flows over the region of separation interaction are shown to be directly dependent upon the conditions at the beginning

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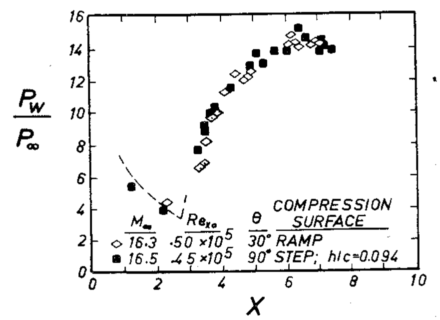
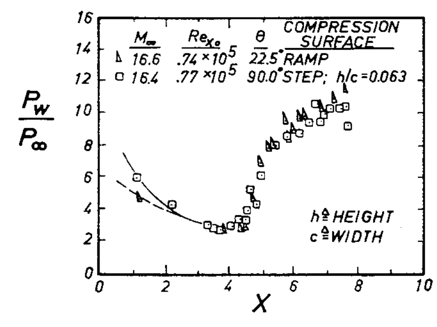
of interaction, and not upon the cause of separation. This is free interaction. If surface pressure measurements are correlated by these variables, then the inference should be that free interaction exists.

A single exception, such as that reported by Korkegi and Ball,[1] would prove that the surface-pressure correlations obtained by Lewis, Kubota, and Lees,[2] and perhaps similarily founded correlations,[3–5] are not sufficient to demonstrate free interaction. Therefore, it is important to know what information reported by Ball and Korkegi in Fig. 3 of Ref. 1 indicates an absence of free interaction. It could not be the fact that the ramp pressures increased with increasing ramp angle, because nothing in the principle of free interaction requires constant pressures in the reattachment region with changing compression conditions. In fact, this empirically founded principle applies only to the separation-interaction region. This region extends from the beginning of interaction to the start of the pressure plateau or to the beginning of the reattachment pressure rise when no pressure plateau develops. The reattachment conditions pose the downstream boundary conditions, and thus fix the size of the separation region. The data in Fig. 3 of Ref. 1 therefore show that as the ramp angle increased, the separation-interaction region grew in size and progressed from a partially developed state (no pressure plateau) to a well-developed state (with a pressure plateau). However, this observation alone also does not indicate an absence of free interaction.

Direct experimental results have proven that free interaction existed for cases of well-developed, two-dimensional, supersonic and hypersonic, laminar- or transitional-separation regions. Other evidence indicates that partially developed separation regions also can be the result of free interaction. Miller, Hijman, and Child's[6] data yields proof of free interaction on a flat plate for a well-developed separation-interaction region (Fig. 1a) and for what may be a partially developed separation-interaction region (Fig. 1b). Chapman, Kuehn, and Larson[3] and Needham and Stollery[7] also have shown by direct experimental proof that free interaction existed for cases of well-developed separation on flat plates. The flow conditions for these proven cases of free interaction



a) **Well-developed separation interaction**



b) **Possible partially developed separation interaction**

Fig. 1 Free interaction shown by replot of data from Ref. 6.

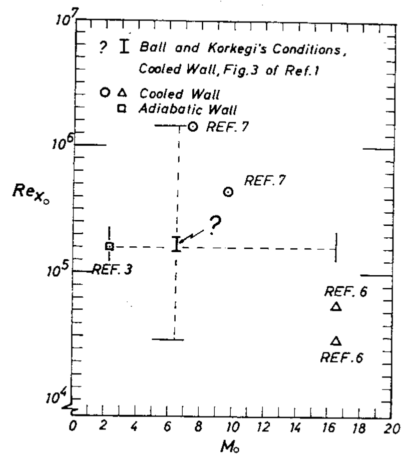


Fig. 2 A comparison of Ball and Korkegi flow conditions and flow conditions for which direct experimental proof of free interaction has been obtained.

partially bracket Ball and Korkegi's experimental conditions (Fig. 2). The writer knows of no direct experimenal proof indicating that free interaction did not exist for a case of supersonic or hypersonic, laminar, two-dimensional separation on a flat plate. Indirect evidence of free interaction is available from comparisons between theory and experiment. The laminar theory of Lees and Reeves,[2,8] which is based on the assumption of free interaction, predicted surface pressure distributions for cases of partially developed and well-developed pure laminar-separation regions on flat plates in supersonic and hypersonic flow. Finally, one should note that Lewis, Kubota, and Lees[2] also correlated, on one curve, surface pressures for both partially developed and well-developed separation-interaction regions.

In conclusion, the data presented by Ball and Korkegi in Fig. 3 of Ref. 1 do not, without further explanation, clearly imply "nonfree interaction." In fact, all indications are that free interaction probably did exist for this case since: 1) these data are reportedly correlated by the free-interaction variables of Lewis, Kubota, and Lees,[2] and 2) the related flow conditions are partially bracketed by direct experimental proof of free interaction.

References

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