Reader's Forum

Brief discussion of previous investigations in the aerospace sciences and technical comments on papers published in the AIAA Journal *are presented in this special department. Entries must be restricted to a maximum of 1000 words, or the equivalent of one* Journal *page including formulas and figures. A discussion will be published as quickly as possible after receipt of the manuscript. Neither the AIAA nor its editors are responsible for the opinions expressed by the correspondents. Authors will be invited to reply promptly.*

Comments on "Effect of Nose Bluntness and Cone Angle on Slender-Vehicle Transition"

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THERE are a number of aspects of Ref. 1 that require clarification. In this regard, the author is asked the following questions:

1) What was the rationale for introducing an inviscid parameter (your X_{EWi}) to correlate a viscous-related phenomena? It has been shown there are two major effects associated with entropy-layer-influenced transition (Ref. 2). These effects are changes in the transition Reynolds number and reductions in the local Reynolds number, as compared to sharp configuration values. Both of these effects have been shown to be directly related to the degree to which the entropy layer is swallowed by the boundary layer. There is no general relationship to relate the inviscid parameter X_{EWi} to the entropy-layer-swallowing distance X_{SW}. Changes that influence the boundary-layer thickness, for example, changes in wall temperature or unit Reynolds number, can make large changes in the distance to swallow the entropy layer. Thus, there is no general way to relate the transition Reynolds number within the entropy-layer-swallowing region to the inviscid parameter X_{EWi}. Good comparisons can be made only for conditions of like wall temperatures and unit Reynolds numbers.

2) Why do you equate entropy gradients to instability? There is no guidance from stability theory to warrant this conclusion. If the entropy layer happens to contain a generalized inflection point (a location where the gradient of the product of density and vorticity is zero), then there is a basis for suspecting instability. Reshotko and Khan[3] addressed this situation for a blunt plate configuration.

3) Why did you say that freestream noise attenuates nosetip bluntness effects? It is clear that increasing freestream noise can produce smaller transition Reynolds numbers; however, there is no evidence to indicate that it attenuates the nosetip bluntness effect.

4) Why did you say that with optimum nose bluntness it is possible to obtain an order of magnitude increase in transition Reynolds number in flight? There is no evidence to support this statement. In fact, a comparison of transition data from a conventional Mach 6 wind tunnel[2] with Mach 20 flight data[4] showed a remarkable similarity. Although the magnitude of the transition Reynolds numbers differed significantly, the percentage changes were very similar. The Mach 6 wind tunnel transition Reynolds numbers, for a unit Reynolds number of 11.2×10^6/ft, varied from about 6.4×10^6 (sharp) to about 10.3×10^6 ($R_N/R_B = 0.03$). The Mach 20 flight data (Re-entry F vehicle) varied from about 40×10^6 (sharp) to about 68×10^6. An order of magnitude increase with optimum nosetip bluntness would suggest that the Re-entry F vehicle could obtain transition Reynolds numbers of about 400×10^6, an unrealistic estimate.

5) Why did you say that boundary-layer transition on a slender cone is of inviscid origin and can be predicted by using embedded Newtonian theory? There are no data available to explain the origin of the instability phenomena. One can only speculate as to the origin of the instability. Reference 5 described the results of an attempt to investigate experimentally the stability of the entropy layer on a sphere-cone. Disturbances were found in the entropy layer above the boundary layer, but there was no clearly defined generalized inflection point, and it was not possible to identify the origin of the instability.

6) How does one visualize an inflexional inviscid instability from a total pressure profile?

7) Why did you say that Softley (Fig. 3) showed that the transition movement forward with increasing Reynolds number greatly speeded up when transition occurred upstream of complete entropy swallowing? Softley showed only that the transition Reynolds number was reduced; however, large reductions in the local unit Reynolds number occur for this situation and the forward movement of transition is slowed down as a result of the local Reynolds number reduction[2]. The rapid forward movement of transition was found to occur much further forward in the entropy layer and could be related to certain threshold conditions on the nosetip.[2]

8) How can you rationalize the "rushing" transition behavior to be a function of the ratio of the nosetip-to-base radius (R_N/R_B)? This would imply that the length of the vehicle had a major effect. Reference 2 demonstrated that the nosetip radius (not the ratio) and the nosetip roughness were the major vehicle parameters. That is, a combination of local nosetip Reynolds number and nosetip roughness determined the "flashing forward" condition.

9) Comment regarding the insensitivity to Mach number. The insensitivity to Mach number in the correlation of Fig. 5 should not be interpreted as a general insensitivity to Mach number. The location of transition on a splender sphere-cone is very sensitive to freestream Mach number, since both the transition Reynolds number and the local unit Reynolds number are very freestream Mach number-dependent.

10) Comment on the spreading of turbulence. The surface location where the turbulence has spread to the surface does not correspond to a conventional definition of transition location. Boundary-layer profiles[6] were found to deviate from a laminar profile shortly after the onset of the spreading of turbulence. The location where the turbulence has spread to the surface is probably closer to the fully turbulent condition than the onset of transition.

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[1]Ericsson, L. E., "Effect of Nose Bluntness and Cone Angle on Slender-Vehicle Transition," *AIAA Journal,* Vol. 26, Oct. 1988, pp. 1168–1174.

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[3]Reshotko, E. and Khan, M. M. S., "Stability of the Laminar Boundary Layer on a Blunted Plate in Supersonic Flow," presented at IUTAM Symposium on Laminar-Turbulent Transition, Stuttgart, FRG, Sept. 1979.

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[5]Stetson, K. F., Thompson, E. R., Donaldson, J. C., and Siler, L. G., "Laminar Boundary-Layer Stability Experiments on a Cone at Mach 8, Part 2: Blunt Cone," AIAA Paper 84-0006, Jan. 1984.

[6]Stetson, K. F., Thompson, E. R., Donaldson, J. C., and Siler, L. G., "Laminar Boundary-Layer Stability Experiments on a Cone at Mach 8, Part 1: Sharp Cone," AIAA Paper 83-1761, July 1983.

Reply by Author to K. F. Stetson

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All of the questions raised by Mr. Stetson in regard to my paper[1] are based on the false premise that a viscous flow phenomenon, such as boundary-layer transition, cannot be controlled by inviscid flow characteristics. Except for the effects of nose roughness and similar viscous flow phenomena unique to the blunted nose itself, the effect of the geometric change from a sharp to a blunted cone is inviscid in nature, occurring via the change in the boundary-layer edge conditions through the "entropy wake" generated by the curved bow shock. This change of inviscid flow characteristics is well predicted by the embedded Newtonian theory,[2,3] as has been demonstrated recently.[4] Changes in wall temperature and unit Reynolds number do, of course, affect the viscous flow characteristics for both the sharp and the blunted cone. However, the effect of a geometric change from a sharp to a blunted cone is still inviscid in nature.

Keeping the above in mind, a careful reading of Ref. 1 will provide all of the answers to the questions raised by Mr. Stetson, keeping in mind that the ratio d_N/d_B tells whether the conic frustum is long enough to experience the inviscid flow effects imprinted on the boundary layer by the "entropy wake."

References

[1]Ericsson, L. E., "Effect of Nose Bluntness and Cone Angle on Slender-Vehicle Transition," *AIAA Journal,* Vol. 26, Oct. 1988, pp. 1168–1174.

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[3]Ericsson, L. E., "Generalized Unsteady Embedded Newtonian Flow," *Journal of Spacecraft and Rockets,* Vol. 12, Dec. 1975, pp. 718–726.

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