Readers' Forum

Brief discussions 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.*

Comment on "Further Experiments on Shock-Tube Wall Boundary-Layer Transition"

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THE paper of Chaney and Cook[1] shows very well the uncertainties which still prevail in the problem of characterization of the transition in the unsteady wall boundary layer behind a moving shock in a classical shock tube. The data obtained by these authors do not differ greatly from those resulting from older experiments, and present similar apparent contradictions. However, in their discussion, the authors do not mention the interpretation that was proposed a few years ago[2,3] after the data of Mark and Mirtich,[4] Boison,[5] Thompson and Emrich,[2] and Brun et al.[3]

Thus, if we consider the results given by these authors (including also those of Ref. 1), which seem to be the only ones to follow the transition along the shock tube during the same experiment, a common point of these data lies in the fact that, for "sufficiently" small values of Re^* (freestream unit Reynolds number), the velocity of the "transition front" U^* is smaller than the one of the inviscid flow U behind the shock, which indicates a recession of this apparent front toward the contact surface. Then, when Re^* increases, U^* tends to the shock velocity U_s.[3,5] In the light of these data, the first point to be noted is that all experimental results obtained in the past at one unique measurement station cannot be used in order to describe correctly the transition phenomenon, and these previous experiments are not significant except for high values of Re^*.

Now, if we represent on X, t diagrams some data of Ref. 3 recorded at six stations during the same test in a square shock tube (8.5×8.5 cm), 8 m long (test gas argon), we obtain diagrams similar to Fig. 1 for Re^* smaller than $1\text{-}2\times10^6$ m^{-1}. For larger Re^* the diagrams are similar to Fig. 2. In these figures, experimental shock and interface trajectories, transition points are represented, as well as lines of slope $1/U$.

From Fig. 1, it is clear that it is possible to find values for Re_T (transition Reynolds number) decreasing with increasing abscissa, depending upon the gage position. However, if we assume that turbulence appears first under the form of large structures (spots)—and not under the form of a compact front—and that these spots are "transported" in the boundary layer at a mean velocity slightly smaller than the freestream velocity, we can explain the results. The spots are finally absorbed by the driver gas behind the contact surface, the velocity U_c of which is greater than U.[6] New spots are then created, develop, and regress; the phenomenon being periodic. It seems also that a new spot cannot be created as long as the preceding one has not "sufficiently" regressed. With increasing values of Re^*, the frequency of spot creation increases and a compact transition front tends to establish in parallel to the shock trajectory in the X, t diagram (Fig. 2); that is, it moves with the shock velocity. More details can be found in Ref. 3. Similar results have also been found for steady flows in the past.[7]

It is obvious that the exact creation point of the spots is very difficult to determine experimentally, and therefore the corresponding values of Re_T cannot be known accurately (many more than six gages would be necessary). The point can only be found for values of Re^* greater than a minimum value (roughly $1\text{-}2\times10^6$m^{-1} for Argon[3]), as previously in-

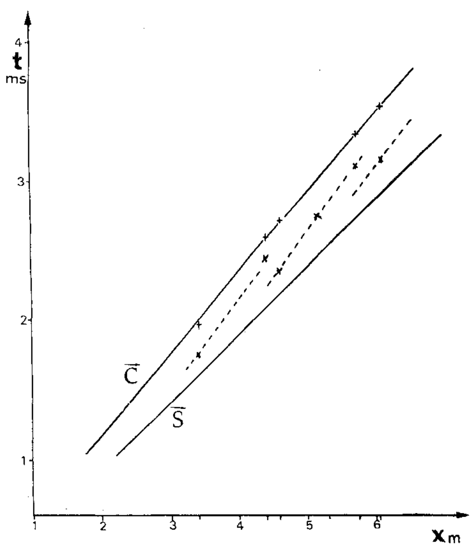

Fig. 1 Experimental (X,t) diagram along the shock tube. Shock Mach number = 5.7; initial pressure = 7.0 mm Hg, $Re^* = 0.64\times10^6$ m^{-1}. $\bar{S}$, shock trajectory; $\bar{C}$, contact surface; x, transition point; ----, lines of slope $1/U$.

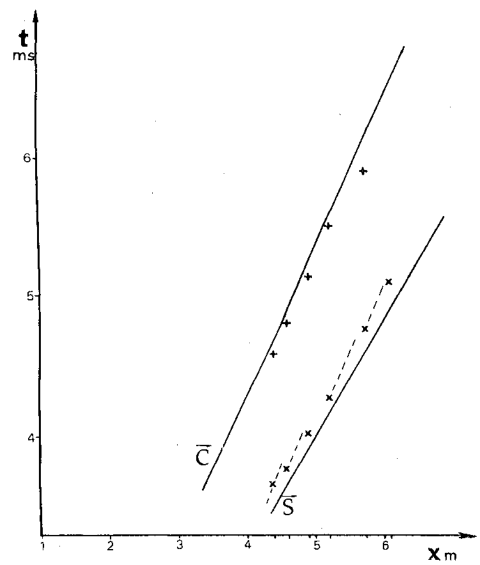

Fig. 2 Experimental (X,t) diagram along the shock tube. Shock Mach number = 3.8; initial pressure = 48.9 mm Hg; $Re^* = 4.06\times10^6$ m^{-1}.

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dicated, but it may be different for air. Furthermore, the influence of other parameters on transition must also be assessed: classical freestream—wall temperature ratio and pressure gradient induced by the presence of the boundary layer, this last parameter being possibly non-negligible in tubes of moderate and small cross sections working at low initial pressures. Furthermore, for large values of Re^*, the transition occurs very close to the shock front; thus, from an experimental point of view, the mounting of gages must be carefully done, trying to avoid any discontinuity in the tube wall. Thus, taking into account these final remarks, new systematic experiments on transition in shock-tube boundary-layer flows are needed.

References

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Reply by Authors to R. Brun

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REMARKS in the Comment suggest that a common feature of shock tube wall boundary-layer transition behavior is that at low unit Reynolds number Re_u the velocity U_T of the front corresponding to departure from laminar flow is less than the laboratory fluid particle velocity U_2, and that with increasing Re_u, U_T progresses toward the shock velocity U_s. Our experimental data do not fully support this hypothesis. In Fig. 2 of Ref. 1 only the largest value of the transition Reynolds number Re_T observed at each T_w/T_e was shown. Examination of the complete data given in Ref. 2 allows some features of the transition path to be identified. These data are presented in Fig. 1, in which experimental Re_T values are shown for the various x stations for each T_w/T_e considered. Estimated uncertainties in Re_T are shown. At a given T_w/T_e (a given shock Mach number) Re_T is proportional to the transition time t_T, the time between the arrival of the shock and the transition front at a given x. Thus, if the transition front travels at a speed less than U_s, Re_T will increase with increasing x, and if $U_T = U_s$ the same value of Re_T would be obtained at all x stations.

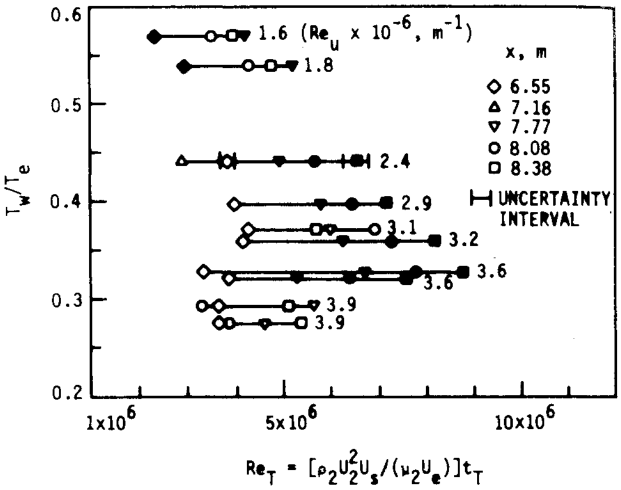

Fig. 1 Transition Reynolds number range for various wall-to-post-shock temperature ratios.

Consider first the data in Fig. 1 in the range $2.4/\text{m} \leq Re_u \times 10^{-6} \leq 3.6/\text{m}$. These data exhibit Re_T values that vary with x. However, a clearly defined transition front velocity exists only for the data represented by the solid symbols; these data closely follow the transition path $U_T = U_2$. Data for five of the six runs in this range exhibit this characteristic, and only data from stations at the three largest values of x behave in this manner. Consider next the data in Fig. 1 at the two lowest values of Re_u. These data are in the range of unit Reynolds number which, according to Brun, should exhibit a transition front velocity less than U_2 and thus should exhibit a pattern of increasing Re_T with x similar to that for $U_T = U_2$ but with even larger increments of Re_T between the measurement stations. The results do not follow this pattern. The data at x stations 6.55 m and 7.77 m (solid symbols) lie very close to the transition path $U_T = U_2$, while the data for the remaining two x stations indicate that U_T is near U_s downstream of $x = 7.77$ m.

The results in Fig. 1 for $Re_u = 3.9 \times 10^6$/m do not exhibit a trend in Re_T that allows clear identification of a transition front velocity. However, both the mean values for Re_T and the Re_T range observed for these runs are smaller than those for the data in the range $2.4/\text{m} \leq Re_u \times 10^{-6} \leq 3.6/\text{m}$. The smaller spread in Re_T suggests a trend toward $U_T = U_s$, as observed by Brun at $Re_u = 4.1 \times 10^6$/m.

Brun associates transition front velocities less than U_2 at low Re_u with the presence of turbulent spots in an otherwise laminar flow. The existence of turbulent spots in the flow would possibly explain results in which measured values of Re_T first decrease and then increase with x. The results in Fig. 1 at $Re_u = 2.4 \times 10^6$/m exhibit this variation with x. These data are from the study conducted to assess the influence of driver-created disturbances on transition (Fig. 1, Ref. 1). Data at this unit Reynolds number were obtained at five x stations for several runs. Mean values of Re_T at each x station are shown in Fig. 1. Turbulent spots are identified on heat flux gage response curves by an increase from the step-like laminar signal and a subsequent signal decrease indicating a return to laminar flow.[3] Records of heat flux gage response for all of the data obtained in this study do not in-

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