Technical Comments

Comment on "Angle of Attack and Leading Edge Effects on the Flow about a Flat Plate at Mach Number 18"

JOSEPH H. KEMP JR.*
NASA Ames Research Center, Moffett Field, Calif.

IN a recent paper, Allegre and Bisch[1] presented some very interesting data obtained on sharp and blunt plates at angles of attack and conditions where the flow is subjected to strong interaction effects. Comparisons are made between the data and the theory of Cheng et al.[2] The data for the sharp plate are found to agree reasonably well with the theory; however, when bluntness effects are examined, the agreement between data and the theory presented is poor. From this comparison the authors conclude that "Cheng's theory yields a good correlation of the effect of incidence but not for the bluntness effect." The purpose of the present Comment is to show that the differences observed by Allegre and Bisch are not due to the failure of Cheng's theory to predict bluntness effects but rather to the effects of viscosity.

Examination of the data for blunt plates considering the criteria established by Dewey[3] indicates that the flow conditions are of such a nature that bluntness, incidence, and viscosity are all of equal importance for most of the data presented. Thus the data should be compared with Cheng's general case solution, which includes the effects of viscosity, rather than with the particular solution used by Allegre and Bisch, which does not include the effects of viscosity. Cheng presented only the heat-transfer solution for the general case; however, the solution for pressure and shock shape can be obtained by standard computer techniques. The present author has computed the required solutions.[4] In Ref. 4 the solution presented is for the theory of Cheng modified to account for the effects of specific heat ratio γ; however, Cheng's solutions can be obtained from these curves by simply redefining the correlating parameters to those given by Cheng.

In Fig. 1 the data presented by Allegre and Bisch for blunt plates at positive angles of attack are compared with the general solutions to Cheng's original theory and with the values predicted by the present author's modification to Cheng's theory. In this example it is quite evident that both Cheng's original theory and the present author's modification to Cheng's theory predict the pressures reasonably well. Hence it can be concluded that the differences observed by Allegre and Bisch are not due to the failure of Cheng's theory to predict the effects of bluntness, but are primarily due to the effects of viscosity which were not accounted for in the theoretical values presented by Allegre and Bisch.

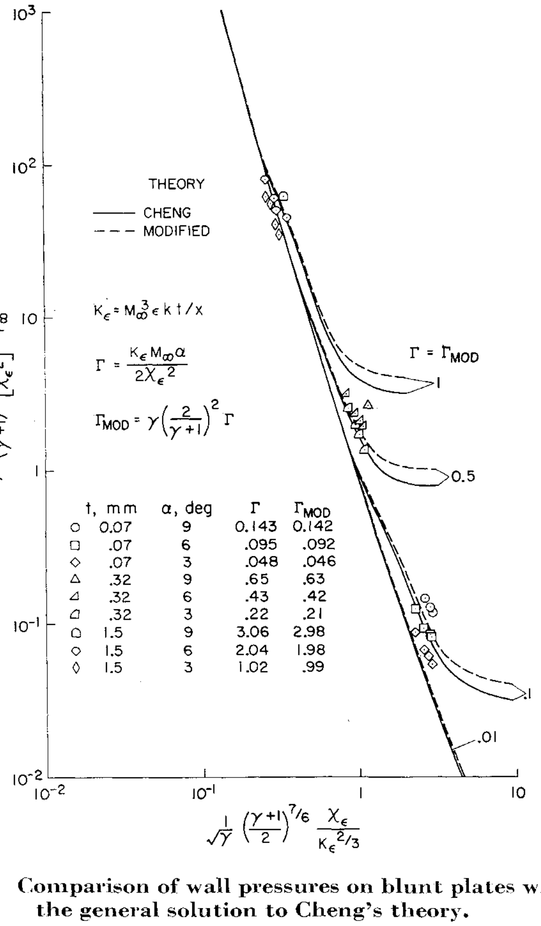

Fig. 1 Comparison of wall pressures on blunt plates with the general solution to Cheng's theory.

Received June 14, 1968; revision received July 22, 1968.
* Research Scientist. Member AIAA.

References

[1] Allegre, J. and Bisch, C., "Angle of Attack and Leading Edge Effects on the Flow about a Flat Plate at Mach Number 18," *AIAA Journal*, Vol. 6, No. 5, May 1968, pp. 848–852.

[2] Cheng, H. K. et al., "Boundary-Layer Displacement and Leading-Edge Bluntness Effects in High-Temperature Hypersonic Flow," *Journal of the Aerospace Sciences*, Vol. 28, No. 5, May 1961, pp. 353–381.

[3] Dewey, C. F., Jr., "Bluntness and Viscous-Interaction Effects on Slender Bodies at Hypersonic Speeds," Paper RM-3832PR, Sept. 1964, Rand Corp.

[4] Kemp, J. H., Jr., "Hypersonic Viscous Interaction on Sharp and Blunt Inclined Plates," Paper 68-720, 1968, AIAA.

Comments on "Some Recent Advances in the Investigation of Shell Buckling"

L. J. HART-SMITH*
Monash University, Clayton, Victoria, Australia

IN Ref. 1, Stein has concluded that the classical thin-shell buckling analyses are basically correct. Confining attention here to the case of cylinders under pure axial compression, his Fig. 1 indicates that the classical theory predicts the same buckling stress whether the ends be completely clamped ($u - \bar{u} = 0$, $v = 0$, $w = 0$, $\partial^2 w/\partial x^2 = 0$) or incompletely restrained ($u - \bar{u} \neq 0$, $v = 0$, $w = 0$, $\partial^2 w/\partial x^2 = 0$). He then compares this theory with only those experiments involving clamped ends. This raises two questions. First, if the theory applies for both end conditions, why should not the experimental results for cylinders with incompletely restrained ends also agree with the theory? Stein, himself,

Received March 8, 1968.
* Senior Teaching Fellow, Department of Mechanical Engineering.

concludes from the total experimental evidence that the end conditions are of vital importance. Second, does the theory really correspond to the situation in the experiments quoted by Stein? The classical theory for the circumferential ring-type buckling,[2] does apply to either completely clamped or incompletely restrained end conditions. However, for the classical solution for the diamond buckling mode,[2] it is necessary [Ref. 2, Eq. (f), p. 464] that the diamond wrinkles extend to the ends of the cylinder, at which $u - \bar{u} = \pm A \sin n\theta \neq 0$. Therefore, the classical solution for the diamond buckling mode is not comparable with any of the experimental evidence quoted by Stein on the diamond buckling mode with completely clamped end conditions. All of his references (4–7) specifically indicate the diamond buckling mode and such severe end clamping as to completely suppress all displacements there. Furthermore, the high-speed movie-camera observations recorded in his Refs. 4 and 6 clearly show that the buckling mode observed was the diamond mode right from the onset of buckling. There is no evidence cited in any of his relevant references (4–7) of any change of buckling mode from the rings to the diamonds.

Therefore, the problem of reconciling the classical equilibrium-bifurcation analysis with the comparable experimental evidence appears to remain unsolved. Consequently, it appears to be premature to conclude that the classical shell-buckling analyses are basically correct.

References

[1] Stein, M., "Recent Advances in Shell Buckling," Paper 68-103, 1968, AIAA; also "Some Recent Advances in the Investigation of Shell Buckling," *AIAA Journal*, Vol. 6, No. 12, Dec. 1968, pp. 2339–2345.

[2] Timoshenko, S. P. and Gere, J. M., *Theory of Elastic Stability*, 2nd ed., McGraw-Hill, New York, 1961, pp. 458, 462–465.

Reply by Author to L. J. Hart-Smith

Manuel Stein*
NASA Langley Research Center, Hampton, Va.

THIS reply is based on the following interpretation of certain of the expressions used by Mr. Hart-Smith (see the preceding comment). The expression "classical analysis" in the comments is interpreted to mean the same as the expression "conventional analysis" in the author's paper.[4] "Clamped" in the comments seems to refer to one type of in-surface restraint ($u = \bar{u}$, $v = 0$), whereas in the author's paper, it referred to a common type of out-of-surface restraint ($w = \partial w/\partial x = 0$). Also, evidently, "diamond buckling results" in the comments refers to conventional results based on the sine-sine configuration [given by Eq. (f), p. 464 of Ref. 2 of the comments) rather than postbuckling results corresponding to the diamond configuration that is commonly seen in experiment.

In as much as Mr. Hart-Smith's comments are directed primarily to the results presented in Fig. 1 of Ref. 4, it is appropriate to review in detail the author's interpretation of those results. Figure 1 indicates that if $v = w = 0$ at the edges, conventional theory predicts the same average buckling stress for the cylinder in axial compression no matter whether the axial displacement or the axial force is held constant at the edges or whether the edge slope or moment is zero. Consistent theory, on the other hand, indicates a variety of buckling loads depending on the edge restraint all within about 20% of the corresponding conventional theory value (see also Fig. 4, $p = 0$). All available near-perfect experimental results were plotted in Fig. 1. In all the experiments, attempts were made to obtain clamped edges ($w = \partial w/\partial x = 0$) with $u = \bar{u}$, $v = 0$; therefore, the experiments should be compared to the consistent theory for the same boundary conditions—the uppermost solid line in Fig. 1. Failure to achieve complete edge restraint would lead to lower experimental buckling loads and may contribute a small portion of the differences between experiment and this theoretical line which are shown in Fig. 1.

The equilibrium-bifurcation analysis for shell buckling has been strongly supported in the author's paper based on the agreement in Fig. 1 between theory and experiment for the buckling load. Mr. Hart-Smith questions the strong support on the basis of his interpretation of comparisons of buckling configurations obtained by experiment with that predicted by theory. This criticism deserves discussion. There has long been some misunderstanding as to what configuration should be seen at buckling. Consistent theory indicates that the configuration that should be expected from a perfect cylinder at buckling is a combination of the axisymmetric prebuckling configuration and the asymmetric initial buckling configuration (not to be confused with the final "diamond-shaped" postbuckling configuration commonly observed in the laboratory). Indication that the question may be resolved appears in Ref. 1 in which evidence has now been obtained through experiments on geometrically near-perfect cylinders that the shape at buckling is indeed a combination of an axisymmetric configuration and the asymmetric buckling configuration.

It is not clear to the author how to interpret Mr. Hart-Smith's comments with regard to "change of buckling mode from the rings to the diamonds." If the Comments refer to change from axisymmetric prebuckling deformations to asymmetric buckling configuration, then it should be remarked that these effects are accounted for in consistent theory and the prebuckling deformations have been observed experimentally.[2] If the Comments refer to change in buckle pattern with change in shell dimensions, then it should be noted that from consistent calculations made so far for the cylinder in axial compression, the critical buckling loads have always corresponded to $n \neq 0$ (see, for example, Table II of Ref. 3) and, therefore, no ring buckling has been indicated. Note that ring buckling loads for consistent theory represent asymptote values rather than bifurcation values.

Mr. Hart-Smith's statement that the classical sine-sine solution is not precisely comparable to experiment because the in-surface boundary condition on u is not satisfied is, strictly speaking, correct. However, this point is irrelevant to the author's comparison of consistent theory with experiment; moreover, the demonstrated insensitivity of both conventional and consistent solutions (Fig. 4) to change in this boundary condition suggest that comparison of even the conventional solutions with laboratory experiments should not be condemned on this basis. In summary:

1) Agreement in buckling load should be obtainable between experiment and theory for the same boundary conditions. It has been obtained for the near-perfect clamped cylinder in axial compression.

2) New evidence has been found to indicate it is possible to get the theoretical buckling configuration experimentally for this loading. The axisymmetric prebuckling configuration has been observed experimentally, but the axisymmetric buckling configuration will probably not appear in thin cylinders buckling elastically in pure axial compression.

3) These results and others cited in the author's paper for this and other loadings all point to the conclusion that equilibrium-bifurcation shell-buckling analysis is basically correct.

References

[1] Tennyson, R. C. and Wells, S. W., "Analysis of the Buckling Process of Circular Cylindrical Shells Under Axial Compres-

Received June 21, 1968.

* Aerospace Engineer. Associate Fellow AIAA.