DISCUSSION

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The question of agreement between theory and experiment for junctions of shells of revolution is clouded somewhat by the large localized effect of radii of fillet welds, as shown by Mershon [8].[5] The discussers' approach has been to carry out an elastic-plastic analysis and on the basis of broad overall agreement decide whether the shell theory is capable of predicting the behavior at the junction of nozzles. Two shell idealizations were used. The first was that of conventional shell theory while the second used a modification suggested by O'Connell and Chubb [9]. This last analysis replaced the vertical and horizontal forces at the junction by equivalent bands of pressure. The two idealizations are shown in Fig. 11. Figs. 12 and 13 show the results for nozzles tested by Cloud [10] and Dinno and Gill [11].

The experimental limit loads obtained for the nozzles are also shown on Figs. 12 and 13. It can be seen that the band replacement results are in good agreement with these. The discussers have concluded from this that the simple shell theory does not hold at junctions and the band replacement idealization is a reasonable theory to use for analysis of stresses at junctions.

Additional References

7 P. V. Marcal and C. E. Turner, "Elastic-Plastic Behavior of Flush Nozzles in Spherical Pressure Vessels," to be published, *J. Mech. Eng. Sci.*

8 J. L. Mershon, "PVRC Research on Reinforcement of Openings in Pressure Vessels," Welding Research Council Bulletin 77, 1962.

9 J. M. O'Connell and E. J. Chubb, "Improved Method of Calculating Stresses at the Intersection of a Cylindrical Nozzle and a Spherical Vessel," *Proceedings, Applied Mechanics Convention*, Institution of Mechanical Engineers, Paper No. 5, 1964.

10 R. L. Cloud, "The Limit Pressure of Radial Nozzles in Spherical Shells," *Journal of Nuclear Structural Engineering*, vol. 1, 1965, p. 403.

11 K. S. Dinno and S. S. Gill, "Experimental Investigation Into the Plastic Behavior of Flush Nozzles in Spherical Pressure Vessels," *International Journal of Mechanical Science*, vol. 7, 1965, p. 817.

Authors' Closure

The authors wish to thank Messrs. Marcal and Turner for their interesting discussion.

It should be noted that there were no fillets in the models tested and that the data were obtained for loadings in the elastic range only. The conventional linear elastic shell analyses (as defined by references [1] and [4]) are not expected to predict accurately the plastic behavior of shells. Neither does it apply to thick shells although correction factors are often used. For fillets of significant size, such innovations as varying the thickness of the shells would make for better agreement between theory based on closed-form solutions and experiment. The authors agree that the band replacement method may well improve the agreement between theory and experiment near the junction.

A method has recently been published for comparing theory and experiment by which the applicability of conventional shell analyses may be investigated [12].[6] Investigations presently being carried out using this method indicate that the stresses measured at the point on the sphere nearest the junction are not consistent with the remaining data if it is assumed that conventional shell theory is applicable. Surprisingly the stresses on the nozzles are consistent.

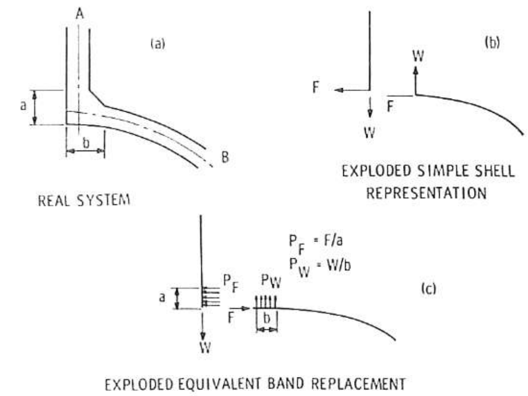

Fig. 11 Shell junction representations

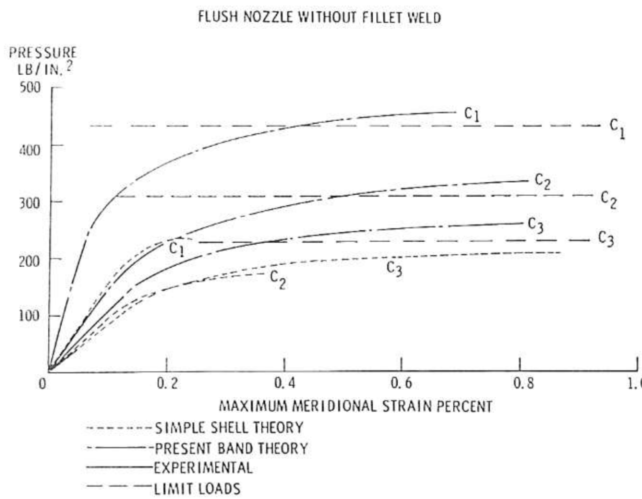

Fig. 12 Flush nozzle without fillet weld

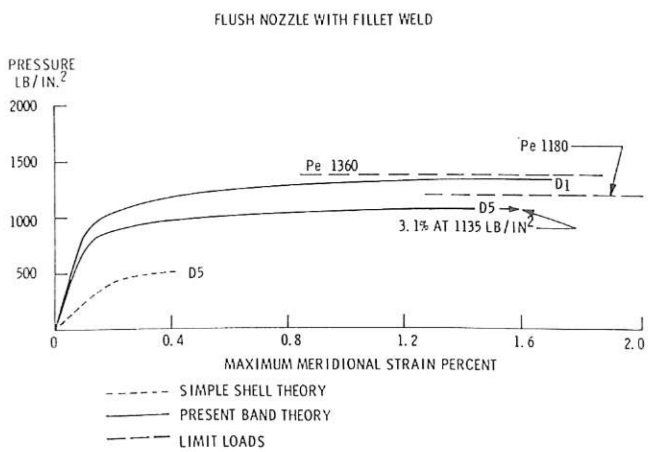

Fig. 13 Flush nozzle with fillet weld

The data presented in the paper support the conclusion that the theory, in an engineering sense, predicts the experimental results. Additional support is given by results from a photoelastic model as seen in Fig. 14. This model is identified as S-5AZ in reference [8] and has only a nominal fillet. The location of the outer surface at the junction is shown by the dashed lines on the spherical shell plots, while the experimental stresses within the wall at the junction are plotted to the left of the zero ordinate in the cylindrical shell plots. The outer surface stresses in both sphere and cylinder agree exceptionally well, even the maximum stresses within the wall at the junction. The near zero meridional or axial stress at the intersection of the inner surfaces is, of course, not predicted by the theory applied here.

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[5] Numbers in brackets designate Additional References at end of this discussion.

[6] F. J. Witt and R. L. Maxwell, "Stress-Fit Applications to Experimental Shell Analyses," *Experimental Mechanics*, vol. 7, no. 1, January, 1967, pp. 36–40.

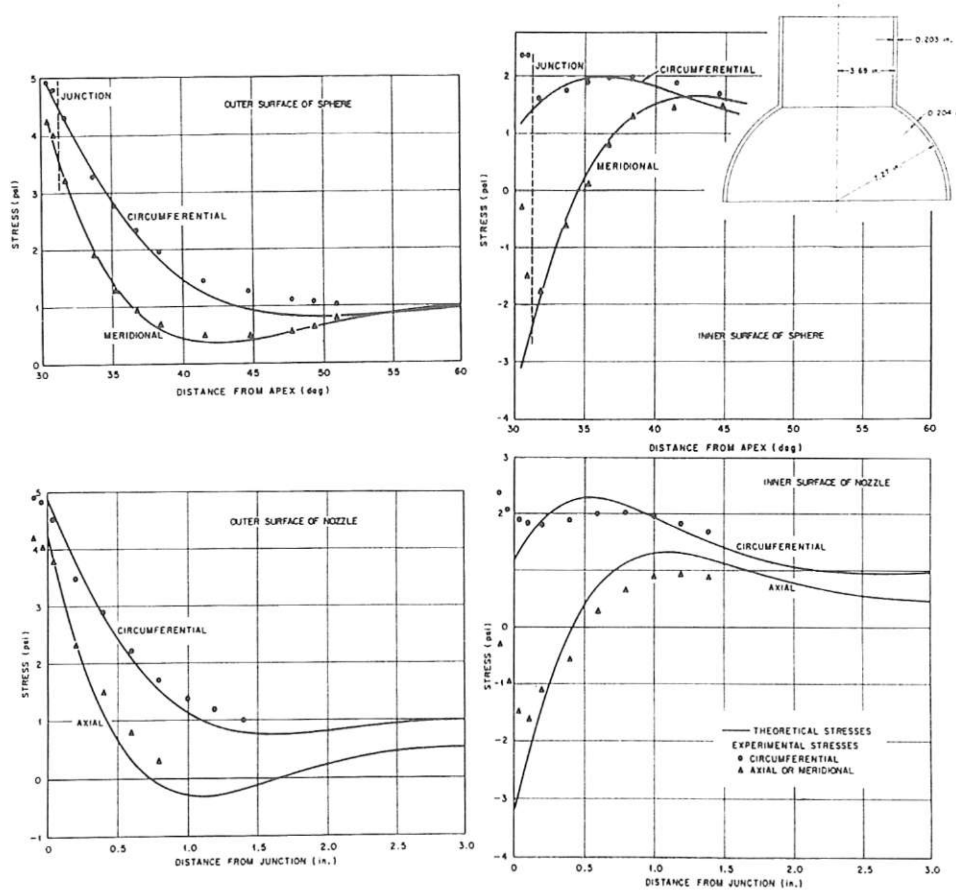

Fig. 14 Comparison of theoretical and experimental stresses on model S-5AZ for an internal pressure of 0.056 psi