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COMPARISONS OF TEST AND THEORY FOR NONSYMMETRIC ELASTIC-PLASTIC BUCKLING OF SHELLS OF REVOLUTION

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(This is an abridged version. See the full-length paper for more: bosor5.papers/1974.galletly.pdf)

ABSTRACT

Experimental and analytical buckling pressures are presented for very carefully fabricated thin cylindrical shells with 45, 60 and 75° conical heads and for cylindrical shells with torispherical heads pierced by axisymmetric cylindrical nozzles of various thicknesses and diameters. Nonsymmetric buckling occurs at pressures for which some of the material is loading plastically in the neighborhoods of stress concentrations caused by meridional slope discontinuities. The buckling pressures for the cone-cylinder vessels are predicted within 2.6 per cent and for the pierced torispherical vessels within 4.4 per cent with use of BOSOR5, a computer program based on the finite difference energy method in which axisymmetric large deflections, nonlinear material properties and nonsymmetric bifurcation buckling are accounted for. The predicted buckling pressures of the pierced torispherical specimens are rather sensitive to details of the analytical model in the neighborhood of the juncture between the nozzle and the head. The buckling pressures of the cone-cylinder vessels can be accurately predicted by treatment of the wall material as elastic, enforcement of the full compatibility conditions at the juncture in the prebuckling analysis, and release of the rotation compatibility condition in the bifurcation (eigenvalue) analysis.

INTRODUCTION

Numerous bifurcation buckling analyses involving plasticity have been applied to simple structures with uniform prestress. Shanley [l] and Onat and Drucker [2] studied columns; Stowell [3], Handelman and Prager [4], and Gerard and Becker [5], investigated plates; and Bijlaard [6], Batterman [7], Jones [8], Hutchinson [9], and others [l0] treated shells. Recently Lee [l1] calculated bifurcation buckling pressures of elastic-plastic ring-stiffened cylinders, including nonlinear and nonuniform prebuckling stress states. Hutchinson [12] gives an excellent survey of the field, providing a firm, rational foundation for the application of bifurcation buckling analysis to predict the failure of practical shell structures.

With the high speed digital computer it is now feasible to calculate elastic-plastic bifurcation buckling loads of rather complex shell structures. In [13] Bushnell gives the nonlinear axisymmetric prebuckling theory for segmented, branched shells of revolution and in [14] the analysis for nonsymmetric bifurcation buckling is presented. The purpose of this paper is to provide evaluation of these analyses by comparison with tests of very carefully fabricated vessels submitted to uniform external pressure. Two series of tests were conducted, the first on six torispherical heads with axisymmetric nozzles (Fig. 1), and the second on three cone-cylinder vessels (Fig. 9).

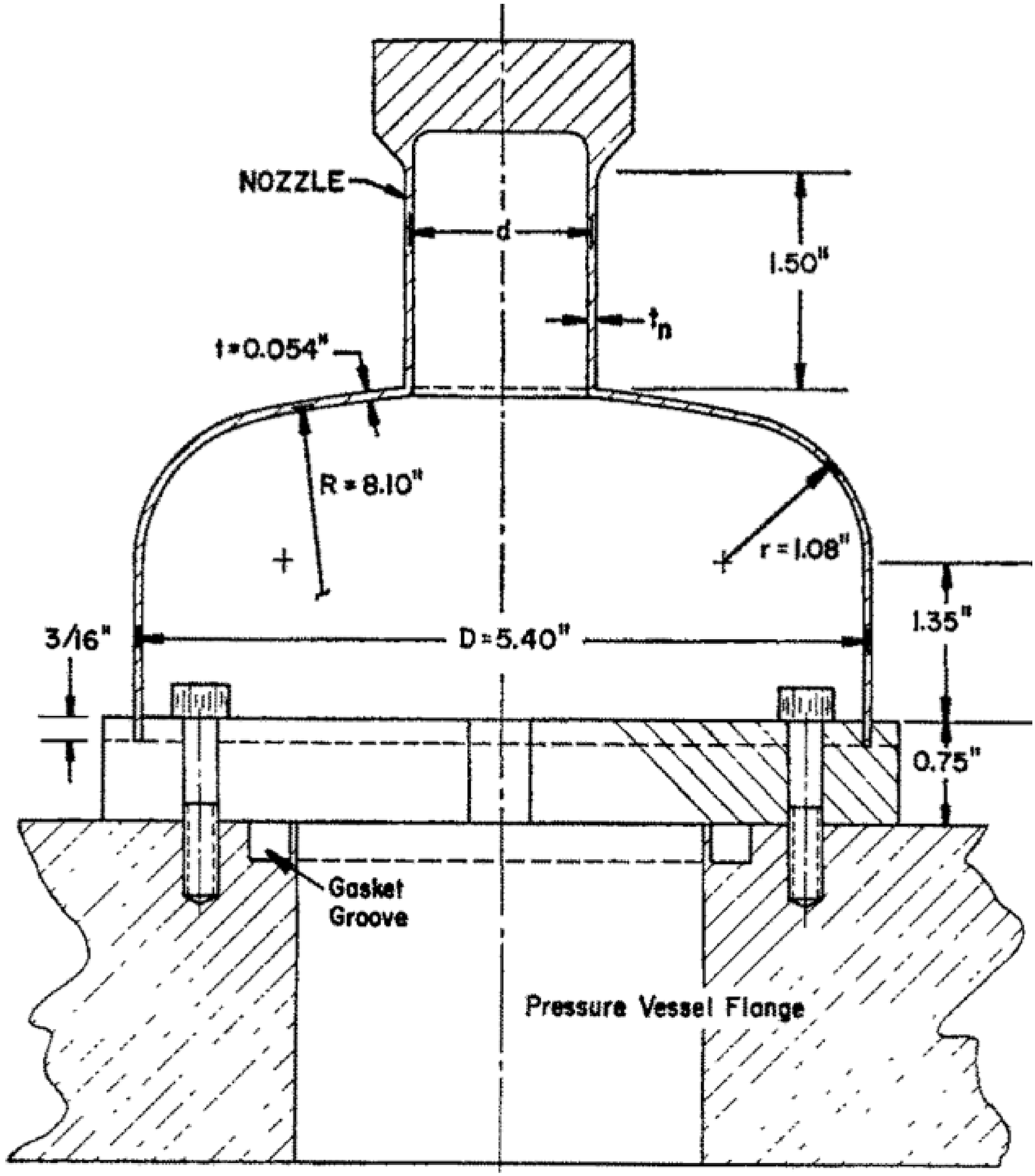
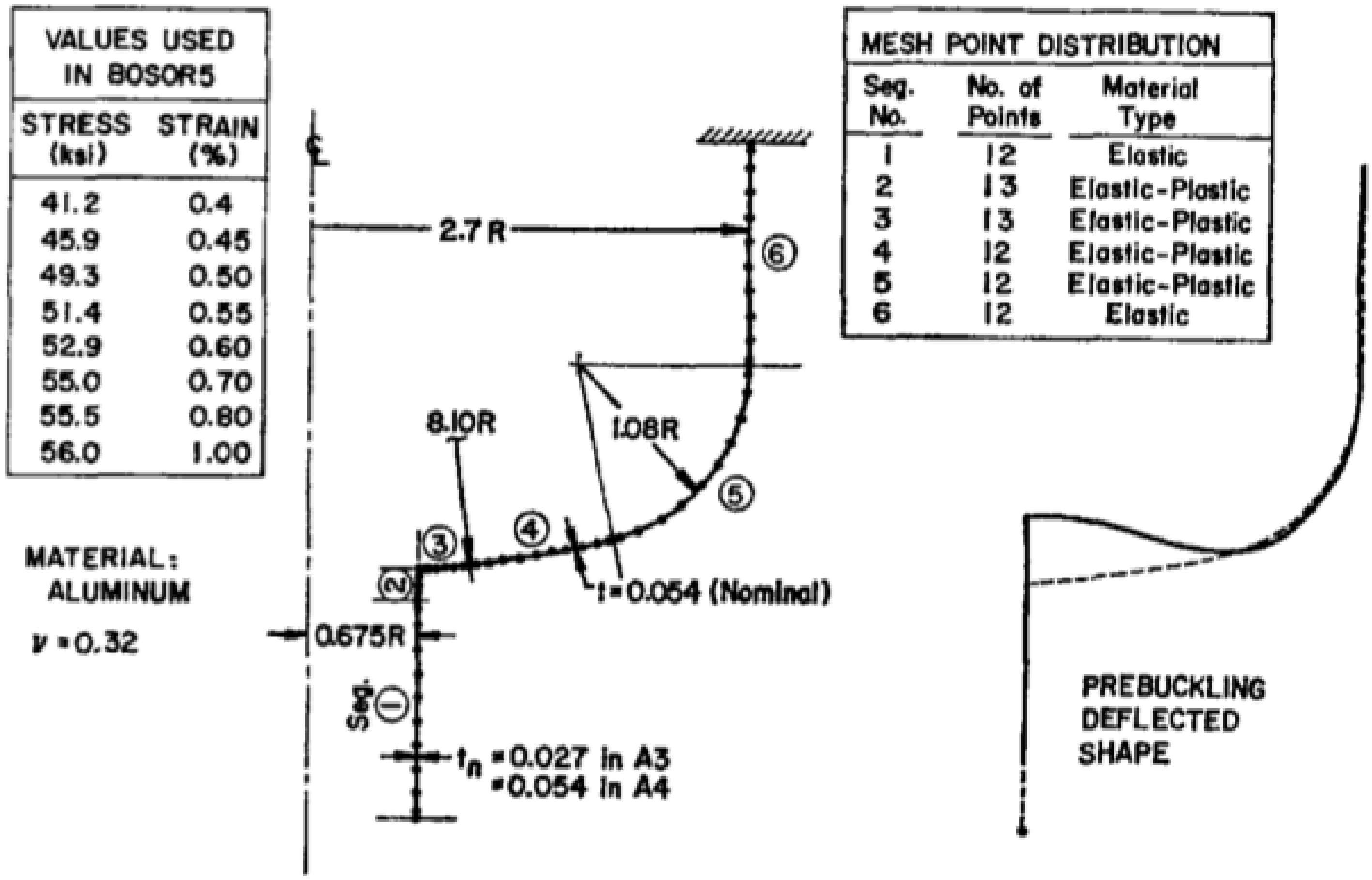


Fig. 1 Torispherical pressure vessel with axisymmetric nozzle tested under external pressure by Galletly at the University of Liverpool. (from International Journal Solids Structures, Vol. 10, pp. 1271-1286, 1974)



VALUES USED IN BOSOR5	
STRESS (ksi)	STRAIN (%)
41.2	0.4
45.9	0.45
49.3	0.50
51.4	0.55
52.9	0.60
55.0	0.70
55.5	0.80
56.0	1.00

MESH POINT DISTRIBUTION		
Seg. No.	No. of Points	Material Type
1	12	Elastic
2	13	Elastic-Plastic
3	13	Elastic-Plastic
4	12	Elastic-Plastic
5	12	Elastic-Plastic
6	12	Elastic

Fig. 2 Discretized model of Specimens A3 and A4 with material properties and exaggerated prebuckling deflected shape. (from International Journal Solids Structures, Vol. 10, pp. 1271-1286, 1974)

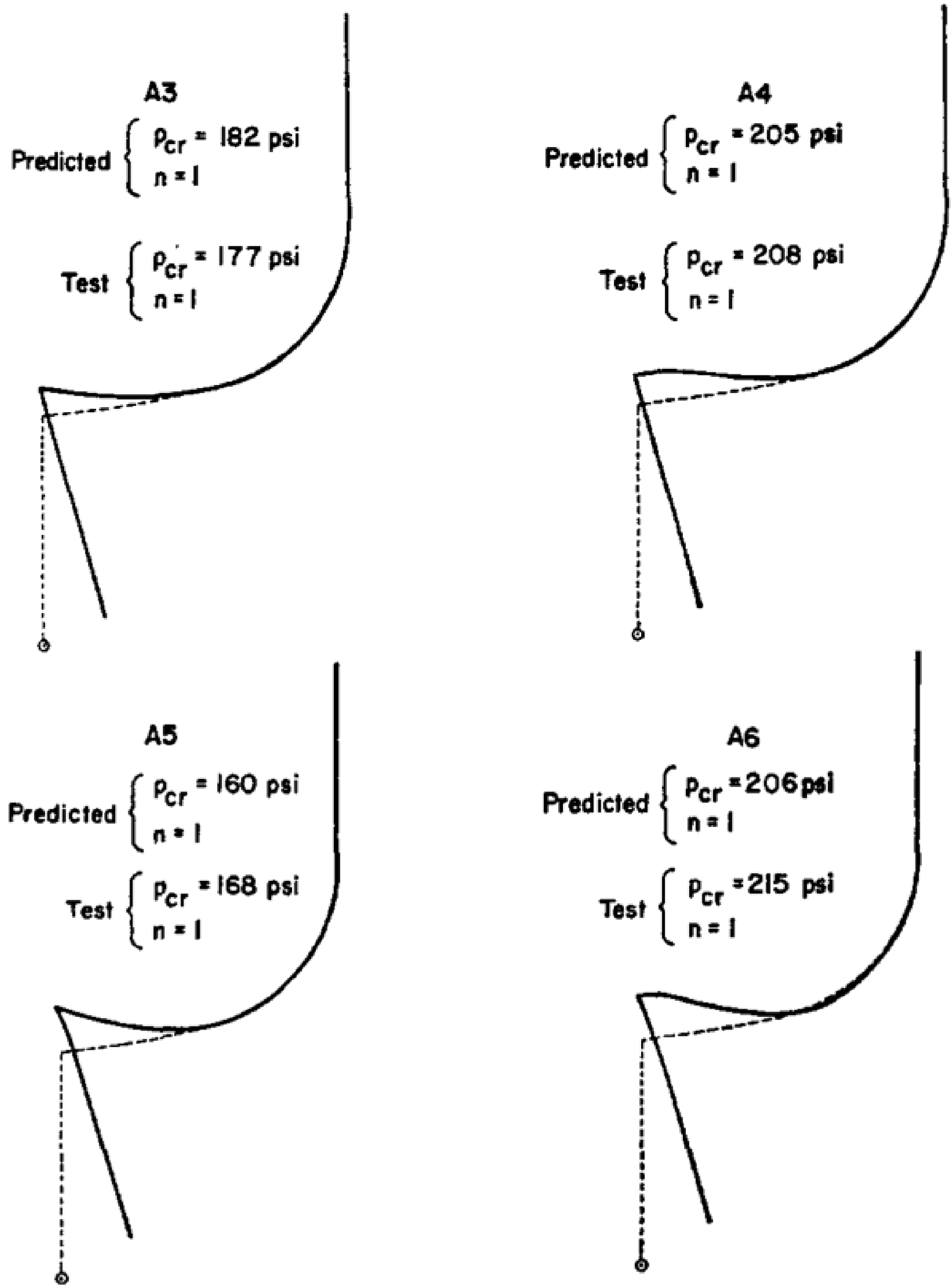


Fig. 5 Predicted bifurcation buckling mode shapes for specimens A3 – A6. (from International Journal of Solids and Structures, Vol. 10, pp. 1287-1305, 1974)