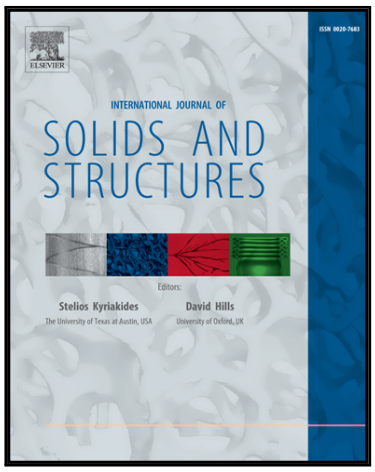

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Imperfections and Energy Barriers in Shell Buckling

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Abstract: The elastic buckling of shell structures such as spherical shells subject to external pressure and cylindrical shells loaded in axial compression is highly sensitive to imperfections and often catastrophic. Recent studies of spherical shells have provided accurate quantitative results for the relation between the buckling pressure and the amplitude and shape of geometric imperfections and, additionally, quantitative results for the energy barrier that must be overcome to buckle the shell by extraneous loadings or disturbances when it is loaded to pressures below the buckling pressure. Results for the simultaneous interaction of imperfections and energy barriers for spherical shells under external pressure will be presented. Numerical studies for probing forces illustrate their use in determining the buckling energy barrier, and new experimental results on energy barriers obtained by others by probing spherical shells will be discussed and compared with predictions. It will be argued that while imperfections determine the buckling load of a shell, the energy barrier at loads below the buckling load supplies important additional information about the relative safety or precariousness of the shell to additional disturbances. Results for the energy barrier for perfect and imperfect spherical shells under external pressure provide important insights into the shell's robustness, or lack thereof, at pressures below the buckling pressure. In particular, the energy barrier trends provide critical insights into the low knockdown factor usually employed in establishing the design load of unstiffened spherical and cylindrical shells. These design loads are shown to correlate with conventional predictions provided that imperfection amplitudes scale as the shell radius.

Key words: Buckling, spherical shells, cylindrical shells, imperfections, energy barrier, knockdown factors

1. Introduction

While shell buckling is not as active a research area as in was in the middle decades of the last century it seems to remain true that "everyone loves a buckling problem" (Budiansky & Hutchinson, 1979). George J. Simitses, to whom this paper is dedicated, certainly projected this attitude in his text book on buckling (Simitses & Hodges, 2006). This paper attempts to provide a unified view of two aspects of shell buckling: the enduring issue of imperfection-sensitivity and the more recently identified concept of the energy barrier to buckling. We first review recent theoretical and experimental results for the effect of dimple imperfections on the elastic buckling of spherical shells under external pressure. Then, the focus turns to the energy barrier that must be overcome by extraneous disturbances to trigger buckling of perfect and imperfect