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Experiments on dented cylindrical shells under peripheral pressure

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ABSTRACT

In spite of numerous papers in the literature on the buckling behavior of cylindrical shell structures, the effect of local large imperfections caused by physical contacts has not been exhaustively examined yet. To this end, this paper reports on an experimental program on the buckling and post-buckling response of thin cylindrical shells with local dent imperfections under uniform external pressure. The results of this study can be used in practical structures with similar geometric features, i.e. D/t ratio.

1. Introduction

Steel shells are commonly used as structural members in the industry. These structures are vulnerable to the buckling phenomenon when they are subjected to compressive stresses. Such structures are sometimes subject to external pressure, which is applied to these structures from outside the surface such as submarine pressure hulls. In some cases, an internal vacuum occurs due to discharge of a liquid so that atmospheric pressure acts as uniform external pressure.

Many researchers have investigated such structures under different loading conditions to assess the buckling capacity of these structures. During the past fifteen years, Showkati and his coauthors exhaustively investigated such structures under vacuum. These experiments were mostly performed on structures with normal fabrication-related geometric imperfections. Showkati and Ansourian investigated the buckling behavior of thin cylindrical shells under external pressure. They thoroughly assessed the effect of boundary conditions on the buckling behavior of such structures [1]. Buckling of thin shells under atmospheric peripheral pressure was investigated by Showkati and Golzan and the effect of small amplitude imperfections was examined in this research [2]. Aghajari et al. conducted experiments on cylindrical shells with varying thickness [3]. They advised the usage of shells with less thickness variation subjected to external pressure. In recent years, Ghanbari Ghazijahani et al. investigated thin-walled steel structures with high D/t ratio [4–9]. It was found that even very small amplitude geometric irregularities may lead to big differences between experiments and theoretical predictions as these structures are highly sensitive to the geometrical features. Buckling behavior of cylindrical shells with longitudinal joints was studied by Wang and Koizumi through both numerical and experimental modeling [10]. It was found that regardless of the geometric dimensions of the models buckling was strongly affected by features of the longitudinal joint, which can be rigid or flexible. Vacuum-induced buckling capacity of shells with D/t ratio of around 800 was investigated by De Paor et al. [11] and the effect of closely measured imperfections was evaluated.

Most recently, weld-induced local imperfections were studied by Showkati and his co-researchers on cylindrical and conical shells [12–14]. Despite large local imperfections, such structures showed a stable post-buckling behavior regardless of initial imperfections. In some cases weld-induced imperfections even had a strengthening effect on these structures.

Rathinam and Prabu, and Ghanbari Ghazijahani and Showkati numerically investigated thin structures with dent imperfections [15–17]. They showed the effect of location and depth of the dent on the critical buckling load of such structures. Despite these studies, no experimental data is found in the literature investigating the effect of dent imperfection on thin cylindrical shells under external pressure. To this end, the present study aimed to explore the real behavior of dented shells under uniform peripheral pressure. 14 specimens were tested which were indented in different depths. The results are compared with the available data

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Fig. 1. Two instances of local dent-shaped irregularities on steel shell structures [18].

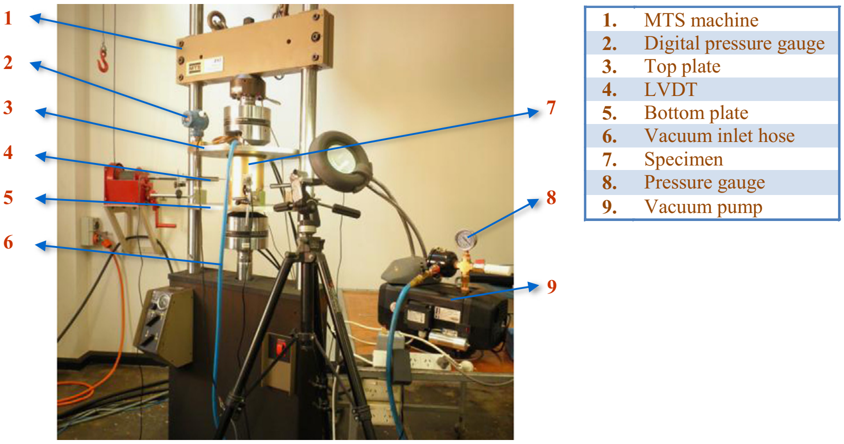

Fig. 2. Overall view of the test apparatus.

in standards and design codes and some recommendations are made for real structures based on the presented results. Two instances of local dent-shaped irregularities on steel shell structures are shown in Fig. 1.

2. Experimental modeling

2.1. Test rig

In the present experimental work, a MTS machine was employed in order to constrain the boundary regions of the pressure chamber, i.e. cylindrical shells (see Fig. 2). Two plates were placed as top and bottom end plates so as to create a circumferential restraint all around the edges of the specimens. A circular groove was machined in each end plate to properly fix the specimens. The grooves were designed with a small tolerance in diameter which allowed the shell specimen to be conveniently installed. The plates were gripped by the MTS machine so that the vertical distance of the plates could be readily controlled. The grooves were fully sealed with a flexible sealant in order to avoid air leakage during the tests.

2.2. Specimens

Precisely fabricated thin specimens with D/t of around 759 ($D=151.77$ mm) and L/D of 1.44 were used in this research (see Fig. 3 and Table 1). The material of the specimens was mild steel. Material properties were obtained from tensile coupon test conducted on the specimens showing a Young's modulus of 210 GPa and $\nu=0.3$ as the main material properties in buckling studies. The specimens had two flat end caps attached, made from the same material as the shell specimens.

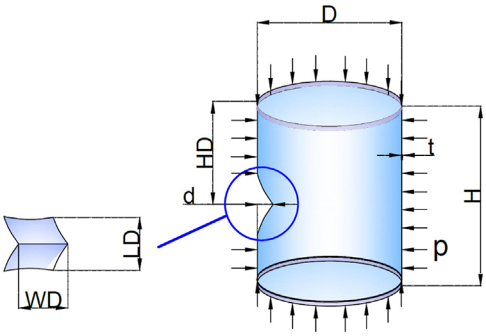

Fig. 3. Geometry of dented shells under external pressure.

Table 1
Specimens and dent specifications.

Geometry	Specimen	Orientation of the dent	*d* (mm)	*HD* (mm)	*HD*/*H*	*WD* (mm)
	EXC.1	–	–	–	–	–
	EXC.2	–	–	–	–	–
	EXC.3	Horizontal	0.9	110	0.5	19
$D/t=758.85$	EXC.4	Horizontal	1.5	110	0.5	31
	EXC.5	Horizontal	2.3	110	0.5	50
$t=0.2$ (mm)	EXC.6	Horizontal	5	110	0.5	68
	EXC.7	Vertical	0.7	110	0.5	21
	EXC.8	Vertical	1.2	110	0.5	31
$H/D=1.45$	EXC.9	Vertical	1.8	110	0.5	54
	EXC.10	Vertical	3	110	0.5	80
	EXC.11	Diagonal (45°)	0.6	110	0.5	20
	EXC.12	Diagonal (45°)	1.6	110	0.5	36
	EXC.13	Diagonal (45°)	2.2	110	0.5	55
	EXC.14	Diagonal (45°)	4.3	110	0.5	78