Buckling Analysis of Thin-walled Cylindrical Shell with Random Geometric Imperfection under Compression

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1. INTRODUCTION

Cylindrical shells are widely used in the most diverse branches of civil engineering technologies because of they combine light weight with high strength [1]. However the buckling strength and post-buckling behavior prediction are extremely complex especially for thin-walled ones. [2] Initial geometric imperfections are normally known to have a strong detrimental on the buckling strength and to be the reason of large discrepancy between experimental buckling loads and theoretical predictions. Moreover random imperfections in real shells are not known at the stage of design and may take a complex form. In order to assess the buckling strength at the design stage, predicted buckling load is reduced by knock-down factor based on design criteria. In order to investigate the effects of geometric imperfections on the buckling strength and post-buckling phenomena of thin-walled cylinders, these investigations were carried out both experimentally and numerically.

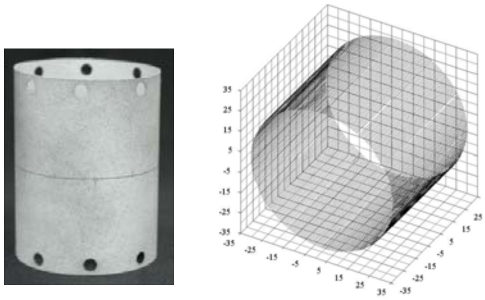
In present paper, a general approach is proposed for modeling the geometric imperfection of thin-walled shell specimens by utilizing 3-D digital image correlation method (DICM), an optical non-contact and full-field measurement, details of this equipment was described in reference [2]. Realistic geometric imperfection of thin-walled shell specimens were obtained and applied in numerical simulation, the thickness of specimens used in this experiment is 0.131mm and the ratio of external diameter (R) to thickness (H) R/H is 250. Procedures of scanning on the geometric imperfection of thin-walled shell specimen and its application in numerical simulation are described detailed in this paper. The experimental investigation agrees well with the numerical simulation on both the strength and buckling behaviors. Therefore by using this effective approach the potential of strength capacity can be tapped in real thin-walled shell structures and it is demonstrated the visualization of buckling behaviors with initial random geometric imperfections by using this digital image correlation technique.

2. EXPERIMENTAL INVESTIGATION

In this experiment, aluminium cylinder shells are employed, parameter details are listed in Table 1 and the schematic of specimen is shown as Figure 1(a). Specimen is cleaned with a degreaser from residue of meld release products used during the manufacturing of the composite panel. A white (or black) base paint is sprayed on the surface of the specimen to form a thin uniform background. After the base colour is dried, a speckle pattern of black (or white) is sprayed on the same face to form a random pattern covering approximately 50% of the face. The speckles should be of the same size as the speckles on the calibration plate used during calibration of the system.

Table.1: Specimens` parameter

Internal diameter R/mm	External diameter R_0/mm	Thickness H/mm	R/H	Length L/mm	L/R_0	Shape factor Z
32.935	33.000	0.131	252	66.0	2.0	963



(a) (b)

Fig.1 (a) Schematic of thin-walled specimen (b) Mesh model of specimen with initial imperfection

In this experiment, by using DICM, initial imperfection of thin-walled specimen is measured every 30 degrees, it means that 12 pieces of pictures are taken, then stretch out views are connect and the mesh model is obtained by using the matching software developed in our lab with the name of DM (DICM Matching). The mesh model is show in Figure.1 (b) and the imperfection distribution measured by this approach is shown in Figure.2 as follows.

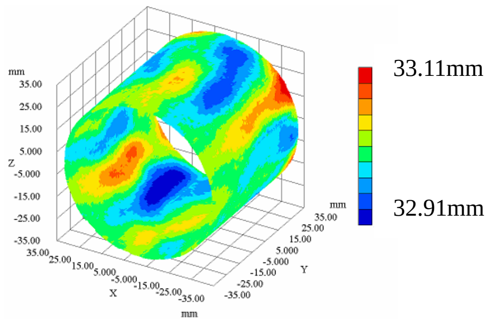


Fig.2 Initial geometric imperfection contour of cylindrical shell specimen measured by DICM

Moreover the compression test was carried out on the same specimen with a control displacement of

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0.15mm and the loading speed is 0.02mm/min by utilizing the servo-compression equipment and optical measurement. Displacement distribution and load displacement curves are compared later in this paper.

3. NUMERICAL SIMULATION

In order to clarify that this optical method can be used to describe the initial geometric imperfection, so that the buckling strength and buckling phenomena of thin-walled shell structures can be evaluated with out experimental investigations, numerical simulations were carried out using the general commercial finite element program MSC.Marc Mentat 2005. Mesh model with geometric imperfections which obtained as above is employed in our numerical simulation, boundary condition is that bottom boundary condition is perfect fixation; the top boundary condition is displacement y free, and a loading method is compression loading. Young’s modulus is 70GPa, Poisson’s ratio is 0.3. Comparison of experimental investigations and numerical simulation are as follows:

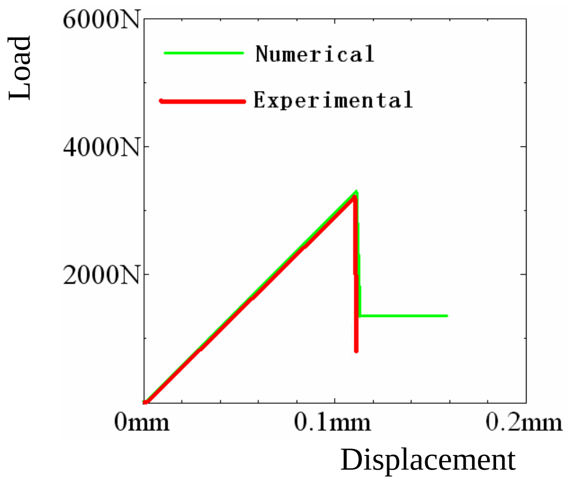
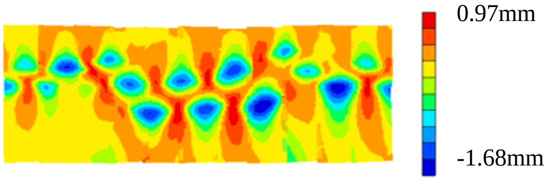
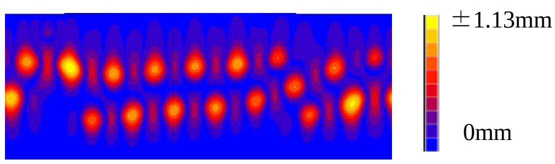


Fig.3 Buckling strength comparison

Figure.3 shows the comparison of experimental results and numerical simulation of thin-walled cylindrical shell specimen with the same random initial geometric imperfections. The experiment strength is 3272N and the simulation one is 3372 which the accuracy is 97%.



(a) Stretch out view of experiment result



(b) Stretch out view of simulation result

Fig.4 Buckling model comparison

As to the buckling model, the experimental result also agree very well with the simulation one as it is shown in Figure.4, the effect of geometric imperfection on thin-walled specimen is obviously in this comparison. Moreover the perfect mesh model is also analyzed and compared as follows in Figure.5

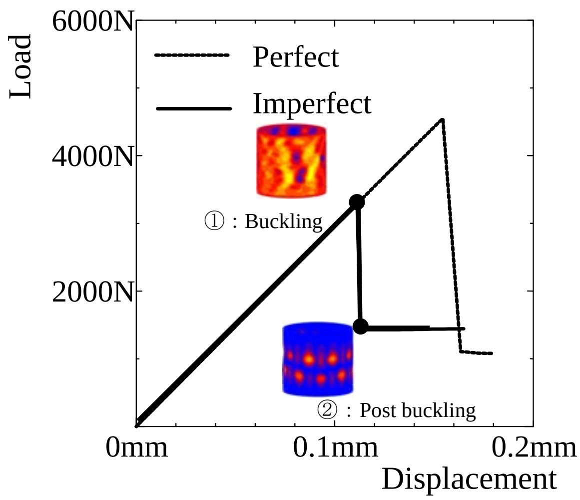


Fig.5 Buckling strength comparison of thin-walled specimen with/without geometric imperfections

The simulation clarify it again that thin-walled shell specimen is sensitive to geometric imperfections as it is shown that the strength can be reduced from 4872N to 3278N which means it is only 67% of the perfect one. While the maximum value of imperfection is within 0.15mm and the average one is only 0.05mm, with is 38% of the shell thickness and 0.15% of the radius of the specimen.

4. CONCLUSIONS

By using DICM, mesh model of thin-walled cylindrical shell specimen with initial imperfection is achieved and can be easily employed in the numerical simulation, which is an efficient and accurate method and would be conduced to the research of thin-walled structures. By the comparison of numerical simulation, it is clarified that the initial geometric imperfections have a great effects on the buckling behaviours of thin-walled cylindrical shell structures. This verified the urgency and necessity again of the application of optical DICM on thin-walled structure studies.

ACKNOWLEDGEMENT

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