Buckling of Thin-walled Cylinder Shell Specimens with Cut-out Imperfections

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Summary

In present paper, effects of imperfections on the buckling behaviours of aluminium thin-walled cylindrical shells under compression are investigated by experimental and numerical methods. The imperfections are produced by one or two circular cut-out on the shell surface. Recently, a lot of numerical analysis have been carried out by using cylindrical shell with imperfections. However, there are a few experimental substantiations. Further more, the combined effect of two circular cut-out on the buckling load of cylindrical shell is not treated from experiment point of view. In this experiment, Digital Image Correlation Method (DICM) was used to obtained 3D displacement and strain data of the specimens during the test. Numerical simulations are also calculated. In this study, the difference between them and the effects of parameter on the buckling load of specimens are also discussed. It is shown that the experimental and FE analytical results combine well. Moreover, the effects of imperfections found to be sensitive to the buckling load of specimens.

Keywords: DICM; buckling; cylinder shell; geometric imperfection; compression.

1. Introduction

Cylindrical shells are commonly used in engineering structures such as aircraft, pipelines, tanks, automobiles, aerospace structures, and some submarine structures. During their service lives, these components are often subjected to axial compressive loading. In addition, these structures often have geometric discontinuities, such as cut-out, which can lead to substantial stress concentrations and subsequently influence the stability of the structures. The buckling research of cylindrical shells has attracted the attention of several scholars for more than a hundred years. Several experimental investigations [1, 2] have proved that the buckling capacity of thin cylindrical shells are often much lower than that predicted by the classical theory. Available numerical and experimental studies on the buckling of imperfect composite shells (e.g. [3]) have shown that the linear buckling analysis provides a lower bound to the experimental buckling capacity. Only a few researchers have considered the effect of cut-out on the buckling behaviours of cylindrical shells. In this paper, a series of non-linear finite element analyses were conducted to examine the influence of cut-out on moderately thin-walled cylindrical shells. Experiments were also conducted to verify the results in moderately thin-walled shells; it is found that the experiments agree well with numerical simulations. The buckling and post-buckling behaviours of these shells were characterized.

2. Experimental Investigations

The axial compression tests of cylindrical shell with circular cut-out using the Digital Image Correlation Method (DICM) were conducted to compare with the analytical results. The measuring range of DICM is half surface of cylindrical shells. The automatic frequency of system shutter is 1 picture/sec, and image data were captured between initial load and maximum load. The 3D Digital Image Correlation Method is an optical instrument for full-field, non-contact and three-dimensional measurement of deformations and strains on components and materials as shown in Figure.1 and Cylindrical shells are made of aluminium alloys (A1070-0) with Young's modulus E = 6×104MPa

https://doi.org/10.2749/222137809796088314
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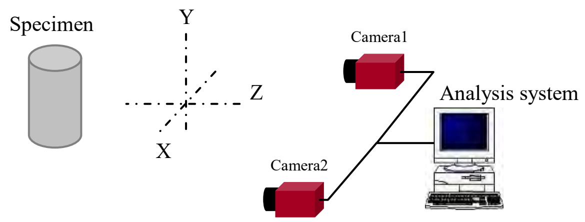

Fig.1: Schematic diagram of DICM

and Poisson ratio ν = 0.3. It's yield strength σ y is 46MPa. Lower boundary are fixed, and Z-axial direction displacement load was used in the compression test. Loading speed is 0.3mm/min. Maximum displacement is 5mm.

3. Numerical Simulation

The numerical simulations were carried out using the general commercial finite element program MSC.Marc Mentat 2005. The shell 139 element (QUAD 4) was used to model the shells. This element is suitable for analysing thin and moderately thick shell structures. The FE model consists of the perfect cylindrical shell, as there is no geometrical asymmetry due to the presence of the cut-out, details of numerical simulation are descript in the full paper with figures and tables.

4. Results

There are a few differences between experimental and numerical buckling loads. Those for specimens S-0 and M-0 are almost 500(N). The maximum influence value between experiment and FE analysis is 954(N) on the M-4-h1. The minimum buckling load is 251(N) on the S-2-h2. The ratio of N (buckling load of perfect specimens) over N0 (buckling load of specimens with cutous) is obtained as a dimensionless value. As to the displacement distribution, experiments show good correlation with simulations. With regard to the experimental results, there are a few influences between each correlation of specimens.

This influence occurred due to initial geometric imperfections of geometry around the cut-out and axial loading or boundary. For example, the circumferential displacement *dR* distribution of initial geometric imperfection of M-2-h2 is shown Fig.2 for comparison, which measured DICM. Present FE model will need the geometric property on these initial geometric imperfections for analysing a perfect simulation.

5. Conclusion

The effects of imperfections on the buckling behaviours of aluminium cylindrical shells under compression are investigated experiment results agreed well with the numerical simulation. The influence of initial imperfections was clarified in both way too. With regard to further researches, it was necessary to investigate initial geometric imperfection sensitivity quantitatively. It will be a probabilistic approach point of view of this research in the future.

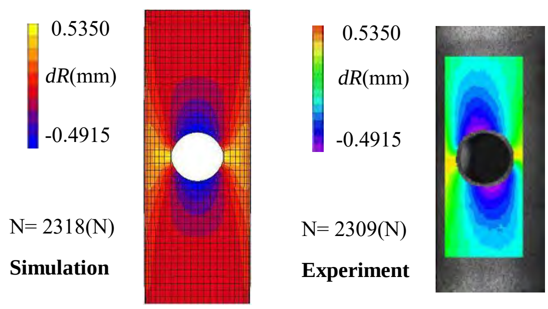

Fig.2 Circumferential displacement dR

Acknowledgement

This work was funded by Sasakawa Scientific Research Grant from Japan Science Society.

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