

Experimental investigation of buckling behavior of cracked cylindrical shells subjected to axial compression

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ABSTRACT – The aim of this experimental research work is to investigate the effect of axial crack length on the buckling behavior of cracked cylindrical shells subjected to axial compression loading. The crack on the cylindrical structures is assumed to be a percentage of the axial length of the cylindrical shell structure. The magnitude of the crack length-to-cylinder axial length is varied between 0.05 and 0.15. Cylindrical specimens are made from mild steel with radius-to-thickness ratio, ranging from 25 to 100. The axial length of the specimens was assumed to be constant. Results indicate that the crack length strongly affect the buckling behavior of the axially compressed cylinder. Also, it was revealed that the buckling load of the cylindrical specimens with high value of radius-to-thickness ratio is more sensitive to the effect of change in crack as compared to cylinder with low value of radius-to-thickness ratio.

1. INTRODUCTION

It is a known fact that the presence of defects such as cracks on a shell structures can play the role of geometrical imperfection and thereby reduce the buckling load of the shell structures considerably [1]. Research into buckling behavior of cracked cylindrical shell structures with the presence of crack can be found in Refs [2-5]. Motivation for the presents work originates from the conclusion of Ref [5], where it was reported that for cylindrical shells with axial crack (longitudinal crack), the change in crack length and increasing the crack length-to-circumference of cylinder ratio, has minor effect on the buckling load of the cylinder. This paper investigate the effect of ratio of axial crack length to cylinder axial length ranging from 0 – 0.15 on the bucking behaviour of axially compressed cylinder. This is purely experimental work.

2. METHODOLOGY

2.1 Background

For this research work, circular cylinders with radius-to-thickness ratio, R/t , ranging from 25 to 100 were subjected to axial compressive loading. The cylinder is assumed to have a constant inner diameter, D , of 100 mm, constant axial length, L , of 111.8 mm and wall thickness, t , of (2 mm, 1 mm and 0.5 mm)

respectively. The cylinder has axial crack of various length introduced along its longitudinal axis as illustrated in Figure 1. The magnitude of axial crack, $2a$, to the cylinder axial length, $2a/L$, was varied between 0.0 to 0.5. Cylindrical shells are assumed to be made from A36 mild steel with material properties presented in Table 1 (see details about material properties extraction in [6]).

Table 1 Average mechanical properties of A36 steel material obtained from uni-axial testing.

Specimen thickness (mm)	E (GPa)	Upper yield (MPa)	UTS (MPa)
0.5	193.7	203.1	305.8
1.0	214.0	256.2	333.2
2.0	241.4	322.1	374.4

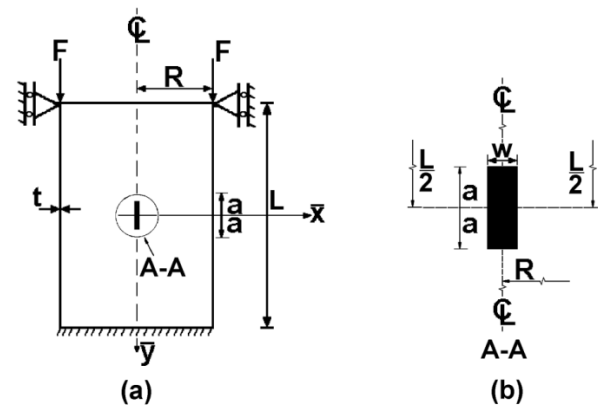


Figure 1 Section through cylindrical shell (Fig. 1a). The insert illustrates the crack region (Fig. 1b).

2.2 Experimentation

For this experiment, cylindrical shells with three different thickness ($t = 0.5, 1.0, 2.0$ mm) were manufactured and tested. Cylinders were manufactured using Metal Inert Gas (MIG) welding process. During the welding process, axial crack of varying length was introduced on all the specimens. The magnitude of axial crack, $2a$, to the cylinder axial length, $2a/L$, was varied between 0.0 to 0.15. Then, all cylinders were subjected to axial compression using INSTRON machine. Incremental axial load was applied at the rate of 1.0 mm/min.

3. RESULTS AND DISCUSSION

During the experiment, the buckling load of the cylinder corresponding to the different values of axial crack length was recorded using the machine controller. Figure 2 depicts the plot of buckling load corresponding to different imperfect cylinders having a crack against increasing length of crack for different radius-to-thickness ratio, R/t . The vertical axis is normalized by the respective collapse load for the perfect cylinder for each radius-to-thickness ratio. The corresponding magnitudes of the buckling loads are presented in Table 2.

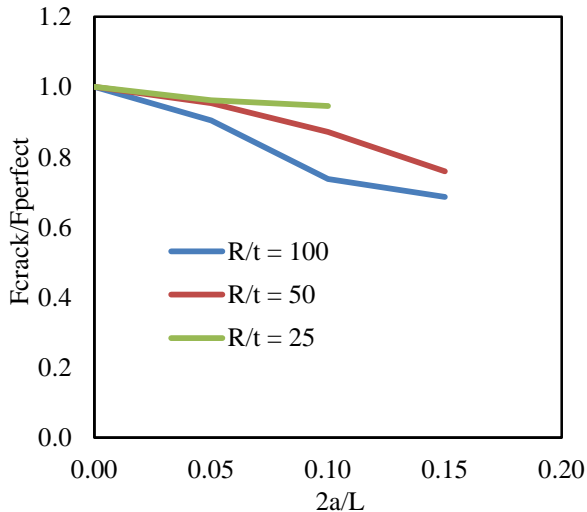


Figure 2 Plot of buckling load versus increasing crack length of axially compressed cylinders with different radius-to-thickness ratio.

Table 2 Magnitude of buckling load obtained with increasing crack length for different radius-to-thickness.

$2a/L$	Buckling load for different R/t (kN)		
	100	50	25
0	30.13	84.67	208.56
0.05	27.24	80.79	200.69
0.1	22.23	73.81	197.18
0.15	20.67	64.28	-

It can be seen from Figure 2 that increasing the crack length of the cylinder results in decrease in the load carrying capacity of the structures. This result appears to be in agreement with published work in open literature as in Refs [2-4], i.e., load carrying capacity of the cylindrical shell structure reduces as the axial crack length increases.

Also, it is apparent from Figure 2 that the effect of axial crack length is more pronounced for cylinder with higher value of radius-to thickness ratio as compared to cylinder with much lower value. For example, with ratio of crack length of axial length of the cylinder, $2a/L$, of 0.05, the percentage drop in buckling loads are 10%, 5% and 4% for radius-to-thickness ratio of 100, 50 and 25, respectively. Whilst, at $2a/L = 0.1$, the percentage

reduction for $R/t = 100, 50$ and 25 , are 26%, 13% and 6%, respectively.

In addition, the experimental data complement the work of Ref [5]. In Ref [5], it was reported that for cylindrical shells with axial crack (longitudinal crack), the change in crack length and increasing the crack length-to-circumference of cylinder ratio, has minor effect on the buckling load of the cylinder. From this work, it has been shown that this is not generally true for ratio of axial crack length to axial length of cylinder within the range of $0 - 0.15$. However, this might be true for ratio of axial crack length to axial length of the cylinder above 0.2.

4. CONCLUSION

The paper provides additional experimental results into the buckling behavior of imperfect cylindrical shell with axial cracks subjected to axial compressive force. Contrary to Shariati et al. (Ref [5]), it can be concluded that for cylinders with axial crack, change in crack length and increasing the ratio of crack length to axial length of the cylinder will cause a considerable reduction in the load carrying capacity of the cylinders, for crack length-to-axial length of the cylinder ratio ≤ 0.2 .

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