UNIVERSITI TEKNIKAL MALAYSIA MELAKA

MONITORING AND EVALUATION OF THE EFFECT OF CRACK ON THE BUCKLING BEHAVIOUR OF WELDED CYLINDRICAL STRUCTURES

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Maintenance Technology)(Hons.)

by

NOREHAN BINTI KASIMAN
B071110292
920523035766

FACULTY OF ENGINEERING TECHNOLOGY
2015

UNIVERSITI TEKNIKAL MALAYSIA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: Monitoring and Evaluation of the Effect of Crack on the Buckling Behaviour of Welded Cylindrical Structures

SESI PENGAJIAN: 2014/15 Semester 1

Saya Norehan Binti Kasiman

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☐ TIDAK TERHAD

Disahkan oleh:

(________________________)　　　　(________________________)

Alamat Tetap:

Lorong Manggis

Kampung Hubong 86900

Mersing, Johor

Cop Rasmi:

Tarikh: ________________________　　　　Tarikh: ________________________

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan d[illegible] perlu dikelaskan sebagai SULIT atau T[illegible].

DECLARATION

I hereby, declared that this report entitled "Monitoring and Evaluation of the Effect of Crack on the Buckling Behaviour of Welded Cylindrical Structures" is the results of my own research except as cited in references.

Signature	:	………………………………………….
Author's Name	:	…………………………………………
Date	:	…………………………………………

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Maintenance Technology) (Hons.). The member of the supervisory is as follow:

………………………………

(Project Supervisor)

ABSTRAK

Kehadiran retak dengan ketara dapat mengurangkan beban lengkokan struktur shell. Dalam kertas kerja ini, tingkah laku yang lengkokan kerang silinder keluli lembut dengan retak di sepanjang paksi paksi yang dikenakan mampatan paksi dibentangkan. Ini adalah kerja eksperimen yang melibatkan ujian di enam silinder keluli lembut dengan nisbah diameter ke ketebalan, D/t ≈ 100, dan dengan garis pusat kepada nisbah panjang paksi, D/t ≈ 1.11. Keputusan eksperimen menunjukkan bahawa apabila peratusan retak paksi meningkat ia menyebabkan lengkokan memuatkan shell silinder berkurangan. Dari ujian eksperimen, mod lengkokan model silinder menunjuk-runtuh lengkokan tingkah laku untuk semua spesimen yang terlibat.

ABSTRACT

Presence of crack can considerably reduce the buckling load of a shell structure. In this study, the buckling behavior of mild steel cylindrical shells with axial crack along the axial length subjected to axial compression is presented. This is an experimental work involving test on six mild steel cylinders with the diameter-to-thickness ratio, $D/t \approx 100$, diameter to axial length ratio, $D/L \approx 1.11$. The first and much needed experimental data on the effect of axial crack on the buckling behavior of axially compressed cylinder has been presented in this study. The experimental results show that when the axial crack length is increased it causes the buckling load of the cylindrical shell to decrease. Also from the experimental data, the buckling mode of the cylindrical models show collapsed buckling mode for all specimens involved.

DEDICATION

To my beloved parents, my siblings, my best friend Nurul Marina and my supervisor Dr. Olawale Ifayefunmi who give me encouragement to complete my final year project work and not to forget special thanks to all my lecturers and friends that give me guideline and support during my final year project research.

ACKNOWLEDGEMENT

First and foremost, I would like to take this opportunity to express my sincere acknowledgement to my supervisor Dr. Olawale Ifayefunmi from the Faculty of Engineering Technology, Universiti Teknikal Malaysia Melaka (UTeM) for his essential supervision, support and encouragement towards the completion of this final year project report.

Special thanks to UTeM short term grant funding for the financial support throughout this project. Particularly, I would also like to express my deepest gratitude to Mr. Fauzi Ibrahim and Mr. Fakhrulnaim, the technicians from fabrication laboratory, Faculty of Engineering Technology.

Special thanks to all my peers, my beloved parents and siblings for their moral support in completing this final year project. Lastly, thank you to everyone who had been a crucial part to the realization of this project.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ASTM	-	American Society for Testing and Materials
CAD	-	Computer Aided Design Software
FEM	-	Finite Element Methods
GPa	-	Giga pascal
MIG	-	Metal Inert Gas
MPa	-	Mega pascal
cm	-	Centimeter
mm	-	Millimeter
min	-	Minute
µm	-	Micrometer
m	-	Meter
F_c	-	Collapse force
F_{ref}	-	Reference load
t_{avg}	-	Average thickness
t_{max}	-	Maximum thickness
t_{min}	-	Minimum thickness
σ_y	-	Upper yield strength
3D	-	3-Dimensional drawing
A	-	Crack area
D	-	Diameter
L	-	Axial length
l	-	Crack length

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

N	-	Newton
t	-	Wall thickness of cylinder
Z	-	Width of crack
F	-	Force

CHAPTER 1
INTRODUCTION

1.0 Background

Cylindrical structures is one of the most common and popular structural geometry used in industrial application such as pipelines, marine structures, aerospaces, large dams, cooling towers, and liquid-retaining structures (Allahbakhsh & Shariati, 2014; Blachut, 2011). When in use, cylindrical shell structures are subjected to different loading conditions such as axial compression, external pressure, internal pressure, torsion etc (Blachut, 2014). For such application, their failure by buckling is of great importance to the structural designer. This technical challenge has sprawned up significant research in the areas of the mechanical behavior and failure of thin shell structure, under the applied load. To successfully carry out buckling analysis of cylindrical shell structure, it is important to understand the factors responsible for the buckling problem. According to (Rotter, 2002) cylindrical shells structures are often subjected to compressive stresses in the direction of the cylinder axis, which can be either uniform or varying throughout the cylinder. The buckling strength of a thin cylindrical shell under axial compression is particularly sensitive to imperfections such as crack in the shell.

This project work focuses on monitoring and evaluation of the effect of axial crack on the load carrying capacity of mild steel cylinder subjected to axial compression using experimental approach. This experimental research investigates the effect of axial crack length on the buckling behavior of mild steel cylinder when subjected to axial compression.

1.1 Problem statement

It is a known fact that the presence of crack will affect the buckling behavior of structural components resulting in failure of the structures especially cylindrical shell structures (Deshpande, et al., 2006). Small deviations from the theoretical geometry and loading can result in a considerable reduction in limit load for shells (Farshad, 1994). According to (Vafai & Estekanchi, 1996) the presence of cracks in a shell structure can play the role of geometrical imperfection and thus reduce the load carrying capacity of a shell structure. Referring to (Jahromi & Vaziri, 2012), cylindrical structures subjected to axial compression are very sensitive to defect in the structural member. From the structural point of view, the biggest impact of crack is the excessive stress, which could result in overall structure failure. Crack could also lead to large localized deformation (e.g. local buckling or plastic deformation), which can alter the structure’s load carrying capacity (Alinia, et al., 2007). Thus, there is a driving need to better understand the effect of crack on the mechanical behavior and structural performance of shells.

From the literature survey, it is evident that there is lack of experimental data on the effect of axial crack on the buckling behavior of cylindrical structures (Estekanchi & Vafai, 1997). (Allahbakhsh & Shariati, 2014; Jahromi & Vaziri, 2012; Starnes & Rose, 1997) using numerical approach introduces crack on the longitudinal axis of the cylindrical shell structure. All this research papers analyze the mechanical behavior of the cylindrical structure by using computerized software and the result obtained based are on numerical simulation. Even though, the numerical analysis tends to predict result close to experimental result, this obtained data still has to be validated by experimental result in order to ensure that all the assumptions made within the modeling are valid. This project work highlights the effect of axial cracks length on the buckling behavior of axially compressed cylindrical shell structure by experimental approach. Thus, provide the first and much needed experimental data in this research area.

1.2 Objectives

Based on the background and problem statement stated above, the objectives of this experimental research are as follow:

i. To manufacture steel cylindrical shell models with axial crack length introduced.

ii. To investigate the effect of axial crack length introduced on the load carrying capacity of the steel cylindrical shell structure under axial compression.

1.3 Scope

The scope of this project work is purely experimental work to investigate the effect of axial crack length on the load carrying capacity of welded mild steel cylindrical shell structure subjected to axial compression. The material used for the cylindrical structures is mild steel. All cylindrical specimens are manufactured to have a nominal thickness of 1mm.

The experimental work involved six specimens subjected to axial compression test using Instron machine. During manufacturing process, axial crack length is introduced along the axial direction of cylindrical steel shell structures. The selected diameter for the cylindrical structures is 100 mm. Six specimen models is labeled as (C1, C2, C3, C4, C5, and C6) with percentages of axial crack length of axial length of cylindrical models (0%, 5%, 10%, 15%, 20%, and 50%) . The load carrying capacity and buckling behavior for all structural models were analyzed.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction of buckling in thin-walled shell of cylindrical structure

Components and structural members, such as thin-walled shells and trusses with different type of geometries, form the complex and deep seated parts in the manufacturing of marine structures, large dams, rockets, airplanes, automobile etc. In engineering applications, the main purpose of such thin-walled shell structures is to support the load which they carry. When these shell structures are subjected to high load they can undergo failure due to buckling (Arbocz & Babcock, 2009). Due to slenderness of the thin-walled structure, buckling failure is one of the most popular failure considerations when designing these structures. According to (Rotter, 2002), buckling is known as nonlinear behavior of structure caused by a combination of large mode of deflections and plasticity of materials when the structure is subjected to compressive stress or heavy load. In light of such broad range practical applications, it is really crucial to investigate the failure behavior of thin-walled shell structures in order to prevent failure which in use. Typical buckling modes for axially compressed perfect cylinders are axisymmetric mode and non-symmetric mode as shown in Figure 2.1.

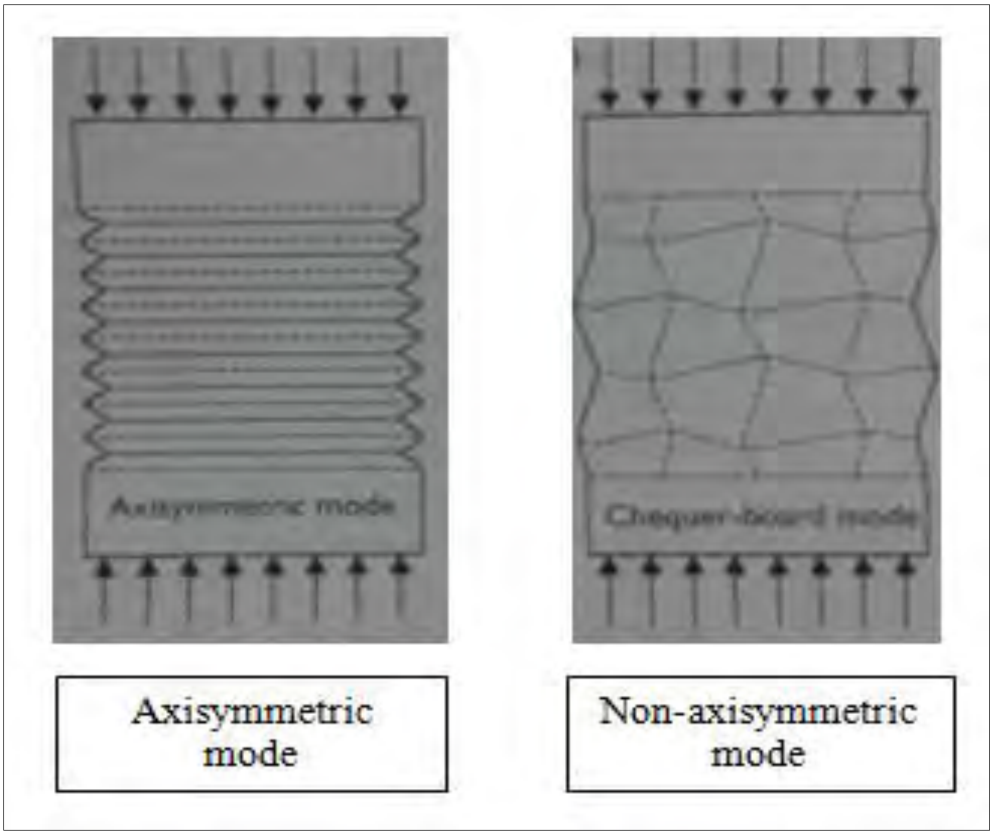

Figure 2.1: Typical buckling modes for axially compressed perfect cylinders (Rotter, 2002)

2.1 Cracks

Material discontinuity is also known as the defects in thin-walled shell structures such as crack which can cause severe and catastrophic failure of the structural member. The presence of crack can alter the structural integrity and compromise the buckling behavior especially in thin-walled cylindrical shell structure (Vaziri & Estekanchi, 2006; Estekanchi & Vafai, 1999; Firmature & Rahman, 2000). Crack is one of the early contributions of fracture in thin-walled structure. Fracture is initiated from micro separations nucleation in a small area around an existing dominant crack (Deshpande, et al., 2006). Figure 2.2 illustrates micro separations of nucleation in a small area around an existing dominant crack that can lead to fracture in structural components. The microstructure and mechanical properties of material make big influence on crack propagation (Leonavicius, et al., 2010)

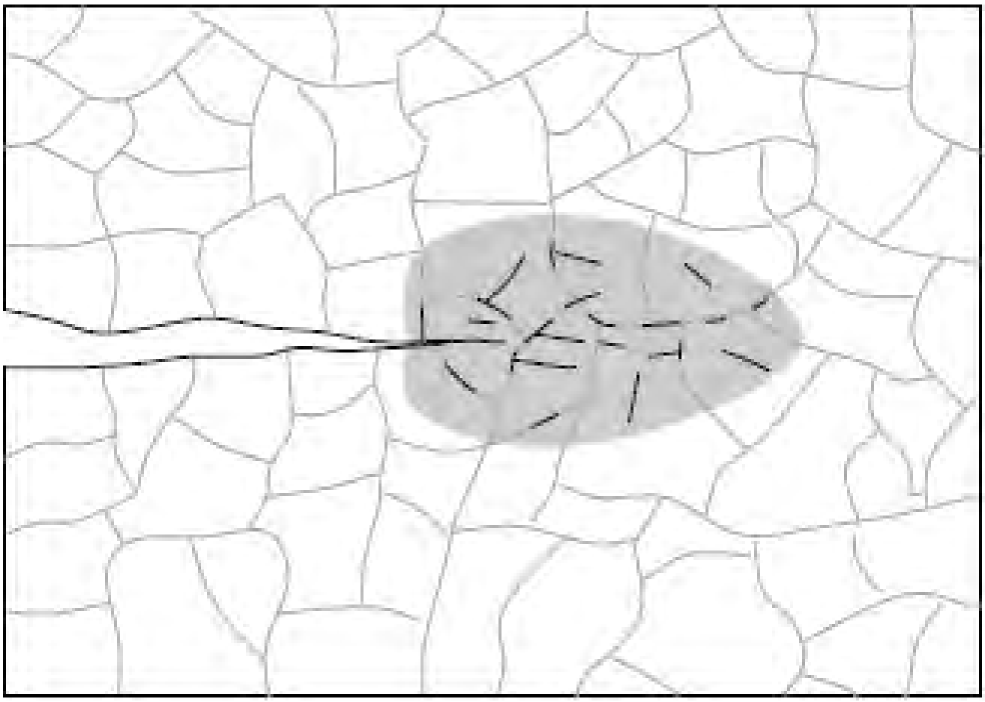

Figure 2.2: Micro separations of nucleation in a small area around an existing dominant crack (Deshpande, et al., 2006)

2.2 Buckling of perfect cylinder under axial compression

Better understanding of buckling for thin-walled cylindrical shells under axial compression is an important factor for structural designer especially in aerospace structure area because the cylindrical structural components mainly in used. Since then the phenomena of shell buckling became the main important design constraint for aerospace structures (Hoff, 1967).

(Rotter, 2002) states that if a geometrically perfect thin elastic cylinder is axially compressed under uniform compression, the load-end shortening relationship is illustrated as shown in Figure 2.3.

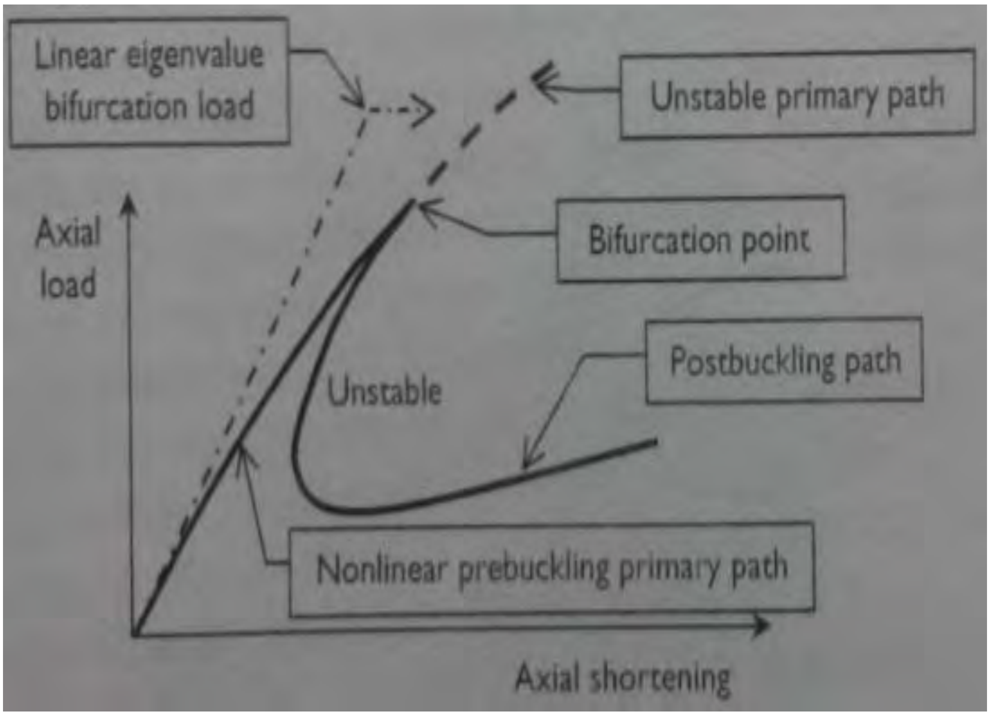

Figure 2.3: Load-end shortening relationship (Rotter, 2002)

Linear pre-buckling path is suddenly terminated as the shell bifurcates into a non-symmetric mode (see Figure 2.1), with several full waves of buckling around the circumference, and usually several waves up the height. During buckling process, the load falls very rapidly, and the cylinder actually increases in length (Figure 2.3) as the displacements normal to the surface grow. When the maximum load of cylindrical structure reached at its point, bifurcation after bifurcation occurs on the shell structures (Rotter, 2002).

2.3 Buckling of imperfect cylinder under axial compression

It is well known that the buckling strength of axially-compressed cylindrical shells can be very sensitive to the presence of crack. (Vaziri & Estekanchi, 2006) studied the buckling of cracked cylindrical thin shells under combined internal pressure and axial compression. This research paper analyzes the effect of crack orientation, crack type, and the size of crack on the buckling behavior of cylindrical shell structures. There are two types of cracks that were taken into consideration which is through crack and thumbnail crack.

According to this research paper, they emphasize that when the cylindrical structures being exposed to the internal pressure, it gives the stabilizing effect against the local buckling for circumferential cracked cylindrical shell. Figure 2.4 shows the computation model of cylindrical shells with circumferential cracked shell structured.

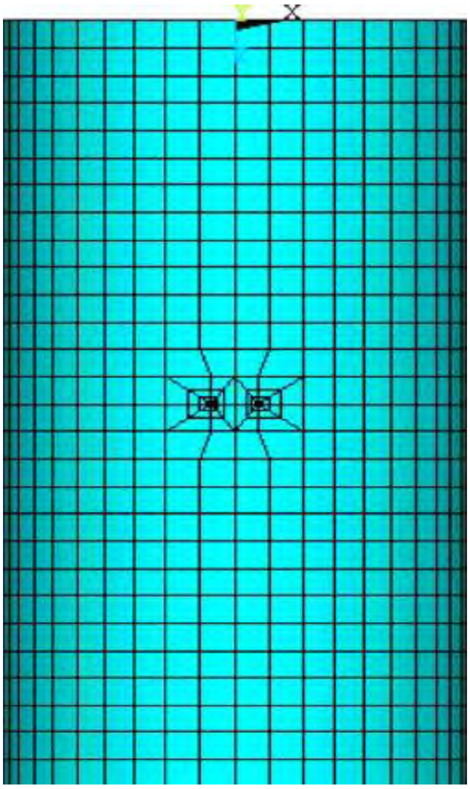

Figure 2.4: Computation model of cylindrical shells with a circumferential crack (Vaziri & Estekanchi, 2006)

(Shariati, et al., 2010), investigates the effect of various crack position and orientation on the buckling and post-buckling behavior of cylindrical shells. They used numerical modeling of cylindrical structure with crack length of (λ = 0.2, 0.3, 0.4 cm) with several orientation ($\theta = 0^0, 30^0, 45^0, 60^0, 90^0$). Results indicate that when the position of crack is changed, it will affect the buckling load of cylindrical structure. The effect of crack length on buckling behavior and post buckling of cracked shell is shown in Figure 2.5.

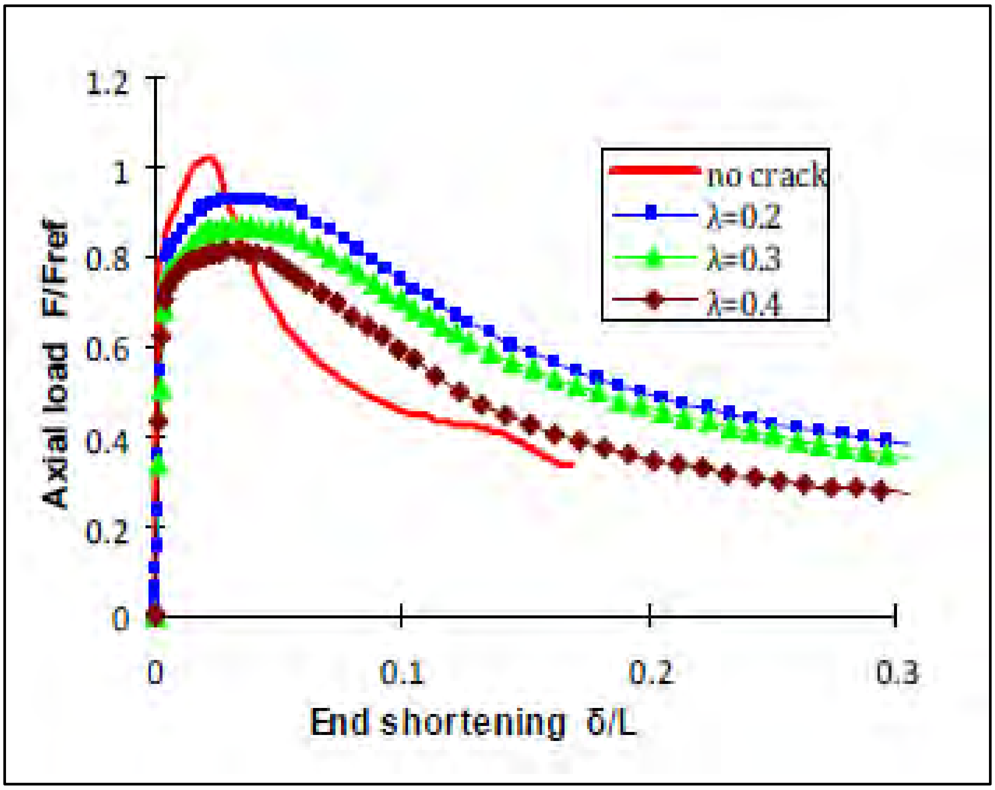

Figure 2.5: Load-end shortening behavior of cylindrical shells with and without crack at various crack length (Shariati, et al., 2010)

The existence of longitudinal crack with the ratio of $\lambda = 0.4$ on the cylindrical shell reduces the shell buckling load to 76% of the buckling load of perfect cylinder. In longitudinal crack, the change in crack length and increasing λ has major effect on the buckling load. Followed by $\lambda = 0.2$ and 0.3 the results depicted the same pattern with $\lambda = 0.4$ on the cylindrical shell buckling load.

Additionally, (Kim , et al., 2013) studied the role of an elastic liner on the buckling behavior of a cracked cylindrical shell by using finite element method. Their research objective is to study the effect of crack geometry with different length and crack orientation as well as the material properties and thickness of the elastic liner on the buckling load and buckling shape of the cylindrical shell.