UNIVERSITI TEKNIKAL MALAYSIA MELAKA

EXAMINATION OF BUCKLING BEHAVIOR OF AXIALLY COMPRESSED CYLINDER WITH UNEVEN LENGTH

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

by

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2017

DECLARATION

I hereby, declared this report entitled "Examination of the Buckling Behavior of Axially Compressed Cylinder with Uneven Length" 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 Degree of Engineering Technology (Maintenance Technology) with Honours. The member of the supervisory is as follow:

………………………………

(Dr. Olawale Ifayefunmi)

ABSTRACT

This research intends to investigate the effect of imperfect length on the buckling behavior of cylindrical shell. Seven mild steel cylinders were manufactured with a constant imperfect wavelength, 2A = 10% of the height of cylinders. All of the samples were manufactured with 1mm mild steel plate and the length-to-radius ratio is 2.4 and the ratio of wavelength to thickness is equal to 11.2. The cylindrical samples were all tested under axial compression. The collapse loads of all samples were validated by comparing the experimental results and the numerical results. In this project, all of the results show a small difference percentage of similarity, which is less than 10 percent between the experimental and numerical results. In addition, the boundary condition used in the numerical analysis was proved to be correct condition, which was $x = 0$, $z = 0$. These results can be validated by compared to the graphs and deformed shapes. From the results, it can be concluded that the collapsed load increases as the number of waves increases.

ABSTRAK

Kajian ini bertujuan untuk menyiasat kesan panjang yang tidak sempurna pada kelakuan gelang silinder shell. Tujuh keluli ringan silinder dihasilkan dengan panjang gelombang tidak sempurna yang berterusan, 2A = 10% ketinggian silinder. Semua sampel dibuat dengan plat keluli ringan 1mm dan nisbah panjang-ke-radius ialah 2.4 dan nisbah panjang gelombang ketebalan adalah sama dengan 11.2. Semua sampel silinder telah diuji di bawah mampatan paksi. Beban runtuh telah disahkan dengan membandingkan hasil percubaan dan hasil berangka. Dalam projek ini, semua hasil menunjukkan peratusan perbezaan kecil yang hampir sama, yang kurang daripada 10 peratus antara keputusan percubaan dan berangka. Keputusan ini dapat disahkan dengan membandingkan graf dan bentuk cacat. Di samping itu, syarat sempadan yang digunakan dalam analisis berangka terbukti adalah keadaan yang betul, iaitu x = 0, z = 0. Dari hasilnya, dapat disimpulkan bahwa beban runtuh meningkat seiring dengan peningkatan jumlah gelombang.

DEDICATION

This report is dedicated to my beloved parents, my family members and my friends who always give me fully support and encourages completing my final year project. In addition, my final year group mates who giving me guidance and assists during the project.

ACKNOWLEDGEMENT

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

Special thanks to UTeM for giving fund required to complete this project. In addition, I would like to thank Mr. Mohd Syafiq Ibrahim and Mr. Fauzi Ibrahim, the technicians from fabrication laboratory, Faculty of Engineering Technology sincerely.

Last but not least, I would like to thank my beloved parents, siblings and my friends for providing mental support throughout this final year project. Thanks to everyone who have been a significant part for the realization of this project.

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LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

Fcyl	-	Elastic Critical Buckling Load of Cylinder
E	-	Young modulus
v	-	Poisson's ratio
t	-	Wall Thickness
$Fref$	-	Reference Buckling Load to Cause Yield
D	-	Diameter of Cylinder
σ_{yp}	-	Yield Stress
SPLA	-	Single Perturbation Load Approach
DESICOS	-	New Robust Design Guideline for Imperfection Sensitive Composite Launcher Structures
SGI	-	Seeded Geometric Imperfection
ABAQUS	-	Finite-element Computer Code
2A	-	Amplitude of Waves
DXF	-	Drawing Exchange Format
MIG	-	Metal Inert Gas

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

For the architects of any ages, shell structure is a favored type of structure. Nowadays, thin shell structures are viewed as an advancement of a type of structure utilized by human being from ancient ages (Ibrahim, 1988). Customarily, people usually use a cylindrical shell in real life. The cylindrical segments are interfaced to make a prime load bearing structure in many situations. For example, when the type of load is axial compression, the relation between two neighboring cylindrical segments becomes a key point (Blachut, 2015).

Thus, the structure stability becomes an essential requirement in most of the fields. The weight savings through decrease in skin thickness must be adjusted in order to increase the stability of structure. The buckling performance of composite structure should be investigated in all fields (Rouhi et.al, 2016).

Unfortunately, some specific factors are found that they actually affect the buckling performance of thin shell structures. For example, the initial geometric imperfections have much impact on the buckling behavior of cyinder structures (Sofiyev, 2011). In fact, other than geometric imperfections, there are still many variables which can affect the buckling behavior of shell structures such as the material properties of shell, boundary condition and the type of applied load (Golzan & Showkati, 2008).

There are some researches shows that, the geometric non-linearity and initial imperfections definitely play a significant role in buckling behavior of homogenous shells. They may cause some unpredictable behaviors in the governing equation of inhomogeneous shells (Sofiyev, 2011). This statement is supported by Arbelo et.al, 2014 too, who agree that cylindrical structures are inclined to buckling under axial compression and they may show sensitivity to geometrical imperfection.

In order to investigate the effect of geometry imperfection on the buckling behavior of the cylindrical shell, numbers of experiments had been conducted. For example, a transverse device equipped with two diametrically restricted low pressure and linear contracting transducers are utilized to mount the cylindrical shell. Then, the result will be recorded and set into program. The effect of geometry imperfection could be then computed by analyzing the imperfection amplitudes and the line of power spectral density (Eglitis et. al, 2009).

From the literature study, it is found that geometric imperfection plays a dominant role in buckling behavior of cylindrical structures. However, there are still other effects which are not studied yet. Hence, this experimental project work aims to examine the effect of buckling behavior of axially compressed cylinder with imperfect length.

1.2 PROBLEM STATEMENT

Generally, thin shell can withstand very high buckling loads and this property has proved that it is an efficient structure. However, thin shells normally have a very unstable post-buckling behavior which can affect their buckling behavior if compare to the plates. It has brought a big challenge to the scientific and engineering fields because of their buckling and post-buckling characteristics (Eglitis et.al, 2009). Due to the difficulty to obtain a close agreement between the experiments and the prediction from numerical modeling, the axially compressed cylinder has become one of the last classical issues in the field of structural mechanics. Therefore, this research should be conducted continuously to figure out the true answer (Eglitis et.al, 2010).

The researchers realize that, the shape imperfections which are unavoidable in manufacturing might affect the critical buckling loads of axially compressed cylindrical shells. Thus, the different amplitudes and forms of initial imperfections might bring a big impact to the critical buckling loads (Korobeynikov et.al, 2014).

Previous researches have proved that, there are various types of causes that might affect the buckling of cylindrical shells. They are geometric and material properties of shells, type of applied load and geometric imperfection (Maali et al., 2012). However, the researchers also proved that the geometric non-linearity and initial imperfections play a significant role in buckling behavior of homogenous shells (Sofiyev, 2011).

The buckling of shell structures should be understood to guarantee the integrity of these shell structures. Hence, the experiments on manufactured specimens are necessary to understand the buckling behavior of cylindrical shells (Golzan & Showkati, 2008). Several tests had been conducted to examine the effects of imperfection on the buckling behavior. Blachut, 2009 had carried out some experiments to examine the buckling behavior of cylindrical shell with uneven length. In the study, there is a non-uniform 'wave' at top side of a single cylinder and a rigid plate is used to exert axial compression force on it.

Among all effects of buckling behavior, the researchers focus more on the investigation of initial geometric imperfection, boundary condition, crack discontinuity and etc. Due to the limitation of data on the effect of uneven length, this project is conducted to collect results for further investigation.

1.3 Objectives

Based on the problem statement discussed, the objectives of this study are:

1. To design and fabricate mild steel cylindrical shells with uneven length.

2. To examine the effects of uneven length on the buckling behavior of axially compressed mild steel cylinder.

3. To validate the experimental results by using numerical analysis.

1.4 Scopes

This project intends to study the effect of buckling behavior of axially compressed cylinder with uneven length. 1 mm mild steel plate was used in designing and fabricating the cylindrical shell.

In this research, 5 different samples of cylindrical shell were designed in 2D and 3D drawing. The first one was original shell, and the other 3 samples were designed to have 4, 8, 10 and 12 sinusoidal waves.

Once the drawing was completed, the fabricating part was the next step of this research. Total of 7 samples were required to be manufactured. 2 sets of original and wave 12 cylindrical shapes were required to validate the accuracy of results. The cylindrical shells were cut by using the water jet machine. The drawing should be ensured to meet the format used in the water jet machine to prevent any wrong cutting of sample. After that, the rolling and welding step should be done to continue the experiment.

Last part of the project was the testing for the effect of buckling behavior of axially compressed cylindrical shell. All of the cylindrical shells were tested and the results were recorded. Numerical analysis was conducted to compare to the experimental results for the validation of data collected. Both results were compared in form of data, graphs and also deformed shape.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to thin wall structures

"Thin-walls" is the most significant parts in the design fields; this is because it helps to ensure the stability of the components. The strength of the thin shell structures in engineering application has improved although the use of materials is minimized in order to reduce cost. Generally, thin-walled structures is definitely important in engineering field, it is widely utilized for the industrial and residential buildings, ship hulls, aircraft skins, box support bridges and in addition covered structures like tanks, pipes, culverts and etc (Gotluru et.al, 2000).

Thin-walled structure is widely used as a part of transport and mechanical industry because of their high stiffness, durability and light weight. Moreover, if the structure is made of aluminium or steel, it can undergo the process of plastic folding to absorb the vitality of axial loading (Cezary and Jan, 2015).

Another significant characteristic of thin-walled structure is there are variety types of shape, causing them to be broadly found in many branches of engineering. Compared to other structural types, the material strength of thin-walled structures is not significant. Instead of the material strength, they have more regular deformation of shell in buckling (Ye, 2015). Numbers of researches have been conducted to test the thin-walled structure, for example, the structure is examined by applying lateral loading on it to figure out the effect of buckling behavior (Cezary and Jan, 2015). Hence, the question, what is buckling?

2.2 Buckling of Structure

When a structural part is subjected to a high compressive stresses, a sudden sideways deflection might happened and this phenomenon can be called as buckling. It is a failure mode in structural field and it is an essential issue that could not be underestimated in structural design (Bhattacharya et.al, 2005). Buckling normally occur in column when it is subjected with compressive or axial forces. The term “deflection” is significant in the engineering field, which mean by the displacement of degree on a structure due to some forces exerted. Normally, this type of deflection is unstable and unpredictable. This is because of, if one of the part start to buckle, some elatic deformations might be occurred if any further load exert on it (Paul, 2016).

Actually, buckling is quite similar to bending. They are both involved with bending moments. However, there is a significant point which is different between them, which is the deflection. Buckling will occur when the moments and deflections are mutually dependent while in bending, the moments and deflections are independent. Hence, this has shown that the deflection makes buckling happened (Wright, 2005).

According to Wright, 2005, buckling is classified into two groups, which are the elastic and plastic buckling.

2.2.1 Buckling of Cylindrical Shell

Elastic buckling is a structure failure that usually occurs on a column due to the compression forces. The column could be said to be buckled when it is deflecting laterally, but not because of direct compression of the material (Demenko, 2015).

To explain the real thing that happened in elastic buckling, a formula should be referred, which is derived based on Donnell type shell theory.This formula is to calculate the critical elastic buckling force for an axisymmetric mode in a cylindrical shell (Ifayefunmi, 2016).

$$Fcyl = \frac{2\pi Et}{\sqrt{3(1-v^2)}}$$

(Equation 2.1)

Where,

Fcyl = Elastic Critical Buckling Load of Cylinder

E = Young modulus

v = Poisson's ratio

t = Wall Thickness

For the plastic buckling, it typically occurs in the case of moderately thick cylinders. The formula of plastic buckling is also correlated to the Donnel shallow shell theory (Ifayefunmi, 2016)

$$Fref = \pi Dt\sigma_{yp}$$

(Equation 2.2)

Whereby, $Fref$ = Reference Buckling Load to Cause Yield

D = Diameter of Cylinder

σ_{yp} = Yield Stress

Hence, these two equations have proved that, there is a relation between the elastic buckling and plastic buckling. The only difference between them is that the equation (2.1) only consist of Young modulus, E and Poisson's ratio, v, but equation (2.2) is includes the yield stress, σ_{yp}. (Blachut & Ifayefunmi, 2010).

Figure 2.1 and 2.2 shows the different shapes of elastic buckling and plastic buckling clearly.

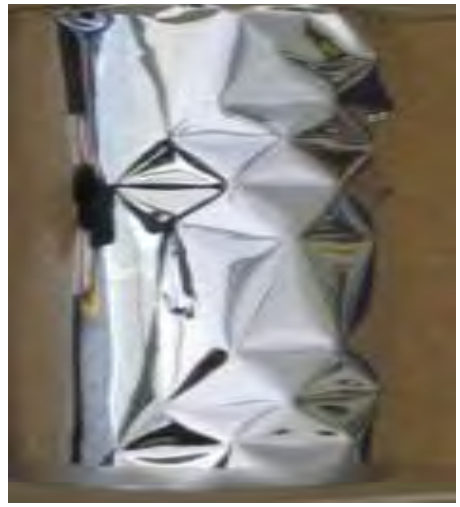

Figure 2.1: Cylindrical Shell with Elastic Buckling (Seffen & Stott, 2014)

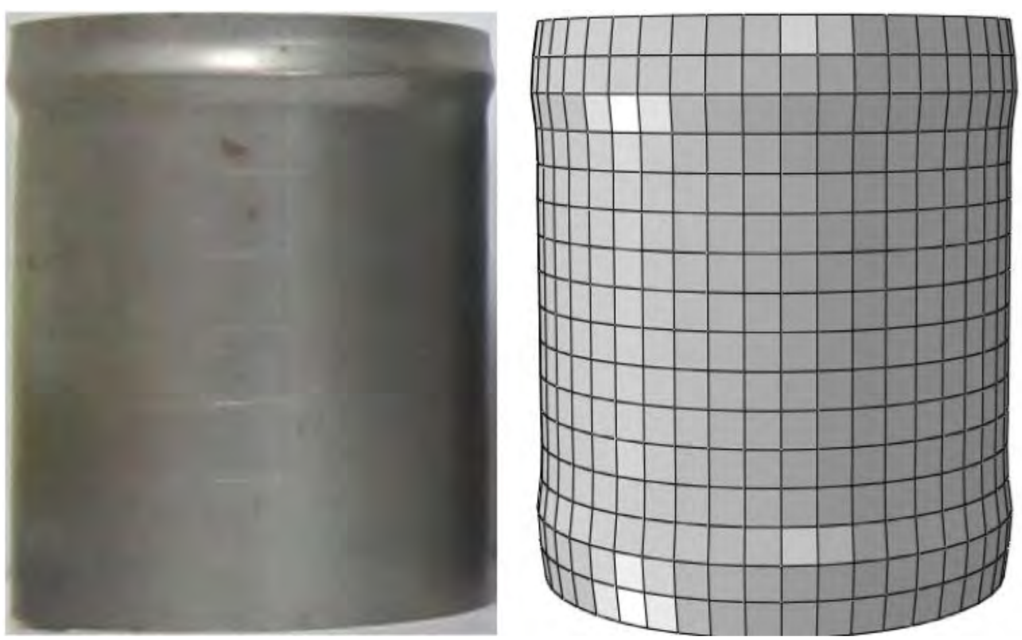

Figure 2.2: Cylinder with Plastic Buckling and ABAQUS Computed Buckling Shape (Ifayefunmi, 2016)

2.3 Buckling Behavior of Axially Compressed Cylinder

Many researchers have studied the complex behavior of imperfect composite cylindrical shells subjected to several conditions such as under axial compression, bending and torsion loads. However, the total understanding of these mechanical issues is still an active area of current researches. (Yengula et al, 2015a)

According to Yengula et al, 2015b, the investigation of cylindrical shells is only confined to the axial compression load. This is actually the major source to arouse the motivation of research work to investigate the buckling behavior of the cylindrical shells with the different types of basic loading. In fact, the buckling behavior of an axially compressed cylinder is said to be one of the last classic problem in the structural mechanic field where it is definitely hard to achieve a close agreement between the theoretical and experimental result. (Ifayefunmi, 2016).

Customarily, a cylindrical shell under axial compression in the meridional direction can actually fail by three factors, they are overall buckling, local buckling or the material strength is being reached. There are several failure mechanisms of composite cylindrical shells have been investigated, which are initial geometric imperfections, boundary condition, loading imperfection, crack material discontinuities and etc. (Priyadarsini, 2012)

2.3.1 Initial Geometric Imperfection

Generally, buckling behavior of cylindrical shells is depend on several factors such as the type of material tested, the boundary condition and the initial geometric properties of shell. Among of these, the initial geometric imperfection has the greatest effect on the buckling behavior of the structure when it is subjected to an axial compression load (Castro et al., 2015).