UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE EFFECT OF AXIAL CRACK LENGTH ON THE PLASTIC BUCKLING OF RELATIVELY THICK CYLINDER SUBJECTED TO AXIAL COMPRESSION

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

by

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2015

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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TAJUK: **THE EFFECT OF AXIAL CRACK LENGTH ON THE PLASTIC BUCKLING OF RELATIVELY THICK CYLINDER SUBJECTED TO AXIAL COMPRESSION**

SESI PENGAJIAN: **2015/16 Semester 1**

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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 (Automotive Technology) (Hons.). The member of the supervisory is as follow:

…………………………………

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ABSTRACT

Buckling analysis was carried out for relatively thick cylindrical shell with axial crack subjected to axial compression using the experimental and numerical approach. Presence of crack can considerably reduce the buckling load of a shell structure. Thus, the effect of the crack size on the buckling behavior was studied. This experimental and numerical analysis work been conducted with eight mild steel cylinders with the inner diameter-to-thickness ratio, $D/t \approx 50$, diameter to axial length ratio, $D/L \approx 0.89$. The experimental results show that as axial crack length increases, the buckling load carrying capacity of the cylindrical shell decreases. It also shows the strength of cylindrical shell decreases with the crack length of five percent and ten percent. Finally, the results of buckling behavior of the relatively thick cylindrical structure depends on the crack length, is discussed.

ABSTRAK

Analisis lengkokan telah dijalankan untuk shell silinder yang agak tebal dengan retak paksi dikenakan mampatan paksi menggunakan kaedah eksperimen dan berangka. Kehadiran retak jauh boleh mengurangkan beban lengkokan struktur shell. Oleh itu, kesan saiz retak ke atas tingkah laku lengkokan telah dikaji. Ini kerja-kerja analisis eksperimen dan berangka telah dijalankan dengan lapan silinder keluli lembut dengan nisbah dalaman diameter ke ketebalan, $D / t \approx 50$, diameter kepada nisbah panjang paksi , $D / L \approx 0.89$. Keputusan eksperimen menunjukkan bahawa sebagai paksi bertambah panjang retak , beban lengkokan membawa kapasiti berkurangan shell silinder. Ia juga menunjukkan kekuatan penurunan shell silinder dengan panjang retak lima peratus dan sepuluh peratus. Akhirnya , keputusan lengkokan kelakuan struktur silinder yang agak tebal bergantung kepada panjang retak, dibincangkan.

DEDICATIONS

I would like to dedicate this report to my parents for the moral support and motivation been given continuously in completing this report. Besides, my friends whom presents on sharing their knowledge on writing report, using software, time management and updating about report scheme.

ACKNOWLEDGMENTS

I would like to thanks my parents for the financial support and motivating me to succeed in completing this report. Besides, I would also like to thanks my uncle, Y. Bhg. Datuk Dr. Siraj Khan on recommending me approach of writing skills. Secondly, I would like to thank my supervisor, Dr. Olawale Ifayefunmi for guiding me with excellent way to complete this thesis and shared many knowledge under short period. I also would like to thank En. Suffian from Faculty of Technology Engineering for his helps on Hypermesh software. Lastly, my supportive friends, they do shares information and knowledge on completing this report successfully.

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LIST OF SYMBOLS AND ABBREVIATIONS

σ_c	=	Stress
σ_y	=	Yield stress
E	=	Young Modulus
Al	=	Aluminium
Cu	=	Copper
Mg	=	Magnesium
θ	=	Angle of degree
L	=	length
mm	=	Millimetre
ρ	=	Density

CHAPTER 1

INTRODUCTION

1.0 Background

Cylindrical shell structures are widely used in the fields of civil and mechanical engineering. In this regard, the use of shell structures in covering large span roofs, tall silos, large dams, pressure vessels, marine structures, airplane and space craft are just few examples (Estekanchi and Vafai, 1999). With the presence of cracks or holes, tensioned plates can easily buckle, showing complex wrinkling deflection patterns in compressed regions around such defects (Roberto, 2005). Shell structures, like other types of structures, are usually susceptible to various types of defects and damages such as initiation and propagation of cracks, corrosion, chemical attack and time-dependent material degradation, which damage their structural reliability. The presence of cracks in a shell structure can play the role of geometrical imperfection and thus reduce the load carrying capacity of the shell structure (Barut et. al, 1997). The buckling of cracked shells has been studied extensively in recent decades. These studies range from development of theoretical approaches to better understand stress distribution and structural behavior of the shell in the presence of defects (Hutchinson, 1971). To successfully carry out buckling analysis of cylindrical shell structure, it is important to understand the factors influencing buckling on the cylindrical structure. Few studies revealed that the sensitivity of the buckling behavior of both plates and shells to the presence of defects highly depends on the loading condition. As an example, one of the researchers is Estekanchi. According (Estekanchi et. al, 2002), the buckling behavior of the cylindrical shells under torsional loading is less sensitive to the presence of a crack than that of a similar axially compressed cylindrical shell.

This project aims to investigate the effect of axial crack length on the plastic buckling of relatively thick cylinder subjected to axial compression. The materials of cylinder are assumed to be made from mild steel.

1.1 Problem Statement

Defects can have a significant influence on the buckling behavior of thin-walled structures. From the structural point of view, the most detrimental consequences of a defect is the excessive stress, which could result in fracture at or near the defect location and possibly overall structural failure (Babak and Vaziri, 2012). Thus, the manufacturing of the cylindrical structure to be handled carefully to ensure there will be no formation of other defects.

Buckling is one of the main failure considerations in the design of cylindrical structures. (Yoontae, 2011) states that the internal pressure decreases the buckling load of the cylindrical shell. Formation of buckling divided into two categories, which is Flexural-torsional buckling and Lateral-torsional buckling. However both type caused by similar root of failure which is crack formation on the cylindrical structure and internal pressure from the load applied. According to (Khamlichi et. al, 2004) geometrical imperfections lead to dispersions, which generally affect the buckling loads obtained from experiments. The geometry structures of cylinders are important factor in influencing the results. As the yield strength of every specimen are not similar. Investigations on the geometry structure of the specimens before the experimental are essential. Numerical analysis is the favourable method for the modern time as to reduce cost and material on actual experiment. It has been proven that numerical analysis has ability to perform the result as accurate as the experimental results. This experiment will validate the results better if there will be comparison between numerical analysis and experimental analysis.

Based on some literature review, it is observed that researchers does emphasize on circumferential crack cylindrical structure and multiple longitudinal crack (Allahbakhsh and Shariati, 2014; Babak and Vaziri, 2012; Starnes and Rose, 1997). This research focus on effect of axial crack length on the plastic bucking of relatively thick cylinder subjected to axial compression by experimental action.

1.2 Objective

This study will highlights on the following objectives:

1. To manufacture cylinder with axial crack of different length introduced.

2. To investigate the effect of axial crack length on the plastic bucking of relatively thick cylinder subjected to axial compression.

1.3 Scope

This is an experimental and numerical research work to determine effect of axial crack length on the plastic bucking of relatively thick cylinder subjected to axial compression. The material used for the cylindrical structure is mild steel. This experiment and numerical research will be conducted by testing eight specimens. The entire specimen are formed from mild steel plate and welded together. During the welding process, crack was introduced axially on the cylindrical structure. Two specimens selected to be tested with no crack. This is to ensure that there is repeatability of experimental data. The remaining specimen will be introduced with crack length of five-percent (5%), ten-percent (10%), fifteen-percent (15%), twenty-percent (20%), twenty-five percent (25%) and fifty-percent (50%) on cylindrical structure. The entire specimen will undergo axial compression test by using the instron machine. The effect of axial crack length on the plastic bucking of relatively thick cylinder will be analyzed, and its result will be compared with the specimen with no crack introduced.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction of buckling of relatively thick of cylindrical structure

Generally relatively thick-walled shell structures are used in engineering application is to build a structure that could retain load when any external or internal force applied on it. Typical applications including manufacturing large tanks, marine structures, pipelines, aircraft structure, cooling towers and etc. These structures may encounter diverse sorts of load in their life span and this will results in buckling. Besides, if the structure has defects such as hole or crack, this may affect their stability. A cylindrical shell under compression in the vertical direction can fail by overall buckling (global/Euler), local buckling or the material strength being reached (Priyadarsini and Kalyanaraman, 2013). Due to weakness of the cylindrical shell structure, possibilities of buckling are wide and may dominate as main failure in designing the structure. (Abdolhossein et. al, 2013) states effect of cutouts on load-bearing capacity and buckling behavior of cylindrical shells is an essential consideration in their design. The impact of size, area and length of crack on the cylindrical shell are dependable on the amount of force acting upon it. However, during manufacturing process of high volume of shell structures, certain defects such as holes or small crack may introduce.

2.1 Cracks on Cylinder Structure

Destruction of material or structural commonly known due to buckling failure when the thickness of a cylinder is small compared to other cylinders, under membrane loading. Though the cylindrical shell under tension loading, the buckling development may occur under particular state where there is presence of cracks at any angle. Presence of defects, such as cracks, may seriously compromise their buckling behavior and endanger the structural integrity (Dadrasi, 2013). Crack could be the spark for the relatively thick cylindrical structure failure in maintaining the strength of the wall. Two types of damage are well-known; the first one is the formation of macro cracks in the most loaded zones and the second is the growth of macro cracks (Daunys and Tarakecius, 2006). Figure 2.1 shows the finite element model used to calculate the crack edge opening displacement for a given crack length and applied load. Manipulation on the crack line reflects on the results of the structure of element. In the recent years, many studies on fatigue crack and other problems has been performed to investigate the point of failure in the structures.

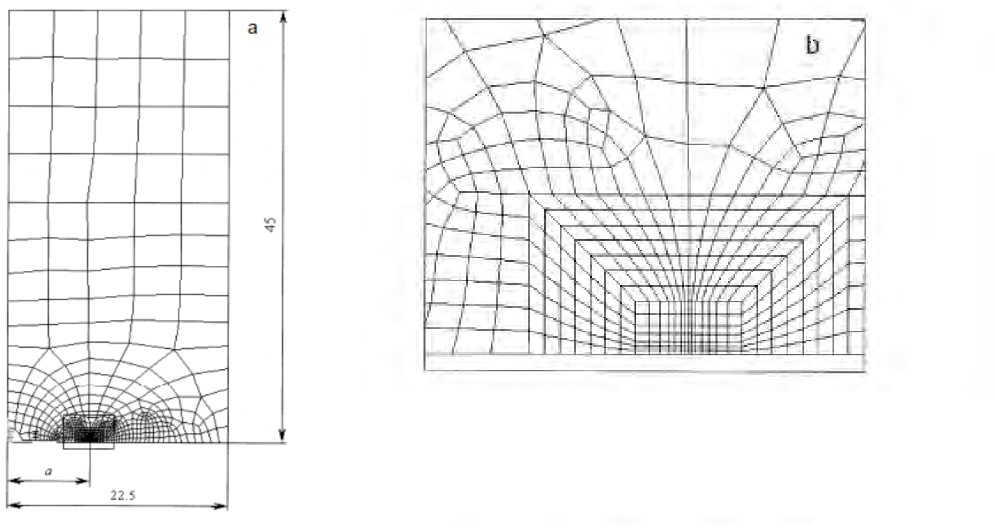

Figure 2.1: Crack edge opening displacement for a given crack length and applied load (Daunys and Tarakecius, 2006).

2.2 Geometrical structure of cylindrical shell.

Geometrical structure is an important factor to be analyzed as it explains the details of structure surface. According to (George, 1986) imperfections include a local bubble in a thin circular cylindrical shell, which makes the geometry locally non-symmetric; a global out of-roundness, makes the geometry globally non circularly cylindrical. Accurately, geometry of cylindrical structure could impact the roundness of the shell which manipulates the outcomes after compression. According to (Brian, 1998), the shell can be constructed of any combination of isotropic or orthotropic materials, including either longitudinal or circumferential stiffeners, and it is required to have "material symmetry" about two vertical planes: $X = L/2$ and $Y = 0$ as shown in Figure 2.2.

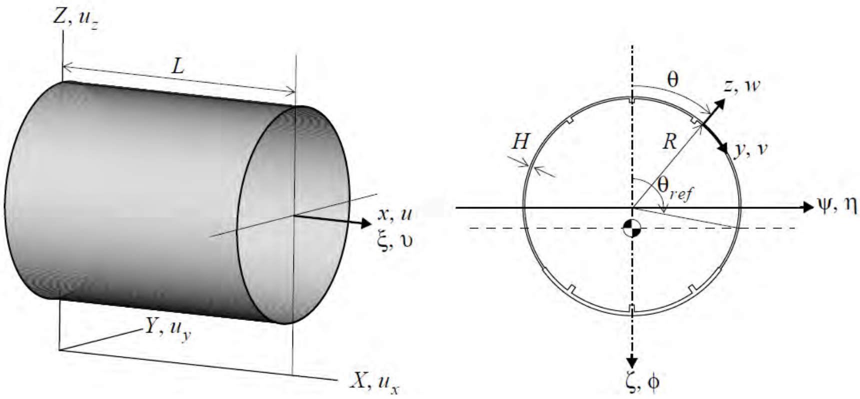

Figure 2.2: Geometry of Undeformed Shell (Brian, 1998)

This research emphasized on mild-steel as the material selected for the testing. Some researcher has carried out study with same concept with different material, where they used fiber material. (Priyadarsini et. al, 2013) conducted numerical and experimental study into buckling of advanced fiber composite cylinder under axial compression. Ultimate strength is affected by the method of loading (static, harmonic), the layup sequence, radius to thickness ratio, and geometric imperfections. The effect of the ratio of the length to the radius is negligible. The results show that, every properties of material has different yield strength but the element that could trigger the capacity of the structure could be similar.

2.3 Buckling behavior of cylinder under axial compression

Buckling is important phenomena to be understood especially for manufacturing process in engineering industry. Cylindrical hollow steel tubes are generally used as segments as a part of numerous auxiliary frameworks. Typical technique of such cylinders when subjected to central pressure and twisting is region clasping almost to the segment end. For instance, hollow steel cylinders are regularly utilized as scaffolding and such span docks endured broad harm and even falls. Throughout the usage, thin-walled cylinders are often subjected to single and combined application of external loads. In resisting these loads, the system is subject to buckling, a physically observed failure mode, which is closely associated with the establishment of its load-carrying capacity (George, 1986).

Buckling proceeds in manner which may be either stable or increases displacement in a controlled way as loads are increased, i.e. the structure ability to sustain loads is maintained (Naidu et. al, 2014). The load carrying capacity of thin shells alongside learning of its postbuckling behaviour has been the subject of many researchers through both theory and experiment. According to (Ismail et. al, 2015) too thin cylindrical shells and larger design loads may make the structures more prone to buckling failure. It can be concluded that many factors influences the buckling behavior and different factors provides different results based on the number of load, type of manufacturing and presence of cracks. Figure 2.3 shows the measure of post buckling stability is plotted directly as a function of σ_c/σ_{cl} for each of the three important cases (Budiansky and Hutchinson, 1966).

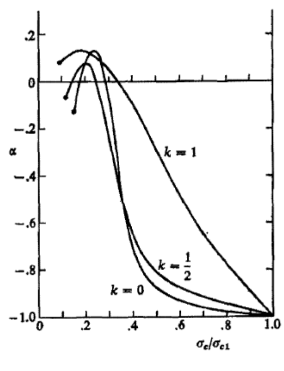

Figure 2.3: Buckling behavior as a function of buckling stress (Budiansky et.al, 1966).