UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE EFFECT OF SEMI-VERTEX ANGLE ON THE BUCKLING OF CYLINDER AND CONES

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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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

The change in semi-vertex angle of the cone can greatly reduce the load carrying capacity of the shell structure. This research aims to study the effect of semi-vertex angle on the buckling of cylinder and cones when subjected to axial compression. This research work involves one cylinder and four cones of different semi-vertex angle that are fabricated using 1 mm mild steel plate. The research conducted was compared in terms of experimental, numerical and theoretical approach. The result data on the effect of semi-vertex angle on the buckling of cylinder and cones are presented in this report. The result of the experiment shows that as the angle of cone increases, the buckling load of the cone will decrease.

ABSTRAK

Perubahan sudut separuh mercu kon dapat mengurangkan kapasiti beban membawa struktur shell. Kajian ini bertujuan untuk mengkaji kesan sudut separuh bucu pada lengkokan silinder dan kon apabila dikenakan mampatan paksi. Kerja penyelidikan ini melibatkan satu silinder dan empat kon sudut separuh mercu berbeza yang direka menggunakan 1mm plat keluli lembut . Kajian yang dijalankan telah dibandingkan dari segi pendekatan eksperimen, berangka dan teori. Data hasil mengenai kesan sudut separuh bucu pada lengkokan silinder dan kon dibentangkan dalam laporan ini. Keputusan eksperimen menunjukkan bahawa apabila sudut kon bertambah, beban lengkokan kon akan berkurangan.

DEDICATIONS

This report is dedicated to my beloved parents, my siblings and not forgets my friends, who always support and encourage me during this final year project work. Last but not least, my final year report group mates who were always there when I needed help during this final year project research.

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LIST OF SYMBOLS AND ABBREVIATIONS

SBM	=	Shape-Based Matching
P_{cr}	=	Critical buckling load
E	=	Young's Modulus
t	=	Shell wall thickness
β	=	Semi-vertex angle
ν	=	Poisson's ratio
P_o	=	Squash load
r_1	=	Top radius of the cone
σ_{yp}	=	Yield stress
P_l	=	Limit load
MPa	=	Mega pascal
GPa	=	Giga pascal
mm	=	Millimetre

CHAPTER 1

INTRODUCTION

1.0 Background

Conical shells are often used as transition elements joining cylinders of different diameters. They find applications in pressure vessels, offshore platforms, pipelines and transition elements between cylinders of different diameters (Blachut and Ifayefunmi, 2009). For such application, their failure by buckling is of great importance to the structural engineer (Rotter, 2002). Fundamentally, they are subjected to a variety of loading conditions including axial compression, external pressure, and torsion. Under these loads, the buckling strength of cones becomes one of the crucial design considerations (Blachut, 2010). This technical challenge has made significant research in the areas of mechanical behaviour and failure of thin shell structure, under the applied load (Rotter, 2002). For thin-walled structures, such as small deviations of the structure from its formal unloaded shape, may also have quite important effects on the load at which buckling will occur (National Aeronautics and Space Administration, 1968). Thus, it is essential that the buckling behaviour of shells is properly understood so that suitable design methods can be achieved (Teng and Rotter, 2003). Shell analysis and design often relies on linear or non-linear numerical stability calculations for predicting the response of thin shells subjected to loads that may lead to buckling failure. Although physical experimentation remains vital in order to display phenomena that cannot be reproduced numerically, to acknowledge unforeseen patterns of behaviour and to verify methods of analysis, the use of numerical models in analysing shell buckling response is widespread (Chryssanthopoulos and Spagnoli, 1997).

This project research mainly focuses on the effect of different semi-vertex angle on the buckling of cylinder and cones subjected to axial compression. Research is carried out in terms of experimental, numerical and theoretical to investigate the effect of semi-vertex angle on the buckling of cylinder and cones when subjected to axial compression.

1.1 Problem Statement

Buckling is one of the complicated phenomena in solid mechanics. This aspect is dangerous for shells that are thin and subjected to compressive force (Boorboor, et al., 2012). For the specific case of cylindrical panels, the buckling and post buckling behaviour has been researched in detail, whereas limited studies is available for the more general case of conical panels (Spagnoli and Chryssanthopoulos, 1998). As a result, conical shells have received much less interest regardless of their use in areas where static stability can be one of the main design constraints (Blachut, 2012). Instability of structural element is one of the factors that limit the amount to which the structures can be loaded or deform (Ifayefunmi, 2014). Due to relatively low slenderness of the specimens, the failure was in all cases greatly affected by plasticity effects (Chryssanthopoulos and Poggi, 2000). Besides, as the cone angle increases, the failure load reduces under the influence of boundary condition (Ifayefunmi and Blachut, 2011). Different parameters change the buckling behaviour of the shell, making it difficult to achieve a general depiction (Golzan and Showkati, 2008).

Even though a number of numerical analysis tends to predict result close to experimental result, this obtained data still has to be established by experimental result in order to ensure that all the assumptions made within the modelling are valid. Moreover, plastic buckling of conical shells on semi-vertex angles have not been researched extensively. As a result, this research project focuses on the effect of various semi-vertex angles on the buckling of cylinder and cones when subjected to axial compression. Therefore, this research work is able to provide more information on the structural stability of conical shells with different semi-vertex angle.

1.2 Objectives

Based on the background and problem statement listed, the objectives of this research study are as follows:

1. To manufacture cylinder and cones with different semi-vertex angles.
2. To investigate the effect of semi-vertex angle on the buckling behaviour of axially compressed conical shells.
3. To compare results between experimental, numerical and theoretical approach.

1.3 Scope

The projects aim is to investigate the effect of semi-vertex angle of cylinder and cones subjected to axial compression. This research consists of one cylinder geometry and four conical geometries where all of them are fabricated using 1 mm mild steel plate. To confirm repeatability of experimental data, nominally identical specimens will be made for each geometry, resulting in a total of 10 specimens. In order to minimize material wastage, calculations and sketches of sample templates were done and examined before moving on to the actual manufacturing process to avoid fabrication error. Then, the cones and cylinder are marked with grids before going through rolling and welding processes. The primary purpose of gridding is to measure the specimens in terms of its thickness, height, diameter, and slant length. After that, the specimens will undergo axial compression test by using Instorn machine to determine the load carrying capacity and buckling behaviour of the shells. On top of that, the grid may serve the purpose of analysing at which part of the specimens will buckle during the test. Finally, a comparison between experimental findings and theoretical calculations will be conducted.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Conical shells are widely used in many parts of engineering because of their efficient geometrical shape (Nedelcu, 2011). Conical shells are often used as transition element between cylinders of different diameters or end closures and sometimes as stand-alone components in various applications such as missiles, spacecraft and nuclear reactors (Sofiyev, 2011). Loss of stability by buckling in shell-like structures is one of the most important and crucial failure phenomena (Jabareen and Sheinman, 2005). According to Blachut and Ifayefunmi (2009), the load carrying capacity of conical shell structures that are primarily used in aeronautical applications is limited by elastic buckling due to the higher radius-to-thickness ratio whereas lower radius-to-thickness ratio typically used in marine and offshore applications, buckle or collapse in elastic-plastic range. Due to the relatively high slenderness of the specimens, the failure is in all cases are significantly influenced by plasticity effects (Golzan and Showkati, 2008). Moreover, it was argued that the buckling resistance of a thin-walled circular cylinder or cone that was not stiffened, under uniform external pressure was extremely poor (Ross, 2001). Between 1958 and 2008 there have been 484 buckling tests on unstiffened cones (Blachut and Ifayefunmi, 2012). National Aeronautics and Space Administration (1968) reported that many studies have been conducted on the elastic stability of conical shells subjected to various loading conditions, however, is not as extensive as the cylindrical shells. Hence, there is still considerable disagreement between experimental loads and the loads predicted by theory. Moreover, the test strengths were found to be very scattered, even when testing is done with great care. The search for the reasons for this major inconsistency led to an enormous amount of research in the past decades (Teng and Rotter, 2003). As a result, for a designer to successfully carry out buckling analysis of conical shells, it is important to carefully study and understand the behaviour of the shell structure (Ifayefunmi, 2014).

2.1 Background into Buckling of Conical Shells

2.1.1 Buckling

Buckling can be defined as a sudden large, lateral deflection of a structure due to a small increase in an existing compression load (Ugural, 2002). A structure may fail to support its load if a member in compression buckles, that is, moves laterally and shortens under a load it can no longer support. Leonhard Euler long ago showed that there was a critical load for buckling of a slender column. A column, of course, is simply a common case of a compression member. With any smaller load, the column would remain straight and support it. With any larger load, the least disturbance would cause the column to bend sideways with an indefinitely large displacement; that is, it would buckle (Calvert, 2007). The way in which buckling occurs depends on how the structure is loaded and on its geometrical and material properties (Sun, et al., 1995). Spagnoli (2003) showed that at a certain aspect ratio of a conical shell, different buckling modes correspond to the same value of critical buckling. On the experiment side, investigations have been undertaken in order to estimate the reduction of the classical buckling load due to imperfections and pre buckling deflections (Spagnoli and Chryssanthopoulos, 1998).

2.1.2 Bifurcation Buckling

As shown in Figure 2.1, the linear buckling analysis assumes the existence of a bifurcation point where the primary and secondary loading paths intersect. At this point, more than one equilibrium position is possible. The primary path is not usually followed after loading exceeds this point and the structure is in the post-buckling state. The slope of the secondary path at the bifurcation point determines the nature of the post-buckling. A positive slope indicates that the structure will have post buckling strength whilst a negative slope means that the structure will simply collapse.

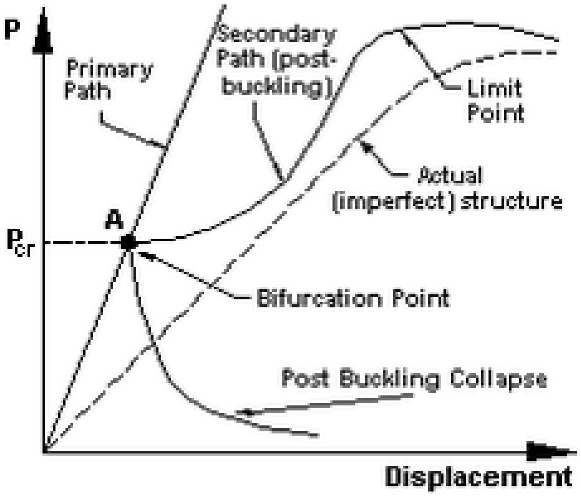

Figure 2.1: Characteristics of Bifurcation Buckling

2.1.3 Snap-through Buckling

As presented in Figure 2.2, snap-through buckling is a particular type of buckling where a structure snaps from one state to another remote state (Wiebe, 2011). The stiffness of the structure or the slope of the load-deflection curve decreases with increasing load. At the collapse load the load-deflection curve has zero slopes and, if the load is maintained as the structure deform, failure of the structure is almost instantaneous. This type of instability failure is often called snap-through (Sun, et al., 1995).

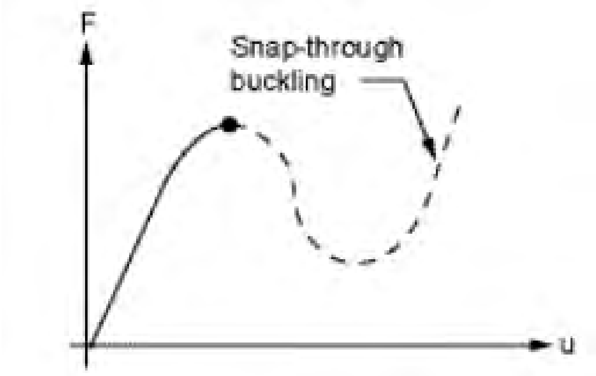

Figure 2.2: Characteristics of Snap-through Buckling

2.1.4 Plastic Buckling

When a material is loaded in compression it may buckle when a critical load is applied. If loading is performed at constant strain-rate, this initial buckling will be elastic and will be recoverable when the applied compressive stress is removed. As the applied load increases on the material, it will eventually become large enough to cause the material to become unstable and buckle. This deformation is permanent and cannot be recovered when the load is removed. Plastic deformation of thin-walled sections is demonstrated clearly on the left specimen in Figure 2.3 (Wright, 2005). Generally, a more significant load is the ultimate load of the structure, which may be reached when the material fails plastically or when the structure collapses (National Aeronautics and Space Administration, 1968).

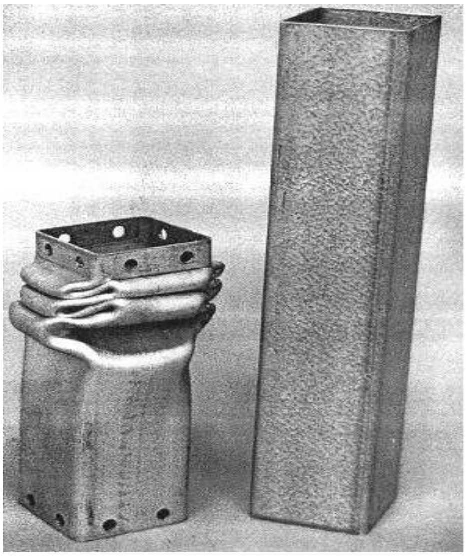

Figure 2.3: Characteristics of Plastic Buckling