UNIVERSITI TEKNIKAL MALAYSIA MELAKA

THE INFLUENCE OF CRACK ON THE BUCKLING OF AXIALLY COMPRESSED TRUNCATED CONES.

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

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

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(Project Supervisor)

ABSTRACT

Presence of crack can considerably reduce the buckling load of a shell structure. The scope of this research work is based on experimental approach to study the effect of crack orientation and crack length towards the load carrying capacity of axially compressed truncated cones. This experimental work involved test on cones with different crack orientation and various length. The top diameter of the cone will be 50 mm and bottom diameter is 100 mm. The first and much needed experimental data on the effect of crack orientation on the load carrying capacity of axially compressed truncated cone were presented in this study. From the experiment, we found that the angular crack shows decrease in collapse load when the length of the crack increase. However for axial and circumferential crack, there was no clear trend.

ABSTRAK

Kehadiran rekahan bole mengurangkan keupayaan membengkok untuk sesuatu struktur. Kajian ini berdasarkan eksperimen untuk menkaji kesan bentuk rekahan dan panjang rekahan kapasiti beban mampu keatas daya beban menegak terhadap kon. Kajian ini merangkumi kone yg terdiri daripada beberapa bentuk reakahan dan panjang rekahan. Diameter atas kone adalah 50 mm manakala diameter bawah kon adalah 100 mm. segala dapatan kajian telah dibentangkan di dalam ini. Daripada kajian dan experiment, kami dapati rekahan sudut menunjukkan beban runtuh menurun melawan panjang rekahan. Untuk rekahan menegak dan rekahan ukur lilit, data yang diperolehi meragukan. Hal ini kerana bahan yang digunakan mempunyai masalah dari segi pembuatan.

DEDICATIONS

To my beloved parents, my siblings and my friends who give me support and guidance to complete my final year project work.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASTM	-	American Society for Testing and Materials
CAD	-	Computer Aided Design
GPa	-	Giga Pascal
MIG	-	Metal Inert Gas
MPa	-	Mega Pascal
cm	-	Centimeter
mm	-	Millimeter
min	-	Minute
μm	-	Micrometer
m	-	Meter
kN	-	Kilo Newton
N	-	Newton
F	-	Force

CHAPTER 1
INTRODUCTION

1.0 Background

A conical shell is one of the common structural elements used in modern airplanes, missile, booster and other aerospace vehicles (Dung et al., 2013). The buckling phenomenon of imperfect shells is one of the most challenging problems of the theory of elastic stability. It is now generally recognized that initial geometric imperfections play a dominant role in reducing the buckling load of certain structures (Sofiyev, 2011). Generally, buckling depends on variables such as geometric properties of shells, properties of the material and types of applied load. Due to the variation of changes in parameters, it is difficult to achieved general depiction (Golzan and Showkati, 2008). The buckling behaviour of conical structures are also influenced by external pressure that exerted on the thin walled conical shell. Previous studies show that geometric nonlinearity and initial imperfections plays a significant role in the buckling behavior of homogenous shells. The geometrical nonlinearity and initial imperfection also influence the governing equation of inhomogeneous shells that may cause unpredictable behaviours (Sofiyev, 2011). The presence of defects, such as cracks, may severely compromise their buckling behavior and jeopardize the structural integrity (Allahbakhsh and Shariati, 2014).

1.1 Problem statement.

The buckling phenomenon of imperfects shells is one of the most challenging problems of the theory of elastic stability (Sofiyev, 2011). It is generally recognized that geometric imperfection play dominant role in reducing the buckling load of certain structures (Sofiyev, 2011).

Generally, the buckling of conical shells depends on the geometric and material properties of the shells, type of applied load and geometric imperfection (Maali et al., 2012). Due to special geometric shapes, it has been widely used in a variety of engineering fields as major load carrying parts (Bich et al., 2013). From the literature study, it was found that buckling capacity of conical shells may differ due to slightest imperfection. Therefore defects investigation becomes extremely important to study the failure phenomenon of conical shells (Maali et al., 2012).

Comprehensive understanding of the buckling response of shell structures is necessary to assure the integrity of these shells during their service life. The best way to understand buckling behavior of conical shells is to perform test on manufactured specimens (Golzan and Showkati, 2008).

From the literature study we found that although geometric imperfection plays dominant role in load carrying capacity, but there are few studies conducted on imperfect cones with crack introduced. This experimental project work aims at examining the effect of crack orientation (i.e., axial crack, circumferential crack and angle crack) with different crack length on the load carrying capacity of conical shells subjected to axial compression.

1.2 Objectives

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

1. To design and fabricate steel truncated cones with crack introduced.
2. To study the effects of crack orientation and crack length on axially compressed truncated cone.

1.3 Scopes

The scope of this is research work is based on experimental approach to study the effect of crack orientation and crack length on axially compressed truncated cone. 1 mm mild steel plate is used in designing and fabricating the truncated cones.

In this experiment, four sets of cones with different crack orientation were used. They are: (i) no crack, (ii) cones with axial crack, (iii) cones with angle crack and (iv) cones with circumferential crack. Initially, it was decided to start with no crack cone to establish the baseline, then followed by the other three with different crack orientation. The crack orientations that were introduced are 0^{o}, 45^{o} and 90^{o}. Six cracks length will be introduced. Starting with 5%, 10%, 15% 20%, 25% and 50%. All of the specimens will undergo axial compression test using the Instron machine. The result of load carrying capacity of each specimen will be analyzed.

CHAPTER 2
LITERATURE REVIEW

2.0 Introduction to thin wall shell structure.

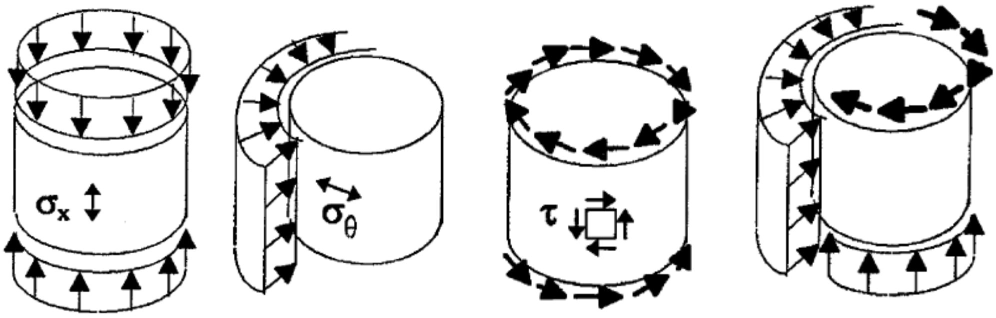
As a common structure, the truncated conical shell has been widely used in various fields such as aviation, submarine, space flight etc; therefore, a lot of research has been conducted on the structure. It is also commonly used as transition elements joining cylinders of different diameter (Blachut, 2011). Considerable progress has been made in these fields and there is now available a valuable body of knowledge on structural crashworthiness and energy absorbing systems, much of which has been achieved through model and prototype testing (Jiang et al., 2006).

Generally, buckling of conical shell depend on many variables such as the geometric properties of the shell, the material properties and the type of applied load. It is well known that geometric imperfection greatly influence the load capacity of a thin shell structure when subjected to axial load (Castro et al., 2015).

2.1 Shells stability

Many researches on truncated cones involves non linear buckling and post buckling behavior of perfect homogenous conical shells. In the study of buckling in thin wall conical shell, the thickness of the wall plays important role to pre buckling deformation; the thinner the wall, the lower the load capacity of a structure. According to (Ifayefunmi and Blachut, 2010), large number of experimental buckling test has been carried out on conical shell, some of the experiment focused on plain conical shell with no reinforcement. (Ifayefunmi and Blachut, 2010) also mention that the majority of the buckling test has been carried out under the application of a single load. According to (Sofiyev et al., 2007) truncated circular conical shells are used in various engineering applications such as hoppers, vessel heads, components of missiles, spacecrafts, and other civil, mechanical and aerospace engineering applications. It is of great technical importance to clarify the buckling behavior of cylindrical and conical shells under combined external pressure and axial compression (Sofiyev, 2011).

The combined stability of a shells component is associated with the action of at least two independent applied loads (Ifayefunmi and Blachut, 2013). Thus, a non-linear theory is probably necessary for such investigations. Figure 2.1 shows the types load that are commonly applied to shell structure, i.e., axial compression, external pressure, torsion and combined loading. It is well known, due to the difficulties emerging from the solution and theoretical analysis of the stability problems of shells, such as suddenly applied loads, has not been studied sufficiently. So it is important to study the dynamic stability behavior of conical shells under suddenly applied loads (Sofiyev, 2007).



Axial compression	External pressure	Torsion	Combined Load

Figure 2.1 Typical load that commonly applied to shell structure (Winterstetter and Schmidt, 2001)

2.2 Buckling

Theoretically, buckling is caused by bifurcation in the solution to the equations of static equilibrium. Buckling is characterized by a sudden sideways failure of a structural member subjected to high compressive stress, where the compressive stress at the point of failure is less than the ultimate compressive stress that the material is capable of withstand. Global buckling is a buckling mode where the member deforms with no deformation in its cross-sectional shape, consistent with classical beam theory. As for localized buckling, it is defined as the mode which involves plate-like deformations alone, without the translation of the intersection lines of adjacent plate elements (Schafer and Adany, 2005). From the experiment conducted by (Hao et al., 2013) the imperfections located near the middle bay usually cause a larger reduction of load-carrying capacity and reduce the imperfection sensitivity. In addition, those imperfection distributions with all the perturbation loads scattered at different panels would produce a larger knockdown of load carrying capacity.

Research conducted by (Bisagni and Cordisco, 2006) confirms that neither failure mechanisms nor any other hazards are visible in the post-buckling range. On the other hand, the collapse due to the failure of the stringers is sudden and destructive. It causes extensive fracture in the skin and in the stringers therefore, after the collapse the shell is not able to support any load any more.

Result from (Hilburger and Starnes Jr., 2004) indicates that a compression-loaded shell with an unreinforced cutout can exhibit a complex non-linear response that is not typically found in the corresponding shell without a cutout. In particular, a local buckling response occurs in the shell that is caused by a localized non-linear coupling between local shell-wall deformations and in-plane destabilizing compression stresses near the cutout. In general, the addition of reinforcement around a cutout in a compression-loaded shell can have a significant effect on the shell response.

(Hilburger and Starnes Jr., 2002) concludes that the traditional and non-traditional imperfections considered in this study could be used to formulate the basis for a generalized imperfection signature of a composite shell. This generalized imperfection signature would include the effects of variations or uncertainties in the shell-geometry, fabrication-process, load-distribution and boundary stiffness parameters. The high-fidelity non-linear analysis procedure used in this study can be used to form the basis for a shell analysis and design approach that includes this generalized imperfection signature. Results had been presented to indicate that the reinforcement can affect the local deformations and stresses near the cutout and retard or suppress the onset of local buckling in the shell near the cutout. For some cases, the local buckling response near the cutout in the shell, results in a stable post buckling response near the cutout. Therefore additional load can be applied to the shell before it undergoes a global collapse. Furthermore, a high-fidelity analysis procedure can be used to addresses some of the critical shell-buckling design criteria and design considerations for composite shell structures without resorting to the traditional empirical shell design approach that leads to overly conservative designs.

By far the most frequent buckling tests had been carried out on cones subjected to a single load. However, buckling tests were also carried out when two or more loads were applied at the same time (Blachut and Ifayefunmi, 2012). It is evident from the available literature that the studies on the buckling of truncated conical shells under combined axial tension and hydrostatic pressure has not been studied yet (Sofiyev, 2009). When the von Mises yield condition and associated flow rule are used, bifurcation analysis predicts buckling loads that are much higher than those observed experimentally (Ramsey, 1977).

2.3 Conical buckling

According to (Ronagh and Naderian, 2015), buckling of thin walled cold-formed steel members could be local, shear, distortional and global. Local buckling is when the cross section of a shell is subjected to large compressive stresses; the structure that makes up the cross section may buckle before the full strength of the member is attained. When a cross sectional element fails in buckling, then the member capacity is reached. Consequently, local buckling becomes a limit state for the strength of steel shapes subjected to compressive stress. Global buckling is a mode in which the member deforms with no deformation in its cross-sectional shape as it undergoes lateral deformations and twist, consistent with the classical beam theory. (Ronagh and Naderian, 2015) also mention that there are few common well-known types of global buckling in cold-formed steel sections such as flexural, torsional, and flexural–torsional which might happen in columns and lateral–torsional that might occur in beams. Treatment of the buckling process of shell-type structures as a linear case has been questioned due to the discrepancies observed between theoretical predictions and experimental results. Therefore, response of these types of structures may be predicted only when one accounts for their geometric non-linear behavior (Sofiyev and Kuruoglu, 2011).

Based on the research conducted by (Ifayefunmi and Blachut, 2011), the buckling strength of conical shell is affected by imperfections. It is found that latter shape distortion appears to be possible from a practical point of view than an initial shape deviation in the form of eigenmodes. It is also stated that the sensitivity of buckling strength may varies if the end condition are relaxed around the full length of circumference.

(Jabareen and Sheinman, 2005) research on the effect of pre-buckling nonlinearity on the bifurcation point of a conical shell on the basis of three shell theories: Donnells, Sanders and Timoshenkos and obtain the following:

- The nonlinear pre-buckling deformations affect the critical buckling load and more significantly the buckling mode.
- For structures characterized by softening behavior, the nonlinear pre-buckling leads to a buckling load lower than the classical one.
- The longer the shell the weaker the effect of the nonlinear pre-buckling deformations.
- The nonlinear pre-buckling effect strongly depends on the in-plane boundary conditions.
- The discrepancy between the shell theories is observed only for cylindrical shells and for conical shells with small vertex half-angle.

2.4 Conical imperfection

Initial geometric imperfection are taken in form of eigenmode, a single wave extracted from the eigenmode and localized smooth dimple. Another common method in analyzing initial geometric imperfections is the use of shape of the eigenmode superimposed on perfect shape (Ifayefunmi and Blachut, 2013). (Ifayefunmi and Blachut, 2013) conducted a research on numerical study into the buckling resistance of geometrically imperfect mild steel cones subjected to axial compression and external pressure. They state that for cones under axial compression only, the collapsed mode has an axsymmetric out ward bulging in the neighborhood of the small radius as shown in Figure 2.2.

Figure 2.2 Collapsed cone subjected to axial compression (Ifayefunmi and Blachut, 2013).

(Ifayefunmi and Blachut 2013) studied on two types of initial shape imperfections that were considered for axially compressed cones. The first imperfection corresponds to the eigenmode type deviations obtained using elastic analysis as illustrated in Figure 2.3 The next imperfection profile is an axisymmetric outward bulge in the neighbourhood of the small end as illustrated in Figure 2.4. This imperfection shapes were superimposed on the perfect cone with different amplitudes. It is seen that the magnitude of buckling load for an axisymmetric outward bulge is smaller than the corresponding result obtained for eigenmode shape deviations therefore; outward bulge leads to weaker cones when compared with the eigenshape imperfection.