Faculty of Mechanical and Manufacturing Engineering Technology

INVESTIGATION OF THE BUCKLING BEHAVIOUR OF AXIALLY COMPRESSED CONE WITH DIMPLE IMPERFECTION

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Bachelor of Mechanical Engineering Technology (Maintenance) with honour

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A thesis submitted
in fulfillment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Maintenance) with honour

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This report is submitted to the Faculty of Mechanical and Manufacturing Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Mechanical Engineering Technology (Maintenance) with honour. The member of the supervisory is as follow:

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ABSTRACT

This study focuses on investigating of the buckling behaviour of mild steel truncated cones under the effect of axial loading. This study will be conduct experimentally using INSTRON 50kN Universal Testing Machine. There are total of 14 sample with various number of dimple imperfection. The effect of dimple imperfection as well as the variation of number of dimple on the load carrying capacity of cones will be investigate. Finally, a comparison between the collapse load of perfect and imperfect conical shells has been conducted. All the objectives has been successfully achieved.

ABSTRAK

Kajian ini menumpukan kepada penyiasatan kelakuan gelendong kon keluli lembut yang dipotong di bawah kesan beban paksi. Kajian ini dijalankan secara eksperimen menggunakan INSTRON 50kN Universal Testing Machine. Terdapat sejumlah 14 sampel dengan bilangan pelbagai lekuk ketidaksempurnaan. Kesan ketidaksempurnaan lekuk dan perubahan beberapa lekuk kepada beban membawa kapasiti kon akan diselidiki. Akhir sekali, perbandingan di antara beban keruntuhan cangkerang konikal sempurna dan tidak sempurna akan dilakukan.

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B	-	Cone semi-vertex angle
r_1	-	Top radius of cone
r_2	-	Bottom radius of cone
h	-	Height of cone
L	-	Slant length of cone

LIST OF ABBREVIATIONS

CAD	Computer Aided Drawing
DXF	Drawing Interchange Format
MIG	Metal Inert Gas

CHAPTER 1

INTRODUCTION

1.1 Background

Conical shell structure is used in the aeronautical, marine, offshore and mechanical industries as structural components. Cones are used to connect two cylinders of different diameters which regularly used in the pressure vessels, pipelines, offshore platforms and transition elements. The load carrying capacity of conical shell when in use is generally restricted by elastic buckling in aeronautical application. This is due to the high value of the thin conical shells radius to thickness ratio. Conical shells also find applications in marine engineering. Shell structures also find multifunctional applications in civil engineering. Silos, roofs, containers, tanks, pipes, pressure vessels, submarines and aircraft wings are some examples that have thin shells as structural components (Deshpande, 2010).

Literally, conical shell structures are subjected to different loading conditions which include axial compression. Several factors determine the limit to which the structures can be loaded or deformed. Instability is one of them. In order to perform buckling analysis of conical shells, one must really understand the behaviour of the shell structure (Ifayefunmi, 2014). Buckling is one of solid mechanics' complex phenomena. This phenomenon represents a threat to shells that are thin and compressive. Buckling's loss of stability is important in many areas such as mechanical engineering, chemical, aerospace engineering, marine industry, etc. For example, when designing columns, vessels with varying suction pressure, longitudinal tubes in steam boilers, ship and submarine bodies, space crafts and vehicles are applicable (Daliri, et al., 2019).

The buckling force of the thin-walled shell under axial compression was found to be particularly sensitive to shell imperfections (Song, Teng and Rotter, 2004). Small geometric imperfections can cause a significant reduction in buckling strength in thin-walled shell structures are among those studying the buckling imperfection stability of shell-of-revolution structures with small geometric imperfections. (Amazigo & Budiansky, 1972; Narasimhan & Hoff, 1971 and Stein, 1968) Practically, imperfections occur locally rather than axisymmetric or have buckling modes shape (Cooper & Dexter, 1974).

1.2 Statement of the Purpose

The purposes this research are:

a) To design and fabricate truncated cones with and without dimple in the middle of its meridional length using mild steel.
b) To study the effect of different dimple amplitude on the buckling behaviour of axially compressed truncated conical shell structure.

1.3 Problem Statement

It was discovered from the literature study that there was not many study on the buckling load of conical shells having a dimple imperfection. Researchers focus more on an initial geometric imperfection, imperfection of loading conditions and uneven length. This study tries to focus on the effect of dimple imperfection on conical shell's buckling behaviour for further investigation due to lack of experimental data on the subject matter.

1.4 Scope

This research is conducted based on experimental approach to study the effect of imperfection with various number of dimple on the buckling behaviour of the truncated conical shell structure subjected to axial compressive loading. The material that was used in designing and fabricating the truncated conical shell structure was mild steel having thickness of 0.5 mm.

In this experiment, in order to achieve accurate data, a total 14 samples were made altogether to be tested. The zero (0) number of dimple was done to establish the baseline. LaserJet cutting machine was used to cut the conical shells. The manufacturing processes of the samples continue with rolling and welding.

All of the truncated cones will undergo axial compression test by using INSTRON Universal Testing Machine. The result obtained from the compression test will be recorded and analysed as the experimental. Result were compared in form of tables, and graphs.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is an overview of the theory and knowledge based on previous researcher which relates to the studies on the buckling load of conical shells having a dimple imperfection. This work carried out to investigates the buckling behaviour of axially compressed cone with dimple imperfection.

2.1.1 Application of Conical Shells in Industries

Conical shell structures are used in aeronautical, marine, offshore and mechanical industries as structural components in engineering applications (Ifayefunmi, 2014). Especially in applications such as pressure vessel, piping, and pipelines (Ifayefunmi and Blachut, 2018). In many fields such as aircraft, rocketry, submarine technology, etc., truncated conical shell has been widely used, as argued by Sofiyev (2011). The non-linear stability analyses of conical shells have been very important in their useful application in recent years and have been of considerable interest in research. One of the thin-walled structures recently considered by researchers is conical or tapered tubes (Jafarian and Rezvani, 2019). For their load carrying capacity performance, they are preferred.

According to Wagner et al. (2018), Hao et al. (2016), conical shell structures are being used as adapters in launch vehicle systems between cylindrical shells of different diameters. Blachut (2016) argued that conical shells are also used in various engineering fields such as tanks and pressure vessels. Also mentioned by Sofiyev (2011) and Hao et al. (2018) submarines, nuclear reactors, jet nozzles and other civil, chemical, mechanical, marine, aerospace engineering structures, missiles and spacecraft are other examples of area where conical shells are being used. Truncated thin-walled conical shells are often used as transition parts between cylinders of different diameters (Khakimova, et al., 2016).

2.2 Buckling Behaviour

2.2.1 Buckling Behaviour of Conical Shells

Over the years, the buckling behaviour of steel plate has been studied. Buckling and instability are among the most important failure modes for shell structures. A long list of research on conical shell buckling such as Seide (1956), Lackman & Penzien (1960) and Tani & Yamaki (1970) has been recorded in history. Volmir (1967) and Leissa (1973) studied conical shells that were formulated using classical shell theory (CST) stability and vibration. It is a phenomenon which occurs in structures which are stiff in a the loaded and slender in another direction (Bhoi and Kalurkar, 2014). This phenomenon is one of the most difficult issues in industry on imperfect shells.

Generally, for structures' buckling load depends on the initial geometric imperfections. When a structure is imperfect, that structure's buckling load will decrease (Sofiyev, 2010). Conical shell buckling behaviour is affected by the material and geometric properties, the type of load applied to it and any geometric imperfections on the shells (Maali et al., 2012). It is very important to study the conical shell failure phenomenon as the slightest imperfection on it can lead to a significant decrease in the structure's buckling capacity. Small geometric imperfections in thin-walled shell structures can cause a significant decrease in buckling strength (Jansseune, et al., 2016). The conical shells stand out from other forms of structure and are usually used in the aerospace, marine and other industries (Ifayefunmi and Blachut, 2013). Another example of a field where buckling of conical shell is of concern is offshore, oil and chemical industries (Blachut, 2012).

The buckling of conical shell can be analysed subject to loads aside axial compression such as pure bending, torsion or complex load conditions (Nedelcu, 2018). The shell geometry plays an important role in the stability of the structure while its mechanical properties will be affected by external loads (Taraghi & Showkati, 2019). The load carrying capacity and conical shell buckling and post-buckling behaviour are very sensitive to initial geometry imperfections when shells were exposed to various types of loading.

2.2.2 Buckling Of Axially Compressed Conical Shells

Wagner et al. (2018) stated that conical shells are subject to heavy payloads and axial compression. There can be a critical gap between theoretical and experimental results of axially compressed conical shells because the buckling load is very sensitive to geometry and loading conditions imperfections. Ifayefunmi and Blachut, (2013) also stated that perfect truncated thick cone with radius, r_1 and r_2, uniform wall thickness, t, height, h, slant length, angle L and semi-vertex, b, shown in Figure 2.1 are subjected to axial compression loading conditions.