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EXPERIMENTAL INVESTIGATION OF BAMBOO-FILLED ALUMINIUM TUBE SUBJECTED TO QUASI-STATIC LOADING

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This report is implemented as to fulfill the requirement of the title of Bachelor in Mechanical Engineering (Structure and Materials)

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PAGE OF CONFESSION

“I admitted that this report is the work of my own except each summary and extraction which I had explained its sourse.”

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ABSTRACT

The research involved experimental works of axial compression of aluminium hollow square tube and bamboo-filled under quasi-static loading condition. The main purpose of the research is to compare the energy absorption between hollow tube and bamboo-filled tube. Initially, related journals and articles were obtained through any resources. Total of eighteen specimens of aluminium with different cross-section dimension were cut off with 300mm in length (9 specimens) and 150mm (9 specimens). The cut area is ensured flat and perpendicular to the length of the tube. Bamboo specimens are all oven-dry. After bamboo specimens had been oven-dry, it is cut into slides. Six specimens with length of 150mm are filled in with slides bamboo. All the specimens (empty tube and bamboo-filled tube) were then subjected to compression load by using INSTRON Universal Testing Mesin Model 5585. The rate of compression is 10mm per minute. Throughout the compression period, photos are taken with every increment and decrement of the load-displacement curve. Videos were recorded throughout entire compression process. This is to obtain the fold formation of the compressed tube. After compression, data and results of the compression test were obtained and load-displacement graphs are drawn to determine the total energy absorption of the tube (area under curve).

ABSTRAK

Tajuk penelitian eksperimental melibatkan mampatan axial pembebanan kuasi-statik balang aluminium persegi berongga dan buluh diisi. Tujuan utama penelitian ini adalah untuk membandingkan penyerapan tenaga antara balang hampa dan balang buluh diisi. Pada permulaaan, jurnal dan artikel yang berkaitan diperolehi melalui sumber maklumat. Lapan belas spesimen dari aluminium dengan dimensi penampang yang berbeza dipotong dengan panjang 300mm (9 spesimen), dan 150mm (9 spesimen). Kawasan memotong dipastikan datar dan bersudut tegak terhadap panjang balang. Semua buluh spesimen dioven-keringkan. Setelah spesimen buluh telah dioven-keringkan, buluh tersebut dipotong. Seterusnya, enam spesimen dengan panjang 150mm diisikan dengan buluh yang telah dipotong. Kemudiannya, semua spesimen (balang kosong dan balang berisi buluh) mengalami mampatan pada mesin mampatan Instron Universal Testing Mesin Model 5585. Kadar mampatan ditetapkan pada 10mm setiap minit. Seluruh tempoh mampatan, foto diambil dengan setiap peningkatan dan penurunan dari graph beban-perpindahan. Video dirakam sepanjang proses mampatan dijalankan. Ini adalah untuk mendapatkan pembentukan lipatan balang dibuka. Selepas process mampatan, data hasil kompresi diperolehi dan beban-perpindahan grafik dilukis untuk menentukan jumlah penyerapan tenaga pada baling hampa dan baling berisi buluh (kawasan di bawah lengkung).

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P_{max} = peak load, N

P_{mean} = mean or average load, N

EA = energy absorption, Nmm

δ_i = axial displacement, mm

t = thickness, mm

L = length, mm

A = area, mm^2

M_c = moisture content, %

m_0 = initial mass of the test specimen, g

m_0 = final mass of specimen after oven-dry, g

D = density of test specimen, kg/m^3

m = mass of specimen after dry, g

V = volume of the test specimen after dry, mm^3

SH = shrinkage of the test specimen, %

I = initial diameter or length, mm

F = final diameter or length, mm

σ_0 = material yield strength, MPa

P_m = average folding force, N

h = wall thickness of the column, mm

C = the half length of every edge in the square cross section, mm

CHAPTER 1

INTRODUCTION

1.1 Background

Based on reference [1], the axial crush response of thin-wall, ductile metallic alloy components (specific geometry and material combination) have been extensively studied for irreversible directional energy absorption capability. It had been studied by Coppa [2], Ezra and Fay [3], Johnson and Reid [4], and finally Reid and Reddy [5]. Due to the significant energy can be absorbed by plastic deformation during the progressive fold formation process that is characteristic of this response, axial crush has many important engineering safety applications in areas including crashworthiness and blast-resistant design of structures.

In early time, an example of the symmetric axial crush response mode by Abramowicz and Jones for an AISI 304 stainless steel, welded square box component tube specimen is shown in Figure 1.1. A crush specimen showing the fold formation and an undeformed tube specimen are shown in Figure 1.1(a). The corresponding axial load-axial displacement curve (subsequently referred to as the load–displacement curve) is shown in Figure 1.1(b) and (c). As also mentioned in reference [1], the axial crush response can be considered to consist of phases or stages. The type of response shown in Figure 1.1 is divided into an ‘initial’ phase and a ‘secondary’ phase. The initial phase phase includes the pre-collapse response prior to the occurrence of the peak or maximum load, the change from axial to bending load-resistance in the sidewalls, and the formation of the first few interior and exterior folds on sets of opposite sidewalls with corresponding increases and decreases in the load–displacement curve. The secondary folding phase consists of the ‘‘steady state’’ fold formation process and the adjacent sidewall interactions and contacting of folds produce subsequent fold formations of constant wavelength along the remaining length of the specimen. Therefore, a cycle in the curve (Figure 1.1(b)) corresponds to the formation of one exterior or one interior fold on both sets of opposite sidewalls with load magnitudes fluctuating between minimum and maximum values. The cycles can be further divided into sections with each section represents the formation of an exterior fold on a specific set of opposite sidewalls and the corresponding formation of an interior fold on the other opposite sidewall pair.

For axial crush response, investigators have used or defined ‘‘crush characteristics’’, also called indicators or parameters, to evaluate and compare the performance of components. These characteristics include both direct data and derived quantities. The emphasis of the current investigation is on the direct data quantities from the load–displacement curve. The characteristics of interest are shown in Figure 1.1(c) for the square box component and include: the initial phase peak load, P_{max} (or P_{02}); maximum and minimum loads, P_{ij}; mean or average loads, P_{meani}; energy absorptions, EA_i; and axial displacements, δ_i. The subscript *i* refers to the initial phase if $i = 0$ and the *i*th cycle in the secondary phase for $i = 1, 2$, etc. The subscript *j* is a sequential number indicator for the maximum and minimum loads in the initial phase or in an *i*th cycle. In general, an energy absorption quantity, EA_i, is the area under the load–displacement curve, and $P_{mean\ i}$ is equal to the energy absorption divided by the axial displacement, δ_i for the initial phase or the *i*th cycle.

The axial crush response has been investigated with respect to types of response modes, geometry-material design criteria for components, crush characteristics to evaluate performance, methods to initiate or modify response, and rate and temperature effects. The effects of material type, material alloying, and process parameters were also investigated on the axial crush response of metallic alloy components. The results shown response mode changes from ductile fold formation to fracture, differences in mode response and crush characteristic magnitudes in the fold formation process.

The analyses involved peak load and overall crush displacement and energy absorption quantities. Secondary folding phase characteristics and details of the materials undergoing severe plastic deformation could not be evaluated because of significant differences in the fold formation process and the load–displacement curve shapes for specimens within each individual study.

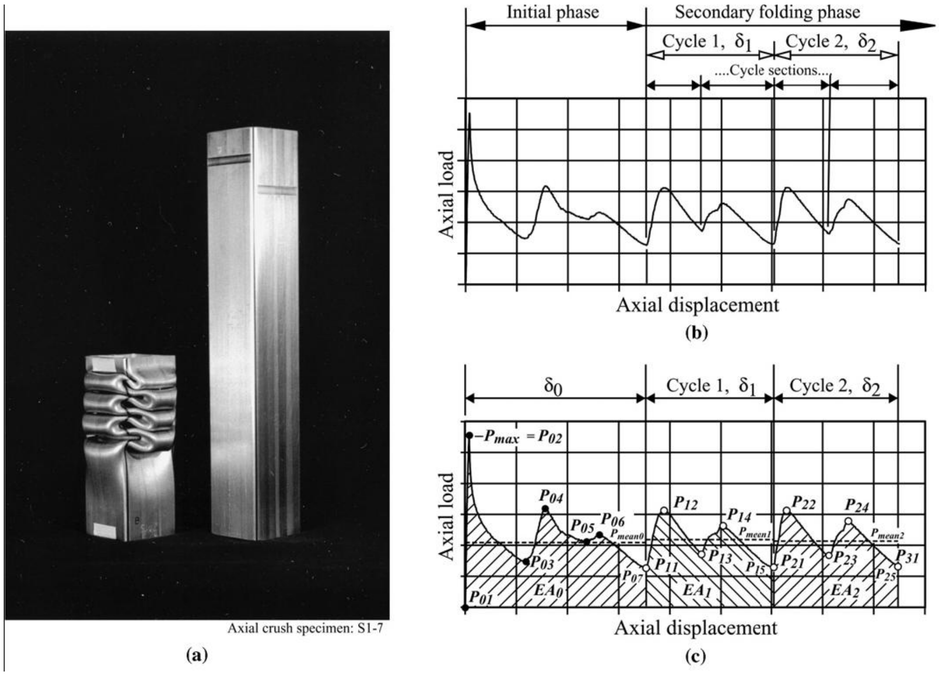

Figure 1.1: Symmetric axial crush response mode – ductile metallic alloy, square box component: (a) axial crush and undeformed tube specimens, (b) curve sections and (c) crush characteristics.

(Source: Dipaolo and Tom, 2006)

The term ‘‘configuration response’’ was introduced in previous research involving AISI 304 stainless steel square box components by DiPaolo [1]. For the symmetric axial crush mode, a specific ‘‘configuration response’’ refers to the combination of a specific fold formation process (verified by fold appearance) and the shape of the corresponding load–displacement curve. An example of fold formation and the corresponding load–displacement curve of an AISI 304 stainless steel tube specimen for the ‘‘Configuration A’’ response that was studied in the previous research [1] is given in Figure 1.2. The results of the research showed that there were several configuration responses of the symmetric axial crush mode and that these configuration responses differed in stationary fold-line locations and traveling fold-line paths for right-circular cylindrical polyvinyl chloride specimens, idealized models, plastic ‘‘hinge lines’’, and for right-circular cylindrical and square specimens. Therefore, there were differed in load magnitudes, energy absorption processes and material performance requirements.

It had demonstrated that axial crush response could be controlled and restricted to a specific configuration response for tube specimens with constant geometry and material and, also, for tube specimens with constant geometry and of the same alloy, but having different uniaxial tensile strength levels.

This capability is important not only for the practical application of axial crush response, but also because it provides the ability to research the influence of material parameters on axial crush characteristic magnitudes and to study details of material behavior such as microstructural evolution and deformation mechanisms during severe plastic deformation.

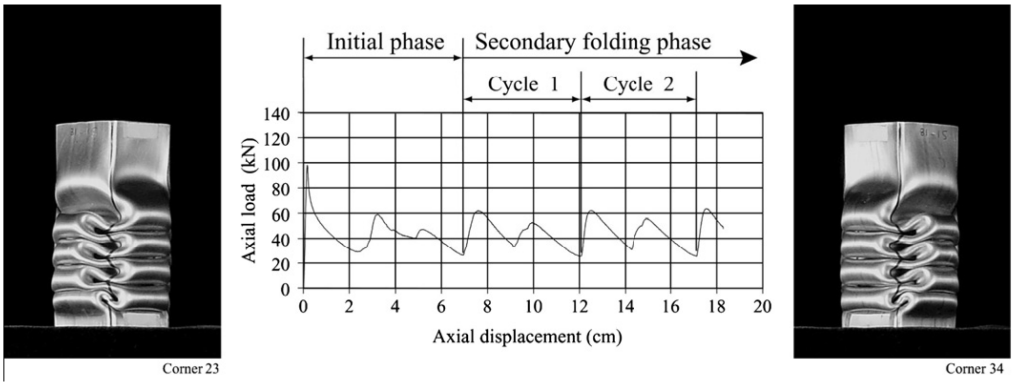

Figure 1.2: Configuration A response – prototype specimen S1-18: fold formation and load–displacement curve.

(Source: Dipaolo and Tom, 2006)

1.2 Objective

The main objective of this research is focused on the capability of the bamboo-filled and hollow empty square aluminium tube to absorb energy during compression. Different cross-section with constant wall thickness and length were studied and tested to compare the behavior of its capability in energy absorption.

In order to achieve the above goal, each tube was investigated its peak and mean loads, plastic folding and energy absorbed of bamboo-filled hollow empty aluminium tube subjected to axial compression. In additional, the study also compared empty and bamboo-filled tube with respect to energy absorption.

1.3 Scope

Aluminium thin-walled tube is selected as the experiment specimen. For comparison among the empty tubes, the tube had three different cross section dimensions but had same thickness and length of 1.5mm and 300mm. While for comparison between empty and bamboo-filled tubes, the length of the tube is decrease to 150mm. The type of bamboo chosen is *Dendrocalamus Asper*. All specimens subjected quasi-static loading with compression speed of 10mm per minute. The characteristic of the empty tube for each cross section is determine through its' peak and mean loads, number of plastic folding, and capability of energy absorbed. As for the characteristic between empty tube and bamboo-filled tube, the specimen's peak and mean loads, and the capability of energy absorbed are also been determine. No simulation work performed in this particular task.