LARGE DEFORMATION OF THIN-WALLED TUBULAR STRUCTURE

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Dedicated *to*

My parents, ***Muhammad Ismail (Late)*** *and* ***Khair-un-nissa****,*

My uncle and aunty, ***Muhammad Ashfaque Asim*** *and* ***Aasma***

My respected supervisor Professor **Dr Mohd Nasir Tamin**

All my family and friends for their immensurable support and love

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ABSTRACT

In automobile and aerospace industries, thin-walled tubular structures have been widely used as key components to improve energy absorption capacity under axial compressive loads, which play an important role in improving the vehicle crashworthiness without increasing body weight. In this project, low carbon steel has been used to study the effect of loading rate onto sheet metal. Metallurgical study carried out to identify microstructure, chemical composition and hardness test of low carbon steel. From tension test at 0.001/s strain rate, stress-strain curve develop to identify the mechanical properties. Johnson –Cook model technique is adopted and parameters of Johnson –Cook model *(A, B, C, m* and *n)* have been extracted and use in FE simulation. Strain gauge rosette inserted on the center of the tube to determine strain at specific points on the structure. Wood of 10mm inserted at the top and bottom of the tube to avoid localized buckling. Then, axial compression test has been conducted experimental and FE simulation to validate the results.

ABSTRAK

Di dalam industri automobil dan aeroangkasa, struktur tiub berdinding nipis telah digunakan secara meluas sebagai komponen yang penting untuk meningkatkan keupayaan penyerapan tenaga di bawah beban mampatan paksi, yang memainkan peranan penting dalam meningkatkan kebolehpercayaan kemalangan tanpa meningkatkan berat badan kenderaan. Dalam projek ini, keluli karbon rendah telah digunakan untuk mengkaji kesan kadar bebanan ke atas kepingan logam itu. Kajian Metalurgi dijalankan untuk mengenalpasti mikrostruktur, komposisi kimia dan ujian kekerasan untuk keluli karbon rendah. Lengkung tegasan-terikan dihasilkan daripada ujian ketegangan pada kadar 0.001/s untuk mengenalpasti sifat-sifat mekanik. Teknik model Johnson-Cook digunakan dan parameter seperti (A, B, C, m dan n) juga diestrak dan digunakan untuk proses simulasi. Tolok tekanan roset diletakkan di tengah-tengah tiub untuk menentukan tekanan pada titik tertentu pada struktur tersebut. Kayu berukuran 10mm dimasukkan di bahagian atas dan bawah tiub untuk mengelakkan lengkokan setempat. Kemudian, ujian mampatan dijalankan sebagai eksperimen dan simulasi adalah untuk pengesahan keputusan.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Automobile structures as shown in figure 1.1 are usually made up of thin-walled, steel plates and metal sheets, subjected to complex loading in a crash event. These structures are widely adopted as main energy absorber for crashing protection attributable to their deformation pattern and energy absorption capacity. The energy absorption capabilities of such structures play an important role due to their high efficiency and cost- effectiveness. With the aid of Finite Element simulation and accurate constitutive model is employed, deformation and failure of sheet metal structures can be characterized after considering careful designed aspects while performing the simulation [1-2].

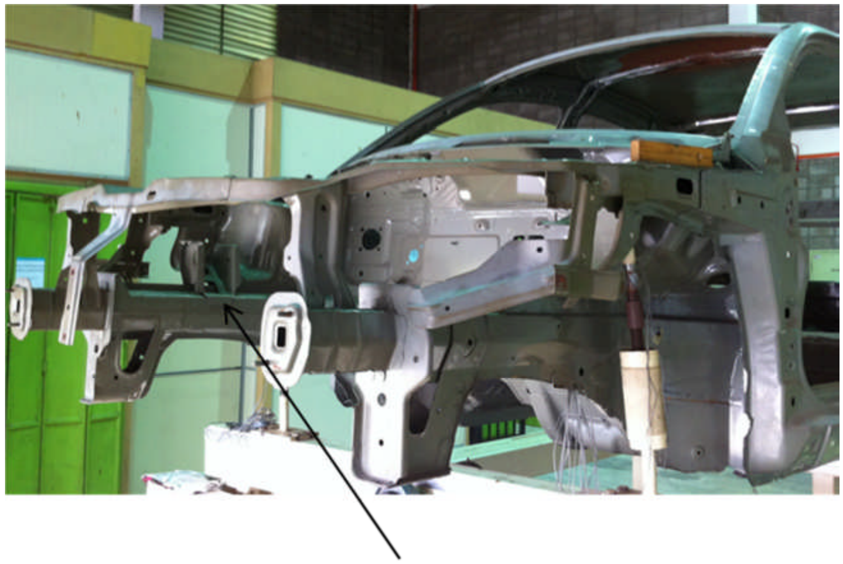

Figure 1.1 Structure of automobile

1.2 Problem Definition

Thin-walled metal tubes with different cross-sections are widely used as energy absorbing structural components in high-volume industrial products such as cars, trains etc. Large deformation occurred when exposed to the crash event. However, expensive apparatus need to conduct an experiment to analyze the behavior after subjected certain loading rate. Thus, finite element simulation is utilized and validates the results with experiment.

1.3 Objectives

The objectives of the project are as follows:

1. To develop a validated FE model of thin-walled steel tube.

2. To establish large deformation characteristics of thin-walled tubular structures when subjected to axial compressive load.

1.4 Scope of Study

The scope of study covers the following points which are as follows:

1. Tension test conducted of extracting Johnson-Cook parameters extraction.
2. Deformation behavior of thin-walled tubular structures involving large plasticity, stress analysis, damage models for metallic materials.
3. Abaqus Finite Element software for simulation of deformation and failure of thin-walled steel structures.
4. Low carbon steel applications consist of axial compression test of thin-walled tube.

1.6 Significant of results

The significance of result is to design a car structure to ensure passenger's safety during crashworthiness and is the desire for cost-to-weight effectiveness. And to demonstrate the results from FE simulation using material Johnson Cook model with experimental results. Predictive capability of the model is measured to establish the behaviour of sheet metals when subjected to various rate of loading.

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LIST OF ABBREVIATIONS

FE	-	Finite Element
FEM	-	Finite Element Method
FCC	-	Face centre cubic
BCC	-	Body centre cubic
HCP	-	Hexagonal close packed
LCS	-	Low carbon steel
HSLA350	-	High strength low alloy 350
TRIP590	-	Transformed-induced plasticity 590
HSLA-65	-	High strength low alloy 65
JC	-	Johnson-Cook
SHS	-	Square Hollow Section
GDS	-	Glow Discharge Spectrometer
AES	-	Atomic Emission Spectroscopy
ASTM	-	American Society for Testing and Materials
ETOTAL	-	Total Energy
ALLIE	-	Internal Energy
ALLKE	-	Kinetic Energy
PEEQ	-	Equivalent Plastic Strains

LIST OF SYMBOLS

E	-	Young's modulus
s	-	Engineering stress
e	-	Engineering strain
σ_y	-	Yield stress
σ	-	True stress
ε	-	True strain
P	-	Load
A	-	Current cross-sectional area
A_o	-	Original cross-sectional area
L	-	Current length
L_o	-	Original length
δ	-	Controlled displacement
$d\epsilon_t$	-	Logarithmic strain
dL	-	Change in displacement
dV	-	Change in volume
σ_x	-	Normal stress at *x*-direction
σ_y	-	Normal stress at *y*-direction
σ_z	-	Normal stress at *z*-direction
τ_{xy}	-	Shear stresses at *x*-*y* plane
τ_{xz}	-	Shear stresses at *x*-*z* plane
τ_{yz}	-	Shear stresses at *y*-*z* plane

ε_z	-	Normal strain at *z*-direction
γ_{xz}	-	Shear strain at *x*-*z* plane
γ_{yz}	-	Shear strain at *y*-*z* plane
P_C	-	Euler load or critical buckling load
α	-	Ferrite
γ	-	Austenite
$\dot{\varepsilon}$	-	Strain rate
T	-	Temperature
T_m	-	Melting temperature
A	-	Johnson-Cook material constant
B	-	Johnson-Cook material constant
n	-	Johnson-Cook strain hardening
C	-	Johnson-Cook strain rate sensitivity
m	-	Johnson-Cook temperature sensitivity
$\dot{\varepsilon}^*$	-	Johnson-Cook dimensionless strain rate
$\dot{\varepsilon}_0$	-	Johnson-Cook nominal strain rate
T^*	-	Johnson-Cook homologous temperature
T_r	-	Johnson-Cook reference temperature