



Faculty of Engineering

**EXPERIMENTAL AND FINITE ELEMENT ANALYSIS TO  
DETERMINE THE STRENGTH OF BEVERAGE CAN**

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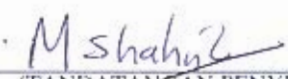
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# EXPERIMENTAL AND FINITE ELEMENT ANALYSIS TO DETERMINE THE STRENGTH OF BEVERAGE CAN

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This project is submitted in partial fulfilment of  
the requirements for the degree of Bachelor of Engineering with Honours  
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- Strength of materials
- Finite element

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## **Abstract**

In the area of strength of materials, problems are primarily of two types which are analysis and design. Problems of analysis involve finding the greatest load that may be applied to a given body without exceeding specified limiting values of stress and strain. Problems of design involve determining the required size and shape of a member to support given loads without exceeding specified limiting stress and/or strain.

In order to determine the strength of material which is beverage can, experimental work and finite element analysis are used. For the experimental work, it is conducted in a laboratory using Testometric machine and Strain Gauge. Compression test is performed on the beverage can to obtain the Modulus of Elasticity (E). Modulus of Elasticity is a measure of the stiffness of a material in its response to an applied load and represents a definite property of material. Material stiffness is defined as the property that enables a material to withstand high stress without great strain. The experiments also been done to know the feasibility of Testometric machine in order to determine the strength of materials.

For finite element analysis, a software called Ansys is used to determine the value of stress and strain. From the stress versus strain graph, the value of Modulus of Elasticity can be obtained. The maximum stress and displacement of beverage can also can be determined. The value of E from Ansys will be compared with the value of E from experimental work. This is to ensure the feasibility of finite element analysis in determining the strength of material.

## Abstrak

Dalam bidang kekuatan bahan, masalah utama biasanya terhadap analisis dan rekabentuk. Masalah dalam analisis melibatkan mencari beban terbesar yang mungkin diaplikasikan ke atas sesuatu objek tanpa melebihi had nilai tekanan dan tegangan atau tarikan yang spesifik. Masalah dalam rekabentuk melibatkan pencarian saiz dan bentuk yang sesuai ke atas beban sokongan tanpa perlu melebihi nilai had tekanan dan tarikan atau tegangan yang spesifik.

Untuk mengenalpasti kekuatan sesuatu bahan iaitu tin minuman, kerja eksperimentasi dan analisis elemen terhad digunakan. Kerja ekperimentasi dilakukan di dalam makmal dengan menggunakan mesin Testometric dan alat pengukur ketegangan. Ujian mampatan dijalankan ke atas tin minuman untuk mendapatkan nilai Modulus Kekenyalan (E). Modulus Kekenyalan ialah ukuran kekakuan sesuatu bahan dalam bertindakbalas ke atas beban yang diaplikasikan dan mewakili sifat ketidakterhadan sesuatu bahan. Kekakuan sesuatu bahan didefinisikan sebagai sifat kebolehan sesuatu bahan menahan tekanan yang tinggi tanpa ketegangan atau tarikan yang kuat. Eksperimen itu juga dijalankan untuk mengetahui kebolehlaksanaan ke atas mesin Testometric untuk mendapat nilai kekuatan bahan.

Untuk analisis element terhad, program Ansys digunakan untuk mendapat nilai tekanan dan tegangan. Dalam graf tekanan lawan tegangan, nilai Modulus Kekenyalan boleh diperolehi. Tegangan maksima dan perubahan dimensi tin minuman tersebut boleh dicari. Nilai E yang diperolehi dari Ansys, akan dibandingkan dengan nilai E dari eksperimen. Ini

untuk memastikan kebolehlaksanaan analisis elemen terhad dalam menentukan kekuatan bahan.

## INTRODUCTION

### 1.1 Objectives

The main objectives of this project are :-

1. To determine the strength of beverage can
2. To see the feasibility of Finite Element Analysis

### 1.2 Cylinder

In many domestic and industrial applications, cylinder is widely used. Cylinder as in figure 1.1 refers to a solid of circular cross section in which the centers of the circles all lie on a single line (i.e., a right circular cylinder). In mathematical usage, cylinder is commonly taken to refer to only the lateral sides of this solid, excluding the top and bottom caps. If a plane inclined with respect to the caps intersects a cylinder, it does so in an ellipse [5].

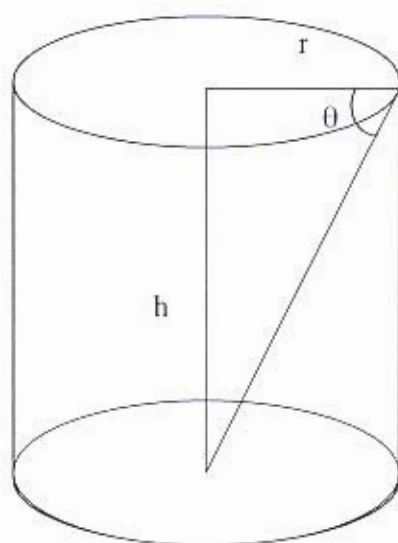


Figure 1.1: Cylinder



Cylinder is called a right cylinder if it is "straight" in the sense that its cross sections lie directly on top of each other; otherwise, the cylinder is called oblique. The lateral surface of a cylinder of height  $h$  and radius  $r$  can be described parametrically by;

$$x = R \cos \theta \quad (1)$$

$$y = r \sin \theta \quad (2)$$

$$z = Z \quad (3)$$

for  $z \in (0, h)$  and  $\theta \in (0, 2\pi)$ . These are the basis for cylindrical coordinates. The surface area (of the sides) and volume of the cylinder of height  $h$  and radius  $r$  given as;

$$S = 2\pi r h \quad (4)$$

$$V = \pi r^2 h \quad (5)$$

Therefore, if top and bottom caps are added, the volume-to-surface area ratio for a cylindrical solid is

$$\frac{V}{S} = \frac{\pi r^2 h}{2\pi r h + 2\pi r^2} = \frac{1}{2} \frac{1}{1 + \frac{1}{r^2} h} \quad (6)$$

which is related to the harmonic mean of the radius  $r$  and height  $h$ . The fact that

$$\frac{V_{\text{sphere}}}{V_{\text{circumscribed cylinder}} - V_{\text{sphere}}} = \frac{4/3}{2 - 4/3} = \frac{4/3}{2/3} = 2 \quad (7)$$

was known to Archimedes.



### 1.3 Applications of cylinders

The most common shape to contain food and drink is a cylinder. Cylinders have many engineering applications and the two most common categories are:-

- i) fluid container such as pipes, pressure vessels and beverage can;
- ii) interference-fitted bearing bushes and the like

Cylinders can act as beams or shafts but in the present context cylinders are loaded primarily by internal and external ( gauge ) pressures due to adjacent fluids or to contacting cylindrical surfaces.

Stresses are identical in cylinders which have geometrically similar cross-sections and which are loaded by the same pressures .Geometric similarity is expressed by a single ratio between two of the three dimensions - inside diameter, outside diameter and wall thickness. Cylinders are usually considered to be either thick in which stress concentration due to relative curvature is significant or thin in which stress concentration is negligible.

Table 1.0 shows the comparisons of the two cylinders

	Thin	Thick
Limiting proportions(approx)	$D_i/t > 20$	$D_i/t < 25$
Analytic treatment	simple approximation	accurate
Statically determinate	Yes	no
Stress state	membrane - ie. biaxial	triaxial
Stress - radial, $s_r$	Zero	varies with radius
- tangential, $s_t$	Uniform	varies with radius
- axial, $s_a$	Uniform	uniform

Physically, thin cylinders are not suitable when the external fluid pressure is much greater than the internal, unless the cylinder is supported or stiffened against local buckling. In this review, thin cylinders with net external pressures which may cause buckling are not considered, unless the cylinders are obviously adequately supported.

Cylinders are classified as being either:-

- i) open - in which there is no axial component of wall stress, or
- ii) closed - in which an axial stress must exist to equilibrate the fluid pressure

Open cylinders are typified by interference-fitted bushes are shown in figures 1.2(a) and 1.2(b) below, in which there are no longitudinal pressures and so no axial stresses. A fluid container sealed by a piston is open 1.2(c) - in this case an external axial force  $F_a$  is mandatory for equilibrium of the overall piston-and-cylinder assembly (a bicycle pump is a common example). If  $A_i$  is the internal circular area then a free body of either piston or cylinder end 1.2(c) must have  $F_a = p_i A_i$  and there is no need for axial wall stresses to equilibrate the fluid pressure.

If an axial stress does exist then it is uniform across the cylinder wall, no matter whether the cylinder is thin or thick. The stress may be found easily from equilibrium in the axial direction, aided by a free body viewed in side sectional elevation. Considering the free body of one end of an internally pressurised closed cylinder 1.2(d) the fluid pressure resultant  $p_i A_i$  is equilibrated by the wall stress resultant  $s_a A_a$  - where the annular wall area is  $A_a = A_o - A_i$  in which  $A_o$  is the outside circular area.

A free body as in figure 1.2(c) of part of a pipe which connects two vessels might be thought open, since no ends are evident and the fluid pressure is self-equilibrating across the free body. However each connected vessel acts as a pipe closure, so the pipe is in fact closed and axial stresses must occur.

In this work, beverage can is chosen as a type of cylinder. The usage of this thin hollow cylinder is mainly as food and drink container. Subsequent section will discuss this in further detail.

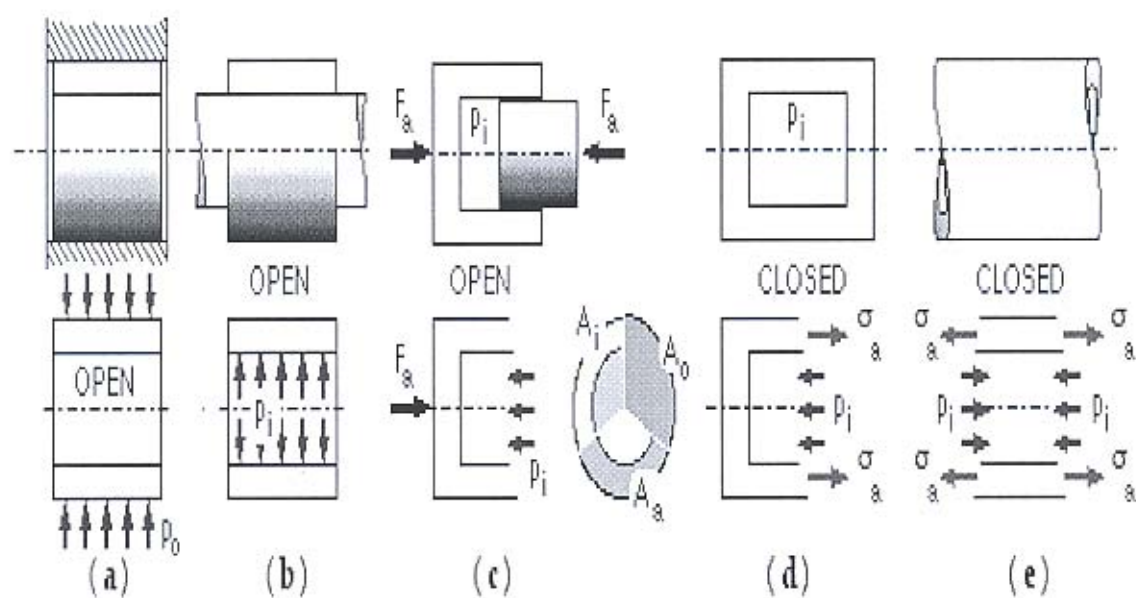


Figure 1.2 :- Typical classification of cylinders

## 1.4 Theory

Strength of materials may be described as a study of relationship between external forces acting on elastic body and internal stresses and strains generated by these forces. Based on the principles of strength of materials, the internal conditions that exist in an elastic body can be established when it is subjected to various loading conditions. In the study of strength of material, the bodies will not be assumed rigid. We will consider machine and structural elements that have application in various fields of engineering technology with respect to both analysis and design.

### 1.4.1 The Engineering Stress $\sigma$

Stress is the internal resistance offered by a unit area of the material from which a member is made to an externally applied load.

#### 1.4.1.1 Stress in Tension

The stress in tension is defined through the equation:-

$$\sigma = F/A \quad (1)$$

With

F = force

A = Original cross section area of the sample



#### 1.4.1.2 Stress in Compression

The stress in compression is defined through the equation:-

$$\sigma = -F/A \quad (2)$$

Because of the force in is reverse direction, therefore, the sign convection for a compressive stress is negative.

#### 1.4.2 The Engineering Strain $\epsilon$

Strain is defined as the change in length of the member. The engineering strain is defined through the equation:-

$$\epsilon = \delta/L_0 \quad (3)$$

with  $\delta$  = the change in length produced by either a tensile or compression load

$L_0$  = the length of the member in its unloaded state

#### 1.4.3 The Relationship Between Stress And Strain (Hooke's Law)

For most engineering materials, a relationship exists between stress and strain. For each increment in stress there is a closely proportional increase in strain, provided that a certain limit of stress is not exceeded. If the induced stress exceeds the limiting value, the corresponding strain will no longer be proportional to the stress. This limiting value is called

proportional limit and may be concisely defined as that value of stress up to which strain is proportional to stress.

The proportional relationship between stress and strain was originally stated by Robert Hooke[8] and became known as Hooke's Law.

The modulus of elasticity or known as Young's Modulus for members in tension or compression is generally represented by the symbol  $E$  and is expressed by the equation

$$E = \text{stress/strain} = \sigma/\epsilon \quad (4)$$

Since strain is a pure number, it is evident that  $E$  has the same units does stress ( $\sigma$ ). For most of the common engineering materials, the modulus of elasticity in compression is equal to that found in tension for all practical purposes. Therefore, it is generally the tensile modulus of elasticity that is determined and used.



## LITERATURE REVIEW

### 2.1 Beverage Can

As early as 1940, can manufacturers began to explore adapting cans to package carbonated soft drinks. The can had to be strengthened to accommodate higher internal can pressures created by carbonation (especially during warm summer months), which meant increasing the thickness of the metal used in the can ends. Otherwise, distortion of the end would strain the seal, creating potential leaks or making cans unstackable for storage and transit.

Another concern for the new beverage can was its shelf life. Even small amounts of dissolved tin or iron from the can could impair the drinking quality of soft drinks. The food acids, including carbonic, citric and phosphoric, in soft drinks present a risk for rapid corrosion of exposed tin and iron in the can. The consequences of off-flavors, color changes and leakage through the metal needed to be addressed. At this point, the can was upgraded by improving the organic coatings used to line the inside, making cans heavier and more encasing [1].

## 2.2 Aluminium

Aluminium is one of the most abundant metals found in the crust of the earth, occurring as an oxide in most clay. Most aluminium is used in the alloyed state. Mechanical properties can be considerably improved by alloying it with small amounts of other metals. Aluminium alloys are generally harder and stronger than the high-purity aluminium. The alloys are widely used for structural and mechanical applications. Among its attractive properties are light weight , good corrosion resistance, relative ease of machining and a pleasing silver-white appearance.

Aluminium and its alloys are divided into two classes according to how they are formed, whether wrought or cast. These products have application within specific fields. Examples are the aerospace industry, architectural buildings, highway structures, tanks, pressure vessels, piping and transportation structures.