UNIVERSITI TEKNIKAL MALAYSIA MELAKA

A Study on the Structural Integrity of Octagonal Shape Bottle Design

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Manufacturing Design) with Honours.

by

MUHAMMAD IDZHAR BIN ISHAK

FACULTY OF MANUFACTURING ENGINEERING

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Date	:	20 Mei 2010

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design) with Honours. The member of the supervisory committee is as follow:

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ABSTRACT

Technology grows rapidly day by day and its contribution to mankind is tremendous especially in the industrial sector. Plastic blow moulding is one of the most important polymer processing operations in making plastic bottles today. In conjunction with this, the design of plastic bottle is vital in order to get the high structural strength to support the required plastic bottle structure. The main objective of this paper is to determine the optimum design for octagonal shape bottle design and to analyze using Solid Work simulation software in order to solve failure on the design of octagonal shape bottle. By using this simulation software, there are several analysis that can be done such as static analysis and buckling analysis. In addition, the analysis is performed based on two scenarios; normal load scenario and critical load scenario. These analysis are necessary to meet the requirement for optimum design before the actual manufacture of plastic bottle.

ABSTRAK

Teknologi berkembang pesat dari hari ke hari dan merupakan penyumbang terbesar kepada manusia terutamanya dalam bidang perindustrian. Plastic blow moulding adalah salah satu proses pengeluaran terpenting dalam pembuatan botol plastik pada masa kini. Oleh yang demikian, rekabentuk botol plastik adalah sangat penting untuk mendapatkan kekuatan struktur yang tinggi bagi menampung sesuatu struktur botol plastik. Tujuan utama kertas kerja ini adalah untuk menentukan rekabentuk optimum botol plastik berbentuk oktagonal dan akan dianalisis dengan menggunakan perisian Solid Work Simulation untuk menyelesaikan masalah kegagalan dalam rekabentuk botol berbentuk oktagonal. Dengan menggunakan perisian ini, terdapat beberapa analisis yang boleh dilakukan seperti analisis statik dan analisis lendingan. Analisis yang dilakukan adalah berdasarkan dua senario iaitu beban biasa and beban kritikal senario. Kesemua analisis ini adalah diperlukan untuk menepati keperluan rekabentuk optimum sebelum pembuatan botol plastik dijalankan.

DEDICATION

Special dedication to my beloved father and mother, my entire sibling and my kind hearted supervisor Mr. Hassan bin Attan, and my dearest friends.

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CAD	-	Computer Aided Design
FEA	-	Finite Element Analysis
HDPE	-	High Density Polyethylene
ISO	-	International Organization for Standardization
LDPE	-	Low Density Polyethylene
PE	-	Polyethylene
PET	-	Polyethylene Terephialate
PP	-	Polypropylene
PS	-	Polystyrene
PSM I	-	Projek Sarjana Muda I
PSM II	-	Projek Sarjana Muda II
PVC	-	Polyvinylchloride
UTeM	-	Universiti Teknikal Malaysia Melaka

CHAPTER 1

INTRODUCTION

1.1 Background

Nowadays, plastic bottles have found wide application in food, beverage and beer industries. Extrusion, injection and blow molding are processes in the manufacturing of plastic bottle. The plastic bottle is a container with a neck that is narrower than its body with an opening at the top. The mouth of the bottle is normally sealed with a plastic bottle cap. Typically, plastic bottles are used to store liquids such as water, soft drinks, cooking oil, medicine, shampoo, milk and ink.

There are several common shapes of plastic bottle such as boston rounds, cosmo rounds, wide mouth rounds, pharmaceutical rounds, cylinders, and ovals. The shape of any plastic bottle is an important characteristic need to consider especially in products packaging process. Usually, material used to make a plastic bottle is from polyvinyl chloride (PVC), polypropylene (PP), high density polyethylene (HDPE) and low density polyethylene (LDPE). The choice of material depends upon its use.

Before the plastic bottle is manufactured, there are some analysis needs to be performed. The analysis comprises static analysis as well as buckling analysis. The purpose is to help the designer to decide whether the design complies with the specification.

1.2 Problem Statement

Usually, the design of octagonal shape bottle is tend to be overdesigned in terms of supporting the structural strength required especially in product packaging process. Hence, appropriate analysis is needed to determine the optimum design which can support a variety of load conditions including top, squeeze, vacuum, and drop impact.

In this research, companies named Fadhilat Herbs Consultant collaborate with Universiti Teknikal Malaysia Melaka (UTeM) in the development of octagonal shape bottle design. Fadhilat Herbs Consultant is one of the dealers in traditional health drink and herbal remedy in Melaka. The objective of collaboration with Universiti Teknikal Malaysia Melaka (UTeM) is to determine the optimum design of octagonal shape bottle design in term of structural integrity.

1.3 Objectives

The objectives of this study are as follow:

- To analyze the structural integrity of the octagonal shape bottle design
- To determine the optimum design of the octagonal shape bottle
- To identify the appropriate analysis need to be performed on the octagonal shape bottle
- To predict the failure on the structure of the octagonal shape bottle

1.4 Scope

The scope of this study is focusing on the analysis of structural integrity octagonal shape bottle design. This study utilizes simulation software to analyze the structural integrity of the octagonal shape bottle design. Polypropylene (PP) is used as a material to make the octagonal shape bottle.

1.5 Thesis Organization

This thesis consists of five chapters. In chapter 1, the background and problem statement of the research are described. It also states the objectives of the research as well as the scope and limitation of study and also organization of thesis.

In chapter 2, a Literature review of the research topic is conducted. The study on the previous structural analysis of plastic bottle is summarized. Besides that, the study on the design analysis, finite element analysis (FEA), structural analysis, static analysis, buckling analysis, blow molding, Polypropylene (PP) properties and anything that helps in the study is also stated in this chapter.

In chapter 3, the methodology of the research is presented. Methods or any particular procedures used to complete the analysis are noted in this chapter. It also includes the chronology of the research.

In chapter 4, the results of analysis are discussed. This chapter is a very important part of this thesis and finally, the conclusions and recommendations are stated in chapter 5.

1.6 Summary

Basically in this chapter is the summary of the whole idea of the project. It begins with the objective of the project, scope of study and research. Throughout the project problems encountered are determined and this will lead to solve problems by studying research and information from various types of resources.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presents all the literature review and some research requiring based on the structural integrity of bottle analysis. This literature review is required to study all the characteristics, requirement needed, and general idea of this. All the information that collected is very important to ensure the project reach their objectives.

There are some parts that need to study about this project such as design analysis, finite element analysis (FEA), structural analysis, static analysis, buckling analysis, blow molding and Polypropylene (PP) properties.

2.2 Design Analysis

The most technically difficult aspect of the design process is analysis. It involves the description of all of the design alternatives in mathematical terms, thereby allowing the engineer to stimulate the operation of the design and to discover any fundamental flaws in the reasoning of his preliminary designs.

In the latter stages of analysis in the design process, through the perspective of mathematics combined with modeling, the most appropriate design will have become obvious and the analysis then will center on the optimization of the design. Many engineers work for most of their professional lives without realizing that their efforts to minimize the cost of a design also should include the cost of the analysis.

For many industries, this is the highest cost aspect of the design process, both in manpower and computing. Another aspect of the design of a product might involve aesthetic factors that to date have no mathematical basis. In addition, it is often desirable to involve a full graphic simulation of the product to enable the design to be fully evaluated from all vantages. There are many levels of abstraction in the mathematical modeling of natural phenomena. The appropriate mathematical model is determined by some agreed-upon level of abstraction.

The development of appropriate mathematical model is one of prime importance in the design process. It is from these models that the information essential to the evaluation of the success of a proposed design is derived. This is the typically the most expensive phase of the design process because development and solution of detailed mathematical models require many man and computational hours. (David E. T., 1999)

2.3 Finite Element Analysis (FEA)

Computer Aided Engineering (CAE) is the application of computer software in engineering to evaluate component and assemblies. It encompasses simulation, validation and optimization of products and manufacturing tools (Technalysis, 2006). The primary application of CAE is used in mechanical, electronic engineering,, aerospace and civil engineering takes the forms of FEA.

FEA is a computer simulation technique used in engineering analysis. It uses a numerical technique called the finite element method (FEM). In general, there are three phases in any computer-aided engineering task are as follow:

2.3.1 Processing

The first step (pre-processing) in using FEA is constructing a finite element model of the structure to be analyzed. The input of a topological description of the structures geometric features is required in most FEA packages. This can be in either 1D, 2D or 3D form, modeled by lines, shapes or surfaces representation respectively. The primary objective of the model is to realistically replicate the important parameters and features of the real model. The simplest mechanism to achieve modeling similarity in structural analysis is to utilize pre-existing digital blueprints, design files, CAD model and/ or data by importing that into a FEA environment. Once the finite element geometric model has been created, a meshing procedure is used to define and break the model up into small elements. In general, a finite element model is defined by a mesh network which is made up of the geometric arrangement of elements and nodes. Nodes represent points at which features such as displacement are calculated. FEA packages use node numbers to serve as an identification tool in viewing solution in structures such as deflections. Elements are bounded by sets of nodes and define localized mass and stiffness properties of the model. Elements are also defined by mesh numbers which allow reference to be made to corresponding deflection or stresses at specific model location.

2.3.2 Analysis (Computation of solution)

The next stage of the FEA process is analysis. The FEM conducts a series of computational procedures involving applied forces and the properties of the elements which produces a model solution. Such a structural analysis allows the determination of effects such as deformation, stresses and strains which are caused by applied structural load such as force, pressure as well as gravity.

2.3.3 Visualization

These results can then be studied using visualizations tool within FEA environment to view and fully identify the implication of the analysis. Numerical and graphical tools allow the precise location of data such as stresses and deflection to be identified.

2.4 Structural Analysis

The function of all structures is to withstand stresses due to imposed load, temperature, shrinkage and so forth. The task of the structural engineer is to propose a suitable structure, to examine its overall stability and finally to calculate structural forces and deformation. The subject dealing with the calculation of reaction (i.e. forces and moment) and deformations (i.e. translation and rotation) in structures due to applied loads is known as structural analysis. (Sarawar, A. R., 2001)

Structural analysis is probably the most common application of the finite element method. The term structural (or structure) implies on mechanical structures such as ship hulls, aircraft bodies, and machine housings, as well as manufacturing product such as bottle, caps and container. There are several types of structural analysis as described below:

2.4.1 Static Analysis

A static analysis calculates the effects of *steady* loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis includes steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads.

Static analysis is used to determine the displacements, stresses, strains, and forces in structures or components caused by loads that do not induce significant inertia and damping effects. Steady loading and response conditions are assumed; that is, the loads and the structure's response are assumed to vary slowly with respect to time. The kinds of loading that can be applied in a static analysis include:

- Externally applied forces and pressures
- Steady-state inertial forces (such as gravity or rotational velocity)
- Imposed (non-zero) displacements
- Temperatures (for thermal strain)

Static analysis can be done on mechanism at various points in their range of movement if zero velocity is assumed. In static analysis, mostly concerned is on the reaction forces on the mechanical system and their joints interconnection forces. Knowing these latter forces is useful in stress analysis to determine engineering criteria such as performance, reliability and fatigue. (Eugene, A. A. *et al.*, 2007)

2.4.2 Buckling Analysis

Based on research conducted by Eduardo, M. S. (2005), buckling is a process by which a structure cannot withstand loads with its original geometry, so that it changes this shape in order to find a new equilibrium configuration. This is an undesired process (from the point of view of the engineer), and occurs for a well-defined value of the load. The consequences of buckling are basically geometric: There are large displacements in the structure, to such an extent that the shape changes. Besides that, there may also be consequences for the material, in the sense that deflections in the bottle may induce plasticity in the walls of the structure. Figure 2.1 shows a buckled bottle.

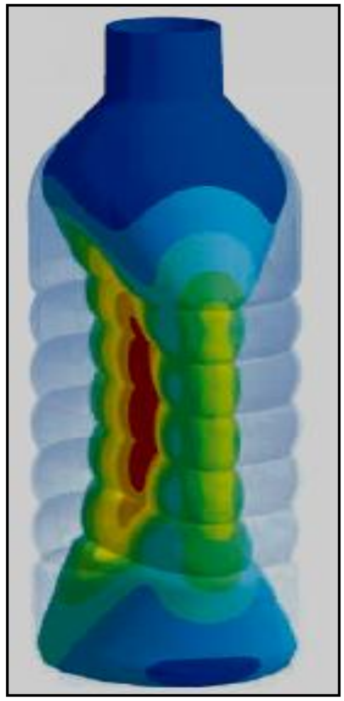

Figure 2.1: Buckling of plastic bottle (University of Alberta, ANSYS Advantages, 2008)

Buckling is associated not just to a structure, but to the complete structural system. To visualize a buckling process it is necessary to consider the load-deflection (P- Δ) diagrams, as shown in Figure 2.2.