VACUUM VESSEL DESIGN FOR FRY DRYING

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‘ I / We* confess that have been read this outstanding piece of works and at my / us * this piece of work is acceptable from the scope and the quality for the awarded Bachelor of Mechanical Engineering (Design and Innovation)’

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This report is submitted
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(Design and Innovation)

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"I declare that all part of this report are the results of my own work except for a few section which extracted and quoted from other resources that as been mentioned"

Signature : ….……

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Date : …....……

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To my beloved mum and dad, brother and sister, Prof. Madya Ir. Mustafar Abdul Kadir, lectures, friends and those supportive people. Your kindness is heartily thanked.

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ABSTRAK

Projek ini adalah bertujuan untuk manghasilkan benjana vakum yang boleh digunakan dalam proses penggorengan kering dengan mengaplikasikan sistem vakum disamping tenaga haba dan memenuhi kehendak rekabentuk di awal proses rekabentuk. Rekabentuk seharusnya mencapai matlamat iaitu untuk mereka dan menghasilkan benjana vakum yang boleh dikurangkan sehingga 2mbar tekanannya serta mengenal pasti bentuk optima untuk benjana tersebut. Proses rekabentuk berdasarkan proses asas rekabentuk bermula dari analisis pasaran, penghasilan spesifikasi produk, rekabentuk asas dan seterusnya rekabentuk menyeluruh. Dalam menyiapkan projek ini, maklulmat-maklumat dikumpulkan dari buku-buku, jurnal dan dari produk-produk yang sedia ada dipasaran dan juga paten. Di Akhir projek ini, rekabentuk yang dihasilkan sepatutnya mencapai tujuannya dan untuk rekabentuk benjana vakum untuk penggorengan kering ini, rekabentuk menyeluruhnya memenuhi objektif utamanya iaitu untuk menghasilkan bentuk optima bagi banjana yang boleh dikurangkan dan dikenakan vakum sahingga 2mbar.

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ABSTRACT

The main idea of this particular project is to design a vacuum vessel which will be use in fry dry process by implementing the vacuum approach in spite of heat energy and fulfills the basic requirements which stated at the first stage of the design. The design should meet the objective of the project which is to develop and create a vacuum vessel that can be evacuated up to 2mbar and determining the optimum shape of the vacuum vessel. This design process is following the basic design process flow starting from the customer needs in market analysis, specification development, conceptual design and finally the detail design. In the process of completing this project, the information is gathered through the books, journals and existing products and patents. At the end of the project, the design should achieve its target or objective and as for this vacuum vessel design for fry dry project, the detail design should meet the main objective which is designing an optimum shape for the vessel and it manage to be evacuated up to 2mbar.

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ABBREVIATIONS

Terms	Meaning
CAD	Computer-Aided Design
FEA	Finite Element Analysis

TRADEMARKS

Product	Owner
Solid Works	Dassault Systemes
COSMOSWorks	Dassault Systemes

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CHAPTER 1

INTRODUCTION

This chapter consists of the background of the project and its problem statement which then followed by the objectives, scopes and its organization.

1.1 Background

In these days, the request for cooking equipment that can cook a desired food without losing the real taste or flavor, smell and color of the food has become the top priority in the food industries due to the demand from the customers are that looking forward for a quality foods. The quality of the food can be maintain by using several approach and one of it is fry drying process. Basically, with the fry drying process, the food will turn out to become crispy since the water inside the food has been absorbed or in other words dehydrated. The pre-fry drying process as well as the osmotic pre-treatment, increases the maximum stress and maximum strain of the food during frying [1].

One simple idea towards increasing the potential and efficiency of the fry drying process in maintaining the food's quality is by implementing the vacuum approach into the design. This new concept of cooking is differed from the existing cooker which is more distressing in subjecting the high pressure towards the food to cook it, which in turns will affect the value or quality of the food.

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Basically, vacuum is defined as a space that is completely empty of all the substances, including air or other gases [2], but in this project, vacuum is reflected to the low pressure that applied to the system and merely a pressure below the atmosphere.

This project covered on the design of the vacuum vessel that can be use for the fry drying process where the main idea is to reduce the pressure up of up to 2mbar and allow the food to maintain its quality.

1.2 Problem statement

The existing cooking appliances in market nowadays are unable to maintain the quality of the food in terms of nutrient, colour, taste and looks. The quality of the food is ruin by the way of cooking it which need to be supply with high heat and temperature. In spite of that, the long period of time taken to cook them affected the quality of the food. It is a major issue in food industry to prioritize the quality of the food. The only way to control and maintain all aspects of the quality in food is by applying the vacuum approach in the cooking process.

The people that involve in food industry are looking forward for some machine or cooking appliance that can increase the quality in their foods. The demand towards this needs increased day by day and some concern inventor and alert company has come out with several equipment that can fulfill the requirements. But the number of them is too small comparing to the demands.

1.3 Objective

The objective of this project is to design a vacuum vessel that suitable for the fry drying process by implementing the vacuum and heat energy approach.

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1.4 Scope

This project covers the design of the vacuum vessel in order to fulfill the main requirement which is could be evacuated up to 2mbar (200pascal @ 1.98m atm). Besides that, it also covers on the optimum shape's design for the vessel itself. Another part in this project is temperature and pressure analyses that reflect the performance of the vacuum vessel. Material that used in developing this project is also one of the scopes in this paper despite of the mathematical analysis or study. The part that not be emphasized on is the thermal analysis part and the prototype but the project is proposed for further fabrication.

1.5 Organization

The first part of the project is identification of the problem statement and development of the objective and scope of the design. Next, the review on the existing product which applies the same approach (vacuum system) with the project took place. Then, it is followed by the design flows which are the specification development and conceptual design. The detail design takes place after that with the mathematical study and material selection. Finally, the analysis of its performance is tested.

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CHAPTER 2

LITERATURE REVIEW

The related information on the vacuum and its related topics such as the vacuum frying, cooking and impregnation is gathered. The fry dry concept also being included together with the vacuum vessel's information and pressure's principles in spite of the heating elements in the heating process. The study on the existing product also covers in this chapter.

2.1 Vacuum

Even though the vacuum system is applied in many processes in the daily life nowadays, not only in the industrial field but also in the medical branch and not forgotten in the food technology; the researches and designers keep on developing and creating new idea on it in order to improve the capability and efficiency of the system.

As vacuum is define as a low pressure that applied to the system and merely a pressure below the atmosphere, the vessel that designed should be able to lasting its ordinary shapes even with the high changes in the pressure that subjected to it.

Vacuum is a volume of space that is essentially empty of matter, such that its pressure is much less than standard atmospheric pressure. The root of the word

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vacuum is the Latin adjective *vacuus* which means "empty," but space can never be perfectly empty. A perfect vacuum with a gas pressure of absolute zero is a philosophical concept that is never observed in practice because quantum theory predicts that no volume of space can be perfectly empty in this way. Physicists often use the term "vacuum" slightly differently and they discussed; ideal test results that would occur in a perfect vacuum, which they simply call "vacuum" or "free space" in this context, and use the term partial vacuum to refer to the imperfect vacuum realized in practice [13].

In quantum mechanics, the *vacuum* is defined as the state with the lowest energy and this is simply a state without particles, referring to its name. However, even an ideal vacuum; thought of as the complete absence of anything, will not in practice remain empty. One reason is that the walls of a vacuum chamber emit light in the form of black-body radiation; visible light if they are at a temperature of thousands of degrees, infrared light if they are cooler. Another reason that the perfect vacuum is impossible is the Heisenberg uncertainty principle which stated that no particle can ever have an exact position. Each atom exists as a probability function of space, which has a certain non-zero value everywhere in a given volume. Even the space between molecules is not a perfect vacuum [13].

Table 2.1 : The vacuum range

(Source : http://en.wikipedia.org/wiki/Vacuum, (2007))

Atmospheric pressure	760 Torr	101 kPa
Low vacuum	760 to 25 Torr	100 to 3 kPa
Medium vacuum	25 to 1×10^{-3} Torr	3 kPa to 100 mPa
High vacuum	1×10^{-3} to 1×10^{-9} Torr	100 mPa to 100 nPa
Ultra high vacuum	1×10^{-9} to 1×10^{-12} Torr	100 nPa to 100 pPa
Extremely high vacuum	$<1\times10^{-12}$ Torr	<100 pPa
Outer Space	1×10^{-6} to $<3\times10^{-17}$ Torr	100 µPa to <3fPa
Perfect vacuum	0 Torr	0 Pa

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Vacuum means the reduction of pressure in a close environment under atmospheric pressure or in simple word is any pressure lower than atmosphere pressure (1013mbar) at sea level [3]. This pressure reduction (evacuation by means of a vacuum pump) is achieved by removing air particles from an enclosed volume which cause the gas pressure and density to reduce. The resultant pressure is known as the end vacuum and defined in mbar as absolute pressure. An absolute pressure of 0 mbar means a perfect vacuum which in realistically unachievable [3].

Based on the JIS (Japanese Industrial Standard), vacuum is defined as the space that exists where the air pressure is less than the surrounding atmospheric pressure [8].

Table 2.2 : The pressure

(Source : Seiko EPSON corporation)

1 atmospheric = 760mmHg (Mercury Liquid Metal) = 760 Torr = 101,325 pa = 10^5bar
1 pa = $1N/m^2$
1N = Force that need for 1kg object at $1m/s^2$
F = m.a = kg .m /s^2 = N

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2.1.1 Vacuum frying

Vacuum frying; in theory, to fry any kind of food we need the cooking medium (in this case refer to the oil) to reach temperatures around 170-180° C. Those temperatures cause the oxidation of the oil and the loss of many nutrients of the foods. In low pressure conditions, however it is possible to fry at 90° C, which prolongs the useful life of the oil and most important guarantees that the retention of the aromas and nutrients of the product will be far greater [12].

The vacuum frying concept functions by creating an artificial low pressure, oxygen-free atmosphere which considerably reduces cooking and frying temperatures, maintaining the texture, colour and nutrients of the food. Moreover, it creates the "sponge effect" by means when the atmospheric pressure is restored; the food absorbed the liquid around it and allowed infinite combinations of foods and flavours. Since the food is prepared in a vessel or container that has most of their oxygen removed, it oxidized at much slower rates and the effects would be as a sliced of fruits or vegetables can last days without turning brown [12].

2.1.2 Vacuum cooking

Vacuum cooking by means when we cook food which is not packed at a pressure lower than atmospheric pressure we can make both the cooking liquid and the product constitution water boil at a temperature lower than 100° C and at this condition, the condition of the food in terms of the flavours and nutrient is preserve [12].

This type of cooking also makes it possible to enrich the product with the characteristics of the cooking liquid. Moreover, the absence of oxygen in the vacuum prevents the oxidation of the food, so that their original colouring is perfectly conserved [12].

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2.1.3 Vacuum impregnation

Normally most of the animal products and vegetable have a rather porous structure. That is why the vacuum produces the “sponge effect” during the cooking process and the air contained in the products expands and comes out when the atmospheric pressure is restored, the food immediately absorbs the liquid in which it is submerged [12].

The fundamental thing is for the texture of the product to be maintained without undergoing the softening caused by maceration, which usually causes dehydration with the consequent loss of firmness of the foods. Vacuum impregnation also serves to speed up the marinades or seasonings, since it helps the transfer of components (salt, sugar, water) towards the interior of the product. The equipment comes with two kinds of basket; one for frying, which prevents the food from being impregnated with oil by means of a system which lifts it and eliminates contact between liquids and solids; and another for cooking with subsequent impregnation, which uses the full capacity of the pot [12].

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