Faculty of Engineering

CONCEPTUAL DESIGN AND ANALYSIS OF SAGO DRYING MACHINE

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Bachelor of Engineering with Honours

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CONCEPTUAL DESIGN AND ANALYSIS OF SAGO DRYING MACHINE

LEW HAO XIAN

A dissertation submitted in partial fulfilment

of the requirement for the degree of

Bachelor of Engineering with Honours

(Mechanical and Manufacturing Engineering)

Faculty of Engineering

University Malaysia Sarawak

2018

Dedicated to My Beloved Family and Friends

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ABSTRACT

The FYP project is about the design and analysis of sago drying machine. The increasing demand of sago flour in various uses mainly in food industry indicates the need to enhance the productivity of sago. The project is to design a machine to make the workers easier in drying process and enhance the efficiency of drying at the same time. The main problem focused in this project is the design and mechanical analysis for the dryer. The mechanical analysis is focused on the tray, support and mixer. Simulation and mathematical model is done to analyse the safety of the product for operation. The mixer is driven by a bevel gear with gear ratio of 3. The rotary motion is transmitted along 15 mm shaft. The motor used is 100 W gear motor and the speed is 200 rpm. The output speed is 70 rpm. One batch of sago flour is 20 kg with expected drying time of 2.7 hours. The simulation shows that the design will not fail as the stress acting on it is within limit of ultimate tensile stress. Small deflection requires no more support at bottom of the tray and tray support. The parts will not fail or break. The simulation results is validated with calculation results showing the simulation can be used to analyse the safety of design structure. The pinion bevel gear have 15 teeth and driven bevel gear have 45 teeth. Gear ratio is 3 and module is 2.5. Input shaft is made up of steel AISI 1050CD with 15 mm diameter whereas output shaft is made up of AISI 1006HR with 18 mm diameter. Static and dynamic analysis shown the design is within the fatigue factor of safety limit of 1.5. The static and dynamic analysis prove that the machine parts operates in a desired safety factor, indicating that the machine will be safe to operate without failure.

ABSTRAK

Projek tahun akhir ini berkaitan dengan reka bentuk dan analisis mesin untuk mengeringkan sago. Keperluan sago semakin meningkat mengikuti kepentingan produk ini dalam industri makanan dan peningkatan dalam penghasilan sago adalah mustahak. Projek ini adalah untuk mereka bentuk mesin pengeringan sago supaya meringankan beban petani dan meningkatkan efisiensi proses pengeringan sago. Kebanyakan bahagian projek ini diberi fokus dalam reka bentuk dan analisis mekanikal. Analisis mekanikal diberi tumpuan dalam tray, support dan pengacau sago. Simulasi dan model matematik digunakan dalam pengiraan. Bevel gear digunakan dalam operasi pengacauan sago. Shaft yang digunakan ialah 15 mm dan 100 W motor dengan 200 rpm dipilih. Mesin in dapat mengeringkan 20 kg sago dalam 2.7 jam. Simulasi menunjukkan reka bentuk ini Berjaya untuk menahan berat tray dan sago. Gear yang digunakan ialah bevel gear dengan 45 gigi dan 15 gigi yang bermodul 2.5. Statik dan dinamik analisis menunjukkan semua bahagian dapat beroperasi dengan selamat.

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IR	-	Infrared
HOQ	-	House of Quality

LIST OF SYMBOLS

M	-	Initial moisture content
m_f	-	Mass of dried sago flour
m	-	Final moisture content
m_d	-	Dry content mass of sago flour
m_w	-	Mass of wet sago flour
M_w	-	Moisture content of wet sago flour
W_w	-	Mass of water need to be removed
m_{wf}	-	Mass of moisture in final dried product
P_v	-	Vapour Pressure
P_a	-	Air partial pressure
P_{atm}	-	Atmospheric pressure
ω	-	Specific humidity
P	-	Pressure
R	-	Ideal gas constant
T	-	Temperature
ρ	-	Density
v	-	Specific volume
m_{air}	-	Mass of air
W	-	Mass of water evaporated
$\emptyset$	-	Specific humidity
$\dot{W}$	-	Drying rate
t	-	Drying time
V	-	Velocity
Q	-	Volume flow rate
R	-	Radius
$\dot{Q}$	-	Rate of heat supply
h_{fg}	-	Specific latent heat of vaporisation
c_D	-	Drag Coefficient
A	-	Area

r	-	Half length of mixer
ω	-	Angular speed
F_D	-	Drag Force
T_t	-	Torque
P	-	Power
σ	-	Stress
y	-	Deflection
p	-	Loading force per unit length
E	-	Elastic Modulus
TH	-	Theoretical value
S	-	Simulation value
a/b	-	Length of the support (side)
r_p	-	Pitch Radius
W_t	-	Transmitted load
W_r	-	Radial Force
W_a	-	Axial Force
M_{tot}	-	Total moment
K	-	Stress concentration factor
d	-	Diameter of shaft
S_{ut}	-	Ultimate tensile strength
k_a	-	Surface factor
k_b	-	Size factor
S_e	-	Endurance limit
n	-	Safety factor
σ_a	-	Amplitude stress
σ_m	-	Midrange stress
T_m	-	Midrange torque
S_y	-	Yield strength

CHAPTER 1

INTRODUCTION

1.1 Background

Sago is a powdery starch which is extracted from the pith inside the trunk of sago palm called Metoxylon Sagu. Metroxylon is derived from the Greek word meaning heart wood. Sago is a primary staple food for the lowland people such as from New Guinea and the Moluccas (Vijay, Vimalraj, Vinith, Vincent, & Vijaymohan, 2017). The people tend to cook and eat the sago in the form of pan cake with fish. In Malaysia, sago is inexpensive and reliable source of starch although it is not a staple food in Malaysia (Mazlina, Kamal, Mahmud, Hussain, & Ahmadun, 2007). Sago palm has the highest production among the starchy crop and it has been named as the 'starch crop of 21st century'(Mustafa Kamal et al., 2017). One sago palm is able to yield around 150 kg to 300 kg sago palm.

The type of sago that planted in Sarawak, Malaysia is called Rumbia (Metroxylon sp.). It is divided into two types which are spiny and smooth types. The harvest period is determined by fertility of soil. On average, the sago could be harvested in 12 or 13 years for mineral soils whereas it takes 15 to 18 years in peat swam area. The sago is harvested by cutting the sago tree trunk into sections and it should not be left for more than 2 days to avoid starch deterioration in the trunk. Sago starch can be used to produce variety of edible products such as biscuits, cakes, noodle and crackers. "Sagu" and "tebaloi" are traditional food from Melanau ethnics which is also made up of sago. Sago flour can also be used to produce glue, textile and plastics. Traditionally, the sago starch drying is done by direct sunlight and wood fired method into the desired moisture content.

This drying process involves the process of dehydration of the products by various way such as introduce heat into the product. The drying process includes heat and mass transfer. Heat transfer involves the transfer of heat into the product by means of conduction, convection or radiation. Mass transfer involves the transfer of evaporated water from the food into the surrounding air. In conventional sago mill, the most economic method in sago drying is wood-fired technique which including the burning of wood (Pendita, Lim, & Junis, 2014). Inefficient usage of the wood fired dehydrator and the greenhouse gas emission are degrading the environment. For solar drying method, the method is time consuming and it subjected to weather constraint especially when cloudy and rainy day. A hybrid dryer which is a combination of solar drying and back up electric dryer can work under problems above. In one research of drying technology, hot air drying process under 50-60°C takes 90-120 minutes to decrease the moisture content in tapioca sago from 40% to 10%. Also, it is found that the tapioca moisture content drop from 30% to 10% in 60 minutes at 30-35°C using hot air dryer (Pandian & Meenambal, 2017).

In this research, the conceptual design of the sago dryer is to be done based on the problems in existing drying method such as economic factor and weather constraint.

1.2 Problem Statement

Sago industry becomes more important as it is a kind of staple food for certain country and it can be used to produce so much variety of food. It is also relatively popular in Malaysia and the largest production is done inside Sarawak. Since the demand for sago is rising, the production is very important to fulfill the demand. However, the production process should be economical to reduce cost for the sago through various process. Traditional drying way of sago is direct sun drying method and wood fire method. Sun drying method is time consuming and not hygienic while wood fired method is not environmental friendly. Common types of dryer include bin (silo) dryers, cabinet (tray) dryers, tunnel (truck) dryers, belt dryers, rotary dryers, fluidized bed dryers, pneumatic (flash) dryers, spray dryers, drum dryers, vacuum dryers, and freeze dryers (Rouvroye, 2014). In this project, the drying process is to be studied to develop a machine to dehydrate the sago moisture level in efficient way in terms of drying rate, energy efficient and so on.

There are many problems or factors that are very important to be considered inside this design research. The optimal temperature is also need to be taken into account so that the quality of the sago starch is no being deteriorated. It is suggested that the drying temperature of the sago starch is best to be 50°C to meet the standard of sago starch moisture content and quality in a research (Mustafa Kamal et al., 2017). Besides, sago that been dried in high temperature will turns brown due to formation of polyphenol oxidase compound which hard to be removed during extraction process. Polyphenols and polyphenols oxidase are sensitive to the drying process (Dina, Ambarita, Napitupulu, & Kawai, 2015). For safe storage of food, the agricultural product should be dried to 9% to 13% (Tiwari, Bhatia, Singh, & Sutar, 1994). The suggested drying technology should be able to operate in the temperature range effectively and economical. The dryer design should have a feasible solution for the farmer or producer of the sago especially in remote area. Optimal space is related directly to the size of the dryer. The dryer should be big enough to contain a large amount of sago in drying process but the space should not be too large. Ergonomic factor is machine design that makes the farmers or producer easy to operate.

Besides, ventilation is also an important factor for the dryer to operate efficiently so the moisture can be drawn out from the sago drier easily to maintain a relatively low humidity inside the dryer chamber. For example, one research in India shown that the volume flow rate of 0.0338m^3/s produces the best quality of the dried banana (Hegde, Hosur, Rathod, Harsoor, & Narayana, 2015). Typically an airflow rate of 180-300mm/min is used for vegetable piece, with dry bulb air temperature of 90°C to 100°C and wet bulb temperature 50°C (Mohammed, 2013).Same goes to this research, the optimal volume flow rate should be found to maintain the best quality of dried sago. The drying method and materials used in the drying machine should be hygienic and comply with food standard. A durable machine with a long life cycle is desired. Figure 1.1 shows a list of factor that should be considered in the design.

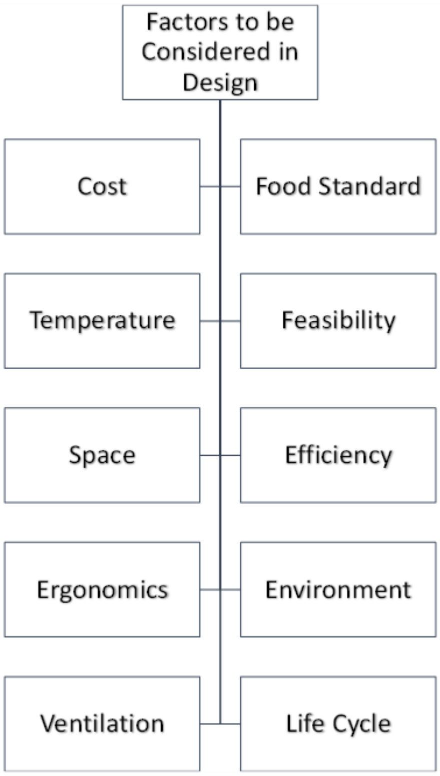

Figure 1.1: Problems to be considered in Dryer Design

1.3 Objectives and Limitation

The objectives of this research are stated as follow:

1. To generate the design concept of a sago drying machine.
2. To perform static and dynamic mathematical analysis on the design concept.
3. To develop bending and stress simulation analysis of the design concept using software.

1.4 Limitation

The fabrication is only limited to small model, which has no exact working function but exhibit the conceptual design physically.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discuss about the research related to the sago flour and drying machine in the market which will help in developing results later.

2.2 Extraction of Sago Starch

Sago starch is extracted from the stem of sago palm. With suitable growing environment and organised farmer practices, the sago yield have a potential to boost up to 25 tonnes per hectare in one year (Karim, Tie, Manan, & Zaidul, 2008). The sago plant takes 7-10 years to mature and is harvested before flowering (Konuma, Rolle, & Boromthanarat, 2012). After the stem of Metroxylon Sagu is chopped down, rasping is done with a board with nails in it. Engine powered rasp which the pith is dug out of the trunk and the rasped. The rasped pith is trampled by foot on a platform. Rotating mesh washer also could be used to separate the sago starch and coarse fibre. The starch slurry is then channelled to the settling pond made of boards. Then the wet sago starch can proceed to drying. Conventional way of drying of the sago starch is sun drying where the modern drying method utilises rotary drum drying followed by hot air drying.

2.3 Properties of Sago

Properties of sago starch are very crucial factor for designing a dryer. Some of the quality problem related to the sago is variable moisture content, colour and so on. The properties below is to show the various factor that is important in sago drying. Konuma et al. (2012) reviews the composition of the harvested sago starch and it has been summarized in Table 2.1 and Table 2.2.

Table 2.1: The Composition of the Major Nutrition in Sago Starch (Konuma et al., 2012)

Nutrients	**Composition**
Carbohydrate	88%
Protein	0.5%
Fat	Minute amount

Table 2.2: The Nutrition of the Sago Starch Expressed in Grams (Konuma et al., 2012).

In every 100 grams	
Nutrients	Amount
Carbohydrate	94 g
Proteins	0.2 g
Dietary Fibre	0.5 g
Calcium	10 mg
Iron	1.2 mg
Fat/ Carotene/ Thiamine/ Ascorbic Acid	Negligible

2.4 Important Parameters in Sago Drying

There are many factors that need to be concerned in designing sago dryers based on the few parameters discussed in this section.