UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF A PROTOTYPE FOR SOLAR POWERED SMART WATER WASTE UNIT (MACHINE ELEMENTS)

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

by

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APPROVAL

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

…….

(Project Supervisor)

ABSTRACT

Tourism and pollution are closely related as humans are the main reason for pollution. Sungai Melaka is a popular tourist spot in Malacca, and it is important that it is well maintained to ensure that it will continue to flourish. This project develops a prototype of solar powered Smart water waste unit, which it is to be placed on the river to collect floating trash. The unit is powered by natural resources, which are solar and river flow hence giving minimal environmental impact. The development aspect which is covered in this paper is the machine elements of the unit. It consist of a water wheel which harvest energy from river flow, a conveyor that carries trash from the river to the bin and a rake system that collects and accumulate the floating trash at the mouth of the conveyor. The design of components are justified by calculations on the machine elements used to operate the unit such as gears, shafts, bearing and power transmission system. A prototype is fabricated at the end to justify the selected design based on Computer-Aided Design drawings supported by calculations and basic Finite Element Analysis.

ABSTRAK

Pelancongan berkait rapat dengan pencemaran kerana manusia merupakan penyebab utama kepada pencemaran. Sungai Melaka merupakan salah satu destinasi pelancongan yang terkemuka di negeri Melaka dan adalah penting untuk kita memeliharanya supaya sektor pelancongan di Sungai Melaka dapat terus diperkembangkan. Projek ini akan membangunkan satu prototaip *Solar Powered Smart Water Waste Unit*, di mana ia adalah satu tongkang yang berfungsi untuk mengutip sampah yang terapung di atas permukaan air. Tongkang ini beroperasi menggunakan sumber semula jadi iaitu tenaga solar dan aliran sungai, justeru ia tidak akan membebankan alam sekitar. Aspek pembangunan yang dibincangkan dalam kertas kerja ini adalah elemen-elemen mesin unit ini. Ia terdiri daripada roda air yang menuai tenaga daripada aliran sungai, satu sistem pengangkut yang membawa sampah dari permukaan air ke dalam kontena dan satu sistem penggaruk yang mengumpul sampah di hadapan sistem pengangkut. Reka bentuk komponen-komponen ini dijustifikasi melalui pengiraan elemen-elemen mesin yang menggerakkan unit ini seperti gear, aci, bearing, dan sistem penghantaran kuasanya. Prototaip yang dihasilkan adalah berdasarkan lukisan berbantu komputer yang disokong oleh pengiraan dan analisis *Finite Element*.

DEDICATIONS

To my beloved family, my mother especially.

And to all my friends which had been on this journey with me.

ACKNOWLEDGMENTS

First and foremost, I would like to express my gratitude towards my project supervisor, Madam Umi Hayati for the opportunity given to me to be involved in this project. Without the chance, I will never come to where I am right now. During the project period, your guidance had shine my path and made the journey much easier. Without you pointing out my mistakes and suggesting ways to further improve my project, the project would never have reached this height and depth. For that I am extremely grateful.

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Finally to my friends, there's an old Chinese saying that goes, "When you're home, you rely on you parents; when you're away, you rely on friends". I sincerely thank you all for allowing me to rely on, for cheering me up when I'm stressed, to accompany me in my endeavours, and sharing of your thoughts to me when I face problems in my project. Maybe you all have not made the journey a lot easier, but you all have certainly made it a lot more fun.

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LIST OF SYMBOLS AND ABBREVIATIONS

2D	=	Two Dimension
3D	=	Three Dimension
ANSI	=	American National Standards Institute
BOR	=	Belt-on-Roller
CAD	=	Computer-Aided Design
CAE	=	Computer-Aided Engineering
CEN	=	European Community for Standardization
EM	=	Effective Microorganisms
FEA	=	Finite Element Analysis
FMECA	=	Failure Modes, Effects, and Criticality Analysis
FTA	=	Fault Tree Analysis
ISO	=	International Organization for Standardization
MSST	=	Maximum Shear Stress Theory
PHA	=	Preliminary Hazard Analysis
PPSPM	=	*Perbadanan Pembangunan Sungai Dan Pantai Melaka*
DFMA	=	Design for Manufacturing and Assembly

CHAPTER 1
INTRODUCTION

1.0 Introduction

We as humans face problems every day, and we also as humans are great problem solvers. New ways are developed every day to counter the problems that we face, and developing new machines is one of the popular methods used. Machines can overcome the physical limits of humans, carrying out task that could not be done by humans or simplifying the work. Machines need to be tailored carefully to ensure that it functions accordingly, therefore machine elements needs to be studied in detail so that we can design the most suitable elements to be used on the machine.

1.1 Background

The tourism industry is a very promising source of income for Malaysia. According to figures from Tourism Malaysia (2015), the amount of foreign tourist arrivals has been gradually increasing for the past 10 years, with the highest recorded total of 27.44 million for the year 2014. According to an article published by *Utusan* Online on 14th March 2015, Malacca alone had received a total of 15.4 million domestic and foreign tourists in the year 2014. Hence, the tourism industry should continue to be flourished to bring more benefit to the country, and adding more attractions or preserving the existing attractions are among the measures that can be taken.

One of Malacca's main tourist products is *Sungai Melaka*, which is flanked by several tourist attractions such as Spice Garden, ruins of Church of Rosario, and Morten Village to name a few. Many efforts have been carried out to preserve *Sungai Melaka* and among the most notable ones is the allocation of RM 285 million on the Melaka River Rehabilitation project. (Jason, 2013) During recent years also, more

and more river based attractions has been added such as the Melaka River Cruise and Melaka River Pirate Park to further promote the tourism of *Sungai Melaka*.

It is clear that *Sungai Melaka* is significant towards the tourism of the state of Malacca. Hence it is important for the upkeep of the river to be continuously carried out to preserve the river's condition so that the river can continue to contribute and benefit the people of Malacca.

1.2 Objective

The purpose of this research is to develop a prototype of a machine which is able to assist in the maintenance of *Sungai Melaka*. This machine is a solar powered Smart water waste unit and it is almost similar to the Inner Harbour Water Wheel at Baltimore City, United States of America. The development is consist of four parts; the overall structure, machine elements, solar power, and sensor system. The development goal focused in this paper is to be able to develop the machine elements as well as the mechanical operations for the water waste unit.

1.3 Problem Statement

A 140-person survey done by Er (2013) on tourists' perspective on tourism development in Malacca shows that there are still 7.14% of the respondents think that Sungai Melaka is not well maintained whereas 22.14% of the respondents think that the shores of *Sungai Melaka* is not well maintained, despite the extensive efforts by local authorities such as the use of Effective Microorganisms (EM) mud balls to naturally purify the river. In another research, Manap et al. (2011) found that tourism gives a strong negative perception towards the environmental impact to the residents residing around. The main environmental impact of tourism is pollution, such that air pollution from vehicle emissions, solid waste and littering at high tourist activity areas, and also sewage pollution where wastewater pollutes rivers and seas.

The solar powered Smart water waste unit is developed focusing on the stated problems above. The water waste unit is a barge placed on the river and it will collect

floating trash on the river surface and removing them from the river. This water waste collecting barge aims to improve the cleanliness of the river cleaning up solid wastes, creating a cleaner environment for the tourists and even act as an attraction itself. This unit must not increase the environmental impact already suffered by the river due to tourism and it can be achieved by utilizing green technology, in line with Malacca state's slogan: "*Melaka Maju Negeriku Sayang, Negeri Bandar Teknologi Hijau*". Green technology uses natural resources without damaging or depleting them. Hence the water waste unit should just be powered by natural resources: solar power and river flow. The development of the unit needs to be able to harvest the two types of resources and utilizing them to drive the machine elements of the unit to generate desired operations.

1.4 Scope

The development of this water waste unit only focuses on its machine elements. Parts to be designed are the mechanical parts, which consist of a water wheel, conveyor, rake, and the machine elements such as gears, shafts, chains and other relevant elements for the water waste unit to carry out its functions. The machine elements will be analysed and calculations will be made to select the most suitable element type and parameters. The parts will then be assembled together in an overall design with correct arrangement and positioning, together with a frame to hold them together. A scaled down prototype with substituted materials will then be fabricated as an early sample to test out each part to ensure they function together accordingly. Other aspects of the development such as the overall structure, solar power and the sensor system will not be covered in this paper.

CHAPTER 2
THEORETICAL BACKGROUND

2.0 Introduction

Literature reviews are based on past works and researches done by other scholars who are published in forms of books, journals, articles and other form of publications. Their publications will be studied, and from them relevant and essential theories or methods are extracted as knowledge to be used and implemented in the project. This chapter reviews and summarize past researches related to this project, which are the water wheel, conveyor, and machine elements. The reviews on the mentioned topics generally consist of the type, design criteria, and relevant calculations and formulas for us to make the best selection.

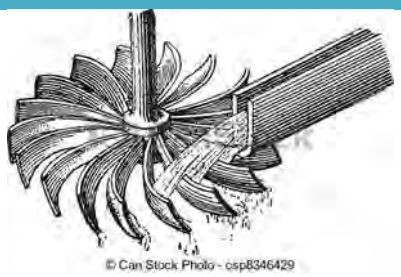
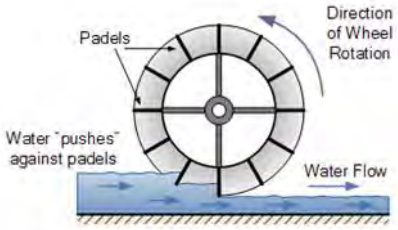
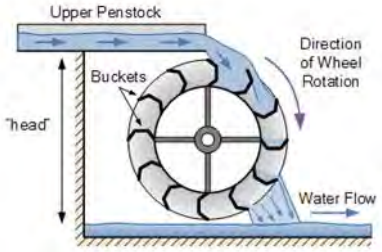
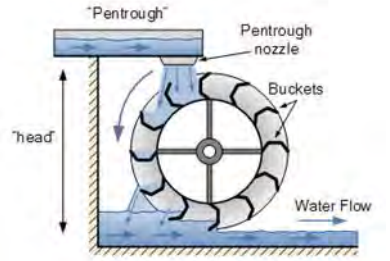
2.1 Water Wheel

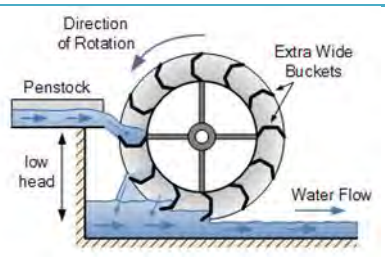
Water wheels, also known as water mills are a type of machine assembly which acts as an energy extractor. The energy extracted by water wheels is the potential energy of flowing or free-flowing water which is converted into kinetic energy in the form of the rotation of the wheel. This is achieved by using the force of the water to move the blades or buckets at the outer rim of the water wheel, creating rotation which can be transferred into other forms of movement.

2.1.1 Types of Water Wheel

Water wheels are generally categorized into vertical and horizontal based on the orientation of their rotating axis. For vertical water wheels, they can be further categorized into four types, which are undershot, overshot, breastshot and pitchback.

Table 2.1: Types of Water Wheel and its Description

Water Wheel Type	Description	Diagram
Horizontal	A horizontal type water wheel acquires its motion from to impact of the hitting waters directed to its blades. It requires high velocity water flow but has very low efficiency.	
Undershot (Vertical)	An undershot water wheel is a type of water wheel where it is partially submerged into the water. It acquires motion from the flowing water that pushes the paddles. This water wheel also has a low efficiency and requires a fast flow of moving water.	
Overshot (Vertical)	An overshot water wheel has buckets to receive the flowing waters and the gravitational force on the buckets of water will then forces the rotation of the water wheel. This type of water wheel type has a very high efficiency however there must be a head higher than the diameter of the water wheel so that the water can be channelled to the top of the water wheel.	
Pitchback (Vertical)	Pitchback water wheel is almost similar to on overshot water wheel as they both receive the driving force from the top of the wheel. The difference of pitchback and overshot waterwheel are the water that was channelled down the wheel will also be used to drive the wheel again by passing underneath the wheel, increasing its efficiency.	

Breastshot (Vertical)	Breastshot type water wheels are required when there is not enough head for the water to reach the top of the wheel. The water can only be channelled to half of the part of the wheel, resulting less gravitational force to power to rotation, thus decreasing its efficiency.	

2.1.2 Water Wheel Design Criteria

To design a water wheel, the main criteria that needs to be considered is the head, which is the velocity of the water, the diameter of the wheel, the number of blades and their spacing, the power of the wheel and the site. A higher head is required for better efficiency as it relates to the impact force of the water hitting the blades, where higher heads means higher potential energy. The amount of potential energy can also be increased by having a larger volume of water. The diameter of the water wheel and its number of blades are determined based on the amount of head, where the head depends on the condition of the site.

For our project, the water wheel will be placed on a river; hence the type of water wheel to be used is an undershot water wheel. Table 2.2 below shows several formulas to be used in the design of the water wheel.

Table 2.2: Water Wheel Calculation Formulas

Parameter	Formula	Description
Head	$H = \frac{v^2}{2G}$ $v = velocity\ of\ stream$ $G = Gravitational\ constant$	The formula used is a formula for sprouting velocity, where it will translate the velocity into head, which is the height for water to fall to reach the velocity.
Diameter of water wheel	$3H \leq d \leq 6H$ $H = Head$ $d = Diameter\ of\ wheel$	Optimum diameter is for the diameter of the water wheel is 3 to 6 times the amount of head.

Number of blades	$n = \frac{C}{H}$ $C = Circumference$ $H = Head$	The distance between each submerged blades need to be equal to or less than the head.
Best revolutions per minute	$s = \frac{v \times 67\%}{C}$ $v = velocity\ of\ stream$ $C = Circumference$	The most efficient energy transfer occurs when wheel speed is 67% to 90% of the water speed. 67% is used to compensate slow river flow. Behrens (1992)
Power of Wheel	$P = p \times A \times v^3$ $p = density\ of\ water$ $A = area\ of\ blade\ in\ water$ $v = velocity\ of\ stream$	The power calculated is the theoretical value. Real power of wheel can only be acquired after knowing its efficiency rating.
Spouting Velocity	$Spouting\ velocity = \sqrt{H \times 2g}$ $H = head = vertical\ height\ of\ water\ from\ water\ level$ $g = gravitational\ acceleration$	Spouting velocity is the velocity of water moving vertically towards the ground due to gravitational force.
Speed of rotation	$Speed\ = \frac{spouting\ velocity}{inner\ circumference}$	Speed of rotation of wheel in terms of revolution per second.

In order for us to determine the actual power for the water wheel, we assume that its efficiency is at 75% based on a previous research done by Muller (2004) on the efficiency of undershot water wheels. A modification that can be done to conventional undershot water wheel is to modify the blades into a Poncelet wheel as per Figure 2.1 where it will increase the efficiency of the water wheel. (Denny, 2003) One final criteria of the water wheel that needs to be designed is the width of the water wheel. There are no certain limitations or restrictions to the total allowable width of the water wheel. The larger the diameter of the water wheel, the smaller the width is preferred. However, Shannon (1997) did suggest that it is best to keep the ratio of diameter to width at 8:5 for the best structural strength.

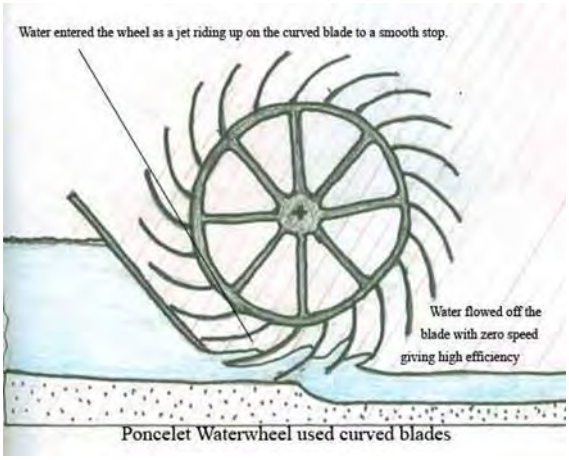


Figure 2.1: Poncelet Water Wheel

2.2 Conveyor

A conveyor system is a type of material handling equipment, where it is generally used to move materials from one place to another which will minimize or even eliminate the need of manual handling. This existence of the conveyer system dates back to 1795, and was used to move grains over a short distance. (Russell, 2004) Over the years, development of conveyor systems allows them to carry heavier objects over a longer distance, and the longest conveyor by date is a total of 60 miles long used to transport phosphate at Western Sahara. Some of the major objectives of conveyor application according to McGuire (2010) are:

- Reduce actual manual handling to a minimum
- Perform all handling operations at the lowest reasonable cost
- Eliminate as many manual operations as possible
- Improve workflow between operations
- Increase throughput

Therefore in general, the objective of implementing a conveyor system is to minimize or eliminate the need of manual handling, at the same time increasing the efficiency of the process.

2.2.1 Types of Conveyor

Over the years, conveyors have been developed where more types of conveyor has been made available to suit different applications. Among them, the main types of conveyors are:

1. Belt Conveyor

Belt conveyors as per named is a type of conveyor that uses a belt to carry materials. Belt conveyors can be used to carry a wide range of materials and is less expensive compared to other types of conveyors, hence they are the most commonly used conveyor system today. Figure 2.2 below shows the standard parts of a belt conveyor. The drive roller drives the movement of the belt whereas the tension roller acts as a counterpart in the same time ensuring the tautness of the belt. The skid pan supports the weight of the material as they are passed through the conveyor.

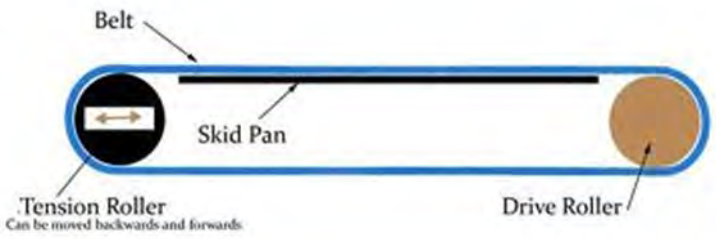


Figure 2.2: Standard Belt Conveyor Parts

Belt conveyors can also be categorized into slider bed conveyor or belt-on-roller (BOR), where for slider bed the top belt is laid on a flat surface whereas BOR conveyors' belt is laid on rollers. There are also other belt conveyor types which are the cleated belt conveyors and troughed belt conveyor. For cleated belt conveyor, the cleats are small barriers attached to the belt as per Figure 2.3 which will carry small objects and they are either bolted on or vulcanized to the belt. On the contrary, a troughed belt conveyor as per Figure 2.4 is mainly used to carry bulk materials where the supporting rollers are arrange in a 'V' shape and it can be installed over very long distances which do not need to be straight or levelled.

Figure 2.3: Cleated Belt Conveyor

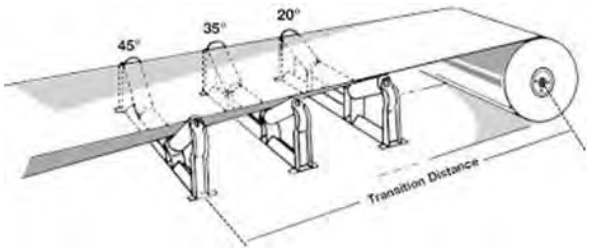


Figure 2.4: Throughed Belt Conveyor

2. Static (Gravity) Conveyor

Static or gravity conveyors are conveyors that do not use any power source to carry the materials. The conveyor is mainly made up of rolling elements connected to shafts aligned together in the same level. The material which is placed on the conveyor will then need to be moved by using human force or else by gravity if the conveyor is mounted on an angle. Static conveyors can be categorized into two main types, wheel and roller conveyors which are shown in Figure 2.5 and Figure 2.6. Due to the reason that static conveyors do not require any power source to be operated, it enables certain flexibility to the conveyor system. They can be extended to different lengths and even curved to accommodate to different layouts, making reconfiguration for different manufacturing process easy. Other than that, hinges can be added to the conveyor to make a gate to allow access of personnel or other equipment. Examples of these two features are shown in Figure 2.7 and Figure 2.8.