

**STRUCTURAL DESIGN AND MECHANISM ANALYSIS OF
OIL PALM HARVESTER**

MICHELLE WONG KHAI SHING

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**STRUCTURAL DESIGN AND MECHANISM ANALYSIS OF
OIL PALM HARVESTER**

MICHELLE WONG KHAI SHING

**This report is submitted
in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering (Design and Innovation)**

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2017

DECLARATION

I declare that this project report entitled “Structural Design and Mechanism Analysis of Oil Palm Harvester” is the result of my own work except as cited in the references

Signature :

Name :

Date :

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Design & Innovation).

Signature :

Name of Supervisor :

Date :

DEDICATION

To my beloved mother and father.

ABSTRACT

Plantation of oil palm becomes focus in Malaysia as it is the top contributors of the economy. In order to match the supply of oil palm fruit with demand, different harvesting methods and tools are used in oil palm estate such as the motorized cutter named Cantas. Although it can reduce the harvesting time and the number of labors involved in harvesting process, the tight arrangement of oil palm fronds and long manually adjusted harvesting pole may cause the inconvenient to the labors. Therefore, this project studies the design of a circular cutter and automatically adjusted telescopic pole with rotational mechanism. It is designed onto an oil palm harvester so that it can reach the oil palm tree with maximum height of 4m. This project is done according to the product development process in designing a product. The concept development of harvester is based on the scientific study on the limitations, customer requirement and engineering characteristics of existing harvesters. It is followed with the selection of best design of harvester that can solve the problems that faced by labors in existing harvester. Different analysis and calculations are also carried out in term of rotational speed, deflection and bending moment for different components in the oil palm harvester. After the selection of suitable materials and dimensions for each component, the design of harvester is done with the aid of CAD software in form of part detail design, orthographic view and exploded view. The automatically adjustable telescopic pole is designed in this project to replace the manually adjusted harvesting pole. Besides, the vibration method in vertical direction that used in the sickle of existing harvester is replaced by circular cutter with rotational harvesting mechanism. The 17cm diameter of inclined teeth circular cutter with rotational mechanism and 3.7m maximum length of telescopic pole with automatically controlled are designed in this project and it could facilitate the harvesting process. With the rotational cutting mechanism, the harvester is not restricted by reaching constraints which was experienced in conventional harvesters. Labors no longer need to find the suitable position to insert the sickle in the middle of fronds with tight arrangement, they can easily reach and harvest the oil palm FFB from the bottom of the bunches with the support of automatically controlled telescopic pole.

ABSTRAK

Perladangan kelapa sawit menjadi fokus di Malaysia kerana ia adalah penyumbang utama untuk ekonomi negara. Bagi memastikan sumber buah kelapa sawit dapat memenuhi permintaan, kaedah dan alat penuaian yang berbeza telah digunakan dalam ladang kelapa sawit seperti pemotong bermotor yang dinamakan Cantas. Walaupun ia boleh mengurangkan masa dan bilangan buruh yang terlibat dalam proses penuaian, susunan pelepah kelapa sawit yang sempit dan batang penuai yang panjang serta dilaraskan secara manual boleh membawa kesukaran kepada buruh dalam proses penuaian. Oleh itu, projek ini mengkaji reka bentuk pemotong bulat dan batang teleskopik yang diselaraskan secara automatik dengan menggunakan mekanisme putaran. Ia juga direka dalam penuai kelapa sawit supaya ia dapat mencapai pokok kelapa sawit yang ketinggiannya maksimum 4m. Proses pembangunan produk digunakan di dalam projek ini untuk mereka bentuk produk penuai kelapa sawit. Pembangunan konsep bagi penuai adalah berdasarkan kajian saintifik mengenai batasan, keperluan pelanggan dan ciri-ciri kejuruteraan daripada penuai sedia ada. Projek ini diikuti dengan pemilihan reka bentuk penuai yang terbaik dan dapat menyelesaikan masalah yang dihadapi oleh buruh dalam penuai sedia ada. Analisis dan pengiraan yang berbeza juga dilakukan dari segi kelajuan putaran, pesongan dan momen lentur bagi komponen yang berbeza dalam penuai kelapa sawit. Selepas pemilihan bahan dan dimensi yang sesuai bagi setiap komponen, reka bentuk penuai dilakukan dengan perisian CAD dalam bentuk lukisan secara terperinci, pandangan ortografik serta lukisan bertaburan. Batang teleskopik yang diselaraskan secara automatik telah direka di dalam projek ini bagi menggantikan batang penuai yang dilaraskan secara manual. Di samping itu, kaedah getaran dalam arah menegak yang digunakan dalam sabit penuai sedia ada juga digantikan oleh pemotong bulat yang berfungsi dengan mekanisme putaran. Pemotong bulat bergigi cenderung dengan 17cm diameter yang berfungsi menggunakan mekanisme putaran dan batang teleskopik dengan 3.7m maksimum panjang yang diselaraskan secara automatik telah direka dalam projek ini dan ia dapat memudahkan proses penuaian. Dengan menggunakan mekanisme putaran dalam pemotong, penuai kelapa sawit dapat mencapai pelepah kelapa sawit yang sempit dengan lebih senang dan dapat menuai tandan kelapa sawit dari bahagian bawah bersama dengan sokongan batang teleskopik yang dikawal secara automatik.

ACKNOWLEDGEMENT

First and foremost, I would like to take this opportunity to express my greatest gratitude to my supervisor, Dr. Mohd Asri Bin Yusuff for his unconditional support, encouragement, guidance and advice in not only the completion of this project, but also in my study life in UTeM. His dedication in providing his best effort in helping and guiding students to achieve their goals has enlightened and inspired me in many ways.

In addition, I would like to thank my PSM examiner, both presentation and report examiners, Dr. Mohd Basri and Mr. Masjuri for their guidance and advice given during the PSM presentation as well as clear explanation and idea in designing a product. Besides, I would also like to extend my deepest appreciation to my parent, who has supported me in pursuing my degree in Mechanical Engineering (Design and Innovation) in UTeM.

Last but not least, a deepest thanks and respondents should give to all my friends, who have supported and helped me directly and indirectly with any kind of resources.

TABLE OF CONTENTS

	PAGE
DECLARATION	iii
DEDICATION	iv
ABSTRACT	v
ABSTRAK	vi
ACKNOWLEDGEMENT	vii
TABLE OF CONTENTS	viii
LIST OF FIGURES	xi
LIST OF TABLES	xv
LIST OF APPENDICES	xvi
LIST OF ABBREVIATIONS	xviii
LIST OF SYMBOL	xix
CHAPTER	
1. INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	3
1.3 Objective	4
1.4 Scope of Project	4
2. LITERATURE REVIEW	5
2.1 Introduction	5
2.2 History of Oil Palm	5
2.3 Oil Palm Tree and Its Fresh Fruit Bunches (FFB)	7
2.3.1 Oil Palm Tree	7
2.3.2 Fresh Fruit Bunches (FFB) of Oil Palm	9
2.3.3 Oil Palm Fruits	9
2.4 Harvesting Method Used in Malaysia	11
2.4.1 Traditional Harvesting Method	11
2.4.2 Motorised Cutter	13
2.5 Other Cutting / Harvesting Tools	16
2.5.1 Date Palm Machine	16

2.5.2	Tree Climbing Robot	17
2.5.3	Portable Trimmer	18
2.5.4	Circular Saw Blade	18
2.6	Product Development Process	19
2.6.1	Quality Function Development (QFD)	20
2.6.2	Product Design Specifications (PDS)	22
2.6.3	Morphological Chart	22
2.6.4	Pugh Concept Selection	23
2.6.5	CATIA	23
2.7	Lead Screw System	24
3.	METHODOLOGY	26
3.1	Introduction	26
3.2	Methods	28
3.2.1	Internet Articles	28
3.3	Specifications and Needs Identification	28
3.3.1	Customer Requirements	29
3.3.2	Engineering Characteristics	29
3.3.3	Quality Function Development (QFD)	29
3.3.4	Product Design Specifications (PDS)	30
3.4	Concept Generation	30
3.4.1	Morphological Chart	31
3.4.2	Conceptual Design	31
3.5	Concept Evaluation	31
3.5.1	Pugh Concept Selection	32
3.6	Embodiment Design	32
3.7	Analysis and Simulation	33
3.8	Detail Design	33
3.8.1	Computer Aided Design (CAD)	34
4.	RESULT AND DISCUSSION	35
4.1	Introduction	35
4.2	Specifications and Needs Identification	35

4.2.1	Customer Requirements	35
4.2.2	Engineering Characteristics	36
4.2.3	Quality Function Development (QFD)	37
4.2.4	Product Design Specifications (PDS)	38
4.3	Concept Generation	40
4.3.1	Morphological Chart	40
3.4.2	Conceptual Design	42
4.4	Concept Evaluation	50
4.4.1	Pugh Concept Selection	50
4.4.2	Best Concept	51
4.5	Embodiment Design	54
4.5.1	Product Architecture	54
4.5.2	Material Selection	55
4.6	Analysis and Simulation	59
4.6.1	Analysis on Cutter	60
4.6.2	Analysis on Telescopic Pole	64
4.6.3	Analysis on Threaded Rod and Nut	73
4.6.4	Analysis on Motor Housing	75
4.7	Detail Design	78
4.7.1	Product Structure	79
4.7.2	List of Components in Oil Palm Harvester	84
4.8	Manufacturing Process and Cost	87
5.	CONCLUSION AND RECOMMENDATION	90
5.1	Conclusion	90
5.2	Recommendation	91
	REFERENCE	92
	APPENDICES	97

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1(a)	Chisel for young palm	2
1.1(b)	Sickle for tall palm	2
1.2	Motorised cutter, Cantas	3
2.1	Percentage share of agriculture by state in 2015	7
2.2	Seedling with bifid leaf	8
2.3	Oil palm trees	8
2.4	Oil palm fresh fruit bunches (FFB)	9
2.5	Oil palm fruits	10
2.6	Traditional harvesting method with chisel	12
2.7	Traditional harvesting method with sickle	12
2.8	Cantas and Ckat	15
2.9	Date palm machine	16
2.10	Tree climbing robot with cutting machine	17
2.11	Portable trimmer	18
2.12	Circular saw blade	19
2.13	Product development process in stage gate format	20
2.14	House of Quality (HOQ)	21
2.15	Pugh concept selection	23

2.16	Lead screw system	24
3.1	Project flow chart	27
4.1	HOQ of oil palm harvester	38
4.2	Datum, Cantas	40
4.3	Concept design 1	42
4.4	Concept design 2	43
4.5	Concept design 3	45
4.6	Concept design 4	46
4.7	Concept design 5	48
4.8	Best concept of oil palm harvester	51
4.9	Sketch of selected oil palm harvester in CATIA	54
4.10	Example of ABS housing	56
4.11	Example of aluminium pole	56
4.12	Example of threaded rod and nut	57
4.13	Example of alloy steel blade	58
4.14	Example of rubber handle	58
4.15	Example of polyester belt	59
4.16	Cutter of oil palm harvester	60
4.17	Deformation on cutter	62
4.18	Von misses stress of cutter	62
4.19	Translational displacement of cutter	63
4.20	Telescopic pole of harvester	64
4.21(a)	Dimension of main pole	65
4.21(b)	Dimension of middle pole	65
4.21(c)	Dimension of end pole	65

4.22	Deflection diagram of telescopic pole	65
4.23	Bending moment diagram of telescopic pole	67
4.24	Deformation on telescopic pole (main pole)	68
4.25	Deformation on telescopic pole (middle pole)	69
4.26	Deformation on telescopic pole (end pole)	69
4.27	Von mises stress of main pole	70
4.28	Translational displacement of main pole	70
4.29	Von mises stress of middle pole	71
4.30	Translational displacement of middle pole	71
4.31	Von mises stress of end pole	72
4.32	Translational displacement of end pole	72
4.33	Threaded rod and nut in oil palm harvester	73
4.34	Lead screws system	73
4.35	Fixed free arrangement of lead screw system	73
4.36	Motor housing of harvester	76
4.37	Deformation on motor housing	76
4.38	Von mises stress of motor housing	77
4.39	Translational displacement of motor housing	77
4.40	Detail design of oil palm harvester	78
4.41	Cutter motor subassembly	79
4.42	Cutter subassembly	80
4.43	Poles subassembly	81
4.44	Pole motor subassembly	82
4.45	Engine subassembly	83
4.46	Orthographic view of oil palm harvester	85

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Specifications of Cantas and Ckat	14
4.1	PDS of oil palm harvester	39
4.2	Morphological chart of oil palm harvester	41
4.3	Concept evaluation of oil palm harvester	50
4.4	Criteria and concept in selected harvester	52
4.5	Properties of steel	63
4.6	End support factor of lead screw system	74
4.7	Manufacturing process for each component	88
4.8	Manufacturing cost for each components	89

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A1	Gantt chart for psm 1	98
A2	Gantt chart for psm 2	99
B1	Isomeric view of oil palm harvester	101
B2	Orthographic view of oil palm harvester	102
B3	Exploded view of oil palm harvester	103
B4	Orthographic view of cutter subassembly	104
B5	Exploded view of cutter subassembly	105
B6	Orthographic view of cutter motor subassembly	106
B7	Exploded view of cutter motor subassembly	107
B8	Orthographic view of poles subassembly	108
B9	Exploded view of poles subassembly	109
B10	Orthographic view of pole motor subassembly	110
B11	Exploded view of pole motor subassembly	111
B12	Orthographic view of engine subassembly	112
B13	Exploded view of engine subassembly	113
B14	Orthographic view of cutter connector	114
B15	Orthographic view of cutter cover	115
B16	Orthographic view of cutter lock	116

B17	Orthographic view of cutter	117
B18	Orthographic view of safety guard	118
B19	Orthographic view of washer big	119
B20	Orthographic view of washer small	120
B21	Orthographic view of locking screw	121
B22	Orthographic view of cutter motor	122
B23	Orthographic view of motor housing	123
B24	Orthographic view of end pole	124
B25	Orthographic view of main pole	125
B26	Orthographic view of middle pole	126
B27	Orthographic view of handle	127
B28	Orthographic view of pole connector	128
B29	Orthographic view of bearing	129
B30	Orthographic view of threaded nut	130
B31	Orthographic view of threaded rod	131
B32	Orthographic view of pole screw nut	132
B33	Orthographic view of pole motor	133
B34	Orthographic view of belt	134
B35	Orthographic view of engine housing	135
B36	Orthographic view of retractable cord	136
B37	Orthographic view of engine housing cover	137

LIST OF ABBREVIATIONS

ABS	Acrylonitrile Butadiene Styrene
AC	Alternative Current
BOM	Bill of Material
CAD	Computer Aided Design
CATIA	Computer Aided Three Dimensional Interactive Application
DC	Direct Current
DOSM	Department Of Statistics Malaysia
FELDA	Federal Land Development Authority
FFB	Fresh Fruit Bunches
GI	Galvanized Iron
HAVS	Hand Arm Vibration Syndrome
HOQ	House of Quality
MPOB	Malaysia Palm Oil Board
MPOC	Malaysia Palm Oil Council
PDS	Product Design Specification
PKO	Palm Kernel Oil
PM	Pugh Matrix
QFD	Quality Function Development
RM	Ringgit Malaysia

LIST OF SYMBOL

C_s	=	Critical Speed
d	=	Diameter
E	=	Young's Modulus
I	=	Moment Inertia
L	=	Length
M	=	Bending Moment
n	=	Rotational Speed
P	=	Load
p	=	Power
r_i	=	Inner Radius
r_o	=	Outer Radius
T	=	Torque
v	=	Velocity
Z	=	Section Modulus
σ	=	Stress
Δ	=	Deflection

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Oil palm is one of the most rapidly expanding equatorial crops in the world and Malaysia is one of the largest oil palm producing countries in Southeast Asia (Koh and Wilcove, 2008). Oil palm is firstly introduced as an ornamental plant to Malaysia in 1870 and the first commercial planting of oil palm took place in Tennamaran Estate in Selangor in 1917. An oil palm fruit is grown in large bunches with weight of 10kg to 50 kg where each bunch has up to 2000 fruits. The oil palm fresh fruit bunches (FFB) need to go through some processing unit operations before it produces as a palm oil product. There is difference in the level of mechanization for each unit of operation. However, the most important and primary stage is harvesting of oil palm FFB from oil palm tree.

At earlier stage, the traditional method was used in harvesting process. The oil palm harvesting involved the cutting of FFB by harvester and allowing it to fall to ground by gravity. It was done manually as the chisel in Figure 1.1(a) was used for young palms while the sickle in Figure 1.1(b) was used for taller palms. However, this manually harvesting operation led to the bruise or damage on oil palm fruits. This method was also extremely inefficient because of the height of palm tree and difficulty to access to fruit.



(a)

(b)

Figure 1.1(a) Chisel for young palm and (b) Sickle for tall palm

Realizing the problem, a motorized cutter which named as Cantas has been invented and developed by Malaysia Palm Oil Board (MPOB). The Cantas which shown in Figure 1.2 can be used to cut the frond and FFB from oil palm tree efficiently as it is powered by a 1.3 hp petrol engine (Jelani et al, 2008). The vibration method is used in designing the operational mechanism of Cantas whereby the vibration action is transferred to vertical direction so that the cutting operation can be performed vertically. Cantas not only reduces the involvement of labor in harvesting process, it also increases the productivity of oil palm with the harvesting capacity of 500 to 700 bunches per day. By comparison, the manual harvesting will only harvest 200 to 300 bunches of oil palm fruits per day (MPOB, 2016). However, there are limitations on the cutter and mechanism of the oil palm harvester. Hence, this project will focus in designing and analyzing of an oil palm harvester for better operational efficiency.



Figure 1.2 Motorised cutters, Cantas

1.2 PROBLEM STATEMENT

Production in the agriculture field becomes focus in Malaysia as it can lead to many advantages especially in economy of the country. Being one of the biggest producers and exporters of oil palm fruit, Malaysia aims to fulfil the growing global need. The rise in demand of oil palm fruits increases the work load of labour in oil palm estate as the harvesting of oil palm FFB is the vital stage of overall process. Although the motorized cutter, Cantas can reduce the harvesting time, the harvesting process of oil palm fruits normally still associated with high prevalence of ergonomic injuries (Ng et al, 2013). One of the reasons is the difficulty in cutting some of the fronds and brunches of oil palm, as the fibre bundles consist of cellulose. Labors might need to use some energy to shove the fronds and brunches physically during the harvesting of oil palm fruits. The tight arrangement of oil palm fronds and FFB on the tree also causes the difficulty in placing the sickle accurately.

During the harvesting process, the Cantas conserves the energy of labours and increases the productivity of oil palm fruits. However, the manually adjusted pole in the oil palm harvester causes the inconvenience to the labours as they need to

change the height of poles manually due to various height of oil palm tree. The length of the pole is considered too long if they need to carry it for whole day long. Besides, they need to find a suitable position during harvesting process so that the oil palm FFB could be harvested accurately. Therefore, an oil palm harvester will be designed and analysed to solve these problems and provide higher operational efficiency.

1.3 PROJECT OBJECTIVES

The objectives of this project are as follows:

1. To design a circular cutter with rotational harvesting mechanism onto an oil palm harvester.
2. To develop a structure of automatically adjustable telescopic pole in the oil palm harvester.

1.4 SCOPE OF PROJECT

The scope of this project is emphasizing on the design of circular cutter and automatically adjustable telescopic pole onto an oil palm harvester that used to harvest oil palm FFB effectively. The oil palm harvester is designed for palm tree with maximum height of 4m. Besides, the operational mechanism of the cutter and telescopic pole are analysed in this project. The CAD work in designing the oil palm harvester is presented in CATIA V5R20.