Faculty of Manufacturing Engineering

Design of Mobile Robot in Agriculture: Development and Analysis of Mobile Robot Body Frame Structure Against Applied Load

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DESIGN OF MOBILE ROBOT IN AGRICULTURE: DEVELOPMENT AND ANALYSIS OF MOBILE ROBOT BODY FRAME STRUCTURE AGAINST APPLIED LOAD

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DECLARATION

I declare that this thesis entitled “Design of Mobile Robot in Agriculture: Development and Analysis of Mobile Robot Body Frame Structure Against Applied Load “is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

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APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Manufacturing Engineering (Manufacturing System Engineering)

Signature	:…….....
Supervisor Name	:…… .....
Date	:…….. .....

ABSTRACT

This report is about carrying out project “Design of Mobile Robot in Agriculture: Development and Analysis of Mobile Robot Body Frame Structure Against Applied Load”, which is specially intended to kick of the main project which is to develop a mobile robot which specialized for agriculture sector activities. On carrying out the project there are several information data and information need to be extracted from journals and research papers in order to ideate the methodological process on analysing the mobile robot frame structure. On talking about mobile robot in other industries, there are few parameters which are significantly different on the field of study of mobile robot in agriculture climate such as the different parameters and requirement due to the implementation of robotic activities in the outdoor which is known to the appearances of water and moist which will have affected some or most of the mechanical and electronics part of the mobile robot. The idea or motivation on kicking off this project is to carry a social mission which is to aid the farmers in level of groups varied from the small scale farmers up until large scale farmers in order to cater the demand on foods on agriculture industries which is known widely the climate problem which is the request or demand on food percent is higher from the production. This due to several aspects such as labour shortage or the dumping of unskilled workers which worsen the situation. From this two issues, the problem had been deepened research to find out the factors of labour shortage which is seen as with the modernization era of technology especially in robotic which is proven capable of aiding human in their task, able to take role to fulfil this humanity mission. In the end, the project will be carried out from idea of this first paper which is the conceptual of the mobile robot and in the future the research able to expand to the wide research of the mobile robot for the agriculture activity. The project started with conducting a study and research from journals and research papers on information regarding mobile robot development concept and parameters especially for agriculture mobile robot. The study also consists of extracting and comparing design from other journal and research papers in order to interpreted it into concept design for this project mobile robot. Other than that, method on analysis for the mobile robot body structure also included in the research to find out how to carry out experiment which to test the strength of

the structural body. The analysis which will involve in this project is by carrying out stress analysis by using Finite Element Analysis software which is embedded in the design software to observe the body stress or pressure generated which lead to fracture once a value of load applied to the body. At the same time to compare between two materials, which are mild steel and stainless steel grade 440c to determine which materials gives better strength to be set on developing the structure for the mobile robot. Once all the information and conceptual design obtained, the design will go through a sketch conceptual design and at then later on the sketch design was translated in 3d form drawing. The purpose of translating into 3d form drawing is to carry out the strength analysis for the structural body to determine if the designed body capable of supporting loads which up to 30kgs of load. On the analysis method, the load was applied by stages which is starting with 10kg load, then continue by 10kgs until 30kgs load to observe the increment of pressure and at the same time to observe on the simulation result the most fracture part from the load applied. This analysis was carried out twice for different materials as mention before to determine which materials gave a better strength to be chosen to develop the body structure. Result shows that stainless steel gave better result in term of strength against load applied but eventually on deciding to finalize the material selection for the structural body, there is no final answer for this paper because the purpose of this project is to find out which materials gave better strength, but in order to finalize the selection there are several more parameters need to be count in such as material fabrication and finishing costing etc.

ABSTRAK

Laporan ini adalah membincangkan tentang projek "Reka Bentuk Robot Bergerak dalam Pertanian: Pembangunan serta Analisis atas Struktur Kerangka Badan Robot Mudah Alih terhadap Beban yang Digunakan", yang bertujuan khusus untuk memulakan projek utama yang bertujuan untuk membangunkan robot mudah alih yang khusus untuk aktiviti dalam sektor pertanian. Bagi menjalankan projek ini, terdapat beberapa perkara dan maklumat yang perlu diekstrak dari jurnal dan kertas penyelidikan untuk memberi idea dalam metodologi untuk menganalisis struktur rangka robot mudah alih. Mengenai robot mudah alih di industri lain, terdapat beberapa parameter yang sangat berbeza dalam bidang kajian robot mudah alih dalam iklim pertanian seperti contoh parameter dan keperluan yang berbeza kerana pelaksanaan aktiviti robot di kawasan terbuka atas sebab kehadiran elemen udara lembap yang akan menjejaskan sebahagian atau kebanyakan bahagian mekanikal dan elektronik robot mudah alih. Idea atau motivasi untuk menjalankan projek ini adalah untuk membawa misi sosial bagi membantu petani di peringkat kumpulan bervariasi dari petani kecil sehingga petani skala besar untuk memenuhi permintaan terhadap makanan di industri pertanian yang diketahui secara meluas masalah iklim dan permintaan terhadap peratus makanan lebih tinggi daripada pengeluaran. Ini disebabkan oleh beberapa aspek seperti kekurangan buruh atau lambakan pekerja tidak mahir yang memburukkan keadaan dalams ektor berkenaan. Dari dua isu ini, masalah telah diperkalamkan penyelidikan untuk mengetahui faktor-faktor kekurangan buruh yang dilihat dengan era modenisasi teknologi terutama dalam robot yang terbukti mampu membantu manusia dalam tugas mereka, dapat mengambil peranan untuk memenuhi misi kemanusiaan ini . Akhirnya, projek ini akan dijalankan dari laporan ini yang merupakan pemula kepada konsep robot mudah alih dan pada masa depan penyelidikan dapat diperkembangkan secara meluas bagi robot mudah alih untuk aktiviti pertanian. Projek ini bermula dengan menjalankan kajian dan penyelidikan dari jurnal dan kertas penyelidikan mengenai maklumat mengenai konsep dan robot pembangunan robot mudah alih terutama untuk robot mudah alih dalam sektor pertanian. Kajian ini juga terdiri daripada mengekstrak dan membandingkan reka bentuk dari jurnal dan kertas

penyelidikan lain untuk menafsirkannya ke dalam reka bentuk konsep untuk robot mudah alih projek ini. Selain daripada itu, kaedah analisis untuk struktur badan robot mudah alih juga termasuk dalam penyelidikan untuk mengetahui bagaimana untuk menjalankan eksperimen yang menguji kekuatan struktur badan robot mudah aluh tersebut. Analisis yang akan melibatkan dalam projek ini adalah dengan menjalankan analisis tekanan dengan menggunakan perisian Analisis Unsur Terhingga yang disediakan dalam perisian reka bentuk untuk memerhatikan tekanan yang dijana yang mengakibatkan risiko struktur patah terhadap beban yang dikenakan kepada rangka struktur robot berkenaan. Pada masa yang sama analisis ini dijalankan bagi membuat perbandingan antara dua bahan, iaitu keluli ringan dan keluli tahan karat gred 440c untuk menentukan bahan mana yang memberikan kekuatan yang lebih baik untuk ditetapkan untuk membangun struktur untuk robot mudah alih. Sebaik sahaja semua maklumat dan reka bentuk konseptual diperoleh, reka bentuk akan melalui reka bentuk konsep lakaran dan kemudian pada reka bentuk lakaran diterjemahkan dalam lukisan bentuk 3d. Tujuan untuk menerjemahkan ke dalam lukisan bentuk 3d adalah untuk menjalankan analisis kekuatan untuk badan struktur untuk menentukan sama ada badan yang direka bentuk mampu menampung beban sehingga 30kgs beban. Pada kaedah analisis, beban itu digunakan secara berperingkat-peringkat yang bermula dengan beban 10kg, kemudian diteruskan dengan 10kgs hingga beban 30kgs untuk melihat kenaikan tekanan dan pada masa yang sama untuk melihat pada hasil simulasi sebahagian paling patah dari beban yang dikenakan . Analisis ini dijalankan dua kali untuk bahan-bahan yang berbeza seperti yang dinyatakan sebelum ini untuk menentukan bahan-bahan mana yang memberi kekuatan yang lebih baik untuk dipilih untuk membangunkan struktur badan. Hasil menunjukkan bahawa keluli tahan karat memberikan hasil yang lebih baik dalam jangka masa kekuatan terhadap beban yang digunakan tetapi pada akhirnya untuk memutuskan pemilihan material untuk tubuh struktur, tidak ada jawapan akhir untuk makalah ini kerana tujuan projek ini adalah untuk mencari bahan yang diberikan kekuatan yang lebih baik, tetapi untuk memuktamadkan pemilihan terdapat beberapa lagi parameter yang perlu dikira seperti fabrikasi bahan dan penamat penamat dan lain-lain.

DEDICATION

This dissertation was dedicated to the memory of my beloved mother, Salmah binti Mohd Salleh who passed away on the journey of master studies, which she was fully supporting me when I was demotivated on my struggle until her last breath. Also dedicated to the memory of my beloved father, Md. Shariff bin Jafar who passed away on my early journey of master study, who was given me all the motivation and moral support not to stop seeking for knowledge and never stop on the study journey until his last breath. As I promised to myself whom I promised to them that I will keep striving for success on my journey and not giving up for thing that I started until the end of the journey. All this effort and knowledge will be contributed in the future for the benefits of nation and sake of future, and for the benefits of both of them in the afterlife.

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LIST OF ABBREVIATION

The following abbreviation need not to be defined

ANSYS	Analysis of System
CAD	Computer Aided Drawing
CEBOT	Cell Structured Robotic System
COG	Center of Gravity
COM	Center of Mass
EMS	Equivalent Von Mises
ICR	Instantenous Center of Rotation
IoT	Internet of Things
MS	Mild Steel
SS-440c	Stainless Steel grade 440c
UN	United Nation
VMS	Von Mises Stress

CHAPTER 1

INTRODUCTION

This chapter will introduce to the project carry out from the problem statement, objective up until scopes of the project. This chapter also will explain about overall of the report structure for the entire report.

1.1 Introduction

Robotic technology has been widely use nowadays in varies type of industries such as manufacturing industry, defences industry and so on. This in include in agriculture sector. The purpose of using robots is to makes life easier (Bhawana and Jagruti, 2014). In agriculture industry, robot had been widely used for improving process involving agriculture activities such as plucking, spraying etc. and in the aspect of agriculture, especially in plantation, there are some parameters need to understand in order to design a suitable robot to suit in with agriculture environment such as dimension and frame, traction, steering, motors and power supply (Rubens, et al., 2011)

Mobile robot is a field of study which consist many root of field in engineering such as mechanical, electrical and computer science. The reason why inventor created mobile robot was because of commercial robot in industry have one major disadvantages which is lack of mobility (Siegwart and Nourbakhsh, 2004). With mobile robot mobile ability, this issue able to be overcame. The motion of mobile robot normally relates with locomotion mechanism. There are varieties of locomotion mechanism can be defined with the mobility of robot based on Siegwart and Nourbaksh in their book *"Introduction to Autonomous Robot"* such as flowing in channel, crawl,

sliding, running, jumping and walking. This depend on the purpose and objective of the mobile robot.

For the past few years, numbers of mobile robot had been designed to fulfil objective and purposed of the task given. Some of mobile robot designs are land type robot which consist of legged robot, wheeled robot, and tracked robot, water type robot such as swimming robot and sea navigation robot such as submarine robot, air type robot such as flying drone and helicopter and lastly miscellaneous type robot which relate to mobile robot .Mobile robots were built on various sizes ranging from huge size up until nowadays with the development of technologies, researchers able to reduce the size of robot down to Nano size to execute tasks on tiny and congested area. Other than that, range of mobile robot from the execution area to the controller also essential for a mobile robot to execute their task. This varies from short range up until the ability to control from far using satellites for the mobile robot to execute their task in the remote area without involvement of human in the area.

In agriculture sector, farmers are struggle to facilitate their rate of production to meet the demand of market nowadays, hence the requirement of mobile robot to serve the task seen able to improve this efficiency on market demand requirement. Some of robot tasks in agriculture include the needs for the robot to travel across the crops area ranging from small scale to hundreds of acres to pluck fruits and vegetables, to water and fertilize hundreds to thousands of crops in the land area, and also able to replace living animals such as dog to guard the crop area. Other than that, involvement of robot into agriculture able to reduce risk of hazards affected into involvement of manpower such as hazards from chemical pesticide, diseases from crops and plant (poisonous plant etc.), hazards with encounter from wild and poisonous animals, and mechanical hazards such as injuries from machinery and tractors.

1.2 Motivation

The motivation of conducting this project is to aid farmers on executing their agriculture activities with the minimal involvement of human activities due to exposure to variety kind of hazards such as heat and chemical reaction from chemical fertilizers and dangerous animals in the crops area such as wild animals or poisonous creatures.

On the other hand, by aiding agriculture industry with robotics technology will improve agriculture activities productivity and encountered labour shortage (Kushawa, et al., 2016) thus this will increase efficiency of national crops production to cater market demand in local and overseas. On the other hand, to implement automation and smart agriculture at the same time will educate farmers on how important technology to aid on increasing crops productivity and at the same time developing one level ahead from conventional farmers into modern technology with tech savvy. Some example of developing farmer's skill towards modern agriculture as mention by (Khorramnia et al., 2014) including collecting, store, restore and analyse field data faster, more accurate and reliable while at the same time encountering labour deficiencies in agriculture sector.

1.3 Problem Statement

On the modern era nowadays, the utilization of robot had been widely used in a lot of industries. This include in agriculture industry. Due to high demand on food, the use of robot in the agriculture industry seems like essential to encounter shortage of labour to work in this field. According to Maarten and Florian (Maarten et al., 2016), based on estimation by UN, currently there are about 7.3 billion of world population and the population numbers expected to grow up to 9.7 billion by 2050. This makes the food demand will increase between 59% to 98% by 2050. In Malaysia situation, the decrement of agriculture seems worry. (Rezuan et al.,2007) recorded in 1980, the local labour in agriculture sectors recorded with amount of 1,911,000 workers but in 2010 it was recorded the number of labours had decreased until 1,458,800 workers (Firuza et al.,2011). With shortage of labour in the agriculture industry, this growing percent of demand seems worrying either the industry can meet this number or not, hence this is where robot play a big role in agriculture industry. In the crop land, the use of mobile robot seems like giving more advantage on multiple utilization. Unlike fixed robot, mobile robot has much better degree of freedom in term of abilities to substitute human task such as exploration, surveillance, patrolling and so on (Himansu, 2016) include multiple task in agriculture field.

To initiate this project, there are some challenges need to be overcome and some knowledge need to be researched which is mainly to understand the design requirement for a mobile robot for agriculture purpose. Several parameters need to be understood before conducting the design that are to decide which locomotion mechanism behaviour is best suit for agriculture task, material selection such as body frame material, suitable power supply and kind of sensor involved to suit with agriculture environment and tasks especially for the Malaysia environment.

1.4 Objective

i. To study about the concept of mobile robot for agriculture purpose.
ii. To design a mobile robot body structure using CAD software.
iii. To analyse the mobile robot body frame structure in term of strength against designated load by using Finite Element Analysis software.

1.5 Scope of Project

This project is conducted on designing the mobile robot body frame in 3D form with aid from Computer Aided Design (CAD) software which is Autodesk Inventor (there will be no physical production for this project). The design of the mobile robot is a land type mobile robot. The mobile robot is designed with size as maximum as 650mm width x 500mm length due to requirement to travel in small area (In this case papaya crop area has been taken for guideline with the area of crop plantation stated in the literature review). Standard wheel track base concept for the mobile robot will be chosen for this study. Due to small scale purpose, to analyse the mobile robot in term of structure frame size and strength vs load capacity, a set of dummy instrument load which is a self-designed agriculture system that consist a spraying system with water tank with capacity load of 10L water and some mechanical instruments with estimation of the overall dummy system is set to maximum of 30kgs.These required to analyse the suitable thickness for the body frame by calculation and simulation analysis. The parameters which is analyse for this project is the structural strength vs load analysis for the mobile robot frame. Choice of sensors, motor speed and power requirement is

neglected to any kind of calculation due to the focus of this project is to analyse on the material strength of the mobile robot body frame versus load. Any kind of dynamic mechanism also was neglected due to purpose of this report just to analyse the suitable design of the body frame. The purpose of dummy agriculture system instruments added to the mobile robot that is just to present on how the mobile robot able to perform agriculture task. The design parameters also based on parameters from papaya crop area which is guided its standard by Department of Agriculture. The comparison of mobile robot design will be compared from the other research papers. As maximum of two different designs were compared in order to produce the mobile robot design.

On the analysis part, the analysis is performed using analysis software which is embedded in the software Autodesk Inventor in order to monitor the Von Mises Pressure analysis on the load set to the frame and also the displacement of the frame. The frame structure was compared by designing the frame using 1.5mm thickness hollow section which is available at the market. Two materials were compared for the analysis which are mild steel and stainless steel grade 440c to determine which materials suite the application of the mobile robot in term of strength against loads applied. The test was conducted starting with load of 10kgs and increment by 10kgs up until maximum of 30kgs in order to monitor the pressure effect to the frame by the load applied.

1.6 Report Structure

The report structure consists of several chapters in order to complete the report. The chapters include: -

i) Introduction

Introduction briefly explain about the background of mobile robot functions in varieties of industry and how mobile robot can be utilized in the agriculture sectors. The introduction also explaining the need for mobile robot in agriculture industry. Follow by the Motivation for the project carry out which is

relate to the point in the introduction which is relate on why the need of this research towards community especially on the demand of agriculture activities towards community demand on foods. The problem statement and objective of the project are emphasized in this chapter together with the scope of project to circulate the limitation of the project so that the objective will be focused on the scope.

ii) Literature review

In this chapter will explain about the review on other researcher papers regarding project idea and implementation. This is important chapter whereby it will link to most of all chapters onwards. Multiple of paper from various researchers will be reviewed to get the idea on how to carry out the project for such as the design idea, the analysis method etc. and for such that all these ideas will be compiled to generate the project methodology which will be explain in chapter 3. For this project will explain about idea on the methodology for mobile robot industry and how to implement mobile robot in agriculture industry plus the analysis methodology for the mobile robot in scope of agriculture environment.

iii) Methodology

This chapter will explain about process on implementing the project to get the result. Idea on the project process gained from chapter 2 which is the Literature Review chapter. Chapter 3 will describe flow by flow regarding how to carry out the project. In this case, most of the process flow will be relate to basic mobile robot construction and analysis.

iv) Result analysis and discussion

All the data obtained from chapter 3 process will be analysed and compiled in this chapter. This includes any drawings, data, table diagram or graphs to explain on the demonstration on the project implementation. This data obtained later will be explained and discussed in chapter 4.

All the obtained data from chapter 4 will be discussed in this chapter nevertheless any kind of data obtain either developing or failure. All the fact obtained from the experiment will be synchronise with the literature review to monitor either the results are aligned with the idea on the result obtain by other paper and methodology process or not.

v) Conclusion

This chapter will conclude the overall of the experiment and project implementation. Space of improvement will be recommended in this chapter so that the project can be continued for a better solution or to develop to another level of this research.

1.7 Summary

This chapter introducing the purpose of carrying out the project which explaining the motivation of this project is to improvise agriculture industry with introducing robotic technology in the sector with implementing mobile robot to take over tasks which known hazardous to human. This chapter also emphasizing the objective of carrying out the project and at the same time narrow down the scope of the project that is focusing on developing the mobile robot body structure with certain limitation. Other than that, this chapter explain on the overall structure of this report starting with chapter one up until the final chapter with simple brief on each chapter content.

CHAPTER 2

LITERATURE REVIEW

This chapter will compile all the information gain from the journal and papers in order to carry out the project.

2.1 Principals of designing mobile robot

In order to initiate on developing a mobile robot, a designer or engineer need to prepare a plan and understand about principle knowledge of process flow or flowchart on designing the mobile robot. In paper titled *"Design of the mechatronic architecture of an agriculture mobile robot"* (Rubens et al. 2010), the author had construct the example of the agriculture mobile robot design based on their project. The authors stated that according to Madsen and Jakobsen (Madsen et al. 2001), the choice of mobile robot architecture concept include traction, steering, the robot dimension, the frame and power supply. The flowchart can be seen in the Figure 2.1.

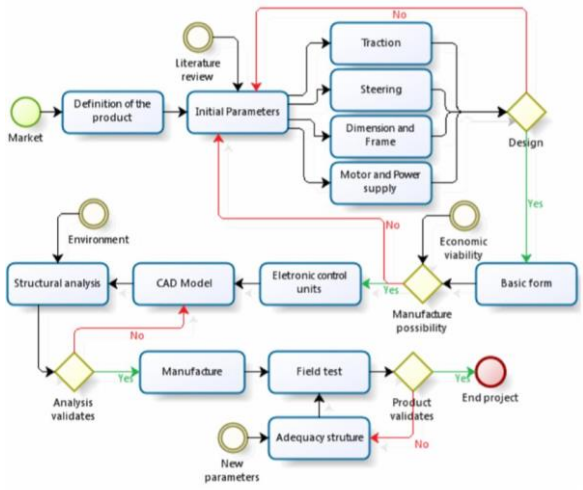

Figure 2.1: The flowchart on designing mobile robot by Madsen and Jakobsen