DESIGN AND ANALYSIS OF LANDING GEAR TRAINER SYSTEM FOR AVIATION MAINTENANCE TRAINING PURPOSES

NUR NADIAH BINTI AZHARI

A report submitted
In fulfilment of the requirement for the Degree of
Bachelor of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

DECLARATION

I declare that this project report entitled "Design and Analysis of Landing Gear Trainer System for Aviation Maintenance Training Purposes" is the result of my own work except as cited in the references.

Signature : .....

Name : NUR NADIAH BINTI AZHARI

Date : 20 JULY 2021

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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.

Signature : .....

Name : Ir. DR FUDHAIL BIN MUNIR

Date : 20 JULY 2021

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ACKNOWLEDGEMENT

First of all, Alhamdulillah, and gratitude to Allah the Almighty for the excellent health and wellbeing that was needed to complete this final year project with ease and time. There is a race of existence in the present world of competition in which those willing to succeed. The final year project is like a bridge between theoretical and practical work. On this opportunity, I would like to express my special gratitude to my supervisor Ir. Dr Fudhail bin Munir who has offered me the opportunity to do this research as my final year project. His guidance, expertise and advice have contributed to a significant help in completing my project. My following most profound appreciation is for all staff and instructors in Aviation Maintenance Engineering Centre (AMEC) that are very kind and helpful in giving me information to finish my research.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Next, I am also grateful to Universiti Teknikal Malaysia Melaka (UTeM) for providing me with such a great opportunity and a chance to work on this project. Next, not forgetting my classmates, who helped, supported a good idea and gave a helpful opinion on how to solve the problem during the final year project and the studies. Last but not least, my deepest gratitude and my family for their endless love, prayers, and encouragement. To those who indirectly contributed to this research, your kindness means a lot to me. Thank you very much.

ABSTRACT

The Landing Gear Mechanism Trainer is an extremely useful piece of equipment for aircraft repair schools' hands-on instruction. It is critical to guarantee that trainees comprehend the theory and are also well equipped to maintain the landing gear system in the best possible condition and in accordance with current safety regulations. The device can also be used in the lecture or during ground school course training. In this field, there is a clear need for aviation maintenance engineers and technicians and to be trained. However, most aviation maintenance school in Malaysia do not own their landing gear trainer system as part of the teaching mechanism because it is too expensive. However, the cost is varying greatly with the material and system used for the landing gear trainer system. The product per performance has greatly improved because of the advanced design work. This project report discussed about market feasibility and the design parameters required to construct a hydraulic landing gear trainer system equipped with retractable main and nose landing gear by applying the previous study of landing gear trainer system model. By using engineering methods which are a market survey, House of Quality (HoQ), and Morphological Method, three conceptual designs of hydraulic landing gear trainer system were produced. The final design was selected by using the engineering approach which is Weighted Decision Matrix (WDM). The final design was designed using CATIA software, and two analysis was done which are Finite Element Analysis (FEA) for the main landing gear structure and the body of the landing gear trainer system. At the end of this project, detailed design including the analysis of the hydraulic landing gear trainer system was produced.

UTeM
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ABSTRAK

Mekanisme pelatih gear pendaratan adalah peralatan yang sangat berguna bagi Organisasi Latihan Penyelenggaraan Penerbangan atau sekolah Latihan praktikal penerbangan. Ini kerana ianya sangat penting untuk memastikan bahawa pelatih penyelenggaraan penerbangan memahami teori pendaratan kapal terbang untuk menjaga sistem gear pendaratan dalam keadaan terbaik dan sesuai dengan peraturan keselamatan yang terkini. Alat ini juga boleh digunakan ketika kuliah atau semasa latihan kursus bagi sekolah rendah. Di dalam bidang ini, ada keperluan jelas bagi jurutera dan juruteknik penyelenggaraan penerbangan untuk dilatih. Namun, kebanyakan organisasi latihan penyelenggaraan penerbangan di Malaysia tidak memiliki sistem pelatih gear pendaratan mereka sebagai sebahagian daripada mekanisme pengajaran kerana terlalu mahal. Walau bagaimanapun, kos pembuatan pelatih gear pendaratan kapal terbang sangat berbeza dengan jenis bahan dan sistem yang digunakan. Prestasi produk telah bertambah baik dengan adanya reka bentuk yang maju.Laporan projek ini membincangkan kemungkinan pasaran dan parameter reka bentuk yang diperlukan untuk membina sistem pelatih gear pendaratan hidraulik yang dilengkapi dengan alat pendaratan kapal terbang utama dan hidung alat pendaratan kapal terbang (nose landing gear) dengan menerapkan data kajian oleh pengkaji-pengkaji lain mengenai model sistem pelatih pendaratan. Dengan menggunakan kaedah kejuruteraan iaitu kaji selidik pasaran, House of Quality (HoQ), dan kaedah morfologi, tiga reka bentuk konsep sistem pelatih gear pendaratan hidraulik dihasilkan. Reka bentuk akhir dipilih dengan menggunakan pendekatan kejuruteraan iaitu Matriks Keputusan Tertimbang. Reka bentuk akhir direka menggunakan perisian CATIA, dan dua analisis dilakukan iaitu Analisis Unsur Terhingga (FEA) bagi analisis struktur gear pendaratan utama dan badan sistem pelatih gear pendaratan. Pada akhir projek ini, reka bentuk terperinci termasuk analisis sistem pelatih gear pendaratan hidraulik telah dihasilkan.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

TABLE OF CONTENTS

DECLARATION i

APPROVAL ii

ACKNOWLEDGEMENT i

ABSTRACT ii

ABSTRAK iii

TABLE OF CONTENTS iv

LIST OF FIGURES vii

LIST OF TABLES ix

LIST OF APPENDICES x

ABBREVIATIONS xi

CHAPTER 1 1

1.1 Background of Study 1

1.2 Problem Statements 3

1.3 Objectives 3

1.4 Project Scope 4

1.5 General Methodology 4

1.5.1 Flow Chart 5

1.5.2 Gantt Chart 7

CHAPTER 2 8

2.1 Maintenance Training Organization (MTO) in Malaysia 8

2.1.1 Aero Malaysian Engineering Centre (AMEC) 9

2.2 Aircraft Maintenance Training System 10

2.3 Existing Design of Landing Gear Trainer 10

2.3.1 Adjustable Landing Gear System 10

2.3.2 Landing Gear Simulator and Trainer 12

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 3 **15**

3.1 Introduction 15
3.2 Project Management 15
3.2.1 Work Breakdown Structure 16
3.2.2 Gantt Chart 18
3.3 Market Feasibility 18
3.3.1 General Need for Product 18
3.3.2 Surveys 19
3.3.2 Description and Estimation of Market Size 25
3.3.3 Competitive Products and Benchmarking 25
3.4 Design parameter 27
3.4.1 Customer Requirement 27
3.4.2 Engineering Characteristics 28
3.4.3 House of Quality 28
3.5 Product Design Specification (PDS) 31
3.6 Concept Generation 32
3.6.1 Feasible Concept 32
3.6.2 Morphological chart 34
3.7 Detail Design 35
3.7.1 Final Concept Design 37

CHAPTER 4 **38**

4.1 Introduction 38
4.2 Finite Element Simulation 38
4.2.1 ANSYS Static Analysis 39
4.2.2 FUSION 360 Static Failure Analysis on Body Design 44
4.3 Thermal Analysis of Landing Gear Trainer System 48
4.3.1 Heat Gain in Hydraulic system through heating 49
4.3.2 Heat Gain in Hydraulic system through losses 50
4.3.3 Heat loss in Hydraulic system through components 51

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 5 **52**

5.1 Conclusion 52

REFERENCES **54**

APPENDIX A **55**

APPENDIX B **55**

APPENDIX C **55**

UTeM
اونيۏرسيتي تيکنيکل مليسيا ملاك
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF FIGURES

Figure 1.1 Hydraulic Landing Gear Trainer Model AS-03 (Aero Train Organization, 2001) 1

Figure 1.2 Thesis flow chart 6

Figure 2.1: Left view of adjustable landing gear 11

Figure 2.2: Landing gear simulator and trainer drawing sheet 12

Figure2.3: Side view of landing gear trainer mechanism for aircraft 13

Figure 3.1: Work Breakdown Structure (WBS) 17

Figure 3.2: Respondent gender 19

Figure 3.3: Respondent age 20

Figure 3.4: Respondent job position at AMEC 20

Figure 3.5: Respondent working experience in aviation maintenance field (year) 21

Figure 3.6: Chart results on 20 respondents on question 1 21

Figure 3.7: Chart results on 20 respondents on question 2 22

Figure 3.8: Chart results on 20 respondents on question 3 23

Figure 3.9: Chart results on 20 respondents on question 4 24

Figure 3.10: Chart results on 20 respondents on question 5 24

Figure 3.11: House of Quality 30

Figure 3.12: Hydraulic Landing Gear Trainer System Design 33

Figure 3.13: Hydraulic Landing Gear Trainer System Design 2 33

Figure 3.14: Hydraulic Landing Gear Trainer System Design 3 34

Figure 3.15: Final design of hydraulic landing gear training system 37

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Figure 4.1: CAD model of main landing gear trainer system 39

Figure 4.2: Meshed model in Ansys workbench 40

Figure 4.3: Boundary conditions and load applied to the model in Ansys. 40

Figure 4.4: Maximum and minimum stresses induced in the model. 42

Figure 4.5: Detailed view of Maximum Equivalent Stress in Link 7 42

Figure 4.6: Maximum mobility obtained in the design. 43

Figure 4.7: Mesh setup 45

Figure 4.8: Meshed design 45

Figure 4.9: Applied Load case on two body parts 46

Figure 4.10: Displacement analysis result 46

Figure 4.11: Stress (Von Mises) analysis result 47

Figure 4.12: Strain (MPa) analysis result 47

Figure 4.13: Material Properties 48

Figure 4.14: Heat balance in the hydraulic system 51

UTeM
اونيۏرسيتي تيکنيکل مليسيا ملاك
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF TABLES

Table 1.1: Thesis Gantt Chart 7

Table 3.1: Comparison of different brands of landing gear trainer system 26

Table 3.2: Customer requirements with the important weight factor 27

Table 3.3: Engineering characteristic and units 28

Table 3.4: Landing gear trainer system design specification 31

Table 3.5: Morphological chart for hydraulic landing gear training system 35

Table 3.6: Detail design of hydraulic landing gear training system 35

Table 4.1: Mechanical properties of the material used. 41

UTeM

اونيۏرسيتي تيکنيکل مليسيا ملاک

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Isometric View	55
B	Bill of Material	56
C	Orthographic View	57

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ABBREVIATIONS

CAD	=	Computer-Aided Design
CATIA	=	Computer-Aided Three-Dimensional Interactive Application
QFD	=	Quality Function Deployment
CRs	=	Customer Requirements
HoQ	=	House of Quality
UEQ	=	User Experience Question
FEA	=	Finite Element Analysis
FS	=	Factor of Safety
WBS	=	Work Breakdown Structure
PDS	=	Product Design Specification
AMEC	=	Aero Malaysian Engineering Centre
MTO	=	Maintenance Training Organization
CAAM	=	Civil Aviation Authority Malaysia
UTS	=	Ultimate Tensile Strength

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 1

INTRODUCTION

1.1 Background of Study

One of the most crucial subsystems found in an aircraft is the landing gear. Not just that, landing gear gives the biggest influence on aircraft structural configuration itself as it is to be said as the most significant load-carrying subsystems of an aircraft (Manjunath.SV, Monisha M, 2018). Mainly, the aircraft's landing gear is to provide a suspension system during take-off, landing, and taxing the aircraft. The landing gear design is made purposely for excellent performance in absorbing and dissipating the landing impact's kinetic energy, hence decreasing the impact loads transmitted to the airframe. Braking the aircraft using a wheel braking system is facilitated by the landing gear and allows the steering system to control aircraft on the ground. Figure 1.1 below shows the hydraulic landing gear trainer model that is used as guidance throughout the project.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

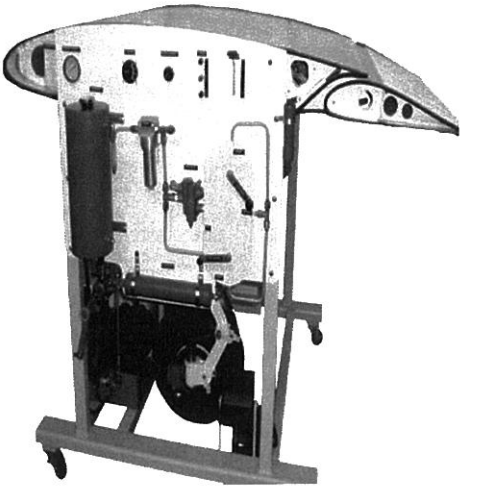

Figure 1.1 Hydraulic Landing Gear Trainer Model AS-03 (Aero Train Organization, 2001)

Landing gear can be further classified into two categories, which are fixed and retractable. Both fixed and retractable gear are designed with different purposes based on the different types of aircraft. This project is focused on analyzing and designing a landing gear trainer system by using a retractable landing gear system with a hydraulic actuation system. This trainer system offers a pressurized hydraulic fluid to stimulate the main and nose landing gears in retraction and deployment mode. The primary benefit of retractable gear is more significant performance and enables the aircraft to climb and cruise faster by drag reduction. A hydraulic landing gear system is used in this project as it has small-sized actuators due to its high-power density, effortless control, and transmission of power. These make the hydraulics system a more preferred choice for compact high-power systems. As stated by (Roscoe I. Markey, Buffalo, N. Y., Merle J. Frank, Pikesville Henry J. Sieradzki, Hagerstowa, 2000), this type of gear has important advantages over other transfer systems in that they achieve a very high density of energy.

Similarly, as an existed training system, this invention uses a hydraulic system for raising and lowering an aircraft landing gear mainly for aircraft landing gear known as a side brace, where the landing gear can move between a generally vertical condition for landing and horizontal condition for within a wing of the aircraft. (ColinRobert Gedge, 2015). Specifically, this project is proposed to provide Aero Malaysian Engineering Centre (AMEC) students with the design of simulator experience needed to understand the landing gear system's principle and understand the aircraft hydraulic landing gear system with functional retractable nose and main landing gear. This design includes complete wheel and tire assembly with a hydraulic landing gear system. Then, followed by the design analysis studies in ensuring the functionality of the landing gear trainer system. This proposed research is expected to be able to provide a complete design of a hyraulic landing gear trainer system and, eventually, a hands-on training environment for aircraft maintenance training.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

1.2 Problem Statements

Practical limitation in learning the principle of hydraulic landing gear could lead to a lack of understanding of how the actual landing gear system works. As a maintenance aircraft technician and engineer, it is crucial to practically know how the gear system works. As stated in research (Sforza, 2014), failures of landing gears in aircraft represent approximately 10% of the aerospace industry's total failures. The failures associated with factors including the environmental and overload causes. These failures can be avoided with good engineering and maintenance practices, commonly conducted in the aerospace industry. Retractable gear aircraft training methods are expensive because they are equipped with high purchase, maintenance, and insurance costs. (Gregg Stockman, 669 Berville Rd., Allenton, 2003). Hence, this project aims to design a landing gear trainer for a more affordable and easier to operate for teaching purposes at aircraft training organization, Aero Malaysian Engineering Centre (AMEC). This ensures that technicians and engineers are qualified to best manage the landing gear system and meet safety protocols in the best possible way. It displays the landing gear mechanism as found in actual aircraft.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

1.3 Objectives

The objectives of this project are such below:

a. To design an affordable aircraft hydraulic landing gear trainer system with a functional retractable nose and main landing gear by using Fusion 360 engineering design software.

b. To make an analysis study on the design of the aircraft hydraulic landing gear trainer system that represents the main component on an actual aircraft landing gear using Finite Element Analysis (FEA).

1.4 Project Scope

The project scopes are as follows:

a. This project will analyze market feasibility towards AMEC instructors.

b. The simulation and modelling of a hydraulic landing gear trainer system will be done in software Computer-Aided Three-Dimensional Interactive Application (CATIA) and Fusion 360.

c. The hydraulic landing gear model type AS-04 (by (Aero Train Organization, 2001) is used as a guideline for designing a lower manufacturing cost of landing gear trainer system.

1.5 General Methodology

This section explains the organization of this thesis shall be conducted to achieve the project's objectives, such as identifying, processing, and analyzing data and information. Chapter 1 is an introduction to this thesis and provides a summary of the background of this thesis. Chapter 2 describes the literature review that consists of introducing the Maintenance Training Organization (MTO), AMEC. It also describes the existing patent design done by other researchers, and comparisons are made to similar works, and later on, it discusses the advantages and disadvantages of previous projects. Entering Chapter 3 of this thesis provides an overview of customer requirements and engineering characteristics, House of Quality (HOQ), comparison of product benchmarks and product specification. This chapter also discusses the development method used in the project, such as material selection, fabrication process, and market feasibility.

Meanwhile, chapter 4 provides the Finite Element Simulation results and engineering analysis of hydraulic landing gear trainer system. Lastly, Chapter 5 states the conclusions drawn from the results obtained and suggests possible future research

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

directions. A graphic flow of the thesis is referred to as the flow chart of the thesis in Figure 1.2.

1.5.1 Flow Chart

Figure 1.2 shows an overall flow chart of the thesis starting from PSM1 to PSM in designing a hydraulic landing gear trainer system. For PSM 1 phase, it consists of a literature review including House of Quality (HoQ) construction to select the critical engineering characteristics and detail design. Entering the PSM 2 phase, the Finite Element Analysis will be generated and studied. This follows with the results analysis and conclusion of the thesis.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

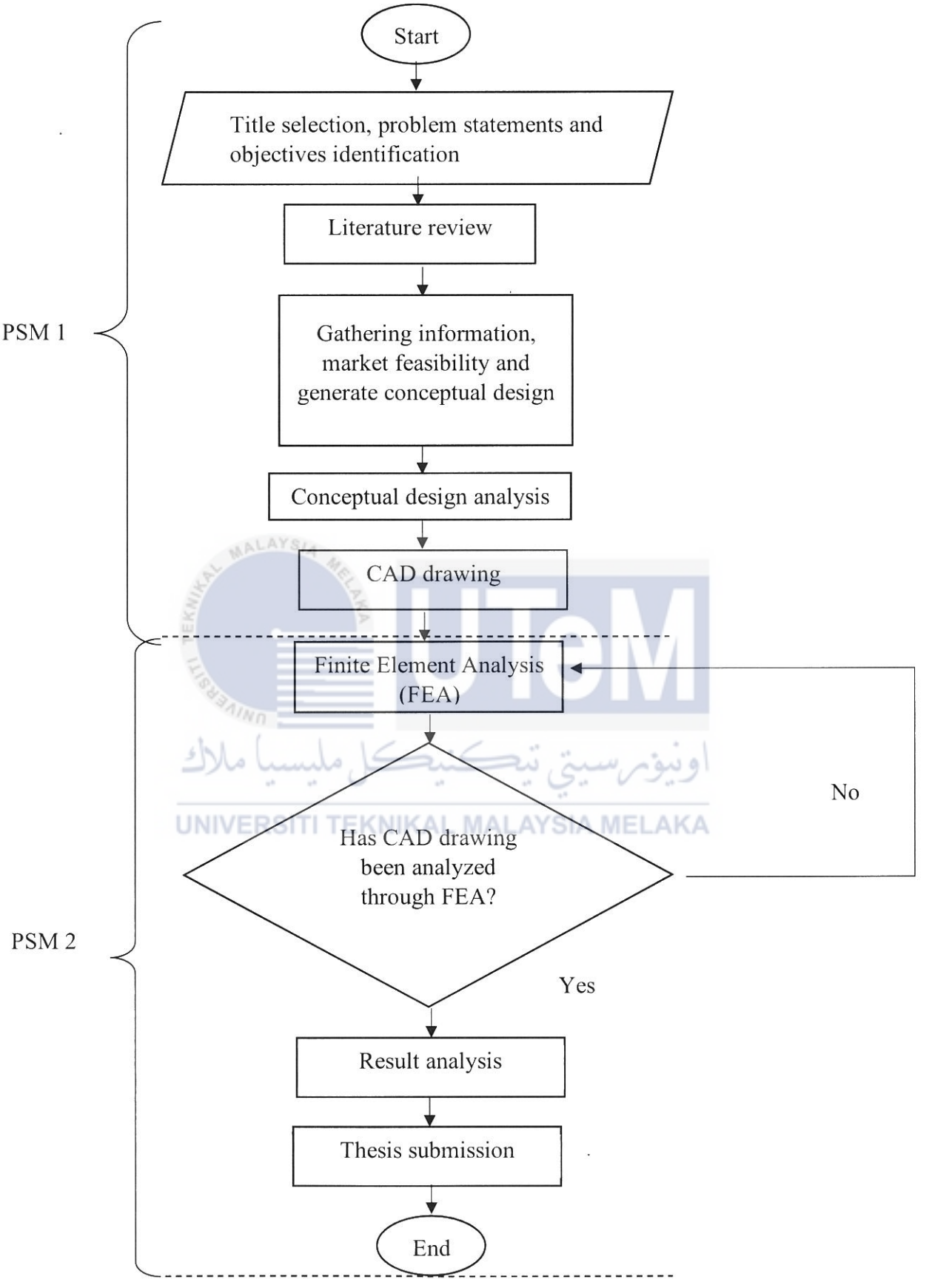

Figure 1.2 Thesis flow chart

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

1.5.2 Gantt Chart

Table 1.1 below shows the thesis Gantt chart that describes the time for each functional element and the estimation of time taken to complete the entire project process.

Table 1.1: Thesis Gantt Chart

No.	Activity	Academic Week															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1.	Project Title Selection																
2.	Literature Review																
3.	Gathering Information																
4.	Develop Conceptual Design																
5.	CAD Drawing																
6.	Finite Element Analysis (FEA) i. ANSYS Analysis ii. Fusion 360 Analysis																
7.	Submission Progress Report																
8	Preparation Final Report																
9	Submission Final Report																
10	PSM Talk																

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

CHAPTER 2

LITERATURE REVIEW

2.1 Maintenance Training Organization (MTO) in Malaysia

Research paper by (Harun et al., 2005) stated that aviation schools worldwide must comply with the industry requirements for their students to have a high rate of employability. Thus any universities or institutions offering studies in aviation or aircraft technology must fulfil the industry requirement. As part of the conditions to be fulfilled prior to the issue of the license, JAR-66 which is an aircraft regulation that establishes the conditions under which a maintenance engineer can work. It requires the applicant to demonstrate sufficient knowledge of the theoretical subject-matter associated with the requested license and to provide proof that clear minimum intervals of functional maintenance experience have been met. The organization are expected to provide the student with a practical experience program that includes an understanding of basic hand-skills and the use of equipment, an understanding of maintenance activities and basic assembly and disassembly techniques, and familiarization with the actual maintenance process and the related control procedures and documentation. Also, said by (Ahmad & Bakar, 2003), training was described by Buckley and Caple (1995) as a planned and organized effort to alter or improve information, skills and attitude through learning experience to achieve efficient performance in an activity or set of activities. In this research paper, the targeted MTO is Aero Malaysian Engineering Centre (AMEC).

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2.1.1 Aero Malaysian Engineering Centre (AMEC)

The Aero Malaysian Engineering Centre (AMEC) was set up to support the aviation industry's national list. In 2016, AMEC became a popular brand among local industrial players for its ability to produce quality semi-skilled employees, increasingly developing its expertise in providing extended technical training. As an independent agency, AMEC has taken further steps to provide CAAM Part66 License (Program for Aircraft Maintenance Engineering) training aimed at generating large numbers of qualified aircraft maintenance engineers and technicians for the local and regional markets, by complying with CAAM Airworthiness Notices No.1101 and 1201, respectively.

Aircraft maintenance training courses provided by AMEC are Licensed Aircraft Maintenance Engineer (Mechanical) (CAAM Part66Category "B1.1" course) and Licensed Aircraft Maintenance Technician (CAAM Part66Category "A1" course) For Category 'A' 2-year program. The main objectives of the company that associate with the thesis objectives are:

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

i. To be the leading organization in the supply of highly qualified aviation professional for local, regional and global aviation industries
ii. Description and operation of airframe, engine, electrical and avionics systems.
iii. Description and operation of controls and indicators.
iv. Identification and location of the main components.

The company's objectives drive the main goals of this research to be accomplished as it is significant for AMEC's student as a future aviation maintenance engineer to get a full view of how an aircraft landing gear works by having the trainer system in their training organization.

2.2 Aircraft Maintenance Training System

Trainee motivation and attitudes play an essential role in determining training effectiveness within their organization, said (Ahmad & Bakar, 2003). It is more likely that trainees with a high degree of job engagement are inspired to learn new skills. This is because people see participating in training programs as a way of rising ability levels, enhancing work performance and growing feelings of self-worth. (Patrick et al., 2012). In the modern manufacturing industry, the reliability and effectiveness of equipment play a dominant role in deciding the corporate production function's performance and the degree of success achieved in the enterprise. (One Yoon Seng, 1396).

In several of aviation fields, virtual reality and maintenance can be found. It has many applications in aviation, from training pilots all the way to the maintenance workers who take care of and build the aircraft. Simulators, for instance, prepare pilots to learn how to fly and perform emergency procedures without ever getting into an actual aircraft. At the same time, maintenance workers will research and understand how systems operate and how maintenance activities are done to reduce the possibility of damage to parts and aircraft. As stated in the research paper by (Jenab et al., 2016), virtual reality is used by engineers to build and construct structures without being forced to waste scarce time and money. By providing an experience that cannot be generated in a conventional classroom setting, students and staff use virtual reality for training and learning.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2.3 Existing Design of Landing Gear Trainer

The study is carried out on several patents. The purpose of the current product study is to make a review on the patent of design that has been proposed for hydraulic landing gear.

2.3.1 Adjustable Landing Gear System

Inventors : Luce, Willliam E.Colleyville, TX 76034 (US)