REVERSE ENGINEERING OF MICRO LIGHT AIRCRAFT SYSTEMS AND DESIGN

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To my wife and my parents
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ABSTRACT

Microlight industry has become popular nowadays and has its own fan in Malaysia. In western side of the world, the microlight boom which started in late 1970s and 1980s was driven by a number of factors that permitted practical flying machines to be produced at lower cost than ever before. Here in Malaysia, most of the aircraft were imported from European and US as the manufacturer are from there. To reduce the cost of manufacturing an aircraft, this paper had tried to study the construction of an aircraft by using proposed reverse engineering process. A microlight aircraft model Quicksilver GT500 has become a subject of study and Autodesk Inventor software is selected as preferred software to remodel the aircraft structure. Remodelling process of the aircraft started with taking actual measurement on the site aircraft guided with manual book of aircraft assembly and maintenance as reference. The CAD model of the aircraft then imposed stress load analysis to study the effect of proposed material to the structure reliability. Maximum take-off weight of aircraft of 1000lbs (454 kg) was used as maximum load on the aircraft while in cruise mode. Three types of aluminium alloy of Al2024, Al6061, and Al7075 have been studied on their influences to the wing structure design. The influence of Center of Gravity to the aircraft balancing is discussed. Wing structural design of joints between tubes is also discussed. Manufacturing process and techniques of the aircraft parts and components are identified. Lastly, the aircraft control system has been studied.
ABSTRAK

CONTENTS

TITLE i
DECLARATION ii
DEDICATION iii
ACKNOWLEDGEMENT iv
ABSTRACT v
ABSTRAK vi
CONTENTS vii
LIST OF FIGURES xi
LIST OF TABLES xvi
LIST OF SYMBOLS AND ABBREVIATIONS xvii

CHAPTER 1 INTRODUCTION 1
1.1 Research background 1
1.2 Problems Statement 1
1.3 Research Objective 2
1.4 Scope of Study 2
1.5 Expected Outcome 3
1.6 Significant of Research 3

CHAPTER 2 THEORETICAL AND LITERATURE REVIEW 5
2.1 Reverse Engineering 5
  2.1.1 Types of Reverse Engineering Techniques 7
  2.1.2 Computer Aided Design (CAD) and Computer Aided Engineering (CAE) 10
2.2 Microlight Aircraft 11
  2.2.1 History of Microlight Aircraft 12
  2.2.2 Types of Microlight Aircraft 12
2.3 Quicksilver GT500 Microlight Aircraft 14
2.3.1 Main Aircraft Component 16
2.3.2 The Wings – Structure 16
2.3.3 Fuselage 18
2.3.4 Empennage 19
2.3.5 Ailerons & Flaps 20

2.4 Materials 21
2.4.1 Aluminium 21
2.4.1.1 Aluminium Alloy 2024 23
2.4.1.2 Aluminium Alloy 6061 23
2.4.1.3 Aluminium Alloy 7075 23
2.4.2 Steel 24
2.4.3 Composite 25
2.4.4 Tubes 26
2.4.5 Bracing Cables 28
2.4.6 Bolts and Nuts 29

2.5 Manufacturing Process and Assembly Techniques 31
2.5.1 Bending 31
2.5.2 Hole Drilling 32

2.6 Structural Analysis 33
2.6.1 Engineering Stress 34
2.6.2 Engineering Strain 35
2.6.3 Young's Modulus - Modulus of Elasticity (or Tensile Modulus) - Hooke’s Law 35
2.6.4 Shear Modulus 36
2.6.5 Von Mises Stress 36
2.6.5.1 Distortion energy Theory 36
2.6.6 Principal Stress 38

2.7 Air-load Distributions 39
2.7.1 Schrenk’s Approximation Methods 40
CHAPTER 3  METHODOLOGY  42
  3.1  Assumptions  43
  3.2  Specification of Quicksilver GT500 Microlight Aircraft  43
  3.3  Data Acquisitions  44
  3.4  Image Modelling  45
  3.5  CAE Analysis  46
    3.5.1  Selection of Material  48
    3.5.2  Simplification of Analysis  48
    3.5.3  Distributed Load on Aircraft Wing  49
    3.5.4  Wing Loading Calculation  51
    3.5.5  Determination of Constrain  52
    3.5.6  Evaluation on Analysis  53
  3.6  Selection of Material  53

CHAPTER 4  RESULTS AND DISCUSSIONS  54
  4.1  Stress Load Analysis  55
    4.1.1.  Loads on the Aircraft  56
    4.1.2.  Determination of Center of Gravity  58
    4.1.3.  CADCAE Analysis  59
      4.1.3.1.  Stress Analysis for Wing Base Structure Using Aluminium 2024  60
      4.1.3.2.  Stress Analysis for Wing Base Structure Using Aluminium 6061  64
      4.1.3.3.  Stress Analysis for Wing Base Structure Using Aluminium 7050  68
  4.2  Built up Material  72
# List of Figures

<table>
<thead>
<tr>
<th>Figure no.</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>Example of the sequences of the reverse engineering (RE) process.</td>
<td>2</td>
</tr>
<tr>
<td>2.1</td>
<td>Basic flow of reverse engineering processes</td>
<td>6</td>
</tr>
<tr>
<td>2.2</td>
<td>Types of reverse engineering technique</td>
<td>7</td>
</tr>
<tr>
<td>2.3</td>
<td>Traditional reverse engineering process according to QingJin Peng et. al. (1998)</td>
<td>9</td>
</tr>
<tr>
<td>2.4</td>
<td>The reverse engineering process based on vision information</td>
<td>9</td>
</tr>
<tr>
<td>2.5</td>
<td>An example of point cloud from 3D scanning</td>
<td>9</td>
</tr>
<tr>
<td>2.6</td>
<td>Fixed wing aircraft</td>
<td>13</td>
</tr>
<tr>
<td>2.7</td>
<td>Flexwing aircraft</td>
<td>13</td>
</tr>
<tr>
<td>2.8</td>
<td>A Quicksilver GT500 microlight aircraft</td>
<td>16</td>
</tr>
<tr>
<td>2.9</td>
<td>Three types of aircraft wings</td>
<td>17</td>
</tr>
<tr>
<td>2.10</td>
<td>Dihedral angle for aircraft wing</td>
<td>17</td>
</tr>
<tr>
<td>2.11</td>
<td>Wing frame main components of Quicksilver GT500 aircraft</td>
<td>18</td>
</tr>
<tr>
<td>2.12</td>
<td>The built up components of an aircraft wings</td>
<td>18</td>
</tr>
<tr>
<td>2.13</td>
<td>Fuselage of GT500 aircraft</td>
<td>19</td>
</tr>
<tr>
<td>2.14</td>
<td>An example of fuselage frame of microlight aircraft</td>
<td>19</td>
</tr>
<tr>
<td>2.15</td>
<td>Empennage structure</td>
<td>20</td>
</tr>
<tr>
<td>2.16</td>
<td>Location of aileron (red area) and flap (yellow area) on aircraft wing.</td>
<td>20</td>
</tr>
<tr>
<td>2.17</td>
<td>An example of landing gear for microlight aircraft</td>
<td>25</td>
</tr>
<tr>
<td>2.18</td>
<td>Modern ultralight airplanes use aluminium tubes as both spars and wing leading edges</td>
<td>27</td>
</tr>
<tr>
<td>2.19</td>
<td>A single-tube frame structure of Maxair Hummer</td>
<td>28</td>
</tr>
</tbody>
</table>
ultralight

2.20 Cable construction is defined by number of strands and
the number of wires per strand

2.21 Basics of bolts installation

2.22 The position of hole that can be drill on the aluminium
tube of wing spar

2.23 Types of load acting on aircraft.

2.24 Condition of engineering stress in solid objects.

2.25 Representation of a pure distortion case.

Stress boundary conditions on a 2 dimensional
element.

2.26 Stress boundary conditions in a 3 dimensional body
and normal stress values induced in it.

2.27 Span-wise and chord-wise loadings on aircraft wing.

2.28 Types of planform wing by aircraft manufacturers.

2.29 Plan-form geometry for Schrenk’s method.

3.1 Reverse Engineering procedure for the project

3.2 Quicksilver GT500 microlight aircraft.

3.3 GT500 mainframe structure.

3.4 The division of subsystem for Quicksilver GT500
microlight aircraft.

3.5 An example of CAD design performs using Autodesk
Inventor 2012.

3.6 An example of stress analysis on aircraft structure that
has been done by CAE software.

3.7 Flowchart diagram on engineering analysis for
determination of material.

3.8 Load distribution on wing.

3.9 Location of constrain at (a) landing gear carry thru, (b)
root tube
4.1 (a) Top view of CAD design for Quicksilver GT500 microlight aircraft structure. (b) Front view of CAD design for Quicksilver GT500 microlight aircraft structure. (c) Side view of CAD design for Quicksilver GT500 microlight aircraft structure.

4.2 Total lift force, Ls distribution on the aircraft wing structure.

4.3 Wing spanwise lift distribution.

4.4 The CG location of Quicksilver aircraft wing determined by using CADCAE software.

4.5 Assembly of main wing structure and the loads acting on the structure.

4.6 Parts and components of wing structure that being replaced by 3 types of material for stress analysis.

4.7 Result of stress analysis on wing structure using Aluminium 2024 material.

4.8 Displacement of structure using Aluminium 2024.

4.9 Safety Factor of structure using Aluminium 2024.

4.10 Result of stress analysis on wing structure using Aluminium 6061 material.

4.11 Displacement of structure using Aluminium 6061.

4.12 Safety Factor of structure using Aluminium 6061.

4.13 Result of stress analysis on wing structure using Aluminium 7050 material.

4.14 Displacement of structure using Aluminium 7050.

4.15 Safety factor of structure using Aluminium 7050.

4.16 Landing gear of GT500 model aircraft are made from high strength steel material.

4.17 The use of polymer material on aircraft bodyskin is more on windshield and safety door application.
(a) Seat bucket for pilot are made from composite materials. (b) Body skin of GT500 aircraft model are made from fibre glass material.

Wing skins of the aircraft are made from lightweight but high strength fabric material like Dacron.

The use of bolts and nuts are being applied on main structure joining for safety purpose. (a) An eyebolt is use to joint vertical stabilizer trailing edge and rudder leading edge assembly. (b) and (c) AN type hexagonal bolts and nuts are use to firmly joint the main structures of the aircraft and received large amount of shear loading from the aircraft body weight. (d) Bolt loaded in double shear with associated bending due to load offset.

Riveting techniques are applied to join non-structural components of the aircraft. (a) Rivet joining on tail boom structure to hold empennage control parts. (b) Rivet is used to hold seat bracket in position on forward fuselage. (c) Rivet is used to assemble body skin to the tail boom tube.

An example of weld joint application on GT500 Quicksilver airplane as can be seen on rudder shaft joining.

Radius of tubing bending.

Location of the drilled holes must be at the centre of the tube structure.

GT500 aircraft surface control system.

A simple mechanical cable operated system found on Quicksilver GT500 aircraft. The cables in this aircraft sometimes are replaced by rods. The control column can be moved by raising and lowering the elevator.
4.27 Location of (A) aileron and (B) wing flap as can be seen on figure above.

4.28 Two main wheels and tail skid are playing important role in landing situation while nose wheel give little support.

4.29 (a) The location of hand brake lever (inside yellow circle) which is on the right side of the pilots give confident to the pilot while landing the aircraft. (b) Mainwheel construction are made from reliable material to give extra safety to the pilot. The mainwheel braking systems are using disc and hydraulic clamping system.

4.30 An overview of pilot cockpit of GT500 aircraft. Basic controller indicator is as displayed on dashboard.

4.31 Instrument panel layout for GT500.

4.32 A Rotax 582/40 rotary valve engine that powered the GT500 aircraft.
## LIST OF TABLES

<table>
<thead>
<tr>
<th>Table no.</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Specification of GT 500 Quicksilver for two type of engine.</td>
<td>15</td>
</tr>
<tr>
<td>2.2</td>
<td>Wrought alloy aluminium series</td>
<td>22</td>
</tr>
<tr>
<td>2.3</td>
<td>Mechanical properties of selected Aluminium alloys</td>
<td>24</td>
</tr>
<tr>
<td>2.4</td>
<td>Comparison of properties for thermoset resins</td>
<td>26</td>
</tr>
<tr>
<td>2.5</td>
<td>Comparison of the wire strength between sizes, material, and number of strands</td>
<td>29</td>
</tr>
<tr>
<td>3.1</td>
<td>Detail specification of Quicksilver GT500 microlight aircraft</td>
<td>43</td>
</tr>
<tr>
<td>4.1</td>
<td>Calculated lift distribution value of aircraft wing.</td>
<td>56</td>
</tr>
<tr>
<td>4.2</td>
<td>Coordination of CG as determined using Autodesk Inventor 2012 software.</td>
<td>58</td>
</tr>
<tr>
<td>4.3</td>
<td>Results summary of stress analysis for Aluminium 2024 material.</td>
<td>61</td>
</tr>
<tr>
<td>4.4</td>
<td>Results summary of stress analysis for Aluminium 6061 material.</td>
<td>64</td>
</tr>
<tr>
<td>4.5</td>
<td>Results summary of stress analysis for Aluminium 7050 material.</td>
<td>68</td>
</tr>
<tr>
<td>4.6</td>
<td>Types of material using on wing’s structure of Quicksilver GT500 aircraft.</td>
<td>72</td>
</tr>
<tr>
<td>4.7</td>
<td>Non-heat treatable alloys applications on aircraft.</td>
<td>76</td>
</tr>
<tr>
<td>4.8</td>
<td>Heat treatable alloys applications on aircraft.</td>
<td>76</td>
</tr>
<tr>
<td>4.9</td>
<td>Selection of fabric types by breaking strength criteria.</td>
<td>80</td>
</tr>
</tbody>
</table>
LIST OF SYMBOLS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAD</td>
<td>Computer Aided Design</td>
</tr>
<tr>
<td>CAE</td>
<td>Computer Aided Engineering</td>
</tr>
<tr>
<td>AoA</td>
<td>angle of attack</td>
</tr>
<tr>
<td>MPa</td>
<td>mega Pascals</td>
</tr>
<tr>
<td>ksi</td>
<td>kilopounds persquare inches</td>
</tr>
<tr>
<td>CG</td>
<td>center of gravity</td>
</tr>
<tr>
<td>CP</td>
<td>center of pressure</td>
</tr>
<tr>
<td>CAS</td>
<td>calibrated airspeed</td>
</tr>
<tr>
<td>$V_{so}$</td>
<td>calibrated stall or minimum flying speed in the landing configuration at maximum take-off mass</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

Reverse Engineering (RE) refers to the process of creating engineering design data from existing parts. It recreates or clones an existing part by acquiring the surface data of an existing part using a scanning or measurement device. It is useful in recreating the CAD model of an existing part when the engineering design is lost or when the model has gone through many design changes.

The application field of reverse engineering techniques are very wide. Many tools and methods had been introduced by researchers and engineers in order to propose the most economical ways of using reverse engineering techniques to the industry. In related mechanical areas like automotives and machineries, the used of reverse engineering become popular since it cost minimums and produce the results at shortest period of time compared to conventional R&D method.

Sokovic and Kopac (2006) have discussed in their publication about the importance of reverse engineering application on rapid product development in automotive industry. To upgrade the whole parts of a car may take a lot of time. However, by applying reverse engineering on certain parts, the new or facelift model can be introduced to the market at quicker time. Figure 1.1 explain the whole process of reverse engineering techniques in manufacturing industries start from digitizing the data, converting into standard computer language and lastly produce the product using CADCAM machining process.
Another popular application of RE besides of engineering fields is in medical fields. The needs of reconstructing the bones of patients requires the doctors to do RE on the patient’s damage bones by using conventional and new technologies. Lin et al (2005) have discuss about the RE technique use in reconstructing the artificial joint for the patients with arthritis types problems. The application of CADCAM technologies not only focus on manufacturing industries as explain by them. The needs of designing the customized prostheses that best matches the human anatomy, according to different patients’ requirement, is gaining more attention.
nowadays. Various kinds of requirement indirectly had boosted the introduction of new technologies in the market to fulfil them.

   RE application in aircraft industries are very similar to automotives industry. The techniques and methods are same as both of them apply general engineering knowledge during the whole development of the product. Further explanations are as in Chapter 2 of this report.

1.1 Research Background

This research will focus on determining the possibility of using RE methods to identify the types of material and manufacturing process involved in fabricating a microlight aircraft. For this research, one model of microlight aircraft will be use as reference upon completing the RE processes. The comparative study will be carry out in terms of the cost of manufacture, time to produce and dimensioning accuracy of both existing and redesign aircraft models.

1.2 Problem Statement

Currently in Malaysia, aircraft industry is developing quite slow due to the high cost of producing aircraft and also limited acquisition of manufacturing technology. These constraints cause a lack of interest from investors to invest in the aeronautics industry. However, in other countries especially Europe, there are a lot of investor and small scale manufacturers who actively involve in producing microlight aircraft to fulfil the demands. To produce an aircraft, a lot of money needs to be invested and very time consuming. Besides, lack of knowledge and limited facilities are the main factors of inability to produce an aircraft in Malaysia.

   Reverse engineering (RE) is the best way to be applied by designers in order to produce their product at short time and at relatively lower cost. By applying RE into aircraft design, the designers are able to concentrate on small modification and upgrading the current product instead of spending a lot of time to built a new one. Most of the manufacturer just selling their products, but not the entire information about the product. Therefore, RE technique is appropriate to identify the
material specifications, manufacturing and assembly process, and also the alternative
design for the product.

1.3 Objectives

The objectives of this research are as follows:
1. To model aircraft mainframe using CAD software.
2. To determine the materials used for structural and skin.
3. To identify the manufacturing methods/techniques to produce the structural frame.

1.4 Scope of Study

The research is limited according to the scopes below:
1. The study of microlight aircraft subsystems is to understand the critical loads effect on structural beam.
2. The reference microlight aircraft is Quicksilver GT500.
3. The structural analysis is implemented by using Autodesk Inventor 2012.
4. The CAD model of the aircraft is developed by using Autodesk Inventor 2012.

1.5 Research Contribution

This research has able to accumulate a comprehensive information on the reference microlight aircraft into CAD modelling, acquire information on built up materials, and related manufacturing process to produce the aircraft.

1.6 Significant of Research

This project is being carried out to prove that reverse engineering techniques is able to reproduce the microlight aircraft with the help of available CAD software in the market. Besides, this project also hopefully will help to boost the manufacturing industry of microlight aircraft in Malaysia by producing it at lower cost.
CHAPTER 2

THEORETRICAL AND LITERATURE REVIEW

Reverse Engineering (RE) refers to the process of creating engineering design data from existing parts. It recreates or clones an existing part by acquiring the surface data of an existing part using a scanning or measurement device. According to Peng and Loftus (1998), RE is useful in recreating the CAD model of an existing part when the engineering design is lost or when the model has gone through many design changes.

2.1 Reverse Engineering

Reverse engineering and rapid prototyping of objects with complex surfaces have received significant attention from both research and industrial communities nowadays. This is happening mainly because of growing global competition that requires manufacturers to deliver more competitive products with better quality and lower prices. Reducing the product development time had become a challenging tasks faced by manufacturing industry. The demanding and competition exist all over the world since most of countries had practice open-air economic system.

Lin et al. (2005) stated that reverse engineering (RE) is an important branch of the mechanical design and manufacture application field. This technique has been widely recognized as a crucial step in the product design cycle. According to Lin et al. (2005), reverse engineering is the process of
engineering backward to build a CAD model geometrically identical to an existing product. As shown in Figure 2.1, Lee and Yoo (2000) define the reverse engineering as the backward process used to recover higher level conceptual elements from physical systems.

In normal automated manufacturing environment, the operation sequence usually starts from product design via computer-aided design (CAD) techniques, and ends with generation of machining instructions required to convert raw material into a finished product. In contrast to this conventional manufacturing sequence, reverse engineering represents an approach for the new design of a product that lacks an existing CAD model.

In the process of the product design and research, the use of RE will largely reduced the production period and costs. Unlike the traditional manufacturing philosophy of designs being transposed into products, reverse engineering measures, analyses, modifies, and produces the products based on existing artifacts (Vergeest and Horvath, 2009). Using 3D point data collected by contact or non-contact method, a CAD model can be created and employed in subsequent manufacturing processes.

![Figure 2.1: Basic flow of reverse engineering processes. (Lee and Yoo, 2000)](image)

Yang and Chen (2005) had presented a new reverse engineering methodology based on haptic volume removing. By using a haptic device, the number of view changes could also be reduced and operating time be shortened. However, the limitation of the workpiece size to be measure makes it impossible to be applied on large size objects. The accuracy of the mirror image still considers low since it is dependent on the voxel resolutions.
The success of reverse engineering is that it not only generates accurate mathematical computer-aided design (CAD) models for design and manufacturing purposes, but can significantly reduce product design lead time.

Reverse engineering always come together with rapid prototyping (RP) technology. Jain and Kuthe (2013) in their publication had mention about a dominant technology for producing physical models for testing and evaluation purposes has been RP. The rapid prototyping processes can be broadly classified into processes that uses laser and ones which does not. RP in other word is a tool or medium to complete the reverse engineering process (Kumar and Kruth, 2010)

### 2.1.1 Types of Reverse Engineering Technique

The acquisition, analysis and transfer of technical data are the key elements of reverse engineering. Figure 2.2 shows the hierarchy of reverse engineering techniques which can be divided into two major groups; non-contact and contact method. Many researchers had published their works about the method of RE. Xinming et al. (2001) mentioned about applying a vision-sensor technique to gain data or digitizing on free-form surface before transferring them into CAD software. Dubravcik and Kender (2012) stressed the importance of 3D scanning techniques for reverse engineering process in automotives industries and can save a lot of time in design development.

![Figure 2.2: Types of reverse engineering technique.](image)
Contact methods consist of using electro-mechanical equipment such as force-sensitive touch probes to mapping the coordinate of the objects surface. One of many popular devices from this category is Coordinate Measuring Machines (CMM). CMM is used for data acquisition of products, especially in the aeronautical and automotive industries where complex surfaces are frequently encountered. Peng and Loftus (1998) mentioned about the important of CMM as the key provider for dimensional inspection (see Figure 2.3). However, high cost of the co-ordinate measuring equipment, supporting software and the time to recover surface details by the measurement process are disadvantages of this technology. In addition, the use of touch-trigger probe technology on the current generation of CMMs may have the following drawbacks:

- Damaging the product surface.
- Misleading readings owing to the deflection of the probe and/or part.
- Erroneous calculation of probe tip compensation.

These disadvantages can be overcome with a non-contact vision system. Vision is the most powerful sense. It provides human with a remarkable amount of information about the surroundings and enables us to interact intelligently with the environment, all without direct physical contact. Through it, the positions and identities of objects and the relationships between them can be identified. In a manufacturing process, the noncontact characteristic of the vision measurement enables the measurement to be taken without suffering from the drawbacks of contact measurement. There is no surface damage to the part, no deflection of the probe or part since there is no contact between the probe and part. Also, a calculation of the probe tip compensation is unnecessary because there is no probe tip in the vision system. Peng and Loftus (1998) also introduce a laser technology that has been used as a non-contact measurement method to replace the conventional technique. Its high energy limits its application in some areas, for example, in medicine (see Figure 2.4). The laser technique using 3D scanning device and the output is the points cloud. For further utilization it is required to customize the points cloud via CAD software into solid part or planes. This points cloud is mostly too large, so for best output data it is necessary to do some editing. (see Figure 2.5)
REFERENCES


http://www.fpna.com/gt500.htm

http://www.lightsportaircraftpilot.com/

http://www.somersetmicrolights.org.uk/aircraft_text.htm

http://www.somersetmicrolights.org.uk/aircraft_text.htm

http://www.ultralightnews.com/

www.avidflyeraircraft.com

www.ultralightflying.com