DESIGN AND ANALYSIS OF INDUSTRIAL SECURITY DOOR

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in fulfillment of the requirement for the degree of
Bachelor of Mechanical Engineering (Design and Innovation)

Faculty of Mechanical Engineering

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DECLARATION

I declare that this project report entitled "Design and Analysis of Industrial Security Door" is the result of my own work except as cited in the references.

Signature : .....

Name : Muhammad Syamil bin Rusdi

Date : 16 December 2016

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 and Innovation).

Signature :

Name of Supervisor : Dr. Siti Nurhaida binti Khalil

Date : 16 December 2016

DEDICATION

To my beloved parents, lecturers, and friends.

ABSTRACT

Creating a reliable and robust security system has become one of the main concerns of the global community in this modernization era which is congested with threats. In industrial sectors, roller shutter is widely used as primary entryway for various purposes such as loading or unloading goods. This study can help to solve some of the security issue concerning the roller shutter as well as the safety of its surroundings. Therefore, this thesis is carried out to design a conceptual door security system using Computer Aided Design (CAD) software which will undergo several analysis tests to determine the strength of the design. The design is then to be equipped water-film system to combat accident that involves fire. Material testing is also included in this study to determine the best material to be assign to the computer generated design. However, the design only limited to certain amount of security measure which is thought to be adequate to prevent intrusion. According to Information Security Principles, there is no such thing as absolute security (J. Breithaupt, 2014).

ABSTRAK

Mencipta satu sistem keselamatan yang teguh dan dipercayai sudah menjadi salah satu keutamaan dalam masyarakat global dalam era permodenan ini yg mana sesak dengan ancaman. Dalam sektor perindustrian, pengatup gulung digunakan secara meluas untuk pintu utama untuk pelbagai tujuan seperti memunngah masuk dan keluar barang. Kajian ini diharap boleh membantu untuk menyelesaikan masalah keselamatan berkenaan dengan pengatup gulung serta keselamatan di kawasan persekitarannya. Untuk itu, tesis ini dijalankan dengan merekabentuk sistem keselamatan pintu menggunakan perisaian Computer Aided Software (CAD) yang akan melalui beberapa ujian analisis untuk mengenalpasti keteguhan rekabentuk tersebut. Rekabentuk ini juga akan dilengkapkan dengan sistem lapisan-air untuk menangani kemalangan yang melibatkan kebakaran. Ujian bahan juga akan disertakan dalam kajian ini untuk mengenalpasti bahan terbaik untuk ditetapkan kepada rekebentuk yang dijana oleh komputer. Bagaimanapun, rekebentuk ini hanya terhad kepada beberapa langkah pencegahan yang difikirkan mencukupi untuk mengatasi pencerobohan. Berdasarkan kepada buku Information Security Principles, keselamatan yang mutlak adalah mustahil (J. Breithaupt, 2006)

ACKNOWLEDGEMENT

I would like to express my deepest appreciation to my supervisor Dr.Siti Nurhaida binti Khalil for giving me this opportunity to conduct and complete my final year project. She never hesitated to give me advice and guidance whenever I was confronted by problems. Furthermore, I am extremely thankful for his patience and advice while leading me in this project.

Other than that, I would like to thank all my lecturers who have bestowed me with their knowledge and broadened my understanding in the field of engineering. I would like to especially thank Mr. Nazim bin Abdul Rahman who taught me Computer Aided Drawing, which really helped me complete my final year project.

I would also like to take this opportunity to thank my course mates for providing me with support and encouragement. Finally, I would like to thank my family for their love, care and support.

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LIST OF ABBEREVATIONS

CAD	Computer Aided Design
CATIA	Computer Aided Three-Dimensional Interactive Application
DFMA	Design for Manufacturing and Assembly
GSM	Global System for Mobile Communications
ARL	Alarm Reminder Locking
SMS	Short Message Service
FAR	False Acceptance Rate
FRR	False Recognition Rate
AFRS	Automated Fingerprint Recognition System
MOFSET	Metal–Oxide–Semiconductor Field-Effect
PDS	Product Design Specification
QFD	Quality Function Development
HOQ	House of Quality

LIST OF SYMBOLS

α	=	Alpha
$^{\circ}C$	=	Degree Celsius
K	=	Kelvin

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Door security has been considered a basic necessity either in residential, commercial or industrial buildings. Lack of security can result in great damage (e.g. burglary, accidental damage, fire, espionage, natural phenomena and etc.) (Safaa A. Mahdi, 2013). Therefore with a befitting security device installed, it can ensures the safeguard of ones' privacy, treasured properties and also lives against any threat for instance, an armed burglary. A report shown in 2014 indicates there were 23,317 cases of break-ins in Malaysia by Crime Prevention and Community Security Department (Utusan Malaysia, 2015). Therefore, a door security device is designed to scale down the break-in substantially against any act of thievery or further damages that might occur to the properties and building's infrastructures. Such device will be design to be unyielding for guaranteed safety and privacy by blocking the entryway from unwelcomed intruders. Several selected material will be tested with stress and Von Misses analysis using 3D Computer Aided Design (CAD) software such as CATIA in order to determine the toughest substance for the pulmonary product. Alarm and sensors will also be electronically connected to the device's design in hope it will deter the criminal simultaneously alerted nearby guards. It will be tested and analyze with various analysis for example stress analysis to determine its quality as well as reliability.

1.2 PROBLEM STATEMENT

Security without quality cannot assert high assurance. The main drawback from the current security door devices has not being properly analyzed in term of quality may be encounter with failure and malfunction. Other than that, the manufacturing of standard security door device generally use substandard materials which can lead to vulnerability to the products.

1.3 OBJECTIVES

1. To design a conceptual door security system using Computer Aided Design (CAD) software.
2. To analyze the designed product using several analysis methods.
3. To identify the most suitable material for the roller shutter using CES EduPack Software.

1.4 SCOPE OF PROJECT

The scopes of the project are:

1. The design of the product can be design and tested in 3-D modeling software.
2. The device is designed specifically for several types of industrial doors.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Literature review is an inquiry that evaluates the available published resources on a given subject or topic for example door security system. The objective of literature review is to survey and gather information to form a summary. By reviewing a collective form of information on the door security system, it will provide insight as to importance of achieving the objectives of this study. The literature review will be focusing on certain areas, such as background, types and development of industrial security doors.

2.2 HISTORY OF DOOR SECURITY

The need of security has been in high demand ever since the world has moved towards industrial and technological advancement, thus showing an increase in services for personal protection. In 18th century, the Industrial Revolution has sparked rapid development of security system in order to protect goods and properties from thievery. Since then, private security evolved from need for additional, individual protection for humans and their property. One of the earliest modern security inventions was created by Reverend Augustus Russell Pope in 1853 which include an electro-magnetic alarm.

A. R. POPE.
BURGLAR ALARM.

No. 9,802. Patented June 21, 1853.

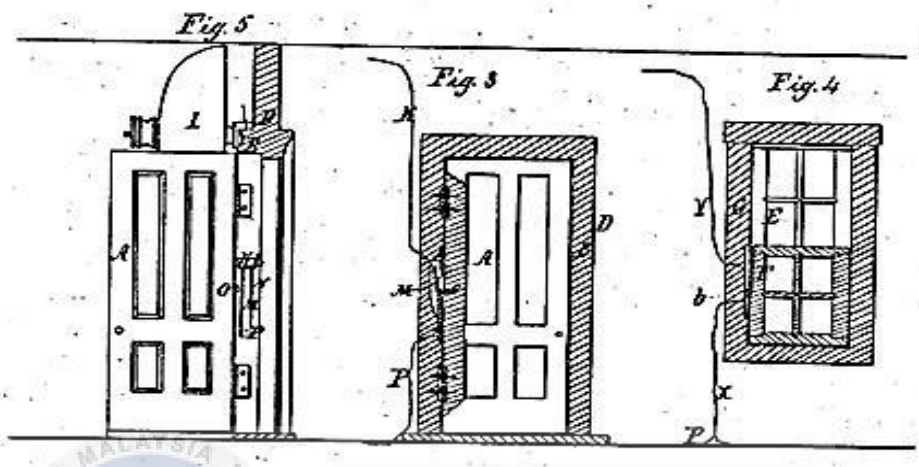


Fig. 2.1: Outside view of the improvement in electro-magnetic alarm device patented (A.R. Pope, 1853).

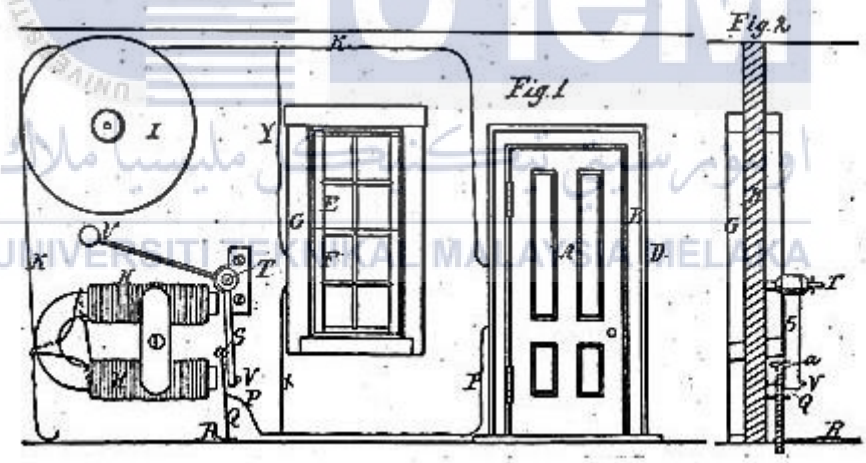


Fig. 2.2: Detailed view of the improvement in electro-magnetic alarm device patented (A.R. Pope, 1853).

The events of the World War I (1914) and the Great Depression (1930) have also played an important role as catalyze to increase operation of security doors and device not only to major countries but also to all countries worldwide. The fear of sabotage, espionage, riot has helped significantly in security advancement either by the governments or private sector.

Today, most threats are ranging from armed burglary to terrorism. Both threats are considered highly dangerous for either occupants of residential or industrial building to ignore. Some security services companies also have incorporated to prevent other unwanted scenarios such as fire and collision as part of their system.

2.3 DEVELOPMENT OF DOOR SECURITY

In the early 20th century, amass of technological inventions has flooded the market affecting various sector including the safety and security sector. Both residential and industrial door security have been revolutionized by integrating mechanical and electrical component together. For example, biometric recognition device was connected to the auto-deadlocking and alarm to ensure any attempt of access by unrecognized personnel will be directly alerted to the person in charge. High standard security companies usually offer various options that not only insure protection but also simplified sophisticated systems.

2.4 GUIDES TO SECURITY DOORSETS AND LOCKING HARDWARE

Door comes in several of designs from standard hinged door to military grade vault door. Both types included with a locking mechanism for privacy and security purposes. The main objective of this guide is to introduce important security features to certain door sets to avoid intrusion.

The material selected to construct a door is as paramount as how it is configured by additional security aspects to prevent forced entry. The table below illustrates on relative effect that different features of a door sets' construction can have resistance on forced entry.

Resistance	Mode of Opening	Number of Leaves	Leaf	Bolting Points	Bolt Engagement	Dead-lockable Operation	Vision Panel
More secure ↑	Inward	Single	Solid	Multipoint deadbolt	Small gap between frame and door and good bolt throw	Deadlock by key on inside only (single cylinder on inside only	None
	Outward		Framed of paneled	Single point deadbolt		Non-lockable (thumb turn)	Laminated security glass containing polycarbonate Laminated security glass containing PVB interlayers
Less secure	Bi-directional	Double		Single point latch bolt	Large gap and minimal bolt throw	Non-lockable (lever handle)	Toughened or wired glass

Tab. 2.1: Relationship between a doors set's design and its resistance to forced entry (CPNI, 2013)

2.4.1 POSSIBLE THREATS

In order to offer solutions, the problems must first be identified which in this particular study is the threats that any infrastructures especially in industrial sector may encounter. These are the possible threats that might occur in these present days. (Centre for the Protection of National Infrastructure, 2013)

1. Accidental damage
2. Espionage
3. Fire
4. Natural phenomena (e.g. flood, high winds)
5. Opportunistic crime
6. Organized crime
7. Protestors

8. Terrorism
9. Vandalism
10. Use (e.g. wear and tear)

The frequency of occurrence of these threats however will depend on other aspect for example the location on site and other security measure which are implemented in the surrounding area of the building.

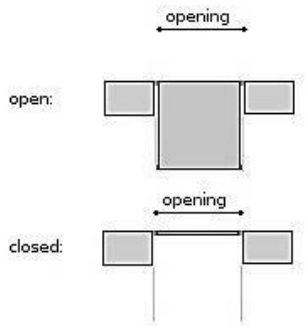
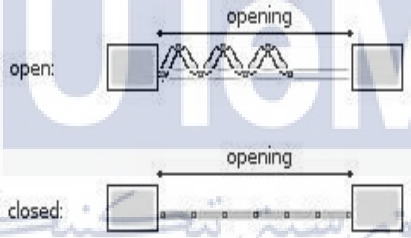
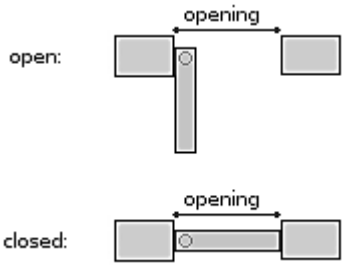
2.4.2 METHODS OF LOCK OPERATION

Considering there are thousands of alternatives of lock operation to a door, the list in the figure below will only covers general type of the operation. The effectiveness will depend on the quality of the materials, reliability of the components and combination of multiple security devices (CPNI, 2013).

1. Keys (e.g. pin tumbler lock key, lever lock key, tubular key)
2. Locks (e.g. padlocks, deadbolts, smart locks)
3. Reinforcement (e.g. strike plates, chains, hinge screw, internal lock)
4. Security code
5. Alarms (e.g. smoke alarms, burglary alarm, sensor alarm)
6. Biometric recognition (e.g. thumbprint, facial, retina)

2.5 INDUSTRIAL DOORS AND TYPES OF INDUSTRIAL DOORS

Industrial doors have distinctive aspect in terms of overall design, security, functions, mechanism and etc. compared to residential doors. However, the most common doors are divided into 3 basic type of mechanism that is suitable to be implemented in industrial infrastructure according Wessex Industrial Door Ltd. Website.

Type of Door Mechanism			
Ref.	Type of Mechanism	Diagram of Mechanism	Application
2.5.1 and 2.5.2	Up and Over / Rolling Mechanism		Used in roller shutter door, sectional overhead door in garage or commercial buildings
2.5.3	Sliding/Folding		Used mostly in residential building and few industrial building.
2.5.4	Hinge		Widely use in almost all type of buildings

Tab. 2.2: Type of common door mechanisms (Industrial Doors for All Types of Businesses and Buildings, 2016)

2.5.1 ROLLER SHUTTER DOORS

One of the earliest improved roller shutter invention was patented in 1929 by B. Negrini and its constructed rectangular metal sheets that is connected to each other by inter-engaging spirally formed beadings constructed along their longitudinal edges so as to allow the coupling of the slats and the shutter being wound up on a roller (United State Patent Office, 1929). Since then, similar contraptions have been an ideal choice for factories and other business outlet.

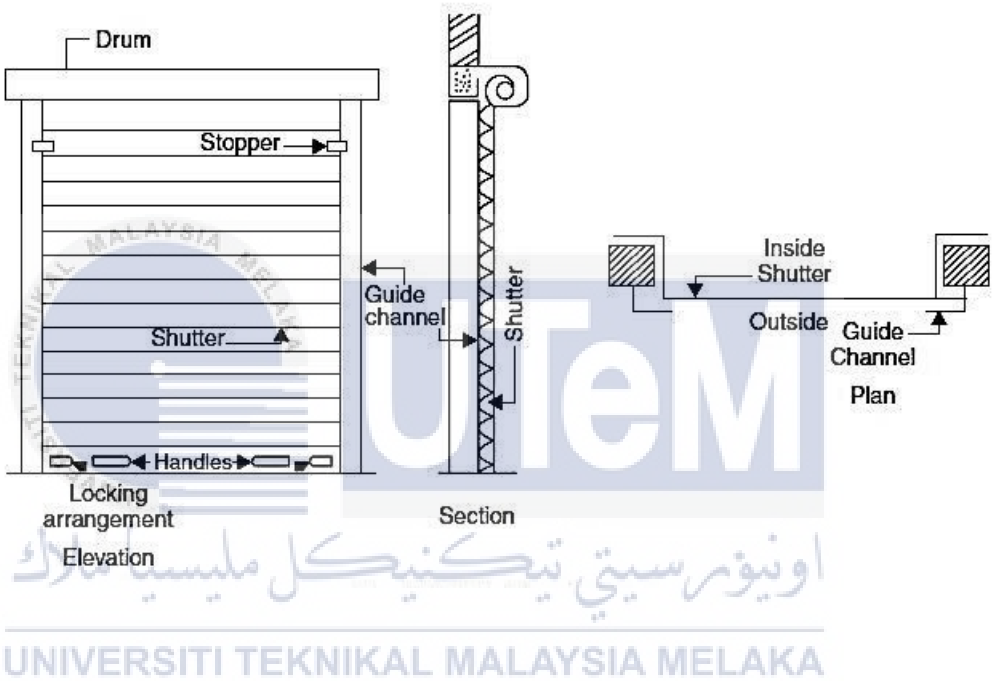


Fig. 2.3: Roller shutter component description (Type of Doors, 2014)

There is a wide range of product regarding roller shutter from security, fire-resistant or insulated that currently available in the market. Most are which have the synonymous mechanism with a few upgrades to accommodate the client's requirement. The operations only compose of manual operation and a single phase electric which are required to lift the shutter upward. It consists of a frame, a drum and a shutter made of thin steel plates. The width of the door may vary from 2 to 3 m. The shutter moves on steel guides provided on sides and can easily roll up. For this counterbalancing is made with helical springs on the drum. The shutter can be easily pulled down. This type of door is commonly used as additional doors to shops, offices, banks, factory, and buildings from the point of safety.

2.5.2 SECTIONAL OVERHEAD DOOR

Sectional doors open vertically upwards and are suspended under the ceiling to save space if compared to roller shutter door. This construction principle means it can make full use of the space inside and in front of the garage. In addition, sectional overhead doors can be fitted in any opening and offer up to 14 cm more passage width than up-and-over doors. They are also optimally sealed with flexible and weather-resistant seals on all four sides.

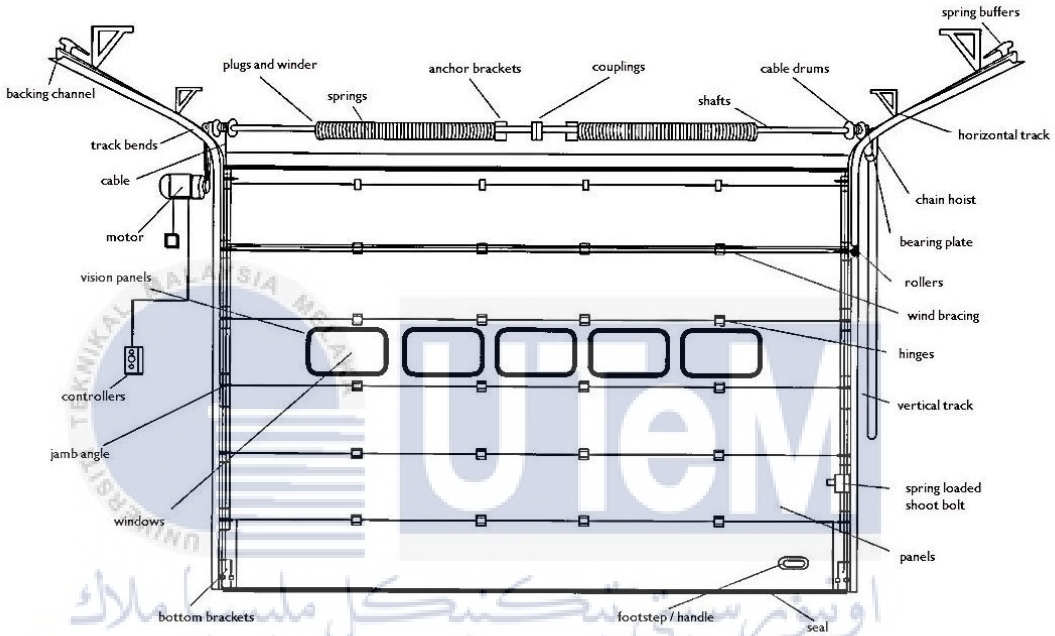


Fig. 2.4: Sectional overhead door component description (Cobra 610 Insulated Sectional Overhead Door, 2016)

Double tensions springs and double cabling on each side safeguard the door leaf against crashing to the floor. In addition, by using the spring-in-spring system, broken springs are prevented from flying out and causing injuries. Sectional doors up to 3 meter wide and 3 meter high include the proven tension spring technology as standard.

2.5.3 SLIDING FOLDING DOOR

In recent decade, sliding folding door has been in-demand in modern residential building typically with a wide range of vision. Some of the industrial manufacturing companies also consider using sliding folding door as their secondary entryway. Materials usually composed of galvanized steel and can be arranged to bunch to either one or both side of an opening. It can also be manually operated or power operated by a gear electric motor with torque limiter though either a push button or a remote system.

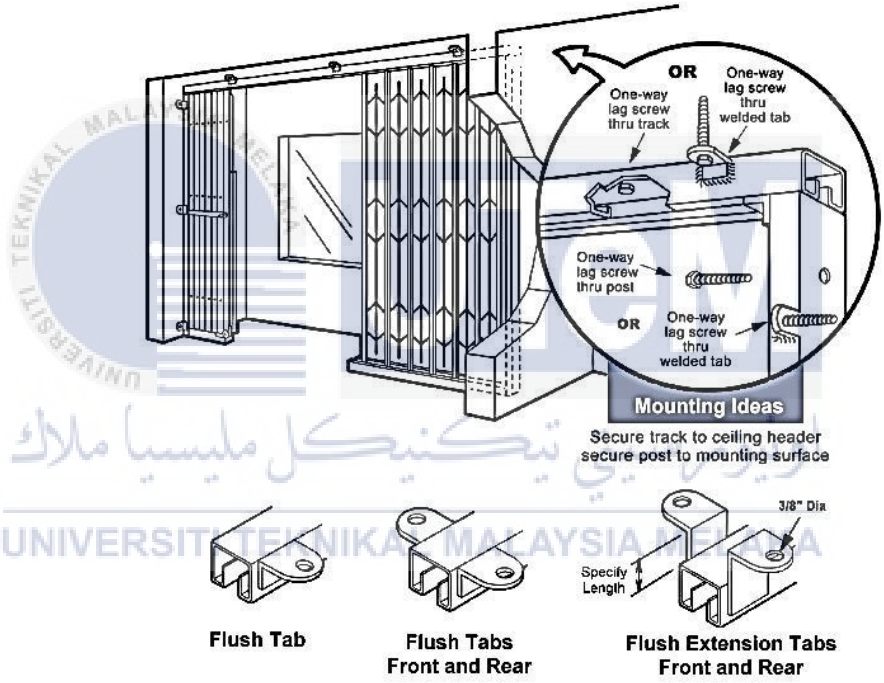


Fig. 2.5: Sliding folding door component description (Max-Guard Storefront Security Gates, 2015)

Company specialized in advance industrial door security device can provide various options including different motor to operate sliding of the door with a pull and push force ranging from 650 N to 850 N at the speed of 8 – 10 cm per second.

2.5.4 STEEL HINGED DOORS

Steel hinged doors are the most commonly used door due to its simplicity and practicality. The mechanism incorporated the door to be hinged along one side to allow the door to pivot from the doorway in one direction. The axis of rotation is usually vertical. However in some cases, such as hinged garage doors, the axis may be horizontal, above the door opening.

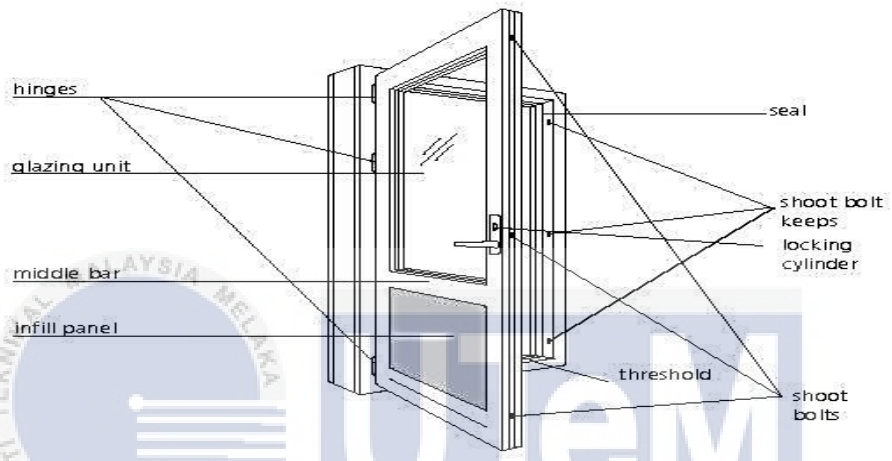


Fig. 2.6: Steel hinge door component description (Door Frame Terminology Diagram, 2015)

Doors can be hinged so that the axis of rotation is not in the plane of the door to reduce the space required on the side to which the door opens. This requires a mechanism so that the axis of rotation is on the side other than that in which the door opens. Such mechanism is applied in trains or airplanes which open inward.

2.6 A NEW INVENTION OF ALARM REMINDER LOCKING (ARL) SECURITY SYSTEM

A recent study conducted by M.S.M. Effendi discussed about the operation of SMS technology to send out alerts regarding break-ins that happen in real-time. The system is composed of Arduino Uno R3 Controller, Global System for Mobile Communications (GSM) technology combined with a few electrical components such as magnetic door sensors, alarm buzzer and solenoid lock for further enhancement of the device they had designed.

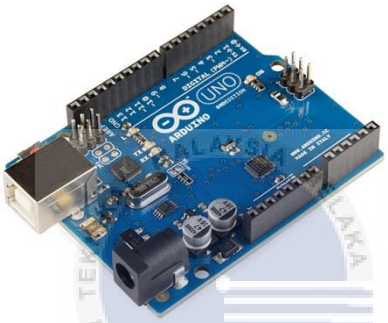


Fig. 2.7: Arduino Uno R3 Controller (Arudino Uno Rev3, 2016)

Fig. 2.8: SIM900 GSM/GPRS for Arduino (IComSat GSM, 2016)

This technology can be integrated to the security doors that are available in any industry and provide information of intrusion situation directly to user's mobile phone. Few advantages of this system are user friendly, low power consumption and reasonable cost to install with any mechanical security structure. According to this paper, here is the flow process if any case of any forced entrance occurs to the installed entryway.

The ARL module will immediately send notification in three different situations which is when the door improperly closed, when the door is automatically locked and intrusion occurrence. These will be operated by a single application system of the ARL.

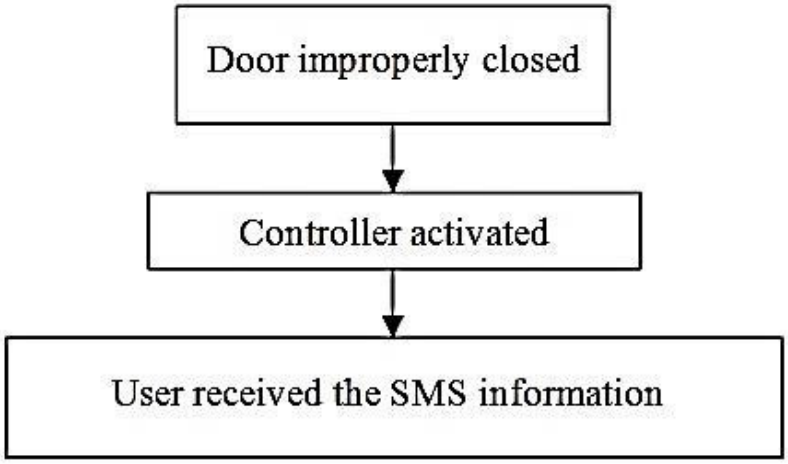


Fig. 2.9: Flow process of improperly closed door (M. S. M. Effendi, 2016)

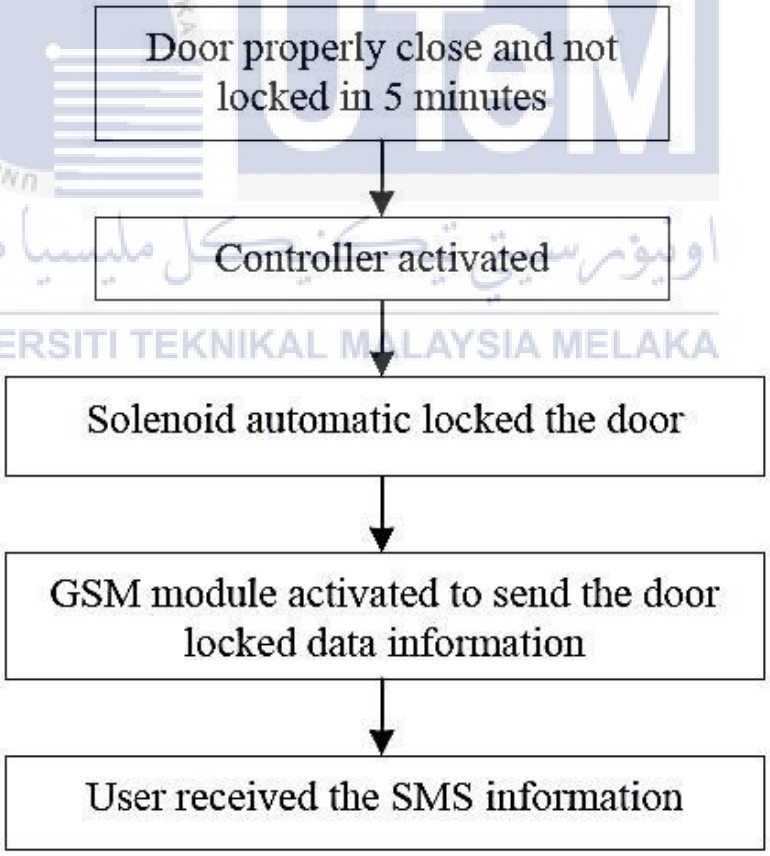


Fig. 2.10: Flow process of automatic locker (M. S. M. Effendi, 2016)

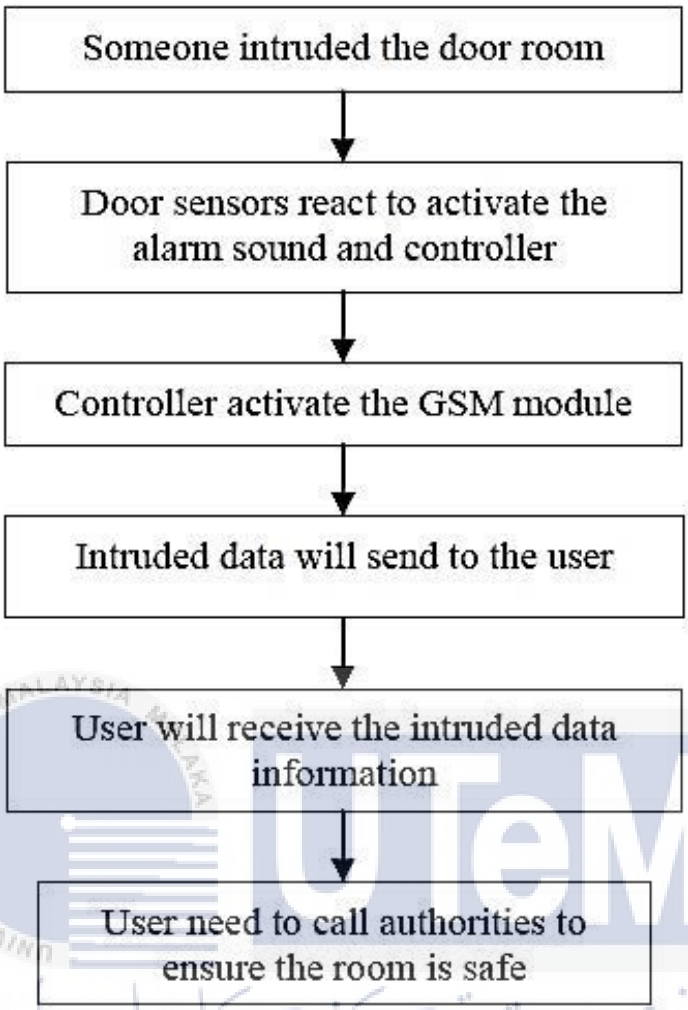


Fig. 2.11: Flow process of intrusion situation
(M. S. M. Effendi, 2016)

2.7 FINGERPRINT BIOMETRIC FOR IDENTITY MANAGEMENT

The application of fingerprint recognition has is no longer considered to be a unique in the past decade. It has been used in both commercial and government to provide access to their employees in places such as building with access control, border control, computer & network access, e-government, ecommerce and forensic and criminology. Fingerprint recognition implemented the image capturing, image enhancement and matching algorithm where it can perform with high accuracy and low False Acceptance Rate (FAR) and False Recognition Rate (FRR). The system familiarly known as Automated Fingerprint Recognition System (AFRS) has 2 stages, enrolment and recognition. The 2 stages are illustrated in the figure below.

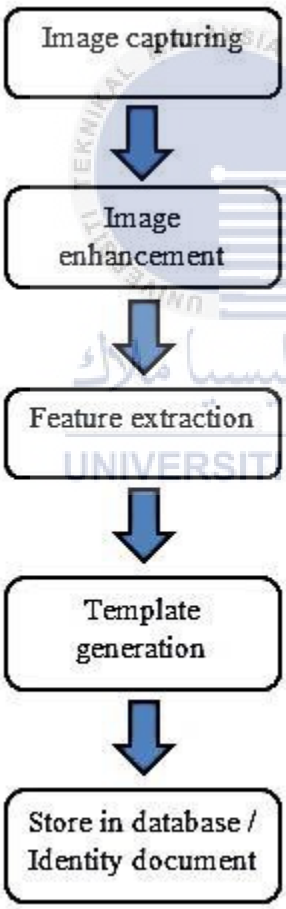


Fig. 2.12: AFRS enrolment stage (N. Manivannan, 2011)

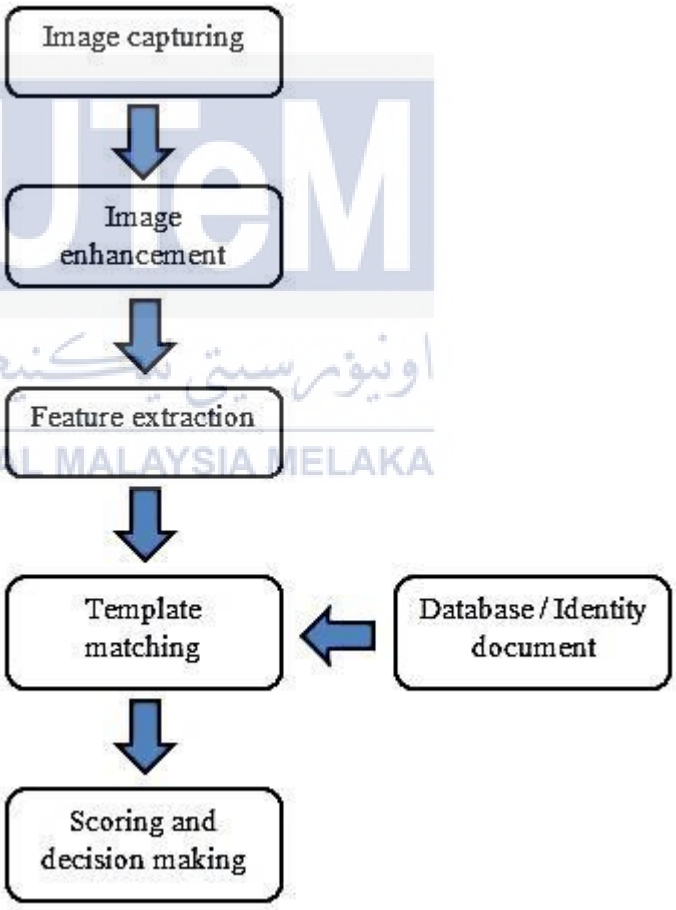


Fig. 2.13: AFRS recognition stage (N. Manivannan, 2011)

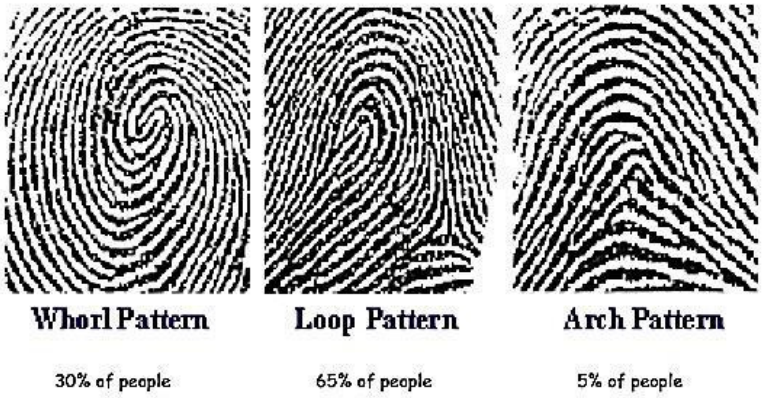


Fig. 2.14: Basic fingerprint template (Fingerprints, 2001)

Overall, AFRS has simplified the complex identification process to a single point (a fingerprint) with many advantages in terms of economy, reliability, robustness, user-friendly, and efficiency. (N. Manivannan, 2011). With that being said, the system has the capability to be installed to further secure the entryway either from unauthorized access or unwanted intruders.

2.8 FIRE RESISTANCE EVALUATION OF A STEEL ROLLER SHUTTER WITH WATER-FILM COOLING SYSTEM

A fireproof roller shutter resembles of the fire door which incorporated as a part of a passive fire protection system to prevent the widespread of fire to other building's compartments. Although metal roller shutter provide flame resistance, it cannot prevent heat resistance. In case of a blaze, the roller shutter can heat up to high temperature and produce a great amount of thermal radiation transmission. This can cause the roller shutter to ignite nearby flammable object or high-degree burn to occupant due to prolonged heating that could outset another blaze. This journal discussed on how to improve the heat-resistance capability of shutter roller by implementing water jet to create a water-film throughout the surface area of the roller shutter as shown in the figure below.

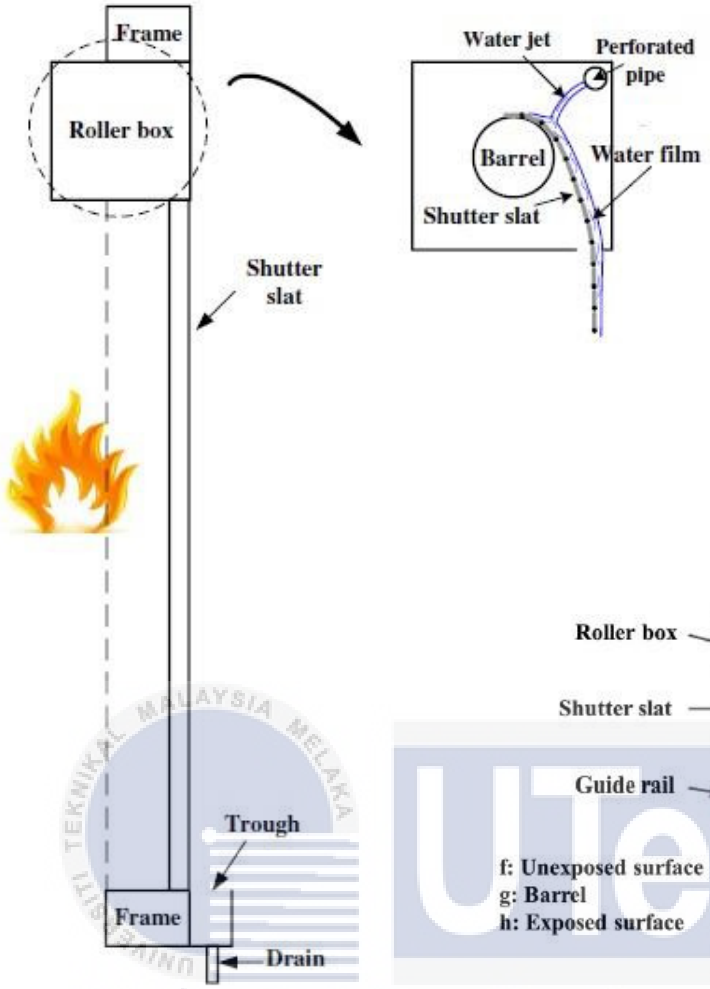


Fig. 2.15: Schematic of the fire resistance evaluation system (S. K. Lee, 2013)

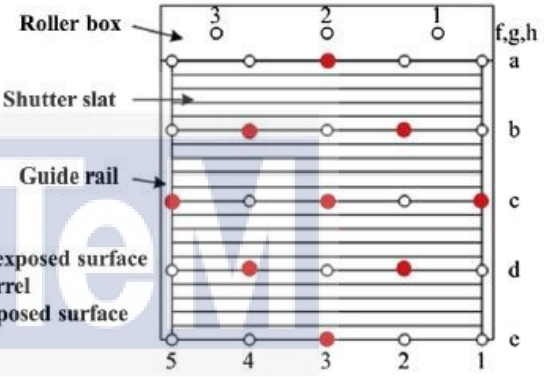


Fig. 2.16: Thermocouple location in fire resistance evaluation system (S. K. Lee, 2013)

The thermocouple serves as an instrument to measure the temperature was attached to the shutter slat before conducting the test run. The result of this experimentation that was included in this paper shows a significant difference of temperature of the shutter slat surface between a system with water-film and without water-film.

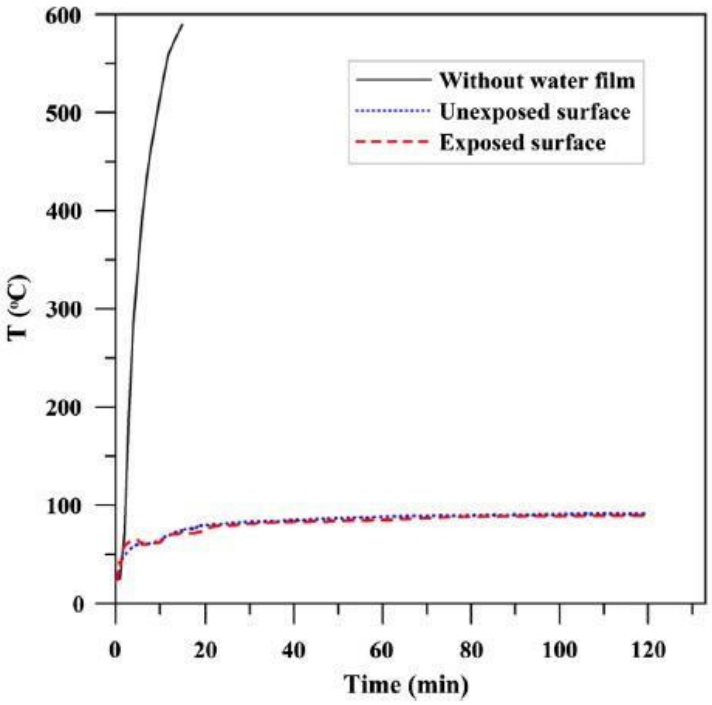


Fig. 2.17: Comparison of shutter slat temperature (S. K. Lee, 2013)

According to the graph shown, the temperature gap between the use of water-film and without the use water-film is 500℃. The drastic temperature drop may provide additional safety assurance of the occupants and commodity. This study has proved the important function of improving the system in the heat resistance of a roller shutter. If the system is designed to make use of fireproof installations, many practical problems must be considered such as water source, pipeline configuration, and the operating time.

2.9 HIGH-SENSITIVITY MINIATURE SMOKE DETECTOR

In this particular area of study conducted by Ezzat G. Bakhoum, focus on the improvement of smoke detector in which utilize the use of α-particle (such as Americium 241) that emits to the surrounding area. The improved device basically relies on the principle of ionization of the air. The α-particles emitted from the source are made to strike directly the gate of an n-channel MOSFET (Metal–Oxide–Semiconductor Field-Effect) transistor instead of emitting the particle to ionization chamber that consists of two metal electrodes separated by air.

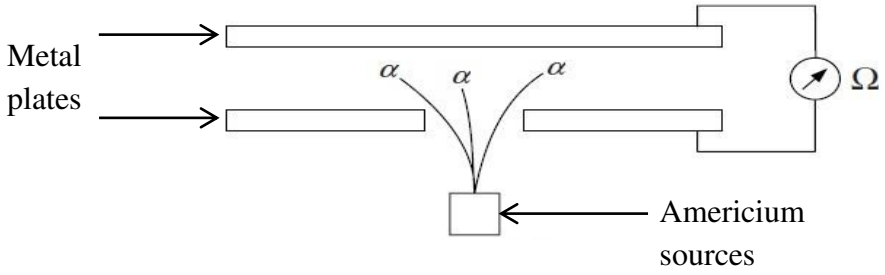


Fig. 2.18: Principle of operation of the traditional α-particle smoke detector (E. G. Bakhoum, 2012)

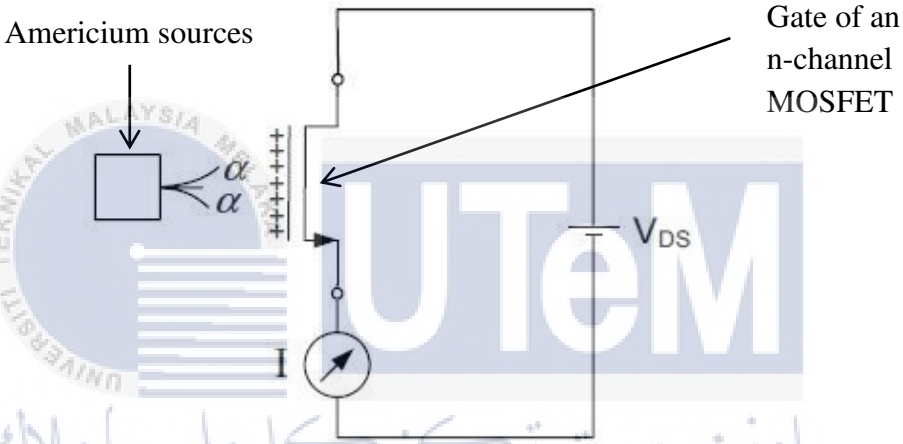


Fig. 2.19: Principle of operation of the new detector (E. G. Bakhoum, 2012)

The sensitivity of this newly applied contraption will result in reduction of time response of the smoke detector to detect possible harm of fire from for example a spontaneous combustion on a specific targeted area. In addition, it also has the capability of detecting every minute of smoke due to its radiation-based application compared to conventional device.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In methodology part, a few methods of study are proposed to better understand and achieve current objective of this paper. The process of this academic work will be describe in details using methodological flow chart and agglomerate information from various literature reviews and the use of computer aided design and analysis software.

3.2 METHODOLOGICAL FLOW CHART AND GANT CHART

The main principle of a flow chart is to represent a set of processes in an order of logical sequence. A chain of actions are recommended to complete this design and analysis of a security door device and the following action is represented in the flow chart below.

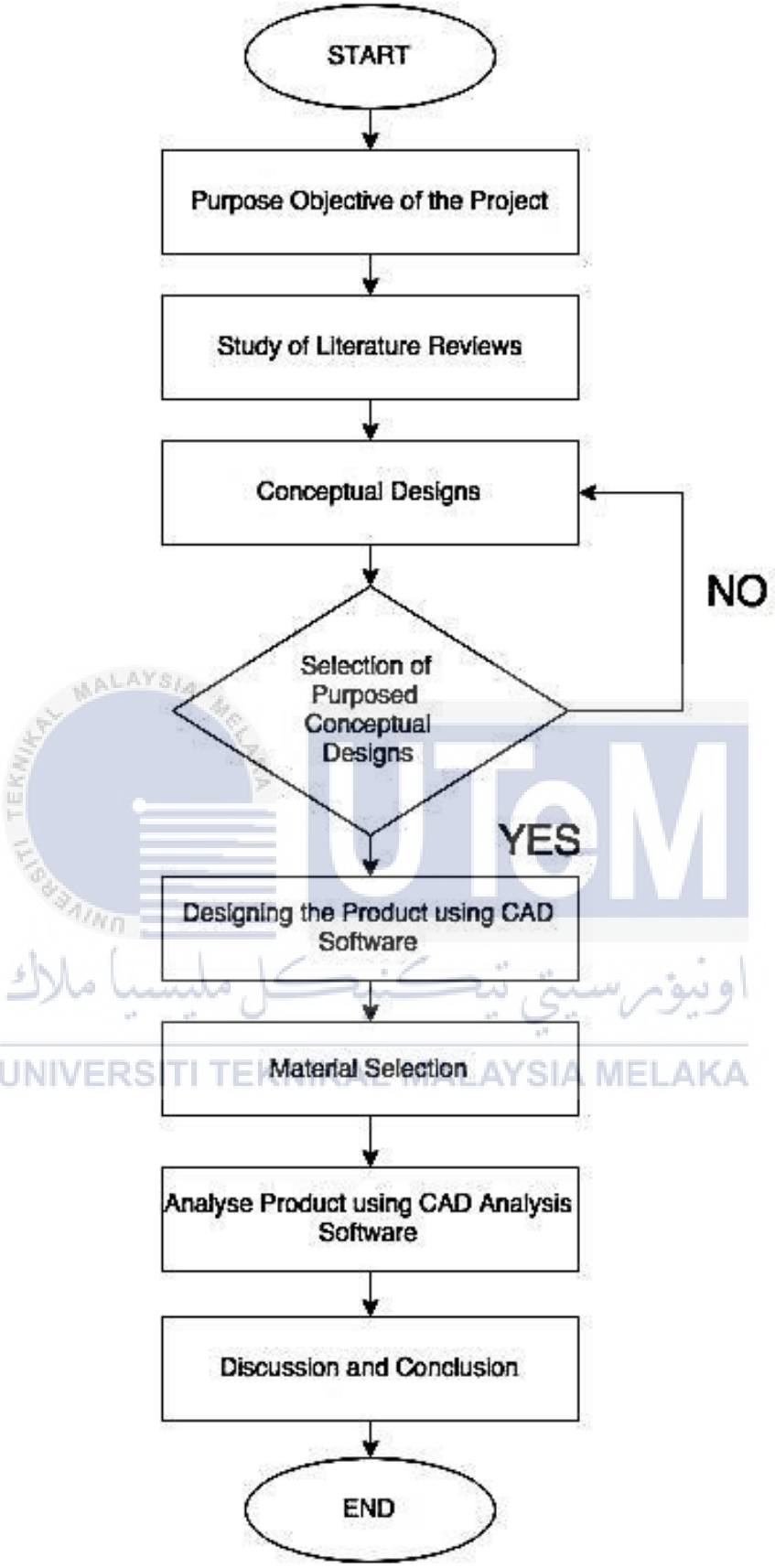


Fig. 3.1: Methodological Flow Chart

No	Weeks / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	PSM Topic Selection															
2	Topic Verification															
3	Objective, Scope and Problem Statement															
4	Problem Identifying															
5	Research															
6	Process Solution															
7	Literature Review and Methodology															
8	Designing of Concept Design															
9	Preparation for Presentation															
10	Presentation															
11	Preparation of Draft Report for PSM 1															
12	Submission Report of PSM 1															

Tab. 3.1: Gantt chart of tasks over time for PSM 1

No	Weeks / Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	PSM 1 Review															
2	Design Selection															
3	Design Evaluation															
4	3D Dimension Modelling															
5	Details Design															
6	Analysis via Graphical Method															
7	Analysis via Analytical Method															
8	Drawing Conclusion															
9	Preparation for Presentation															
10	Presentation															
11	Preparation of Draft Report for PSM 2															
12	Submission Report of PSM 2															

Tab. 3.2: Gantt chart of tasks over time for PSM 2

3.3 STUDY OF LITERATURE REVIEWS

Any information related to the study of security door device is collected to aid in accomplishing the targeted objective. Every known source such as journals, online articles, catalogues, patents and other reading materials regarding this specific project will be reviewed. This can be observed in the previous chapter where the studies of previous researchers on this topic are discussed in detail for a better understanding of the topic at hand. These previous studies will be implemented in the conceptual design of the project later on. Integration of multiple security structures is implemented in hope to further improve the security measures against any possible threats.

3.4 CONCEPTUAL DESIGN

A concept design of the security system is proposed including the selected type of industrial door had to be proposed prior to selecting the final design. The design will help in developing a design idea into a realistic interpretation using computer modeling software (e.g. CATIA, SOLIDWORKS, and AutoCAD). The purpose of having a concept design is to be able to modify earlier design before proceeds to the software design. It will also serve a purpose as a guide for the 3D modeling product.

The diagram as shown below is the example of what will be executed in the 3D modeling software, CATIA. The sketch only provides the view of complete product of assembled parts and components. Since the study is dealing with industrial security door, a conceptual design of a roller shutter will be used in this study. Detailed view of parts and components will be provided in draft form which will be generated electronically using the software.

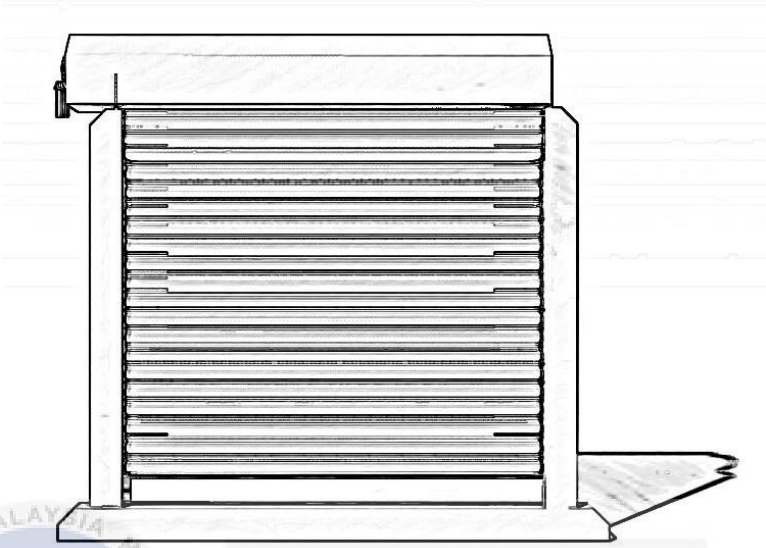


Fig. 3.2: Conceptual design 1

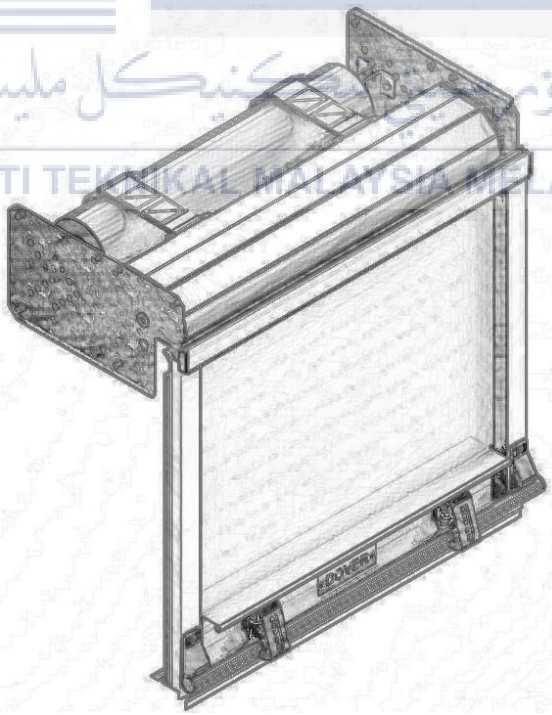


Fig. 3.3: Conceptual design 2

3.5 PRODUCT DESIGN SPECIFICATIONS

The main purpose of design process planning is to identify, search as well gather as much information in order to determine if the product development will be a good investment for the company or manufacturer in marketing the product in the future. Product design specification (PDS) is an important document in design process since this part contains the information of the product included market planning for industrial security doors.

Tab. 3.2: Product design specification for industrial security doors

Product Design Specification for Industrial Security Door
Product Identification • Security based roller shutter is used to minimize the risk of burglary, invasion, espionage as well as acting as a protective medium between accident (e.g. fire) and the product or goods. • This design is focused towards improvement of safety and security.
Special Features • Fingerprint biometric recognition access. • Fire-resistance integrated with an alarm. • Real time intruder alert notification. • Low cost maintenance.
Key Performance Target • Ensuring the security of the infrastructure as well as the property. • Dimension is customizable. • Highly reliable for extended period of time. • Easy to maintain and operate.

Service Environment

- Shops, garage, industrial buildings.
- Design is compatible with a wide space of entryway
- In case of fire, it can withstand up to 600 °C temperature

Design Description

- Scale: 1:1
- Average width: ~ 3.4 meters
- Height: ~ 3 meters
- Curtain width: ~ 2.7 metres
- Material: Aluminium or stainless steel

Major Components

- Motors
- Slats
- Guide rails
- Water-film system
- Fingerprint recognition device

Market Identification

- Target market of the product will be personal, business and industrial sectors.

Life Cycle Target

- Useful life 10 years and beyond.
- Maintenance at least once for every 6 month

3.6 QUALITY FUNCTIONS

Certain quality of criteria is selected in order to be applied to the concept selection methods such as Quality Function Development (QFD) and House of Quality (HOQ). The list of the criteria selected is as follows:

1. Safety
2. Compatibility
3. Durability
4. Operation
5. Cost
6. Reliability

These criteria's were obtained by the customer's requirement that the designers need to consider before sketching the conceptual designs. The design concept will then go through the QFD process which will be the House of Quality and the Pugh method.

3.7 DESIGN EVALUATION

The conceptual design will be evaluated to further determine its practical characteristic using several methods of Quality Function Deployment. These methods are as follow:

1. House of Quality (Y. Akao, 1990)
2. Pugh Method (Stuart Pugh, 1988)

3.7.1 HOUSE OF QUALITY

The House of Quality in a table that represent the basic design tool of the management approach known as Quality Function Deployment (QFD). The foundation of the house of quality is that the designed products should reflect customers' desires and tastes. The quality design of the security roller shutter will be represented in the form of House of Quality as shown in the table below:

The main function of House of Quality is to aids product designer or manufacturer in how a product should reflect the customer's need. This correlation matrix not only capable of storing a lot of information but can be used to define the relationship between customer's needs and the product capabilities. Each of the value assigned to customer requirements and engineering characteristics represent the ratings are evaluated to utilized a planning matrix to relate between those two criteria. The ratings are then used to calculate the absolute weight and relative weight of the whole relationship to determine which of the engineering characteristic should be focused on in priority rank order.

-	-	ENGINEERING CHARACTERISTIC	Security measures	Ergonomic	Size	Material toughness	User friendly
NO.	CUSTOMER REQUIRMENTS	WEIGHT (1-5)	-	-	-	-	-
1	User's Safety	5	10	6	5	9	-
2	Compatibility	3	5	5	5	-	-
3	Durability	5	8	-	-	7	-
4	Operation	4	7	-	7	5	9
5	Cost	4	7	7	9	5	7
6	Reliability	5	8	-	5	7	7
-	Absolute weight	-	201	73	129	155	99
-	Relative Weight (%)	-	30.6	11.1	19.6	23.6	15.1
-	Rank Order	-	1	5	3	2	4

Tab. 3.3: House of Quality evaluation for the proposed design

Formula for the House of Quality

$$Absolute\ weight = rating\ \times weight$$

$$Total\ of\ absolute\ weight = 657$$

$$Relative\ weight\ (\%) =$$

$$\frac{Absolute\ weight\ of\ engineering\ characteristic}{Total\ of\ absolute\ weight} \times 100$$

3.7.2 PUGH METHOD

Pugh method or also known as Decision-matrix method is an evaluation process for selecting a concept amongst it basis multiple concepts by using a scoring matrix. This method only work for multiple solution alternatives. Usually the scoring is done relatively (better than, neutral, or worse than). Therefore, the Pugh method will be used to determine which concept design is with higher quality.

A basic Pugh Method table must consist of a set of criteria option that is scored and summed to gain a total score which can then be ranked. It is prevent the quick selection process to the product and the evaluator must score the weight appropriately. However, before starting to evaluate any conceptual design by using Pugh Method, a datum must be set as an initial concept. The main purpose of the datum is to set a standard for the strengths and weaknesses of improved design concepts. The advantage to this particular method is that subjective opinion of one's alternative can be made objectively. Thorough study towards the conceptual designs also be performed by studying the decision matrix.

-	-	-	DESIGN CONCEPT		
ROW	CRITERIA	WEIGHT (1-5)	0	1	2
1	User's Safety	5	DATUM	+	+
2	Compatibility	3		+	-
3	Durability	5		+	+
4	Operation	4		+	-
5	Cost	4		-	+
6	Reliability	5		+	+
-	TOTAL of +		0	5	4
-	TOTAL of -		0	1	2
-	OVERALL SCORE		0	4	2

Tab. 3.4: Pugh Method selection for selecting best concept design

Based on the table above, the Conceptual Design 1 shows more strength compared to Conceptual Design 2 in term of compatibility and operation. However, the cost of constructing Conceptual Design 2 is lower. Overall, Conceptual Design 2 outweigh by 2 against the other design which means it will be going to the next order of this study

CHAPTER 4

DETAILED DESIGN

4.1 INTRODUCTION

Based on the conceptual designs provided in the previous chapter, the actual design is then constructed using a CAD modeling software, CATIA. The details such as the draft of isometric, front view, top view and side view are also included in the appendix for future reference.

4.2 PRODUCT DESIGN USING CATIA SOFTWARE

Conceptual design A is selected as product design considering the design evaluation using Pugh Method and House of Quality. Using the conceptual sketches as guidance, a 3D design of the product is constructed using the CAD software, CATIA.

4.2.1 ASSEMBLY DRAWING

The figure below, created in 1:1 ratio shows the final design of the roller shutter, where all the parts had been assembled. It consists of various rails, box lids, slats, motor, shaft and etc.

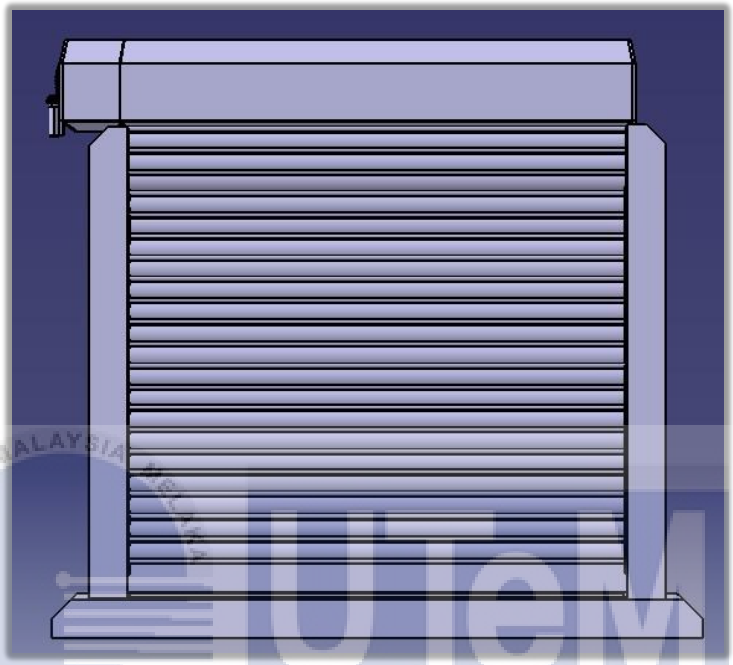


Fig. 4.1: Assembly design of industrial roller shutter

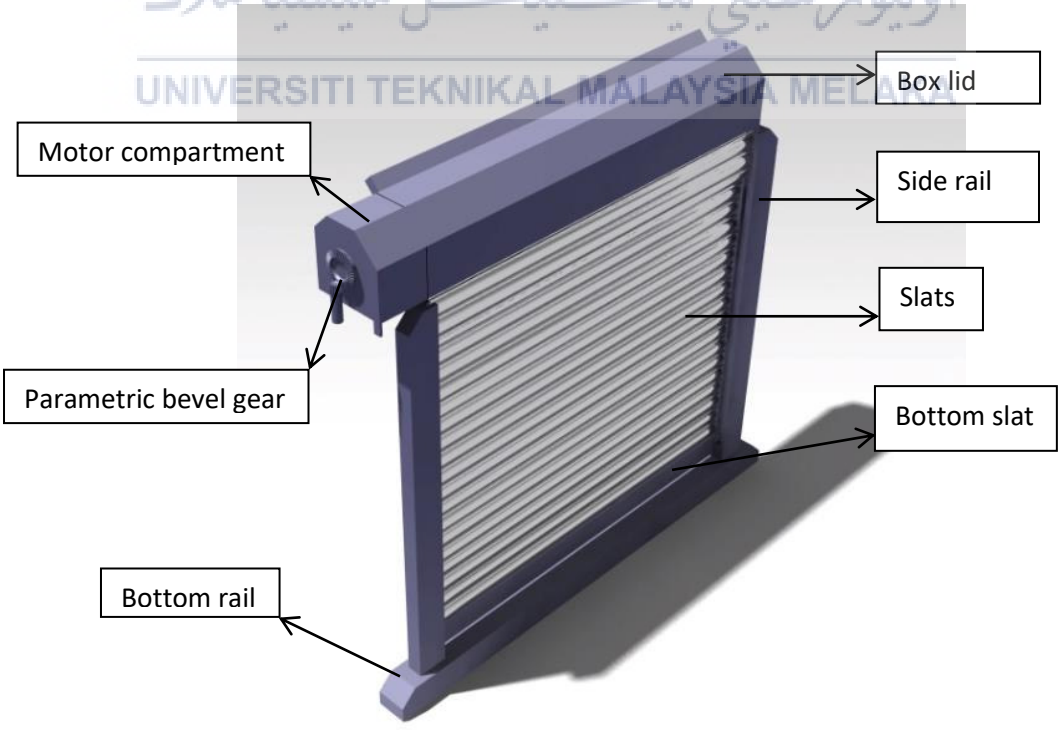


Fig. 4.2: Rendered image of the roller shutter (Front)

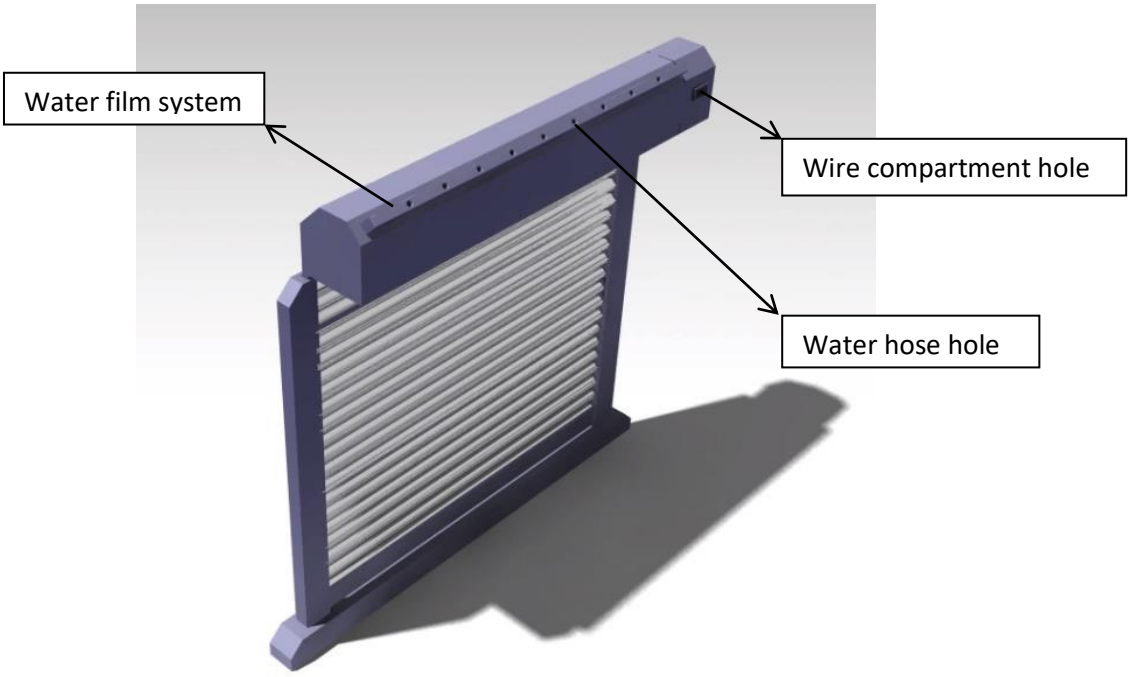
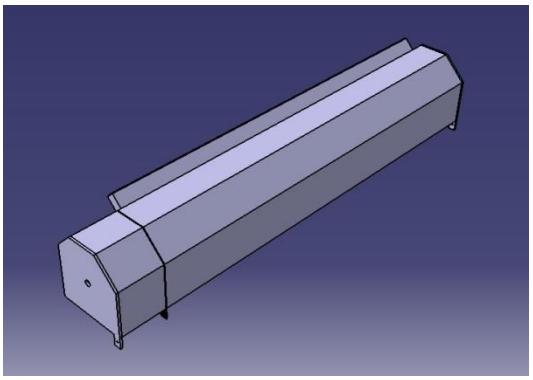
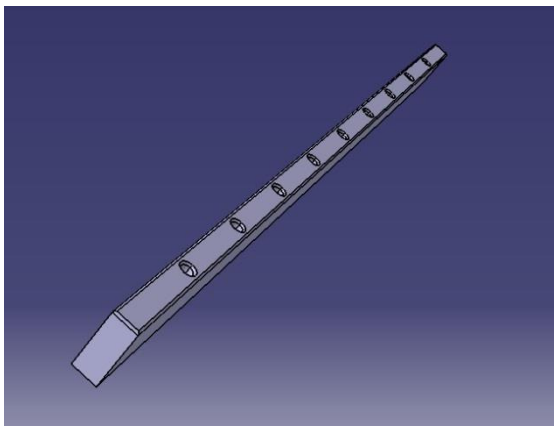
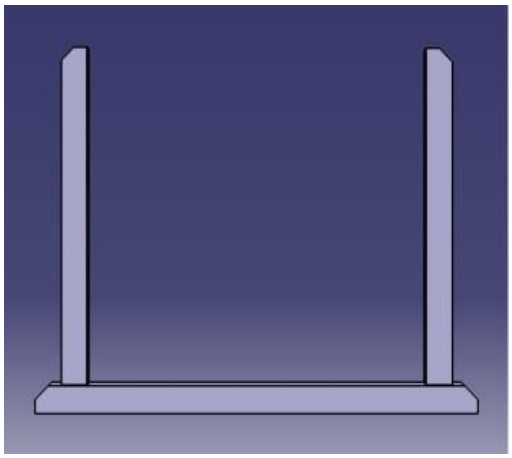
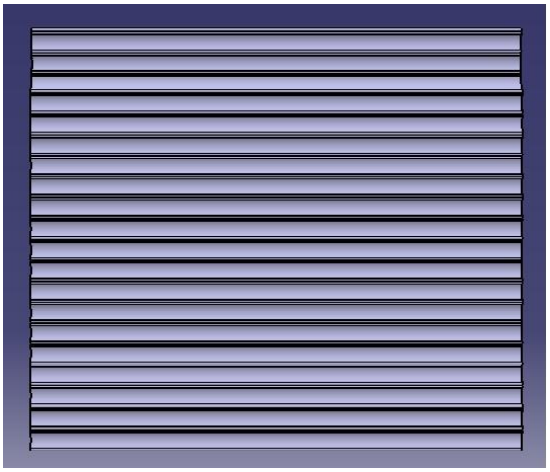
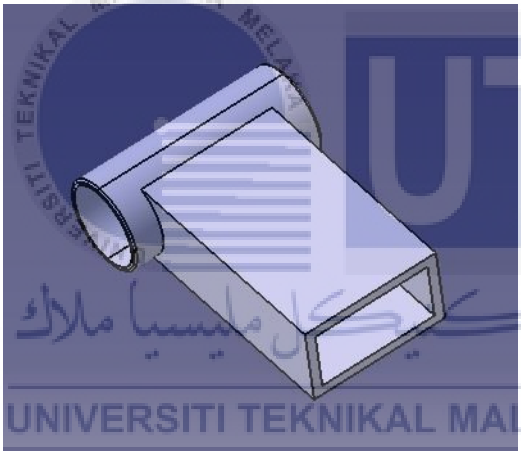
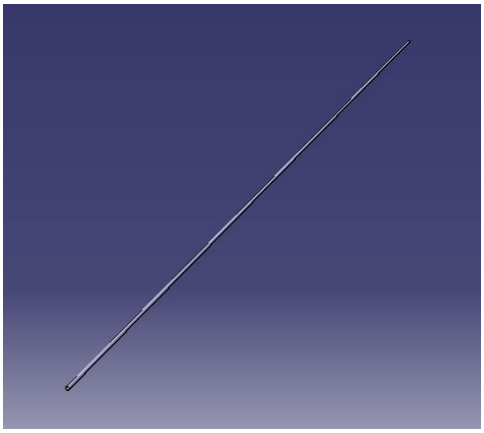


Fig. 4.3: Rendered image of the roller shutter (Back)

4.2.2 PARTS DRAWING

No	Figure	Name of Part	Description
1		Box Lid	Enclosed the entire structure and provide protection to the inner mechanical component

2		Water-film system	Parts where water hose will be connected and water-film is flowed to the slats.
3		Parametric bevel gear	Act as manual operating mechanism in case of electronic malfunction via chain hoist if installed.
4		Various rails	Provide support and extra security for the slats.

5		Slats	Act as an entryway and protection against outside entities.
6		Shaft holder and cable box	Holds shaft in its place that connects directly to cable box for neat cable management
7		Connecting rod	Connects all the slats together and further enforcing them.

4.3 PRODUCT FUNCTION DESCRIPTION

The roller shutter designed in this project is to focus on security and safety while also incorporating user friendly experience and low maintenance cost. This includes the manual door opening and closing is facilitated by the tension spring assembly which will keep the shutters in place. The tension spring assembly also reduces wear on the mechanical door and the operating technology. It can be moved with little force for user's convenience. A chain hoisted can be installed to the parametric bevel gear for further convenience.

The slats are designed in purpose of protecting from both sides and bottom is a step up in securing the slats from any damage from burglary instrument such as a crowbar. Besides the rails, the slat is aligned and enforced by another layer of metal sheets that act as the second layer of protection to the slats. The material of the slats will be chosen later according to the Von-Misses analysis which will determine the toughness of the materials.

Other main function of the roller shutter is the water based film system integrated with smoke detector to increase the heat resistance of the slats and reduce the metal temperature from as high as 500°C to as low as 100°C. The system is to make use of fireproof installations for the designated area to provide safety and protect goods.

4.4 REQUIREMENTS IN MATERIALS SELECTION

Every concept product has to go through material selection phase before proceeding to mass productions. It is vital to test which material is the most suitable to be assigned permanently as it affect strength, reliability, cost, and most importantly safety. Based on the data on previous analysis, the structure can withstand the applied force; a variety of material will first be chosen. Then the material will be compared based on sets of properties that portray the customers demand. The part that will undergo material selection is only the slats and rails because it the most critical part in the product, where the material used for the slats is the one that determines the strength and reliability of the product. All three materials meet the specs and will be further analysis for its characteristic using CES Software to get the best material possible. The materials are:-

- Aluminium
- Stainless Steel
- Galvanized Steel

All three materials are known to be a rust-free material, making it suitable for this project and meet one of the important points demanded by the customer. Based on study by Dr Girish (2010), aluminium ultimate tensile strength is enhance by the introduction of other materials in it such as TiO_2, while in another related study done by K. Raghuram (2015), that mentions, stainless steel is preferable in the field of defence and nuclear science due to its excellent corrosion resistance. Besides that, according to N. Coni (2009), steel is well suited for vast choices in engineering field and coated steel such as galvanised steel have help improve the one thing steel prone to which is oxidation. Based on these researches, all three materials are well suited for the project.

All materials will be compared by related general and mechanical properties, which are:-

4.4.1 TENSILE STRENGTH (MPa)

Tensile strength is the maximum force a material could withstand without breaking the material. This property is chosen because it is important to choose material with suitable tensile strength so the shutter could withstand the force that will be applied to the slats.

4.4.2 YIELD STRENGTH (MPa)

Yield strength is also known as yield point is the stage where a material will start to deform from its original shape and remain deformed. In this project, knowing such properties will help the process of choosing the material where material with low yield strength will reduce the effectively of the slats and also the rails.

4.4.3 YOUNG MODULUS

Also known as Modulus of Elasticity, it represents the properties of stiffness of a material. In this project, Young Modulus of material chosen will help to determine whether the shutter can elongates by how much when exposed to compaction force. Too elastic will affects the end product while too stiff will exposed the structure to fracture.

4.4.4 COEFICIENT OF THERMAL EXPANSION

The value of the linear thermal expansion in this study is referring to when an object is heated or cooled, its length change by an amount proportional to the original length and the change in temperature. Since the study of the roller shutter involve resistance to fire-based accident, this value is crucial in determining if the water-film system effectiveness.

4.4.5 PRICE (MYR)

One of the most important aspect in any engineering design project, price of material will greatly effects which material will be chosen. The ratio of price against other properties must be appropriately proportionate. Material with low price and average rating of properties is more suitable compare to material with high price and high rating of properties.

4.5 MATERIALS SPECIFICATIONS

The material chosen for this project must meet the customer's demand which mean the material used must be parallel to the requirements stated above. Therefore, the material chosen must have these requirements stated below:-

- Rust-free
- Can withstand at least 5kN of distributed force
- Has high melting point
- Affordable

4.6 MATERIALS SELECTION

Based on the specific requirements discussed in previous subchapter, the selected material is listed in the table below to be compared with each other based on their general properties. On the basis of this information, the results can be compared and evaluated against experience gathered and technical values.

	Aluminium, Wrought	Galvanised Steel.	Stainless Steel, Wrought
GENERAL PROPERTIES			
Price (MYR/kg)	7.85	2.1	7.33
MECHANICAL PROPERTIES			
Young's Modulus (Pa)	$7x10^{10}$	$2.07x10^{11}$	$1.97x10^{11}$
Tensile Strength (Pa)	$2.5x10^{8}$	$5.02x10^{8}$	$7.25x10^{8}$
Yield Strength (Pa)	$1.24x10^{8}$	$3.14x10^{8}$	$3.67x10^{8}$
Average Linear Temperature Expansion Coefficient $(m/m.K)$	23.0	12.0	17.3

Tab. 4.1: Properties of aluminium, galvanized steel and stainless steel

CHAPTER 5

PRODUCT ANALYSIS & DISCUSSION

5.1 INTRODUCTION

Product analysis is one of the most vital parts in any manufacturing process. It is to detect the aftermath such as deformation and breaking points. In this particular study, the product analysis is divided into two parts which is the structural analysis and temperature field analysis. It would help in better understanding the reaction of the product if put into certain simulations.

5.2 MATERIAL PROPERTIES COMPARISON

In order to compare the material properties such as tensile strength, yield strength, Young's modulus and price, CES EduPack software is used to put the properties from the chosen materials into a data representation of a graph. This software will compare the properties of the three proposed materials which is aluminium, galvanized steel and stainless steel that will help determine the suitable material to be used in later analysis.

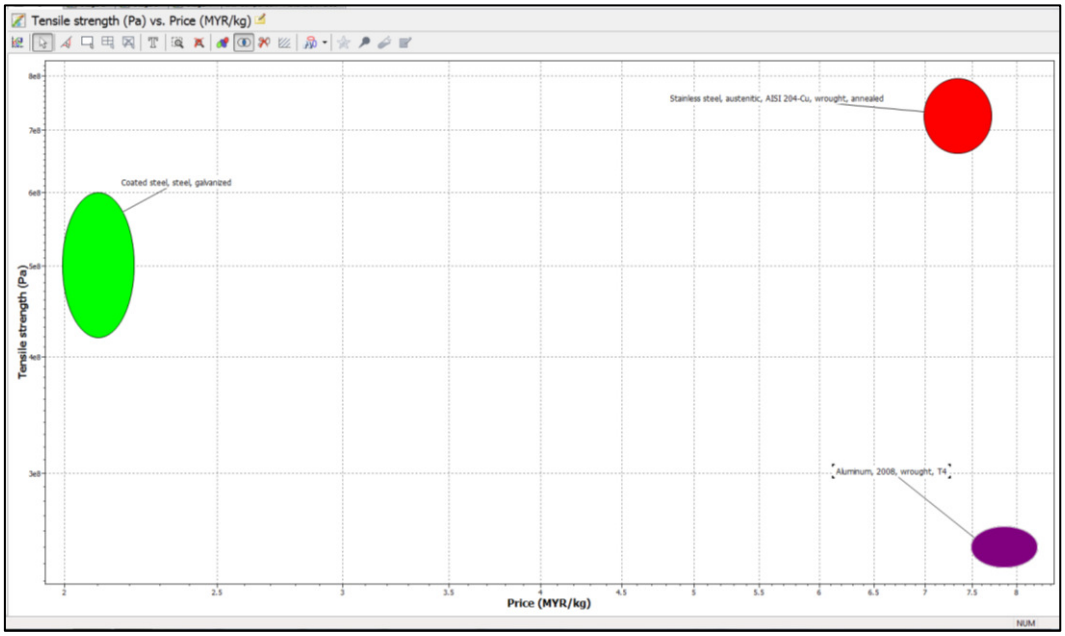


Fig. 5.1: Graph of Tensile Strength (Pa) against Price (MYR/kg)

Based on the result obtained by CES EduPack software, stainless steel (red) has the highest tensile strength compared to the other two metals. Galvanized steel (green) comes second and aluminium (purple) lowest tensile strength in the graph. As for price range, both aluminium and stainless steel is considered expensive despite aluminium having lowest tensile strength. Galvanized steel is the cheapest and have a high tensile strength.

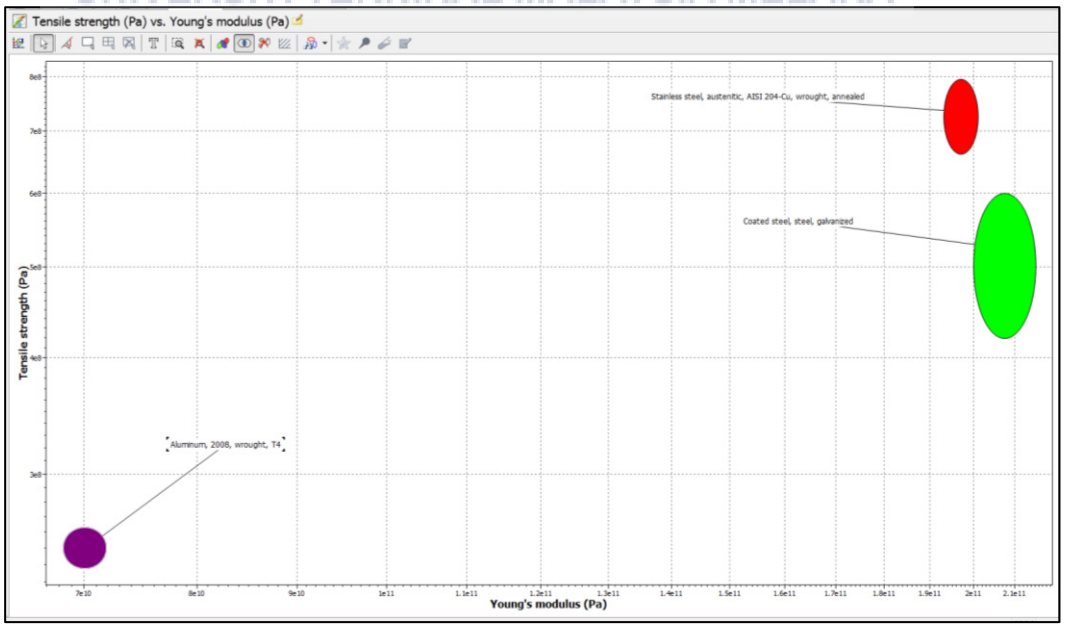


Fig. 5.2: Graph of Tensile Strength (Pa) against Young's modulus (Pa)

According to Figure 5.2, stainless steel dominated among the three materials in the overall graph of tensile strength against Young's modulus while aluminum has the lowest rating. However, galvanized steel has a slightly higher Young's modulus in comparison to stainless steel.

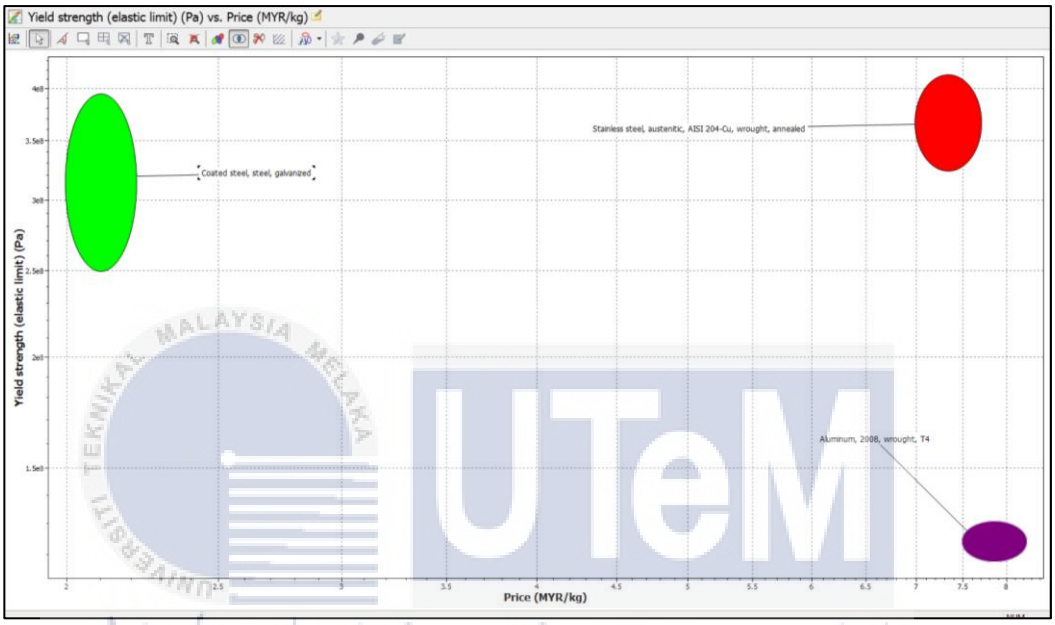


Fig. 5.3: Graph of Yield Strength against Price (MYR/kg)

In this graph, it shows that yield strength for galvanized steel and stainless steel is around the same. But in the comparison to the price range, there are significant differences between galvanized steel versus both stainless steel and aluminium making it the cheapest among those three materials.

5.3 FINAL MATERIAL SELECTION

After considering all three graphs, the material selected to be proceed to the analysis process is galvanized steel mainly due to its relatively low cost compared to stainless steel and aluminium. Although stainless steel has shown better results in

tensile strength, Young's modulus and yield strength against galvanized steel, the differences is not that significant.

5.4 STRUCTURAL ANALYSIS

The selected material for purpose of analysis of the study was predetermined in previous chapter that have been discussed at length. Steel was to be chosen into the CATIA software as the 'apply material' that would later be analyzed. The amount of force used as distributed force in the software is 17139N which is an average sized car weighing 1234kg (Proton Waja, 2000) would exert moving at 60 km/h from the distance of 10 meters. This situation is created in order to simulate a speeding car crashing the roller shutter to observe the reaction of the slats towards the incoming force.

The force of impact can be calculated using the formula as shown below:

$$F_{avg}d = -\frac{1}{2}mv^2$$

Where:

F_{avg} = Average force of impact(N)

d = $Distance\ (m)$

d = $Mass\ (kg)$

v = $Velocity\ (m/s)$

The results of the structural analysis are as shown below:

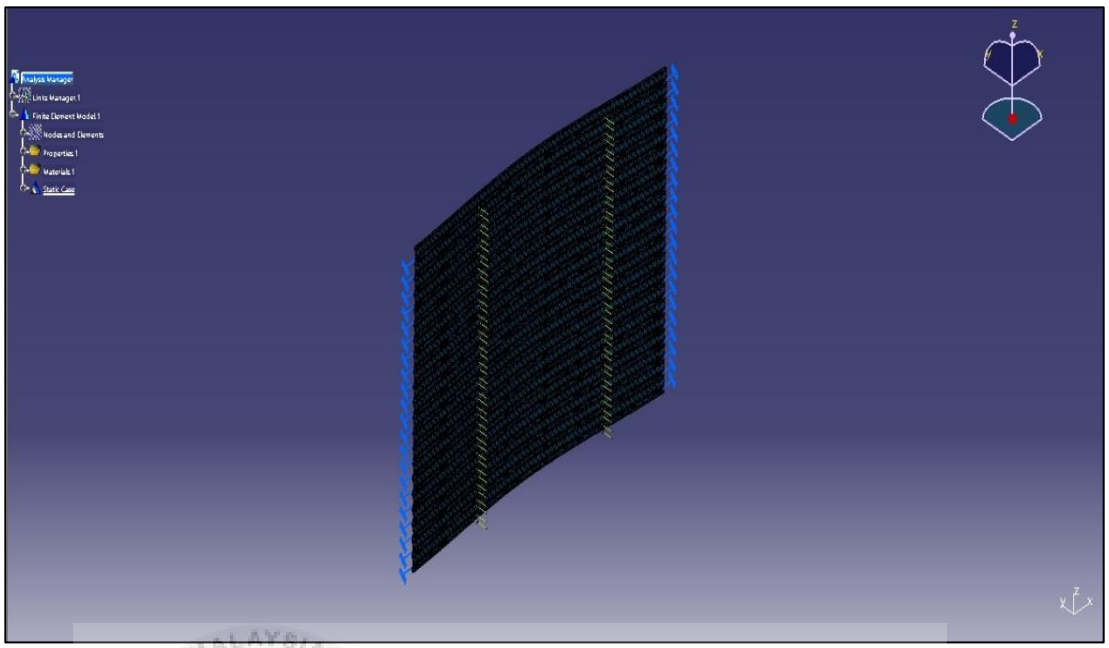


Fig. 5.4: Deformation on the surface of the slat when force is applied

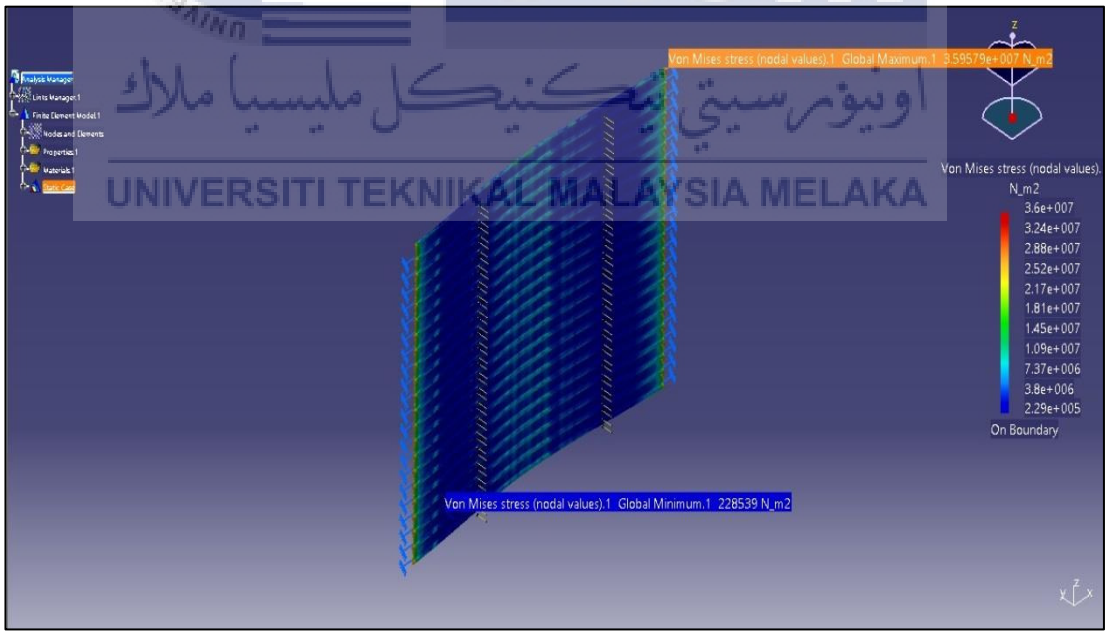


Fig. 5.5: Representation of Von Mises Stress on the shutter

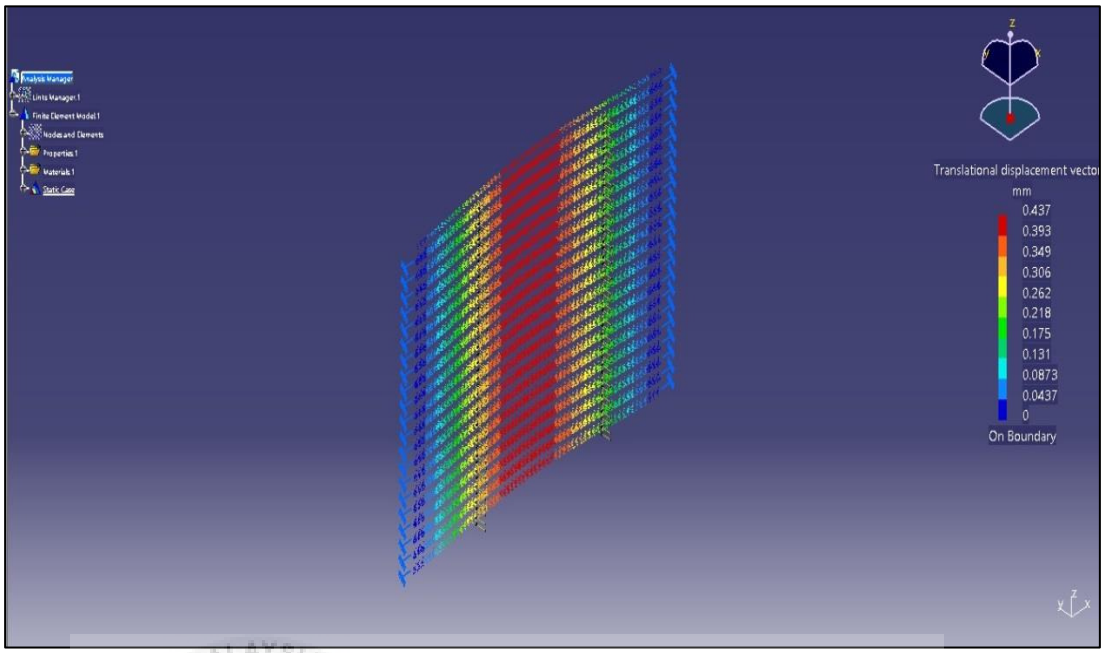


Fig. 5.6: Resultant translational displacement vector on the shutter

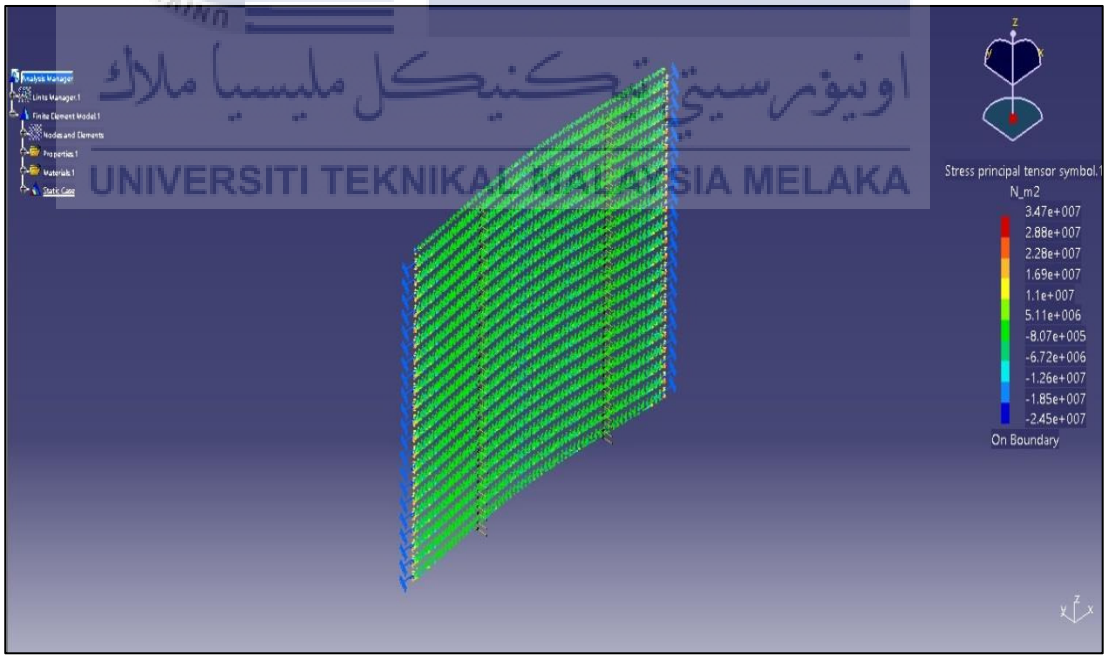


Fig. 5.7: Stress principal tensor acting on the shutter

5.4.1 STRUCTURAL ANALYSIS DISCUSSION

The shutter which composed of 21 slats connected to each other act as the means of opening and also a protection for either commercialized or industrial buildings. Due to its function, most of the force that would be applied by the simulation is received by the shutter. The result of this structural analysis will shows the deformation that happens when force is applied, the amount of size displace when force is applied, the points that receives the most and least stress and also shows the distribution of stress of force applied.

On top of that, the design durability can be seen in Figure 5.2, where it can be summarized that the design will be able to sustain the applied force while taking minimum damage against a massive force of 17,139N. The highest data on the Von Mises Stress analysis is 36,000 kPa, marked with red colour while the lowest is 229 kPa, represented by blue colour. Figure 6.6 also shows the area that is most prone to failure which is the red in colour area. Furthermore, based on Figure 5.3, the highest displacement occurs on the body is 0.437 mm, which is at the middle of the shutter. Lastly, at Figure 5.4, the highest principal stress that occurs on the body is 34,700 kPa, but the structure can contains such stress due to the stress being well distributed as shown in the figure.

5.5 THERMAL ANALYSIS

Since a water-film system is incorporated as a part of the safety action that would operate in case of fire-related accidents, the shutter needs to be tested on extreme temperature. In the study of roller shutter by S. K. Lee in 2013, the shutter's surface were exposed to 600°C (873K) to observe the impact of water-film system in reducing the heat at its surface. The result of the study can be referred in Figure 2.17. Therefore in this thermal analysis, the main focus is on how temperature at 100°C and 600°C affect the structure of the shutter. Below were the results obtained from conducted simulation using Temperature Field function in CATIA.

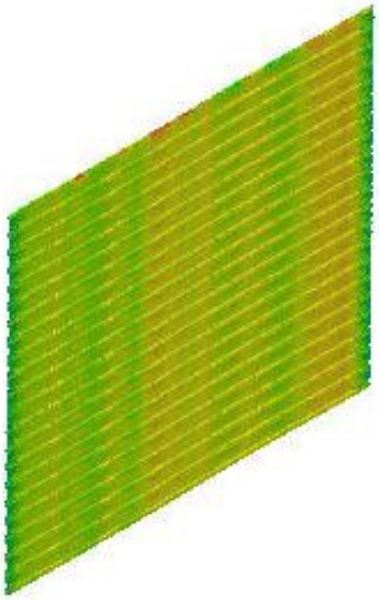


Fig. 5.8: Structure of shutter at the temperature of 100℃

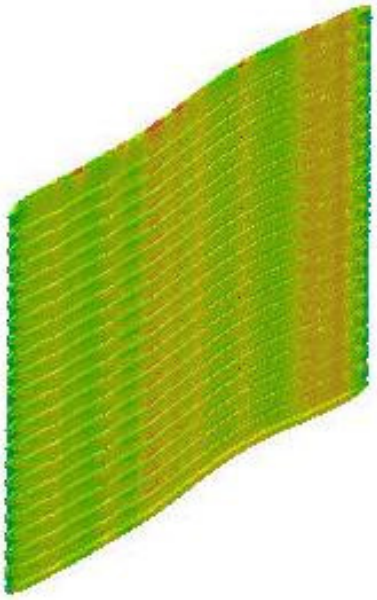


Fig. 5.9: Structure of shutter at the temperature of 600℃

5.3.1 THERMAL ANALYSIS DISCUSSION

Based on the results obtained, the temperature difference has a significant influence towards the structure of the shutter. The immense heat (at temperature of 600℃) will force the metal to undergo thermal expansion thus will bend it out of shape while at the temperature of 100℃, the metal can still maintain its normal shape.

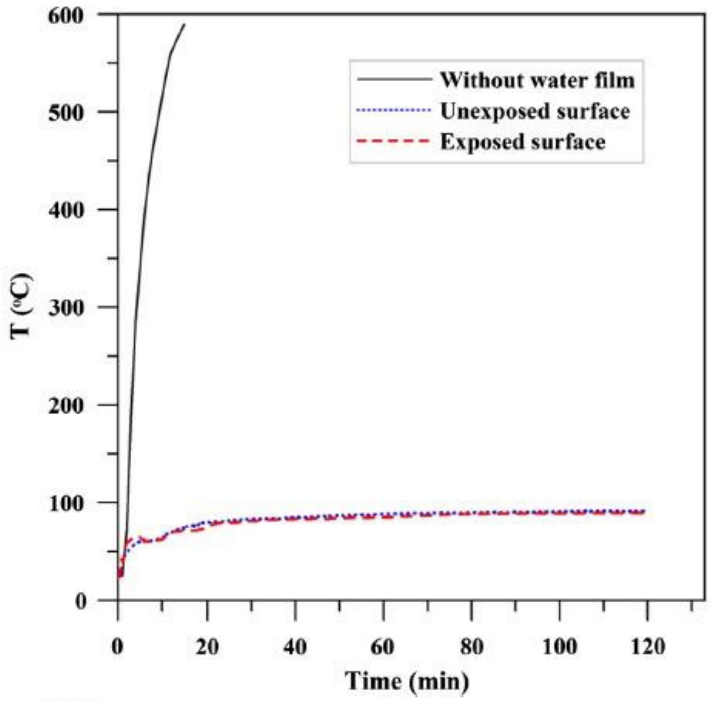


Fig. 5.10: Comparison of shutter slat temperature (S. K. Lee, 2013)

According to graph developed by S.K. Lee in his journal, the water film can greatly reduce the surface temperature of the slats and can prevent it from deformation caused by extensive heating. Therefore the installation of water-film into the roller shutter design will prove to be a wise choice. A great amount of thermal radiation transmission also can be reduced and preventing from the fire to ignite nearby flammable object inside the building or high-degree burn to occupant due to prolonged heating.

CHAPTER 6

CONCLUSION & RECOMMENDATION

6.1 INTRODUCTION

Based on the results of analysis in previous chapter, conclusion and recommendation is drawn. This part will discuss about the advantages and some recommendation that might be able to improve the roller shutter with further study on this matter.

6.2 CONCLUSION

As was mentioned in the beginning of this study, the main objective is to design a conceptual door security system using Computer Aided Design (CAD) software; to analyze the designed product using several analysis methods and to identify the most suitable material for the roller shutter using CES EduPack Software. All of the objectives are achieved as shown in the previous chapters.

The idea of testing the roller shutter is to provide better securities against either unwanted crimes or unwanted incidents. Properties such as temperature and force will result in significant difference in real life application. Therefore, these two attributes were tested in certain theoretical conditions to observe the results. A well-chosen material in this case, galvanized steel will help to increase strength and reliability of the shutter if a large force is applied to it. Meanwhile the water-film system will help prevent deformation that may form if the shutter is ever exposed to fire.

Lastly, this study is also a way to stress the importance of safety and security towards human life, infrastructures and the properties especially in the industrial sector. Hopefully this study could help scale down the break-in substantially against

any act of thievery or further damages that might occur to the properties and building's infrastructures from unwanted incident.

6.3 RECOMMENDATION

For this project, there are a few recommendations that could help initiates further studies. These recommendations are sparked during the ongoing process of the study and cannot be done during this project due to time and resource limitation.

I. Since the software CATIA only have limited type of material in analysis tools, it is difficult to analyse any new composite metal that might be available in the current market. The material of the structure and shutter can further be improved by analysing other newly developed materials that is deemed suitable.

II. Other security features such as biometric recognitions, real-time burglary notifications and others can be applied into the system of the roller shutter. Each feature will drastically improve the level of security to the roller shutter against any threats and accidents.

REFERENCES

1. Arudino Uno Rev3. (2016). Retrieved from Arduino Store USA, https://store-usa.arduino.cc/products/a000066

2. Cobra 610 Insulated Sectional Overhead Door. (2016). Retrieved from HVPShutters, http://www.hvpshutters.co.uk/sectional-overhead-door.php

3. N. Coni, M.L Gipiela, A.S.C.M. D'Oliviera, P.V.P Marcondes, Study of the mechanical properties of the hot dip galvanised steel and galvalume, Journal of the Brazilian Society of Mechanical Sciences and Engineering, Vol 31,2009

4. CPNI (2013). Guide To Security Doorsets And Associated Locking Hardware. Centre for the Protection of National Infrastructure. Retrieved from CPNI, http://www.cpni.gov.uk/documents/publications/2013/2013012-security_doorsets_locking_hardware.pdf

5. Door Frame Terminology Diagram. (2015, May 21). Retrieved from DoorFrameOtri Blog, http://doorframeotri.blogspot.my/2015/05/door-frame-terminology-diagram.html

6. E. G. Bakhoum (2012). High-Sensitivity Miniature Smoke Detector. IEEE Sensors Journal, Vol. 12(No. 10)

7. Fingerprints. (2001). Retrieved from Behind The Crime, https://behindthecrime.wordpress.com/about/fingerprints/

8. IComSat GSM. (2016). Retrieved from RobotShop, http://www.robotshop.com/en/icomsat-gsm-gprs-shield-arduino-compatible.html

9. Industrial Doors for All Types of Businesses and Buildings. (2016). Retrieved from Wessex Industrial Door, http://www.wessexindustrialdoors.com/industrial-doors

10. J. Breithaupt (2014). Information Security Principles and Practices (2nd Ed.). Pearson

11. K.D. Raghuram, K.N Hansoge, B. Aditya, G.K. Amit, S.K. Swadesh, (2015), Mechanical Properties of Austenitic Stainless Steel 604L and 316L at elevated temperature, Journal of Material Research and Technology, Vol5, Issue 1, 2016, pg 13-20.

12. Max-Guard Storefront Security Gates. (2015). Retrieved from AC Folding Gates, http://www.acfoldinggates.com/html/max-guard_security_gates.html

13. M. S. M. Effendi, Z. Shayfull, M. S. Saad, S. M. Nasir, & A. H. Badrul Azmi (2016). A New Invention of Alarm Reminder Locking (ARL) Security System. International Journal of Engineering and Technology (IJET)

14. N. Manivannan, C. Tigli, A. Noor, & S. Memon (2011). Fingerprint Biometric for Identity Management. International Journal of Industrial Engineering and Management (IJIEM), Vol. 2(No. 2)

15. Pope, A. R. (1853). U.S. Patent No. 9802. Washington, DC: U.S. Patent and Trademark Office.

16. S. A. Bakar. (2015, July 14). Elak Jadi Mangsa Pecah Rumah. Retrieved from Utusan Online, http://www.utusan.com.my/berita/wilayah/elak-jadi-mangsa-pecah-rumah-1.113750/penjenayah-sentiasa-mencari-peluang-semasa-cuti-perayaan-untuk-melakukan-jenayah-pecah-rumah-semasa-1.113774

17. S. K. Lee, M. C. Ho, J. J. Chen, C. Y. Lin, & T. H Lin (2013). Fire Resistance Evaluation of a Steel Roller Shutter with Water-film Cooling System. Applied Thermal Engineering

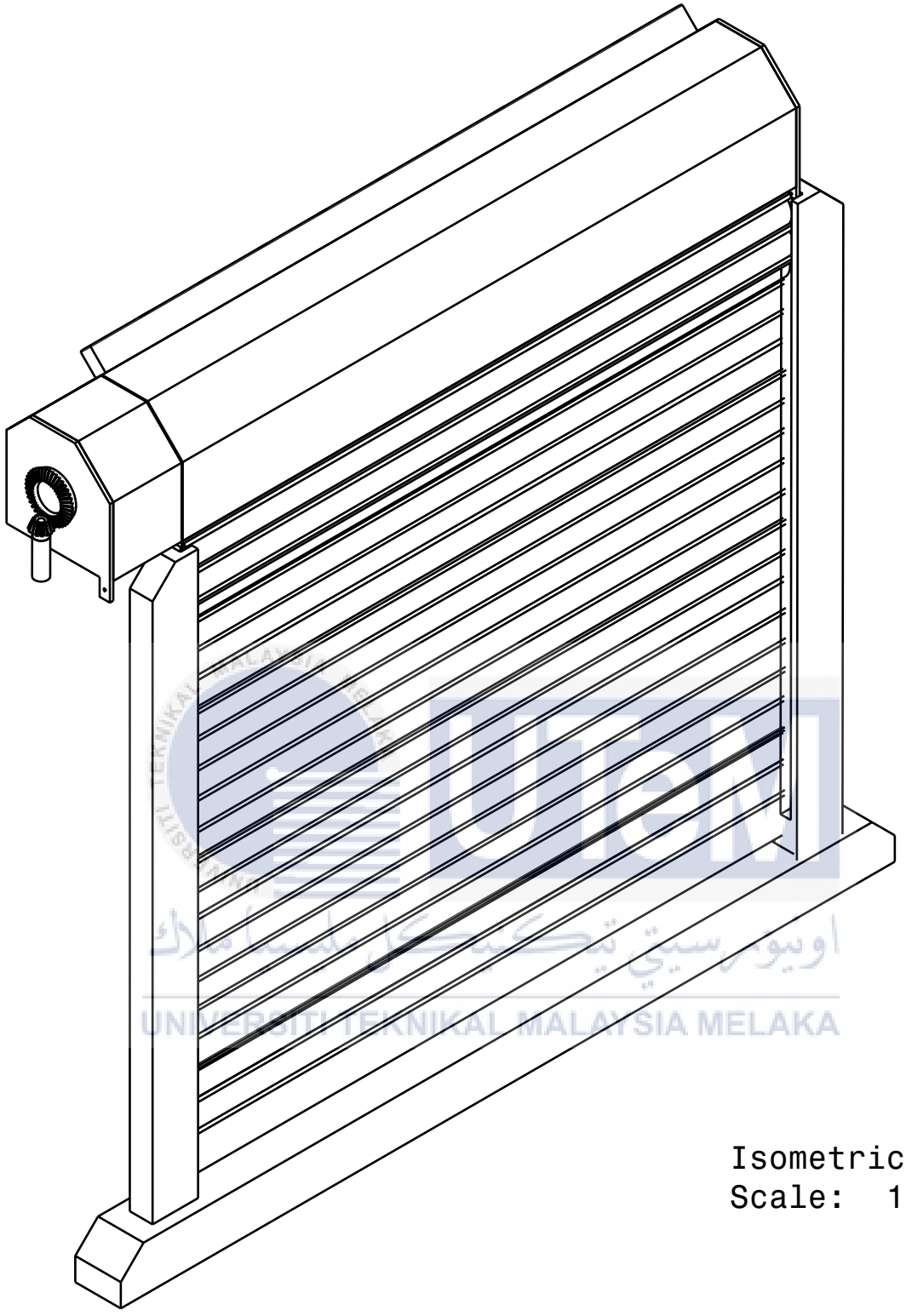
18. S. Pugh (1988). Total Design: Towards a Theory of Total Design (First ed.)

19. Type of Doors. (2014, June 12). Retrieved from Civil Engineering, http://www.civilengineeringx.com/construction/types-of-doors/

20. Y. Akao (1990). Quality Function Deployment: Integrating Customer Requirements into Product Design (First ed.)

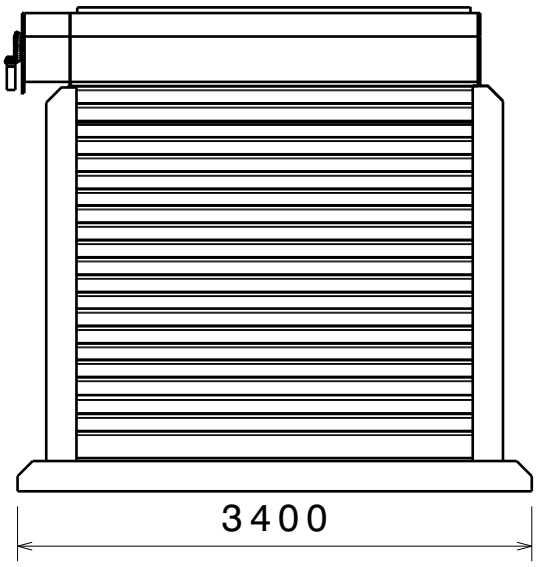
APPENDICES

1. Isometric View of Roller Shutter in Draft Drawing
2. Front View, Top View and Side View of Roller Shutter in Draft Drawing

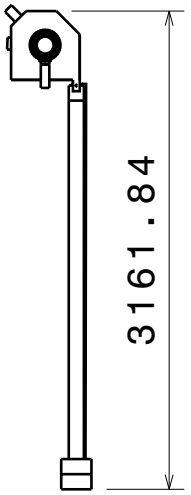


Isometric view
Scale: 1:20

DESIGNED BY: Muhammad Syamil DATE: 03/05/2017	Roller Shutter		I _
CHECKED BY: XXX DATE: XXX			H _
			G _
			F _
SIZE A4	DASSAULT SYSTEMES		E _
			D _
			C _
SCALE 1:20 / WEIGHT (kg) XXX / DRAWING		SHEET 1/2	B _
This drawing is our property; it can't be			A _



Front view
Scale: 1:50



Left view
Scale: 1:50

Top view
Scale: 1:50

DESIGNED BY: Muhammad Syamil DATE: 03/05/2017	Roller Shutter		
CHECKED BY: XXX DATE: XXX			
SIZE A4	DASSAULT SYSTEMES		
SCALE 1:50	WEIGHT (kg) XXX	DRAWING	SHEET 2/2
This drawing is our property; it can't be			

I	_
H	_
G	_
F	_
E	_
D	_
C	_
B	_
A	_