



**Faculty of Manufacturing Engineering**

**DESIGN AND ANALYSIS OF AUTO SECURITY DOOR  
LOCKING SYSTEM**

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**Master of Science in Manufacturing Engineering**

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**DESIGN AND ANALYSIS OF AUTO SECURITY DOOR  
LOCKING SYSTEM**

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**A thesis submitted  
in fulfilment of the requirements for the degree of Master of Science  
in Manufacturing Engineering**

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## DECLARATION

I declare that this thesis entitled "Design and Analysis of Auto Security Door Locking System " is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : ..... Lim Si Qing .....

Date : .....

## APPROVAL

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

Signature : .....

Supervisor Name : Prof. Ir. Dr. Sivarao Subramonian  
.....

Date : .....

## **DEDICATION**

I dedicate my thesis to my kin and acquaintances. A peculiar feeling of gratitude for my beloved family, whose words of encouragement and a push for tenacity is ringing in my ears. I dedicate this work and convey my special thanks to my respective lecturers and supervisor for the knowledge and guidance given. I also dedicate this thesis to my friends for being there with me throughout the entire postgraduate program.

## ABSTRACT

Mortise locks are generally used for exterior doors due to its high durability in sustaining the security level of house access systems. This type of door lock systems have been implemented on all kinds of houses for more than 70 years. However, the mechanical principle of present mortise locks have remained the same, even though they differ slightly in terms of their exterior that caters to the design of security doors. The mortise principle of this type of lock requires a definite key to lock and unlock the security door. One main drawback of the existing security door lock is that, it is almost impossible to instantly lock the door by inserting the key exactly into the hole of the lock especially during times of emergency. This is the reason why recent burglary reports claim that there is no evidence of breaking-in but the house owner is robbed. Burglary is a crime where unlawful enter a resistanceless house or building through several entrances such as door or window. Burglary may not always happened through the door, yet the percentage of forced entry through housing doors is very high. In addition, this will not only lead to the threat for valuable items, but also to human life. The weak security protection of conventional mortise locks literally renders the premise defenceless against burglaries. The call to enhance functionality of security door locks is imminent. Thus, this present study is undertaken to overcome the drawback stated above by devising and developing an innovative idea of security door locking system. The features of security door locking system included does not require a key or electricity to lock the door, cannot unlock the door without the key and can lock the door instantly. Analytic Hierarchy Process (AHP) decision making tool as well as multi-aspect Quality Function Development (QFD) method are utilised during the stages of design and operational screening. Moreover, sensitivity analysis also had implemented in this study and justified that Concept 1 is the most appropriate design concept of security door locking system compared with another two concepts. The fabricated prototype had go through the simulation and analysis process for performance evaluation and validation. Consequently, the Auto Security Door Locking Syatem (ASD-Lock) will be proposed to attract manufacturers as this solution has high potentials in overcoming the drawbacks of the current mortise locks.

## ABSTRAK

*Kunci tanggam biasanya dipasang pada pintu pagar kerana ia mempunyai ciri ketahanan yang tinggi bagi memastikan tahap keselamatan sistem akses rumah. Jenis kunci pintu ini mencatatkan penggunaan selama lebih daripada 70 tahun. Walau bagaimanapun, prinsip mekanikal kunci tanggam ini tidak melalui pengubahsuaian, walaupun rekabentuk fizikalnya disesuaikan dengan reka bentuk pintu keselamatan. Prinsip tanggam jenis ini sentiasa memerlukan kunci utama untuk mengunci dan membuka. Kelemahan kunci pintu keselamatan ini adalah, kesukaran untuk mengunci pintu dengan segera terutamanya berada dalam masa kecemasan. Laporan pecah rumah baru-baru ini tidak mencatatkan bukti kukuh tentang rumah yang telah dipecah masuk sedangkan rompakan telah berlaku. Pecah masuk adalah salah satu jenayah yang melanggar undang-undang untuk memasuki rumah tangga atau bangunan yang kurang rintangan melalui pintu masuk atau tingkap. Walaupun pecah masuk tidak selalu berlaku melalui pintu, tetapi kebarangkalian pecah masuk melalui pintu perumahan adalah sangat tinggi. Ini bukan sahaja akan membawa kepada kehilangan barang-barang berharga, tetapi membawa bahaya kepada kehidupan manusia. Kes kecurian tidak dapat dikurangkan kerana secara literal didapati bahawa kunci tanggam konvensional tidak menjamin keselamatan. Dengan itu, kajian ini dijalankan untuk mengatasi kelemahan yang dinyatakan di atas dengan merekacipta idea inovatif untuk mengubahsuaikan sistem kunci pintu. Ciri-ciri sistem kunci pintu tanggam ini termasuk tidak memerlukan kunci atau elektrik semasa mengunci pintu, tidak boleh membuka pintu tanpa kunci dan boleh mengunci pintu dengan serta-merta. Analytic Hierarchy Process (AHP) dengan Pembangunan Fungsi Kualiti (QFD) adalah kaedah yang digunakan pada peringkat reka bentuk dan pemeriksaan operasi. Selain itu, analisis sensitiviti juga dijalankan dalam kajian ini dan membuktikan bahawa Concept 1 adalah konsep reka bentuk yang paling sesuai untuk sistem kunci pintu tanggam berbanding dengan dua konsep lain. Prototaip telah direka melalui simulasi dan analisis proses untuk penilaian prestasi dan pengesahan. Oleh itu, Auto Security Door Locking System (ASD-Lock) dicadangkan kepada pengeluar sebagai penyelesaian untuk mengatasi kelemahan kunci tanggam yang sedia ada pada masa kini.*

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## TABLE OF CONTENTS

	<b>PAGE</b>
<b>DECLARATION</b>	
<b>APPROVAL</b>	
<b>DEDICATION</b>	
<b>ABSTRACT</b>	<b>i</b>
<b>ABSTRAK</b>	<b>ii</b>
<b>ACKNOWLEDGEMENTS</b>	<b>iii</b>
<b>TABLE OF CONTENTS</b>	<b>iv</b>
<b>LIST OF TABLES</b>	<b>vi</b>
<b>LIST OF FIGURES</b>	<b>vii</b>
<b>LIST OF APPENDICES</b>	<b>x</b>
<b>LIST OF ABBREVIATIONS</b>	<b>xi</b>
<b>LIST OF PUBLICATIONS</b>	<b>xiii</b>
<b>CHAPTER</b>	
<b>1. INTRODUCTION</b>	<b>1</b>
1.1 Background	1
1.2 Problem Statement	2
1.3 Objectives	4
1.4 Scope of Study	4
1.5 Significance of The Study	5
1.6 Summary	5
<b>2. LITERATURE REVIEW</b>	<b>6</b>
2.1 Physical Barriers	6
2.2 Types of Door Locks	8
2.3 Reasons that Induced Cases of Burglaries	13
2.4 Weaknesses of Mortise Lock	16
2.5 Cylindrical Lock Mechanism	19
2.6 Standards and Essential Features	21
2.7 Potential Use of ASD-Lock	25
2.8 Design and Analysis Methods	27
2.9 Summary	29
<b>3. METHODOLOGY</b>	<b>30</b>
3.1 Introduction	30
3.2 Project Planning	30
3.3 Project Flow Chart	32
3.3.1 Ideation and Concept	33
3.3.1.1 Design Consideration	34
3.3.1.2 Customer Requirement Evaluation	38
3.3.1.3 Improvement Strategies	43
3.3.1.4 Concept Generation	44
3.3.2 Concept Selection	53
3.3.3 Detailed Design	54
3.3.4 Finite Element Analysis	55

3.3.5	Prototyping	56
3.3.6	Performance Evaluation and Validation	58
<b>4.</b>	<b>RESULTS AND DISCUSSION</b>	<b>60</b>
4.1	Design Considerations for Customers	60
4.2	Improvement Strategy Identification	63
4.3	Concept Evaluation and Selection	68
4.4	Sensitivity Analysis	70
4.5	Final Design Detail Description	75
4.5.1	Handle-Carrying Spindle	78
4.5.2	Key Spindle Assemble	80
4.5.3	Driver Bar	81
4.5.4	Push Button Stem	82
4.6	Stress Analysis	83
4.7	Cost Analysis	89
4.8	Functionality Validation	92
4.9	Market Competitiveness Analysis	95
<b>5.</b>	<b>CONCLUSION AND RECOMMENDATIONS</b>	<b>98</b>
5.1	Conclusion	98
5.2	Avenues for Future Research	100
	<b>REFERENCES</b>	<b>101</b>
	<b>APPENDICES</b>	<b>114</b>

## LIST OF TABLES

<b>TABLE</b>	<b>TITLE</b>	<b>PAGE</b>
1.1	Performance of conventional door locksets	3
2.1	Burglaries entry method in year 1998 until 2000	14
3.1	Scale ranges of $a_{ij}$ values	39
3.2	Table of random index ( $RI$ )	41
3.3	Pros and cons of each concept	52
4.1	Global weights for each design consideration (manual calculation)	62
4.2	Results obtained by simulating four scenarios	74
4.3	Comparison between initial parts and modified parts	91
4.4	Market competitiveness between mortise lock and ASD-Lock	96

## LIST OF FIGURES

<b>FIGURE</b>	<b>TITLE</b>	<b>PAGE</b>
2.1	Types of security door	7
2.2	The earliest time key and lock	8
2.3	(a) Chain lock (b) Gap latch	9
2.4	Common architecture of mortise lock	10
2.5	General features of rim-mounted lock	11
2.6	General features of tubular lock	11
2.7	General features of cylindrical lock	12
2.8	General features of unit lock	12
2.9	Overall look of mortise lock	16
2.10	Types of mortise lock	18
2.11	The overview of cylindrical lock	20
2.12	Latch bolt with anti-shim device	22
2.13	Long-throw deadbolt	23
3.1	Flow chart of seven steps product design	32
3.2	Hierarchy structure for customer requirements	42
3.3	Four interlinked phases in QFD	44
3.4	Front view of cylindrical lock	45
3.5	Isomatic view of cylindrical lock	45

3.6	Concept 1	47
3.7	Concept 2	49
3.8	Concept 3	51
3.9	Hierarchy structure for ASD-Lock concept selection	54
3.10	Front view and side view of ASD-Lock	57
3.11	Locking time experiment setup	58
4.1	Comparative matrix for four customer requirements criteria	60
4.2	Priority ranking for four main criteria	61
4.3	Global weights for each design consideration	61
4.4	Product requirements planning – phase I	64
4.5	Improvement strategies planning – phase II	66
4.6	Standard of security by design planning – phase III	67
4.7	Comparative matrix for four selection criteria	69
4.8	Priority ranking for four main criteria	69
4.9	Overall score for concepts	70
4.10	Sensitivity graphs of the main criteria – the goal	71
4.11	Sensitivity graphs of the main criteria – cost	72
4.12	Sensitivity graphs of the main criteria – quality	73
4.13	Sensitivity graphs of the main criteria – performance	73
4.14	Sensitivity graphs of the main criteria – manufacturability	74
4.15	Final design of the ASD-Lock	76
4.16	Detailed view of the modified parts	77
4.17	Detailed drawing – handle-carrying spindle	79

4.18	Detailed drawing – key spindle assemble	80
4.19	Detailed drawing – driver bar	81
4.20	Detailed drawing – push button stem	82
4.21	Stress distribution – push button stem	84
4.22	Factor of safety – push button stem	84
4.23	Stress distribution – driver bar	85
4.24	Factor of safety – driver bar	86
4.25	Stress distribution – handle-carrying spindle	87
4.26	Factor of safety – handle-carrying spindle	87
4.27	Stress distribution – key spindle assemble	88
4.28	Factor of safety – key spindle assemble	88
4.29	Comparison cost between initial parts and modified parts	90
4.30	ASD-Lock – locked	93
4.31	ASD-Lock – unlocked	94
4.32	Locking response for mortise lock and ASD-Lock	95
4.33	Price range for metals in CES EduPack	97

## LIST OF APPENDICES

<b>APPENDIX</b>	<b>TITLE</b>	<b>PAGE</b>
A	Project activity gantt chart	113
B	Cost – the relative preference and priorities	115
C	Quality – the relative preference and priorities	117
D	Security – the relative preference and priorities	119
E	Eco-friendly – the relative preference and priorities	121
F	Sub-criteria – the relative preference and priorities	123
G	Cost analysis – handle-carrying spindle (original)	125
H	Cost analysis – handle-carrying spindle (modified)	126
I	Cost analysis – key spindle assemble (original)	127
J	Cost analysis – key spindle assemble (modified)	128
K	Cost analysis – driver bar (original)	129
L	Cost analysis – driver bar (modified)	130
M	Cost analysis – push button stem (original)	131
N	Cost analysis – push button stem (modified)	132
O	Questionnaire	133

## LIST OF ABBREVIATIONS

$a_{ij}$	-	Assessment values
AC	-	Alternating Current
ACPO	-	Association of Chief Police Officers
AHP	-	Analytic Hierarchy Process
ANSI	-	American National Standards Institute
ASD-Lock	-	Auto Security Door Locking
BC	-	Before Christ
CAD	-	Computer-aided Design
CAE	-	Computer-aided Engineering
CI	-	Consistency Index
CR	-	Consistency Ratio
DC	-	Direct Current
FEM	-	Finite Element Method
HoQ	-	House of Quality
MPa	-	Mega Pascal
$n$	-	Number
$PV$	-	Priority vector
QFD	-	Quality Function Deployment
$RI$	-	Random Index



Rw	-	Relative weight
SBD	-	Secured by Design
UK	-	United Kingdom
$\lambda_{\max}$	-	Maximum Eigen value

## LIST OF PUBLICATIONS

### Published:

AHP Based Decision-Making in Concept Selection of Keyless Grill Locking System (2014). *International Journal of Mechanical & Mechatronics Engineering IJMME / IJENS*, ISSN: 2077-124X (Online) 2227-2771 (Print).

### Submitted:

Innovative Design Development of Keyless Locking Mechanism for Security Door, *International Conference on Knowledge Transfer (ICKT'15)*, 1<sup>st</sup> – 3<sup>rd</sup> December 2015.

AHP-QFD-SBD Incorporated Framework for Improvement Strategies on Security Door Lock. Submitted to: *Journal of Mechanical Science and Technology*.

# CHAPTER 1

## INTRODUCTION

### 1.1 Background

Security door locks that are available in the market have remained largely similar in terms of the locking mechanism despite some variance of the design. Mass production of door locks for decades reveal that most of the lock designs are largely similar. The existing design of the security door lock employing mortise principle requires a definite key to be inserted while locking and unlocking it. A major drawback of this lock design in comparison to its counterpart, the cylindrical lock is that it cannot be used instantly at times of emergency.

National Crime Victimization Survey (NCVS) claim that burglary is categorised as crime of property (NCVS, 2014). According to Jorgustin (2014), it is surprising to discover that 80% of the burglary cases happened through the front door, window, and the back door due to weak door locking system implementation. Catalano (2010) found that from 2003 to 2007, an estimated of 3.7 million household burglaries occurred each year. 28% of all household burglaries, a member of the household was present at home and 7% of them had experience some form of violent victimization. Recent crime statistics reveal that more females fall victim to robbery because they are overpowered by the assailants before they could engage the mortise lock with their key. Besides that, HomeServe (2016) claims that the typical lock problems which users typically faced are, keys getting stuck , hard to turn, key turn but does not work, key won't go in lock, and latch stuck. It is not possible for

anyone, no matter how alert they are, to be able to respond to the situation promptly by locking the door with their key. This is serious as not only the property of the victim is subject to loss, but personally the integrity of the victim is at threat.

In order to overcome the abovementioned drawback, it is necessary to adopt a thorough selection process by screening through various designs and ideas to arrive at the most effective solution. The Auto Security Door Locking System (ASD-Lock) which solves the shortcoming of the existing mortise locking principle has a great potential to be highly commercialised in the market due to its security features.


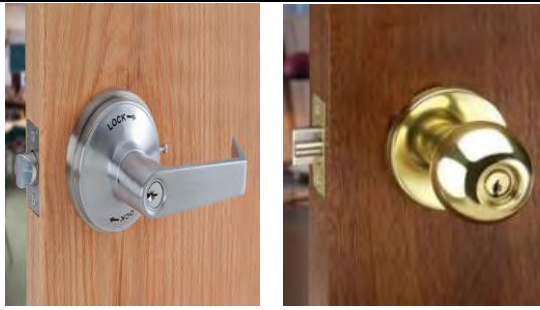
## **1.2 Problem Statement**

The aim of the security door locking system is to prevent unwanted access into a building through built doors. The conventional key-based mortise lock in the market is inadequate in securing safety of human life and tangible property. Thus, there is a dire need for major improvement especially in its performance aspect in terms of locking speed and security protection.

The existing mortise security door lock requires a specific key to lock and unlock the door. It is not possible to arm the locking mechanism without a key, thus it is unsuitable to safeguard a person against intruders in emergency situations. On top of that, the frequent use of the key to lock and unlock will cause it to wear-off and leads to key breakage due to metal fatigue. This would also result in the need to duplicate the key. According to LockRite (2016), the national locksmith company found that the common houses' door lock problems are warping, broken key, key stuck in lock, difficulty to turn the key, and faulty lock. Due to the extra step of using the key to lock and unlock the door, some users would prefer not to lock the security door, rendering them exposed to burglary

either day or night. Cylindrical lock on the other hand has outperformed mortise lock as it is more easy to use whereby it can be locked instantly by simply pressing the push-lock button. However the cylindrical lock is not suitable to be installed on the security door as it can also be easily unlocked by simply twisting the door knob or lever. As shown in Table 1.1, the pros and cons of conventional mortise lock and cylindrical lock are listed.

Table 1.1: Performance of Conventional Door Locksets (Guida Inc., 2016)

Conventional Mortise Lock	Conventional Cylindrical Lock
	
<ul style="list-style-type: none"> <li>▪ Key to locking and unlocking operation</li> <li>▪ Cannot lock instantly</li> <li>▪ High usage rate of key</li> <li>▪ Weak defense of lever cylinder</li> <li>▪ Door-handle fails under damage torque</li> </ul>	<ul style="list-style-type: none"> <li>▪ Push button for lock operation</li> <li>▪ Can lock instantly</li> <li>▪ Low usage rate of key</li> <li>▪ Weak defense of lever cylinder</li> <li>▪ Can be unlocked by twisting the lever/knob</li> </ul>

The time-consuming act of locking and unlocking the security door with a mortise locking system has led users to avoid arming the lock, thus indirectly defeating the purpose of installing a security door. The weaknesses and limitations of both the conventional door lock mechanisms have resulted in an innovative solution that is the ASD-Lock.

### **1.3 Objectives**

The main goal of this study is to establish an Auto Security Door Locking System.

Thus, the primary objectives of this research are to:

- i. Conceptualize a new approach of auto security door locking system.
- ii. To optimize the concept selection methods and analyze the auto security door locking system.
- iii. Develop and validate a full scale prototype of auto security door locking system for market acceptance.

### **1.4 Scope of Study**

Dual face key mortise locks are conventionally used on security doors. Instead of merely enhancing the mortise lock design, other types of door lock designs are referred to in this study in the innovative quest of inventing a new door lock system. The design development of an auto security door locking system is more suitable for application on common household security door. In order to fit the auto security door locking system onto a wooden door, width modification needs to be done on the locking system. This study mainly focuses on the pure mechanical principles of operating locks without the involvement of the electrical principles. The design development of security door locks and the implementation of an analysis process in ensuring the locking system's practicality and functionality is the main concern of this study.

## **1.5 Significance of The Study**

The replacement of the existing mortise locks with ASD-Lock results in several advantages as follows:

- i. Does not require a key to lock the security door;
- ii. Does not require electricity to lock;
- iii. Prevents unlocking from the other side, especially by the burglar;
- iv. Reduces key usage and key breakage;
- v. Enhances security;
- vi. It is a cost effective solution;
- vii. In the event of an emergency the security door can be locked instantly.

Given its advantages of not require electricity to lock the security door while providing enhanced security of door access system, there is relatively high chance of this futuristic ASD-Lock to replace the mortise lock that is commonly used worldwide in security door access systems.

## **1.6 Summary**

In this chapter, the purpose of this study is to introduce the background of the security door lock. Meanwhile, in order to allow the readers to have better understanding the overall idea of the study, problem statement, objectives, and scope of study are stated and described. At the end of the chapter, the advantages of the study had been summarized in the significance of the study.

## **CHAPTER 2**

### **LITERATURE REVIEW**

#### **2.1 Physical Barriers**

Doors can be defined as building entrances or exits, which act as barriers that provide physical security functions at access points, besides allowing authorised entrance and preventing unauthorised entrance. They can be fabricated from several types of material which include wood, glass, aluminium, metal and so on. As the physical barrier for building entrance, doors must be impenetrable by ordinary means as well as offer maximum delay time before penetration by extraordinary means (Gigliotti and Jason, 2004). For almost all occupants, security doors are the first level security frames, which are fitted before the wooden door. Security doors mainly reinforce the wooden door where the wooden door can be left open while the security door is locked (Waterman and Bell, 2013). Usually, they are made of metal or iron bars which provide tougher resistance for burglars to break-in or trespass whilst providing full viewable communication with a person outside the security door.