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Design Concept of a Motorcycle Secondary Electronic Lock

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Abstract: Design process of a motorcycle secondary electronic lock system is reported in this paper. The design of a smart lock was established based on an available conventional lock in the market. The process began with design generation to gather related idea and design concept. The design then was subjected to concept evaluation through a design matrix to determine the best option. In addition, selection of internal component and mechanism were evaluated through a morphological chart. The design and component were selected based on the highest score in term of functionality, fabrication, safety and marketability. The chosen design was then converted to a 3D model using computer aid design (CAD) and a simulation strength test was applied to the model by using a commercial software. The simulation using common hacking tool used by theft was successfully conducted and showing positive results on its robustness.

Keywords: Motorcycle anti-theft lock, motorcycle disk brake lock, smart disk brake lock

1. Introduction

Vehicle theft is categorized as a property crime and is one of many global issues affecting the world. In Malaysia, motorcycles lost due to theft are highly frequent and are increasing. Although the Royal Police Malaysia department aggressively trying to arrest the thieves and prevent stolen activity, the thieves have continuously used alternative ways to steal within a short time. Therefore, an alternative way to help prevent the problem is by providing useful information for the owners to be more careful about their motorcycle so that it would easily not been stolen [1–3]. The awareness of such issues is considered mandatory, but preventive actions such as improving the locking system would be gold.

The use of anti-theft motorcycle locking systems such as mechanical locks or padlocks has been widely used since 1924. But until now, research and development of the mechanical locking system are still being explored to get the simplest and the safest locking system. The existing anti-theft motorcycle locking system can be categorized into two main groups which are; the ready-made-factory build-in and additional also known as secondary by the owner to make it more secured. The secondary anti-theft locking system provided by the owner had shown that the installation device such as wheel lock or also known as "disc brake lock" is among the popular prevention alternative. This type of lock is the most popular due to its simple yet firm enough for destruction or dismantlement by simple tools [3].

Benchmarking of commercially available products is the process of designing new products or upgrade the existing by analyzing their strength or weakness such as the tensile stress test [4]. This is also known as a continuous process of design to generate superior performance for best practice implementation [5,6]. This procedure should be capable of utilizing product dissection in terms of hands-on learning exercises and integration of simultaneous design. Integrating a

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mechanical lock with an electronic system is a smarter path to manage the security system with a wide range of applications from home, transportation and industry [7–9]. Further improvements using biometrics had gain popularity because of its universality, uniqueness and impossibility to loss. Among biometrics security systems such as face recognition, eye retina and voice recognition, fingerprint identification is the simplest biometric system to be implemented in the locking system [10]. Therefore, it can be accepted that biometrics are secure methods for identification and security system [11–12]. The objective of this research is to identify the specification of existing wheel lock device products at the market and analyze it accordingly to the strength and weakness towards the integration of new product design, straightly to develop a mechanical wheel lock device integrated with fingerprint identification scanner.

2. Methodology

Engineering design is defined as a method of the decision-making process. It is applied to determine the process of producing a functional product based on end-user (humankind) demand. This leads to a big contribution to the human achievement of problem-solving equipment. The main purpose of engineering design is to determine and list down all specification demand by end-users (customer) [13]. Thus, engineering test and analysis are executed once prototyping is ready to make sure the product full fill the requirement and archive the objective [4–6]. The design is an interactive and evolving process accordingly to the requirement and constraints due to several contextual aspects such as materials, technology and organization [14]. The criteria for choice of the materials for the various components of the machine is on the type of force application, applicability, environmental condition in which they will function, useful physical and chemical properties, cost and availability in the local market[15]. The design process model mainly depends on the feedback loop as the results of a market survey literature striking for improvements. Whereby, all aspects such as engineering science, practical knowledge, production methods and commercial need to be merged so call important decision can be made accordingly. The design outcome should meet the objective at most quality without any delay to secure any failure [5–8].

2.1 Engineering Design Process

In this work, the preliminary product development specification was done by studying the currently available product in the market. Problems with the existing design were identified, and current needs by the end-user (customer) were taken into consideration. The generation and evaluation of design concepts were generated by using the criterion elements as follows:

i. Difficulties for robbery
ii. Ease of use
iii. Cost and manufacturing methods

In developing the product architecture, the sizing of the device is considered an important parameter. It is important to avoid unsuitable sizes either too small or too large, which might cause problems during installation at the motorcycle disk brake. The parametric design is to fix a variable factor affecting the operation, properties and use of important factors that will be gathered in the schematic drawing.

2.2 Concept Generation

The concept generation is to collect ideas and is the most critical step in the engineering design process. Starting with a set of what is needed and target specifications, the process concludes with an array of product alternatives from which a final design is selected. There were multiple steps involved in the generic concept generation process, as well as various approaches. Before coming up with many possible solutions, familiarization with some background information is needed. Perhaps the most important thing in a situation where people are looking to develop a solution to the needs, the specification and problem deconstruction forms the foundation of this background information. Based on actual market standard motorcycle locking devices, Table 1 shows three sketch ideas of the most popular product used by motorcycle owners.

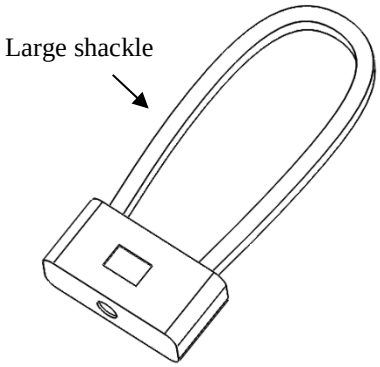
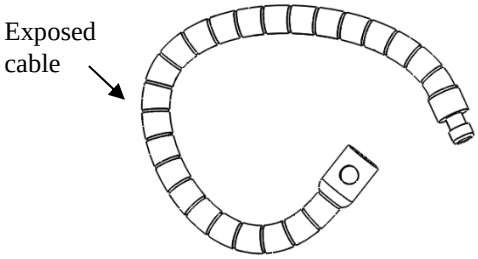
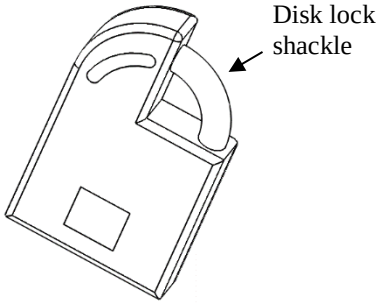
Also, the sketch idea was used to identify the potential of integrating conventional padlock with a fingerprint system. The first sketch was generated from a conventional lock pad and added a fingerprint system on the lock body. From the design, it is clearly shown that the shackle is vulnerable to theft and easily cut using a cutter or a grinder. For the second sketch, the design concept was based on a motorcycle tyre with the front fork or rear swingarm, and the third sketch also based on available lock in the market which designated for motorcycle disc brake or chain sprocket. This design has more coverage area and less vulnerable points for the theft to pick on.

2.3 Concept Evaluation

To evaluate the concepts effectively, some sort of criteria was needed to evaluate the concept in a semi-quantitative manner. Concept evaluation is a form of analysis, but it rarely takes on the highly quantitative aspects. A very popular tool for evaluating concepts is a decision matrix. Table 2 and

Table **3** below show the decision matrix for this motorcycle smart lock design based on the average score of 20 evaluators. Several main criteria need to be clarified to select the most optimum motorcycle smart lock design.

Table 1 - Various sketches of motorcycle lock

No.	Descriptions	Design
1	- Option 1 - Based on conventional lock pad - Used to lock wheel and fork of the motorcycle	
2	- Option 2 - Lock-on motorcycle tyre with the fork bike	
3	- Option 3 - Lock-on motorcycle disk brake and chain	

The new solution of the existing product has been achieved by using interpreting idea and concept generation achieved from the fore mentioned phase. The evaluation of the selected design was carried out by using a weighted rating method to compare which of the design produced the highest rating. The weightage criteria are based on the priority of the safety blueprint principle. The rating has been carried out by evaluating each design with the score 0 to 5 which is 0 is the lowest and 5 is the highest. The nominated alternative plan will be allocated with an evaluation score and multiplied by a factor of reputation weightage. The overall score is sum up and then the total weighted score of individual design is gained. From the decision matrix table, Option 3 had the highest total score and passed for the further design process.

The next process in the design system is the morphological chart evaluation for screening possible options for smart lock characteristics and components. This morphological chart is usually used by the designer to encourage the use of a new possible solution to encounter the existing problem. Other than that, the morphological chart evaluation is also being used to identify the combination and constituent or element that will be implemented in the new design and automatically combining the parameters (characteristic, factor, variable, or aspect). The morphological chart of the motorcycle lock

system has been constructed to inspect numerous probable combinations as shown in Table 4. From all the combinations, only one best combination will be selected and implemented into the smart lock.

Table 2 - Score evaluation of each option

Score	Description
1	Very poor
2	Poor
3	Moderate
4	Good
5	Very good

Table 3 - Decision matrix for smart lock option

		OPTIONS					
		Option 1		Option 2		Option 3	
Criteria	Weighting	Average Score	Total	Average Score	Total	Average Score	Total
Functionality	0.10	3.10	0.31	4.05	0.41	4.45	0.45
Durability	0.06	3.35	0.20	3.50	0.21	4.35	0.26
Quality	0.05	3.30	0.17	3.65	0.18	3.40	0.17
Affordability	0.15	4.15	0.62	2.45	0.37	3.45	0.52
Fabrication	0.10	4.85	0.49	2.35	0.24	2.30	0.23
Usability	0.02	3.45	0.07	3.70	0.07	2.30	0.05
Maintainability	0.05	2.15	0.11	4.40	0.22	2.25	0.11
Safety	0.25	3.25	0.81	4.30	1.08	4.40	1.10
Smart ability	0.12	3.20	0.38	3.70	0.44	3.55	0.43
Marketability	0.10	1.25	0.13	2.15	0.22	3.75	0.38
Total score		3.28		3.43		3.68	
Rank		2		3		1	
Continue?		no		no		yes	

Table 4 - Morphological chart of smart lock system

		Alternative Methods		
No	Subsystem	1	2	3
1	Power Sources	Battery	Ac Power Plug	Solar
2	Microcontroller	Arduino Uno	Arduino Nano	Arduino Micro
3	Charging port	USB mini	USB micro	Magnetic
4	Identification	Key	Keypad	Biometric
5	System wake	Button	Touch	Voice
6	Mechanism	Sensor	Solenoid	Mechanical
7	Eject	Spring	Rubber	Manual
8	Power train	DC Motor	AC Motor	Actuator
9	Material	Galvanized steel	Stainless steel	Aluminium
10	Shape	Round	Square	Oval

The selection of a smart lock system power source emphasizes the mobility of the smart lock itself. Thus, built-in battery-powered is desirable to ensure the smart lock is portable. Secondly, since the battery will eventually use up over time the necessity of charging port is compulsory. The magnetic charging port has the ability for quick fit for charging connection and free from built-up dirt after being exposed in all weather conditions because it has no hole, unlike other USB types. The microcontroller chosen is Arduino Nano because of its small size to fit in the smart lock and easy to program. The identification is using a biometric fingerprint scanner to unlock the smart lock. Furthermore, the fingerprint scanner can store multiple fingerprints unique to an individual and free from losing any key. The system is put into

standby mode to ensure long-lasting battery life. Hence, a button is required for activating the system during its system standby for the identification and authentication process. Unlike touch and voices wake up would cause the battery to drain much faster due to the system loop waiting for the input during standby.

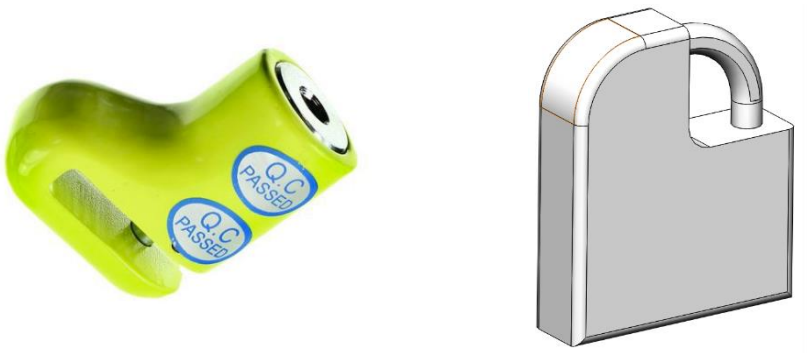
Table 5 - The allocated role of the smart lock

Sub System	Alternative Method	Role & Function
Power Sources	Battery	Act as a power source for the electronic components
Microcontroller	Arduino Nano	To govern specific operation for the electronic part
Charging Port	Magnetic	Connectivity for battery charging
Identification	Biometric	To activate the system for unlocking
System wake	Button	To wake the system from idle
Mechanism	Mechanical	As the main system lock and unlock
Eject	Spring	Act as pop up of the barrel lock
Power Train	Dc Motor	As the driver for the lock system
Material	Aluminium	Casing body to store the component of the lock system
Shape	Oval	Easy to machine

The mechanism of the unlock system was chosen to use a mechanical system driven by a DC motor to unlock the actuator system. To ensure one-hand operation during locking and unlocking, the ejection mechanism is supported by a spring for smoother operation. An aluminium body was selected because it possesses excellent machinability and relatively cheap compared to other materials. Also, a square body helps in the machining process since it required less work than other shapes. It will also help to reduce the manufacturing cost so that the final product can be marketed at a competitive price. All of these combinations were listed in Table 5.

2.4 Design Development

The concept of the design was modeled by using commercial software which is Solidworks 2018. The 3D model was inspired by a commercial disk lock shown in Fig. 1 (a) and the final design of the motorcycle lock was shown as Fig. 1 (b). The component of the lock system was chosen using the previous phase step. All components were fitted into the lock design thus determining the final size of the lock. The proposed design that was already done drawn in 3D modeling was further analyzed to test the functionality of the lock mechanism. The lock shows a low possibility to be picked and hacked by theft due to limited accessibility on the pin plunger. This increased the safety of the motorcycle from being stolen. The lock mechanisms are fully functioning and ready for integrating with the electronic components such as the motor and fingerprint sensor. The space required for installing electronic components is shown in Fig. 2.



(a) (b)

Fig. 1 - (a) Original disk brake lock; (b) 3d modelling of smart lock using solidworks

A few design features were taken into consideration in designing the lock. The features emphasize the locking, unlocking and security of the lock. The features comparison between disk brake lock and new Smart Lock is listed in Table 6. The comparisons show that the new Smart Lock operation only requires one hand to lock and unlock which is very convenient in a tight spot. Instead of using keys, to unlock the lock it is required a user fingerprint without worrying

about losing the key and finding the keyhole during the dark. Furthermore, without the keyhole to unlock, the risk for lock tempering can be reduced by eliminating possible methods to lock picking through the keyhole. The security of the new Smart Lock is further increased by increasing the size and weight of the lock. A heavier body has more material which makes it more difficult to damage and break.

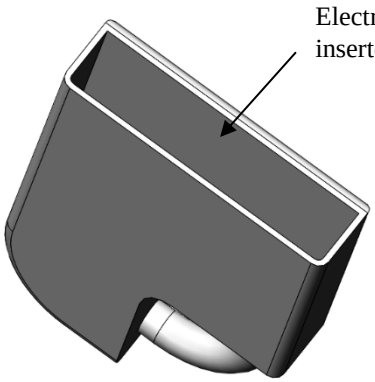


Fig. 2 - Illustration 3D modeling of the electronic compartment

Table 6 - Features comparison between the existing lock and new smart lock

Features	Disk Brake Lock	New Smart Lock
Locking operation	Two hand operation for locking	One-hand operation for locking
Unlocking operation	Two hand operation for locking	One-hand operation for locking
Unlocking mechanism	Require key to unlock	Using registered fingerprint
Lock Security	Exposed keyhole for tempering	No keyhole to temper

3. Result And Discussion

The design of the motorcycle secondary electronic lock has been analyzed in the critical area where the possibility of hacking is high. The analysis purpose is to determine the displacement of the shackle when using a different type of tool commonly used for hacking. The tools chosen are a long screwdriver, pipe wrench, crescent wrench and spanner wrench. The force applied based on normal human muscle strength using the tools was obtained from a previous study by Mital and Kumar [18]. The maximum stress, strain and displacement applied on the shackle were calculated using Solidworks software and the results were presented in Table 7.

Table 7 - Result of the simulation strength test applied to the model

Tool	Forces, Nm	Max. stress, N/m^2	Max. displacement, mm	Max. strain
Long screw driver	3.2	6.92×10^{7}	1.13×10^{-2}	2.43×10^{-4}
Crescent wrench	30.0	6.49×10^{8}	1.06×10^{-1}	2.28×10^{-3}
Spanner wrench	33.6	7.27×10^{8}	1.19×10^{-1}	2.56×10^{-3}
Pipe wrench	40.0	8.655×10^{8}	1.412×10^{-1}	3.042×10^{-3}

The result was arranged in ascending order from the smallest to the biggest force applied based on the tool used. A long screwdriver has the smallest force, followed by a crescent wrench, spanner wrench and pipe wrench. Based on the force applied, the stress exerted and strain produced in the model was obtained from the simulation. Also, the maximum displacement of the shackle can be seen in the final result shown in Fig. 3. From the figure, the displacement of the shackle is based on the force applied to result in deformation at the end of the shackle. Pipe wrench produced 8.655×10^{8} N/m2 stress, 3.042×10^{-3} and maximum displacement 1.412×10^{-1} mm at 40.0 Nm applied force. However, the displacement calculated is very small even for the higher force applied using a pipe wrench. Thus, this design is safe enough to prevent heavy conventional unwanted practice to break the lock.

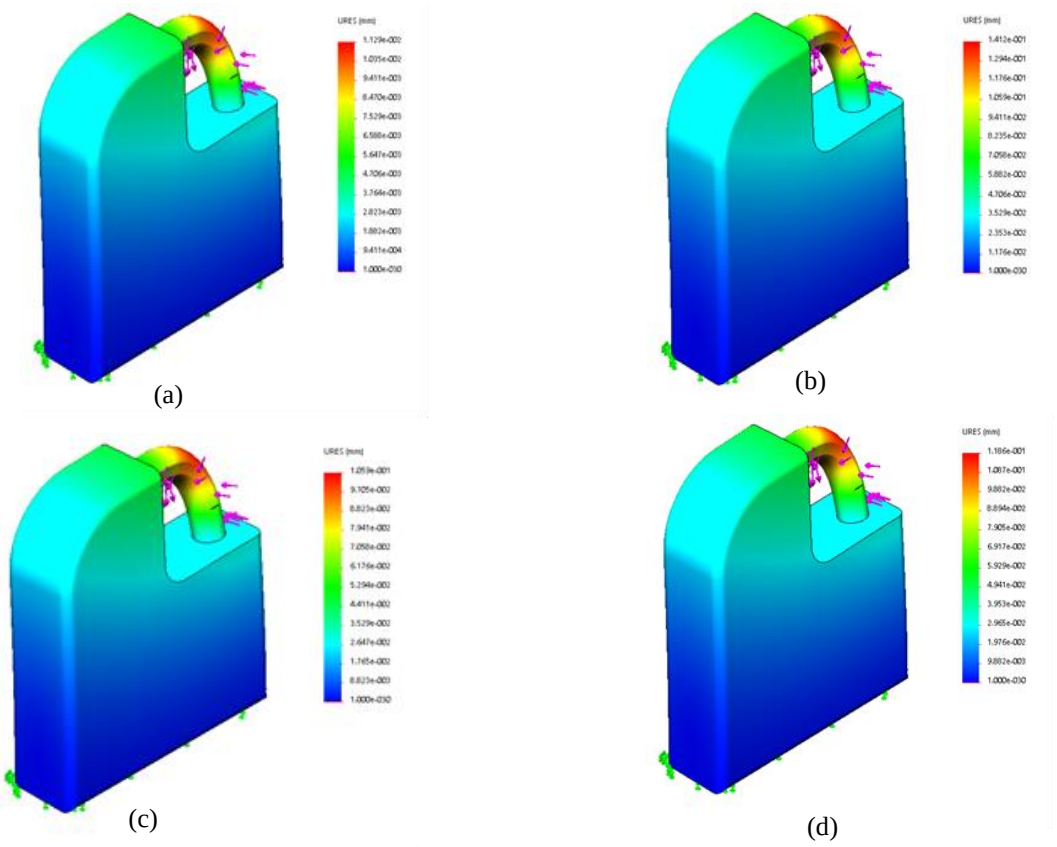


Fig. 3 - Simulation of a static test to the design by using multiple types of tools; (a) spanner wrench; (b) long screwdriver; (c) pipe wrench; and (d) crescent wrench

4. Summary

From the concept generation, the third design option was selected because it has a more robust body and limited space for hacking by theft. The result of the design matrix also gives a positive result on the third design. The overall score shows that the design has high scores in functionality, affordability, fabrication, safety and marketability. The internal components and mechanism combination were also selected to transform the conventional lock into the smart lock. The lock has a special feature of locking and unlock using one hand. Also, there is no key to unlock the lock, it uses a battery, DC motor and fingerprint scanner to release the plunger pin. This lock is the evolution of the conventional lock to a smarter one for more convenient handling in the motorcycle safety system. This research is the first step in the complete investigation development design of the motorcycle lock. Then, further analysis would then be carried out on the other side of the real-world testing such as weatherproof and electrostatic test.

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