A study for prevent theft of the bike design and analysis

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Abstract. This research will deal with the analysis and design of an anti-theft bicycle. At the first, the structure of the bicycle lock device will be focused. Therefore, all related academic journals, dissertations, and patent were collected, ordered, classified, and analysis in order to understand the phase of the developing tendency towards the bicycle lock apparatus presently. Nowadays, a wave of riding bicycles all over the world is quite prevailing. Also, the bicycles incline to be high-price sporting and recreational equipment. Due to this, the rate of stolen bicycles has increased as well. Even though there are many different types of bicycle locks sold on the market, they are unable to work out effectively to prevent from being stolen because they are easy to be broken. In this case, the target design in this research will be mainly put on the simple structure and facile use enabling users feeling secure to park their bicycles. The design also includes a lock that works together with the bicycle frame to provide a new option of anti-theft design for bicycles. We defined the functional requirements by the process of an innovative mechanical design, before designing the fundamental bicycle structure of the present anti-theft bicycle and finally integrate all the requirements of design. The SolidWorks software was used to draw a 3D model of the anti-theft bicycle; the ANSYS software was also used to do CAE analysis, to understand the distribution of stress, so that the design and the requirements of use are met.

1. Introduction
As bicycles provide people to move around in the outdoor or a park at leisure, they are increasingly used as a transportation instrument in the era with emerging environmental awareness. Yet, as the prices of bicycle keep increasing, bicycle theft has become a problem that cannot be taken lightly. Funds and human power are thus pumped into research, development and production in advanced countries, which helps the markets for bicycle develop well. However, as the materials used as the bike frame are becoming more light-weight thanks to technological breakthrough in recent years, the number of bicycle thefts keeps increasing. Anti-theft design thus is at present an important issue taken seriously by R&D personnel. How to make bicycles hard to steal and easy to use is a pressing question. When the body per of a bicycle is also an anti-theft device, the theft rate can be decreased as a result of the body structure and strength being compromised at the same time when the lock is sabotaged, which causes a safety problem with riding.

2. Patent analysis and classification
According to the documents, academic periodicals and patent gazettes from which this study gathered data, the devices with the structures for bicycle lock are largely divided by the locking method in five categories:
(1) **Locking rod device**
This locking rod device is a fixed block that is fixed to either fork or either tubing of the seat stay of a bicycle, comprising a lock which can be controlled by a key to be turnable or be fixed. Patents [1] and [2] that were found by the search both disclose a way of theft prevention by locking with a rod, which is hereby discussed. As Fig. 1 shows, [1] is a method that inserts a rod through the spokes, making the wheel unable to turn, and in turn locking the bicycle.

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![Fig. 1 Application of locking by a rod [1]](image1)

![Fig. 2 Fork with a lock [3]](image2)

(2) **Fork-locking**
The fork-locking device provides a lock mechanism in a fork, in which the lock mechanism is enabled when the bicycle is parked, making the fork unable to turn. Patents [3], [4] and [5] all use a fork-locking device to lock a bicycle; here Patent [3] is particularly discussed. As Fig. 2 shows, [3] discloses a fork that is provided with an exterior hole, and a link, which is disposed, fixed inside said fork, having an internal hole that corresponds to said exterior hole; a positioning plate is fixed to said fork on said exterior hole, a bushing is provided on the positioning plate at the position corresponding to said exterior hole, and a lock is fixed to said bushing; by means of the locking of said lock, it is possible to make the handle bar unable to turn, achieving the effect of locking the bicycle.

(3) **Rigid-lock**
A rigid-lock device forms a close lock with rigid rods or tubing that go through the wheel axel, which is a device so strong that it is difficult to break, and thus achieves the effect of theft prevention. Patents [6], [7] and [8] were found; here we elaborate on [6] and [7]. Fig. 3 shows [6] as a rigid-lock device for bicycles, which is a locking device installed in front of the forks, which includes a steel wire; when the wire is pulled up, it pulls two L-shape rods on both sides so that they go through the wheel and form a closed locking device. Fig. 4 shows that [7] provides a lock on the rack of a bicycle, said rack comprising a fixed rod, a pivot rod disposed fixed to the end of said fixed rod, and two support rods that are pivotably joined to said pivot rod at both ends and are supported by the rod that runs through the wheel’s axel; said lock comprises a U-shape rod and a lock head, characterized by that said U-shape rod is disposed with its ends pivoting on said pivot rod of the rack and, when the lock head is removed, can swivel to a position where its front end is by the sides of the wheel allowing the lock head to lock the wheel or swivel to a position parallel to the fixed rod of the rack and be fixed with the lock head.

![Fig. 3 Structure of a rigid lock for bicycles [6]](image3)

![Fig. 4 Structure of bicycle lock [7]](image4)
(4) Flexible lock device
A flexible lock device uses flexible materials, such as rope and steel cable, for locking device. When locking, the flexible lock is handy in going around any object that is attached to ground, such as railing. Patents [9], [10], [11] and [12] all disclose a means of locking using flexible materials; we discuss particularly [9], as shown in Fig. 5. It is a lock device built with the bicycle frame as an integral body, it being a lock disposed at one end of the bicycle rack and having a first end and a second end; a cable, which is fixed to said first end of the lock on one end and the other end goes around the frame and back to be removably attached to said send end of the lock, and which can be in a folded status and fit against the frame, whereby the cable is free from being pendulous, and thus ensures of the safety during riding.

![Fig. 5 Locking by flexible lock [9]](image1)

![Fig. 6 Locking device by bike parking rack [13]](image2)

(5) Bike parking rack and lock device
Bike parking racks are a device disposed by roadsides; this bike parking rack is a special lock device, with its ring freely rotatable to any position and any orientation to lock a bicycle on the forks, the top tube, the rear brake or the wheel; it is an omni-directional lock device, as [13] shown in Fig. 6.

3. Design conditions for theft bikes
We analyzed and sorted the available documents and patents on bicycle lock structures and devices to understand the advantages and disadvantages of the anti-theft devices available in the market. Through regulations and market survey, we set out the design conditions for new bicycle anti-theft devices before designing them, so as to render this bicycle locking structure or device with maximum functions, letting users be assured to use this device [14] [15] [16].

(1) The bicycle can structurally withstand a load up to 100kg (980N) to ensure of user safety.
(2) For handiness, safety and versatility, this study makes the simplest design of locks.
(3) The design herein enables easy locking when in the outdoor.
(4) A minimum of two methods of locking is required: locking with the tire and locking onto utility poles.
(5) The innovative design herein aims at decreased theft rates and thus consideration is given to combining the lock with the bike frame, whereas they are joined in a fixed manner, such that once the lock is damaged, the bike frame is also damaged.

4. Research and design results
The review herein of existed patents revealed that most bicycle locks are portable and some are installed on the bicycle, but the locks, being of steel wires, are easy to cut. Out design thus was made for the specific requirements of an anti-theft bicycle, which are materials that are difficulty to cut and using roadside bike parking racks as locking means. Based on these two design requirements, this study came up with two design concepts, one being that the lock is partly the bicycle’s frame, thus when the lock is damaged from sabotage, the bike will collapse due to under-strength to support the load. The other concept is to design locks that can be mounted on bicycles of all kinds.

4.1. Dedicated anti-theft type of bike
For this anti-theft bicycle, we use part of its top tube as a part of the lock; the lock, which, as Fig. 7 and Fig. 8 show, is consisted of three tubes as a locking device with five degrees of freedom, is installed on the seat tube with rivets in a fixed manner. Fig. 9 is the perspective view of this lock device. In the event that it is damaged, the bicycle will suffer from the loss of support by the top tube and tends to collapse. As such, this design can discourage a thief to steal the bike. In addition, this lock device is designed to allow the rider to lock the wheel when he wishes to park the bicycle or when there is not a parking rack nearby, so as to protect the bicycle. Fig. 10 is the perspective view of our exclusive anti-theft bicycle.

4.2 Lock bike
This lock device is a stand-alone device, as Fig. 11 shows. It can be installed on the seat tube, the top tube, the forks or the chain stay of a bicycle. When installed on a seat tube, a top tube or a down tube, the lock device can lock the wheel or lock with a utility pole or a bike parking rack against theft, as Figs. 12 and 13 show. If installed on the fork or the down tube, though it cannot lock the wheel, it can lock with a utility pole or a bike parking rack.

4.3 Innovative anti-theft bike design
With the above-mentioned two design concepts and the required design criteria defined, we can begin to make detailed design of the anti-theft bicycle. To create a 3D model in diagrams of parts and assembly, the SolidWorks 2016 software was used. Fig. 14 shows the diagram of locking function of the lock device.
4.4 Analysis of Frame Structure Strength

Following the completion of model creation was a stress analysis to ensure the bicycle is free of safety concern under loads. To do this, an ANSYS Workbench module was run on the ANSYS 11.0 software. As the first concept herein features taking part of the top tube of a bicycle as a rod piece of the lock device, while the second concept features the adoption of existed bicycles available in market, the stress analysis will be applied only to the exclusive anti-theft bicycle of the former. We applied user’s body weight on the bike frame, ignoring the stresses, distribution and variation thereof caused by the weight of the frame itself, whereby to understand whether each rod is adequately strong, as reference for designing.

We began by creating a static analytic model, which was used on the bike frame and the lock device, of the material of 7005 aluminum, in two applications of forces exerted on the frame, as Fig. 15 and Fig. 16 show. In the first application, a 980N force is exerted on the seat tube, and in the second, a 980N force is divided in 490N forces, each of which is exerted on the seat tube and the bottom bracket, respectively, for analysis. The analytic results were put to stress diagrams herein by the Von Mises Stress, as Figs. 17, 18 and 19 show, which are the diagrams for stress distribution on bike frame and for the Von Mises Stress. Such results indicated that the area where greater stresses focus was at the top of the seat tube in both the first and the second applications, with the maximum stresses at 66.679MPa and 33.571MPa, respectively. As according to the material database, the 7005 aluminum has a yield strength at 280MPa, because the stresses on the current bike frame under analysis in the three applications were all within the tolerable range, the anti-theft bicycle with our exclusive frame meets the strength requirement. In addition, through the industrial design to use this result to do the concept of design, as Figs. 20 show.

5. Conclusion

This study developed, by searching for extensive types of bicycle lock structure and device and sorting and analyzing various locking means, a new type of anti-theft device for bicycles. In the process, consideration was given to locking methods in different situations and the purpose of increased handiness and reduced mechanical complexity; hence, compared with other products, the design herein is characterized by the following:
(1) The use of kit-type lock device, wherein the current lock device is characterized by being able to installed on the top tube, seat tube or the fork of any kind of bicycle and able to lock the bicycle wheel itself as well as with the utility pole or bike parking racks.

(2) The adoption of an exclusive bike rack-incorporated lock device, wherein part of the lock device is also the top tube, such that any damage to the lock will also damage the bicycle, thus making it less liable to theft. Also, the locking methods include locking the wheel of the bicycle itself as well as locking with a utility pole or bike parking racks on road side.

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