ED3010: Human Factors In Design
Project Report
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Ergonomic Bicycle Locking Mechanism

1 Abstract

Presently all the locking mechanisms in bicycles require the user to get down and do ample amount of mechanical work so as to lock the bicycle. This procedure is time consuming as well and could be replaced by a mechanism which caters to all the human factor issues such as time, force and cognition. The anticipated outcome of this report is to find such a mechanism which is more efficient and more advanced from an anthropometrical perspective. Couple of concepts were proposed and suitable calculations and a CAD model were prepared to back the concepts.

2 Background

The existing bicycle locking mechanisms involve the user to get down from the bicycle in order to lock the bicycle. This complete process includes bending so as to be able to operate the lock and ensues in taking up extra time. Repetitive action in doing this process has influences on our physical as well as cognitive systems and is inconvenient to a person as a whole.

So to resolve the excessive bending and the unnecessary time wastage, a new design of the same locking mechanism can be thought of which includes the placing of locking mechanism at the handle of the bar, emulating the mechanism of locking in motorbikes and using the same principle in bicycles. By incorporating this mechanism, the locking can be made less stressful from a human factors' perspective and the bicycle locking will be more viable.

3 <u>Types of Existing Bicycle Locks</u>

3.1 D-locks:

- The D part attaches to the crossbar section, and to lock the bicycle, it has to be physically locked with some other object like a pole.
- These kind of locks are resistant to cutting, so they are considered pretty good when security concerns are taken into account.
- These kind of locks are very heavy and difficult to carry around, so this makes it a frustrating problem to deal with.

3.2 Cable Locks:

- Often come with locking mechanism already integrated in them, this type of lock doesn’t require a pole like object to lock it with.
- Are light in weight and easy to carry around and can be locked with any other part such as seat bar when not in use
- Can be vulnerable to cutting tools, for keeping it light weighted, cable made generally are quite thin, so not a great lock considering the security concerns.

3.3 Wheel Locks:

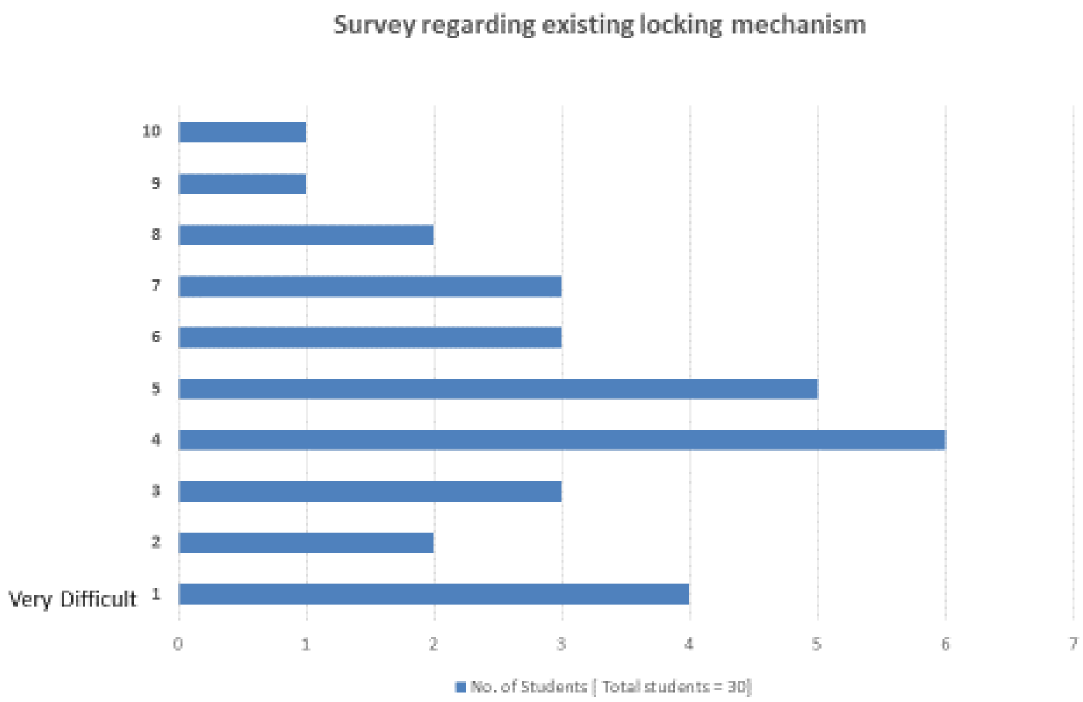
- In this mechanism, the lock is mounted on the frame that prevents the rear/front wheel movement by a steel bolt that runs through the spokes.
- Ensues quick locking and time saving and doesn’t need the lock to be carried around as it is already mounted to the wheel frame
- Can be lifted from the locked wheel (rear/front) and rolled away, so a mediocre locking mechanism when security concerns are considered.

4 <u>The Human Factors Approach</u>

The human factors approach is the design process which is completely "**user-centred**" i.e. user is kept at the centre of the design process and he is the focal point. The ergonomist or the human factors engineer will attempt to design from the viewpoint of the user with the use of various methods and techniques.

4.1 Motivation for new design

Users were asked about their experience while using the current locking mechanisms. They are the indirect systems of finding the bugs in the current design to use them as a base for the new design. The asked user may present their perceptions and expectations of using the product.



4.2 Task Analysis

This part of the approach involves various techniques to explain and evaluate the interaction system of humans with either machines or humans. Task analysis has been termed as a method of collecting and interpreting collected data to evaluate human performance.

In this project, task analysis is advantageous in the dissection of the principal task i.e. <u>locking the bicycle</u> into corresponding sub-tasks required i.e. activities to perform the principal task. This shall help us in figuring out the complications and exertions in the current design.

4.2.1 List of Subtasks Performed in order to complete the principal tasks

- **Principal Task:** Lock the bicycle

- **Subtasks:**

i. Stop bicycle
ii. Get off the bicycle
iii. Push stand down
iv. **Bend down**
v. **Locking:**
For a wheel lock system, pull down the lever of the lock. The key should get unturned.
For a cable lock system, open the lock, lock around the wheel.
vi. Pull out the key
vii. Work done

4.3 Human Reliability Assessment:

This methodology is used after the completion of "Task Analysis". This technique helps us to identify the particular error that is being made in the defined subtasks to improve upon that particular subtask. This method helps us to get an idea about the impact of that particular "error" and find the means of prevention for that.

In this project the "flawed" subtasks can be identified as

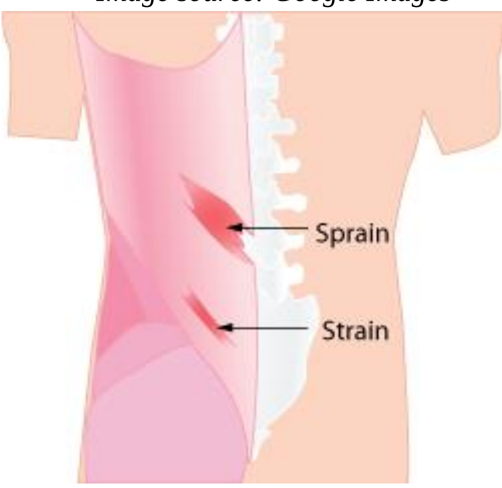
i. Bend down and
ii. the manual locking

Issues with the Repetitive Bending

Repetitive bending motion can result in back aches in the lower back initially, then leading to muscle sprains and discomfort and then to permanent damage to the body. Some of the primary issues and injuries on repetitive motion are mentioned below:

- *Cumulative Trauma Disorders (CTD)* are the kind of disorders that are aggravated or caused by repetitive exertions and motion of the body.
- Inflammation of muscles and tendons is known as *Tendinitis* and is caused by repetitive movements incorrectly.
- Tendons and coverings of the tendons becoming inflamed is a condition known as *Tenosynovitis.*

Image source: Google Images



Issues with the locking mechanism

Some of the major problems in the current locking mechanism are explained below:

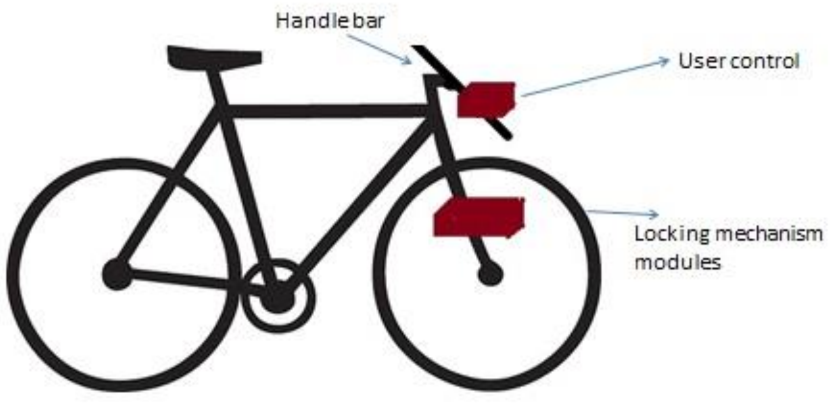
- In low brightness or complete dark, the rider has to do a lot of struggle to find the key-hole and place the key inside it in order to unlock.
- The current locking mechanism is time consuming as well
- In some of the lock types such as cable locks and D locks, key needs to be kept safe always. There is always a chance of losing it while riding and then struggling to lock it later on.

5 <u>Concept Generation</u>:

Considering the above explained human factors approach for eliminating the primary issues with the current mechanisms, a new concept can be thought for mechanisms which are ergonomically advanced **do not require the rider to get down to lock the bicycle.**

We plan to develop a concept which will support the mechanism which is closer to the reach of the rider and can be accessed while sitting itself. Inspiration of such a mechanism can be taken from motorbikes where the locking mechanism is closer to the handlebar and requires a key to be placed in it all the time except when locked.

A module will be fixed rigidly to the front tyre’s frame and the control of that shall be given to the rider with another user control module mounted at the handlebar which will operate only with the access of the key.



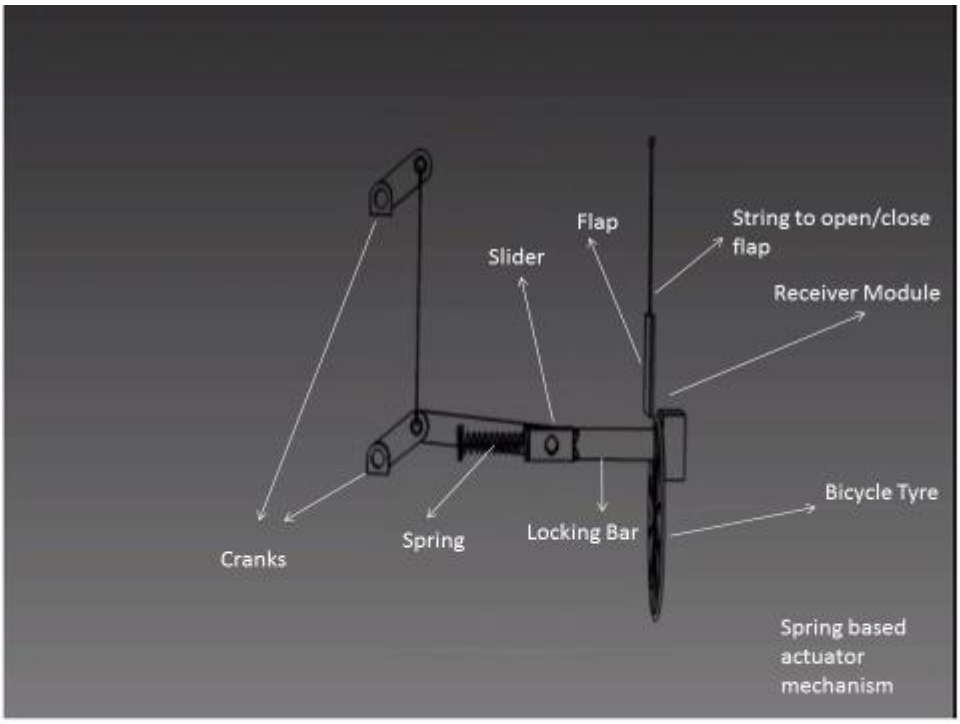
Locking mechanism rigidly fixed to the frame at the front wheel, with the control at the handle bar of the bicycle.

Image source : google images

6 Mechanism Developed:

6.1 Spring Based Actuator connected with a Crank Slider Mechanism:

- The module mounted at the frame of the tyre will be of a spring actuating type, consisting of a locking bar and a slider with a spring connected to it, which will eventually be connected with a four bar mechanism. The locking bar and slider will be the parts going to and fro by the motion of cranks to lock and unlock the bicycle.
- A "Flap" is used to keep the spring compressed by keeping the lock bar in position(Unlocking), on removal of the flap the restored spring force will push the lock bar forward into the receiver module around the tyre, thereby locking it.



- The control of this locking system is transferred to the module mounted on the handle bar, the module will have a keyhole in it, in which after placing the specific key and the locking module would be accessible.
- The four bar mechanism only contributes in the unlocking part, on applying force on the cranks through the control modulator on the handle bar, cranks will rotate which will result in motion of slider and the compressing of the spring and pulling back of the locking bar. The spring will get compressed and flap will be dropped to keep the lock bar in position and tyre will be free to move.
- For the locking part, the control will be transferred again to the module mounted on the handlebar, on rotation of the key in the other side, the flap will get lifted up thus forcing the compressed spring to push the slider and the lock bar and therefore locking the bicycle.

The mechanism has been showed in the video attached along with report for better understanding

In the above mechanism, instead of a spring, a two way string can be used to simplify the design and increase mechanical advantage

6.2 Activities to be performed by the user:

In the spring based actuator model, the user needs to perform the following sequence of operations in order to lock/ unlock the bicycle (includes only the working of the mechanism):

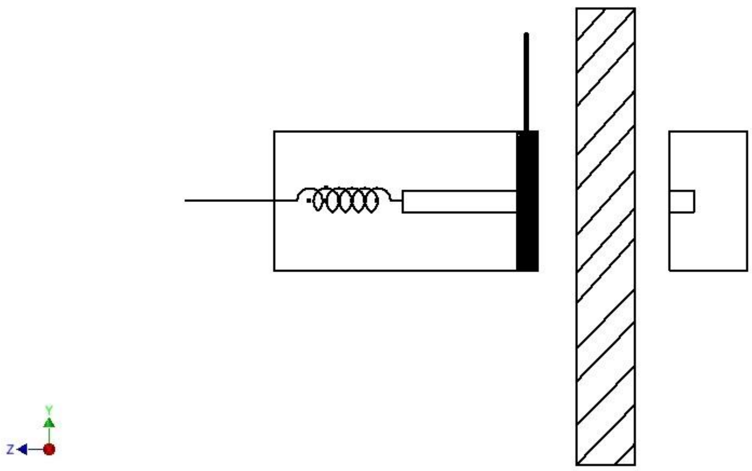
Unlocking:

1) Place the key in the handlebar module
2) Rotate the key so as to rotate the cranks and thereby pulling the locking bar into the actuator module
3) Drop the flap
4) The locking bar will be constrained by the flap and tyre will be able to move freely

Locking:

1) Rotate the key to the other side so as to lift the flap
2) Spring force will help us in pushing the lock bar
3) The lock bar will pass through the tyre and will be finally received by the receiving module.
4) Bicycle is now locked as tyre can’t move freely.

7 Calculations:



7.1 Design Parameters:

The following parameters have to be decided after force analysis of the proposed locking mechanism:

- Length of the two modules
- Spring parameters
- Length of the locking bar
- Tension required in the string to pull back the locking bar

7.2 Spring parameters:

- Diameter of spring wire, (d) : 0.75 mm
- Outer diameter of spring, (D_{Outer}): 20 mm
- Free length of spring, (L_{free}) : 30 mm
- Compressed length of spring(L_{solid}) :7.5 mm
- Number of active coils,(η_a) : 8
- Young's Modulus of material, (E) : 200 GPa
- Poisson's Ratio, (ν) : 0.3
- Density of material, (ρ) : 7500 Kg/m^3

7.3 Force Analysis:

$$G = \frac{E}{2(1+\nu)}$$

G is the "shear modulus"

$$G = \frac{200 * 10^9}{2(1+0.3)} pa$$

$$G = 76.92\ Gpa$$

$$k = \frac{Gd^4}{8D^3\eta_a}$$

$$Where\ D = D_{Outer} - d$$

$$D = (20 - 0.75) = 19.25mm$$

$$k = \frac{76.92 * 10^9 * 0.75 * 10^{-12}}{8 *}$$

$$k = 53.3\ N/m$$

$$Coil_{pitch} = \frac{L_{free}}{\eta_a}$$

$$Coil_{pitch} = \frac{30}{8} = 3.75mm$$

$$Maximum\ displacement = \left(L_{free} - L_{solid}\right)$$

$$Maximum\ displacement = 30 - 7.5 = 22.5\ mm$$

$$F_{max} = k\left(L_{free} - L_{solid}\right)$$

$$F_{max} = 53.3 * 22.5 * 10^{-3} = 1.2N$$

8 <u>Conclusion</u>;

In the proposed concept for the new mechanism, we have the following improvements over the existing mechanisms:

- The total time consumed to perform the locking operations has been reduced by a significant factor.
- It reduces the number of subtasks performed to get to the main task i.e. locking, so the new mechanism is less complex and efficient.
- By removing the redundancies such as getting down and bending, the new concept removes the possibility of sprains and discomforts due to repetitive bending.

9 <u>References and Acknowledgements</u>:

- Human Factors for Engineers, Carl Sandom, Roger Harvey
- Google Images
- Patents:
  - US3800575A
  - CN202624447U
  - US677907A

- Acknowledgements:

  Concept was thought as a team project with the following members:
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  - Tanay Garg(ED13B053)