Design of chainless bicycle transmission system using four linkages mechanism

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Abstract. Bicycle is one of the most popular transportations in the world because it is emission-free and can be used by everyone. Bicycle is always evolving in accordance with the latest technology. Various designs have emerged to change the shape of the bicycle to the present. Design is important in making new concepts to overcome existing problems. The design of a bicycle transmission system without a chain intends to overcome the problem of maintenance needs of a chain-equipped bicycle. The design of the bicycle chain transmission system was changed using a four linkages mechanism. Two types of models were made using the same principle. These two types of bicycle system designs use a four linkages connecting mechanism. The system motion simulation is created using Fusion 360. Motion simulation of this system shows that bicycle transmission without chain works properly. The two types of designs will be compared based on the force needed to move the bike and the results of the simulation. Keyword: Bicycle without chain, four linkages mechanism, Fusion 360.

1. Introduction

Transportation is an important tool in human life, so they can travel quickly and save energy. Various means of transportation have been made both land, sea and air transportation. The increasing number of means of transportation also raises new problems namely the problem of pollution and environmental pollution. Bicycles are one of the first means of land transportation that has been made. Along with the times, the bike underwent various developments both in terms of design and from the driving system. Bicycles can continue to survive and develop because they are used by all people and are environmentally friendly.

Simply put, a bicycle can move due to the transfer of power from the rider's foot to the bicycle pedal so the rear wheels can move. At present the bicycle uses a simple transmission system in the form of chains and sprocket to drive the rear wheels. Chain and sprocket transmission systems have various shortcomings, namely maintenance of chain and sprocket transmission systems in the form of chain lubrication and tightening. If the chain and sprocket transmission system is not properly maintained the chain may break or come out of the sprocket. Chain and sprocket transmission systems can also cause serious injury. Losses that exist in the bicycle transmission system with chains can be eliminated by replacing the transmission system
without chains. Chainless transmission systems can also improve the efficiency of power expended by cyclists [1-4].

2. Method
The design method used in this design is the French method so that we need some data to calculate the needs and end with a design drawing and simulation results. The design starts from analyzing the lack of a bicycle transmission system with a chain. The design is only centered on the transmission system because the bicycle frame uses a folding bicycle frame and is considered strong. Made a second bicycle transmission system design on Fusion 360 software. The design of a bicycle transmission system without a chain using a four connecting rod mechanism aims to overcome the shortcomings of a bicycle transmission system with chains.

Link dimensions are determined based on Grashof’s equation [5-7] and adjusted to the position of the bicycle pedal with the chain transmission. The second CAD model is the design of a bicycle transmission system without chains and then simulates the movement by the 360 fusion software. Then the results of the design simulation and the calculation of the style needs to be a conclusion on the design carried out. The following is a flowchart of designing a bicycle transmission system without chains:

![Flowchart of designing a bicycle transmission system without chains](image)

3. Result and Discussion
This bicycle transmission system without chains uses a four bar mechanism to replace the bicycle transmission system using chains [8]. The folding bicycle frame that will be used is made in CAD modeling in Fusion 360 software. There are two types of designs made in the
CAD model and a motion simulation is performed. Here are the results of modeling CAD bicycle transmission systems without using chains:

![Figure 2. Bicycles with transmission system without chain (design no.1)](image)

The first design of bicycle without chain transmission system has a pedal angle of 34°. Pedals in the 0° position are considered in the middle position ie when the left and right pedals are in a parallel position. The bicycle pedal on top position or maximum position at 18° and is at the bottom at 16°. The following is a picture of the mechanism of a bicycle transmission system without the first design chain and its specifications.

![Figure 3. Bicycle chainless transmission system mechanisms (design no.1)](image)

### Table 1. Specifications of a bicycle chainless transmission system (design no.1) [6-7]

| No | Part                              | Dimensions                          | Material               | Qty |
|----|-----------------------------------|-------------------------------------|------------------------|-----|
| 1  | Pin pedal                         | Ø15 mm x 60 mm                      | s45 c                  | 1   |
| 2  | Shaft in pedal                    | Ø20 mm x 218 mm                     | s45 c                  | 1   |
| 3  | Pin link pedal coupler            | Ø17 mm x 42 mm                      | s45 c                  | 2   |
| 4  | Pedal link                        | 405 mm x 40 mm x 20 mm              | Aluminium 6061 t6 hollow (1,2 mm) | 2   |
| 5  | Coupler link                      | 285 mm x 40 mm x 20 mm              | Aluminium 6061 t6 hollow (1,2 mm) | 2   |
| 6  | Pin coupler flywheel              | Ø17 mm x 32 mm                      | s45 c                  | 2   |
| 7  | Flywheel                          | Ø70 mm x 10 mm                      | s45 c                  | 2   |
| 8  | Shaft at flywheel                 | Ø20 mm x 218 mm                     | s45 c                  | 1   |
| 9  | Shaft at flywheel Bearing (FBJ 6904) | d =20 mm, D = 37 mm  
  t = 9 mm | -                      | 2   |
| 10 | Shaft at pedal Bearing (FBJ 6904) | d =20 mm, D = 37 mm  
  t = 9 mm | -                      | 2   |
| 11 | Couple link bearing (FBJ6803)     | d =20 mm, D = 37 mm  
  t = 9 mm | -                      | 4   |
The first design of chainless bicycle transmission system had a flywheel diameter of 14 cm so that when the bicycle was assumed to move at a speed of 20 km/h [8-9] it had torque at the flywheel of 77.34 Nm. In the second design there are different mechanisms but still use the principle of the four bar mechanism [2]. The differences in the first and second designs can be seen in the following figure.

![Figure 4. Bicycles with transmission system without chain (design no.2)](image)

The second design chain bicycle transmission system has a paddle angle of 56°. Pedals in the 0° position are considered in the middle position ie when the left and right pedals are in a parallel position. The bicycle pedal is at the top or maximum position at 27° and at the bottom at 29°.

![Figure 5. Bicycle chainless transmission system mechanisms (design no.2)](image)

The first design of a bicycle transmission system without a chain has a diameter of 10 cm flywheel so when the bike is assumed to move at a speed of 20 km / h it has a torque at the flywheel of 39.46 Nm. The specifications of this folding bike frame have not changed. Both designs have different specifications, especially on the width of the transmission. The width of the bicycle transmission in the first design is 298 mm, while the width of the second transmission is 270 mm. Calculation of pedal force needs by using a static force analysis [4, 11-13] on a bicycle assuming a bicycle speed of 20 km/h is performed at five pedal positions, the following five pedal positions are carried out by static force analysis as follows:

| Pedal position       | Design no.1 | Design no.2 |
|----------------------|-------------|-------------|
| Top                  | Position 1  | Position 1  |
| Between top and middle| Position 2  | Position 2  |
| Middle               | Position 3  | Position 3  |
| Between middle and bottom | Position 4 | Position 4  |
| Bottom               | Position 5  | Position 5  |
Table 3. Specifications of a bicycle chainless transmission system (design no. 2) [6-7]

| No | Part | Dimensions | Material | Qty |
|----|------|------------|----------|-----|
| 1  | Pin pedal | Ø15 mm x 60 mm | s45 c | 1 |
| 2  | Shaft at pedal | Ø24 mm x 35 mm | s45 c | 2 |
| 3  | Pin link pedal coupler | Ø22 mm x 47 mm | s45 c | 2 |
| 4  | Pedal link | 430 mm x 50 mm x 25 mm | Aluminium 6061 t6 hollow (3 mm) | 2 |
| 5  | Coupler link | 225 mm x 40 mm x 20 mm | Aluminium 6061 t6 hollow (3 mm) | 2 |
| 6  | Pin coupler flywheel | Ø20 mm x 32 mm | s45 c | 2 |
| 7  | Flywheel | Ø50 mm x 10 mm | s45 c | 2 |
| 8  | Shaft at flywheel | Ø15 mm x 200 mm | s45 c | 1 |
| 9  | Shaft at flywheel bearing (FBJ 6902) | d = 20 mm, D = 37 mm t = 9 mm | - | 2 |
| 10 | Pedal link bearing (FBJ 6905) | d = 20 mm, D = 37 mm t = 9 mm | - | 2 |
| 11 | Link coupler-flywheel bearing (FBJ 6803) | d = 25 mm, D = 26 mm t = 5 mm | - | 2 |
| 12 | Link pedal-coupler bearing (NTN 60/22) | d = 22 mm, D = 14 mm t = 12 mm | - | 2 |

From the two designs after static force analysis on the five positions of the two designs of bicycle transmission systems without chains, the magnitude of the force is as follows:

![Figure 6. Bicycle pedal force requirement against pedal position](image)

4. Conclusion
Based on the results of the design of a bicycle transmission system without a chain can be concluded:

a) CAD models made according to calculations and worked properly based on simulations of bicycle movements without chains.
b) The biggest force for pedaling a bicycle with a chainless transmission in the first design is 180.86 Newton when the pedal on top position, while the biggest force for pedaling a bicycle with a transmission without the second design chain is 208.46 Nn with pedals between middle and top position.

c) Based on the transmission system table the second design bicycle is better than the first design, depending on the angle of the paddle in the second design of 56° while for the 34° design is smaller 24° compared to the first design.

5. References

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