Fabrication and Design of Bicycle for Low Weight to Strength Ratio

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Abstract
A bicycle is one that is used for a normal leisure activity. However, its weight and cost have been overwhelming for people such as women and children who just enjoy bicycle riding as a simple exercise. This paper mostly focuses on a possibility of making a bicycle cheaper and lighter with less material used. A modified design is drawn in PROE and ANSYS simulation is also included for testing a possibility of a fracture of the design. Based on the modified design and data collected from the simulation, a real bicycle is fabricated and its process is described in detail.

Keywords
PROE, ANSYS, Simulation, Stress, Strain, Deformation

I. Introduction

A bicycle has been one of mostly chosen equipment for a casual leisure activity. This equipment traditionally has two wheels, a handle, and a seat. Also a gear system is installed to transfer power easily and many bars are set up to support a whole structure of it and whatever weight applied on it [1, 2]. As various kinds of need arise, a bicycle has been changed in its form such as design, structure and etc. For one thing, mostly to transfer power easily to wheels has been essential since such rough activities accompanying bicycle on a place like mountain has been popular among men [3]. However, ever since a lot of roads for only bicycle were constructed, bicycle's popularity has been rising between women and children. With that, need for a light-weighted bicycle has been rising. However, a cost of the bicycle has been too much expansive for non-professional bicycle riders since material of it is also too expensive. So, we tried to come up with a way to make a bicycle lighter without using expensive material such as titanium with modification of a bicycle structure [4-5]. In this project, we examined two ways to make a bicycle lighter and a possibility of making it by using two engineering programs: PROE and ANSYS. PROE is a cad designing software and ANSYS is analysis software [6-8]. A new design that is shown would help a lot of people who just ride a bicycle for a simple outdoor leisure activity and help them get a bicycle without paying too much money to get it.

II. Design

In general a bicycle consists of a complicated frame made of bars. Also it has two wheels, one seat, two pedals, and one gear system, etc. Of these parts, we tried to think which parts could give us a way to reduce weight. With that two ways were suggested. First way was to simplify a bicycle frame and the other was to get rid of a gear system including a chain. We mainly focused on these two ways. For measuring, a 21-inch wheel real bicycle was used and components size was modified when needed in comparison to the real one.

A. Simplification of a Bicycle Frame

In this part simplification of a frame was a main priority. Generally a bicycle frame has a triangle shape with three bars. We tried to remove two bars and have the remaining bar support the whole bicycle structure. Also a length of the reaming bar was shortened. Since only one bar was used, its thickness was changed bigger than it was.

B. Removal of Gear System

Another part to consider was a gear system. Since it always contains a chain and gears, getting rid of it was necessary to reduce the weight. We were worried about power transmission, but, this problem was solved by using a mechanism used in single wheel bicycle. Also it was expected that we could have a lower cost by removing it.

C. First Design

In the first design, Fig. 1, as it was planned, all the unnecessary frames were removed. However, it was pointed out that it could cause a serious safety issue: toppling. It was that a location of a seat was inappropriate. Also since most of parts are located in the front compared to the location of the seat, a distance between the seat and the center of gravity of the bicycle was too far, which could cause toppling easily. So an angle was needed to be added to the rear part of the bar. Plus, forks were too thin to support wheels and a seat.

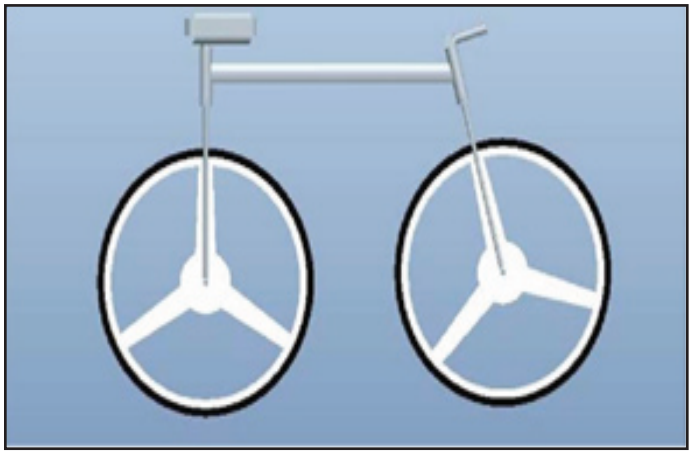

Fig. 1: First Design

D. Revised Design

As mentioned above, in the revised design, we gave an angle to the rear part of the bar. Also pedals were assembled and we made sizes of bars bigger for safety. The thickness of fork became bigger too.

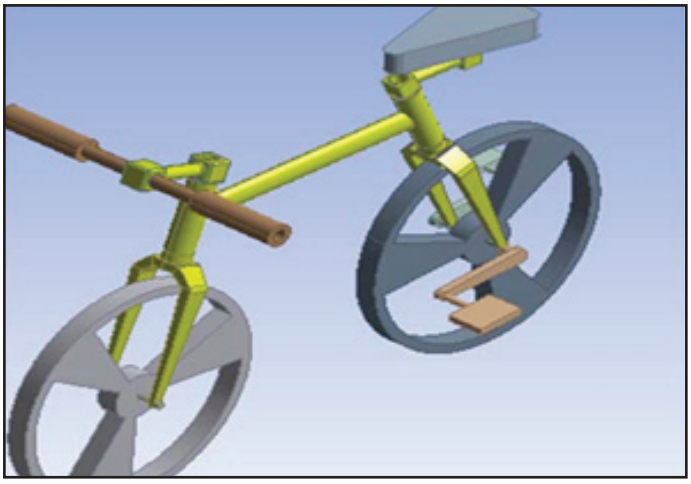

Fig. 2: Revised Design

E. Parts

Each of parts is fig. 3 to fig. 9 below. A size of the bar was made bigger in the body drawing as mentioned above. And we represented each of parts in more detail.

F. Material

To have the lighter weight and support the structure of the bicycle, aluminum was used. This material is known as one that provides high yield stress and light weight. The yield stress of aluminum is 280Mpa.

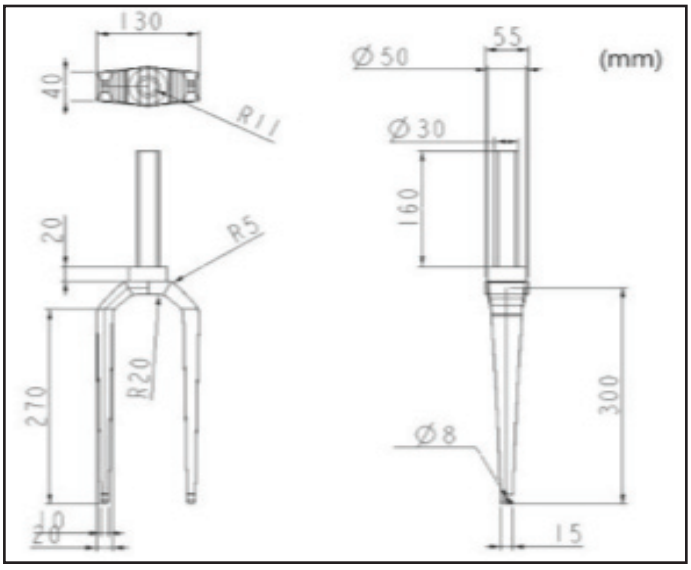

Fig. 3: Back Fork

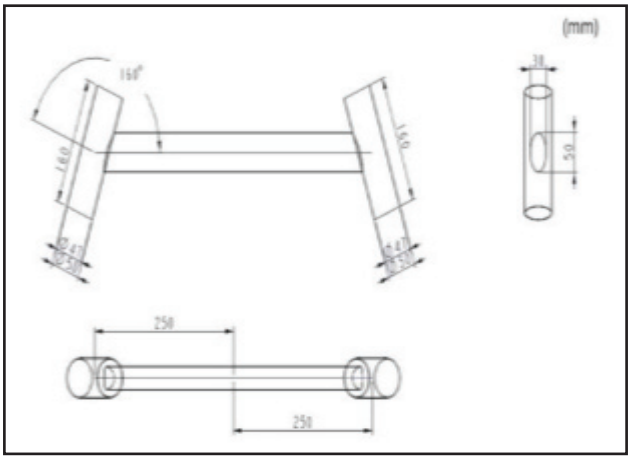

Fig. 4: Body

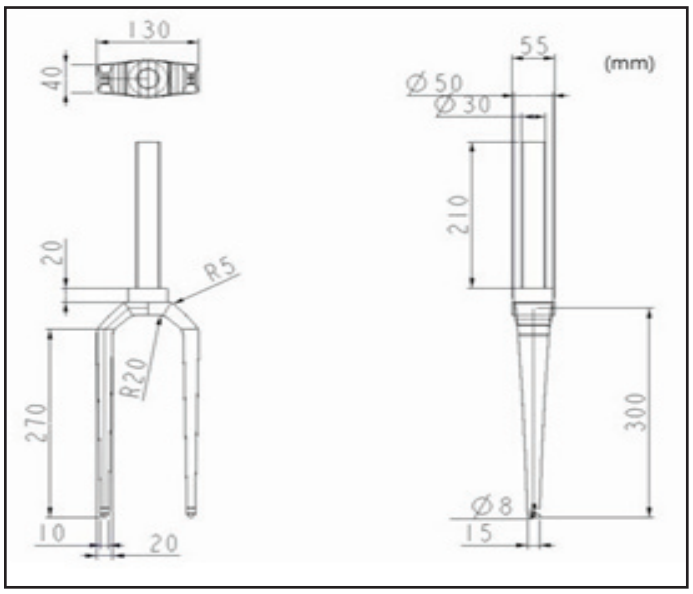

Fig. 5: Front Fork

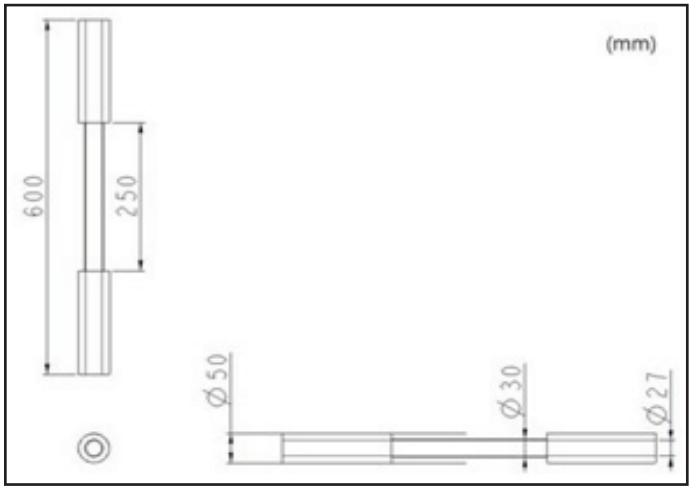

Fig. 6: Handle

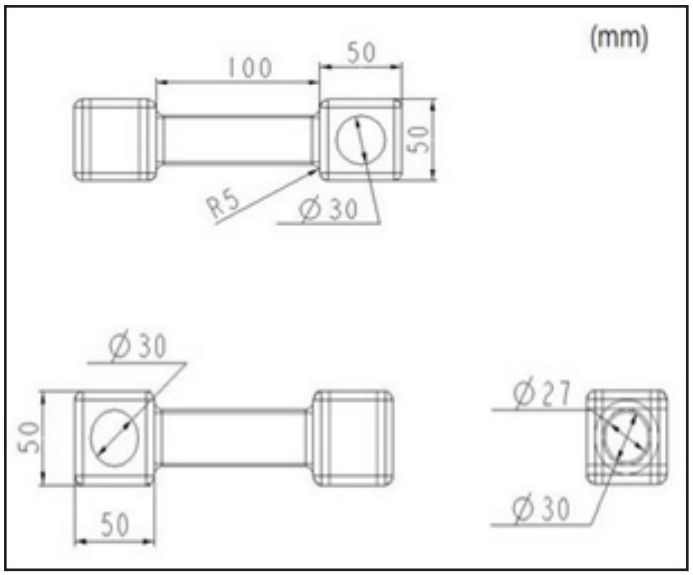

Fig. 7: Handle Connecter

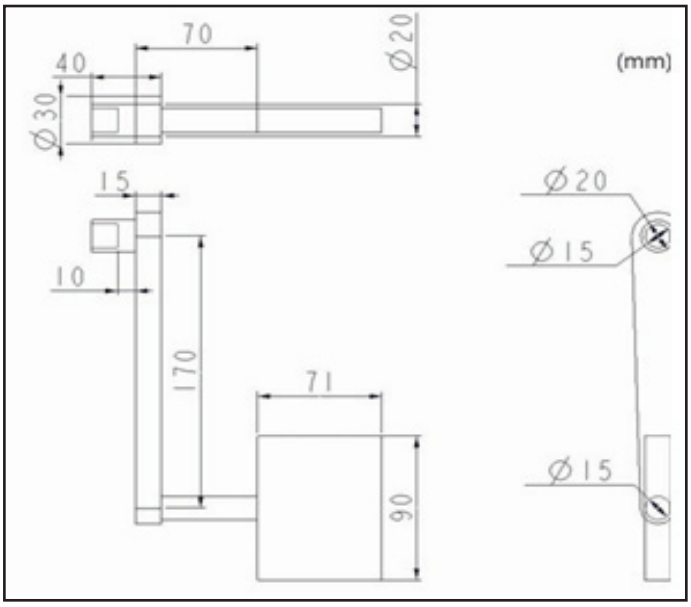

Fig. 8: Pedal

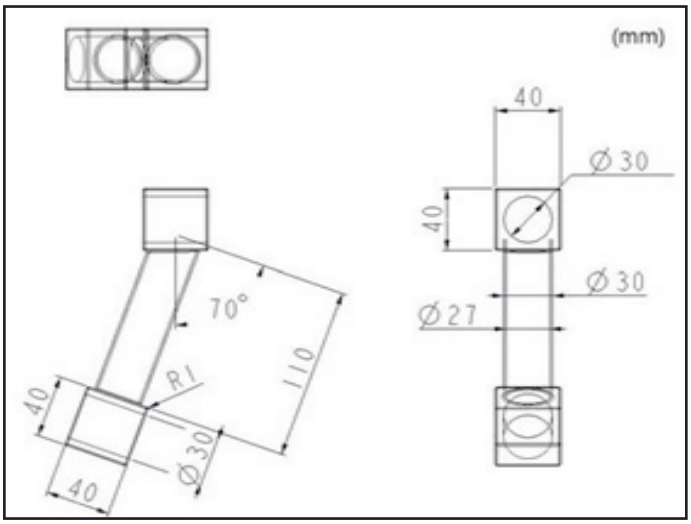

Fig. 9: Seat Connector

III. Analysis

To examine stress and strain, it was assumed that 100kg person as a maximum weight was placed on the seat. Since a weight is also exerted on a handle when person rides on it, we applied 100kg on the handle. We fixed the bottom of both wheels. Under these conditions simulation was executed. Mainly we focused on three aspects: equivalent stress, total deformation, equivalent elastic strain. After simulating the bicycle, we compared this yield stress of aluminum for a possibility of fracture. All the pictures were taken in a double scale. Each of pictures includes each maximum point.

A. Stress

Fig. 10 is the simulation for stress. The maximum stress is 140Mpa. It was found out that the maximum stress of the bicycle is lower than the maximum aluminum yield stress of 260Mpa. It means that it is safe to fabricate the bicycle with this design since the maximum stress of the design was almost an half of one that aluminum has. As we expected, the maximum stress was shown on a seat connector.

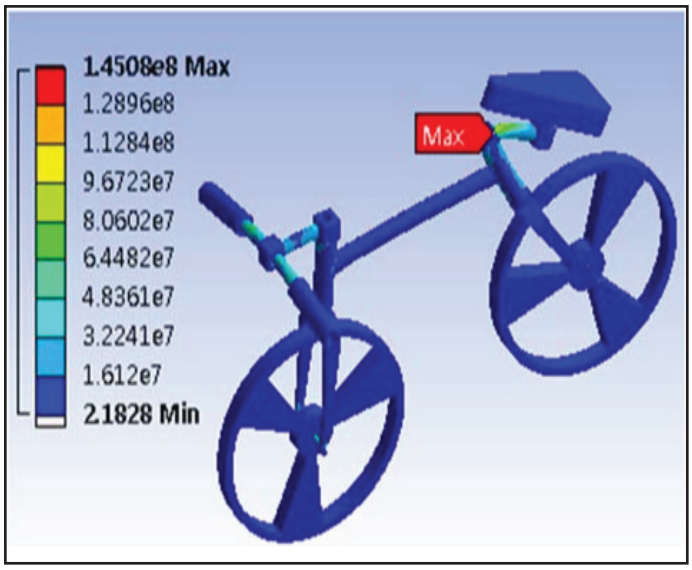

Fig. 10: Stress

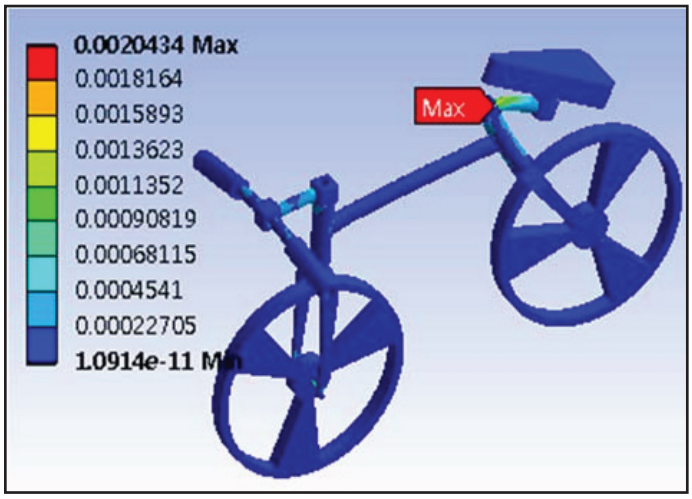

Fig. 11: Elastic Strain

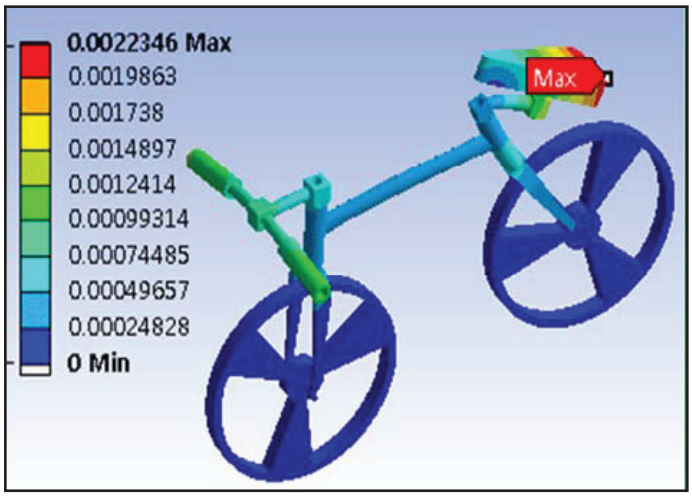

Fig. 12: Total Deformation

B. Elastic Strain

Elastic strain is shown in fig. 11. The maximum elastic strain was also shown on the seat connector. We concluded that this strain was very trivial and had no influence on the fracture.

C. Total Deformation

The total deformation in fig. 12 was not that much different from the elastic strain. But, a position of the maximum was changed.

The maximum point was on the rear part of the seat. A reason for this was because when a person rides on it, one's body weight is mainly applied at the edge of the seat.

IV. Fabrication

Based on simulation and cad designing data, we fabricated our concept into a real exquisite piece of equipment. For fabrication, first we purchased two bicycles and disassembled their structure to combine them into one bicycle.

A. Tools

For the fabrication a variety of tools were used. A wrench set was used for fastening and loosening screws. A vernier-caliper was used for measurements and a grinder was used to shape the main bar as we needed. A saw was used for cutting and a vise was used for fixing when the main bas was shaped and cut.

B. Wheel and Handle

As shown in fig. 13 and fig. 14, wheel parts including forks were cut off for assembly. The handle, wheels and forks were used as shown in fig. 13. Sizes of these components were bigger than one used in analysis, which means it is safe to use them.

C. Main Bar

The main bar in fig. 16 was cut from a bicycle. Since the wheel parts were round shape and had to be inclined as shown fig. 2 it was fixed and grinded based on the cad design shown in fig. 4

D. Pedal

The pedal was one of the most important parts since it is in charge of transferring power to the wheel. For this, a concept of a single wheel bicycle was applied. How this works is that a specially made hub that makes it possible to isolate its rotation from an axis of a wheel rotation is installed, which means that a rotation of a crank controls the wheel rotation.

E. Assembly

For assembly, arc welding was used. The main bar and two wheel parts are directly attached and welded. Also as explained in the pedal part, pedals were installed with the concept of a single wheel bicycle [9, 10]. Fig. 18 is the picture of bicycle we fabricated.

Fig. 13: Front Wheel and Handle

Fig. 14: Rear Wheel

Fig. 15: Connection Part

Fig. 16: Main Bar

Fig. 17: Grinding of Bar

Fig. 18: Fabricated Product

V. Conclusion

It was pretty obvious that bicycle is not only a toy for children but also expensive equipment for a lot of leisure activities. At the same time it contains various mechanical concepts such as dynamics, solid mechanics and mechanical design. Along studying these subjects, we were only able to learn concepts in text books without having a chance to confirm how it is applied to real machine. Also the fact that these concepts are connected closely was surprising as we progressed with the project. Fabricating the bicycle, everything did not work out well as we designed. Cutting and sawing had to be done in a delicate way and welding was not easy as we thought. It was literally laborious work. In addition, choosing material was such complicating work. We all had to know about material well more than we thought. Through all the process during this study, we realized everything has to be in balance otherwise designing fails.

References

[1] Budynas R. G., Nisbett Jones J. K., "Shigley's Mechanical Engineering Design J 9th edition", McGrawHill., New York., pp 7 1-126

[2] Beer, F. P., Johnston, E. R. Jr., Eisenberg, E. R.,"Vector Mechanics for Engineers: Statics 8th edition", McGrawHill., New York., pp. 286 – 304, 2007.

[3] Gere B. J., Goodno B. J.,"Mechanics of Materials 7th edition", Cengage Learing., Toronto., pp. 454 – 513, 2009.

[4] Hibbeler R. C.,"Engineering Mechanics Dynamics 11th edition", Pearson., Jurong, pp. 385 – 441, 2007.

[5] Smith W. F.,"Foundations of Materials Science and Engineering 3rd edition", McGrawHill., New York., pp. 877- 878, 2004.

[6] Wohlers T. T.,"Applying Auto CAD 2010", McGrawHill, pp. 1 - 341, 2009.

[7] Lamit L. G.,"Pro Engineer WildFire", Thomson, 2004.

[8] Lawerence K. L.,"Ansys Tutorial Release 11.0", SDC Publication, 2007.

[9] Geary D.,"Welding", McGrawHill, New York, 2000.

[10] Jeffus L.,"Welding Principle and Application -5th edition", Thomson, USA, 2004.

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