Design and Fabrication of Foldable Bicycle

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Abstract

In the present day lifestyle man is not able to dedicate specific time for his health, importance is least given to exercise and body fitness due to time shortage and stressful life. To cope with time deficit, we can utilize the time spent on commuting efficiently to exercise by using bicycles, thereby also contributing to pollution control. But regular bicycles occupy sufficient space to park, are not easy to carry around and are probable to theft. Transport has been one of the most important issues to be dealt with in the present day situation as commuting from place to place within the city has become a tedious and an expensive task. It is very difficult to reach the nearest public transport facility and in many cases the destination will be very far from the main roads where the public transport might not be able to commute or it might be very expensive. To overcome a common problem faced by the society, an idea is conceptualized to design and fabricate a foldable bicycle. We already have seen many foldable bicycles in the global market but the main idea of this project is to provide a foldable bicycle which is light & sleek yet rigid & safe, easy to handle and easy to maintain. Unlike the conventional cycles, this bicycle will occupy very less space and also is very easy to be carried around. The main objective is to design and develop a foldable bicycle which is comfortable to ride and economical.

Keywords - *Foldable bicycle, health, transport, conventional bicycles, comfort and economy*

I. INTRODUCTION

In the present day lifestyle man is not able to dedicate specific time for his health, importance is least given to exercise and body fitness due to time shortage and stressful life. Obesity is one of the common issues seen in the society, which leads to many health hazards. Exercises are advised for health promotion, and treatment for many diseases. Among the exercises aerobic exercises are appropriate for these purposes. To do aerobic exercise many methods are available for example: running, jogging, walking, cycling and others.

Transport has been one of the major issues in developing cities such as Bangalore since commuting from one place to another has become tedious and expensive. With the petrol and diesel prices increasing day by day, almost all the modes of transport are becoming expensive. It is difficult to reach the nearest public transport facility and in many cases the destination will be far from the main roads where the public transport might not be able to reach due to the small roads, to avoid which most people use vehicles of their own, which in turn leads to issues with parking, traffic, etc. But not all can opt for having own vehicles as it is expensive. With such issues in health, transport, space for parking, etc. one solution that comes to mind is bicycle. Bicycles are being promoted in the corporate and educational sectors. But how convenient is it to use a conventional bicycle? In many cases there is no special facility provided for locking the bicycles and even if one is present, it is probable to theft, which is one of the fears that obstruct use of bicycle. Conventional bicycles occupy sufficient space and hence providing one at work place or at home are quite difficult. They are probable to be exposed to the weather outside and do require frequent maintenance. With all such issues in the conventional bicycles, the next possible solution is the usage of foldable bicycle. With foldable bicycles, there is no issue since the bicycle can be folded and carried around to the work place or even it can be used to reach the nearest public transport facility and then folded and carried along. Since the bicycle is being folded, it occupies very less space and doesn’t require any special parking space. They are not exposed to the weather since they can be carried inside buildings with ease and hence prone to less maintenance. The usage of foldable bicycle helps combine the different modes of transport as mentioned above, which helps in cutting down some cost involved in travelling.

Foldable bicycles are available in the market, but are expensive since they are being imported. There are very few recognized foldable bicycle manufactures in India. Hence we ceased the opportunity to provide a low cost, locally manufactured foldable bicycle.

II. DESIGN OF HINGE AND FRAME

First the existing designs of the foldable bicycles were studied. It was found that almost all the bicycles have a very similar frame design and folding mechanism. That gave us way to change the design of the frame and also improve the folding mechanism by making it simple. Once all the survey on the existing designs were done, few hand sketches were done. The feasible ones i.e. the ones that were having proper ergonomics and were easy to manufacture were selected for comparison.

The bicycle frame concepts developed were based on the ergonomics of the convention bicycle frame. The concept designs were built with reference to the following frame structure.

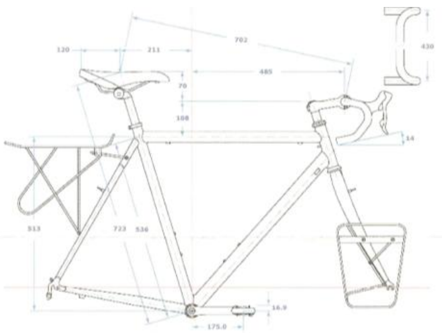

Fig 2.1: Standard Bicycle Frame Size

The following are the selected designs for further comparison.

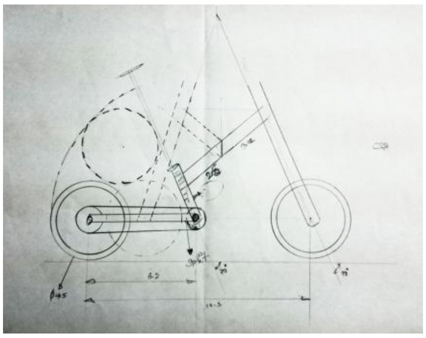

Fig 2.2: Alternative I

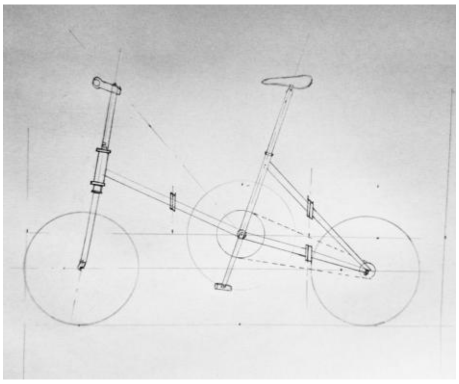

Fig 2.3: Alternative II

A. *Comparison of the Concept Designs*

The first design is one which employs a single fold in the bicycle and a swiveling joint is provided near the hub so that the rear wheel folds over. This design made the bicycle fold to an approximate box of 36” X 24” X 15” in volume which seemed a little bulky. The axis of the hinge was made perpendicular to the ground and the cross-section of the frame used is elliptical.

On the other hand the second alternative has two folds, one at the front and one at the rear. On approximating the dimensions of this design, after folding, it occupies a volume of 25” X 20” X 15” which is a pretty good improvement compared to the first alternative. Similar to the former, even this design employs hinges with axes perpendicular to the ground. But this design is based on frame with a circular cross-section.

On comparing both the designs for volume occupied, ease of fabrication and cost of fabrication, it was found that the second alternative was advantageous over the first as it occupied less space and the fabrication didn’t seem complicated. Hence after many brainstorming sessions, the second alternative was selected.

B. *Material Selection*

Next was the selection of suitable material for the frame. It was important to make the frame sturdy, yet light. After long sessions of discussion it was finalized to use the standard material used in conventional bicycles i.e. Mild steel.

Mild steel is easily available in the required diameter and length and is also not expensive. One main advantage of using mild steel is that it is easy to fabricate with it as welding of mild steel is by arc welding process which is cheap compared to other welding methods. Use of other materials like alloys of aluminum was not selected as the availability is less and also the fabrication cost is high.

Mild steel tubes of 1”, 1.5”, 0.5” are easily available in the market and are the ones used for conventional bicycle manufacturing. The hinge found in the market is also made of mild steel which eases the process of joining the frame to the hinges.
The following are the chemical composition and mechanical properties of mild steel.

Chemical composition

Carbon	0.16-0.18%
Silicon	0.40% max
Manganese	0.70-0.90%
Sulphur	0.040% Max
Phosphorus	0.040% Max

Mechanical properties

Max Stress	400-560 n/mm^2
Yield Stress	300-440 n/mm^2 Min
0.2% Proof Stress	280-420 n/mm^2 Min
Elongation	10-14% Min
Young’s modulus	210 Gpa

C. *Hinge Design*

The hinge being a very important member of the frame required utmost attention. The hinge is the load bearing member. After a long survey of the existing hinge mechanisms used in the foldable bicycles, it was found that most of the bicycles used similar kind of hinge and locking mechanism.

The mechanism used was simple, but manufacturing something similar with available resources turned out to be expensive. But the hinge mechanism or the simplest hinge mechanism used in Brompton bicycle caught our interest. This mechanism was very simple and used a screw and spring loaded mechanism to lock the hinge. The design was simple yet strong and chances of failure is minimal.

The following figure shows the hinge mechanism used in the Brompton bicycle.

Fig 2.4: Brompton Hinge Clamp Mechanism

This design inspired us to come up with something similar with locally available resources. First a hunt for the right type of hinge to be used was done. The Specification report on Steel butt hinges by Bureau of Indian Standards gave us the following information regarding the heavy duty square hinges.

Table 7 Dimensions of Heavy Weight (Type 2) Mild Steel Butt Hinges
(*Clauses* 3,5.1, 6.2.2, 6.3, 6.4 *and* 6.4.1)

Size	Length	Breadth	Thickness of Flap	Diameter of Hinge Pin	No. of Knuckles	No. of Screw Holes	Holes for Screw No.
	A	*B*	*C*	*D*			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
mm	mm	mm	mm	mm			
50	50 ± 0.5	38 ± 1	2.00 ± 0.08	3.15 ± 0.08	3	6	6
65	65 ± 0.5	43 ± 1	2.10 ± 0.08	3 55 ± 0.08	5	6	6
75	75 ± 0.5	48 ± 1	2.45 ± 0.08	4.00 ± 0.08	5	6	7
90	90 ± 0.5	53 ± 1	2.50 ± 0.08	5.00 ± 0.08	5	6	7
100	100 ± 0.5	59 ± 1	2.60 ± 0.08	5.60 ± 0.08	5	8	8
125	125 ± 0.5	65 ± 1	2.80 ± 0.08	5.60 ± 0.08	5	8	9
150	150 ± 0.5	75 ± 2	2.80 ± 0.10	6.30 ± 0.08	5	8	10
175	175 ± 0.5	80 ± 2	3.20 ± 0.10	6.30 ± 0.08	5	10	11
200	200 ± 0.5	90 ± 2	3.50 ± 0.10	6.30 ± 0.08	5	10	11

NOTE — Dimension *B* is for uncranked hinge. For cranked hinge, this dimension will increase accordingly.

Table 2.1: Dimensions of Heavy Weight Mild Steel Butt Hinges

We identified the proper hinge for our bicycle, we selected the 50mm X 50mm hinge, it was up to us to modify it for the purpose. A normal mild steel hinge was to be converted into a member that can lock after the bicycle was unfolded. This was a challenging task. Once the required data was gathered regarding the dimensions of the hinge and frame, the hinge was modeled using 3D tools.

The clamping mechanism was also designed with the hinge.

The following figures show the hinge clamp mechanism.

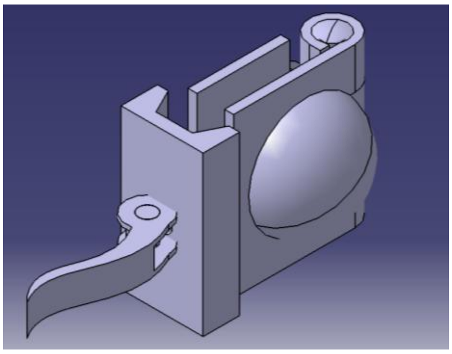

Fig 2.5: 3D Model Of Hinge Mechanism

The Hinge was so designed that welding the mild steel tubes to it any angle was an easy task, which is achieved by using the half cups on each face of the hinge. An M6 25mm long nut was to be welded on the inner face of the hinge to facilitate clamping.

The clamp was designed based on the dimensions of the hinge. The clamp is so designed that the hinge can be locked with minimum effort yet there is no compromise with the strength of the clamp. The following figure shows the CAD drawing of the clamp that has to be machined.

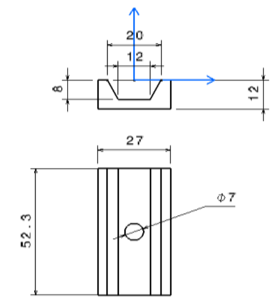

Fig 2.6: Draft of Hinge Clamp

D. 3D Model of the Frame

The 3D model of the bicycle frame was developed based on the concept design. First a 2d draft of the design was done in AutoCAD with the required dimensions and angles, then a skeleton of the bicycle frame was developed with the position of the hinges.

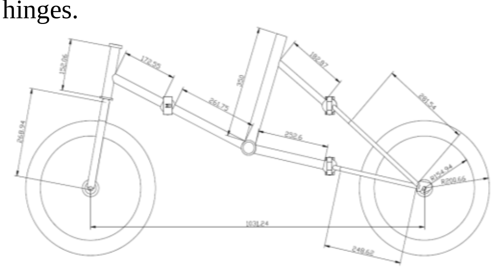

Fig 2.7: Draft Showing Measurement of Frame Members

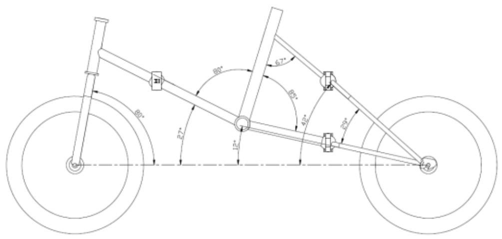

Fig 2.8: Draft Showing Angles Between Frame Members

III. FABRICATION

The fabrication of the bicycle was done with the help of the CAD drawings. First the hinges were fabricated, followed by the frame.

A M6 25mm long nut was welded on the inside of the hinge first. The two half cups were welded on the outer faces of the hinges. Once that was complete, the machined clamp and was assembled with the hinge with the help of quick release levers.

The hinge after fabrication is as shown in the figure below.

Fig 3.1: Fabricated hinge clamp system

Once the hinge was successfully done, the fabrication of the frame started.

First the bottom shell was taken and the seat tube was welded to it. The figure shows how the fabrication was carried out. Once the seat tube was fixed, came the tricky part where the frame tube, the rear part of the frame etc. were to be welded at different angles. With reference to the CAD drawing, the angles were measured and the welding was done carefully and rechecked for errors in angle and straightness of the members. Once the tubes were welded to the right angle and cut to the required dimension, the hinges were welded to the ends of the tubes, making sure that all the hinge axes were perpendicular to the ground. After the hinges were welded, the hinges were clamped tight and then the rest of the welding began. After the members welded, they were folded and checked for errors. The above figure shows how the rear part of the bicycle folds. Welding of the front end of the frame and the head tube assembly followed. After the welding was done the whole frame was checked for alignment errors and once the errors were rectified the weld was finalized and the process of grinding the joints was carried out. Once the whole frame was ready, the wheels were assembled to the frame and the alignment was checked. Then the frame was folded and checked for errors. After the folding errors were checked, the frame was tested for load carrying capacity.

IV. TESTING FOR BENDING AND COMPRESSION LOADS

A. Bending Test

The tube used to fabricate the bicycle was subjected to bending test. A tube of outer diameter 1 inch, 16 gauge and length 10 inches was used as the test specimen. The specimen was mounted on the UTM with necessary arrangements to perform bending test. The specimen was supported by two v-blocks and then the bending test was done. It was observed that the tube does not show much deflection till a load of 4 KN, but the since the tube is hollow first the outer surface of the tube was bent then the whole tube started bending. The bending test was carried out till a deflection of 8.5 mm was observed. The variation of the deflection with respect to the load is as shown in the graph below.

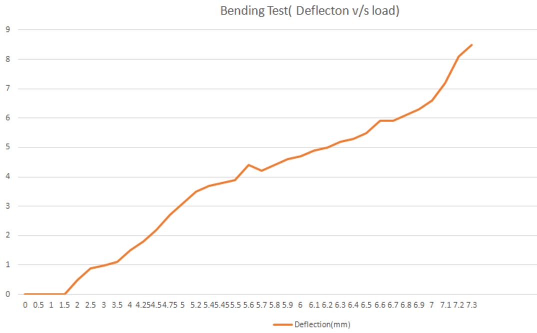

Fig 4.1: Graph of Deflection v/s Load for bending test

The following figure shows the specimen setup on the UTM and the specimen after the bending test was performed.

Fig 4.2: Specimen Setup on UTM for Bending Test

B. Compression Test

The mild steel tube was cut and welded to the angle as in the frame design and tested on the UTM till fracture. The mild steel tube of outer diameter 1 inch and 16 gauge was used to build the specimen as per the required dimensions. Compressive load was applied on the specimen. It is observed that there is very less deflection up to a load of 4 KN and then the joint shows plastic deformation at 5KN and then fractures at a load of 6.5 KN. The result of the test is plotted as a graph of deflection versus load and is as shown in the below figure.

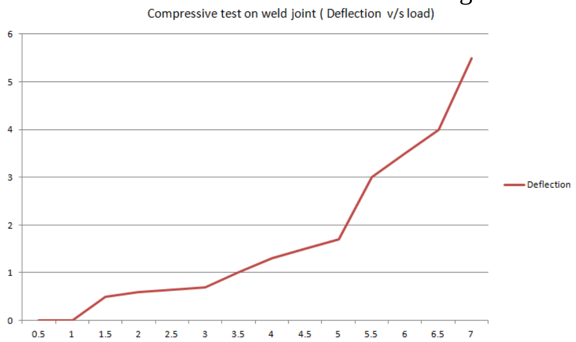

Fig 4.3: Graph of Deflection v/s Load for Compression Test

C. Practical Testing

Once the bicycle frame was fabricated with reference to the design, it was practically tested to check if any bending was observed near the hinges. It was found that there was a considerable bending in the front portion of the frame. The figure shows the region where the bending was experienced. As this was one major problem to be dealt with, a slight modification had to be done on the frame which is clearly explained in the next chapter.

Fig 4.4: Area of Failure Highlighted

V. MODIFICATION & FINISHING

As it was found that the frame was bending at the joint, the design required a modification. The only possible solution was to reinforce the frame. The frame was reinforced by adding an extra member in between the seat tube and the head tube. The figure shows how the design was modified.

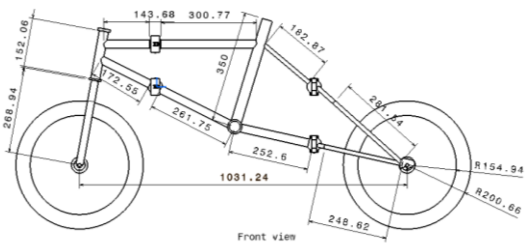

Fig 5.1: Dimensions of Modified Frame

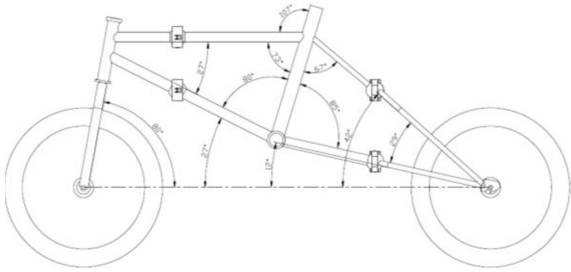

Fig 5.2: Angles Between Members in the Modified Design

Once the design was finalized, the frame was modified. After the fabrication, the frame was tested again to check for any other faults. After the modification, the frame looked as in the figure.

Fig 5.3: Modified Frame

The bicycle was folded and checked for flaws. The figures show the bicycle after folding.

Fig 5.4: Modified frame Folded

VI. CONCLUCION

The design of the foldable bicycle was based on the standard data available. The fabrication was done using locally available materials.

Compared to the foldable bicycles existing in the market, our bicycle is economical and occupies less space. The weight of our bicycle is with par with light weight bicycles available in the market, though the material used for fabrication is mild steel.

The bicycle has adjustable seat and handle positions enabling both children and adults to use the same bicycle.

Though the bicycle is foldable, sleek and having small wheels, complete justice is done to the ergonomics of the rider hence making it comfortable.

The idea of providing a foldable bicycle which is light & sleek yet rigid & safe, easy to handle and easy to maintain has been met.

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