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Design And Fabrication Of Foldable Bicycle

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ABSTRACT

The basic purpose of this invention is to conduct the design and fabrication of a foldable bicycle, which can be folded into its smallest possible form and stored in minimal spaces, thereby enabling the user to carry and transport with ease. The main frame folding is achieved by a combination of thrust and ball bearings positioned in between the seat tube and the top tube. The rider's position is thus fixed at a position so that the load does not concentrate on the bearings. Upon folding the front frame, the handle bar can be folded to a 90 degree angle w.r.t top tube and locked at the position to obtain a two-part frame which lies virtually parallel. The assembled frame is fixed in riding position by using Nut and Bolt mechanical joints. Apart from the folding characteristics, a provision to detach the bicycle into two separate frames is provided by a bar-in-tube linkage, which constitutes the top tube. The design and analysis is done using Autodesk Inventor Professional 2015 and verified using Abaqus 6.13 FEA software. Following the design, fabrication processes were done by using standardized operations of Manufacturing, with Mild Steel and Aluminium as the selected materials.

KEYWORDS: Folding Cycle, Bicycle Frame, Design and Analysis, Eco-Friendly

1. INTRODUCTION

1. Field of the Invention

This present invention is in relation to folding bicycles or the like.

2. Background of the Invention

The design of the invention correlates to a bicycle which can be folded into its most compact form and can be carried and stored in minimal spaces, enabling the user to have an affinity towards cycling, the eco-friendly method of transport. It has all the characteristics of a normal bicycle, but has the ability to be petite and neat. The bicycle can support the weight of an average adult, and still can be transferred physically with ease anywhere he goes.

The previous inventions in the field have been referred to and studied thoroughly while adopting the idea. In 1965, Carnielli [9] brought forward the exclusive design behind the foldable bicycle. Since then, there have been numerous inventions recorded in this interest up to the 2011 by Wang-Hsing Lin[13]. The study involved totally 13 references within the above mentioned time range, each one helping understand and work on improving the design. The papers **[1]**,**[2]**,**[4]**,**[5]**,**[11]**&**[13]**titled"Foldable Bicycle" and **[3]**,**[6]**,**[7]**,**[8]**,**[9]** &**[10]** titled "Folding cycle", imposing a clear, distinct and specific conceptual design for implementing in this invention.

But the existing designs are handicapped when it comes to cost and foldable ease. This arises due to use of composite materials and complex kinematic linkages that require more manufacturing requirements to implement.

Innovative designs have been brought about from the previously existing ideas and thus the final outlook of the invention was set. **Fig.1** shows the side-view of the drawing of the Foldable Bicycle when it is in the riding condition. The important parts of the structure have been labelled using numbers in the figure, and will be thoroughly explained in the sections to come. **Fig.2** depicts the drawing of the folded form of the invention shown from the side-view. The detachable design is convincingly showed in **Fig.3**, helping to easily understand the mechanism without any difficulty as such.

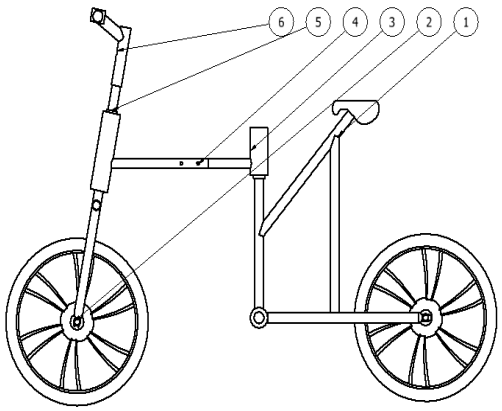

Fig.1

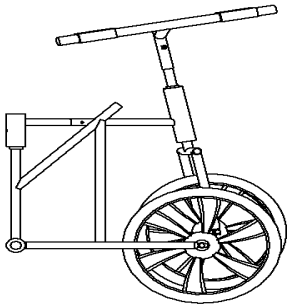

Fig.2

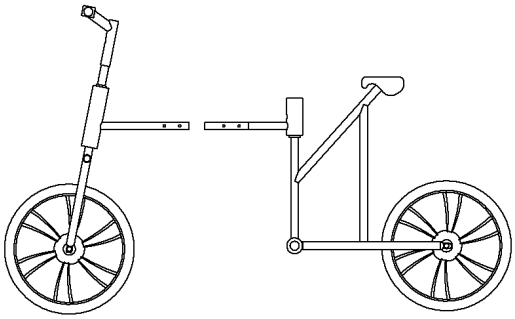

Fig.3

The invention's objective is to overcome the above mentioned disadvantages and implement a design that uses basic mechanical joints to assemble a frame that is foldable by an individual of average human height and strength.

2. DESIGN OF THE INVENTION

According to the invention, the main frame folding is achieved by a combination of thrust and ball bearings positioned in between the seat tube and the top tube. A rearward folding mechanism which is easy and quick is thus achieved through this invention. The assembly can be separated into Front support and Back support assembly. The front support assembly consists of the handle bar, fork blades to support a front wheel there-between with the front hub and brakes relative to it, and a section of the top tube. The Back support assembly consists of the free wheel hub supporting the rear wheel; chain attached to the crankset and pedals, seat post & seat tube, and most importantly the remaining section of the top tube. The folding section which comprises of a pipe fitted with a combination of thrust and ball bearings, set vertically and welded to an end of the top tube and the seat tube. The novel description of this invention is thus the addition of a two-part seat tube, avoiding the application of any load on the folding joint. The load of the rider is thus being supported by a more durable truss design, which has the capability to carry an 800N load on the saddle.

Apart from the main fold, there consists of an alternative fold at the handle bar to obtain a parallel setup for easier storage facility. The handle bar has the capability

to be folded to a 90 degree angle with respect to the top tube, and can be locked at the position to obtain a two-part frame which lies almost parallel to the frame.

The Front support and back support assembly, each consist of a section of the top tube. This is to provide the concept of a detachable frame apart from the foldable concept. The detachable mechanism is by using a bar-in-tube linkage, which has the ability to be locked and unlocked at will.

The invention has a simple objective and that is by the use of simple mechanisms. Thus the locking mechanism for all the movable joints during the riding situation are done using Nut and Bolt mechanical joints at specific locations for fixing the frame of the bicycle perfectly and provide necessary constraints.

According to the structure of the bicycle and the mechanisms stated above, one can obtain immense benefits from this invention due to its simple, quick and innovative mechanism. Bicycle Geometry charts were referred throughout the process of the invention, so that there will not be any compromise to the ergonomics during the use.

The Design was finalised after going through different papers by learnt scholars, and it was done by using the Autodesk Inventor Professional 2015 software. The material for the fabrication of the invention was chosen from Pugh's and Numerical concept selection method. The appropriate material for fabrication was found using Ashby's Charts. Mild Steel and Aluminium was thus decided as most apt and efficient material at for the invention in hand. The final conceptual design has been shown below considering different conditions.

Fig. 4

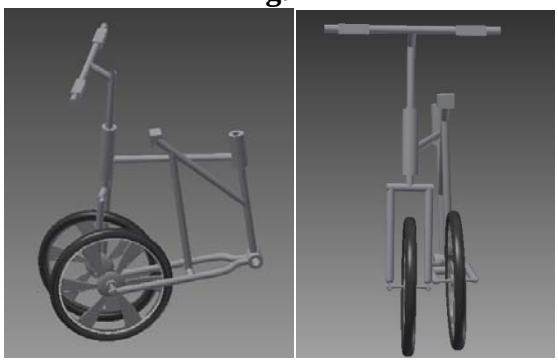

Fig. 5a & Fig. 5b

Fig. 6

The design section using Autodesk Inventor Professional 2015 helped in easier and less time consuming design creation. **Fig.4** has shown the Foldable Bicycle in riding condition, having all its movable joints locked in place using Nut-and-Bolt Joints. **Fig.5a** & **Fig.5b,** have shown the side-view and front view of the bicycle, respectively, at its folded and compact condition. **Fig.6**, depicts the detachable form using the software.

3. FEA-ANALYSIS OF THE STRUCTURE

The invention was taken through a structural analysis for finding its durability and resistance to failure at different load conditions. The Analysis was initially conducted using Autodesk Inventor Professional 2015 software, and followed up using Abaqus 6.13 FEA software for a comparative study, with the latter being considerably more precise and accurate.

The final result yielded from the analysis in Inventor was **334MPa** of **Von Mises Stress**for a load of 80kg at the seat and 1.5kg evenly distributed along the handle as shown in **Fig. 7**. The result was verified in Abaqus 6.13 FEAsoftware, and a **factor of safety (FOS)** of **2.4** was obtained. The **Dynamic Analysis** (Implicit) yielded a Maximum Von Mises Stressof **72MPa** for a tabular varying load, shown in **Fig.8**.

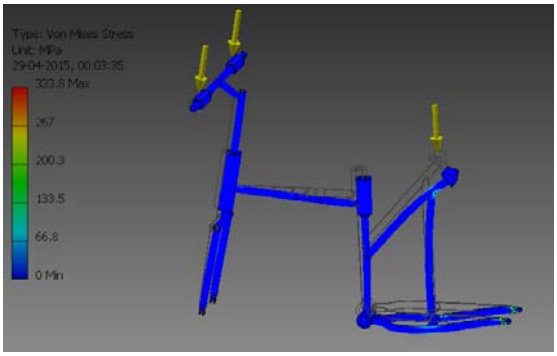

Fig. 7

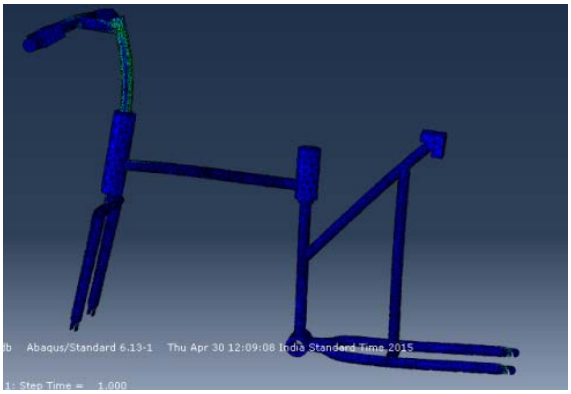

Fig. 8

4. FABRICATION OF THE STRUCTURE

Finally, the second part in the title of the inventionspecifies the fabrication part of the invention and it is thus carried out using the basic manufacturing processes. Here, the invention has been carried out by using Mild Steel as the material due to ease of its availability and to reduce the cost.

Steps in Fabrication Process:-

1. Tube Cutting:- The 1inch Outer Diameter pipes and rods of required lengths are cut using the cutting machine
2. Lathe, Grinding and Bending:- The cut tubes are fine finished and the following processes are thus carried out.
3. Drilling:- Holes are drilled at specific locations based on design. 8mm holes are used universally for the invention to avoid the confusion during Nut and Bolt Mechanism.
4. Joining:- Welding is carried out at specific locations according to the design in hand
5. Assembly:- The basic parts of the bicycle are fixed to the invention
6. Painting:- Simple method to avoid rusting or corrosion.

5. BRIEF DESCRIPTION OF PREFERRED EMBODIMENT

Considering all the parts described in FIG. **1**, the embodiment is being specified clearly in this section. Indicated by reference numeral **3** is the most important part considering the design of this invention, the Bearing which acts as the source of the main fold of the bicycle. It validates the approach of a rearward foldable mechanism to the bicycle frame for the impact features of this invention. The Bearing is secured by Two Nut-and-Bolt joints for locking it during the riding condition for stability of the frame. The bearing provides a rotational motion of close to 180 degrees, thus helping the front and back wheels **(2)** to be aligned parallel to each other. The Bearing is attached to the Top Tube **(4)** and Seat Tube **(1)** at its two ends**.**

The Top Tube **(4)** is attached to the front fork **(5)**. The front fork has bearings attached to its interior so as to provide mechanism for rotating the handle bar **(6)**,

which is attached to the top of the front fork **(5).**The Handle bar **(6)** has been locked using Nut-and-Bolt Mechanism, and has the ability to be rotated to 90 degrees with respect to the wheel, and thus locked by the same mechanism.The lower end of the front fork **(5)** has the wheels **(2)** attached to them. Now to specify the detachable condition of the Top Tube **(4)**, a Bar-in-tube linkage is used, which is not visible on the exterior until detached. Again, locking done using the Nut-and-Bolt joints.

Indicated by reference number **1** is the Seat tube, the position where the riders load acts. Here a two-part seat tube is used so as to avoid riders load on the core of the bicycle. Chain stay and Rear Wheels constitute the Back Frame Assembly. The Chain stay and top tube dimensions were taken from a standardised chart for a road bike for an average man of height 5.5ft. The frame load is mainly concentrated on the rear fork ends (evident from stress analysis). This portion is reinforced using appropriate welds.

In reference to FIG. **2**, the final fold achieves a near perfect coincidence of the front and rear fork ends, thus enabling a fold of full **180** degrees.

6. CONCLUSION

In this study, a unique foldable bicycle design has been developed and fabricated, as shown in **Fig.9**. Initially, conceptual designs were made and evaluated using the Pugh's and Numerical concept selection methods. Bicycle geometry charts were used to ensure that the bicycle is ergonomically fabricated. Material was chosen with the help of Ashby's material selection chart and the design was validated by Finite Element Analysis under static loading conditions.

Fig. 9

The complete folding is done with minimal effort and time unlike the existing designs which is either time consuming or has a relatively complicated folding mechanism. The bicycle is currently weighing around 17kg when mild steel is being used, but when Aluminium is adopted, the weight gets reduced by 47%, to 8kg. To focus on the dimensions, the invention adds up to only 708.6 mm after being folded and can be stored with ease. The parallel setup helps the storability in cupboards,

under the bed and in the boot space of a hatchback, as shown in **Fig.10**. Thus, being compact, inexpensive, light-weight, eco-friendly, cost effective and exclusive, it can bypass the use of air polluting individual vehicles and set a new positive trend in India.

Fig. 10

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