Design and Analysis of Cycle Frame with Different Materials

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Abstract—A bicycle is the most primitive forms of transportation and it consists of a frame attached to two tyres. A bicycle is still the main method of transportation in various parts of the world and also the most popular type of vehicle (viz. Flying Pigeon model of the cycle in China). However though the cycle seems to be ‘perfect’ form of transportation for short to medium distances and being environmental friendly since it produces no toxic gases while working, a cycle can be termed as the cleanest means of transportation. However, there are certain sectors where the cycle can be improved further, for instance the material used in bicycle frame though a bicycle weighs between 19-15 pounds still we believe there is a room for weight reduction and also at the same time the traditional materials used (hot rolled steel or aluminium rods) are harmful to the environment as they are not easily bio-degradable. Therefore, there is a need to counter these two shortcomings the traditionally used hot rolled steel/aluminium rods were replaced with bamboo of required diameter and length to provide sufficient strength to make the bicycle safe for practical purpose, also the cost of bamboo is also very low as compared to a metal rod of same length and requirement additionally weight of the bamboo is substantially less metal rod.

Keywords—FEA (Finite Element Analysis), Factor of Safety, Meshing, Impact Force, Impulse-Momentum Equation.

I. INTRODUCTION

A traditional bicycle frame is basically a two triangle type of frame which is a optimized design between weight of the frame and strength. This basic design is used worldwide for manufacturing of bicycles however the length, diameter and internal thickness of the rods may vary for different age groups for whom the bicycle is to be manufactured as the bodily dimensions vary in different age groups and also the weight of the driver also differs in each case so a different value of diameter and internal thickness is required so that an optimization between the strength required and weight of the frame is obtained for each case.

So in order to analyse the strength of the bicycle frame we needed to create a CAD model of the bicycle frame with optimized dimensions, but since the dimensions of the members of the frame vary from one age group to another we decided to go with the dimensions of the most common age group viz. 18-30 years of age and created a CAD model on CREO 2.0 with those dimensions and later on analysed it for various forces on ANSYS 14.0 for checking the safety of the bicycle for a average weight of the driver in that age group (worldwide) with those specific dimensions(length, diameter et cetera) of bamboo.

II. CAD MODEL

The CAD model of the frame was developed considering the dimensions of the most populous age group and the CAD model was developed on CREO 2.0 and later on this model was further used for simulation of forces on it.
The CAD model shown in the above pictures was designed on CREO 2.0.

Here in the above CAD model two sizes of bamboo are used.

The Bamboo members used in Front triangle are of 38 mm in diameter (solid).

The Bamboo members used in Rear triangle are of 25mm in diameter (solid).

The CAD model was prepared in two steps, at first the CAD model was developed as a solid model and was analysed for the forces on specific points and the magnitude of the impact forces were calculated considering the Newton’s Impulse-Momentum equation.

The Model so prepared was a complete solid model and therefore the force analysis done on it though safe but practically it is not possible to create a frame with bamboo members joined together with some sort of adhesive or a emulsion so in order to counteract this problem yet another frame was modelled in CREO 2.0 but this time in an assembly format and the bamboo members were attached together by using fabricated metallic joints and later on this assembled model was analysed for the forces.

III. FRAME ANALYSIS

The Frame of the cycle was designed on CREO2.0 and it was simulated for various forces applied on it considering bamboo as the material on ANSYS 14.5.

1. Front Impact

The above picture shows two points A and B where point A shows the member of the frame which is taken as rigid support and point B is the member on which the force of magnitude 2250 N is applied.

The Force was calculated from Newton’s Impulse-Momentum Equation.

Which is:

\[
\text{Force} \times \text{impact time} = \text{change of momentum}
\]

\[
\text{Force} = \text{mass} \times \text{change of speed}
\]

Mass of the cycle including driver = 80 kilogram.

Change of speed = \((8.475 - 0) \text{ m/s}\) (considering perfectly elastic collision where velocity of cycle reduces to 0 after impact)

Impact time = 0.30 sec.

Force = 2250 N
The force simulation on the CAD model of the frame revealed that the maximum value of stress generated was of the magnitude $2.15 \times 10^8$ Pa which is less than the maximum stress value of the bamboo material. (Figure 5)

The Factor of safety of the frame for a impact load of 2250 N on analysis was found to be of 1.62 which means it can be considered practically feasible.

2. Rear Impact

A force was applied on the cycle frame on the member represented by point B, the magnitude of the force was taken to be 750N, as we considered the weight of the rider to be of about 75 kilograms.

Therefore, Force = weight x gravitational acceleration
= $75 \times 10$
= 750N

As shown in the picture the point A shows the member which is taken as fixed support for the rear impact analysis and Point B is the member on which the force is applied. (Figure 8)

The simulation results for the rear impact test revealed that the maximum stress generated on the frame is of the magnitude of $6.86 \times 10^7$ Pa which can again be considered to be well within the strength of the bamboo material. (Figure 9)
The factor of safety of the frame for rear impact simulations was of about 5.101 which are considered pretty safe for practical purposes.

3. Central Loading

When a rider is riding the bicycle a certain magnitude of the force is applied on the frame of the bicycle which acts on the vertical member due to the weight of the rider and another force applied due to pedalling of the rider.

The magnitude on the vertical member was taken to be 1000N on the safer side and the pedalling force on the lower joint where the pedals are to be mounted is taken to be 250 N.

The loading force due to the weight of the driver is applied on B point and point A represents fixed member and the pedalling force on the member represented by point C.

The force simulation results revealed that the maximum stress generated developed on the cycle frame was of $2.87 \times 10^8$ Pascals.[1][2]

IV. COMPARISON

The table shown above reveal force simulation results of the frame with different materials.
CONCLUSION

The bicycle frame can be made of different materials and can still be practically feasible and safe. However, using bamboo as a frame member will not only aid in weight reduction of the frame which will lead to reduction in effort needed for riding the bicycle, another advantage of using bamboo as frame members is that it is harmless to the environment and is biodegradable unlike steel or any other metal. Yet another advantage of bamboo being that it is cheaper as well as compared to steel or metal used.
REFERENCES

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