DESIGN AND FABRICATION OF SUSPENSION INCORPORATED IN BICYCLE WHEEL

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Abstract: The bicycle's invention has had an enormous effect on society, both in terms of transport and way of living. Several components that eventually played a key role in the development of the automobile were initially invented for use in bicycle, including ball bearings, pneumatic tires, chain-driven sprockets, and tension-spoked wheels. This study presents a suspension system which is placed inside a bicycle wheel.In traditional suspension systems the isolation is provided by spacious and complicated mechanisms, and mainly in the vertical direction.In case of SIIBW system vertical as well as horizontal isolation is provided. All the experiments are conducted at lower speeds and limited loads.
Keywords: Suspension incorporated in Bicycle wheel (SIIBW)

I. INTRODUCTION

One of the major subsystems in a modern passenger car is the suspension system. The suspension system of a road vehicle refers to the assembly between the chassis and wheels. It transfers forces and moments from contact patch to the chassis . Vehicle suspension systems are designed to provide ride comfort. The major challenge in the In wheel suspension is space limitation . The suspension system should fit inside the vehicle's wheel without altering its outer dimensions. This design requires selection of proper materials for flexible suspension components and optimization of the shape of the components for most energy absorbance efficiency. Also the design should be simple and easy to manufacture.

Although the current suspension systems effectively isolate the sprung mass from road excitations in vertical direction, but the sprung mass' horizontal connection to the ground is almost rigid. The slight horizontal isolation is achieved by suspension mounts and tire (Reimpell, et al., 2001). Furthermore, traditional suspension systems usually consist of spacious three dimensional mechanisms with heavy components. The higher suspension system mass (part of the un-sprung mass) not only decreases the isolation effectiveness (Dixon, 1996), but also results in lower fuel efficiency. A study of European vehicles weighing less than 1000kg shows that a 10% increase in vehicles' mass, increases the fuel consumption by 7-8%. In order to overcome the limitations of conventional suspension systems, a new concept of the SIIBW is proposed. The SIIBW concept not only improves the horizontal isolation but also eliminates the spacious suspension mechanisms by embedding the suspension system inside the vehicle's wheel. The development of SIIBW is based on the idea of fitting the spring and damping elements inside a vehicle's wheel.

The traditional suspension systems usually consist of spacious 3D mechanisms with heavy components . The higher suspension mass not only decrease the isolation effectiveness but also results in lower fuel efficiency . In order to overcome the limitations of conventional suspension systems , the concept of Suspension incorporated in Wheel system was proposed . The reason behind is, it eliminates the spacious suspension mechanisms by embedding a specially designed suspension system inside the vehicle's wheel. The development of Suspension in wheels system is based on the idea of fitting the spring and damping elements inside a bicycle wheel .

II. LITERATURE REVIEW

For any road vehicle, a common method to isolate passengers from undesirable excitation caused by road roughness or onboard sources is the use of a suspension system (Gillespie, 1992). Suspension systems have been utilized on different types of vehicles, such as motorcycles, passenger cars, trucks and bikes. Suspension is basically an assembly of spring and damper components used to reduce the transferred excitations to a vehicle's chassis. The spring element can be a coil spring, leaf spring, torsion bar, or an air spring. The damper element is usually a shock absorber. Different forms of suspension systems such as McPherson, double wishbone, and multi-link suspensions have been adapted to passenger vehicles.

Rotating version of this is designed for NASA's Mars rover (National Aeronautics and Space Administration (NASA)). The low temperature, lack of atmosphere, and also weight restrictions prevent the use of inflatable rubber tires in projects like the Mars rover. Another example is that of Michelin active wheel which integrates an electrical motor, the power-train, the suspension system, and the braking system inside the wheel. Likewise, Siemens VDO's eCorner concept embeds an automobile's drive-train, shock absorbers, brakes, and steering, into its four wheels.Although the Michelin and Siemens wheels embed different automobile subsystems, including the suspension system, inside its wheels, but the suspension system is still limited to isolation in the vertical direction. However, adding an additional degree of freedom to the suspension system of a high speed automobile requires more in-depth studies and considerations which are beyond the scope of this project.This chapter has presented a survey of some of the researches for using the available space inside a vehicle's wheel. This place is used for placing useful parts such as suspension components, steering mechanisms, and even the power-train. However these researches are still in the primary stages, and there is no precise performance data or design guidelines presented. In the following chapters the practicality and performance of placing a suspension system inside a vehicle's wheel is studied in more detail. Loop wheel is one such reinvention of wheel. A Loopwheel is a wheel with integral suspension, designed for better shock-absorbing performance. The carbon springs absorb tiring vibration, as well as bumps and shocks. Loopwheels provide tangential suspension, meaning they work in every direction. So they respond to a force hit head-on in the same way as they do to a force from below.

Our idea is also to reinvent the wheels but with a different shape, material, aesthetic and ergonomic properties.

III. PROBLEM STATEMENT

In the fundamental bicycle wheel, strength is determined by the number of spokes , arrangement of spokes , interfacing of spokes with the hub and the rim . If you look at a normal "three cross" wheel, the spoke leaves the hub at an angle nearly tangential to the hub circumference. This way the stress on the hub is minimized. Hence the strength of the wheel depends on the number of spokes.

.Weight is reduced by using more exotic materials (especially for the rim), and by reducing spoke count. The more exotic the rim, the more intimately the design of the rim ties into the speaking scheme. Some slight weight reduction is also possible by reducing the "cross" of the speaking.

Bladed spokes are marginally more aerodynamic than round spokes. At the very high end, there are some wheels that use fettuccine-like strips of carbon fiber in place of steel spokes—these may cost as much as a very nice bike themselves.

The spokes in the wheelchairs tends the disabled to apply more effort due to the above mentioned problems. Hence a new change in the wheel is necessary so that it will be more effective for the disabled along with the cost efficiency.

The spokes which is present in the conventional wheels needs to be maintained at regular intervals. Stiffness plays an important role in the soft riding of the bicycle. Stiffness of the conventional spokes is high as compared to the bow spokes being used in our project. To improve the stiffness of the wheel spokes are adjusted. During this stress is produced which in turn damages the rim. A fatigue crack is the result of this high stress.

A check with the dishing tool showed it to be offset 2mm to the non-drive side, which is expected in this circumstance. In a ‘dished’ wheel, where the rim does not lie exactly centered between the two hub flanges, the spokes on the non-dished side – non-drive in the case of a rear wheel for derailleur gears – have a more effective axial, or sideways, pull on the rim thanks to the angle at which they act on it.

Air resistance obviously increases with spoke count, and is affected by the profile of the spoke as well. Although air resistance is important to pro racers because the top of the wheel is moving forward at twice the speed of the bicycle, it's probably safe to say that the air resistance due to spokes on a standard 32-spoke three-cross wheel would not be noticed by most average bikers, even at fairly high speeds.

The most common wheel problem is a lateral or sideways bend. Wheels that are severely bent cannot be repaired easily. You cannot have the spokes pulling hard against a rim that is very bent. This would cause a weak wheel that may bend again, or perhaps some spokes may break eventually. Bending of the wheel due to uneven distribution of force is a common problem faced by high-end bicycle riders.

IV. METHODOLOGY

This chapter covers the Design and stepwise process of manufacturing the SIBW. It contains the material and weight of all the parts used, the manufacturing and finishing process along with the Solidworks modeling and analysis. Following are the steps followed during this project work , Designing the project wheel in Solidworks , Analysis of the same design using Ansys by applying load at different points , Determining the dimensions of all the components , Selection of Stainless Steel as the basic material , Laser cutting of the parts according to the dimensions. The Hub was prepared by cutting the designed profiles phase by phase. The profiles were introduced to reduce the overall weight of the wheel , The phases were then welded together to form the hub for the wheel , The bearings and the bolt for holding the wheel were then welded to the slot , Grinding of the surface was done for finishing of the component , For spokes stainless steel strips were used of 3mm thickness. These strips were also laser cut and then grinded for finishing , The straight strips were then bent using a motorized jig , Holes were drilled on the strips to attach it to the hub using nut and bolts , The rim to be used was dismantled from the cycle and the conventional spokes were removed along with the hub and bearing. The same bearings were then used in the new designed hub , Finishing process was done on the rim to remove any rust or decolourisation , Then the bend steel strips, hub and rim were assembled together using nuts, bolts and washer , The tire and tube were then assembled on the rim , The wheel was then attached to the cycle by the bolt present on the hub , Final detailing and finishing was done along with spray painting of the wheel.

V. FABRICATION

This chapter consists of the designing and fabrication method of the hub, spokes and the rim. The designing of the same was done in Solidworks and the material selection was done on the basis of the values obtained by calculations. After the manufacturing, Finishing process was also conducted.

TABLE 1

PARTS	WEIGHT (kg)
Nut	0.750
Hub	1.130
Spoke	0.400
Rim	0.800

Considering the weight and the load to be applied dimensions are determined:

Strength : The cold work hardening properties of many stainless steels can be used in design to reduce material thicknesses and reduce weight and costs. Other stainless steels may be heat treated to make very high strength components.

Aesthetic appeal :Stainless steel is available in many surface finishes. It is easily and simply maintained resulting in a high quality, pleasing appearance.

Hygienic properties : The cleanability of stainless steel makes it the first choice in hospitals, kitchens, food and pharmaceutical processing facilities.

Life cycle characteristics : Stainless steel is a durable, low maintenance material and is often the least expensive choice in a life cycle cost comparison.No.4 Finish was applied for the final finishing of the hub and bow spokes.

The No.4 Finish is the brushed finish you see in most restaurants and professional kitchens. You can use the custom cut feature to design stainless sheet to fit as required. Other material used can be Copper or Brass. The width used is 3mm for optimum stiffness and damping.

VI. WORKING

We invented the wheel which is having incorporated suspension. It includes newly designed square hub made of stainless steel for higher stiffness and durability. The present invention relates to a shock-absorbing performance wheel comprising bow-shaped spokes which act as bows or springs to dampen acceleratory jerks brought on by unwanted shock. The said invention also comprises a non-circular hub onto which a plurality of "bow-spokes" are directly affixed to the periphery of said hub. A system that incorporated shock absorption directly into the wheels, making them capable of flexibly rolling over bumps instead of just rebounding . If any damage occurs in hub can be designed and manufactured at home and by increasing or decreasing the length of bow spokes different stiffness can be achieved.

VII. CALCULATION

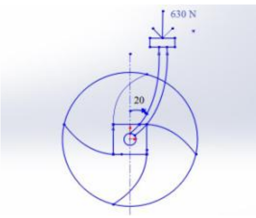
The 5th chapter of the report contains the calculations required for designing the hub, spokes and rim are calculated. This is important so that appropriate quantity of material is used to absorb all the loads.

Passenger weight 157kg

Weight distribution in bicycle is around = 60-40 %

Wheel fork is at 20 degree angle so weight on hub = 60sin20 =50kg

[1] STIFFNESS OF ONE CURVED SPOKE:



Total weight of the cycle = 150 kg+ 7 kg(cycle) = 157 kg

Weight distribution= 60(rear)/40(front)

Weight at front wheel = 40% of 157 = 63kg

Vertical weight on the wheel = 533 N

K= stiffness = force / x

Where x=displacement

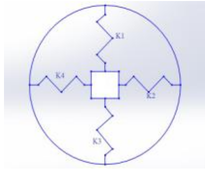
=1 inch

=25.4mm

Therefore,

K= 533/25.4 = 23.35 N/mm

Therefore the stiffness is,



K= K1+K2+K3+K4

But K2=K3=K4=K1

K= 4K1

K1= 5.84 N/mm

Therefore stiffness of one curved spoke is 5.84 N/mm

[2] MATERIAL STIFFNESS WHEN FLAT (actual values)

Width = 35mm , Length = 490mm

Thickness = 3mm , Stiffness of plate is,

Where, A= cross section area ie 35*3 = 105

E= 190 to 203 GPa , Consider E= 197 GPa = 197000 N/

L= 490 mm . Therefore,K = 42212.3 N/mm ,

K= 42214.3 N/mm

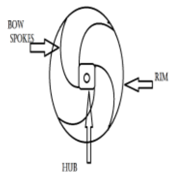
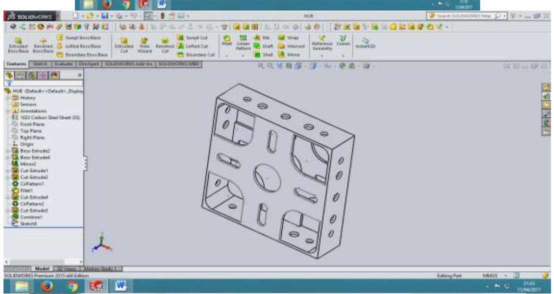


Fig 4.8 Modelling of hub



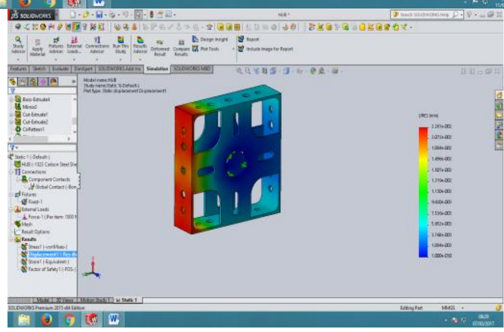


Fig: Solid works Simulation

VIII. RESULT AND CONCLUSION

The shock absorbing capacity of the wheel mainly depends on the weight of the wheel. In our model we removed the spokes from the wheel and replaced it with a bow shaped spokes. What we observed was an increase in the weight of the wheel which was 2.2 kg to 3.08 kg. So as the weight of the wheel increases the toughness also increases and hence the shock absorbing capacity. In our newly fabricated wheel the comfort we obtained is far better than the earlier conventional wheel. Also the life span is better than earlier. The increase in weight results in better stiffness of the spokes making it durable. The observations we achieved from the calculations and analysis were similar rather what we obtained after design were as expected.

In this project an idea of suspension system was studied. The studied suspension system is placed inside a vehicle's wheel and is also called a Suspension incorporated in wheel system .a mechanism based SIBW which was previously designed for a wheelchair by static methods was investigated for dynamics response in. The dynamics simulations demonstrated the influence of different design parameters on the wheel. The results from these showed the feasibility of designing a rotating suspension with a linear stiffness rate and minimal fluctuations. The results also concluded that a rotating suspension system's performance is undermined at higher speeds. Moreover, the effectiveness could be improved by reducing the mass of the suspension's rigid links. Experimental results verified the simulation results with less than five percent of error. The cause of the increase in stiffness is short length and large width. This can be rectified by increasing length and decrease the width of the curved spoke.The SIBW system, like other suspensions should provide desired stiffness and damping rates. It should also allow the maximum possible wheel travel. For the rotating SIBW in addition to the conventional suspension properties, the stiffness fluctuation should be considered as well. The rotation of the suspension system which is embedded inside the vehicle's wheel, changes the orientation of the suspension elements at each rotation angle of the wheel. Consequently, the change in the suspension component's orientation can lead to undesired stiffness fluctuations. These fluctuations are sensed by the sprung mass as periodic vertical or horizontal vibrations when moving on a flat surface. The major challenge in the SIBW design is the space limitation. The suspension system should fit inside the vehicle's wheel without altering its outer dimensions. This design requires selection of proper materials for flexible suspension components and optimization of the shape of the components for most energy absorbance efficiency. Furthermore, the design should be simple, easy to manufacture, and also retrofit.

IX. Future Works

The developed wheel shows the feasibility and practicality of the SIBW concept. However, employing the current design in a commercial application requires further optimization and tuning. Moreover, this research has studied the simple case of a non-powered, rotating concept wheel for low speed vehicles; however future research can be conducted on more complicated SIBW designs such as powered applications and designs for road vehicles. The main challenge in the powered rotating incorporated suspension design is achieving infinite rotational stiffness in addition to the requirements of a non-powered wheel. In a rigid mechanism design, the rotational stiffness can be attained by using parallel mechanisms. However maximising the rotational stiffness for a compliance design is a more significant challenge. Preliminary results show enhancements in the rotational stiffness, yet the unsymmetrical configuration of the spokes of the wheel axis yields different rotational stiffness rates in clockwise and counterclockwise directions.

The suspension incorporated in wheels can be used in low speed vehicles by further research on material and stiffness. Non heavy duty vehicles can use this wheel as maintaining and changing the wheel does not require trained personnel. The braking used for this wheels can be improved by adding a disk brake or a wireless braking system for long run. The slots for placing the disk is added during the manufacturing stage.The different materials that can be used are materials with flexibility and appropriate stiffness to take the loads and behave as suspension system. For example Aluminium alloy, different types of composites, Carbon Fibre, etc.

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