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Design, Fabrication and Analysis of Spokeless Wheel

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Abstract: From the observation of the wheel in the cycle, the spoke is an important and integral part of the load carrying device in the wheel. The spoke not only provides load carrying support but also helps in transferring the impact observed thus by studying the spoke the load carrying mechanism can be changed by altering the design of the spoke. In this the number of spokes added to it will provide considerable comfort but our idea is to remove the spoke and add a leaf spring type attachment that can provide the self suspension in wheel. This idea also can be used to reduce the damage on the wheel occurred during accident by elastically deforming and reforming to its original shape. The impact induced on the person driving the cycle will also be reduced while riding over bumps and pits. The amount of material usage can be reduced in the side of manufacturing. Unlike the new development of adding fabricated spoke to the wheel this would be more advantageous and cost worthy. A lot of modifications and changes have evolved in bicycles (for ex: introduction of suspension, gears, advanced tyres etc.). These changes are introduced in order to comfort the rider. Thus keeping in mind the same we have done this project.

Key words: Bicycle · Exerciser · CATIA software · Spokless Wheel

INTRODUCTION

The wheel which we have designed and fabricated has a typical leaf spring action. This enables the availability of suspension and cushioning during the bicycle [1] riding. It reduced damage to the cycle wheel and the rider during accident by deforming and reforming within its elastic limit. Movement is the essence of life. All animals move to find food, attack prey, or escape a predator. Snakes slide, caterpillars crawl, kangaroos hop, horses trot and men walk. Of all animals, humans move the most. Most travel a few Kilometers to their workplace and back every day, go visiting relatives to a city a few hundred kilometers away or travel halfway across the globe to a business meeting. Some travel purely for fun or adventure. For compulsive travelers humans are not particularly well equipped. A cheetah can out run the best of men by 10 to1. A horse has much more endurance and consumes only about one-half the energy per kilogram of body weight. But humans design machines which increase their physical capacity. The invention of the wheel is the single most important milestone in the human attempt to increase locomotion. Oxen, horses and camels at first and then steam and gasoline engines increased human movement dramatically. But the idea of using its own muscular effort in driving a wheel has always fascinated man. It is interesting to note that the bicycle was perfected much after railway trains were in full commercial operation and the horseless carriage was just knocking on the doors. Inventors everywhere are struggling even today to perfect a flying machine driven by muscular effort alone eighty-five years after the first successful petrol-engine powered flight. The humble bicycle has a glorious past. First conceived as a plaything of the rich, it soon evolved into an efficient and convenient means of transport. The coming of the automobile, however, relegated it to a role of an exerciser or a sports machine, though in large parts

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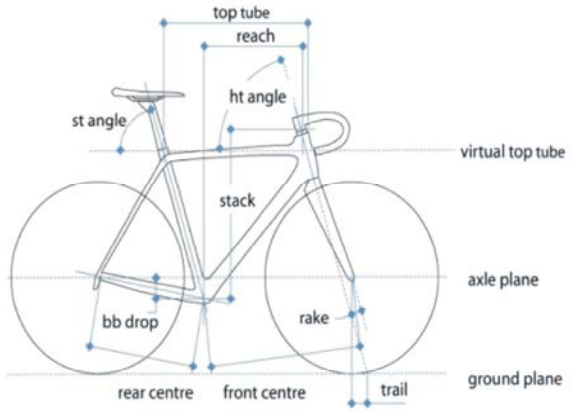
of the world, notably China and Southeast Asia, it is still used as the primary means of daily transportation. In the industrialized world it seems to have come a full circle. The bicycle is re-emerging as a vehicle of choice for short runs in urban areas. It does not pollute the atmosphere. It is almost noiseless. It does not take up precious parking space and wide roads. It has been estimated that for distances up to 8 km in city centre's a bicycle may be faster than a car given the time taken for taking a car out of a garage, finding parking space and walking from the car park to the place you intend to go. And above all, a bicycle provides you valuable physical exercise while you ride to work.

First Step: The first mention of a two-wheeled vehicle propelled by the rider himself occurs for a 1791 toy-like machine which was simply a wooden beam on two wheels, one behind the other. The rider sat on the beam and drove the machine by pushing his feet alternately against the ground, as if skating. One could not turn this machine except by lifting and dragging the front wheel to one side. It didn't even stay erect if both feet were off the ground. The velocipede, though a bicycle in the true sense of the word, was never a commercial success and not many persons knew about its bold design. For the following forty years the design of the bicycles stagnated at least in the method of converting the motion of feet into the rotary motion of the wheel. The first commercially successful bicycle appeared in 1863. It had a pair of pedals connected to the front wheel and was ridden in the same manner as the basic children's tricycles of today. Its wooden wheels (with iron tyres) on the cobbled roads of the day gave the rider such a rough ride that it was nick-named the bone-shaker. In a bicycle we are interested in increasing the velocity ratio and the decreased mechanical advantage is the price that we pay for it. The increased diameter of the front wheel is only one of the ways of obtaining a large velocity ratio. A simple pair of Unequally sized gears a belt over two pulleys, or a chain running between a large chain-wheel and a small sprocket (a toothed wheel) are some other ways. In each of these cases the velocity ratio is the ratio of the sizes of the two wheels, gears or sprockets. From the automobile practice, where gears are used almost exclusively for the purpose, the velocity ratio is commonly referred to as the gear ratio. Each of the above transmissions (that is, the method of transmitting power from the pedals to the wheel while obtaining a mechanical advantage) has its own advantages and disadvantages. For example, the performance of a belt drive, which depends upon the presence of the resistance to slipping of the belt on the pulley (i.e., of the friction), decreases sharply when the belt becomes dirty, grimy or loose. Gears give better performance, but are more expensive rigor of cycling. The bicycles were used by vendors.

Common Wheel Types: Wheels are the most essential moving parts of the bicycle. These wheels have under gone many changes in terms of its size, shape and environment in which they are used. Likewise the tyres used for the wheel also have undergone many changes Such as rough road tyres, racing wheels, mountain biking wheels, etc. The knobs used in the tyres are also of different types with respect to the wheel such as auto, presto, woods. Even though a lot of evolutions have occurred in the cycle wheel the rim of the wheel is the only part that has under gone limited or no changes in these 100 years.

Wheel Geomentry: In the bicycle wheel [2], wires replace the rigid spokes of wooden wheels. Although wires are strong; they cannot directly replace wooden spokes that carry loads in compression. In order to work, wires must be tensioned to prevent their buckling under load. Even though the wheels only vary with the no of spokes used the wheel geometry is studied in order to take care on the load acting which causes buckling and wheel collapse. Spokes and rims are the wheel components that fail most often. They fail both from sudden loads, as in a crash and from fatigue. Although the progression of Fatigue failure is mostly invisible; it can be substantially retarded through Appropriate wheel building techniques. Hubs and spoke nipples are not subjected to sufficiently large dynamic loads to cause significant metal fatigue. Aluminum nipples sometimes fail during wheel building, but rarely during use. Spokes break and rims crack mainly from fatigue. However, rims can also fail from brake abrasion. Road grit, swept up into the brake pads in wet weather, abrades rim sidewalls until they become too thin to contain tire pressure. They then bend outward and release the tire, causing a blowout. The commonly used geometrical measures of a sprocket are given as in the fig.



Bicycle Modifications: A number modifications has been made in the bicycle in the last 20 years, these are done by the invention of balloon tyre, hybrid designs, adjustable gears, hydraulic suspensions, composite fiber and aluminum frames, traction technology in tyres and yet to go on. The introduction of latest technology and design software helped in developing a perfect design which suites for comfort riding and load acting on them during static and dynamic conditions. About 20, 000 designs have been introduced in a year due to the availability of virtual design analysis technology.

Safety: Safety is the most important aspect that is required after evolving with a great idea. During the time of evaluation of the bicycle a huge amount of accidents taken place due to the rustiness in design of the cycle (for ex:Dogs, pigs, chicken and children, bricks and potholes in the road, all could easily cause the infamous 'header'. So also could a row of bricks, a taut length of string, or a stout rod poked among the spokes. A high wheeler seemed to bring out the worst in people. One could also easily gat a foot or clothing entangled in that great expanse of spoke work that the big wheel was.) In early days of evolution of the cycle stabilizing the cycle was one of the most looked out problem. Then comes the introduction of freewheeling and then the bucking in rim.

Hence a large amount of money and time are invested to create a safer ride.

Comfortness: Comfortness and safety comes together. Every invention is evolved due to the availability of need which is intern the requirement of comfortness.

Modifications, evolutions, inventions are only done due to the requirement of comfort. If radio is thought enough then television would be not invented which evolved due to the need. Similarly a large amount of modifications are done and evolved to comfort the rider. That is the inventions of weightless cycle are introduced to improve the speed and handling of the cycle. Easy carry bicycles are introduced for riders who need to take bicycles to a larger distance. Tubeless tyres are introduced in order to avoid the chances of blow out. Alloyed rims are introduced to with stand continuous impact loads and avoid collapsing to an extent.

Description of Parts

Central Hub: The central hub is the major load and impact carrying system which allows the seating of roller ball bearing which enables the rotation of the wheel. The central hub is made up of mild steel material. Since no spokes are used the hub can be of any considerable diameter.

Roller Ball Bearing: The roller ball bearing in made to seat inside the central hub in order to support the smooth movement of the wheel when kinematic motion is enabled. The roller ball bearing helps to bolt the steering along with the wheel. In a normal wheel spokes are attached to the roller ball bearing. Wheels with large-flange hubs, spooked tangentially, are about twice as stiff, Torsionally, as small-flangehubs. Such small-flange hubs develop about 200 Newton-meters (Nm) torque per degree of hub windup. This means that the average rider, using a two-to-one chain ratio (42 tooth chain wheel and a 21 tooth freewheel sprocket) and 170 mm cranks, would have to press on the pedals with 2500 Newton's (N) to.

The Rim: The rim is the outer casing which holds the tyre and the spokes here the rim holds the arc spring. The arc spring is welded along the inner sides of the rim.The rim is made up aluminum now a days they are made up of alloys of aluminum. Torque is a twisting force in the hub that produces or retards wheel rotation. As the chain turns the rear wheel sprocket it exerts torque on the hub. The lever arm is the distance by which the line of the spoke misses intersecting the centerline of the rear axle. The force is the total change in tension among the spokes, some of which become tighter and some looser.

ARC Spring: Arc spring is the major load carrying setup in this design. These arc springs holds the central hub and the wheel rim. The arc spring keeps intact both the hub and rim. The arc spring is made up of stainless steel 304 material. The arc spring is held in contact by welding

it along the hub and the rim by using arc Similar to leaf spring the arc spring expands and contracts that is it compresses and attains its original state with its elastic limit. The dimensions of the arc spring are given in the figure.

Working Principle: The working the this modified design is simple, the hub along with the roller Ball bearing is the secondary load bearing parts, they absorb the axial loads and Transmit the loads to the arc spring. The arc spring absorbs the load and gets Compressed which is the primary load bearing part. The compression of the Spring retain as long as the load works on them. By repeated compression and Expansion suspension and cushioning is achieved. During the time of force Action along the surface of the tyres which in turn induces it on the arc spring. This to and fro motion of the arc spring helps in providing proper suspension for the wheel.

Manufacturing Process

Cutting Process: Cutting of materials is done using normal cutter machine. Machine cutting makes it easier to cut and reshape the material as required. Machine cutting gives accurate cutting with good surface finish.

Welding Process: The central hub is a joint construction of small square plates attached together by welding process. Arc welding is done to connect the arc spring and the central hub. Welding of stainless steel 304 is done using TIG welding. MIG welding can also be done for welding stainless steel 304.

Fig: Welding of SS Plate

Surface Finishing: Surface finishing is done normally by using grinding machine. Even though perfect surface finishing is not obtained a considerable surface finish is obtained by using the grinding machine. Surface finishing process is done to smoothen the surfaces which are altered during the other machining processes. Uneven surfaces are also processed and made even during this process.

Drilling Process: Drilling work is done in order to create hole in the central hub to seat the roller ball bearing. The required diameter in our case is 26mm thus normal drilling is not possible since only up to 12mm dia is only available, thus core drilling is done in this process.

Design Calculation

Wheel Structure Calculation:

a = length of the arc spring
b = distance between the rim and the further hub edge
c = radius of the inner rim = 27mm
d = distance between two consecutive arc spring
e = length of the central hub = 13.5mm
f = half the length of the central hub = 6.75mm
To find the length "a"

Using Pythagoras theorem
$b^2 = c^2 + f^2$
$b^2 = 27^2 + 6.75^2$
b = 27.83mm

By considering "b" as the dia of the inner circle formed we calculate the arc spring length as:

Perimeter of the inner circle:
$p = 2\pi r = 2*\pi*13.917 = 87.43mm$

Length of the arc spring "a"
$a = (n')/(360) * 2\pi r$
a = 180/360 * 87.43
a = 43.715mm

The length of the arc spring is "43.715mm".
To calculate the value of "d".

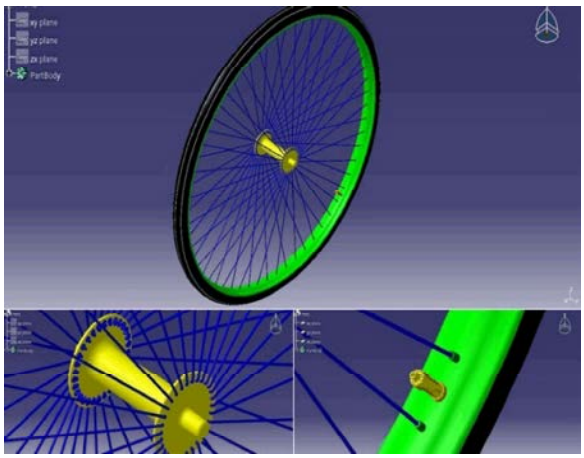
Inner rim perimeter = $2\pi r$
$P = 2*\pi*27 = 169.646mm$
d = p/4 = 169.646/4 =42.412mm.

Distance between the consecutive arc springs is "42.412mm".

Load Calculation: This calculation involves the displacement of the arc spring with respect to the load applied at the axis of the central hub the wheel .

S.NO	Load Applied (kg)	Displacement (mm)
1	20	8
2	25	9
3	30	11
4	35	13
5	40	14
6	45	16
7	50	17
8	55	18
9	60	20
10	65	21

Existing Wheel Design in Catia: The below diagram shows the existing wheel design drawn in CATIA software.

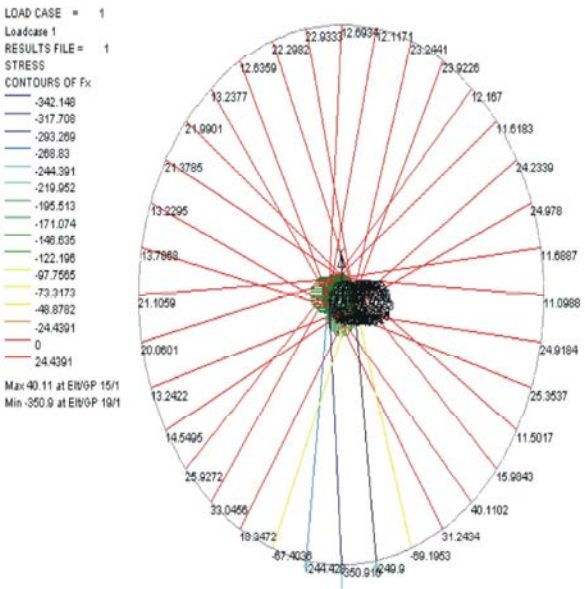


Modified Wheeldesign in Catia: The below diagram shows the modified wheel design drawn using CATIA software.

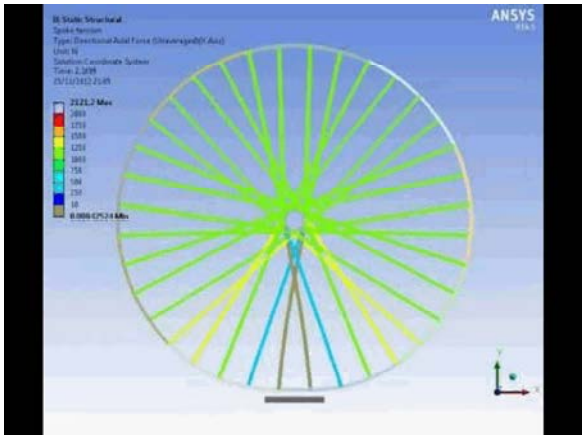
The 3d view of the modified cycle wheel is drawn as a single part diagram.The central hub, arc spring, rim are considered to be made of same material as stainless steel 304.Separate part projection is not taken thus usage of bolt for connection of arc spring and rim is eliminated in the design. In the physical working condition central hub and arc spring are connected by Welding and the arc spring and rim are connected by bolt and nut welding can also be done at thick rim of 3mm thickness.

ANSYS: The company was founded in 1970 by Dr.JohnA.Swason as Swanson analysis system, Inc (sasi). Its primary purpose was to develop and market finite element analysis software for structural physics that cloud simulate static (stationary) and thermal heat problems. Ansys has acquired a number of companies since 2000 including ICEM, CFD, CADOE S.A. ANSYS MECHANICAL is comprehensive FEA analysis (finite element) tool for structural analysis, including linear studies. The engineering simulation product provides a complete set of element behavior, material models and equation solvers for a wide range of mechanical design problems. In addition ANSYS MECHANICAL offers thermal analysis and coupled physics capabilities involving acoustic piezo electric, thermal –structural and thermo –electric analysis.

Analysis of Existing Design in Ansys: The existing cycle wheel design is first analyzed in order to gain information about the strength and weakness involved during static and dynamic loading. Analysis of existing design involves structural deformation occurring during static loading in the surface and axial loading, chances of occurrence of buckling, collapsing, etc.

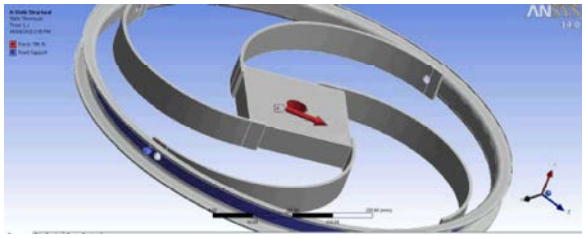


Load acting over the surface of the tyre by completely constraining the bottom rim surface. A load of 400 N is applied which deforms the rim to 4mm distance.

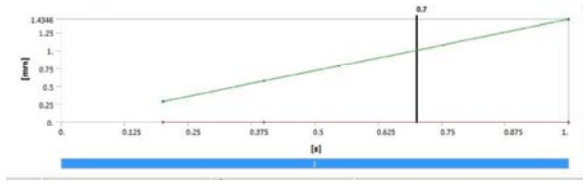


A load of 700N completely buckles the rim and creates a over redevelop of about 20mm towards the upper portion since only a small area is constrained.

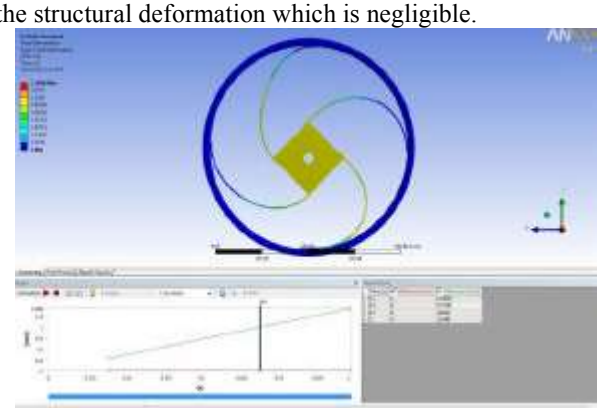
Analysis of Modified Wheel Design in Ansys: Load of 300N is given over surface of the wheel which creates a partial deformation which is negligible.



The above diagram shows the completely constrained area and the load acting area.



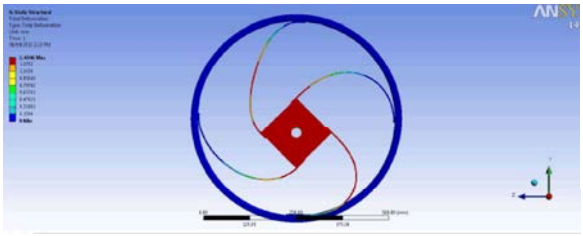
The above diagram shows that the load action and the structural deformation which is negligible.



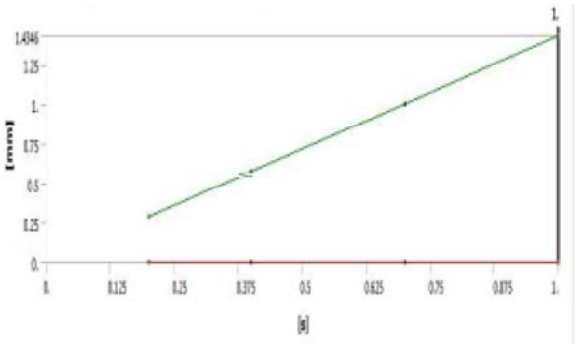
The above graph shows that a constant load of 300N over the axis of the central hub does not alter much of the shape and the time interval of action of the force with resultant displacement.

Final Result Obtained in Ansys: The above ansys diagram shows the start of deformation on loading The time vs deformation curve for the load of 500N is given above.

From the above table it can be seen that the deformation increases .5 mm for every additional second of load action.



The above ansys result shows that at a load of 700N the complete deformation occurs which is indicated by the red color.



	Time [s]	Minimum [mm]	Maximum [mm]
1	0.2	0.	0.28693
2	0.4	0.	0.57385
3	0.7	0.	1.0042
4	1.	0.	1.4346

The time vs deformation graph shows that continuous increase in deformation occurs at equal interval of time for a load of 700N. The above ansys result shows the extreme suspension of the modified wheel after this the arc spring will cross over it elastic property and deforms permanently. The above diagram depicts a load of 1500N action at a point on the surface of the rim and the bucking takes place at its surface.

Advantages and Disadvantages: In a normal wheel buckling takes place when undergoing an impact load of 800N but in our modified design bending takes place at an impact load of 1500N. During ever cycle accident cases damage in critical at the front wheel thus this modified wheel is paced only at the front portion which reduced the impact induced over the rider by absorbing a part of the load. The only disadvantage in it is usage of material, high quality alloyed aluminum arc spring is required which is costly, this is the only reason that we have used Stainless steel 304. This modern bike is made completely of carbon fiber.

CONCLUSION

The project carried out by us will make an impressive mark in the field of bicycling. It is very usefully for the nation in run out of power sources. This project has also reduced the cost involved in the concern. The project has been designed to perform the required to solve the present and future problems of buckling, accidental damages and comfortless in riding a bicycle.

ACKNOWLEDGEMENT

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