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DESIGN OF SHOCK ABSORBING WHEEL FOR BICYCLE

AMIT PANDEY, AWADHESH SHARMA, ARPIT KUMRAWAT and BHUPENDRA SIKARWAR

Department of Mechanical Engineering
Medicaps University
Indore, India
E-mail: amitpy92000@gmail.com
awadhesh619@gmail.com
arpitkumrawat35@gmail.com

Abstract

In today's world, bicycles are the most preferred choice when it comes to causes like health, pollution, and the environment. Several types of research have been done to make the ride comfortable. Peculiar sorts of cycles have been designed for different applications like Commuter Bikes, Mountain Bike, and Racing bicycle. Shock absorber wheels offer you a more tranquil ride. Shock absorber wheel springs are generally comprised of a steel material specifically designed to offer ideal pressure and horizontal soundness and quality and strength. The three shock absorbers in each wheel work along as a self-amending framework. This suspension framework between the centre point and the edge of the wheel gives suspension that constantly acclimates to bumpy landscape padding the rider from irregularities in the street.

Introduction

This project shows a study of an In-Wheel suspension system which is installed inside a bicycle wheel. In conventional suspension systems, the isolation is provided by spacious mechanisms, and mainly in the vertical direction. However, the in-wheel suspension system, not only fits the suspension mechanism inside the unused space between a wheel's rim and hub but also provides isolation both in vertical and horizontal directions.[2] The main focus of this project report is to study, examine, and show the practicability of applying such a suspension system to a vehicle. In this project, the wheel is designed such that the suspension system is integrated

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within wheel for higher shock-absorbing performance and better cushioning in an obstacle. This wheel offers a smoother ride. The springs used in this wheel are gas springs that offer optimum compression and lateral stability as well as strength and durability. The three springs in every wheel work along as a self-correcting system. This spring system between the hub and the rim of the wheel provides suspension that continuously adjusts to uneven terrain cushioning the rider from irregularities on the road. The In-wheel suspension structure separates the spring-mass from excitations like regular suspension frameworks and describes its applicability. The research begins with the static analysis of an in-wheel suspension system. The Static model evaluates the response of the suspension system and investigates the influence of various design parameters on the in-wheel suspension.

Objectives

- **Comfort:** Absorbs shock and vibrations on all types of terrain and provides maximum cushioning for the rider.

- **Safety:** Keeps the rider steady while going over bumps and obstacles, and remains stable and rigid over flat terrain.

- **Health:** Can help reduce back and neck pain, and reduce a rider's exhaustion at the end of the day.

Significance

By providing on-demand cushioning, the In-wheel suspension decreases the vibrations that are transmitted to the body of a rider. The design also allows riders to maintain their forward momentum, which can help reduce tiredness after a long day of riding in a bicycle.

Specifications of Gas Spring

The dimensions of the gas spring are taken from the standard pre-built gas spring NitroliftGS6-15-180-220. The dimensions of the gas spring are explained with the following figure [1].

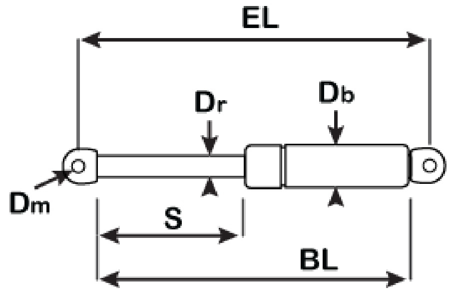


Figure 1. Dimensions of a gas spring.

Table 1. Specifications of gas spring.

Rod Diameter(Dr) (mm)	6
Body Diameter(Db) (mm)	15
Stroke (S) (mm)	180
Base Cylinder Length (BL) (mm)	400
Extended Length(EL) (mm)	430
Force (N)	50-400
Eyelet Diameter (Dm) (mm)	8.1

Calculations of Gas Spring

Calculation of pressure:

Body diameter =15mm

Therefore, cross-section area of the piston $= \pi/4^{*}(Db)^2 = \pi/4^{*}15^{*}15 = 176.7145\text{mm}^2$

(i) For minimum force, $F = 50N$

We know that $P = F/A$

$= 50/176.7145\text{mm}^2$

$PI = 0.2829N/\text{mm}^2$

(ii) For maximum force, $F = 400N$

We know that $P = F/A$

$= 400\pi/176.7145 \text{mm}^2$

$P2 = 2.2635 N/\text{mm}^2$

Now, when spring is fully extended,

Volume of gas = Area*(length of cylinder)

$= 176.7145^{*}180$

$V1 = 31808.61 N/\text{mm}^2$.

By ideal gas equation,

$PV = nRT$

Calculation of V2:

1. Assuming adiabatic compression of gas spring,

$P1 = (V1)^{\gamma} = P2(V2)^{\gamma}$ [4]

(Where 1 is the condition when the spring is fully extended And, 2 is the condition when spring is fully compressed.)

Where, $\gamma = 1.4$ (Adiabatic Index) [5]

$= 0.2829^{*}(31808.61)1.4 = 2.2635^{*}(V2)1.4$

$= V2 = 7201.7708 \text{cub.mm}$

Now, with the help of $V2$ we can find the uncovered length by the piston when the spring is fully compressed

$V2 = 7201.7708 \text{mm}^3$

Area $= 176.7145 \text{mm}^2$

We know that, Area * Length = Volume

Therefore, 176.7145 * length = 7201.7708

$= 40.75\text{mm}$

Range of Piston Displacement:

Range = Max. Stroke length- Uncovered length (When the spring is fully compressed)

$= 180 - 40.75$

$= 139.25\text{mm}$

At $P = 0.5\text{N/mm}^2 \quad V = 0.0000211\text{m}^3$

At $P = 1\text{N/mm}^2 \quad V = 0.0000129\text{m}^3$

At $P = 1.5\text{N/mm}^2 \quad V = 0.000096\text{m}^3$

At $P = 2\text{N/mm}^2 \quad V = 0.0000786\text{m}^3$.

2. Assuming polytropic compression of gas spring

$(PV^n = C)$ where $n = 1.3$

i.e. $(P1V1)^n = (P2V2)^n$[1]

(Where 1 is the condition when the spring is fully extended And, 2 is the condition when spring is fully compressed.)

Where n = Polytropic Index

= 0.2829*(31808.61)n = 2.2635 (V2)n

= V2 = 6424.15mm^3

Now, with the help of $V2$ we can find the uncovered length by the piston when the spring is fully compressed

$V2 = 6424.15\text{mm}^2$

Area $= 176.7145\text{mm}^2$

We know that, Volume = Area* Length

Therefore, 6424.15 = 176.7145*Length

Length = 36.35mm

Range of piston displacement:

Range= Max. Stroke length- Uncovered length (When the spring is fully compressed)

= 180 – 36.35mm

= 143.64mm

At $P = 0.5\text{N/mm}^2$ $V = 0.0000205\text{m}^3$

At $P = 1\text{N/mm}^2$ $V = 0.0000120\text{m}^3$

At $P = 1.5\text{N/mm}^2$ $V = 0.0000881\text{m}^3$

At $P = 2\text{N/mm}^2$ $V = 0.00007.6\text{m}^3$.

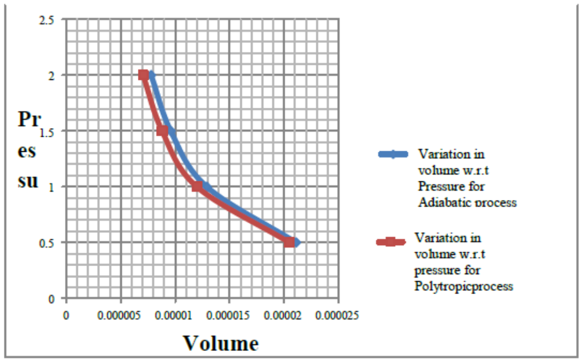
Therefore, Percentage Error = (Displacement in ideal cycle – Displacement in actual cycle)/ Displacement in ideal cycle

= (40.75 – 36.35)/40.75 = 1079%.

Representation of Variation of Volume W. R. T Pressure

Table 2. Comparison of volume in actual and ideal process.

Pressure	Variation in volume	
(N/mm^2)	Adiabatic process (m^3)	Polytropic process (m^3)
0.5	0.0000211	0.0000205
1	0.0000129	0.0000120
1.5	0.0000096	0.00000881
2	0.00000786	0.00000706



P-V Curve of the Gas

X-Axis = Volume (m^3)

Y-Axis = Pressure $(\mathrm{N/mm}^2)$

Graph clearly shows the variation of pressure and volume in between two thermodynamic processes. As the volume of the gas in the spring decreases i.e. when the spring is compressed the pressure in the spring also increases.

Assembly of In-Wheel Suspension

The suspension system is centered around the hub at an equal circumferential distance and equal angle of 120 degrees. The one end of the suspension is connected to the rim brackets and another to the hub using the gudgeon pins.

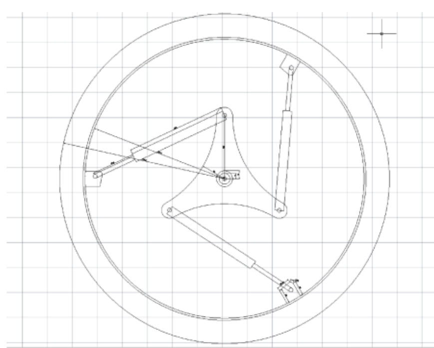


Figure 2(a). Design of wheel in Auto-Cad with Accurate Dimension.

The 3D Design Is Made Using Creo Software

Figure 2(b). Design of wheel in Creo with Accurate Dimension

Figure 2(c). Design of wheel in Creo with Accurate Dimension.

Analysis

The following static analysis on various components of a system are carried out for a value of 400N.

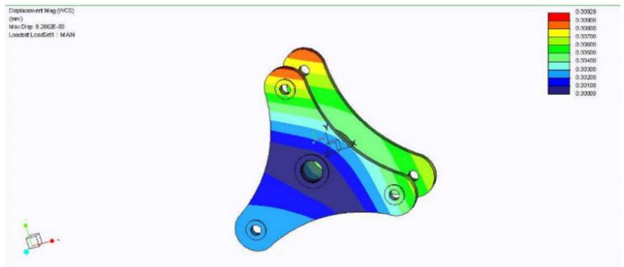


Figure 3(a). Stress distribution on hub.

Figure 3(b). Displacement distribution on hub.

Figure 3(a) shows the stress distribution (MPa) on hub on the basis of distortion energy theory, indicating the dark blue as the safest section of hub, followed by the stress value and red region as the danger zone with maximum stress value.

Similarly, figure 3(b) shows the displacement distribution magnitude (in mm) across hub.

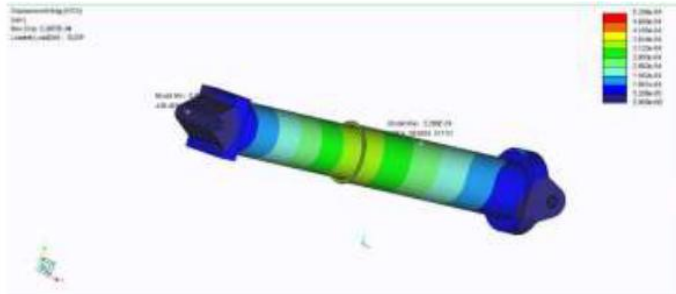


Figure 4(a). Stress distribution on gas spring.

Figure 4(b). Displacement distribution on gas spring.

Figure 4(a) shows the stress distribution (MPa) on gas spring on the basis of distortion energy theory, indicating the dark blue as the safest section of gas spring, followed by the stress value and red region as the danger zone with maximum stress value. Similarly, fig. 4(b) shows the displacement distribution magnitude (in mm) across gas spring.

Figure 5(a). Stress distribution according distortion energy theory on rim.

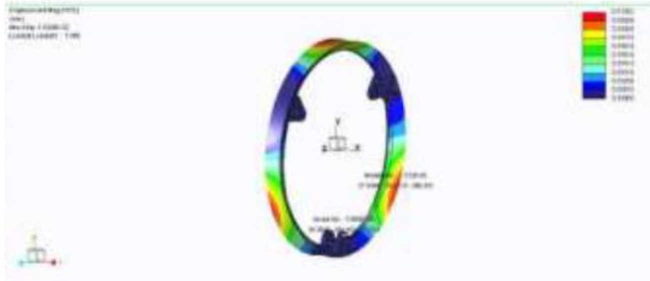


Figure 5(b). Displacement distribution on rim.

Figure 5(c). Stress distribution according maximum shear stress theory on rim.

Figure 5(a) shows the stress distribution (MPa) on rim on the basis of distortion energy theory, indicating the dark blue as the safest section of rim, followed by the stress value and red region as the danger zone with maximum stress value.

Similarly figure 5(b) shows the displacement distribution magnitude (in mm) across rim and figure 5(c) shows the stress distribution on the basis of max shear stress theory on rim followed by stress value.

Conclusion

Bicycle with In-wheel suspension system gives a smoother ride, high shock absorption capability eliminates the requirement of the additional suspension system. Also, this wheel can find their applications in bicycle, wheelchairs, mountain bikes because of their ability to adjust to bumpy terrain, cushioning the rider from irregularities on the road. A spring framework between the centre point and the edge of the wheel pads the rider from knocks and potholes in the street since the suspension framework is situated inside.

The comparison had been made between ideal and actual cycle. The ideal cycle follows the adiabatic process with the piston displacement of 40.75 mm but in actual condition the process follows polytropic cycle with the obtained piston displacement of 36.35 mm. Hence, in actual cycle, the piston displacement is 4.4 mm less than ideal cycle. The result obtained by the comparison of actual and ideal cycle possesses an error of 10.79%.

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[5]https://www.google.com/url?sa=t&source=web&rct=j&url=https://www.concepts-of-physics.com/thermodynamics/specific-heats-cv-and-cp-for-monatomic-and-diatomic-gases.php&ved=2ahUKEwib8uyPpdPnAhXC6nMBHXlGA0gQFjACegQIDxAN&usg=AOvVaw0-IyJx0lNWBksVo9OjmdRh&cshid=1581760775843