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Design and Analysis of Puncture Assistant Device (PAD)

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Abstract

Objectives: Two wheeler riders find themselves in distress whenever there is a puncture for want of locating the closest puncture/tire repair shop. A device is required which a rider can use to place under the two wheeler and conveniently drag it to the nearest puncture shop. **Methods:** The apparatus consists of a simple trolley which can bear the weight of the motorcycle and the rider and can rigidly move without slipping out from the cradle of the trolley. The trolley and cradle has been designed using Mechanical Design principles and FEM analysis and validated by testing. Tribological considerations have been used from the state of art to set a low pulling load for driver. We have optimized the weight and configuration of the device and have reduced the effort required to drag the vehicle to the smallest possible value. **Findings/Statistical Analysis:** In AUTO sector, motorcycle's users are increasing day by day. According to industrial body SIAM Indian Two-wheeler market is expected to double every four years till 2020.So demand of customers in term of ergonomics, aesthetics and efficient engine are also increasing. Customer expects that vehicle which they purchase should be resistance to all type of failure or company should provide easy solution whenever they get any problem in their vehicle. In other words human factor involved while handling sick vehicle should be very ergonomic. **Applications/Improvements:** Customer getting punctured tire or flat tire in their vehicle is serious condition which disturbs their mind, brings anxiety and health issue if they are forced to pull punctured vehicle. When a punctured vehicle is dragged the tire also gets damaged. Puncture Assistant Device is unique concept for helping driver to pull vehicle easily to punctured shop.

Keywords: Assistant, Health, Human Factor, Punctured Tire, Trolley, Two Wheeler

1. Introduction

1.1 Problem Definition

When a two wheeler gets punctured, the rider has to drag the vehicle as close as possible to the shop for repair. When the vehicle is dragged in such a condition the nail or object stuck in the tire often damages the tire in multiple places when the wheel rotates on the road. This causes a total damage to the tire and often requires replacement earlier than its normal expiry date.

To alleviate and address this problem, a simple solution is required to cater to stranded users of urban two wheelers.

The principal objective is to provide an efficient method and device for easier way of addressing to the sick two wheeler which has a punctured tire. We need to reduce the occurrence of increase of punctures in an already punctured wheel, while it is getting dragged in the conventional method on its way towards the tire puncture shop. We need an easy way to take the punctured two wheeler to a puncture shop in an efficient manner[1].

To locate mechanics / tire shops in the vicinity GPS based assistance has been mounted in the apparatus, so that the closest puncture shop vendor can come to assist the rider.

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Table 1. Summary of Literature Survey

S.No.	Alternate available in Market	Problems
1.	Anti- puncture solution	Solidify in tire (creates hammering effect which causes uncomfortable driving)
2.	Tubeless tire	When it gets punctured, possibility of bursting tire increases16 which damages tire.
3.	Punctured vehicle Kit	It's not possible for all to handle it (not user friendly) and to repair puncture by oneself.
4.	Stepney-on rent	Costly and difficult to get it in remote area.
5.	Tow Truck (closest tempo)	It takes time to reach the damaged vehicle.
6.	Punctured free tire-solid or fibre tires	R&D is going on but depends on Road conditions and fuel efficiency decreases with air free tires.

1.2 Problems Faced by Customer

A two wheeler rider has difficulty in getting Quick Roadside Assistant. No stepney or spare wheel has been provided with two-wheeler (motor-bike models). Whenever the wheel gets punctured he/she has to depend on various factors to get out of that anxiety. A portable device is not available in the market to reduce human factor involved during flat tire condition. Customers have experienced punctures, engine failures or empty fuel tank in the middle of the journey and far from garage. In the absence of stepney, it necessitates the rider of the two wheeler to drag their vehicles to the nearby workshop where the tire& tube of the wheel is set right by fixing up of the puncture through vulcanizing of the tube[1]. This dragging of vehicle causes very serious physical disorders like back pain, fatigue, cramp etc to the user. The degree of difficulty is more highly felt for pulling of the vehicles by women, and riders who are in their middle age for they feel it as a great drudgery to perform the act. These Health hazards create additional financial strain on customer which has to be addressed by growing technology. The quantity of waste or damaged tires will also increase and it will create serious environmental pollution.

1.3 Conclusion

A device is needed for two wheelers which will save drudgery for two wheeler riders. This is the objectives with which this project has been initiated. Some sort of hardware is required to solve the above problem as well as some mobile application is also required to identify the nearest puncture shop by GPS.

2. Literature Survey

Literature survey has been done to find out what the main causes for tire getting punctured and the possible solutions[2-5] (Table 1).

A flat tire is a deflated pneumatic tire, which can cause the rim of the wheel to ride on the tire tread or the ground potentially resulting in loss of control of the vehicle or irreparable damage to the tire. The most common cause of a flat tire is puncturing of the tire by a sharp object, such as a nail, letting air escape. Depending on the size of the puncture, the tire may deflate slowly or rapidly.
Causes for flat tire:

- Failure of or damage to the valve stem;
- Rubbing of the tire against the road, ripping the tire, or separation of tire and rim by collision with another object;
- Excessive wear and tear of the tire treads allowing explosive tire failure or allowing road debris to enter through it.

Some tires, particularly a slow leak, can be repaired and re-inflated; others, especially those from worn tread, must be replaced[6].

3. Objective of Work

The main aim is to design portable trolley system for punctured two wheeler. It is named as PAD (Punctured Assistant Device). This will be assisting the users of two wheeler when they encounter a condition of punctured tires at places located in remote areas far from location of service outlets. It is aimed to protect the tire of the two wheeler, from getting further punctured and deteriorated & damaged in the event of occurrence of a puncture and while being taken to the tire workshop for getting the puncture set right by conventional method, i.e., dragging the sick vehicle (due to punctured wheel) to the nearby

location where the tire workshop can be found[7]. Therefore device should be designed which can resolve the above problems.

An extendable trolley device for assistance in movement of a two wheeler with a punctured tire has to meet the following criteria which will be the main objectives in designing this Punctured Assistant Apparatus[8].

- Pulling force for punctured vehicle has to be reduced by 50-60% when we use apparatus with sick vehicle.
- Tire with proper inflation pressure has minimum rolling friction, but when it gets flattened then contact area between road and tire interface increases so main aim will be to reduce this rolling or sliding friction from surface contact to line contact.
- To remove health hazards like back pain, cramps in body due to pulling of vehicle.
- To reduce fatigue and anxiety of people that further causes health hazards.
- To enable user for easy pulling in dark surrounding.
- To reduce our dependency on other people when the tires get punctured.
- Apparatus has to be portable so that the rider can attach it without difficulty to his/her vehicle.
- Quick assembly of apparatus and quick assistance in needful situation of sick vehicle.
- Smart software application has to be made which will enable TIRE doctor (PAD) to locate by GPS.
- Ergonomically designed for sporty and good look.

4. Conceptual Model Development

4.1 Modeling

Pre-requisite for modeling

- Weight of model has to be kept less because apparatus will be resting on motorcycle as one of the accessories, so the efficiency of vehicle will not be altered by overweight. So provisions are made to reduce weight of system.
- It should be strong enough to hold weight of motorcycle (and person if front tire is punctured).
- Model should occupy less space on vehicle so it should be thin not bulky.
- Tires of apparatus should run very smoothly.
- Fixing mechanism between tire rim and apparatus should be tight enough.

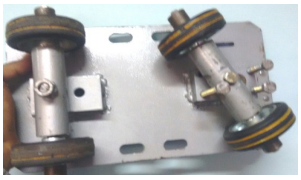

Figure 1. Model 1.

Plate type chassis is used for taking load of vehicle. In this model, aluminium material is used for constructing chassis and wheel frame. Rotation of apparatus is possible by revolving of front shaft in restricted angle as shown in Figure 1. One major problem for this model is, tire slips over the chassis in lateral as well as in longitudinal direction because of plane surface. So, Model 2 is proposed to remove this slipping problem.

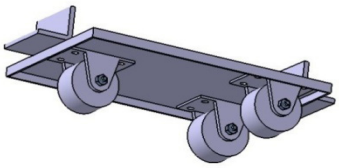

Figure 2. Model 2.

Plate type chassis with stopper has been provided to top slipping of motorcycle in longitudinal direction as shown in Figure 2. Auto-rickshaw type wheels are attached for weight reduction. Cost increases as castor are expensive. Because of Small tire diameters, the wheels are getting locked up on discontinuous road. Also there is slipping of tire on plate in lateral direction. So model 3 is proposed.

Figure 3. Model 3.

Tubular structure is used for making chassis to remove slipping of tire in lateral as well as longitudinal direction[9]. For support to flat tire when placed on chassis, cross link are welded as shown in Figure 3. This has remove problem

of slipping and weight of chassis is reduce. Disadvantage is mounting of this model on motorcycle due to its rectangular size. So model 4 is proposed.

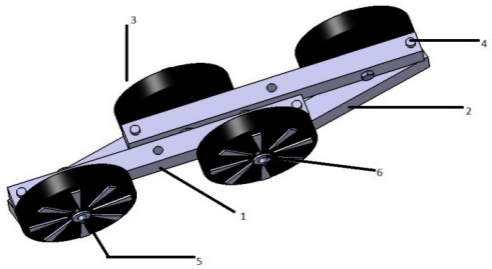

Figure 4. Model 4.

- Two long hollow pipe
- Two short hollow pipe
- Four caster sporty wheels.
- cotter pin (rivet)
- circlip
- washers

Foldability plays a very role in current scenario because everything has to be fitted in limited space. So in previous model all welded joint of tubes are replace by revolute joint and tubes are attached accordingly as shown in Figure 4. So our frame has been foldable which consume has space on vehicle. This foldable model can be easily fitted on crash bar of different vehicle as seen in Figure 5.

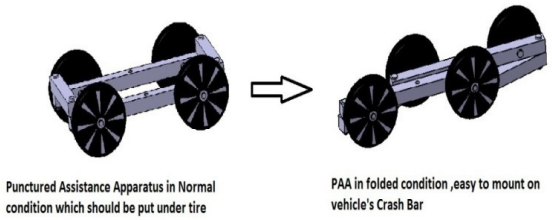

Figure 5. Foldability of model.

5. Methodology

In the event of the tire of the two wheeled vehicle getting punctured the rider can perform the following steps:

- Placing the vehicle on the existing kickstand.
- Arranging of the specially designed trolley contraption under the punctured wheel
- Securing of the Puncture assistance apparatus to the rim with the help of the belt to the wheel.
- Tightening of the belt / Fastening Means to prevent movement of the trolley as shown in Figure 6.
- Removing of the kickstand in case of

1. In the event of the front wheel of the two wheeled vehicle, riders could ride the vehicle to the puncture repair shop of his choice

2. In the event of the rear wheel or the drive wheel of the two wheeled vehicle has been punctured. The vehicle has to be dragged to the nearest help location at a reduced effort.

Figure 6. PAD under Punctured Tire.

6. Design

6.1 Bending strength of beam[10-12]

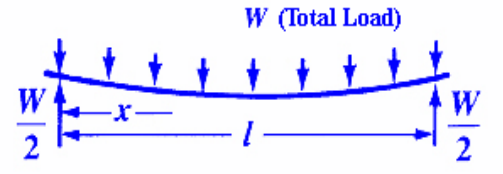

Figure 7. Loading of simple supported beam.

Calculate the required section modulus based upon the given load condition

Maximum bending moment in beam shown in figure 7, occurs at mid point

$$M_{max} = \frac{ql^2}{8}$$

Where q= total load per unit length = 300 kg/260mm

L=length of span= 260 mm

$$M_{max} = \frac{3000 \times 260}{8} = 97500 \text{ N-mm}$$

The required section modulus is

$$S = \frac{M_{max}}{\sigma_{allow}}$$

σ_{allow} = 160 N/mm^2

S= 609.375 mm^3

1. Select a trial size for the beam 20*20*1 mm (from standard size available in market)

2. Section modulus for required beam section is S = I/0.5b

$$I = \frac{b^4 - (b-2t)^4}{12}$$

Where b= outer length of square cross section

T= thickness of square cross section

For our case b=20 mm and t= 1.5 mm

So I= 6373.25 mm^4

S= 637.325 mm^3

3. Section modulus of square tube S= 637.325 mm^3 is greater than required modulus S= 609.375 mm^3

4. Stress developed = $\frac{Mmax}{S} = \frac{97500}{637.325}$

=152.9832N/mm^2

Which is less than allowable stress i.e. 160 N/mm^2, so apparatus is safe from bending failure.

5. Deflection in chassis

Actual deflection at centre = $\frac{5}{384} \times \frac{WL^3}{EI}$

Where

I= Moment of inertia

E= Modulus of elasticity

W= load in N

Actual $\delta = \frac{5 \times 3000 \times 260^3}{384 \times 200000 \times 6373.25}$

= 0.5386 mm

6.2 Design for revolute joint[13]

Permissible stresses are 80MPa in tension (σ_t), 120 MPa in crushing (σ_c), 60 MPa in shear (τ).

Diameter of rivet

As the thickness of the plate is less than 8 mm, the diameter of the rivet is determined by equating the shearing resistance to the crushing resistance.

$$F_s = F_c$$

$$\frac{\pi d^2}{4} \times \tau = d \times t \times \sigma_c$$

$$\frac{\pi d^2}{4} \times 60 = d \times 2 \times 120$$

d = 5.093 mm

The nearest standard diameter of the rivet recommended, d= 6 mm

6.3 Design of mounting Bracket

As discussed above, customer needs this device to be portable. So, foldable model was designed and manufactured accordingly. Now this has to be mounted on crash bar with proper locking system so that it should not be stolen.

This bracket should tightly hold crash bar pipe so that while driving our apparatus will be properly hanging with help of this bracket.

Locking provision is provided on this bracket as shown in figure 8.

Bracket is made of steel so that it should withstand or hold wt of our apparatus and also vibrations from crash bar in driving condition.[14]

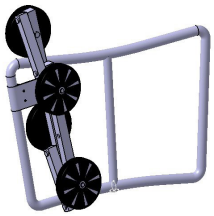

Figure 8. Assembly of Bracket on Crash bar with PAD.

6.4 Wheel Selection

Parameters for Wheel are:

- Load weight and wheel size
- Operating environment and wheel material
- Caster classifications
- Floor conditions

As discussed earlier, Castor wheel diameter is decided based on the gap left between tire and road surface when motorcycle is hanging on main stand.

Average loading on front wheel is 40kg and on rear wheel is 60 kg. Considering factor of safety loading has been considered to be 100 kg on each wheel which finally goes on to castor wheel.

By observing that height of different motorcycles, maximum height is 5-6 cm. So radius of castor wheel should not be greater than 7 cm.

Floor conditions are of different variant because device will run on Indian road.

Different materials (plastic, rubber, polycarbonate, fibre etc) are tested for 100 kg load and 5 km/hrs on tire testing machine.

After testing we found that Trackling Rubber Wheels of 4 inch diameter are successful in above test.

7. Testing

This pulling load test has been carried out on different terrain such as

1. Cement Road
2. Concrete Road
3. Muddy Road
4. Sand & Gravel road
5. Road with potholes, bumps and gradient.

Table 2. Pulling Load Test

Motorcycle	Pulling load for puncture tire	Pulling load with PAD
100 cc	60 N	36 N
100-150 cc	70 N	44 N
More than 150 cc	100 N	69 N

Type of test	Analytical	Numerical
Bending Stress	152 N/mm^2	100.183 N/mm^2
Deflection	0.5386 mm	0.3 mm

Allowable stress for Steel = 250 N/mm^2

Allowable Deflection = 1.27 mm

Fatigue Testing:

Applied Load: 100 Kg

Test Speed: 5 kmph

Test time: 30 Minutes

8. Result

- Tracking Rubber wheel with metal bush inside, Test was successful in fatigue testing Lab.
- Pulling load has been reduced by 40% with our device attached to puncture tire as shown in Table 2.
- Chassis is safe under Static and Dynamic loading.
- Tension belt is easy to close and open for tightening of PAD with tire rim.
- PAD is successful on different terrain of road surface.
- Motorcycle's handle with PAD attached at any of the wheel can be rotated on turning road because tightening of rim and PAD is proper with tension belt.

9. Conclusion

The proposed apparatus reduces the physical efforts involved in the conventional methods of taking a punctured two wheeled vehicle for a repair in the most user friendly and preferred manner.

PAD is very useful for end user because:-

1. Portable and aesthetic (sporty look attracts young generation).
2. User friendly for mounting and handling on wheel.
3. No anxiety to carry it separately (as it can be fixed on crash bar of motorcycle).
4. Economical as compared to other solutions available 4. in market whose cost is above 2000rs (PAD under 1000rs)
5. It is light weighted (under 3 kg)
6. Financial loss due to tire damage and tire change will be eliminated (approx 8k- 10k is spend in a year for tire change)
7. People will get rid of health hazards caused by pulling vehicle.
8. Environmental pollution caused by dumping waste tires will be reduced in some extent.

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