Improving the safety of two-wheeler pillion rider by modified footrest joint

M Palanivendhan¹, Vengatesan Subramanian∗, Ritvik Mishra¹, B S Harshavardhan¹
¹Department of Automobile Engineering, College of Engineering and Technology, SRM Institute of Science and Technology, Kattankulathur - 603203, Kanchipuram, Tamil Nadu, India.
∗E-mail: vengates@srmist.edu.in

Abstract

Two-wheeler with higher cc engine (180 or above) or even lower cc bikes which has aerodynamic elevation for pillion section has many problems regarding safety as well vehicle’s balance at high speed with pillion riders. Sudden braking, sudden acceleration or jumping of vehicle due to road variation can be dangerous for the pillion rider. Two-wheeler especially motorbikes and scooters have extra safety hook design extension for pillion rider to hold for safety. Sudden braking causes the bike to decelerate. the upper and the lower body of the rider riding the bike will also decelerate. For the pillion rider his/her upper body will not experience the same forces as experienced by the rider. Pillion rider lower body will decelerate with the bike as its contact with the foot of the pillion rider at footrest. To properly balance his/her upper body, the pillion rider has to hold the hook extension provided, or by holding a bike structure or by holding the bike rider. Similarly, in case of acceleration, pillion rider’s upper body tends to lean backward. To balance the force again the pillion rider has to hold the hook extension or bike rider or any other bike structure for support. In this work decided to rectify this by introducing a retrofitted joint to ensure extra safety with proper seating angle for pillion rider either during acceleration or deceleration. The modification will help to reduce the drag and lift force experienced by the pillion rider. To do this have considered “TVS Apache rtr 180” beast model to carry out our simulation to find out suitable characteristics for retrofitted joint. To carry out part designing using SOLIDWORKS software. To find out suitable characteristics for retrofitted point by simulation using MATLAB software.

Keywords: Footrest joint, two-wheeler safety, pillion Rider safety.

1. Introduction

In India, bike manufacturers are keen to produce the best mileage and performance in lower cc engines. But for safety purposes they generally stick to old ways of pillion support and uncomfortable seating angles in semi-sports bike. Most of the people in India opt to buy lower cc engines because they are affordable with low maintenance and low service charges. But to keep the bike to best of its performance is still not the best quality in an automobile for people to buy. A comfortable ride with proper rider safety is the main quality what buyers search before buying a bike in India. [1] The front leg guard is major safety feature on a two-wheeler for the rider but for the pillion rider it's a disaster during accidents. In India there are more than 278 accidents per hour during working days and it's a major cause of deaths in India. Higher cc two-wheeler in India has the most chance to get rammed during accidents and the rider or the pillion rider dies due to various reasons. [2]
According to the World Health Organization and the United Nations Children’s Fund, children of age between 3-12 are rarely spotted on the backs of motorcycles in most of the developed countries, which is contrary to most Southeast Asian countries where children are often spotted on the backs of two-wheeler as pillion rider. There have been many discussions about safety of two-wheeler pillion riders. [3] In India hook extensions in many bikes has been seen for the support of the pillion rider, ‘saree guard’ for women for their safety purposes, ‘rear-axle ABS system’ all are very important safety measures for the pillion rider. For safety concerns, to design a retrofitted joint which not only helps the pillion rider but it’s a major modification which has positive affect on bike comfort, design and aerodynamics. It will also benefit engine performance by using the retrofitted part and removing the big iron hook extensions for support or balance the unbalanced forces.

2. Literature Review

Deals with the study of ‘effect of air-resistance’ or ‘air-impact on the two-wheeler aerodynamics’. Air-resistance or impact plays major role in the performance of the two-wheeler. It has major impact over power output, acceleration, deceleration, top-speed etc. It has also a major impact on comfort for the rider as well as pillion rider. High pressure and low-pressure areas or vortex created during riding a two-wheeler totally depends on the aerodynamics. The design of the bike’s chassis and visor decides the low vortex and the high vortex areas.[4] It helps us understand the impact of air-resistance on a two-wheeler. Aerodynamics is branch of dynamics which deals with the motion of air, with the forces acting upon object in motion through the air, or with an object which is stationary in a current of air. In effect, in motorcycle aerodynamics is concerned with various distinct parts. These parts may be defined as the motorcycle, the relative wind, and the atmosphere. An air foil is a surface designed to obtain a required reaction from the air through which it moves.

Before designers develop a product for a market where the audience is unique and the market and society have a huge influence on design. This paper outlines distinctive features of motorized two-wheeler (e.g., Hero Honda, TVS, Bajaj, KTM) in India and a design approach to address the individuality of the market and its social influences. A literature review provides a basic of all the characters such an economic, environmental, policy, cultural, and physical use of passengers.[5] The members of the research team emulated the behaviours of users in order to develop their design with respect to Indian roads and passengers which also includes interview of users who tested the prototypes and models. The team was able to design a product where the drive train and rear wheel that could be protected, keeping in mind the use likelihood of saree and other traditional long dress worn by Indian women) would be caught, while increase in comfort for the pillion saddle for the pillion rider and driver. By employing these market-based methods other designers can identify safety, comfort, and convenience issues in all tyres of transportation and develop conceptual designs to meet the requirements of the end user.

It has the study of drag-reduction techniques of racing-class as well as passenger-class vehicles. It can be done either by simple modification of air vents or hoods or by creating an aerodynamic smooth exterior body which deals with the low pressure and high-pressure vortex created during moving of the vehicle. There are certain flow control techniques which used different air-flow sensors and two-wheeler dynamometer which creates a moving vehicle environment to understand how to reduce drag.[6] There are several different types of flow control devices including vortex generation, suction or a blowing jet. The suction and blowing-
jet devices are not mandatory as it does not create the exact environment in which the vehicle is moving with that intensity and power. On the other hand, vortex generation method is quite useful in case of aerodynamic testing for drag reduction as creates the exact vortex-flow created during the moving of the vehicle as well as it does not external powered to create variable environment. For this test metal vortex vanes are used with damp tape place all over the vehicle’s body to evaluate the aerodynamics of vehicle’s body. It is done in two phases one with ‘Closed Wind Tunnel’ method and the other with ‘ALL Tunnel Wind Environment’. The vehicle body is kept stationary on the metal base with metal vortex vanes on all sides with damp tape over vehicle’s body to ensure proper testing of air-resistance. Despite the effects of tunnel blockage on the vortex generator, it was found that vortex generators could effectively reduce the drag. Therefore, it is possible to use vortex generators to reduce the drag on a motorcycle.

In India vehicle’s especially two-wheeler is the main source of transport. This is due to three reasons. Firstly, the two-wheeler manufacturers in India are mainly focused on mileage in lower cc bikes. Thus, it affordable. Secondly, these lower cc bikes have less maintenance and can be transported anywhere because of its compactness and less weight. Thirdly these bikes ensure lower service charges and longevity. The major cause of accidents in India are due to road obstacles and also due to these lower cc engines having lack of vehicle’s safety features. In this thesis different design aspects have been discussed for safety and further comfort of pillion rider as well rider riding the bike. This journal is aimed to be an innovation to help protect riders from fatalities and also gives us various future automotive facilities to create comfortable and safe ride to its riders.

3. Methodology

New retrofitted joint is designed manually using designing software and the same joints are considered as in stock footrest bracket. The footrest is fixed on the newly designed footrest bracket with hydraulic-spring cylinder system and the whole retrofitted part is connected to the bike chassis using u-joint with springs crew combination for compact movement.

After designing the component, its free body diagram shows us the required forces to work on. To work further road characteristics like frictional force, sudden acceleration, sudden deceleration, wind speed etc. can be obtained from the literature survey thesis on "Motorbike Aerodynamics". After considering all the forces on the free body diagram, it can resolve all the forces according to the average weight that sits as a pillion rider, average frictional force by road, acceleration and deceleration. Using MATLAB Simulink, it can make a graphical representation and can find out different values of spring stiffness, its length and fluid’s viscosity present in the cylinder that can balance the unbalanced forces. To do the simulation the derived a formula that fully balances all the factors.

3.1 Formula Used

For Drag Force- \( kl+n*A*dv/dx \) and

For Lift force \( m*g+kl-n*A2*dv/dx \)

Here,
\( k \) = spring resistance
l = length of the cylinder (Considering 15cm)
n = viscosity of fluid
A = area of cylinder
dv/dx = velocity gradient (Here considered = 0.25)
m = mass of pillion rider (Average weight of Man or Woman in India = 50-85kg)
g = acceleration due to gravity (Known 9.81 m/s²)

3.2 Modelling of retrofitted system

The retrofitted joint is made by a 3d software called SOLIDWORKS. The joint consists of two cylinders as shown in Figure 1 with a beam connection that is linked with the bike’s chassis with stock pattern using u-joint. The cylinders contain spring and resistive fluid so that it can balance the drag and lift force. The stiffness, the viscosity of resistive fluid, and the length of spring and cylinder could be found out by simulation using literature survey’s information about aerodynamic forces and frictional forces acting on vehicles body. The hydraulic cylinder is closed from one side and movable with the spring on the other side. This enables the retrofitted part to provide enough resistance to counter the extra lift and drag force. On the other hand, the hydraulic cylinder’s casing is made up of light weight carbon fibre which further relieves us of extra weight on the vehicle as well as gives a nice outer look. As per assumptions taken the outer radius of cylinder is 0.05cm and length is 0.15cm. The viscosity of the fluid is discussed in further chapters with variable stiffness for different weight on the footrest (weight of different pillion riders).

Figure 1: 3D modelled modified footrest

We know,
Drag force = k*l + n*A*dv/dx And Lift force = m*g + k*x + n*a*dv/dx
Therefore, the average weights of passenger sitting on a pillion seat into account from 55-90 kg.
For example,
Let consider drag force equation as (a) and lift force equation as (b) then,
Considering equation (a) m*a = k*x + n*A*dv/dx
Therefore, Lift force i.e. \( b = mg + ma \)

According to initial values,

\[ m \times 4.16675 = k \times 0.15 + n \times 3.15 \times 0.05 \times 0.05 \times 0.25 \]

This becomes,

\[ m \times a = k \times 0.15 + n \times 0.0019625 \]

Taking 0.15 common both sides

Equation becomes \( 4.16675/0.15m = k + n \times 0.0019625/0.15 \)

\[ 27.7783m = k + n \times 0.01308 \]

Thus, \( k = 27.7783m - n \times 0.01308 \)

Now considering the viscous liquid as Motor Oil (SAE 60) which is very easy to get as well as has the highest viscosity of 2000 centipoise or 2 Pa s for to be used in automobiles?

Thus, \( k = 27.7783m - 2 \times 0.01308 \)

Thus, for different values of \( m \) there will be different requirement for stiffness of spring. Therefore, using the end value of \( m \) to get the highest stiffness so that it would not break or fracture in future.

4. RESULT

The graph in the computational model chapter shows the different stiffness in case of different weight which acts on the footrest (the pillion rider’s weight). Here according to this choose the material according to stiffness and the minimum strain that can be neglected. Here the average weights of pillion rider from 55 – 90 kg. So according to this that the least stiffness coefficient is 1527.780 N/m and the highest stiffness coefficient is 2499.98N/m. Based on the mass of the pillion rider the stiffness values are tabulated in table 1 and table 2.

**Table 1:** Result Tabulation (Weight from 55-71kg)

| S.No | Mass/Weight of pillion passenger [kg] | Stiffness [in N/m] |
|------|--------------------------------------|-------------------|
| 1.   | 55                                   | 1527.780          |
| 2.   | 56                                   | 1558.558          |
| 3.   | 57                                   | 1585.337          |
| 4.   | 58                                   | 1611.115          |
| 5.   | 59                                   | 1636.893          |
| 6.   | 60                                   | 1666.671          |
| 7.   | 61                                   | 1694.150          |
| 8.   | 62                                   | 1722.223          |
| 9.   | 63                                   | 1750.907          |
| 10.  | 64                                   | 1777.785          |
| 11.  | 65                                   | 1805.563          |
| 12.  | 66                                   | 1833.341          |
| 13.  | 67                                   | 1861.120          |
| 14.  | 68                                   | 1888.898          |
| 15.  | 69                                   | 1916.677          |
| 16.  | 70                                   | 1944.555          |
| 17.  | 71                                   | 1972.233          |
Table 2: Result Tabulation (Weight from 72-90kg)

| S.No. | Mass (Weight of pillion passenger in kg) | Stiffness (in N/m) |
|-------|----------------------------------------|--------------------|
| 1.    | 72                                     | 2000.611           |
| 2.    | 73                                     | 2027.700           |
| 3.    | 74                                     | 2055.668           |
| 4.    | 75                                     | 2083.566           |
| 5.    | 76                                     | 2111.124           |
| 6.    | 77                                     | 2138.660           |
| 7.    | 78                                     | 2166.681           |
| 8.    | 79                                     | 2194.460           |
| 9.    | 80                                     | 2222.238           |
| 10.   | 81                                     | 2250.161           |
| 11.   | 82                                     | 2277.794           |
| 12.   | 83                                     | 2305.573           |
| 13.   | 84                                     | 2333.351           |
| 14.   | 85                                     | 2361.129           |
| 15.   | 86                                     | 2389.906           |
| 16.   | 87                                     | 2417.686           |
| 17.   | 88                                     | 2445.464           |
| 18.   | 89                                     | 2473.242           |
| 19.   | 90                                     | 2500.021           |

According to the derivations and result we can select both spring as well as viscous fluid in our retrofitted part. The design of retrofitted part ensures proper load of itself also. To reduce that we can use light weight carbon-fibre material for outer casing as well as cap of the hydraulic cylinder.

5. Conclusion

The stiffness of the spring calculated based on the mass of the rider and the values are extracted using MATLAB software. This retrofitted setup maybe change the entire ergonomics requirement for pillion rider. It can be implemented easily with cylinder spring arrangement as modelled in this work. The future scope for this work may be extended to change the orientation of the setup to make more comfortable ride.

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