

Design and Analysis of Mono Brake System with Variable Brake Force Distribution

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Abstract - The mono brake system with variable brake force distribution is a mechanism used in two wheelers that activates the front and rear brakes at the same time by using one brake lever. Motive is to reduce the threat of accidents due to misuse of the front brake when braking. As there are a wide range of BFD ratios in the front and rear wheel, the mono brake system Variable brake force distribution (MBSVBD) can be achieved using riding comfort and high braking effort Same time, provided that the BFD ratio is Appropriately designed. This paper is aimed to develop the design method for (MBSVBD) and performance of load sensing BFD in a two wheeler.

Keywords: motorcycle; bike; system; brake force; declaration; stopping distance; weight transfer; dynamic; static; front wheel; rear wheel; weight distribution.

1. Introduction

Mono brake system with variable brake force distribution in two wheeler is a mechanism that activates the front and rear brake at the same time by using a single brake lever. The driver just has to operate a single brake lever to activate braking at the both wheels to decelerate or try to get the vehicle to a halt. In conventional braking system there are two brake levers which enhance individual braking at each wheel. Excessive use of the front brake is very risky as it can lead to rollover accidents as the rider will lose control over the vehicle in case of heavy braking at the front wheel. MBSVBD in two wheeler is the mechanism that overcomes the risk of accidents as it distributes the braking force at both wheels hence, preventing excessive braking in the front wheel. Thus MBSVBD improves the safety aspect of the vehicle along with enhancing hassle free riding experience and increasing right comfort.

2. Methodology

Influence of Dynamic Weight Transfer

In a bike which is in standstill state the distribution of total weight will be fixed in contact patch of front wheel and rear wheel.

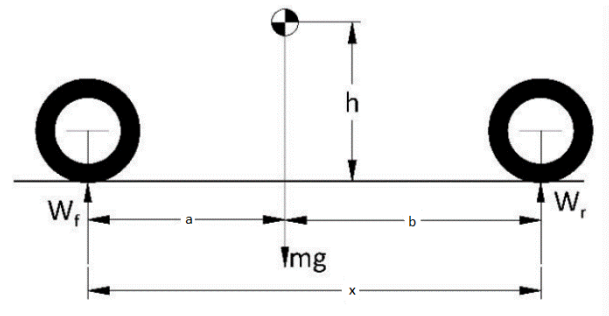


Figure 1: Motorcycle Side-view model

Taking moment at front wheel and rear wheel

Which is W_f and W_r

$$\sum M = 0$$

$$=W(a+b) - gam$$

$$\sum M = 0$$

$$=gbm - W(a+b)$$

Thus,

$$W_f = \frac{mg \times b}{(a+b)} = \frac{W \times b}{x} \text{ ----- (i)}$$

$$W_r = \frac{mg \times a}{(a+b)} = \frac{a \times W}{x} \text{ ----- (ii)}$$

Where,

W = Weight of the whole system

a = distance of front wheel from the center of gravity

x = Wheelbase of the motorcycle

b = distance of rear wheel from the center of gravity

m = Mass of the system

W_f = Static load at front wheel

W_r = Static load at rear wheel

The load at front wheel and rear wheel can be calculated by placing a weighing scale at front wheel and rear wheel, and

the location of center of gravity can be calculated using following equations;

$$a = \frac{W_r}{W} \times x$$

$$b = \frac{W_f}{W} \times x$$

When a motorcycle stops or we can say decelerates, the load at front wheel and at rear wheel will change.

At the state of deceleration, the dynamic weight transfer can be calculated using reference to the diagram shown in Figure 2.

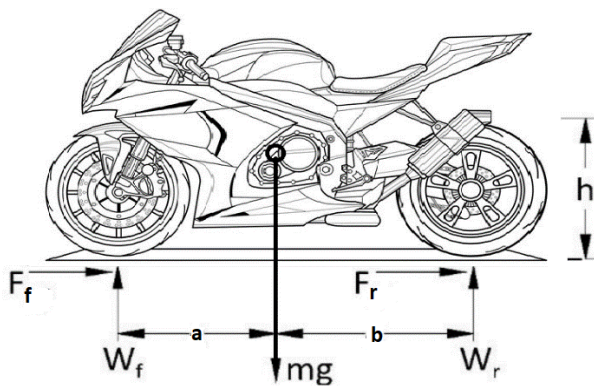


Figure 2: Free body diagram of motorcycle

In the figure h is the height from ground to center of gravity of the bike, the forces F_f and F_r are deceleration forces, if the bike decelerates at the steady state with the deceleration force which is denoted by d , using the Newton's law we can derive following equations;

$$\sum F_x = md_x = F_f + F_r$$

$$\sum F = 0$$

$$W'_f + W'_r - mg = 0$$

$$\Rightarrow W'_r = mg - W'_f$$

Where,

W'_f =load on the front wheel (Dynamic)

W'_r =load on the rear wheel (Dynamic)

$$\sum M_{CG} = 0$$

$$h(F_f + F_r) + W_r(b) - W_f(a) = 0$$

$$= ma_x h + W_r(b) - W_f(a)$$

Following equations can be used to calculate the instantaneous load on each wheel while braking.

$$W'_f = \frac{mgb}{x} + \frac{md_x h}{x} \text{-----(iii)}$$

$$W'_f = \frac{mga}{x} + \frac{md_x h}{x} \text{-----(iv)}$$

The static load on the wheel can be shown by first term of the equation and weight transfer (dynamic) can be defined by second term of the equation, the equations (iii) and (iv) can be written as;

$$W'_f = W_f + W_d$$

$$W'_r = W_r - W_d$$

At the time of deceleration the dynamic weight transfer can be presented as;

$$W_d = \frac{m \times h \times d_x}{x}$$

3. Distribution of Braking Force

In a normal BFD both the front and rear wheels get locked at the same time as maximum braking occurs when the both tires do the maximum work related to braking. The maximum braking force at each tire is in direct proportion to the load, as long as the same coefficient of friction is present at both contact surfaces of the wheel. To achieve maximum braking performance the BFD between the two wheels should be proportional to the instant will loads while breaking. To achieve maximum braking performance the proportion of braking must be properly distributed among the front wheel and rear wheel. The maximum braking force is required at the front wheel because the front wheel has more traction than the rear wheel while braking. If the load at the rear end of the motorcycle is more, then the braking force at the rear wheel will be increased and at the front wheel it will be slightly decreased to decrease the stopping distance.

4. Mathematical Modeling

For calculating the breaking efficiency and performance of a bike, 2018 RV 213 V this bike is used for mathematical modeling, here is the calculations of brake force distribution of the bike.

- Weight of bike (W_m) = 147 kg.
- Weight of rider (W_r) = 60kg.f
- Total weight of the system (W) = 227 kg. ($W_m + W_r$)
- Front weight bias (W_f/W)= 0.6
- Wheelbase (x) = 1435 mm
- CG height (h) = 610 mm
- Maximum coefficient of friction at tire-road surface in dry road condition (μ_p) = 0.80

5. Calculations

Static Weight Distribution:

In the absence of acceleration, a motorcycle's weight distribution remains constant, and as a result, both wheel support a fixed value of the total weight.

Weight on the front wheel = Total Weight × front bias weight

$$W_f = W \times \frac{W_r}{W}$$

$$\therefore W = 207 \text{ kg} \times 9.81 \times 0.6 = 1218.402 \text{ N}$$

Similarly,

Weight on the rear wheel = system Weight × Rear bias weight

$$W_r = W \times \left(1 - \frac{W_f}{W}\right)$$

$$\therefore W = 207 \text{ kg} \times 9.81 \times (1 - 0.6) = 812.268 \text{ N}$$

The location of center of gravity can be calculated using following equations;

$$c = \frac{W_r}{W} \times x$$

$$c = \frac{812.286 \text{ N}}{207 \times 9.81} \times 1435 = 574 \text{ mm}$$

And,

$$d = \frac{W_f}{W} \times x$$

$$d = \frac{1336.122 \text{ N}}{227 \times 9.81} \times 1435 = 861 \text{ mm}$$

Dynamic Impact on the Motorcycle:

At the state of deceleration, the forces acted on front wheel and rear wheel will change, the amount of weight transfer depends upon the design and geometry of the bike.

We know,

$$W_d = \frac{m \times h \times d_x}{x}$$

The maximum COF (coefficient of friction) at the tire and road contact surface provides the deceleration for a bike.

$$d_x^{\max} = \mu_p \times g$$

For the motorcycle-rider maximum attainable deceleration is;

$$d_x^{\max} = 0.8 \times 9.81 = 7.357 \text{ m/s}^2$$

Hence, all calculations will be performed for the deceleration value of 7.357 m/s^2 at the dry road with maximum COF 0.75

The amount of weight transfer can be calculated by following equation, when deceleration rate is about 7.357 m/s^2

$$W_d = \frac{207 \times 7.357 \times 610}{1435} = 647.364 \text{ N}$$

During braking the load at the front wheel will be increased, the transferred load is added to the front wheel static load and reduced from the rear wheel static load.

$$W_f' = W_f + W_d$$

$$\therefore W_f' = 1218.402 \text{ N} + 647.364 \text{ N} = 1865.766 \text{ N}$$

Similarly,

$$W_r' = W_r - W_d$$

$$\therefore W_r' = 812.268 \text{ N} - 647.364 \text{ N} = 164.904 \text{ N}$$

Influence of Dynamic Weight Transfer:

The maximum braking force that a tire can produce under static conditions is defined by the following relationship.

$$F_{bf}^{\max} = \mu_p W_r$$

$$\therefore F_f^{\max} = 0.8 \times 1218.402 \text{ N} = 974.7216 \text{ N}$$

And,

$$F_{br}^{\max} = \mu_p W_f$$

$$\therefore F_r^{\max} = 0.8 \times 812.268 \text{ N} = 649.8144 \text{ N}$$

As the maximum braking force that a tire can generate is modified as a result of dynamic weight transfer during deceleration given as follows:

$$F_{bf}^{\max} = \mu_p W_f'$$

$$\therefore F_r^{\max} = 0.8 \times 1865.766 \text{ N} = 1492.6128 \text{ N}$$

And,

$$F_{br}^{\max} = \mu_p W_r'$$

$$\therefore F_f^{\max} = 0.8 \times 164.904 \text{ N} = 131.9232 \text{ N}$$

Braking at Front Wheel:

Maximum braking force a front brake can produce is same as load on the wheel multiplied by the maximum COF available at the tire and road contact surface, if the braking is only done at front wheel.

$$d_f^{max} = g \frac{\mu_p \left[\frac{g}{x} \right]}{1 - \mu_p \left[\frac{h}{x} \right]}$$

$$d_f^{max} = 9.81 \times \frac{0.8 \left[\frac{861}{1435} \right]}{1 - 0.8 \left[\frac{610}{1435} \right]} = 7.076 \text{ m/s}^2$$

In this scenario, by using the following equation we can calculate the maximum braking force:

$$F_f^{max} = \frac{\mu_p \left[W_f + \frac{h}{x} F_r \right]}{1 - \mu_p \left[\frac{h}{x} \right]}$$

Putting $F_r = 0$ in the equation above, we get:

$$F_f^{max} = \frac{0.8 \times \left[1336.122 + \frac{600}{1435} \times 0 \right]}{1 - 0.8 \left[\frac{600}{1435} \right]} = 1606.145 \text{ N}$$

Braking at Rear Wheels:

Maximum braking force a front brake can produce is same as load on the wheel multiplied by the maximum COF available at the tire and road contact surface, if the braking is only done at front wheel.

$$d_f^{max} = g \frac{\mu_p \left[\frac{a}{x} \right]}{1 + \mu_p \left[\frac{h}{x} \right]}$$

$$d_f^{max} = 9.81 \times \frac{0.8 \left[\frac{574}{1435} \right]}{1 + 0.8 \left[\frac{610}{1435} \right]} = 2.352 \text{ m/s}^2$$

In this scenario, by using the following equation we can calculate the maximum braking force:

$$F_f^{max} = \frac{\mu_p \left[W_r + \frac{h}{x} F_r \right]}{1 + \mu_p \left[\frac{h}{x} \right]}$$

Putting $F_r = 0$ in the equation above, we get:

$$F_f^{max} = \frac{0.8 \times \left[1336.122 - \frac{610}{1435} \times 0 \right]}{1 + 0.8 \left[\frac{610}{1435} \right]} = 533.956 \text{ N}$$

6. Conclusion

Mono brake system with variable brake force distribution along with the load sensing BFD between the front and rear wheels of a two wheeler is a mechanism that improves the braking performance in a two wheeler hence improving safety aspects of the vehicle. The MBSVBD Also reduces the stopping distance compared to conventional braking system along with enhancing Hassle free braking to eliminate the

reliance on rigid constraints and rider judgment. The motorcycle load sensing brake force distribution system must adjust the front BFD factor to match the vehicle's front weight bias during Braking, thus making motorcycles more efficient.

REFERENCES

- [1] Jeffery K. Ball, Richard Stone, "Automotive Engineering Fundamentals", Society of Automotive Engineers, 2004. ISBN 9780768009873.
- [2] Rao V. Dukkipati, Jian Pang, Mohamad S. Qatu, Gang Sheng, ZuoShuguang, "Road Vehicle Dynamics", Society of Automotive Engineers, 2008. ISBN 9780768016437.
- [3] Thomas D. Gillespie, "Fundamentals of Vehicle Dynamics", Society of Automotive Engineers, 1992. ISBN 9781560911999.
- [4] Lieh, Junghsen, "Closed-form Method to Evaluate Bike Braking Performance", Human Power eJournal, Article 19, Issue 7, April 24, 2013.
- [5] John Forester, "Effective Cycling", MIT Press, 2012. ISBN 9780262516945.
- [6] <https://www.sheldonbrown.com/brakturn.html>
- [7] William F. Milliken, Douglas L. Milliken, "Race Car Vehicle Dynamics, Society of Automotive Engineers, 1994. ISBN 9781560915263
- [8] <https://motogp.hondaracingcorporation.com/rc213v - 2018/>
- [9] Yukimasa, N.; Kanau, I.; Tetsuo, T.; Yoshiaki, S. Research on dual combined brake system (Dual-CBS) for motorcycle. HONDA R D Tech. Rev. 1993, 5, 100–108.
- [10] Ghosh, S.; Samy, B.A.; Balwada, R.S.; Kaushik, R. Mechanical combined braking system design and validation for scooter. SAE Pap. 2014.
- [11] Tetsuo, T.; Kanau, I.; Yoshiaki, S.; Yukimasa, N.; Hiroyuki, N. Further research on new combined brake system (dual CBS) for motorcycles. HONDA R D Tech. Rev. 1994, 6, 194–201.

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