Designing of Variable Biasing System (VBS)

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Abstract - *The braking action of any vehicle is vital for its stability. The braking technology has developed over the years & the most advanced systems are ABS, ESP & TCS.*

In two-wheelers, combo braking is also used in which a percentage of hydraulic pressure is transferred in another master cylinder for dual braking action hence increasing the stability while braking.

ABS is way more efficient than CBS but is also quite expensive, so there is a need to design a braking system that increases stability while braking and also has a cheaper cost.

***Key Words*: braking distance, skid, dynamic stability, effectiveness, stopping distance, hydraulic pressure, brake force, Arduino UNO, servo motor, master cylinder, brake caliper, ABS (Anti-lock Braking System), CBS (Combo Braking System). VBS (Variable Braking System), TCS (Traction Control System), ESP (Electronic Stability Program)**

1. INTRODUCTION

VBS is a cheaper alternative to ABS. ABS is a mechanism that varies the brake pressure and applies brakes in a pulsating manner to avoid locking of brakes.

Whereas in VBS when we apply brakes, the applied brake force gets transmitted to the rear wheel and the front wheel receives brake force in a certain ratio corresponding to the speed of the vehicle.

At high speed when the brake is applied, the biasing automatically adjusts itself in such a manner that less hydraulic pressure is generated in the front caliper. This also allows the driver to steer the vehicle. As the vehicle decelerates, biasing changes respective of vehicle speed that more and more hydraulic pressure is generated in the front brake caliper.

Due to this varying force by both calipers, the deceleration value of the vehicle increases enormously as it retards. This variable action of VBS outstands it from CBS.

2. DESIGN & LAYOUT

After understanding the braking action of VBS, we look forward to designing a mechanism with which variable force on the master cylinder can be achieved. The perfect solution could be achieved via mechatronics.

The components used in VBS are:

1. Arduino UNO
2. Accelerometer
3. High power servo motor
4. Electronic brake lever
5. Brake system

The input devices of VBS are an electronic brake lever & accelerometer. Arduino is the processor and the servo motor will provide output in the form of linear motion.

Now, when the driver actuates the brake pedal, electronic signals are transferred to Arduino. The Arduino reads the speed rating of the vehicle from an accelerometer and processes the data. The algorithm in Arduino is programmed in such a manner that at different speeds, the front servo gets signaled to apply different proportions of force the rear servo applies. This force of the motor is respective to the speed rating of the vehicle. Such that;

SPEED RATING OF VEHICLE	FRONT: REAR FORCE DISTRIBUTION
60km/hr & above	0.33 : 1
60km/hr to 40km/hr	0.66 : 1
40km/hr & below	1 : 1

3. CALCULATIONS

For calculations, "Honda CB Hornet CBS" with CBS system and for VBS system the same bike with varying biasing and mechanism are compared.

The stopping distance of Honda CB Hornet CBS is;

SPEED	DISTANCE
80km/hr to 0	36.30m
60km/hr to 0	20.11m
40km/hr to 0	08.99m

Now, for a vehicle with VBS:

Some of the parameters like mass, wheelbase, wheel track, disc diameter is the same as of Honda Hornet.

3.1 Parameters

Disc Diameter (D_D) = 270mm (front) & 200mm (rear)

Force on piston = F_P

Wheelbase: L = 1330mm

Total weight: $W = W_F + W_R$

Weight on front axle under braking = W_{2F}

Height of front & rear wheel hub from ground = H_1 & H_2

Deceleration in braking per g (09.81 m/sec); $a^- = d/g$

Area & pressure of master cylinder = A_{MC} & P_{MC}

Area & pressure of caliper piston = A_{CP} & P_{CP}

Braking torque on front & rear disc = T_{BF} & T_{BR}

Brake force on front & rear = F_{BF} & F_{BR}

Weight on front & rear wheel = W_F & W_R

Biasing ratio of front: rear = $K_{BF} : K_{BR}$

Weight on front & rear axle = W_F & W_R

Now,

Force applied by driver on lever,

F_P = 40N; leverage = 4 : 1

Force on MC = M × F_P

= 04 × 40

F_M = 160N

Area of Master Cylinder (A_{MC}) = $(\pi \times b^2) \div 04$

$= (\pi \times 14^2) \div 04$

= 153.938 mm²

Pressure on MC = $F_M \div A_{MC}$

= 160 ÷ 153.938

P_{MC} = 1.039 N/mm²

For both front & rear caliper

Area of Caliper Piston (CP);

$A_{CP} = (\pi \times b_{CP}^2) \div 04 = (\pi \times 27^2) \div 04$

= 572.555 mm²

Force on CP (F_{CP}) = $A_{CP} \times P$

= 594.884 N

For 2 piston calipers;

$F_P = 02 \times F_{CP}$

= 1189.76 N

Force on disc;

$F_D = \mu_P \times F_P = 0.4 \times 1189.76$

= 475.90 N

3.2 Braking Torque

Front Disc,

D_{DF} = 270 mm (Outer) & 210 mm (Inner)

Effective Diameter = (Outer + Inner) ÷ 02 = 240 mm

$T_{BF} = F_D \times (D_{DF} \div 02)$

= 475.90 × (240 ÷ 02) = 57108.925 N-mm

T_{BF} = 57108.925 N-mm = 57.108 N-m

Rear Disc,

D_{DR} =200 mm (Outer) & 140 mm (Inner)

Eff. Diameter = (Outer + Inner) ÷ 02 = 170 mm

$T_{BR} = F_D \times (D_D \div 02)$ = 40451.5 N-mm

T_{BR} = 40451.5 N-mm = 40.451 N-m

3.3 Braking Force

Front,

$F_{BF} = T_{BF} \div (D_W \div 02)$ = 57108.925 ÷ (450 ÷ 225)

F_{BF} = 260 N

Rear,

$F_{BR} = T_{BR} \div (D_W \div 02)$ = 40451.5 ÷ (450 ÷225)

F_{BR} = 180 N

3.4 Weight Distribution

Dynamic Weight;

Front,

$W_F = (W \div L) \times [L_2 + (a^- \times h)]$ = 1317.573 N

Rear,

$W_R = (W \div L) \times [L_1 - (a^- \times h)]$ = 592.426 N

Static Weight;

Weight Distribution = Front: Rear = 45:55

= 859.5:1050.5 N

CONDITION	FRONT WHEEL	REAR WHEEL	TOTAL WEIGHT
Without rider	61kg	80kg	140kg
With rider	71kg	120kg	191kg

3.5 Center of Gravity

Height of CG; $h = H_1 + [(W_{2F} \times L \times L_N) \div (W \times H_2)]$

Length of CG from rear; $L_R = (W_F \times L) \div W$

Length of CG from the front; $L_F = L - L_R$

CONDITION	FRONT(L_1)	REAR(L_2)	CG(h)
Without rider	754.6mm	515.39mm	470.25mm
With rider	835.6mm	494.39mm	622.18mm

3.6 Deceleration

From sources, the stopping distance of vehicle with CBS at,

S_{V1} = 40kmph = 09.82m

S_{V1} = 60kmph = 20.11m

S_{V1} = 80kmph = 36.3m

Deceleration value;

$S = v^2 \div (2 \times a^{-})$

40kmph, $a^{-}_{40} = 0.71$ G

60kmph, $a^{-}_{60} = 0.70$ G

80kmph, $a^{-}_{80} = 0.69$ G

By value of g & formula;

80kmph,

$W_F = 131$ kg

$W_R = 60$ kg

60kmph,

$W_F = 133$ kg

$W_R = 58$ kg

Now, in vehicle equipped with VBS the biasing of braking mechanism is [0.3 :1]

As a result,

At 80 kmph;

Biasing = 0.33:1

$K_{BF}/ K_{BR} = 0.33/1$

$a^{-}_{80} = [\mu \times (L_2 \div L) + (K_{BF} \times F_R)] \div [K_{BF} - \mu \times (h \div L)]$

(μ=0.6, between road & tire)

$a^{-}_{80} = 0.70G$

At 60 kmph;

Biasing = 0.66:1

$a^{-}_{60} = [\mu \times (L_2 \div L) + (K_{BF} \times F_R)] \div [K_{BF} - \mu \times (h \div L)]$

$a^{-}_{60} = 0.71G$

At 40 kmph;

Biasing = 1:1

$a^{-}_{40} = [\mu \times (L_2 \div L) + (K_{BF} \times F_R)] \div [K_{BF} - \mu \times (h \div L)]$

$a^{-}_{40} = 0.72G$

Now, when the vehicle is at 80kmph, the biasing is 0.33:1

From 80-60 kmph

$S_{80} = (v^2 - u^2) \div (2 \times g \times a^{-}_{80}) = 15.74$m

From 60-40 kmph

$S_{60} = (v^2 - u^2) \div (2 \times g \times a^{-}_{60}) = 11.06$m

From 40-0 kmph

$S_{40} = (v^2 - u^2) \div (2 \times g \times a^{-}_{40}) = 08.73$m

Total stopping distance of vehicle

$= S_{80} + S_{60} + S_{40}$

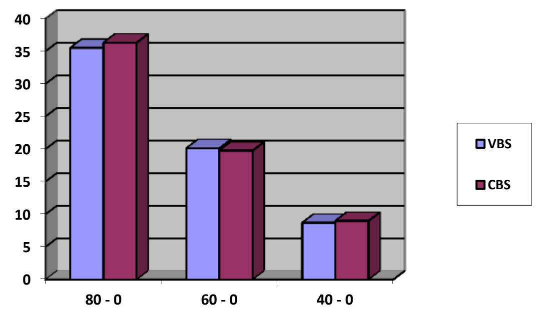
= 15.74 + 11.06 + 08.73

= 35.5m

SPEED RANGE	ACTUAL (before revamping)	PROPOSED (after revamping)
80kmph to 0	36.30m	35.50m
60kmph to 0	20.11m	19.76m
40kmph to 0	08.99m	08.70m

4. CONCLUSIONS

Therefore, from the above calculations and results, we can observe that the braking distance for each case has decreased by a considerable margin.



Hence, a vehicle equipped with this system i.e. VBS is capable of reducing the braking distance, when traveling at 80 kmph, from 36.30 meters to 35.50 meters.

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