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STUDY OF INDIAN SINGLE TRACK (100CC) VEHICLES FOR THEIR ACCELERATION PERFORMANCE.

GOPALAREDDY*, Dr. K. M JAGADEESHA [1]

* Assistant Professor, Mechanical Engineering Department, Cauvery Institute of Technology, Mandya, Karnataka, INDIA

[1] Professor, Automobile Engineering Department, PES College of Engineering, Mandya, Karnataka, INDIA.

Email: *gopalreddykonkal@gmail.com, [1] kmjagadeeshmys@gmail.com

Abstract

Recent statistics shows that there has been an increased motorcycle sales momentum in various parts of the world. India is emerging as one of the world's fastest growing passenger car markets and second largest two-wheeler producer in world. Due to comfort, availability, economical operations and aesthetic look etc. there is gradually increasing the demand for two-wheeler vehicles in India and other parts of the world. Usually in INDIA and some other economically developing countries, the motorcycle consumers focus only on economical operations, low cost and better aesthetics and vehicle manufacturing companies also give much more importance to consumer requirements by sacrificing the factors viz. vehicle mass, tyre and other parameters which creates the dynamic imbalance to the motorcycles.

Even though motorcycles have been developed and manufactured in the 19th century, they are still known to possess behavioural/dynamical problems, which can seriously compromise rider safety with possible loss of control and serious injury/loss of life as a result. Recall that, last decade about 1600 French people [1] and 39,353 Indians are killed each year, it accounts 28.6 per cent of total number of persons killed in road accidents.

In this work, much concentration has been accorded towards the study the Indian single-track vehicle (100cc) for their acceleration performance and comparing the acceleration performance of different vehicles of same category namely Hero passion, Hero splendor and I 3 smart under different conditions by considering tyre, aerodynamics parameters and location of CG. With the help of Experimental and numerical methods, the tyre, aerodynamics parameters and C.G location of Hero passion, splendor I smart and Hero splendor motorcycles has been examined on different road conditions by varying the inflation pressure, vertical load on tyres and speed of motorcycle, while other parameters have been taken from the previous work or have been suitably assumed.

***Keywords**:* Co-efficient of friction, C.G, Acceleration performance

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1. Introduction

In recent years there has been an increased motorcycle sales momentum in various parts of the world. Although motorcycle are produced in many countries, the major top five producers-China, India, European Union, Taiwan, and Japan are responsible for 87 per cent of global production. In India the Hero MotoCorp sold 16.7 lakh motorcycles in the year of June 2014 with increased rate of 42.29 per cent from April 2013 to June 2014 and Royal Enfield INDIA sold 9,651 motorcycles in the year of Feb 2014 with increased rate of 48.64 per cent from the same month in the next year. India's vehicle demand is quite different from other top automobile markets, in that two-wheelers constitute a significant portion of vehicle demand in the year 2009-2010, more than 76 per cent of the Indian market is in two-wheelers (see Fig.1)While, according to the Japan Automobile Manufacturers Association in the year 2008, Japan produced 12 lakh motor cycles.

India is emerging as one of the world's fastest growing passenger car markets and second largest two wheeler producer in world. In recent years, India had an upgrade market potential due to raise in demand. As a result there is an increased production to tap the growing demand both at home and in the foreign market. Needless to say, there is lot of investment nowadays goes into motor design and development of state-of the-art high technology machines.

Usually in INDIA and some other economically developing countries, the motorcycle consumers focus only on economical operations, low cost and better aesthetics and vehicle manufacturing companies also give much more importance to consumer requirements by sacrificing the factors viz. vehicle mass and other parameters which affects dynamic imbalance to motorcycles. The dynamic imbalance may be due to neglecting the mass of the vehicle, tyre parameters, variation in location of CG, coefficient of adhesion(μ) and etc, when the vehicle accelerates/brakes or when vehicle taking turn on a curvature or when the vehicle moving up/ down the gradient.

Aside from aerodynamic and gravitational effects, all other forces and moments affecting the stability/motion of single track vehicle are applied through the tyre ground contacts. Tyres play a predominate role on the dynamic behavior and handling characteristics of vehicle on the road, thus dynamic behavior of motor cycles are, to a great extent, governed by dynamic properties of motorcycle's tyres. Also it is learnt that various tyres conditions, such as internal pressure or inflation pressure, vertical load on tyre, tyre make, width, tread pattern, tread curvature, and the drum curvature influences the dynamic properties of single track vehicles. It is very important to study the stability of the motorcycle, in order to secure its safety in the run.

The purpose of this work is to study the Indian single track vehicle (100cc) for their acceleration performance and comparing the acceleration performance of different vehicles of same category namely Hero passion, hero splendor and I 3 smart under different conditions by considering tyre, aerodynamics parameters and location of CG with the help of experimental and numerical methods, the tyre, aerodynamics parameters and C.G location of Hero passion, splendor I smart

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and Hero splendor motorcycles has been examined on different road conditions by varying the inflation pressure, vertical load on tyres and speed of motorcycle.

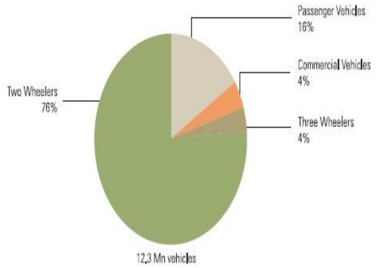

Fig.1. Indian Automobile Market 2009-10 Domestic Sales Volumes. Source: SIAM

2. Factors affecting on acceleration performance of ground vehicles

2.1. Coefficient of friction (μ):

One of the very basic safety requirements on roadways is the skid resistance. It plays major role especially during wet and rainy conditions. Friction on road surface plays an important role in keeping a vehicle safe on the road surface. It can dramatically influence braking distance and on acceleration with safety. Friction on road surface is a force which opposes the relative movement between a tyre and a pavement surface. The force can be described by non-dimensional coefficient of sliding friction, which is defined as a relation of tangential friction force F_T and normal force F_W between tyre contact area and pavement surface.

$$\mu=\frac{FT}{FW} \tag{1}$$

There are so many factors that influence on Coefficient of friction (μ).The most important factors that affect the friction coefficient are:

1. Road surface,
2. Tyre factors,
3. Weather conditions,
4. Vehicle speed,
5. Wheel slip and drift angle

2.2. Coefficient of rolling resistance (μR):

Just like grip or coefficient of adhesion (μ), the rolling resistance of tyres is due to the visco-elasticity of the rubber. This makes an energy loss each time the material undergoes distortion. Usually engineers looking for more grip and less rolling resistance therefore may seem contradictory. Like coefficient of adhesion there are so many factors influence the rolling resistance of tyre, which are as follows.

1. Tyre,
2. Road surface, and
3. Vehicle speed

2.3. Mass position centre (C.G):

The mass position centre(CG) also effects on the performance of the vehicle, it is defined as, it is the point where the whole mass is concentrated at that point the whole body is in equilibrium. Where the weight, and also all accelerative forces of acceleration, braking and cornering act through it. The mass position centre (CG), depends up on mass of vehicle and total mass on the vehicle and also depends up on the shape of the vehicle.
When making an analysis of the forces applied on the vehicles, the CG is the point to place the vehicle weight, and the centrifugal forces when the vehicle is turning or when accelerating or decelerating. The centre of mass height, relative to the wheelbase, determines load transfer between front and rear. The vehicles momentum acts at its centre of mass to tilt the vehicle forward or backward, respectively during braking and acceleration. Since it is only the downward force that changes and not the location of the center of mass, the effect on over/under steer is opposite to that of an actual change in the center of mass. A lower centre of gravity is a principal performance advantage of sports cars, compared to sedans and (especially) SUVs.

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3. Experimentation details

Fig 2. Weighing front tyre contact forces on a horizontal surface.

Fig.3. weighing rear tyre contact forces by lifting

3.1 Measurement of C.G

As we discussed earlier along with tyre parameters, centre of gravity also influences the performance of single track vehicle. In our work, we calculated the CG of Indian single-track vehicle by an analytical method by measuring the reaction force on both front and rear wheels on a horizontal surface, then on a slope.

$$l_1=\frac{Wr * L}{W} \tag{2}$$

$$b=\frac{(W * l1-Wr1 * L)\cos\theta}{W * \sin\theta} \tag{3}$$

So now we can find the horizontal distance from the front axle to the centre of mass G and for the vertical distance b from the front axle to the centre of mass and by adding the radius of the tyre, we can find the CG distance from ground level h. Finally, angle θ can be determined from a measurement of rear wheel height h and known wheelbase *l*, from equation (4)

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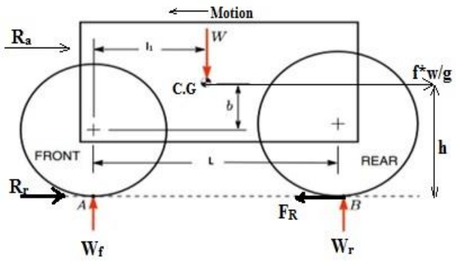
$$\text{Sin}\,\theta = \frac{h}{L} \Rightarrow \theta = \sin^{-1}\frac{h}{L} \qquad (4)$$

The accelaration perfoemance of the vehicle is nothing but achiving maximum achiveable acceleration when the vehicle is saverly accelerated without compromising the capability of following the curve and the driver safety. This performance is different for different operating conditions which are as follows

3.2 Acceleration performance

a. The governing equation of acceleration of the vehicle when moving on level road:



$$\frac{f}{g} = \frac{\frac{L}{\mu_r}(R_a + R_r) - R_a h - W l_1}{W\left[h - \frac{L}{\mu_r}\right]} \qquad (5)$$

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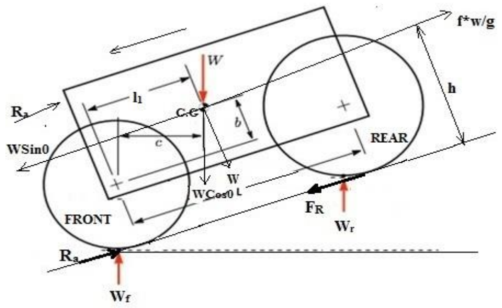
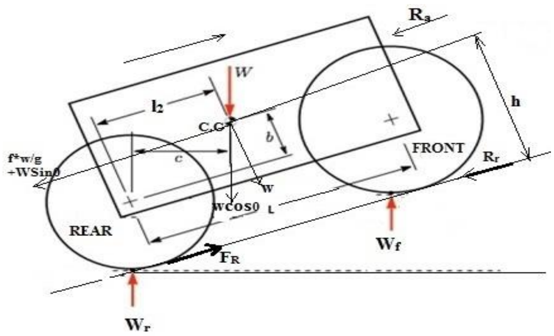
b. The governing equation of acceleration of the vehicle when down the gradient:



$$\left(\frac{f}{g}\right)=\frac{\frac{L}{\mu_r}\left[R_a+R_r+W\sin\theta\right]-h\left[R_a-W\sin\theta\right]-Wl_1\cos\theta}{W\left[h-\frac{L}{\mu_r}\right]}$$

(6)

c. The governing equation of acceleration of the vehicle when moving up the gradient.



$$\left(\frac{f}{g}\right)=\frac{\frac{L}{\mu_r}\left[R_a+R_r+W\sin\theta\right]-h\left[R_a+W\sin\theta\right]-Wl_1\cos\theta}{W\left[h-\frac{L}{\mu_r}\right]}$$

(7)

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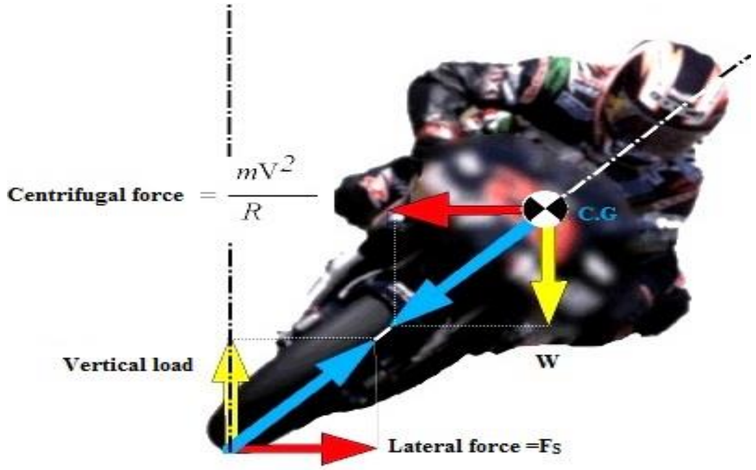
d. The governing equation of acceleration of the vehicle when negotiating the curvature.



$$\left(\frac{f}{g}\right)^2 = \frac{\frac{L^2}{\mu_r^2}\left[R_a^2 + R_r^2 + \left(\frac{Wv^2}{gR}\right)^2\right] - (R_a h)^2 - (Wl_1)^2}{W^2\left[h^2 - \frac{L^2}{\mu_r^4}\right]} \tag{8}$$

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4. Results and Discussion

There are many factors that influences the aceeleration and braking performance of the vehicles, with the help of governing equations the factors are studied. In the following section the details of the studies obtained and are discussed. The acceleration timings are calculated to accelerate the vehicle from 0-60 kmph without slip.

a. Effect of co-efficient of adhesion on Acceleration performance of different vehicles on level road, and in gradient

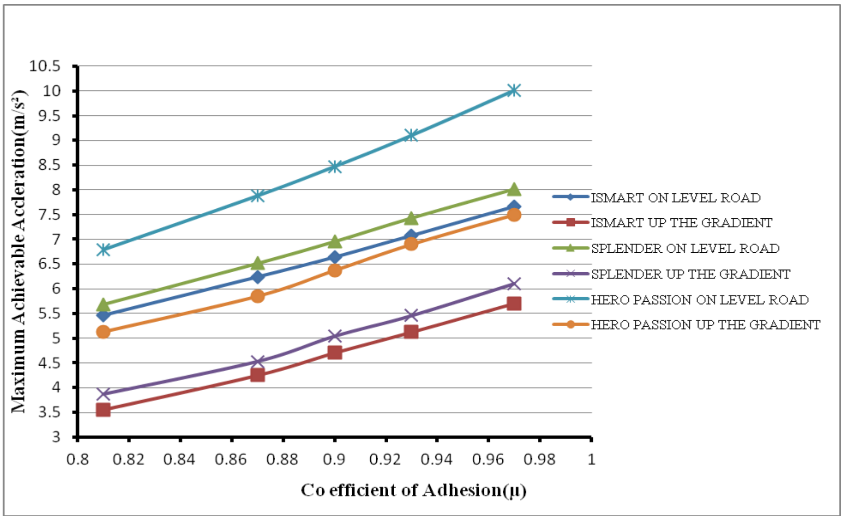

Fig.4.Variasion of maximum achievable acceleration v/s variation coefficient of adhesion when negotiating the gradient and on level road

From Fig.4, it is clear that, when the vehicle negotiating the gradient the acceleration performance of the vehicle reduces than when vehicle moving on level road. On level road the Hero passion has maximum value of acceleration (i.e. 10.01m/s²) than other two vehicles namely Hero splendor and I 3 smart. But when negotiating the gradient the acceleration rate reduces from 10.01m/s² to 8.2 m/s². By comparing the all three vehicles hero passion has maximum value of acceleration than other two vehicle in both on level road and when negotiating the gradient.

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b. Effect of C.G height from ground level on acceleration performance of different vehicles in level

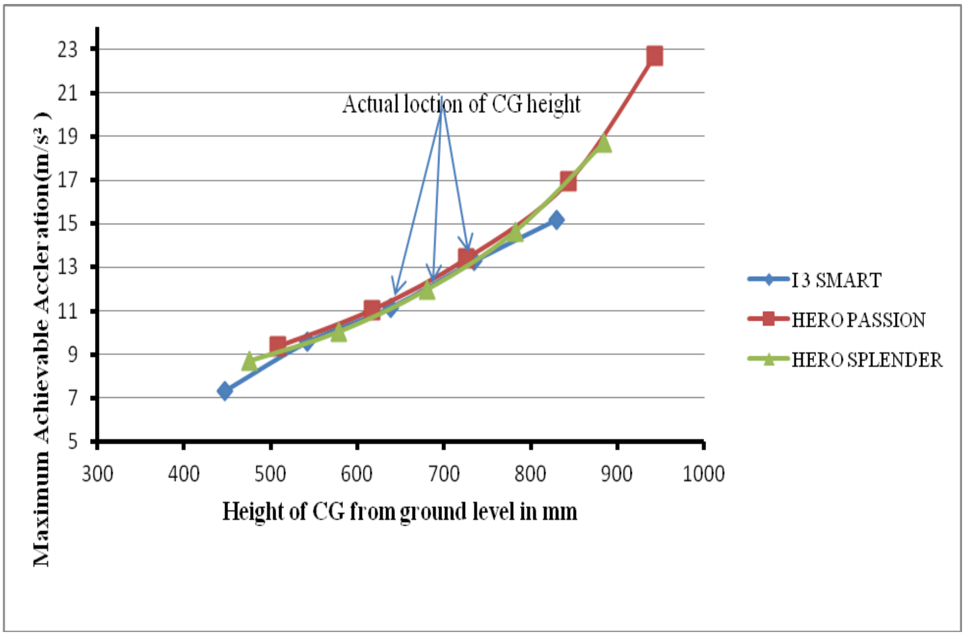

Fig.5. Effect of C.G height from ground level on acceleration performance of different vehicles in level road.

From Fig.5, show that that increasing the C.G height the maximum achievable acceleration rate increases and also maximum achievable acceleration time decreases and same trend follows in when the vehicle moves up or down the gradient. The Hero passion motorcycle has the maximum rate of acceleration i.e.15m/s² and I 3 smart has lower value of acceleration 4.47 m/s² at an height of 370mm and Hero passion take very less time i.e. 1.092 sec to accelerate from 0-60 kmph.

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c. Effect variation of CG from front wheel axle on acceleration performance of different vehicles in level road

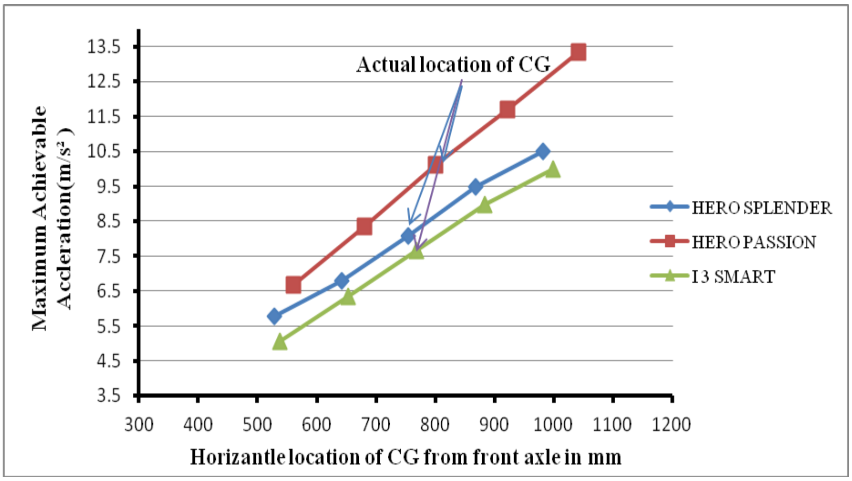

Fig.6.Variation of maximum achievable acceleration v/s variation of CG from front wheel axle

From Fig.6. It's clear that increasing the location of CG from front wheel axle results in increasing the acceleration rate and decreasing the acceleration timing. The hero passion has maximum achievable acceleration rate and minimum acceleration time but I 3 smart has lower acceleration rate and high acceleration time.

d. Acceleration performance of different vehicles in turing/ curvature

When the vehicles nagotiating a curve there may be a chance of reduction in performance of vehicles because when the vehicles nagotiating a curve the lateral forces comes in to picture i.e. centrifugal force, which results in reduction verticale reaction on tyre.

i. Effect of vehicle speed in turning on acceleration performance

When the vehicles nagotiating a curve there may be a chance of reduction in performance of vehicles because when the vehicles nagotiating a curve the lateral forces comes in to picture i.e. centrifugal force, which results in reduction verticale reaction on tyre.

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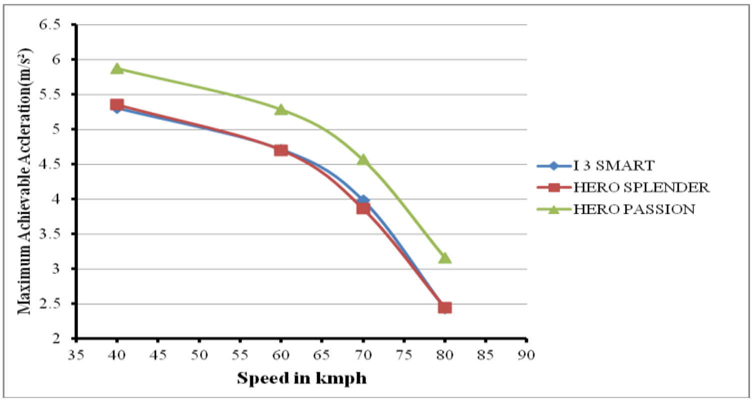

Fig.7.Variation of maximum achievable acceleration v/s variation vehicle speed in kmph.

From Fig.7. we can easily conclude that increassing the vehicle forward speed results in decreases the acceleration performance. The hero passion has high acceleration rate at low speed i.e. 5.88 m/sec² at 40 kmph and I smart has low acceleration rate i.e.2.43 m/sec² at 80 kmph.

ii. Effect radius of curvature on acceleration performance

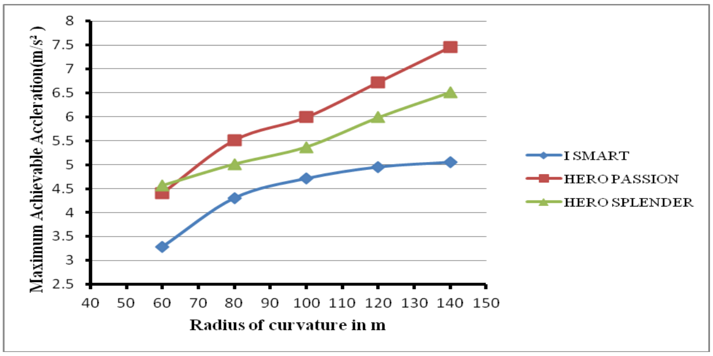

Fig.8.Variation of maximum achievable acceleration v/s variation radius if curvature

From Fig.8.it is show that that increasing the radius of curvature results in increasing the acceleration performance of the vehicles. Hero passion has maximum value of acceleration rate and I 3 smart has very low value of acceleration rate i.e.3.28m/sec² at 140m of radius of curvature.

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e. Comparison of acceleration performance of different vehicles in curvature and in straight road

By comparing the accleration performance of different vehicles when moving in a stright road and when negotianting the curvature we can easily find the effect of curvature on accelartion performance of the vehicles.

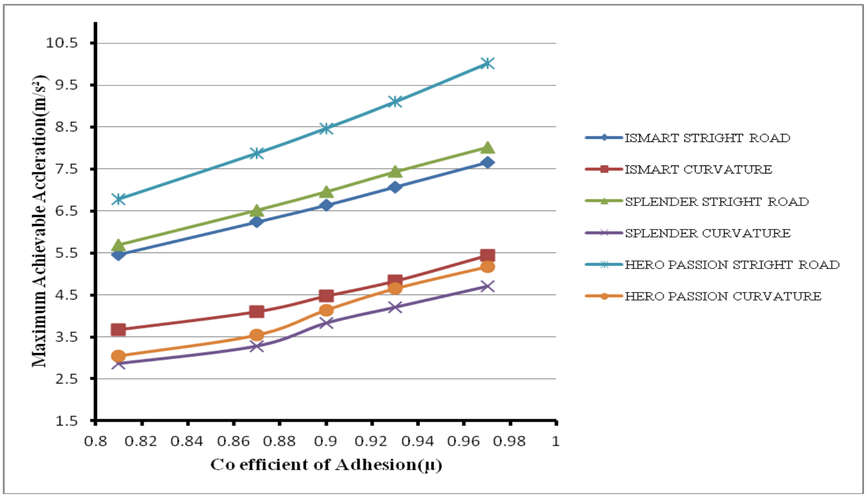

Fig.9.Variation of maximum achievable acceleration v/s variation coefficient of adhesion in straight and curved road

From Fig.9, it is clear that the vehicles in straight road have maximum achievable acceleration performance than in curved road. In straight road Hero passion has maximum acceleration and I 3 smart has lower value of acceleration but in case of curved road I 3 smart has maximum acceleration and hero splendor has lower value of acceleration i.e. 2.68m/s².

4. Conclusion

Based on the study results, the following conclusions are drawn,

1. The position of C.G in both vertical and horizontal direction influences acceleration performance in very large extent. Increasing the height of C.G increases acceleration performance of the all three vehicles. This is very merely reverse if we consider the

overall stability criteria. This makes manufacturers to in dilemma regarding giving the importance to acceleration performance or other stability criteria's.

2. Co-efficient of tyre road adhesion makes very large difference in acceleration performance of all the vehicles. Increasing the co efficient of adhesion results in increasing the performance of the vehicles.
3. The turning / curvature affect the acceleration performance of the vehicles. Increasing the vehicle forward speed the acceleration performance drastically reduces and increasing the radius of curvature increases the acceleration performance of vehicles.
4. When the vehicle negotiating the gradient the additional resistance comes in to play. Due to this additional resistance the acceleration of the vehicles reduces when the vehicle negotiating up the gradient or the down the gradient than the level road.

Finally, based on the study we can conclude that hero passion has good acceleration performance among other two vehicles namely hero splendor and I 3 smart in most of the conditions, but in case of turning I 3 smart shows the better acceleration performance than the hero passion and hero splendor.

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