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Motorcycle Dynamics

ACHA4003

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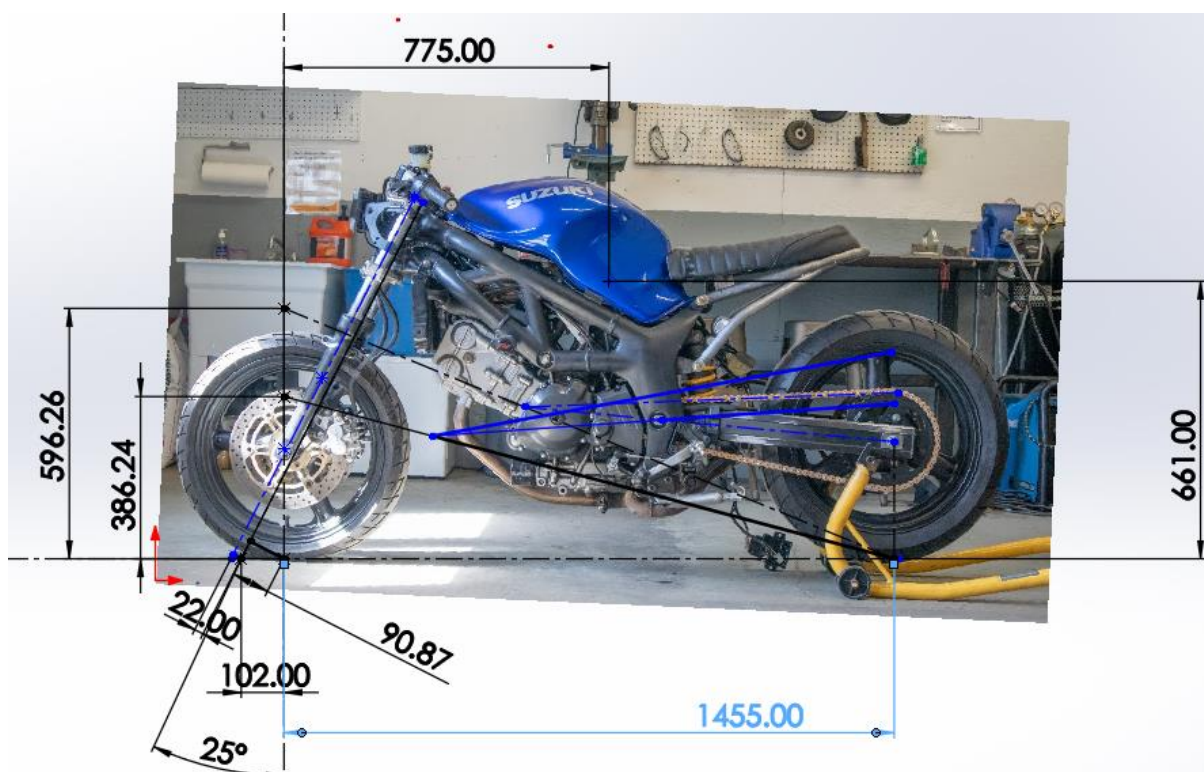
December 2022

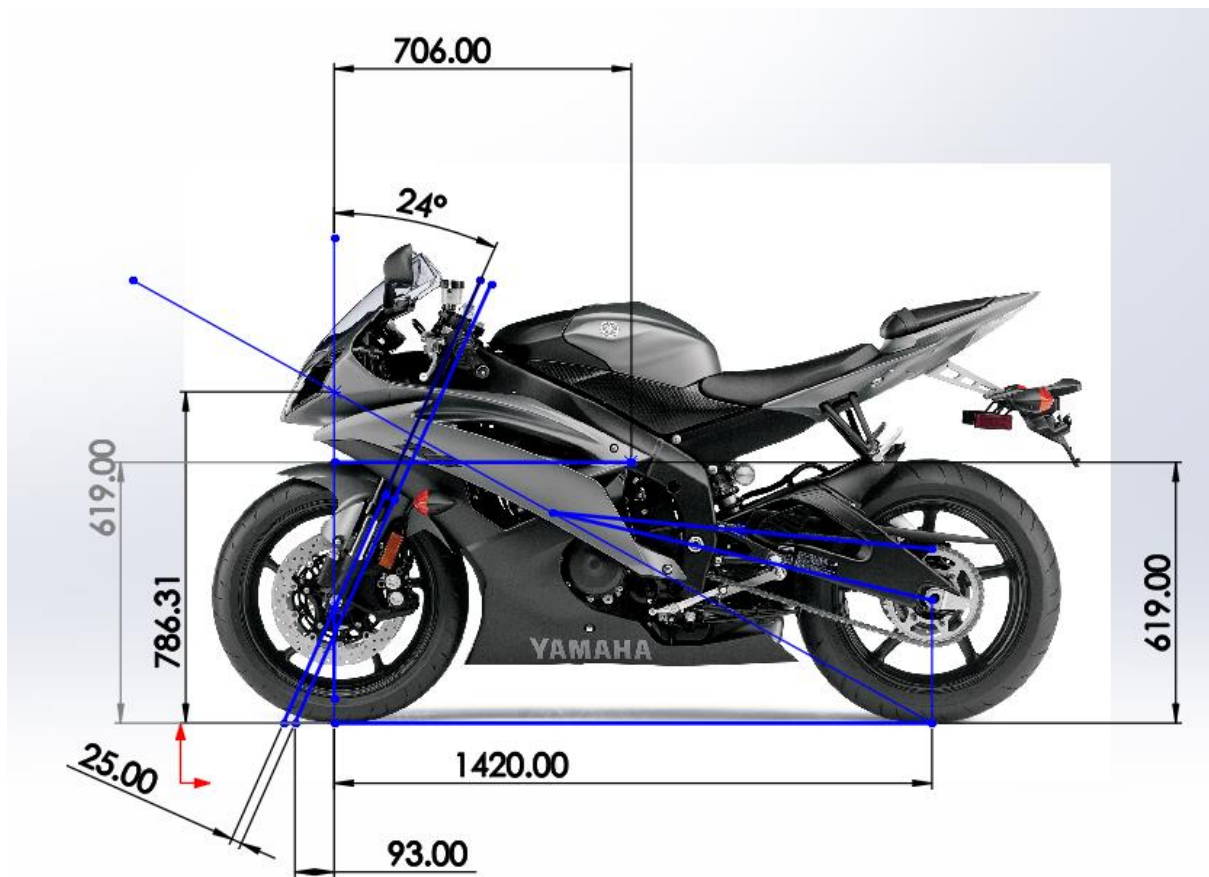
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1 Measured Geometry

Geometry Data	SV650	R6
Rake (°)	25	24
Real Trail (m)	0.99	
Trail (m)	0.102	0.93
Wheelbase (m)	1.455	1.42
Weight (kg)	157	160.55
Offset (m)	0.022	25
Unladen CoG x (m)	0.728	0.663
Unladen GoG y (m)	0.514	0.536
Laden CoG x (m)	0.775	0.706
Rider weight	68.15	59.3
Rider weight	68.15	59.3
Laden GoG y (m)	0.661	0.619
Squat Line (m)	0.596	0.786
Squat Line 2 (m)	0.386	N/a
Anti Squat 1 (%)	90.16641452	126.9%





Suzuki SV650 Power Requirements

Yamaha YZF-R6 Power Requirements

As shown above the required Power to reach the top speed of the SV is 67BHP, which is what is commonly accepted to be the rear wheel power figures for a gen 1, perhaps slightly lower.

The R6 on the other hand does not make 274BHP, or even close to.

Suzuki SV650 CofG

SV650 after snetterton, 45 or 46 sprocket, long wheelbase/ swaingamr for chain play, empty tank						
	level	level w rider		lifted	lifted w rider	
Front wheel	78.3	105		87	121	
Rear wheel	78.3	119.75		79.5	113.6	
Wheelbase	1.455			Bike weight (Kg)	156.6	
Rw Rad. (m)	0.305			Rider weight (Kg)	68.15	
Fw Rad. (m)	0.29			Total weight (Kg)	224.75	
Raverage.	0.298					
stool height	0.315			Stool weight (Kg)	6.4	
lifted angle	12.60					
					%F	%R
Xcog (m)	0.728	Ycog (m)		0.514	50.00	50.00
Xcog With	0.775	Ycog W. rider		0.661	46.72	53.28

Yamaha YZF-R6 CofG

R6 2014						
	level	level w rider		lifted	lifted w rider	
Front wheel	85.55	110.5		91.1	120.2	
Rear wheel	75	109.4		75.75	105.15	
Wheelbase	1.42			Bike weight (Kg)	160.55	
Rw Rad. (m)	0.309			Rider weight (Kg)	59.35	
Fw Rad. (m)	0.32			Total weight (Kg)	219.9	
Raverage.	0.315					
stool height	0.31			Stool weight (Kg)	6.4	
lifted angle	12.71					
					%F	%R
Xcog (m)	0.663	Ycog (m)		0.536	53.29	46.71
Xcog With	0.706	Ycog W. rider		0.619	50.25	49.75

3 Comparison SV/R6

The rake angle (angle between the vertical and axis of steering) is 1 degree steeper on the R6. Rake angle in isolation has very little effect on the handling of a motorcycle other than affecting then reducing the effective steering angle between tyre and ground compared with the angle of the bars. (Foale, 2006) Importantly however it effects other measurements such as wheelbase and trail which is what changes the characteristics mores significantly (Bradley, 2018)

Trail is measured in two ways; ground trail is the distance between the steering axis and contact point along the ground, real trail is however measured perpendicular to the steering axis. Trail gives the steering of a motorcycle a self-centring effect. Caused by the fact the contact patch is rotated around the axis of steering, producing a frictional force perpendicular to the centreline of the wheel. The effect of a smaller real trail value is a smaller moment generated by these lateral forces. (Cossalter, 2006)

Trail is affected by fork offset, wheel radius and rake angle. In this instance the difference in wheel radius is negligible. (Bradley, 2018)

Therefore, the R6 with a steeper rake angle and greater offset has a shorter trail value by 9mm. This will therefore decrease the stabilising forces produced by trail.

Wheelbase:

The wheelbase is also 7mm longer for the SV, The wheelbase does two things, firstly affects how the bike steers.

For a given radius corner a longer wheelbase requires more steering angle, this results in an increase in force the rider must input to the bars to overcome the lateral moment caused by trail.

This does give an increase in straight line stability compared with the shorter wheelbase. (Foale, 2006)

Secondly it decreases the speed of yaw, for example when the rear begins to slip

CofG position:

The laden weight distribution on the R6 is 50.25%/49.75% front to rear and a Y CofG measurement of 0.536m/0.619m static/laden. The weight distribution is also typical of modern sports bikes which have near 50/50 (Bradley, 2018) as they generally have the capacity to be stood on one wheel during braking or acceleration.

The SV has 46.72%/53.28% front/rear weight distribution laden and a y CofG position of 0.514/0.661m static/laden. Comparitively this leads to decrease in the normal force on the front which will manifest in a higher potential to understeer in the midcorner where there is little load transfer. (Bradley, 2018)

CofG in relation to Acceleration:

When accelerating the R6 has its laden CofG placed both lower and further forward, bringing it further away from the 1G line when compared with the SV.

Wheelie is caused where Load on the front equals 0 therefore using $s=mg(b/h)$ (Cossalter, 2006) to calculate the maximum driving force before wheelie, 2478N for the r6 which is an increase in 2.6%over the SV.

The SV however can only produce this much driving force in 1st gear, whereas the R6 with standard

final drive ratio will lift the front through second. Also the given road speeds of the R6 in first and second gear are much higher when compared to the SV which reaches a maximum of 48mph in first, opposed to 85mph for the R6 in second; meaning around a circuit the R6 will spend considerably more time in a range where wheelie is possible, the SV only in corners such as shaws hairpin would be doing the speeds for 1st to be utilised, however it is most likely the rider would use 2nd gear regardless for a smoother mid-corner throttle response, more controlled entry and faster exit, not needing to shift more than one gear through the subsequent chicane.

This is of course a comparison in isolation, not considering factors such as rider position, Anti-squat values, Aerodynamic lift and road plane angle, all of which are dynamic and/or adjustable.

CofG in relation to roll:

To initiate lean, roll torque must be generated around a roll axis such as gyroscopic reactions, wheel camber but predominantly the reaction due to gravity and the lateral forces at the tyres, as shown in

Fig 1

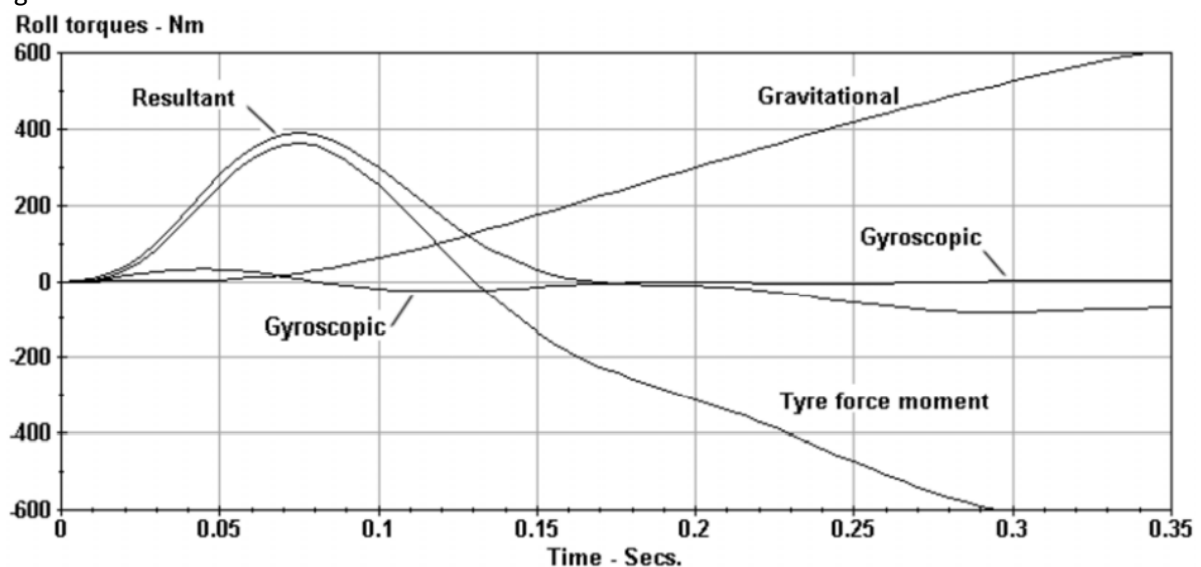


Fig. 1 (Foale,2006)

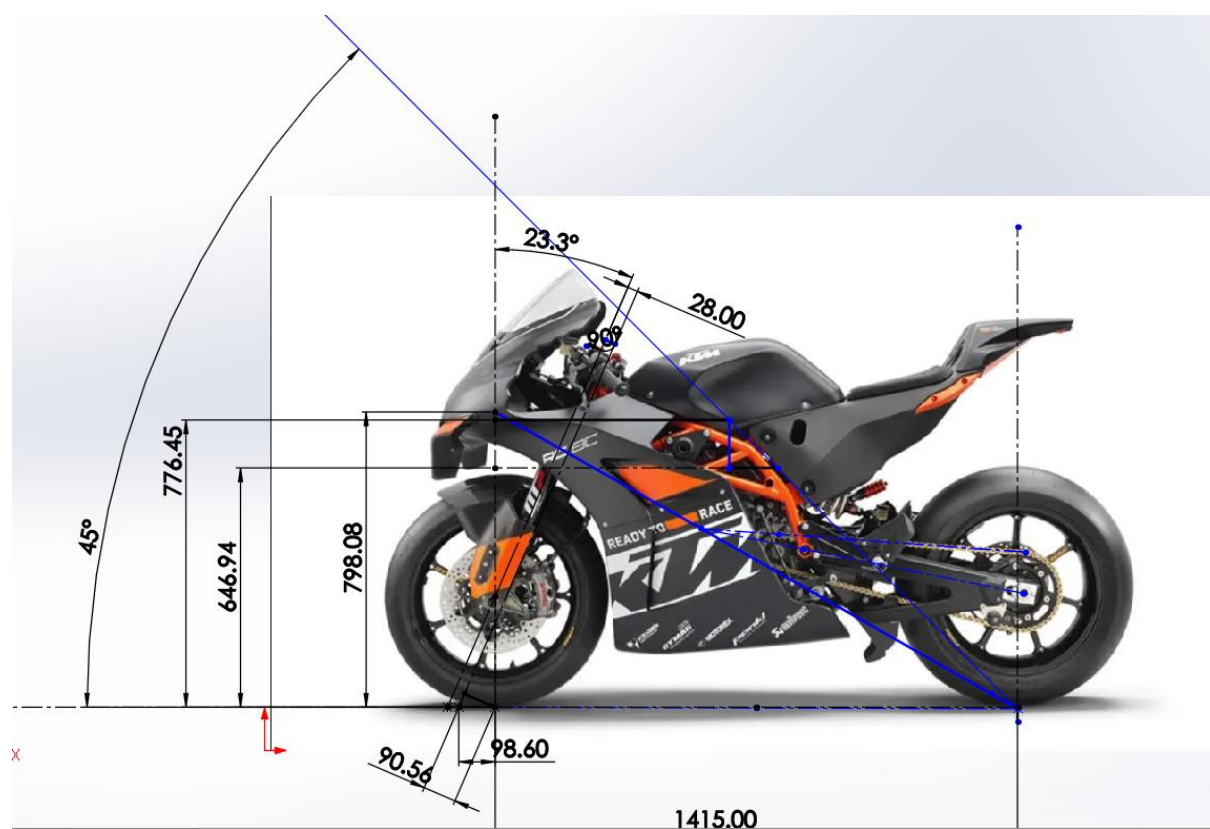
To increase the roll rate the roll torque must be increased, which is affected by mass of the motorcycle and the height of its centre of gravity position.

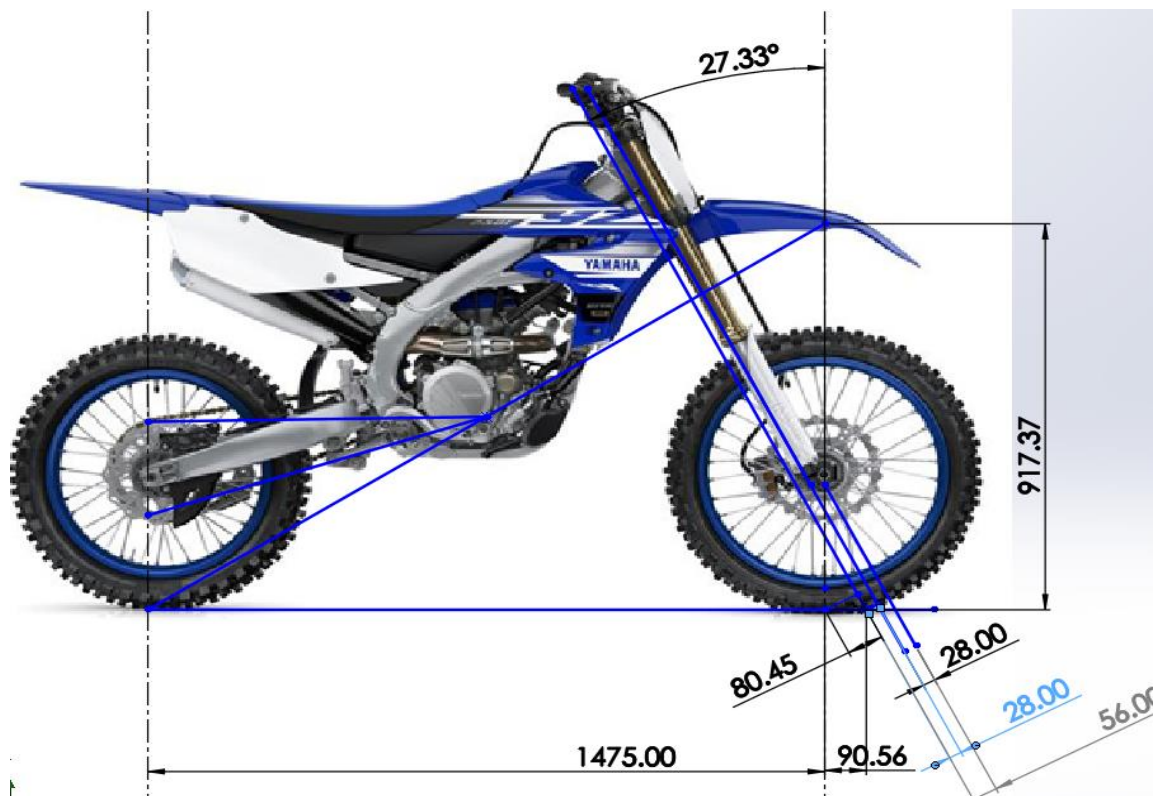
Therefore a higher CofG leads to a motorcycle which is faster to roll, or as perceived, change direction.

The CofG position is higher on the SV along with the increased weight resulting in a bike more willing to lean.

4 Acquired Geometry and Comparison

Geometry Data	YZF	KTM
Rake (°)	27.33	24.3
Real Trail (m)	80.45	90.56
Trail (m)	0.119	98.6
Wheelbase (m)	1.475	1.4
Weight (kg)	106	140
Offset (m)	22	28+28(Stem/Axle)
Unladen CoG x (m)	Est. 0.7375	N/A
Unladen GoG y (m)	N/a	N/A
Laden CoG x (m)	Est. 0.885	N/A
Rider weight	Est. 65	Est. 65
Rider weight	Est. 65	Est. 65
Laden GoG y (m)	N/a	Est. 0.6-0.75
Squat Line (m)	0.917	0.798
Squat Line 2 (m)	N/a	N/A
Anti Squat 1 (%)		Est. 83%-102%





Rake, Trail and offset

The rake angle of the YZF is substantially higher than the KTM, likely to aid in performance over rough terrain, which along with a larger front wheel radius leads to a greater trail value even though the YZF does have a greater offset, 22mm at the triple clamps and an additional *****,mm at the axle.

CofG

Exact values in this instance are not known but it is typical of a MX bike to have a near 50/50 weight distribution static, whereas the KTM would be slightly more front bias (Foyle, 2006). When comparing the two, the rider (estimated 65kg) on the YZF makes up 38% of the total mass, compared to 31% for the KTM, however the riding position of the Yamaha allows the rider to move much further forwards or back, giving far greater control of the loadings of each when riding. This makes the bike much more controllable in certain circumstances, such as when riding over tall obstacles in the track, e.g. logs or ruts, or when accelerating on loose surfaces having more load on the rear wheel increases traction. This is not so important on the KTM due to the intended road surface tending to be very smooth, the rider can still adjust the position in order to minimize wheelie, however this is much more difficult due to the riding position; rider tending to also lower their body on the throttle to reduce the cog height, therefore reducing the value of h in $s = mg(b/h)$ (Cossalter, 2006) and increasing the driving force required to wheelie.

Suspension:

Another important factor in this comparison is the suspension travel, the YZF has more travel 176mm front and 191mm travel rear to accommodate for the difference in road surface.

5 Recommended Improvements

To change the centre of gravity on the SV could be one way in which the handling may be improved. Specifically moving the centre of gravity forwards creating a more 50/50 weight distribution may lead to improvements in the mid-corner.

A common request from the rider was to try and increase the agility of the bike, therefore having the ability to raise the centre of gravity may also be required. Note there is geometry based options for this however in this case the wheelbase, fork height and shock height are all nearing the maximum adjustment positions to make the bike turn in quicker.

When moving the centre of gravity it must be considered there may be consequences, in this case also decreasing stability, decreasing the force required to lift front and rear wheels.

Therefore having a level of adjustability may be advantageous.

Finally, the centre of gravity will change through a race due to the change in fuel load.

To Implement these changes the position and shape of the fuel tank could be altered to be as shown in the overlay in Fig.2 as well as decreasing the volume to 7L from 11.8L. This would bring the X CofG position to 0.776m, resulting in 0.73% increase in static load on the front wheel with a full tank with 0.07% change to the height of the CofG between the two tank designs

importantly the change in centre of gravity positions between full and empty changes by 0.8%/0.14% X/Y

What would also be beneficial would be to make the position of the rider adjustable as well since the fuel tank and subframe are one unit in this case, incorporating a level of adjustment into the riders seat position in relation to the bikes CofG would be easy to implement; with changes to bar offset, peg height and tank cover position so the rider remaining in the same relative position. , This would be desirable due to the fact the rider makes up a much greater percentage of the total mass, therefore has a much greater impact on the CofG position. In this case bringing the rider forward by 50mm would increase change the X Cofg by 1.5%. The Y CofG could also be changed in this manner.

Having this level of adjustment and being able to test the bike initially with the same CofG as previous would be advantageous as currently there is no data on how the bike performs dynamically, and weather a change in CofG in any direction is necessarily required.

6 References

Foyle, T. (2006) Motorcycle Handling and Chassis Design. P.4-9, A8, 3-5, 3-15.

Bradley, J. (2018) The Racing Motorcycle Volume 3. P163, 166, 167, 181, 182

Cossalter, V (2006) Motorcycle Dynamics. P84.