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Motorcycle Geometry Analysis and Dynamic Handling Investigation

Motorcycle Technology ACHA4003

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1 Introduction

In this report, the geometry and handling characteristics of four different motorcycles will be analysed. These four motorcycles include a Bucci 140cc Supermoto Pit Bike, a Ducati 1199 Panigale, the Honda RC213V MotoGP bike and the Yamaha R1 World Superbike. For the Bucci and the Ducati, there will be several points of geometry that will be measured. Some of these points include trail, rake and wheelbase along with a few others. From here, the centre of gravity for both bikes will be calculated, as well as some gearbox calculations to figure out the maximum possible top speeds for both the Ducati and the Bucci.

2 Background

The Ducati Panigale 1199 is a high-spec sports bike released in 2012 and produced up until 2014, with a powerful 1199 V-twin engine, a new chassis design and an advanced electronic system which included electronic suspension adjustments (Ducati 1199 Panigale and 1199 Panigale S (2012-2014): [Review & Buying Guide], May 2023). This production bike was also used in the World Superbike championship in 2013 and piloted by Carlos Checa and Ayrton Badovini (WorldSBK, September 2011)



Figure 2-1 - The Ducati Panigale 1199

The Bucci F20SM is a Supermoto Pit Bike usually raced in various Minibike race series. These bikes are initially designed and produced as dirt bikes. However, they have been adapted so that they can be used on tarmac tracks, such as changing out the spoked wheels for magnesium wheels and changes to the front forks and rear shocks (F20SM SPECIFICATIONS | BucciMoto UK, 2024).



Figure 2-2 - The Bucci FS20SM

3 Geometry Results and Analysis

The first area that was to be calculated for both motorcycles was the centre of gravity, but a few data points were needed beforehand. These were the rear wheel load, the total weight of the bikes, the average wheel radius, the wheelbase, the load on the rear wheel when lifted and the angle that the bike was lifted. From here, the x and y values for the centre of gravity could be calculated. For the x value, the rear wheel load and wheelbase were multiplied together, and this value was divided by the total weight. For the y value, the wheelbase was multiplied by the difference between the lifted and static weight on the rear, which was divided by the total weight multiplied by the lift angle with the wheel radius added on.

For the Bucci, the x centre of gravity was 0.59 meters, and the y centre of gravity was 0.54 meters. This meant that 49.1% of the weight was on the front wheel, with 50.9% on the rear giving a fairly even weight distribution.

Parameters		
Rake Angle	19.48 Degrees	0.33999
Offset	20 mm	
Wheel Radius	250 mm	
Trail	67.21709	
Rear Wheel Load	38.1 KG	
Total Weight	74.9 KG	
Wheelbase	1.16 m	
Load on rear wheel when lifted	26.75 KG	
Lift Angle	31.147 Degrees	0.543618
Average Wheel Radius	0.25 m	
xCoG	0.590067 m	
yCoG	0.540856 m	

Figure 3-1 - Bucci Parameters

For the Ducati, the x centre of Gravity was 0.76 meters, and the y centre of gravity was 0.58 meters. This meant 47.7% of the weight was on the front, and 52.3% of weight was on the rear.

Parameters		
Rake Angle	25.66 Degrees	0.447851
Offset	27 mm	
Wheel Radius	310 mm	
Trail	118.9724	
Rear Wheel Load	97.9 KG	
Total Weight	187.25 KG	
Wheelbase	1.445 m	
Load on rear wheel when lifted	76.9 KG	
Lift Angle	31.147 Degrees	0.543618
Average Wheel Radius	0.31 m	
xCoG	0.75549 m	
yCoG	0.578146 m	

Figure 3-2- Ducati Parameters

After all this information had been gathered, both bikes were plotted as a schematic on SolidWorks, where the rake and the trail could be calculated.

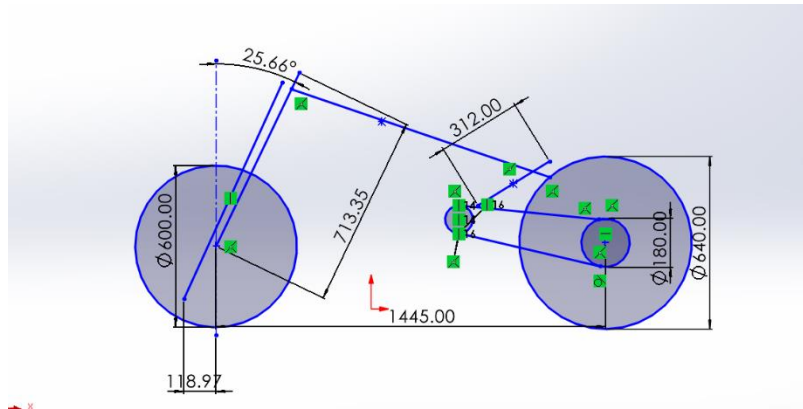


Figure 3-3 - Schematic of the Ducati Panigale 1199 including rake, trail, wheelbase, wheel radius, front fork and rear shock lengths and centre of gravity point

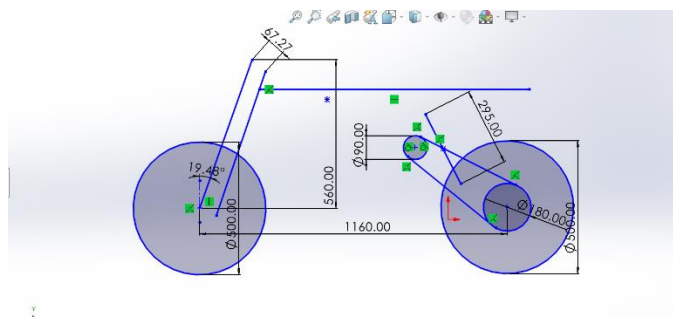


Figure 3-4 - Schematic of Bucci FS20SM including rake, trail, wheelbase, wheel radius, front fork and rear shock lengths and centre of gravity point

To calculate the rake angle, a side on image of the motorcycles was imported into SolidWorks and sketched around. For the Ducati the rake angle was 25.66 degrees, whereas the Bucci had a rake angle of 19.48 degrees. To calculate the Trail value, the front wheel radius was multiplied by the sin of the rake angle with the triple clamp offset taken away, with all of this divided by the cosine of the rake angle. This gave values of 118.97mm and 67.27mm for the Ducati and Bucci respectively.

Comparing the centres of gravity for both motorcycles, the Ducati has a higher centre of gravity than the Bucci meaning that the Ducati is able to transfer more weight during the braking and acceleration stages of a corner. Also, as the Ducati has more weight towards the rear it will also have more rear grip than the Bucci. However, as the centre of gravity is higher for the Ducati it will be more inclined for the front wheel to come off the ground and wheelie. As the Bucci has a lower centre of gravity it means it will be more stable under braking, and as the weight distribution is more even it will be less likely to understeer on corner exit compared to the Ducati which has less percentage of weight at the front. One of the main differences for the Bucci having a lower centre of gravity is the fact it is a minibike designed for kart tracks, whereas the Ducati is designed for big tracks such as Silverstone and Donnington Park. The Bucci also has a shorter wheelbase than the Ducati.

Comparing the rake values, the Bucci has a more acute Rake angle than the Ducati. This means that the Bucci will be less stable under braking than the Ducati, but it will be more agile in corners and will be able to turn quicker. This is also seen in the trail values. The Bucci has a much lower trail value than the Ducati. With the lower value, the Bucci will again be more unstable, and the steering on the Ducati will be heavier. However, with the applications of both bikes, this will help both help them in their intended environment.

4 Gearbox Calculations

There were several steps in calculating the theoretical top speeds of the two motorcycles. Firstly, the frontal area needed to be found. To do this, two front on images of the bikes were imported into SolidWorks. From here, a sketch was made around the outline of the bikes then dimensioned correctly.

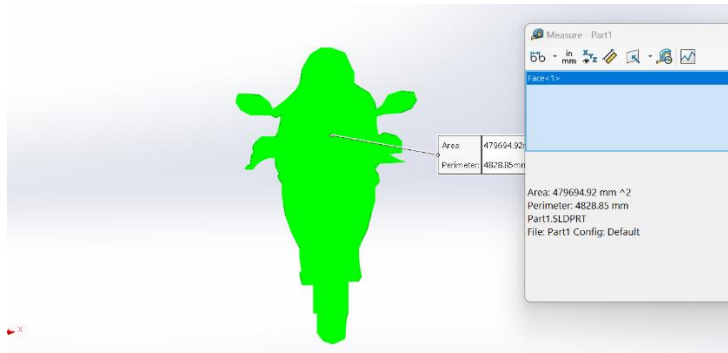


Figure 4-1 - Frontal area of the Ducati Panigale 1199

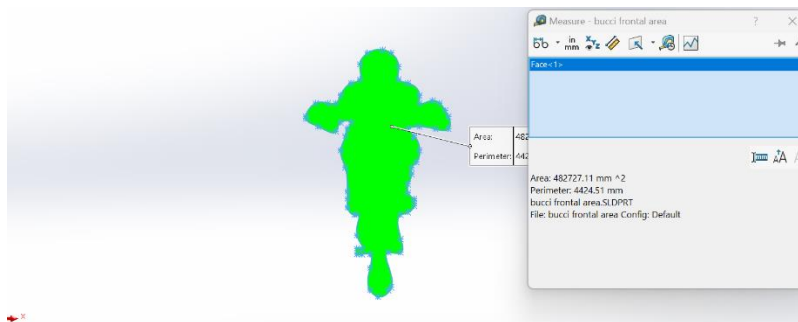


Figure 4-2 - Frontal area of the Bucci FS20SM

As seen in the figures above, the frontal area of the Ducati was 0.479694 meters squared and the Bucci's was 0.48272 meters squared. This was multiplied by the drag coefficient of the two bikes, at around 0.7. The Aero drag force and rolling resistance then needed to be calculated, as these two added together give the overall drag force on a level plane. To get this, the density of air, drag coefficient, frontal area and the velocity squared are all multiplied. The rolling resistance is 0.02 times the mass and gravity.

The gear ratios found in the workshop manuals for the Ducati are shown in the figure below.

Gearbox Calculator			
Ducati Panigale 1199			
Primary	30	53	
Final	15	39	
Diameter	0.64 m		
RPM	12000 rev/min		
		Speed (KM/H)	Revs
1st	15	37	127.7851018 12000
			9121.622 2878.378
2nd	16	30	168.1084006 12000
			9600 2400
3rd	18	27	210.1355007 12000
			10000 2000
4th	20	25	252.1626009 12000
			10472.73 1527.273
5th	22	24	288.9363135 12000
			10541.67 1458.333
6th	24	23	328.9077403 12000

Figure 4-3 - Ducati Panigale Gearbox Calculator

Also seen in this figure is the theoretical top speed of 328.9km/h. The force needed to overcome the resisting drag forces is 1805.09N and needs 164.4Kw of power. At this speed, the Ducati has a driving force of 1371.2N and makes 125.3Kw of power at 12,000RPM. This means the Ducati could not reach its theoretical top speed.

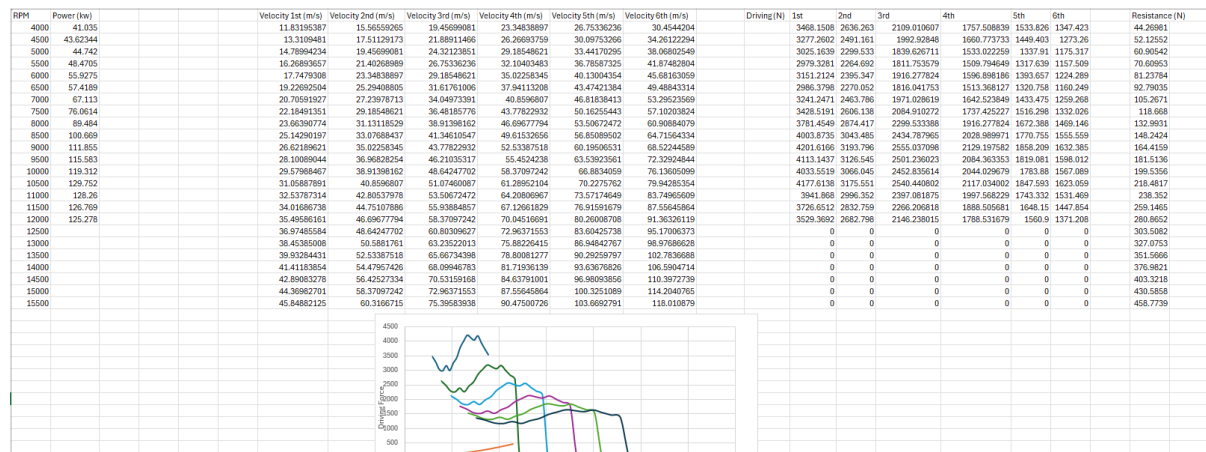


Figure 4-4 - Forces and Powers at different RPMs for the Ducati

Gearbox Calculator			
Bucci 140			
Primary	18	67	
Final	16	39	
Diameter	0.5 m		
RPM	12000 rev/min		
		Speed (KM/H)	Revs
1st	11	36	38.09359357 12000
			7104.167 4895.833
2nd	16	31	64.34577682 12000
			8379.507 3620.493
3rd	17	23	92.14734887 12000
			9313.043 2686.957
4th	20	21	118.7332787 12000

Figure 4-5 - Bucci Gearbox Calculator

For the Bucci, the calculated top speed on a level plane was 118.7km/h. The forces acting against the bike would total 244.75N and would require 8.1Kw of power. The Bucci has a driving force of 121.3N and makes around 4Kw of power at 118.7km/h, meaning it would not be able to reach this speed.

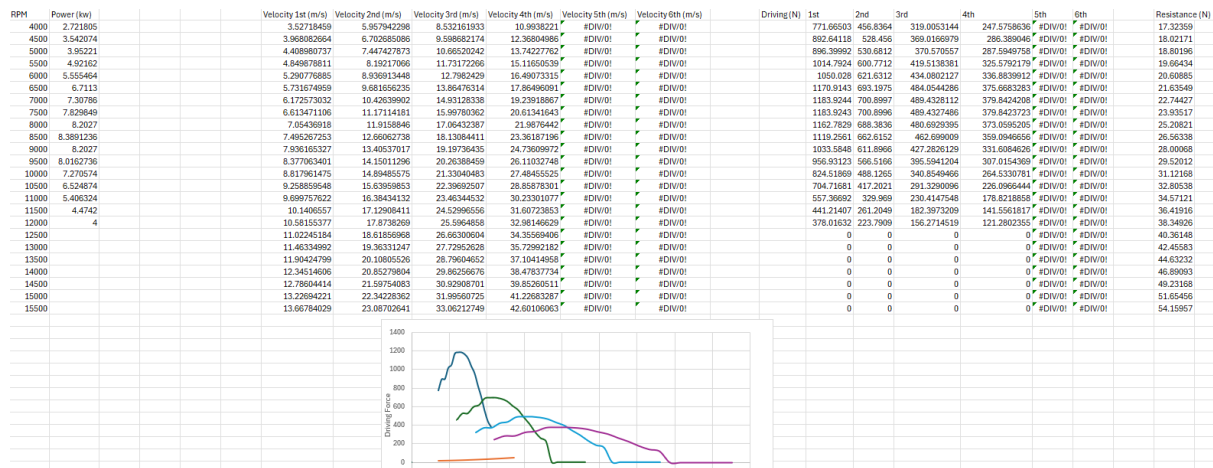


Figure 4-6 - Forces and Powers at different RPMs for the Buccia

5 Modern Motorcycle Geometry

For the Honda RC213V, there were a few geometry points available from Honda themselves (Honda Racing Corporation, 2024). The wheelbase of the bike is 1435mm, with an overall height of 1110mm and width of 645mm. With use of a side on image, a schematic was drawn.



Figure 5-1 - Side on image of the Honda RC213V

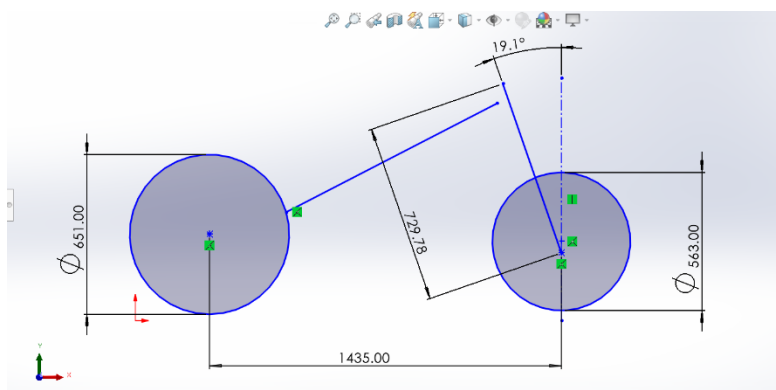


Figure 5-2 - Schematic of the Honda RC213V

From this schematic the rake angle could be found, giving a value of 19.1 degrees. With quite a low rake angle, it could mean instability for the Honda especially under braking. However, with a long wheelbase and a shorter overall height, it means the centre of gravity of the bike will be lower allowing for increased stability. Also, with features such as the rear ride height device and winglets this helps further lower the centre of gravity and increases stability.



Figure 5-3 - A side on image of the factory Yamaha R1 World Superbike

Similar to the RC213V, there were several geometry points available for the Yamaha R1 World Superbike. The wheelbase of the R1 is 1450mm, which can be changed by 15 degrees in both

directions, the height being 1150mm and a width of 690mm. The rake angle of the bike is around 24 degrees(Yamaha R1 GRT WorldSBK - Yamaha Racing, n.d.). With a standard offset of 28mm (IMA Adjustable Billet Triple Clamp - Yamaha YZF R1 2015> | IMA_TRIPLECLAMP_MOD8_CP1 | Reactive Parts, n.d.), the trail value can be assumed to be around 109.6mm

Parameters	
Rake Angle	24 Degrees
Offset	28 mm
Wheel Radius	315 mm
Trail	109.5972

Figure 5-4 - Parameters for the Yamaha R1 World Superbike

Comparing this information to the Honda RC213V, parameters such as the rake angle are much higher. This is likely due to the Yamaha R1 being a production motorcycle that the World Superbike model is derived from. Being a road bike at its core, there is only so much Yamaha can do to modify their production bike for maximum performance. With the rake angle being around the average of a sports bike but higher than a prototype Grand Prix bike, it means in situations such as change of direction the Yamaha would be slower, but the R1 still has a fairly short wheelbase and low height to help with lowering the centre of gravity giving the R1 a bit more stability.

6 Conclusion

In this conclusion, potential improvements to the Bucci's geometry and parameters will be analysed.

One way in which the handling on the Bucci could be improved is by increasing the rake value. With a higher rake value, it will give the Bucci more stability whilst the front wheel is under load. There is the disadvantage of the bike then becoming heavier to steer and the fact the bike could understeer on corner exit, but with the Bucci only weighing 74.9kg this should not affect handling too much. With an increased value, it also extends the wheelbase. This means the centre of gravity would be lowered and also potentially mean more weight would be towards the front of the bike, again helping with stability. It would also mean that the rider would be able to get on the throttle harder, as the bike would be able to transfer more weight during the acceleration stages. This does mean that there would be less weight over the rear, however with the Bucci not producing a lot of power this isn't as vital as the noticeable rear wheel slide will be negligible.

7 References

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