

A photograph of a motorcycle accident on a racetrack. A rider in a red and yellow racing suit is lying on the asphalt next to a crashed motorcycle. A large fire is burning from the engine area of the bike. The rider's helmet is black with white stars. The motorcycle is black and red. The background is a dark asphalt track.

# Motorcycle Dynamics

Centre of Gravity

# Centre of Gravity



The Centre of Gravity of a motorcycle has a big effect on how it will handle around a circuit, here are some basics

- A higher CoG enables more load transfer but if too high then when accelerating/braking the front/rear wheel comes off the ground too easily.
- A lower CoG gives more stability under braking, but if too low this could cause more wheel slip when accelerating/braking.
- To gain rear grip, it is common to shorten the rear swing arm, this moves the CoG towards the rear and puts more load on the rear tyre. Unfortunately this also is cause for more under steer as you have taken the load off the front.

# Centre of Gravity



There are two ways of working out the CoG of a motorcycle, the first we will look at is the theoretical or design method and secondly we will look at the practical method. When calculating the CoG we are interested in both the X and the Y position.

- Design Method

If we had no complete physical bike to measure, but we knew all of the components of the motorcycle and their CoG positions then it would be possible to calculate the theoretical position of the complete motorcycle's CoG by using the following calculation.

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$$W_t \cdot X_{CoG} = W_{rw} \cdot X_2 + W_r \cdot X_3 + W_e \cdot X_4 \dots \text{Etc}$$

Where –

$X_{\#}$  = X position of the component CoG from the front axle.

$W_{rw}$  = Rear Wheel Weight

$W_r$  = Rider Weight

$W_e$  = Engine Weight

The above equation could also be written –

$$X_{CoG} = \frac{W_{rw} \cdot X_2 + W_r \cdot X_3 + W_e \cdot X_4}{W_t}$$

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So we can see that we are just adding the masses and the CoG positions of each components together and dividing them by the total weight, and you would do this for all of your known components. The front wheel is not included in the  $X_{CoG}$  calculations as the X position is taken from the centre of the front wheel, but for the Y position (CoG height) you would need to include the front wheel and the positions are measured from the ground plane.

$$\frac{Y_{CoG} = W_{fw} \cdot Y_1 + W_{rw} \cdot Y_2 + W_r \cdot Y_3 + W_e \cdot Y_4 \dots \text{Etc}}{W_t}$$

# Centre of Gravity

- Practical Method

For the practical method you need to place the bike with scales under each wheel, firstly in a level position and secondly in a position where one wheel is raised on a block. In both of these positions we need to take the weights, but for the  $X_{CoG}$  we only need the level weight.

$$X_{CoG} = \frac{(W_r \times L)}{W_t}$$

Where –

$W_r$  = Load on the rear wheel

$W_t$  = Total weight of motorcycle

$L$  = Wheelbase

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$$\blacksquare Y_{CoG} = \frac{L \times (W_r - W_{\text{lifted}})}{W_t \times \tan\theta} + R_{av}$$

Where –

$W_r$  = Load on the rear wheel

$W_{\text{lifted}}$  = Load on the rear wheel when lifted on block

$W_t$  = Total weight of motorcycle

$L$  = Wheelbase

$\Theta$  = Angle of lifted bike (=  $\sin^{-1}(\text{height of block}/L)$ )

$R_{av}$  = Average wheel radius

To measure the Y CoG we need to weight the rear wheel whilst the bike is level, and again when the rear wheel is lifted onto a block, this will show a reduced rear weight.

# Centre of Gravity



Below are the dimensions and weights from an old steel framed CBR600 –

| Honda CBR 600 |        |               |                |                |         |
|---------------|--------|---------------|----------------|----------------|---------|
|               | Level  | Level W/Rider | Lifted         | Lifted W/Rider |         |
| Front Wheel   | 94.Kg  |               |                | 98.5Kg         |         |
| Rear Wheel    | 82.Kg  | 137.Kg        |                | 80.Kg          | 126.5Kg |
| Wheelbase     | 1.42mm |               | Weight of Bike |                | 176.Kg  |
| Rw Rad        | .305mm |               | Rider Weight   |                | 75.5Kg  |
| Fw Rad        | .32mm  |               | Total Weight   |                | 251.5Kg |
| Rav           | .313mm |               |                |                |         |
| Stool Height  | .345mm |               | Stool Weight   |                | 5.Kg    |
| Lifted angle  | 14.06° |               |                |                |         |

# Centre of Gravity



Below is a worked example for the  $X_{CoG}$  using the dimensions on the previous page from the old steel framed CBR600 –

$$X_{CoG} = \frac{82 \times 1.42}{176} = 0.662 \text{ m}$$

Where –

$$W_r = 82 \text{ Kg}$$

$$W_t = 176 \text{ Kg}$$

$$L = 1.42 \text{ m}$$

# Centre of Gravity

- $Y_{CoG} = \frac{1.420 \times (82 - 80)}{176 \times \tan 14.06} + 0.313 = 0.377 \text{ m}$

Where –

$$W_r = 82 \text{ Kg}$$

$$W_{\text{rflted}} = 80 \text{ Kg}$$

$$W_t = 176 \text{ Kg}$$

$$L = 1.420 \text{ m}$$

$$\Theta = 14.06^\circ$$

$$R_{av} = 0.313 \text{ m}$$

Next we can calculate the same bike but with the rider and see how the CoG is affected.

# Centre of Gravity



Below is the  $X_{CoG}$  for the old steel framed CBR600 with a rider –

$$X_{CoG} = \frac{137 \times 1.42}{251.50} = 0.774 \text{ m}$$

Where –

$$W_r = 137 \text{ Kg}$$

$$W_t = 251.50 \text{ Kg}$$

$$L = 1.42 \text{ m}$$

# Centre of Gravity

- $Y_{CoG} = \frac{1.420 \times (137 - 126.50)}{251.50 \times \tan 14.06} + 0.313 = 0.549 \text{ m}$

Where –

$$W_r = 137 \text{ Kg}$$

$$W_{\text{rli\text{fted}}} = 126.50 \text{ Kg}$$

$$W_t = 251.50 \text{ Kg}$$

$$L = 1.420 \text{ m}$$

$$\Theta = 14.06^\circ$$

$$R_{av} = 0.313 \text{ m}$$

By doing these calculations we can see how much of an influence the rider has on the CoG position. The CoG moves back 0.112 m and up 0.172 m.

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With this information it is also useful to work out the percentage split of the load on each wheel, this can be done in two ways –

- $\%_{of} = \frac{W_b - X_{CoG}}{W_b} \times 100$

$$\%_{or} = \frac{X_{CoG}}{W_b} \times 100$$

Or

- $\%_{of} = \frac{W_f}{W_t} \times 100$

$$\%_{or} = \frac{W_r}{W_t} \times 100$$

# Centre of Gravity



These methods give the following results with no rider –

$$\blacksquare \%_f = \frac{1.42 - 0.662}{1.42} \times 100 = 53.41\%$$

$$\%_r = \frac{0.662}{1.42} \times 100 = 46.59\%$$

Or

$$\blacksquare \%_f = \frac{94}{176} \times 100 = 53.41\%$$

$$\%_r = \frac{82}{176} \times 100 = 46.59\%$$

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And with the rider –

$$\blacksquare \%_f = \frac{1.42 - 0.774}{1.42} \times 100 = 45.53\%$$

$$\%_r = \frac{0.774}{1.42} \times 100 = 54.47\%$$

Or

$$\blacksquare \%_f = \frac{114.51}{251.5} \times 100 = 45.53\%$$

$$\%_r = \frac{137}{251.5} \times 100 = 54.47\%$$