Cornering Analysis of Motorbike

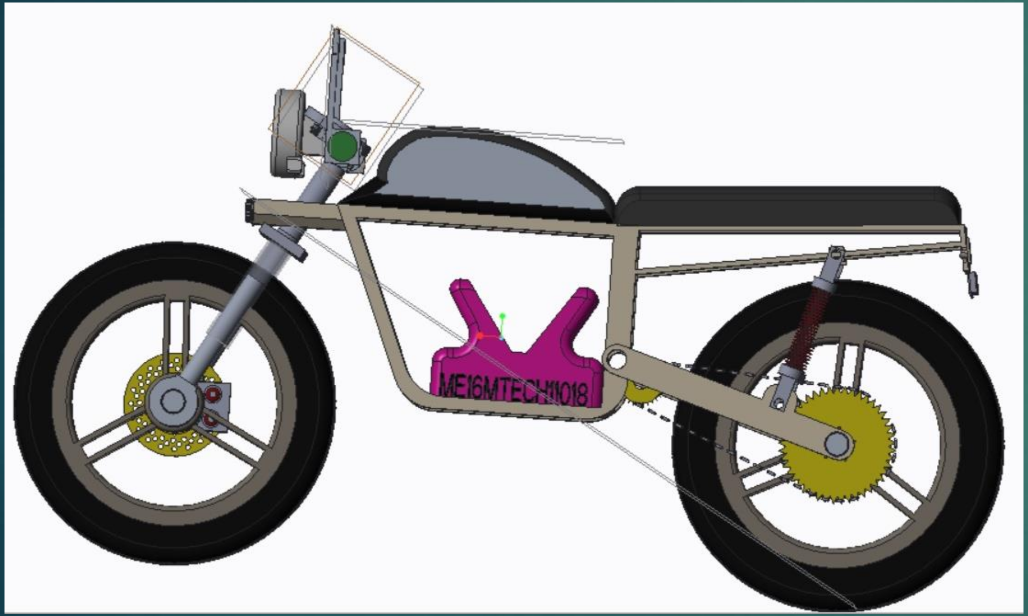
GROUP-G

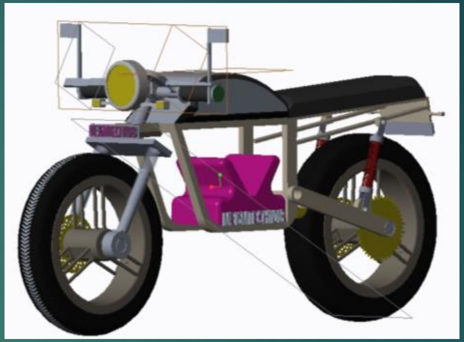
ME16MTECH11005	M Yoganandh
ME16MTECH11014	Ravi Kamani
ME16MTECH11017	Sudarshan Khandagale
ME16MTECH11018	Troglio Rodrigues
ME16MTECH11019	Chetan Ganji

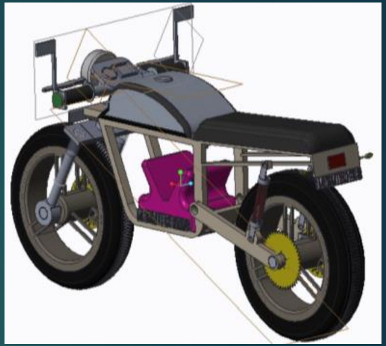
Introduction

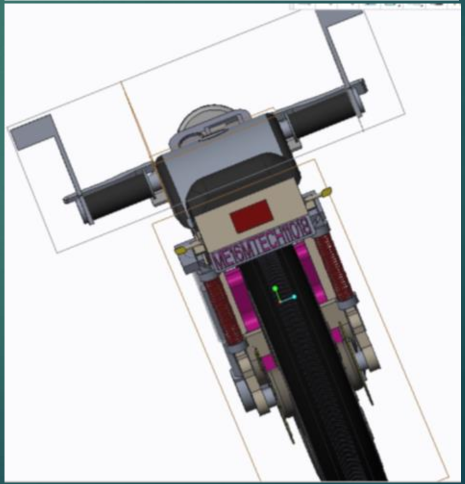
- Two-wheelers exhibit interesting dynamic characteristics.
- They are statistically unstable but when forward speed increases the instability goes on decreasing.
- Cornering of a two-wheeler deals with interaction between gravitational force, centrifugal force and the moment applied to the handle bar along with the geometry of the two-wheeler and rider.
- Leaning the two-wheeler in to a corner and maintaining an appropriate forward speed allows the gravitational force to balance the centrifugal force leading to the control and stable cornering.

Solid model of Motorbike



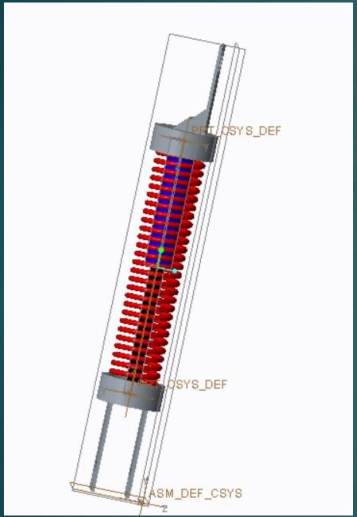


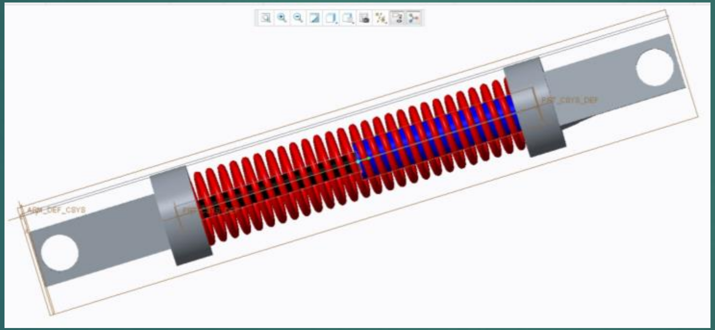


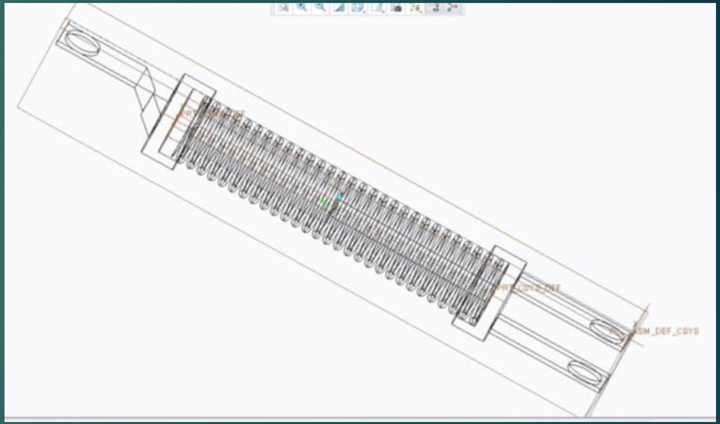


Component of Motorbike

- Rear Suspension shock absorber.



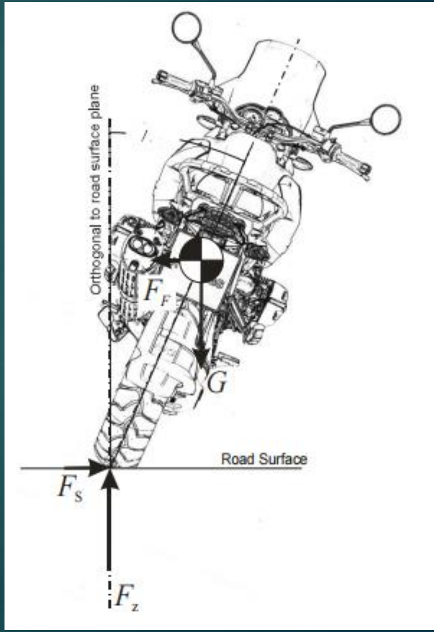




Driving Stability

The most obvious difference between four- and two-wheeled vehicles is the banking while cornering. The roll angle(λ) depends mainly on the lateral acceleration

$$\lambda = \arctan\frac{F_F}{G} = \arctan\frac{\ddot{y}}{g} = \arctan\frac{v^2}{R \cdot g}$$

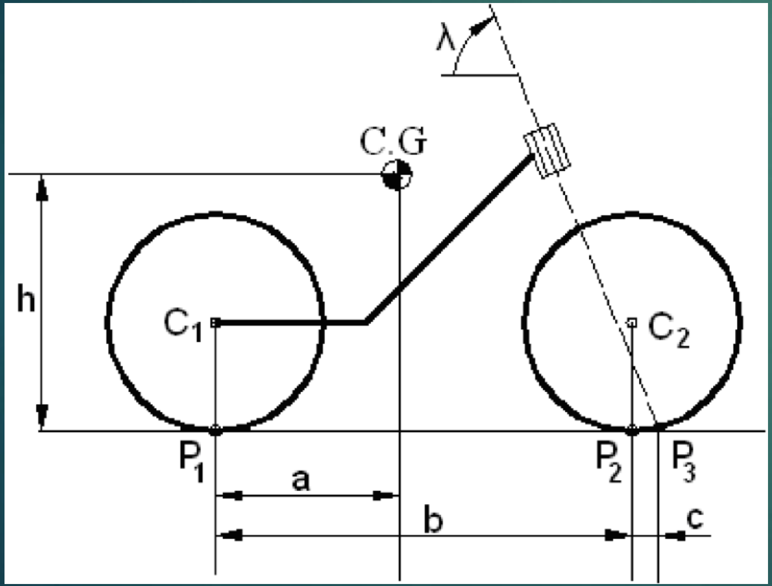


the centrifugal force F_F, the weight force G, lateral acceleration $\ddot{y}$, gravity g, cornering radius R and velocity v.

The equilibrium for the roll angle is unstable. Small perturbations generate a roll momentum that would either cause a overturn motion or a flip-over of the vehicle

Cornering of Two-wheeler without braking

- A simple Two-wheeler model is used for the analysis as shown below

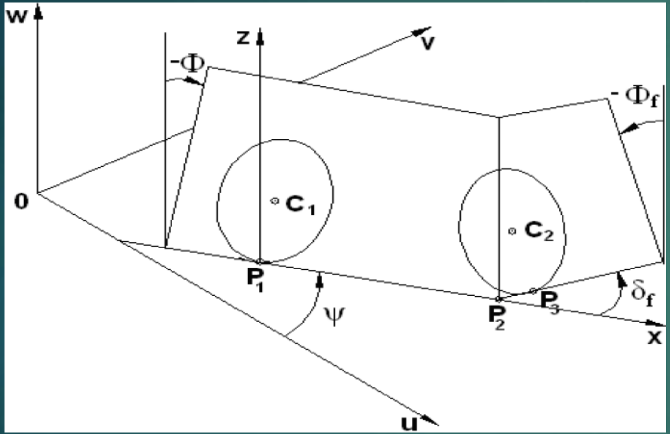


Where

- ‘h’ Position of C.G in plane containing rear wheel
- ‘λ’ is the head angle due to tilt in steer axis
- ‘a’ Position of C.G along X-axis
- ‘b’ Length of wheel base

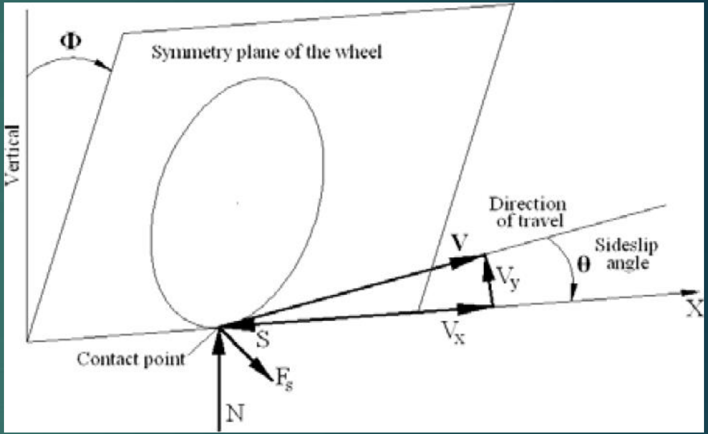
Cornering of Two-wheeler without braking

- The coordinates used to analyze the two-wheeler is shown in below figure



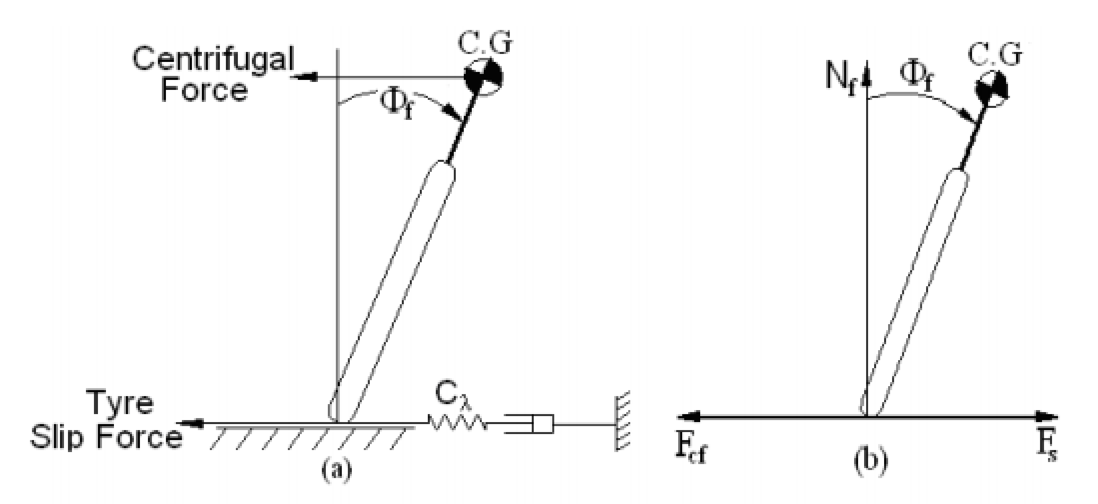
Where
'ϕ_f' is the effective front fork roll angle
'δ_f' is the effective front angle due to tilt in steer axis by λ
'ψ' indicating the orientation of rear wheel plane.

- The tire forces and side slip angle



Contd...

- Forces acting on tire during cornering



(a) Tire model

(b) Reaction forces on front wheel

The effective front fork roll angle is given by

$$\phi_f = \phi - \delta \cos \lambda$$

Normal reaction force on front wheel excluding dynamic and centrifugal effect

$$N_f = \frac{amg}{b}$$

Effective centrifugal force on front wheel

$$F_{cf} = \frac{amv^2 \sin \lambda}{b^2} \delta$$

Lateral force resisting sideslip

$$F_s = C_\lambda \times \theta + C_\phi \times \phi_f$$

Contd…

- Governing stability equation during without braking

$$J\ddot{\emptyset} + \frac{\phi}{bK_\lambda}\dot{\emptyset} + [K_v C_\phi \sin\lambda - mgh]\phi = \frac{Dv}{bcK_\lambda}\dot{T} + \frac{K_v}{c}T - [K_v C_\lambda \sin\lambda]\theta \quad (1)$$

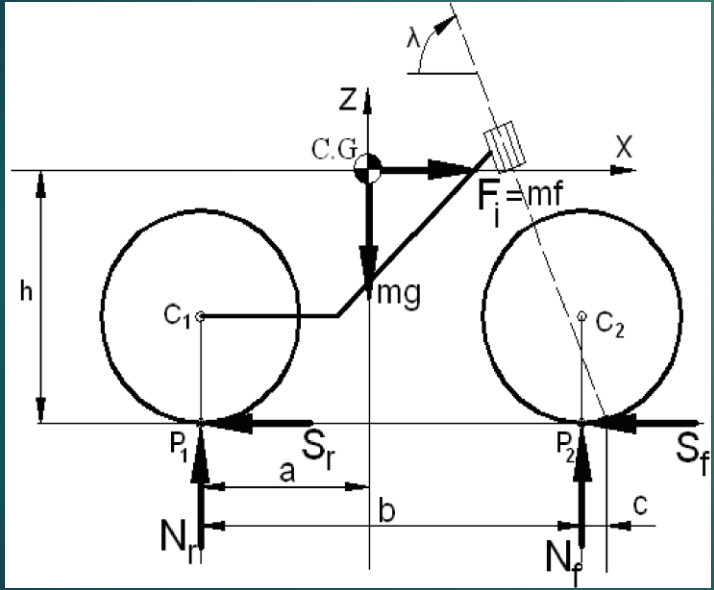
Where

$$K_\lambda = \frac{amv^2 \sin\lambda - b^2 C_\phi \cos\lambda}{b^2} \quad , K_v = \frac{m(v^2 - acg)}{bK_\lambda} \quad , D = mah \quad \& \; J = mh^2$$

The above equation reveals that torque at the handle bar has a great influence on roll angle as well as stability of the two-wheeler.

Cornering of Two-wheeler with braking

- For stability analysis of the two-wheeler during cornering with braking the model considered is shown below figure



Forces acting on the two-wheeler during braking

Where

- N_f Normal force at front wheel, N
- N_r Normal force at rear wheel, N
- F_i Inertia force due to braking
- S_f Front braking force
- S_r Rear braking force
- C Cornering stiffness

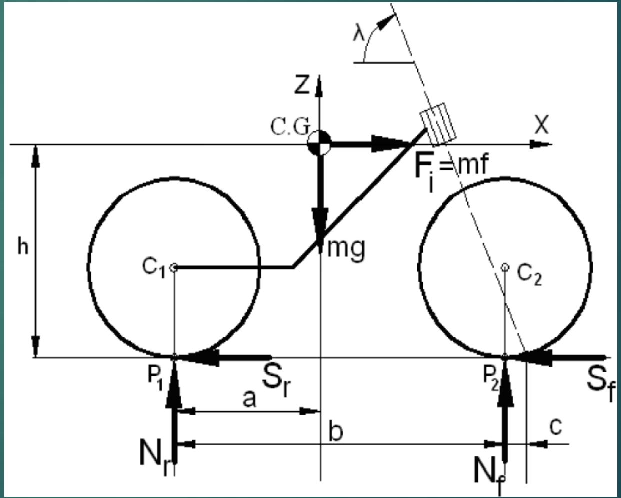
Cornering of Two-wheeler with braking

- Forces acting on the two-wheeler during braking

Vertical reaction force due to braking on front and rear wheel

$$N_{fb} = \frac{amg}{b} + \frac{mJh}{b}$$

$$N_{rb} = \frac{(b-a)mg}{b} - \frac{mJh}{b}$$



Cornering of Two-wheeler with braking

- Governing Stability equation during braking

$$J\ddot{\emptyset} + \frac{DvC_\phi \sin\lambda}{bK_\lambda}\dot{\emptyset} + [K_1 C_\phi - mgh] \times \phi = \frac{Dv}{bcK_\lambda}\dot{T} + \frac{K_1}{c\sin\lambda}T - [K_1 C_\lambda]\theta \qquad (2)$$

Where

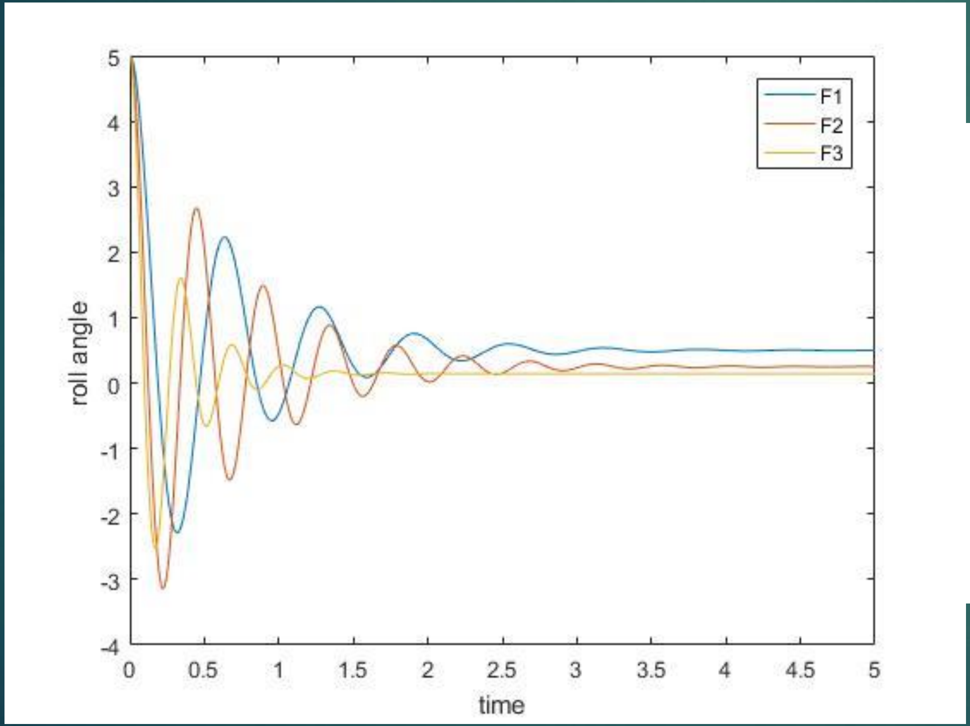
$$K_1 = \frac{m\sin\lambda}{bK_\lambda}\left[v^2 h - acg - \frac{2Dav^2\sin\lambda}{b^2 K_\lambda}\right] \;\&\; f = \frac{F_i}{m}$$

- Stability equation during braking derived considering deceleration due to braking and therefore, velocity as a variable with time.
- Breaking force largely affects the stability of the two-wheeler which can be controlled suitably by applying torque on the handle bar.

Thus equations (1) and (2) provide stability of the two-wheeler without braking and with braking conditions.

Simulation using Matlab

- *Response of roll angle with time*



Two-wheeler Parameters:	Value	Unit
Mass (m)	200	kg
Length of wheel base (b)	1.54	m
Position of C.G in plane containing rear wheel (h)	0.6	m
Position of C.G along x-axis from P_1 (a)	0.513	m
Head angle (λ)	70	Deg.
Trail (c)	0.117	m
Sideslip angle (θ)	2	Deg.

Conclusions

- We have considered a simplified two-wheeler for analyzing the stability under braking and without braking conditions.
- To balance the centrifugal force and the gravity force a two-wheeler in a turn must lean towards the centre of turn. This is essential for ensuring the stability of the two-wheeler.
- The peak amplitude is less with harder braking force, stability of the two-wheeler in a curve under such condition of hard braking may be better if proper road condition is met.

Tools & References

Tools

- Creo & Mat lab

References

- PERSPECTIVES FOR MOTORCYCLE STABILITY CONTROL SYSTEMS
  by Patrick Seiniger, Kai Schröter Jost Gail

- Stability Analysis of a Two-wheeler during Curve Negotiation under Braking
  by M Ghosh, S Mukhopadhyay

- Vehicle Dynamics by Thomas D Gillespie

Thank You!!