

Lecture 1 - Vehicle Forces & Chassis

12 September 2019
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Vehicle Technology L1

VEHICLE TECHNOLOGY

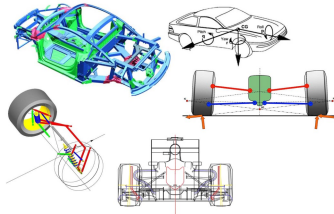
BENG MOTORSPORT / AUTOMOTIVE ENGINEERING



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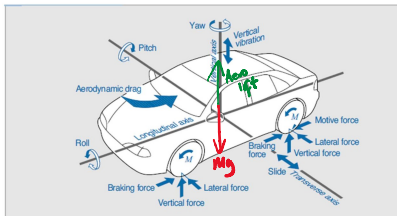
TOPICS

- Vehicle Performance
- Chassis
- Tyres
- Suspension Layouts
- Suspension Geometry (kinematics)
- Springs & Dampers
- Load Transfer
- Steering
- Braking Systems
- Aerodynamics



VEHICLE FORCES & AXES

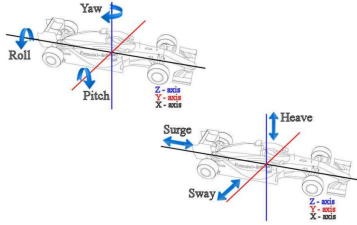
- Acceleration Forces
 - Centripetal
 - Centrifugal
 - Linear Acceleration
 - Linear deceleration
- Vertical Forces
 - Mass
 - Reactions
- Most forces act through the contact patches



Why are we interested in forces?
→ Acceleration
$$F=ma$$

VEHICLE FORCES & AXES

- 6 Degrees of Freedom
 - Roll
 - Pitch
 - Dive
 - Squat
 - Yaw
 - Bounce / Heave
 - Surge
 - Sway



VEHICLE ACCELERATION & DECELERATION

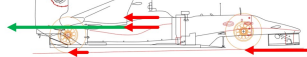
- Rear Tractive Effort (Rear tyres only)
 - Torque generated by engine and transferred to rear tyre
- Rolling Resistance
- Aerodynamic Drag

$$F = ma$$

$$F = ma = \text{Tractive Effort} - \text{Rolling Resistance} - \text{Drag}$$

$$F = ma = \text{Brake Force} + \text{Rolling Resistance} + \text{Drag}$$

- Braking Forces
 - Both front and rear from brake torque
- Rolling Resistance
- Aerodynamic Drag



Which forces act on a race car? - Straight line & cornering
(see Newton's Motorsport)



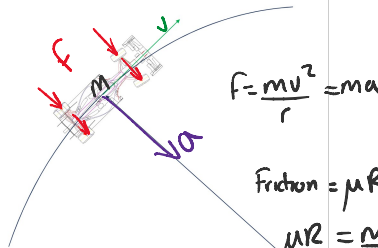
The mesmerizing display of simulated forces and physics in Live for Speed



VEHICLE CORNERING

- The car in the picture on the right weighs 7350N. Ignoring aerodynamic forces calculate the maximum speed at which it can travel around a corner of radii 100m given its tyres generate a coefficient of friction of 1.4

- What are our assumptions?
- Which equations can we use?
- If the car produced 5000N of Downforce what would be the cornering velocity?



$$F = \frac{mv^2}{r} = ma$$

$$\text{Friction} = \mu R$$

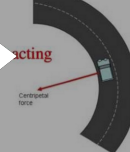
$$\mu R = \frac{mv^2}{r}$$

$$1.4 \times 7350 = \frac{7350 \times v^2}{10 \times 100} \rightarrow v = 37.4 \text{ m/s!}$$

forces acting on a car going round a bend

Consider a car which is going round a bend on a level road.

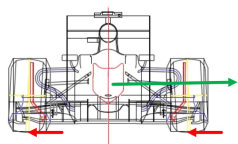
What are the forces acting on the car?



VEHICLE ACCELERATION IN CORNERING

- Centrifugal / Centripetal Force
 - Centrifugal force doesn't exist
 - It's the resultant centripetal force that accelerates the car towards the centre of the corner
- Lateral Loads
 - From Contact Patches

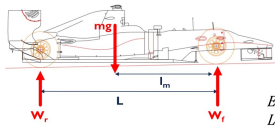
$$F = ma = \frac{mv^2}{r} = \text{lateral grip}$$



$$1.4 \times (7350 + 5000) = \frac{7350 \times v^2}{10 \times 100}$$

$$v = 48.5 \text{ m/s}$$

MASS DISTRIBUTION & CENTRE OF GRAVITY



$$w_r = mg \times \frac{l_m}{L}$$

Example:

$L = 3235 \text{ mm}$

$l_m = 1920 \text{ mm}$

$m = 754.3 \text{ kg}$

$W_r = ?$

$W_f = ?$

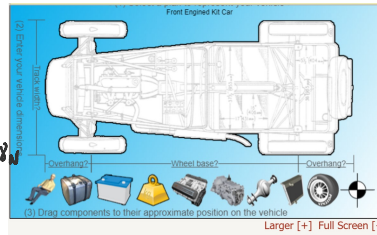
% Balance = ?

$$W_r = (754.3 \times 9.81) \times \frac{1.92}{3.235} = 4391.8 \text{ N}$$

$$W_f = (754.3 \times 9.81) - 4391.8 = 3007.9 \text{ N}$$

$$\% \text{ Balance} = \frac{W_f}{W_f + W_r} \times 100 = 39\%$$

<https://www.racinggaspirations.com/apps/weight-distribution-calculator/>



Results:

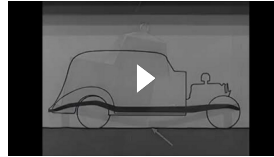
Corner Weights	Front to Back	Side to Side	Total
Front Right	0	0	0
Front Left	0	0	0
Rear Right	0	0	0
Rear Left	0	0	0
			0 kgs

CHASSIS

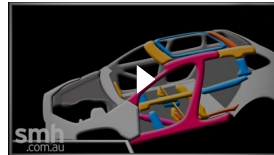
- Vehicle Frame
- Component Connection
 - Engine
 - Transmission
 - Suspension
 - Steering
 - Occupant
 - Bodywork
 - ...
- Crash Protection



[Car chassis design factor and consideration](#) (7 Mins)



[Cars are designed to crumple](#) (3 Mins)



CHASSIS TYPES

- Ladder
 - Discussion
 - Chassis Requirements?
 - Advantages & Disadvantages?
- Spaceframe
 - Stressed Skin
- Monocoque
 - Steel
 - Aluminium
 - Composite
- Unibody
 - Most Common Road



LADDER CHASSIS

- Oldest and simplest design
- 2 symmetrical longitudinal beams / rails for whole length of vehicle
- Rails are connected by transverse cross members
- Body bolts to frame



- Heavier than alternatives
- Poor impact protection (side)
- Torsional stiffness poor

SPACEFRAME CHASSIS

- Developed in racing – Maserati Birdcage
- 3 Dimensional tubular design
- Sometimes 'skinned' with riveted or bonded panels



- Stronger / stiffer than ladder design
- Better impact protection (side)
- Torsional stiffness improved
- Lighter than ladder construction
- Stressed skins further increase protection and stiffness.

MONOCOQUE

- Monocoque is French for 'Single Shell'
- External skin supports most loads
- Body and structure are combined
- Can be steel (spot welded), Aluminium (bonded or riveted) or Composite (GRP or Carbon fibre)



Carbon Fiber Monocoque Chassis

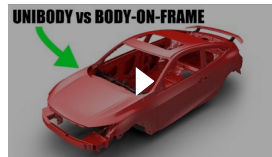


- Increased stiffness
- Loads distributed throughout entire structure
- Weight advantage - lighter
- Excellent crash protection
- Better space efficiency
- Some versions can be very economical to produce

FORCES

- Where are the forces to accelerate a vehicle generated?

[Unibody vs Body On Frame - Which Is Best? \(5 Mins\)](#)
Engineering Explained



[What Actually is A Monocoque Chassis? | Carfection 4x \(6 Mins\)](#)

