The Novel of Vehicle Dynamics

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Abstract: ***Vehicle Dynamics talks about isolation and control. Isolation is basically the isolation of passengers from external disturbances like road irregularities, bump, rebound etc and the control involves the response to the driver input. There are various factors which effect vehicle dynamics like drive train, suspension, brake, steering, chasis etc. Their effects on the Vehicle in Vehicle Dynamics. Many dynamic aspects talk about the vehicle behaviours in Vehicle dynamics like roll steer, bump steer, noise, harshness, vibration, ride quality, roll, pitch, directional stability etc. These are some of the things Vehicle Dynamics consist of Vehicle dynamics is a part of engineering primarily based on classical mechanics.***

Keywords: Vehicle Dynamics, Caster, camber, DOF, Suspension, Steering, Quarter-Car model

1. Introduction

Vehicle Dynamics is the study of forces and reaction when the vehicle is in motion, what type of forces are acting their reactions, drivers input and how much output will he get, and a lot more factors are considered over here.

The study is disintegrated into,
1.1 Power module where engine, drive boxes, axle like stuff is considered
1.2 Chassis module where suspension, steering, brakes, tyres, are taken, and
1.3 Body module in which the bonnet, roof, doors, and other main outer body parts are taken under study.

2. Degree of Freedom

DOF is an acronym for Degrees of Freedom. A degree of freedom simply is an aspect of the system that is not constrained. If you are modeling a system, that aspect of the system will require a variable, not a constant. As an example, if you are riding on a train track you have only one DOF. You can only go forward or backward. The track and gravity constrain your motion in any other direction. If you are in a car or boat you have 2 degrees of freedom. You can travel backward and forward AND left and right. A bird has 3 degrees of freedom. It has the ability to do everything a car or boat can do and it can move in the vertical plane too. These are examples of spatial DOF's. Other systems can have any number of different kinds of degrees of freedom; rotation, polarity, etc.

3. Automotive Components – Vehicle Dynamics

3.1 Chassis

A chassis is the load-bearing framework of an artificial object, which structurally supports the object in its construction and function. An example of a chassis is a vehicle frame, the underpart of a motor vehicle, on which the body is mounted; if the running gear such as wheels and transmission, and sometimes even the driver's seat, are included, then the assembly is described as rolling chassis. It needs to have very high strength and rigidity.

Figure 3.1: Chassis

3.2 Bodywork

It is the outer covering of the vehicle which takes care of a number of non-operational aspects. The body work takes care of the aesthetic appeal and also the aerodynamics of the vehicle.

Body work and Integral Construction:

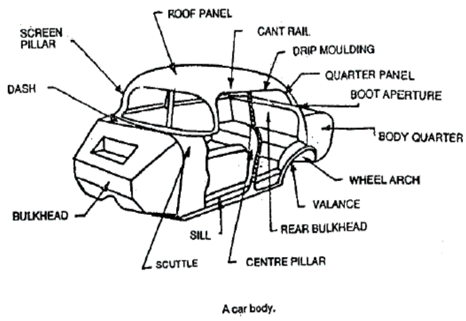

Figure 3.2: Bodywork

3.3 Powertrain

It is responsible for the transmission of power from the power unit to the wheels of the vehicle. It consists of a large number of different components. The main component is the power unit which delivers the power to be used, engine is the power unit followed by a number of other transmission components.

Figure 3.3: Power Train

3.3.1 Power Unit or Engine

The power unit which is mostly the engine or battery for the vehicle is the one which delivers the power to drive and run the vehicle.

3.3.2 Transmission shafts

Transmission shafts deliver the power from the power units to the gear boxes and ultimately to the wheels of the vehicle.

3.3.3 Gearbox and Differentials

The gearbox is responsible for reducing or increasing the torque or RPM of the transmission shafts as and when needed.

3.3.4 Axles and Joints

The axles are responsible for transmitting power from the gearbox to the wheels and joints are used for transmitting power between different shafts and the axles.

3.4 Suspension System

Suspension is the system of tires, tire air, springs, shock absorbers and linkages thatconnects a vehicle to its wheels and allows relative motion between the two. Suspension systems must support both road holding/handling and ride quality,which are at odds with each other. The tuning of suspensions involves finding the right compromise. It is important for the suspension to keep the road wheel in contact with the road surface as much as possible, because all the road or ground forces acting on the vehicle do so throughthe contact patches of the tires. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear. The design of front and rear suspension of a car may be different.

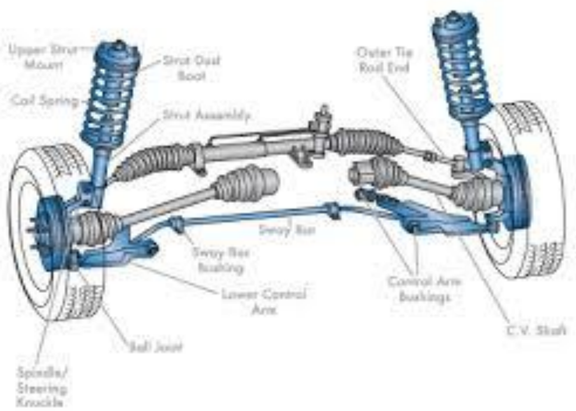

Figure 3.4: Suspension System

3.5 Steering System

Steering is a system of components, linkages, etc. which allows any vehicle to follow the desired course. An exception is the case of rail transport by which rail tracks combined together with railroad switches provide the steering function. The primary purpose of the steering system is to allow the driver to guide the vehicle.

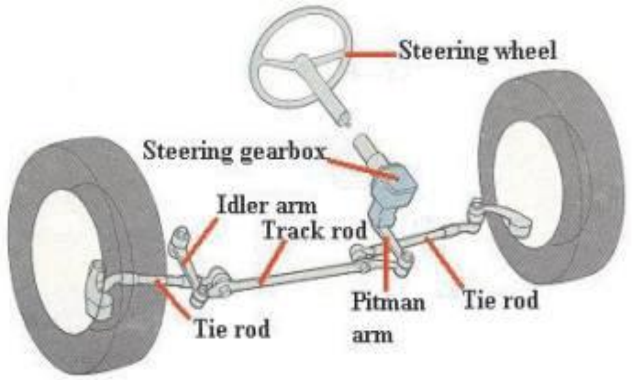

Figure 3.5: Steering System

3.6 Braking system

The braking is responsible for providing the stopping forces which can make sure that the vehicle does not undergo any accident or risky dynamics. It also governs the dynamics of a vehicle in certain situations.

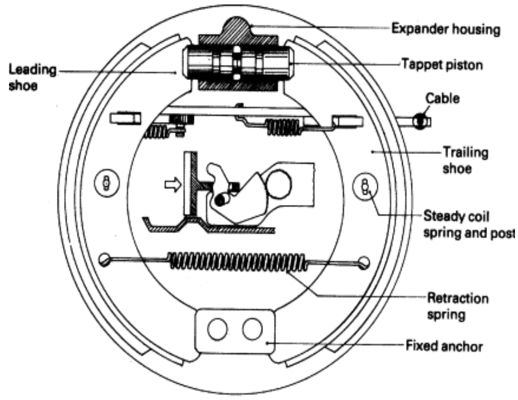

Figure 3.6: Braking System

3.7 Electronics system

The electronics system takes care of a lot of different subsystem and integration of the various electromechanical systems.

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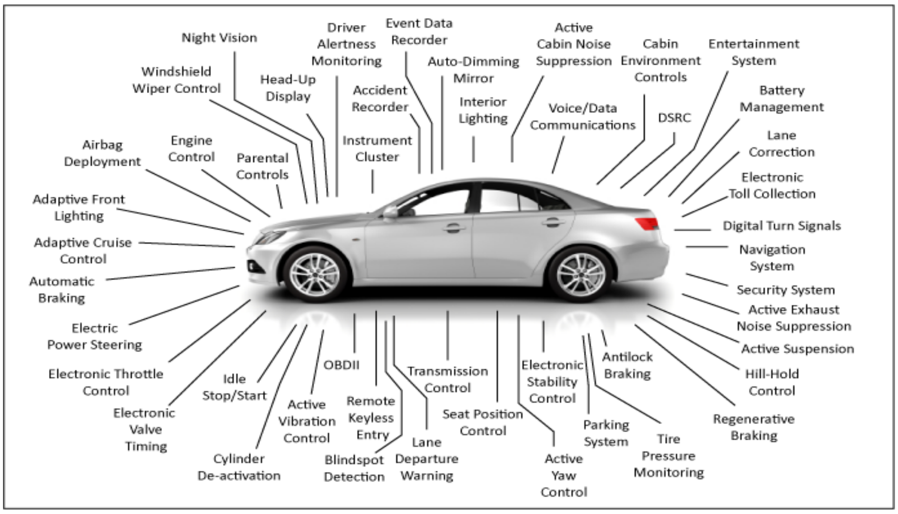

Figure 3.7: Electronics System

4. Suspension System

The suspension system has the following primary tasks to perform in vehicle:

1) Provide safety and comfort to the driver and passengers
2) Uphold the structural integrity of the vehicle by dissipating forces arising from the ground
3) Make sure that the vehicle does not undergo dangerous dynamic conditions such as roll over, toppling, side slipping etc.

The major components of the suspension system are:

4.1 Spring damper system (Shock absorber)

The shock absorber consists of two components spring element and damping element

4.1.1 Spring element:

Provides stiffness and passive force proportional to the displacement of the element

F = Kx

K= Spring constant

X = displacement of the spring

4.1.2 Damping element:

Provides damping in the system and passive force proportional to velocity of motion of the element

F=Cv

C=damping coefficient

V=Velocity of damper

Figure 4.1: Shock absorber

4.2 Mainly two Suspension types

4.2.1 Twin tube suspension system

Also known as a two-tube shock absorber, this device consists of two nested cylindrical tubes, an inner tube that is called the working tube or the pressure tube, and an outer tube called the reserve tube. At the bottom of the device on the inside is a compression valve or base valve. When the piston is forced up or down by bumps in the road, hydraulic fluid moves between different chambers via small holes or orifices in the piston and via the valve, converting the shock energy into heat which must then be dissipated.

4.2.2 Mono tube Suspension system

Monotube shock absorbers feature a single valve assembly that evenly distributes pressure over the entire region circumference of the shock. Monotube offer better response than twin-tubes since the valve assembly acts as one unit.

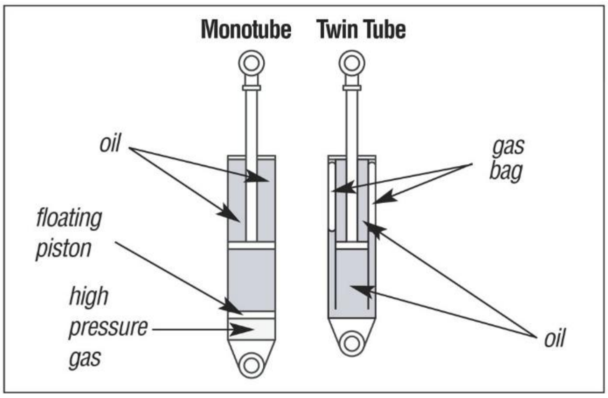

Figure 4.2: Types of Shock absorber

4.3 Control arms

Suspension control arms can be different shapes and sizes depending on the type of suspension.

Figure 4.3: Control Arm

4.4Wheel Assembly

The wheel assembly includes all the components which connect the suspension arms to the wheel along with the wheel and the rim itself.

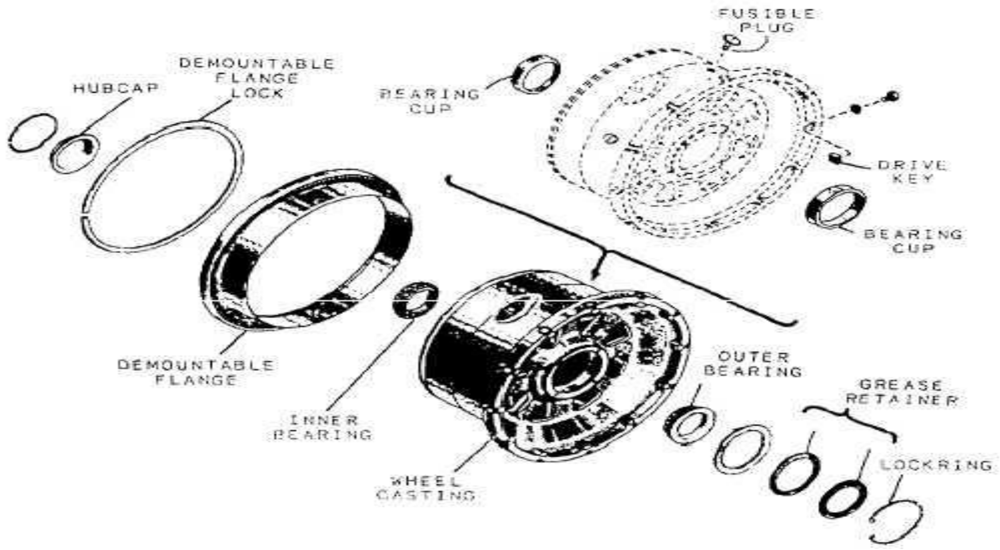

Figure 4.4: Wheel Assembly

5. Steering System

The steering system consists of a number of parts and components which together do the task of performing the necessary vehicle steering in different situations. The components are not as much and not as complex as the suspension system but important nevertheless. The major components of the steering system are:

5.1 Steering and steering column

The steering is the point of contact between the driver and the steering system. The shape and size of the steering decides the required torque for the steering mechanism. The steering and the steering shaft are rigidity attached without any non-aligned or flexible joints.

5.2 Steering mechanism

The steering and the steering column provide rotational motion while the wheels require translational motion to be steered. The conversion of the rotational motion to translational motion (Rack and pinion mechanism)

5.3 The rod and steering arm

The tie rod connects the steering rack to the upright of the wheel assembly and further transmits the translational motion from the steering rack to the wheels of the vehicle. The steering arm on further acts as the moment arm to turn the wheel around its turning axis.

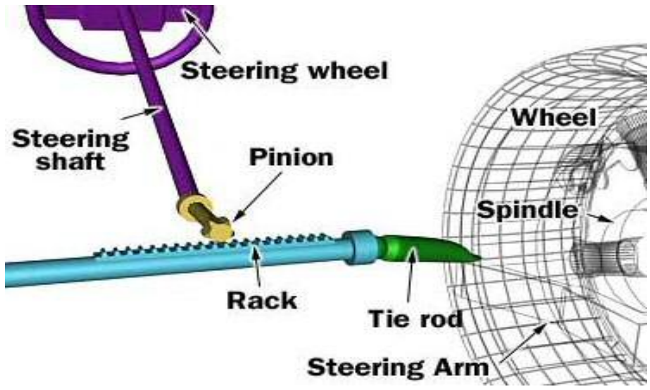

Figure 5: Steering System

6. Quarter-Car model

A quarter-car model is used to investigate the vibration response of cars with uncertainty under random road input excitations in this paper. The sprung mass, unsprung mass, suspension damping, suspension stiffness, and tyre stiffness are considered as random variables. The road irregularity is considered a Gaussian random process and modelled by means of a simple exponential power spectral density. The power spectral density, mean value, standard deviation, and variation coefficient of the vehicle's natural frequencies and mode shapes are obtained by using the Monte Carlo simulation method. The computational expressions for the numerical characteristics of the mean square value of the vehicle's random response in the frequency domain are developed by means of the random variable's functional moment method. The influences of the randomness of the vehicle's parameters on the vehicle's dynamic response are investigated in detail using a practical example, and some useful conclusions are obtained.

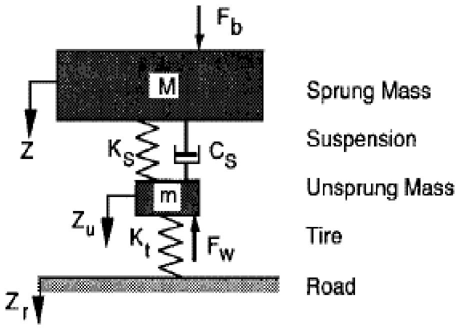

Figure 6.1: Quarter Vehicle Suspension Model

$$M\ddot{Z} + C_s\dot{Z} + K_s Z = C_s\dot{Z}_u + K_s Z_u + F_b$$

$$m\ddot{Z}_u + C_s\dot{Z}_u + (K_s + K_t) Z_u = C_s\dot{Z} + K_s Z + K_t Z_r + F_w$$

where:

Z = Sprung mass displacement
Z_u = Unsprung mass displacement
Z_r = Road displacement
F_b = Force on the sprung mass
F_w = Force on the unsprung mass

Figure 6.2: Mathematical Model

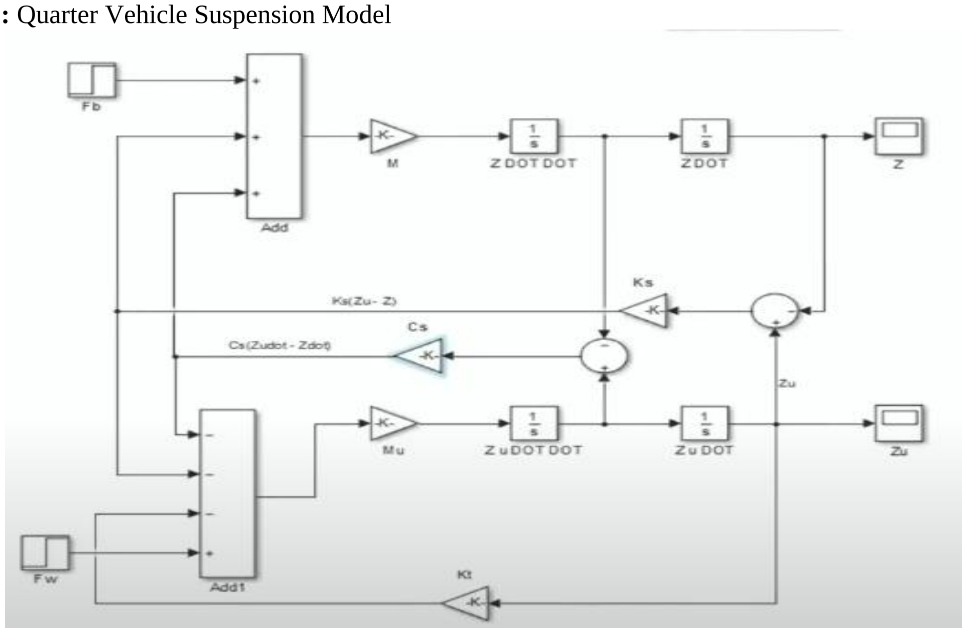

Figure 6.3: Simulink Model

7. Unpredictable steering

The position of the center of mass of the vehicle is often responsible for creating some unpredictable steering effects.

7.1 Under-steering effect

7.2 Over-steering effect

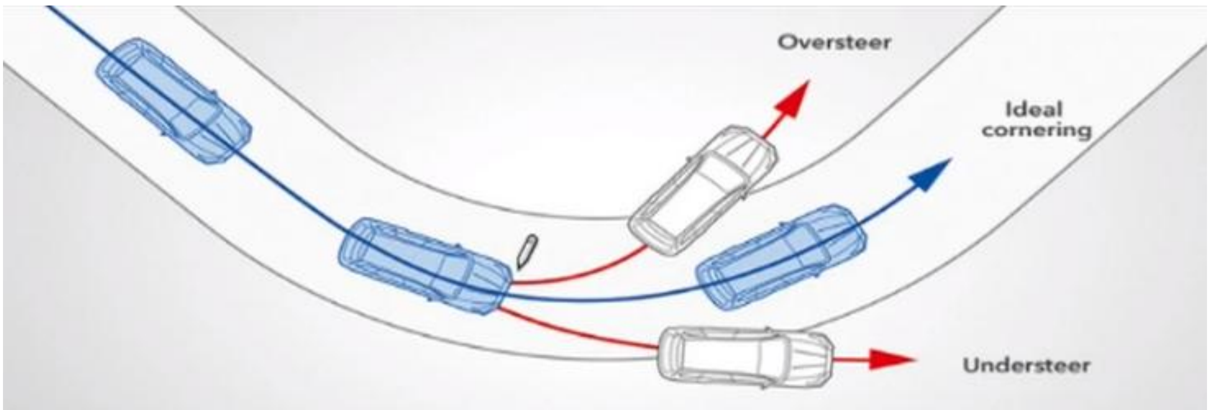

Figure 7: Unpredictable Steering

8. Wheel Alignment parameters

8.1 Caster Angle

The caster angle or castor angle is the angular displacement of the steering axis from the vertical axis of a steered wheel in a car, motorcycle, bicycle, other vehicle or a vessel, measured in the longitudinal direction. It is the angle between the pivot line (in a car an imaginary line that runs through the center of the upper ball joint to the center of the lower ball joint) and vertical. In automobile racing, the caster angle may be adjusted to optimize handling characteristics for a particular venue. This is all connected to the front wheels.

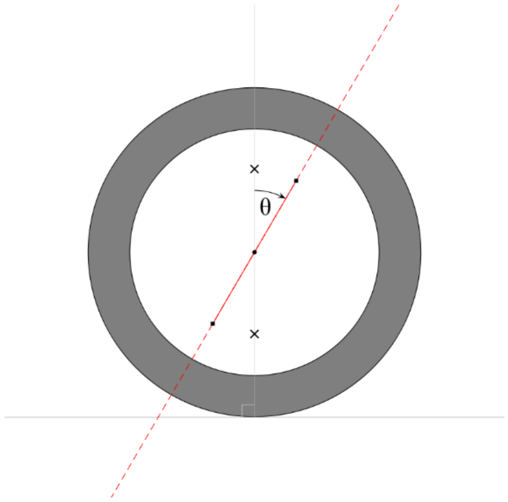

Figure 8.1: Caster Angle

8.2 Camber Angle

Camber angle is one of the angles made by the wheels of a vehicle; specifically, it is the angle between the vertical axis of a wheel and the vertical axis of the vehicle when viewed from the front or rear. It is used in the design of steering and suspension. If the top of the wheel is farther out than the bottom (that is, away from the axle), it is called positive camber; if the bottom of the wheel is farther out than the top, it is called negative camber.

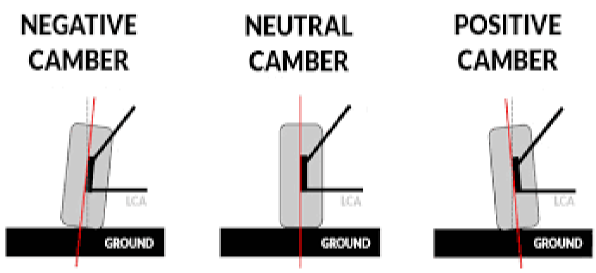

Figure 8.2: Camber Angle

9. Conclusion

Vehicle dynamics decides how the vehicle will react to the driver's inputs on a given solid surface. So,it looks into drivetrain and braking, suspension and steering, distribution of mass, aerodynamics, and tires. It gives an idea about how design changes will affect vehicle behavior, and how forces influence vehicle motion and vice versa.

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