دانشگاه سمنان

Semnan University
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دانشکده مهندسی مکانیک

دانشکده مهندسی مکانیک

درس طراحی سیستم های شاسی خودرو

Vehicle Chassis Systems Design

Chapter 1 – Introduction

Class Lecture

- ***Contents:***

MOTOR VEHICLE AGE

- Nicholas Joseph Cugnot (1725-1804)
  - 1769: built a three-wheeled, steam-driven vehicle

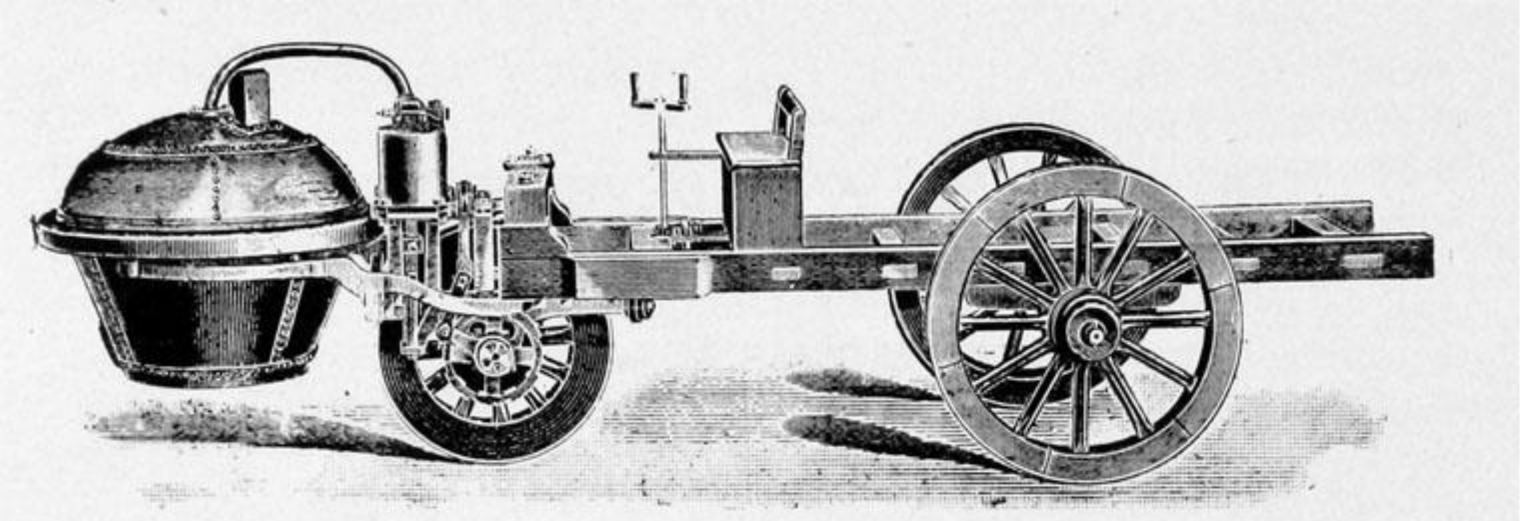
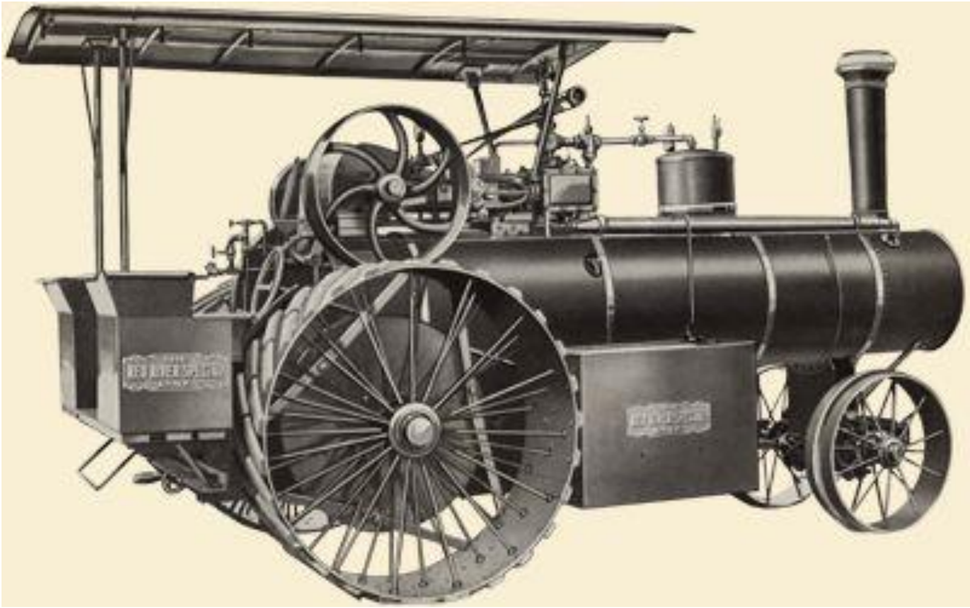


FIG. 2.—CUGNOT'S STEAM DRAY.

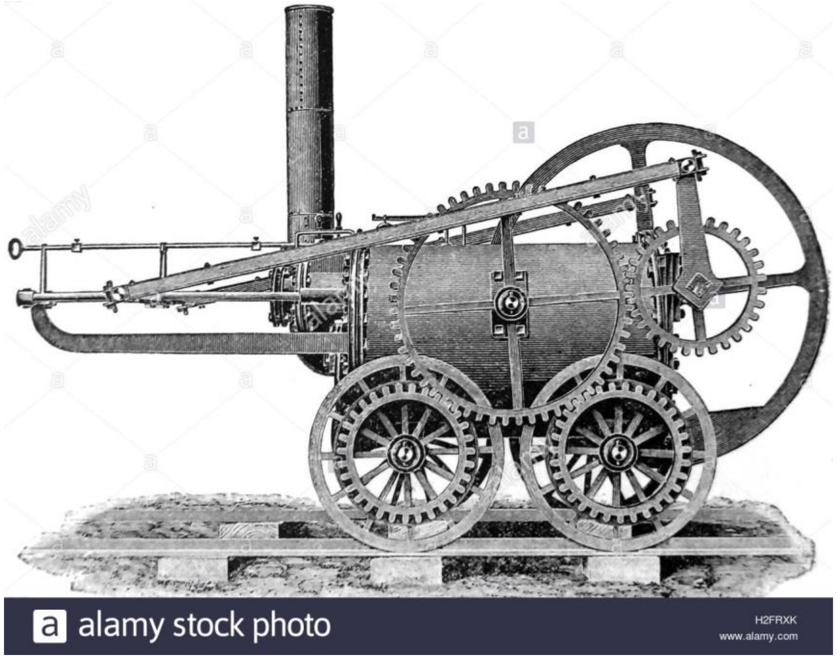
MOTOR VEHICLE AGE

- James Watt (1736-1819)
  - 1784: a steam-powered vehicle



MOTOR VEHICLE AGE

- Richard Trevithick (1771-1833)
  - 1802: developed a steam coach



MOTOR VEHICLE AGE

- Karl Benz (1844-1929) and Gottlieb Daimler (1834-1900)
  - 1886: The first practical automobiles powered by gasoline engines

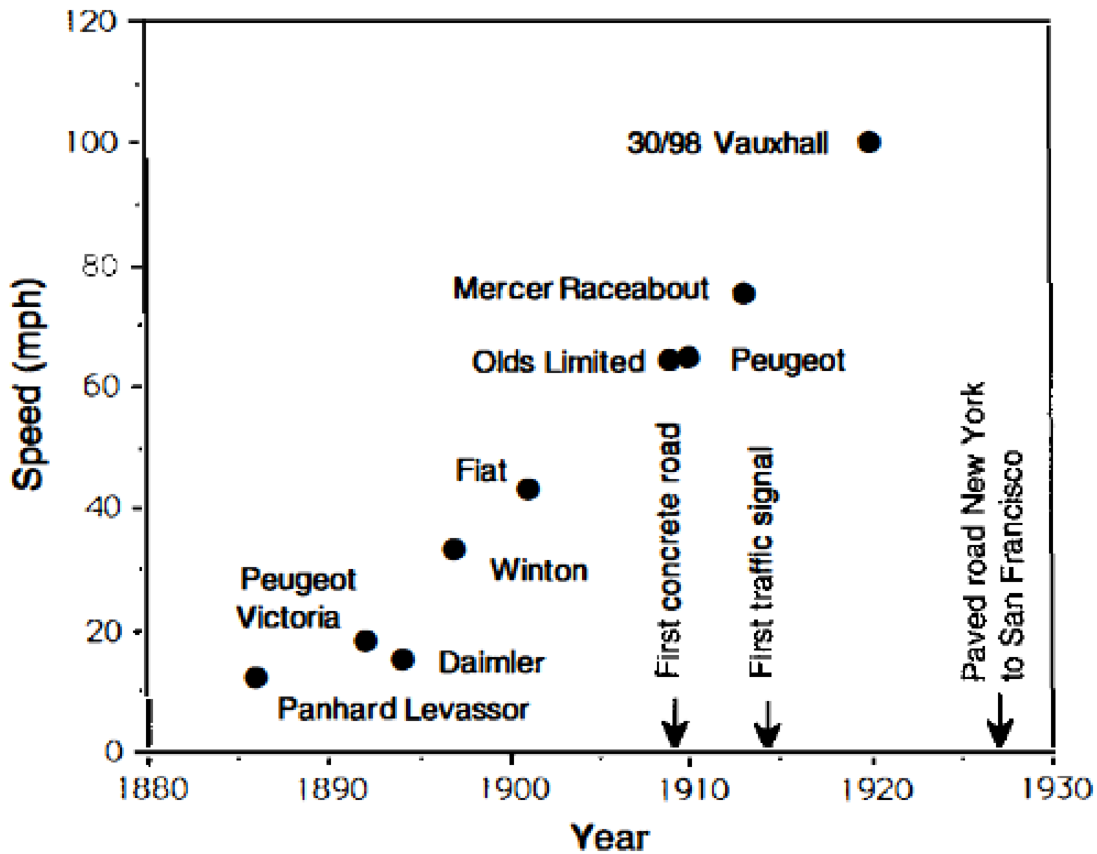
MOTOR VEHICLE AGE

- 1908 the automotive industry was well established in the United States with Henry Ford manufacturing the Model T and the General Motors Corporation being founded

- In Europe the familiar companies like Daimler, Opel, Renault, Benz, and Peugeot were becoming recognized as automotive manufacturers.

MOTOR VEHICLE AGE

- The speed capability of motor vehicles



INTRODUCTION TO VEHICLE DYNAMICS

- The primary forces by which a high-speed motor vehicle is controlled are developed in tires-road contact.

- Performance of a vehicle:
  - Accelerating
  - Braking
  - Cornering (handling)
  - Ride

INTRODUCTION TO VEHICLE DYNAMICS

- Understanding vehicle dynamics can be accomplished at two levels:
  - Empirical Method:
    - ✓ derives from trial and error by which one learns which factors influence vehicle performance, in which way, and under what conditions
  - Analytical Method:
    - ✓ attempts to describe the mechanics of interest based on the known laws of physics so that an analytical model can be established
    - ✓ models can be represented by algebraic or differential equations that relate forces or motions of interest to control inputs and vehicle or tire properties

FUNDAMENTAL APPROACH TO MODELING

- Lumped Mass
  - all components move together. For example, under braking, the entire vehicle slows down as a unit
  - it can be represented as one lumped mass located at its center of gravity (CG) with appropriate mass and inertia properties
  - For ride analysis, it is often necessary to treat the wheels as separate lumped masses. In that case the lumped mass representing the body is the "sprung mass," and the wheels are denoted as "unsprung masses."

FUNDAMENTAL APPROACH TO MODELING

- Vehicle Fixed Coordinate System
  - SAE Vehicle Axis System

x - Forward and on the longitudinal plane of symmetry

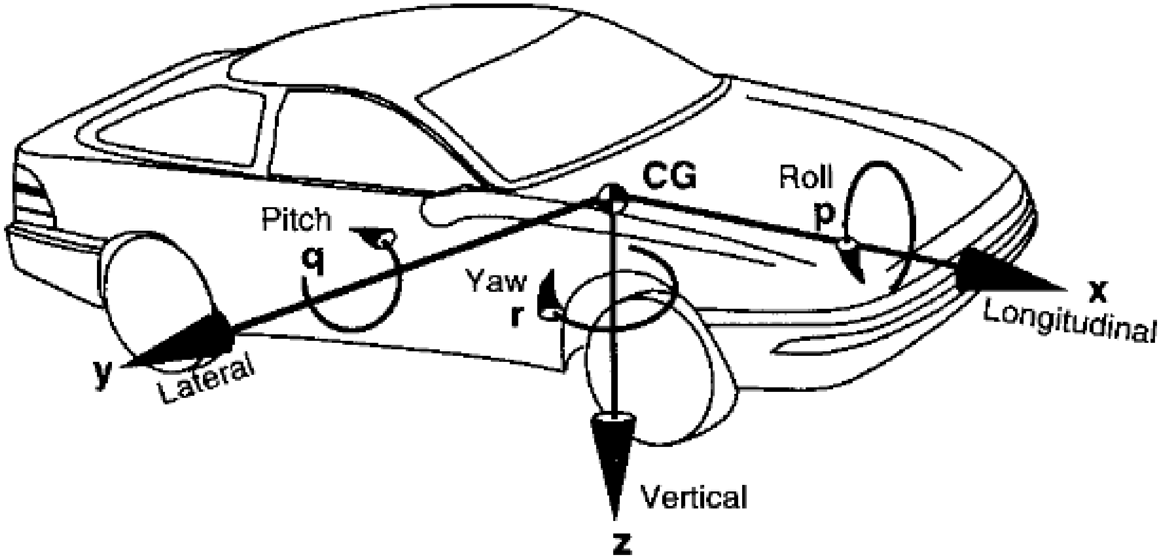
y - Lateral out the right side of the vehicle

z - Downward with respect to the vehicle

p - Roll velocity about the x axis

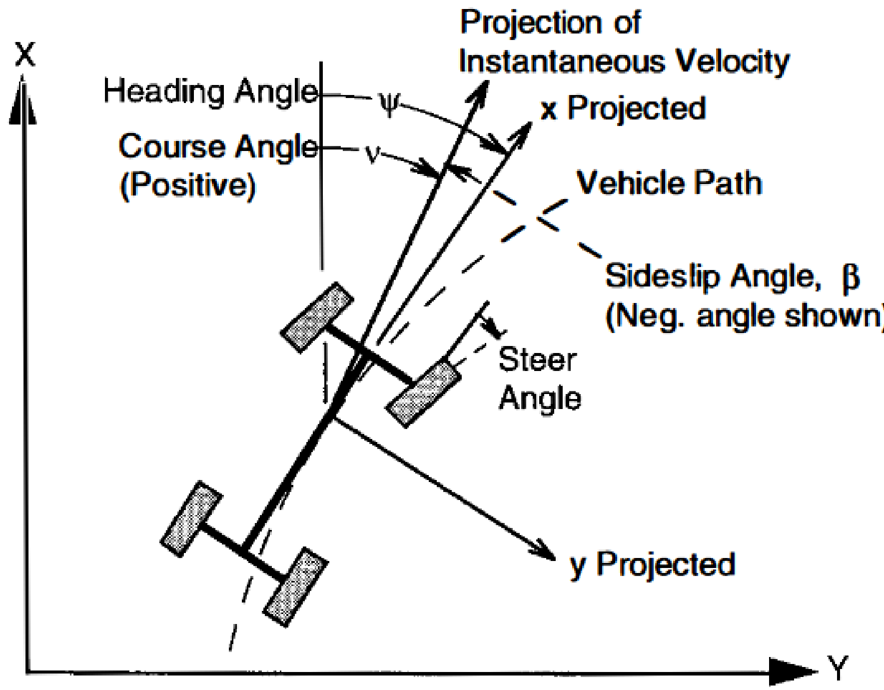
q - Pitch velocity about the y axis

r - Yaw velocity about the z axis



FUNDAMENTAL APPROACH TO MODELING

- Earth Fixed Coordinate System



X - Forward travel

Y - Travel to the right

Z - Vertical travel (positive downward)

ψ - Heading angle (angle between x and X in the ground plane)

ν - Course angle (angle between the vehicle's velocity vector and X axis)

β - Sideslip angle (angle between x axis and the vehicle velocity vector)

FUNDAMENTAL APPROACH TO MODELING

- Euler Angles
  - The relationship of the vehicle fixed coordinate system to the earth fixed coordinate system is defined by Euler angles

- Forces
  - Forces and moments are normally defined as they act on the vehicle

FUNDAMENTAL APPROACH TO MODELING

- Newton's Second Law

  - Translational systems

$$\sum F_x = M \cdot a_x$$

F_x = Forces in the x-direction
M = Mass of the body
a_x = Acceleration in the x-direction

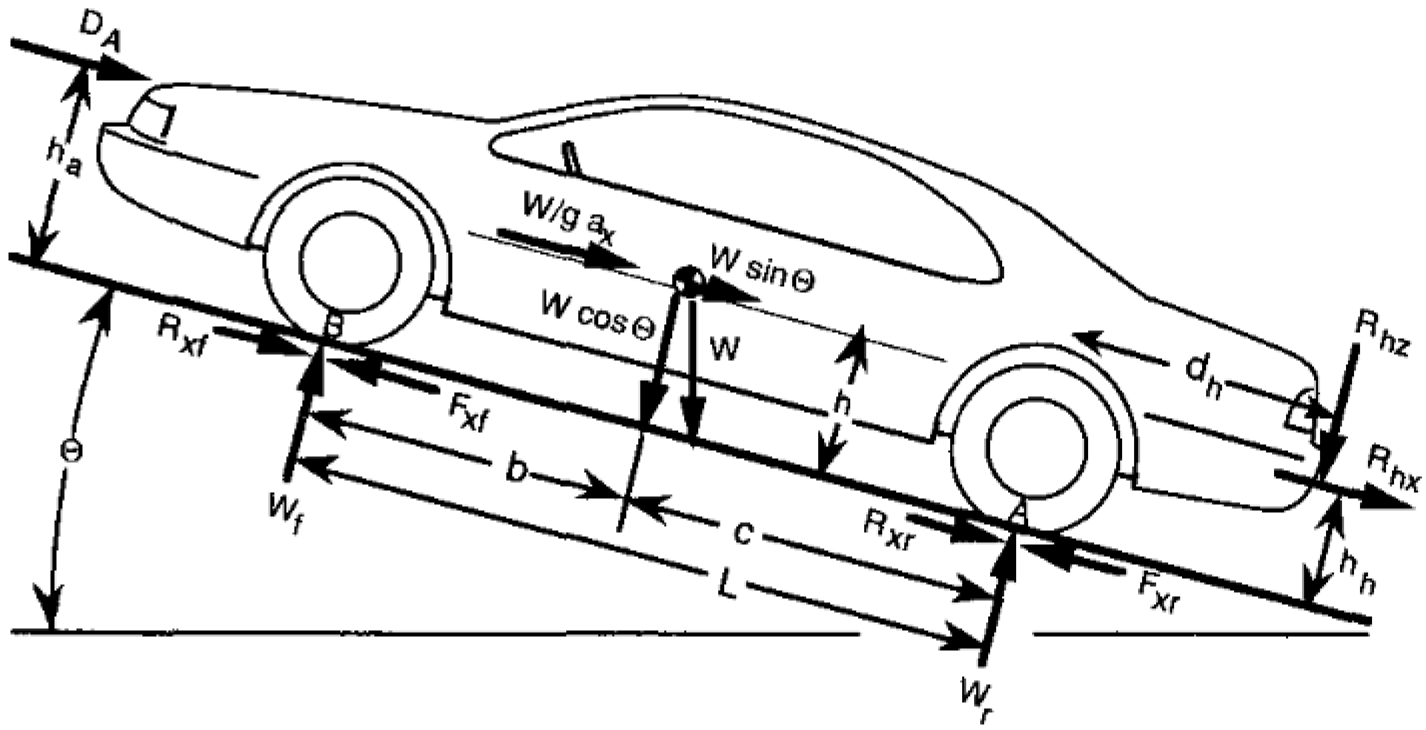
  - Rotational Systems

$$\sum T_x = I_{xx} \cdot \alpha_x$$

T_x = Torques about the x-axis
I_{xx} = Moment of inertia about the x-axis
α_x = Acceleration about the x-axis

Dynamic Axle Loads

- Significant forces acting on the vehicle



Dynamic Axle Loads

- " W " : weight of the vehicle acting at its CG
  - W = mg
  - On a grade it may have two components:
    - ✓ a cosine component which is perpendicular to the road surface
    - ✓ a sine component parallel to the road

- " W/g·ax " : (max)
  - vehicle acceleration equivalent inertial force (known as a "d'Alembert force“)
  - acting at the center of gravity opposite to the direction of the acceleration

- " Wf " and " Wr " : The tires force normal to the road
  - dynamic weights carried on the front and rear wheels.

Dynamic Axle Loads

- " Fxf " and " Fxr " : Tractive forces

- " Rxf " and " Rxr " : Rolling resistance forces

- " DA " : aerodynamic force acting on the body of the vehicle
  - acting at a point above the ground indicated by the height, "ha", or by a longitudinal force of the same magnitude in the ground plane with an associated moment

- “ Rhz " and " Rhx " : vertical and longitudinal forces acting at the hitch point when the vehicle is towing a trailer.

Dynamic Axle Loads

- The load on the front axle can be found by summing torques about the point "A" under the rear tires
- Presuming that the vehicle is not accelerating in pitch, the sum of the torques at point A must be zero

$$W_f L + D_A h_a + \frac{W}{g} a_x h + R_{hx} h_h + R_{hz} d_h + W h \sin\Theta - W c \cos\Theta = 0$$

- The axle load expressions:

$$W_f = (W c \cos\Theta - R_{hx} h_h - R_{hz} d_h - \frac{W}{g} a_x h - D_A h_a - W h \sin\Theta)/L$$

$$W_r = (W b \cos\Theta + R_{hx} h_h + R_{hz} (d_h + L) + \frac{W}{g} a_x h + D_a h_a + W h \sin\Theta)/L$$

Dynamic Axle Loads

- Static Loads on Level Ground

$$W_{fs} = W \frac{c}{L}$$

$$W_{rs} = W \frac{b}{L}$$

- Low-Speed Acceleration

$$W_f = W \left(\frac{c}{L} - \frac{a_x}{g}\frac{h}{L}\right) = W_{fs} - W \frac{a_x}{g}\frac{h}{L}$$

$$W_r = W \left(\frac{b}{L} + \frac{a_x}{g}\frac{h}{L}\right) = W_{rs} + W \frac{a_x}{g}\frac{h}{L}$$

Dynamic Axle Loads

- Loads on Grades
  - Grade is defmed as the "rise" over the "run "
  - That ratio is the tangent of the grade angle, θ
  - The common grades on interstate highways are limited to 4 percent.
  - On primary and secondary roads they occasionally reach 10 to 12 percent

$$\cos \Theta = 0.99^{+} \cong 1$$

$$\sin \Theta \cong \Theta$$

$$W_f = W\left(\frac{c}{L} - \frac{h}{L}\Theta\right) = W_{fs} - W\frac{h}{L}\Theta$$

$$W_r = W\left(\frac{b}{L} + \frac{h}{L}\Theta\right) = W_{rs} + W\frac{h}{L}\Theta$$