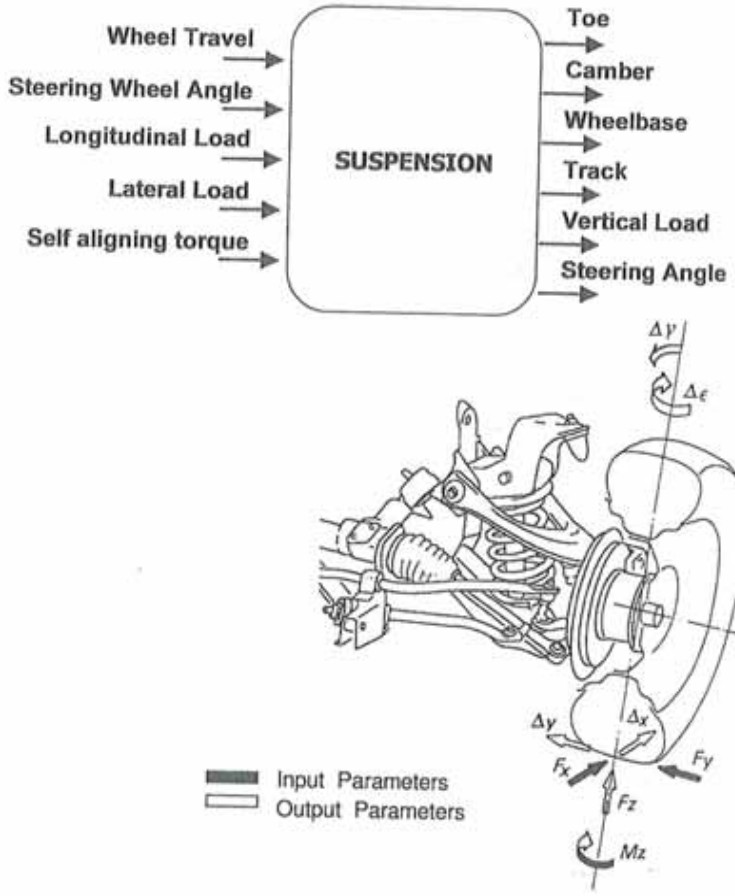
Basics of Vehicle Dynamics

Module H3

Suspension Characteristics

- Geometrical data
- Elasto-kinematics analysis
- Suspension typologies and their characteristics
- Suspension model

SUSPENSION FUNCTIONAL MAP



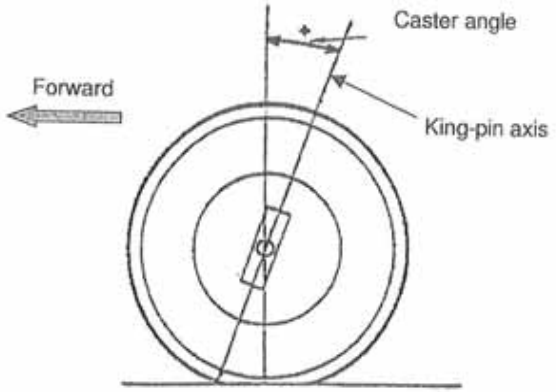
SUSPENSIONS GOALS

- Cockpit Isolation from road noises
- Guarantee tires optimal performances in energy operational condition (steerability, motricity)

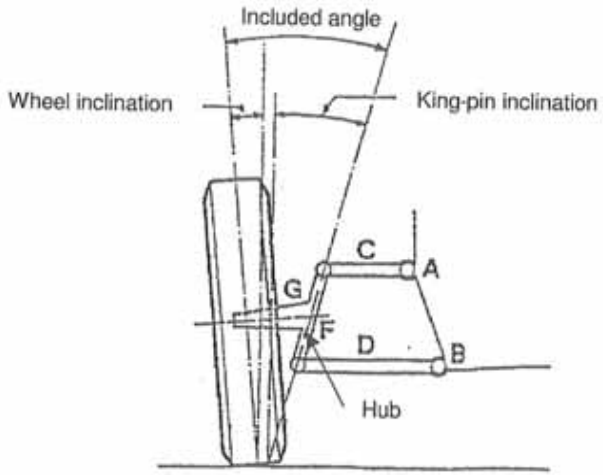
Geometrical Data

CHARACTERISTIC KING-PIN ANGLES

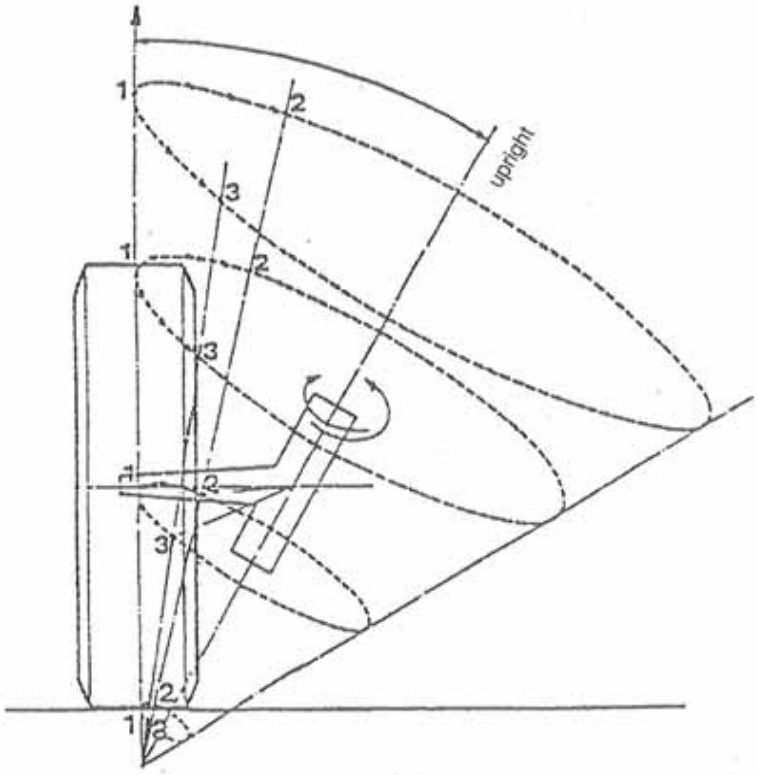
SIDE VIEW



FRONT VIEW

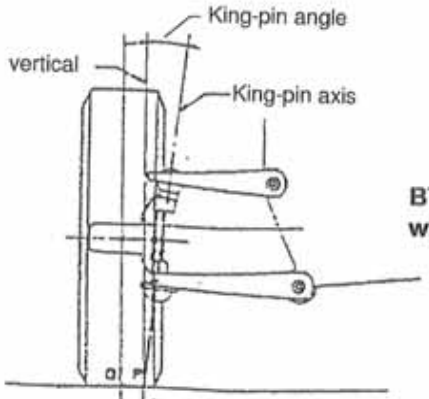


WHEEL PATH



BASICS OF VEHICLE DYNAMICS
Module H3
Suspension Characteristics

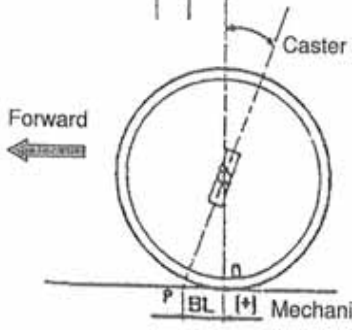
OFFSETS AND TRAIL



BT >0 if P is internal with respect to 0

BT (+) Offset or scrub radius

BTcr (+) scrub radius at centerline (offset at centerline)

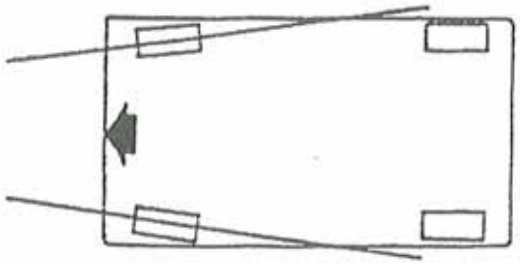


BL >0 if P position is forward with respect to 0

P BL (+) Mechanical trail or caster trail

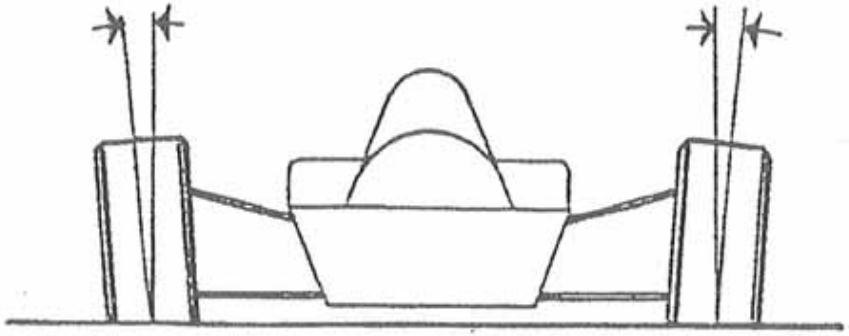
WHEELS CHARACTERISTIC ANGLES

TOE



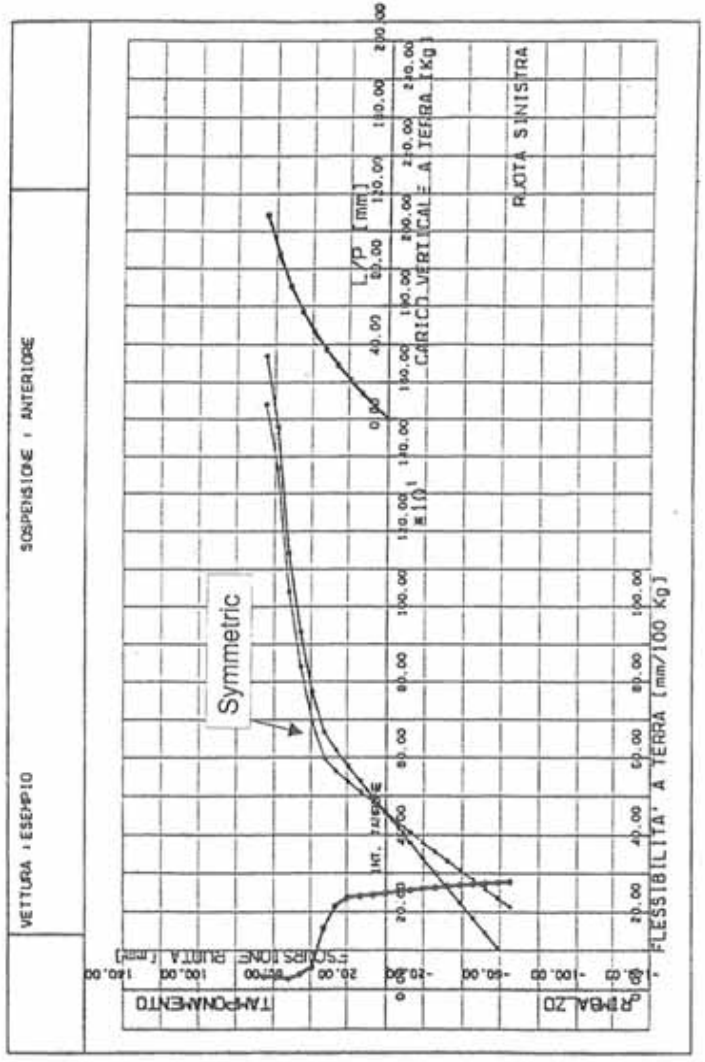
Toe > 0

CAMBER

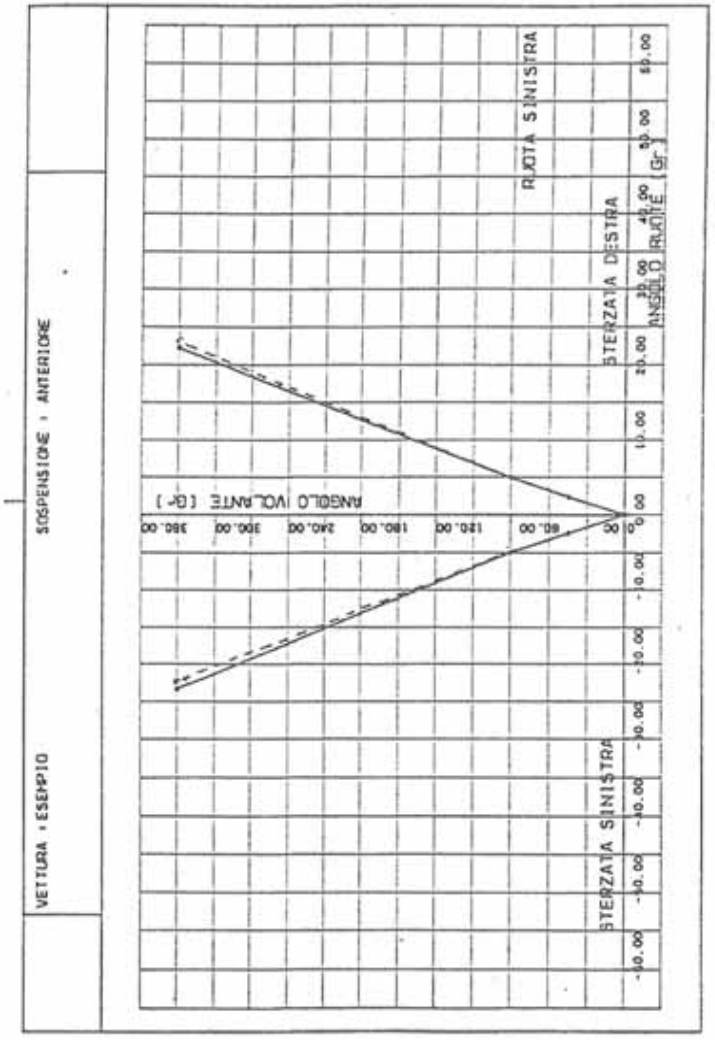


Camber >0

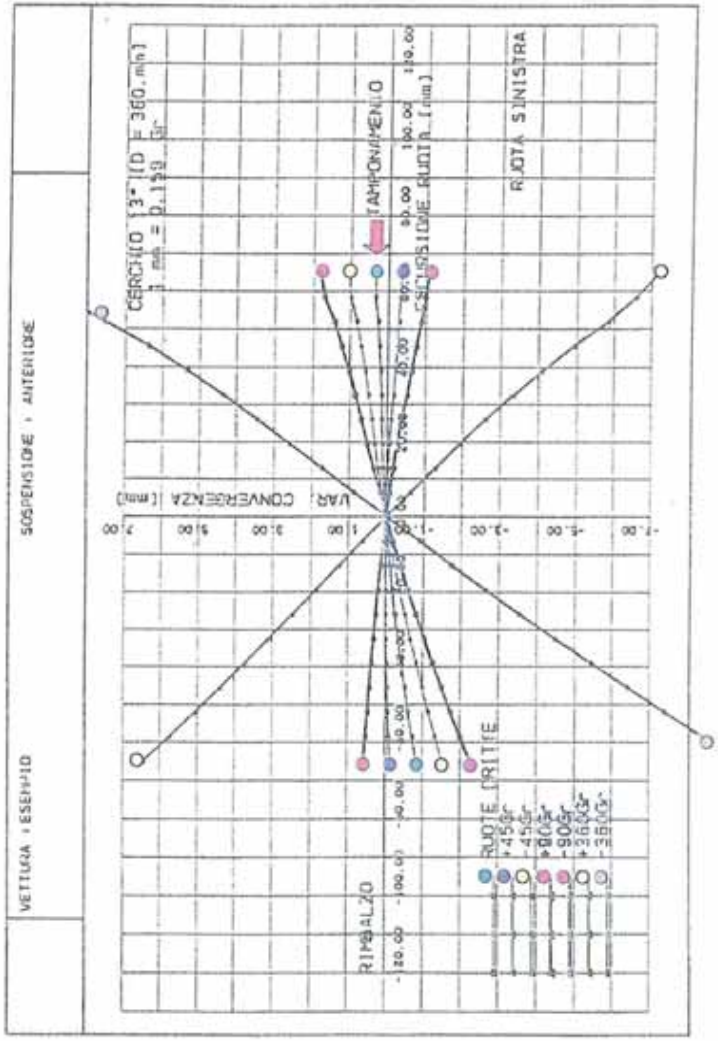
VERTICAL LOAD vs WHEEL TRAVEL



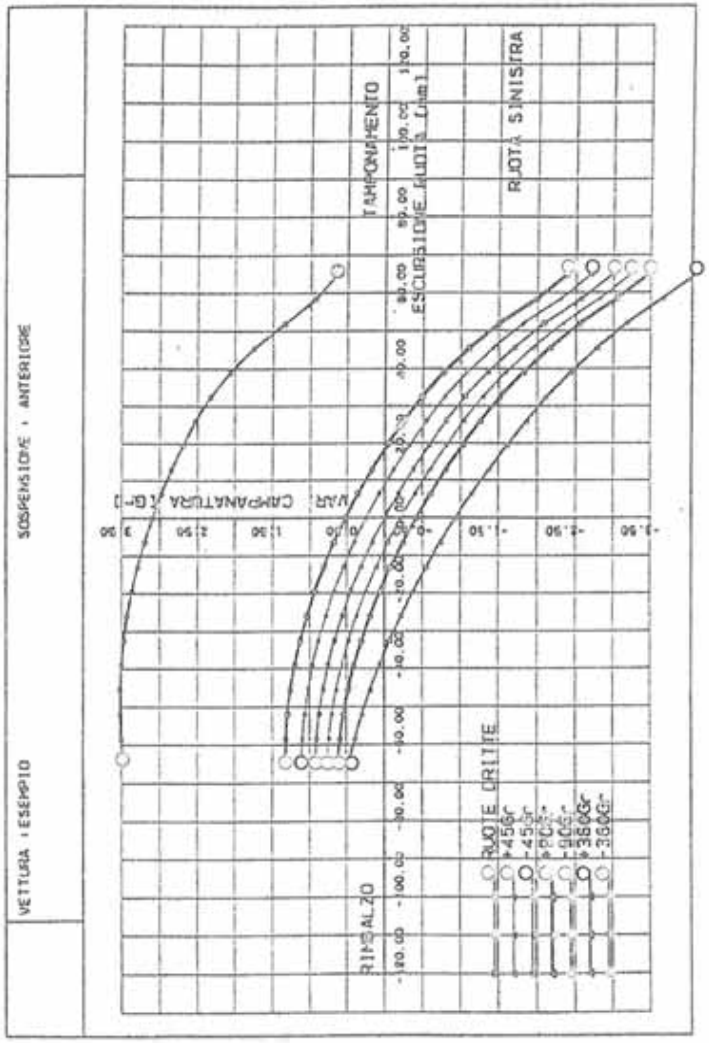
STEERING WHEEL ANGLE vs WHEELS ANGLE



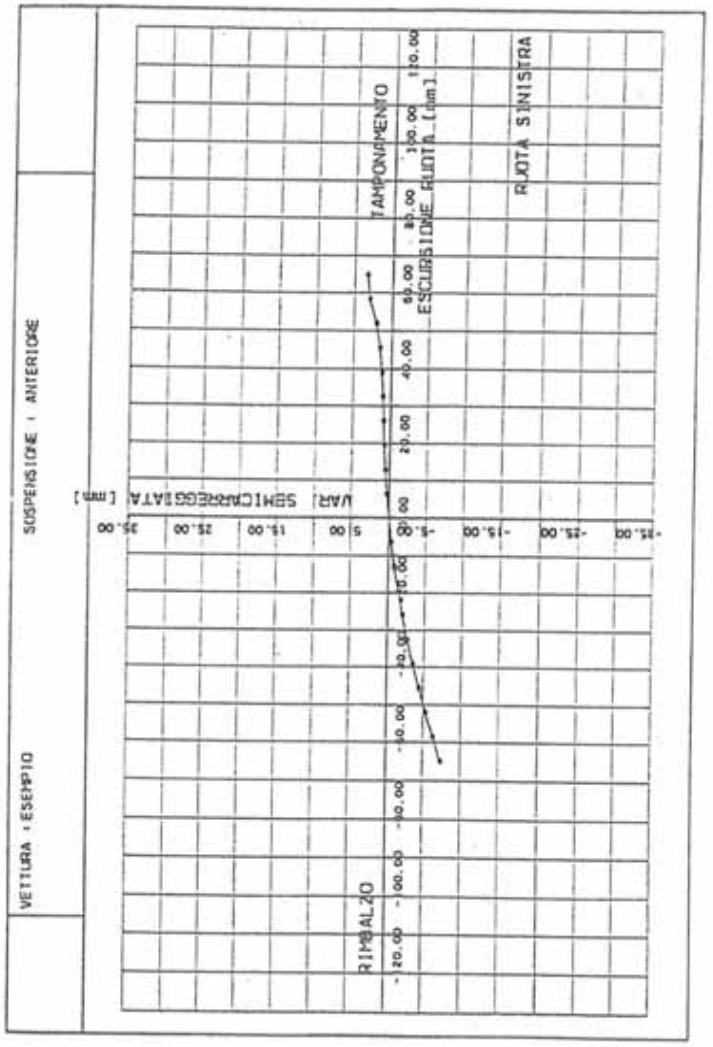
TOE CHANGE vs WHEEL TRAVEL



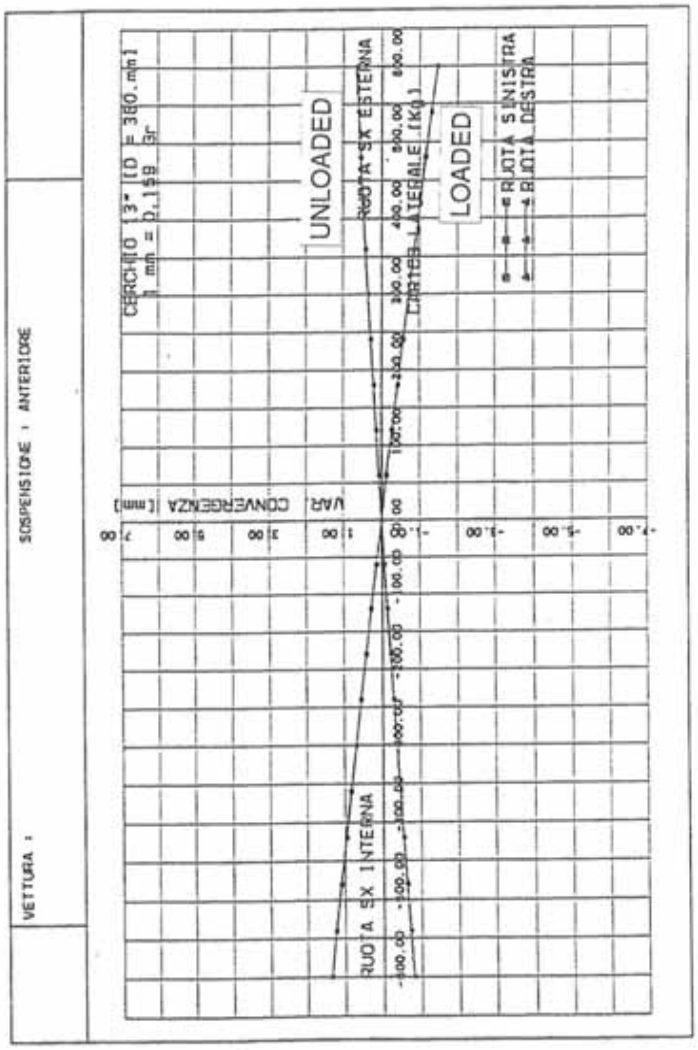
CAMBER CHANGE vs WHEEL TRAVEL



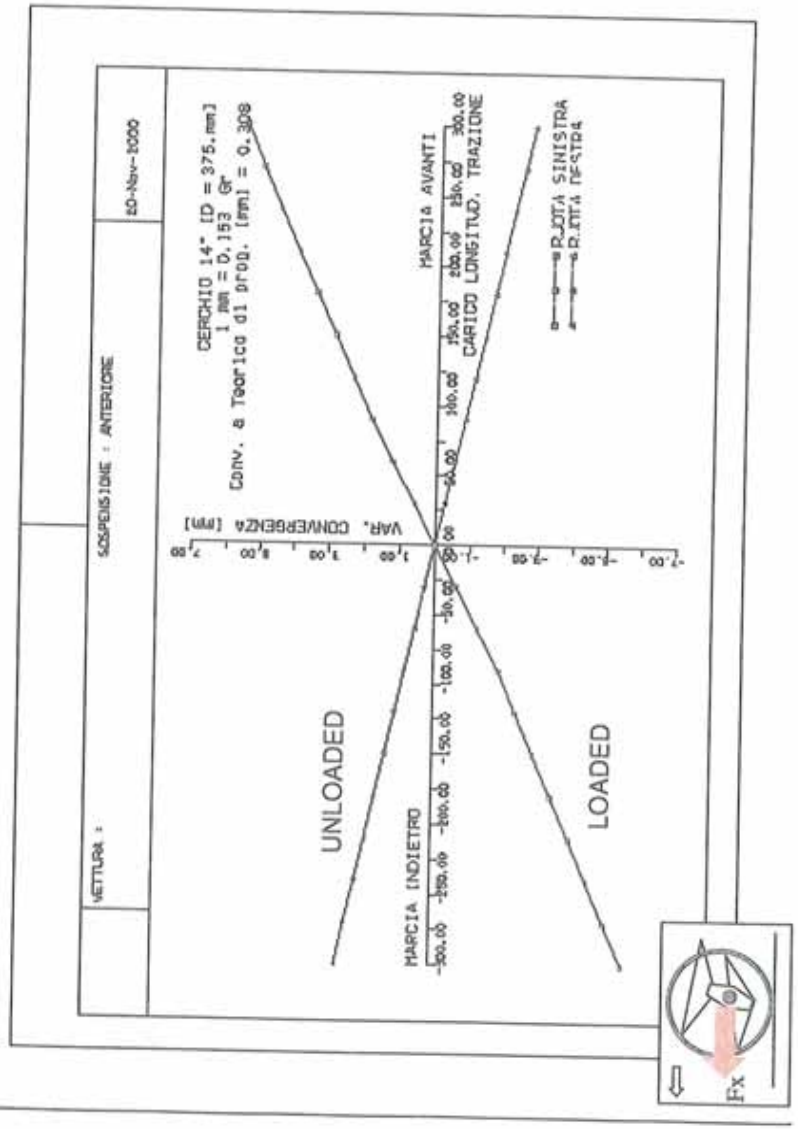
TRACK CHANGE vs WHEEL TRAVEL



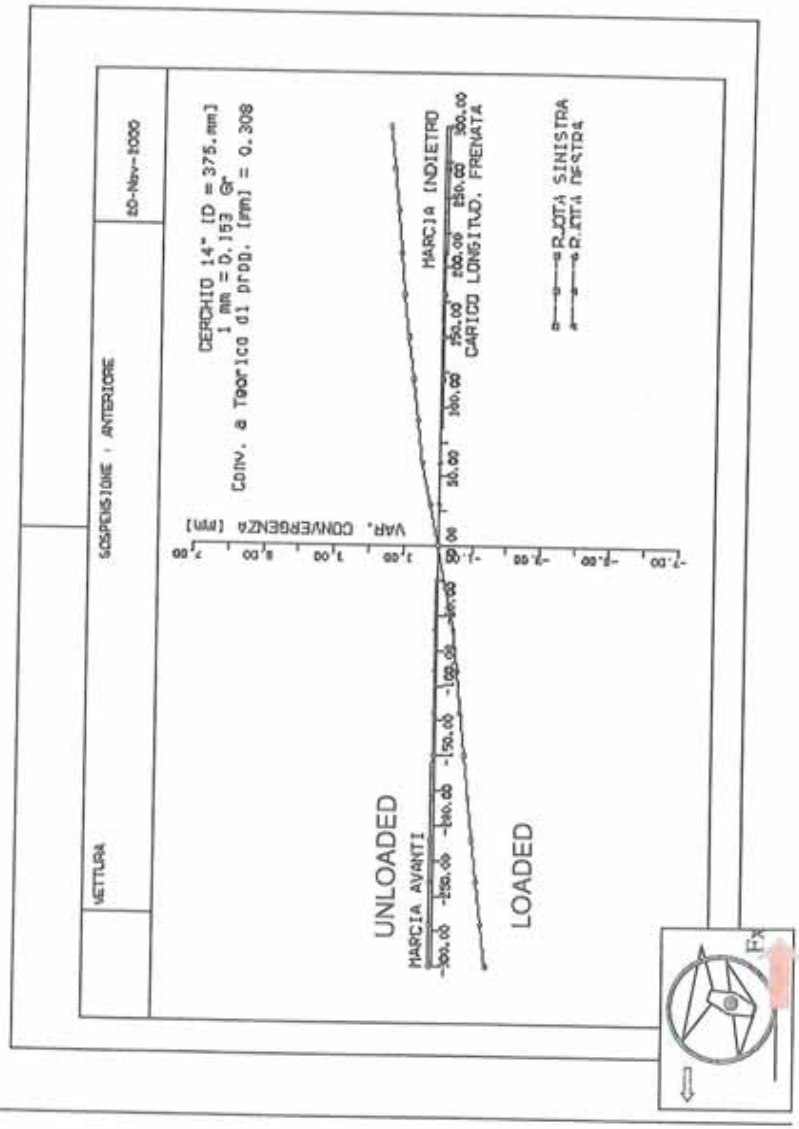
TOE CHANGE vs LATERAL LOAD



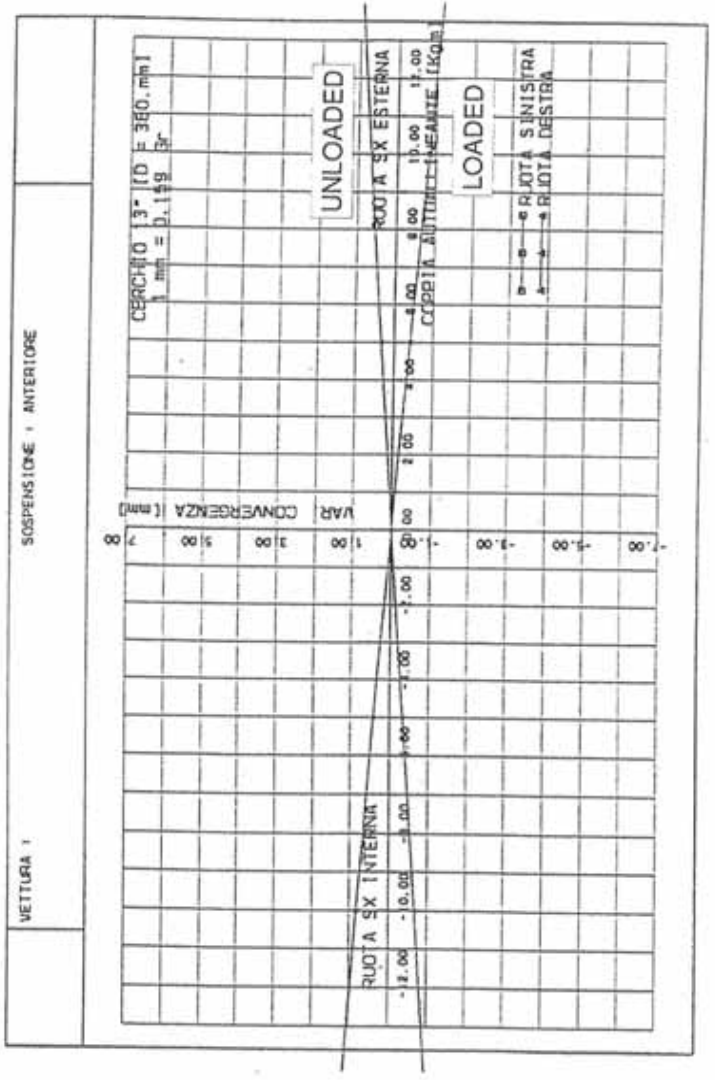
TOE CHANGE vs LONGITUDINAL LOAD (TRACTION)



TOE CHANGE vs LONGITUDINAL LOAD (BRAKING)

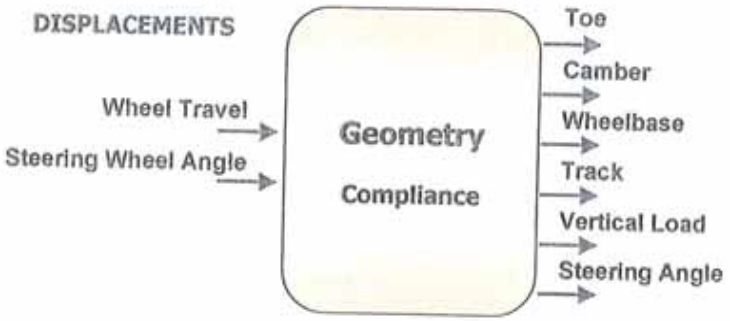


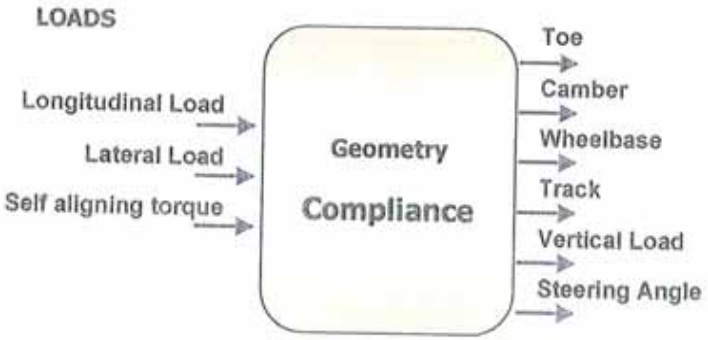
TOE CHANGE vs ALIGNING TORQUE



Elasto-kinematics Analysis

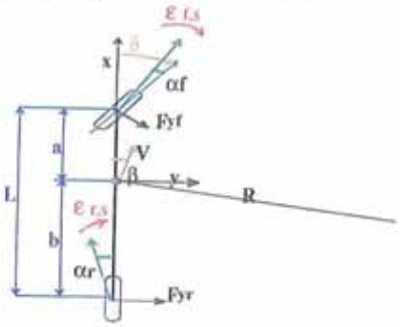
SUSPENSION ELASTO-KINEMATIC ANALYSIS





SUSPENSION EFFECTS: STEADY STATE CORNERING

Supposing: $\alpha_{t,s} = (\alpha_t - \varepsilon_s)_{t,s}$



$\alpha_{t,s}$: slip angle at front / rear axle

α_t : slip angle induced by tyres $= \frac{F_y}{C_t} = \frac{m_{t,s}}{C_t} \cdot a_y$

ε_s : steer angle induced by suspension (Toe)

Toe static values

$$\beta = \frac{b}{R} - \alpha_r = \frac{b}{R} - (\alpha_{r,s} - \varepsilon_{r,s}) = \frac{b}{R} + \varepsilon_{r,s} - \frac{m_r}{C_{r,s}} \cdot a_y$$

$$\delta_{vol} = \frac{L}{R} \cdot \tau - (\alpha_f - \alpha_r) \cdot \tau = \frac{L}{R} \cdot \tau + (\alpha_{f,s} - \varepsilon_{f,s} - \alpha_{r,s} + \varepsilon_{r,s}) = \delta_{vol0} + \varepsilon_{f,s} - \varepsilon_{r,s} + \left(\frac{m_f}{C_{f,s}} - \frac{m_r}{C_{r,s}} \right) \cdot a_y \cdot \tau$$

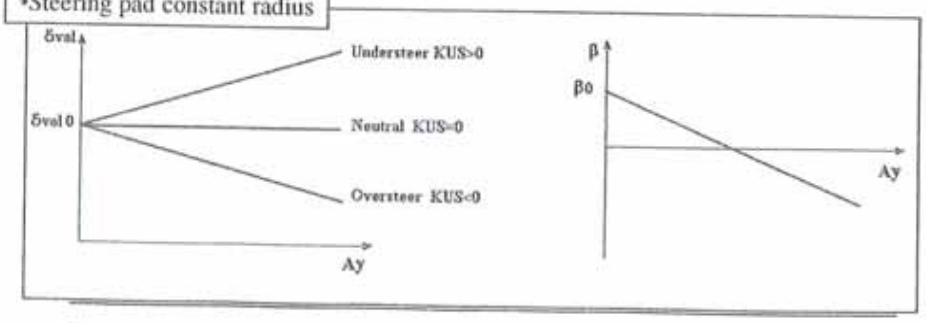
Toe variation

Linear variation with respect to wheel displacements and loads $\Rightarrow \frac{\partial \varepsilon_s}{\partial a_y}$

$$\beta = \frac{b}{R} - \alpha_r = \frac{b}{R} - (\alpha_{r,s} - \varepsilon_{r,s}) = \frac{b}{R} + \left[\frac{\partial \varepsilon_{r,s}}{\partial a_y} - \frac{m_r}{C_{r,s}} \right] \cdot a_y$$

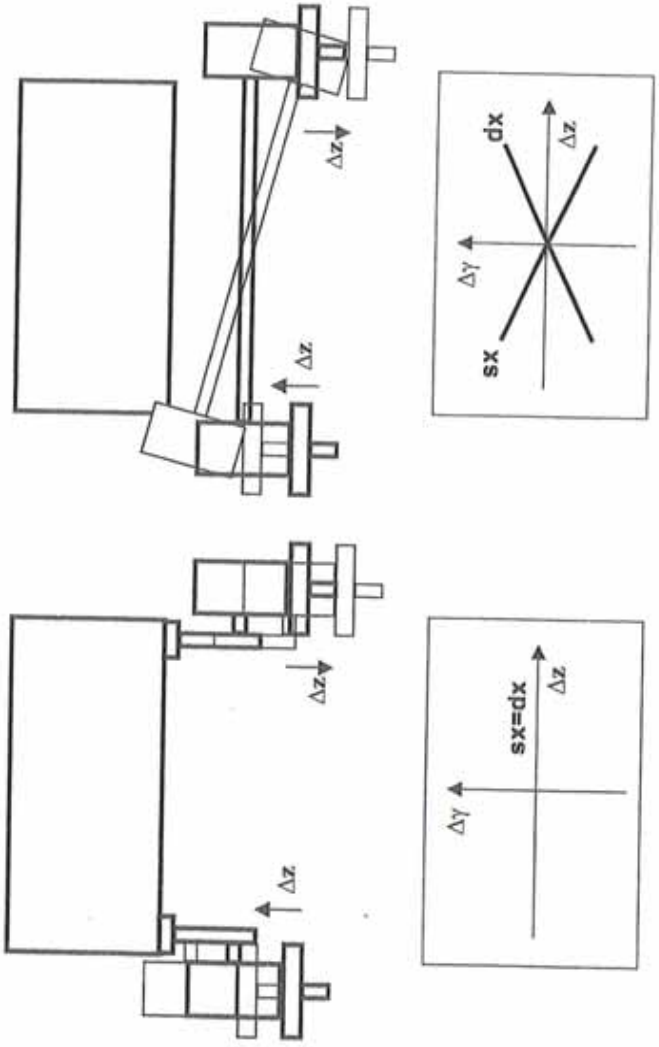
$$\delta_{vol} = \frac{L}{R} \cdot \tau - (\alpha_f - \alpha_r) \cdot \tau = \frac{L}{R} \cdot \tau + (\alpha_{f,s} - \varepsilon_{f,s} - \alpha_{r,s} + \varepsilon_{r,s}) = \delta_{vol0} + \left[\frac{\partial \varepsilon_{f,s}}{\partial a_y} - \frac{\partial \varepsilon_{r,s}}{\partial a_y} + \left(\frac{m_f}{C_{f,s}} - \frac{m_r}{C_{r,s}} \right) \right] \cdot a_y \cdot \tau$$

•Steering pad constant radius

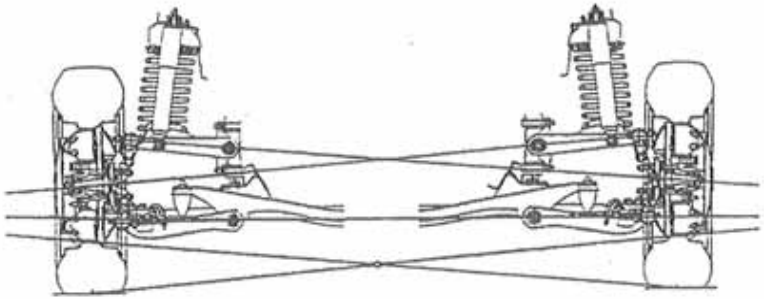


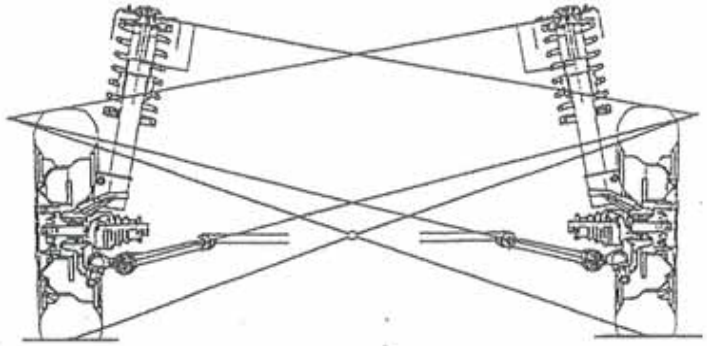
Suspension typologies and their characteristics

TYPICAL CHARACTERISTIC EXAMPLE

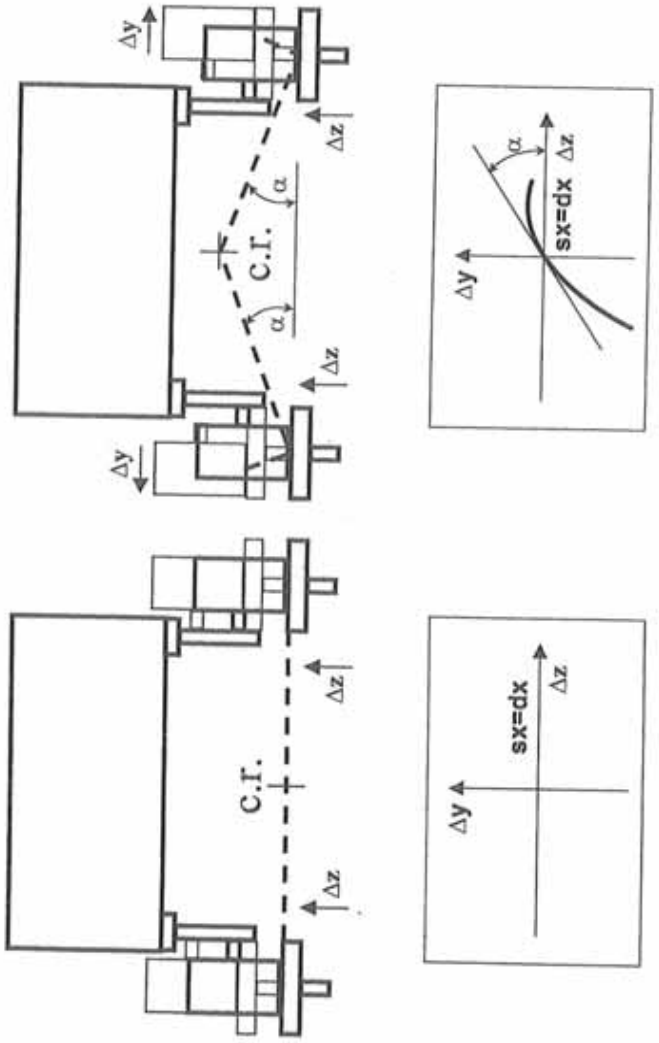


ROLL CENTER





ROLL CENTER CALCULATION BY TRACK VARIATION IN SUSPENSION KINEMATIC RIDE HEIGHT



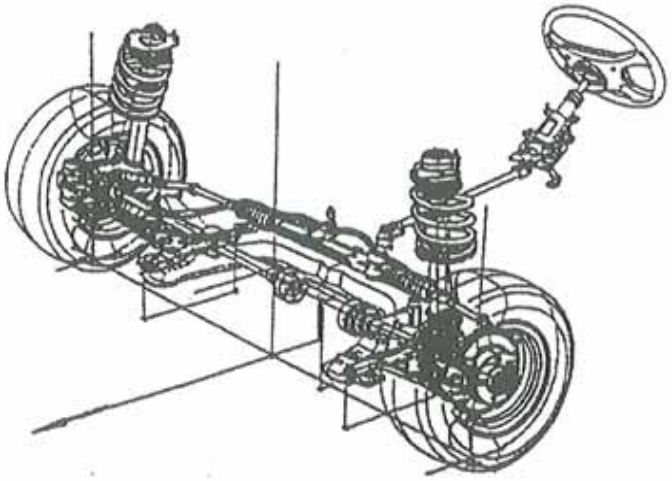
MC-PHERSON SUSPENSION

ADVANTAGES

- Good for reasons of space
- Low cost
- Small unsprung mass
- Reasonable control of kinematics parameters

DISADVANTAGES

- Structural shock-absorbers
- High hysteresis
- Shock-absorber wear
- Low camber gain



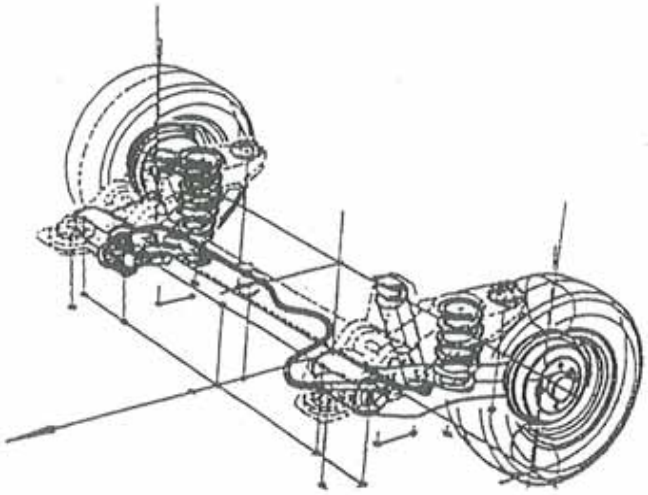
TRAILING ARM SUSPENSIONS

ADVANTAGES

- Good for reasons of space
- Low cost
- Small unsprung mass
- Low hysteresis

DISADVANTAGES

- No camber gain
- Large displacements under lateral loads
- High compliance under lateral loads
- Low control of kinematic parameters



BASICS OF VEHICLE DYNAMICS
Module H3
Suspension Characteristics

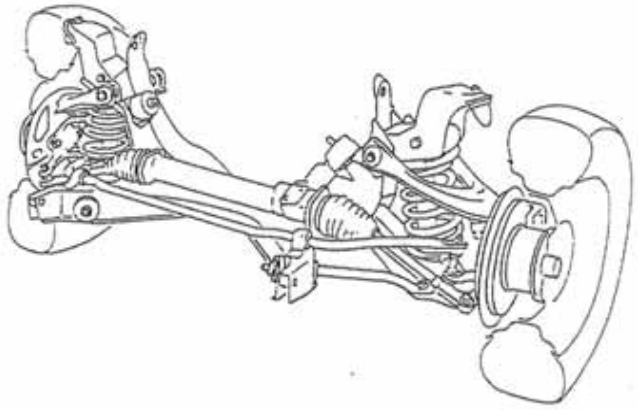
DOUBLE WISHBONE SUSPENSION

ADVANTAGES

- Full control of kinematic parameters
- Compliance control available
- Small unsprung mass

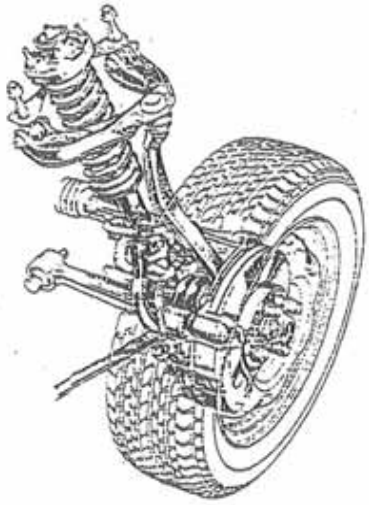
DISADVANTAGES

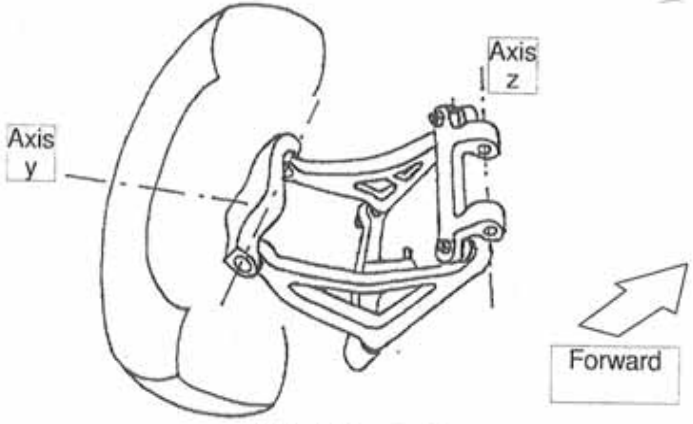
- High cost
- Not suitable for front - wheel drive
- High loads on points



DOUBLE WISHBONE SUSPENSIONS

PARTICULAR CASES





BOTTOM VIEW

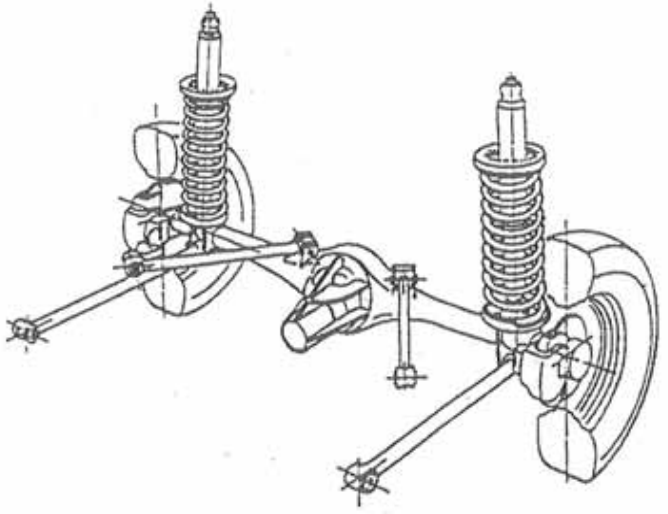
BEAM AXLE SUSPENSION

ADVANTAGES

- Robustness
- Total camber gain
- Good handling on flat road

DISADVANTAGES

- Not good for reasons of space
- Low rolling stiffness
- High unsprung mass



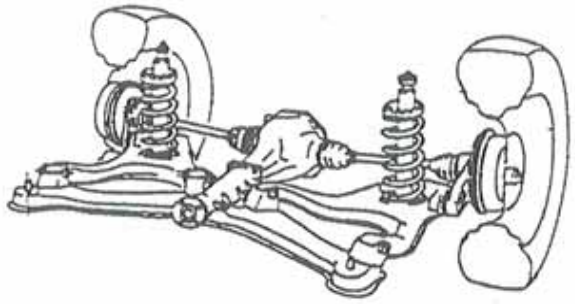
SEMI-TRAILING ARM SUSPENSION

ADVANTAGES

- Small vertical dimensions
- Reasonable control of kinematic parameters
- Small unsprung mass
- Easy assembling

DISADVANTAGES

- Large transversal dimensions
- Too large track change (tires wear)



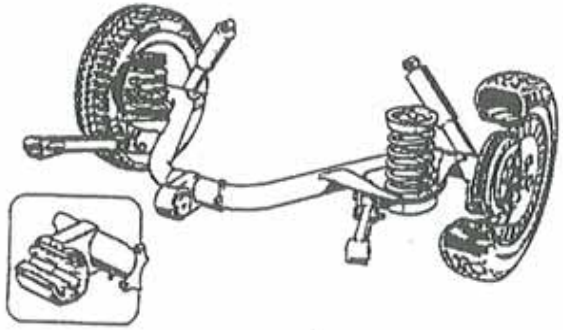
OMEGA BEAM AXLE SUSPENSION

ADVANTAGES

- Good handling on flat road
- Small vertical dimension
- Small camber gain
- Toe control in rolling condition
- Easy assembling

DISADVANTAGES

- Large transversal dimension
- Bushings action in symmetric bump



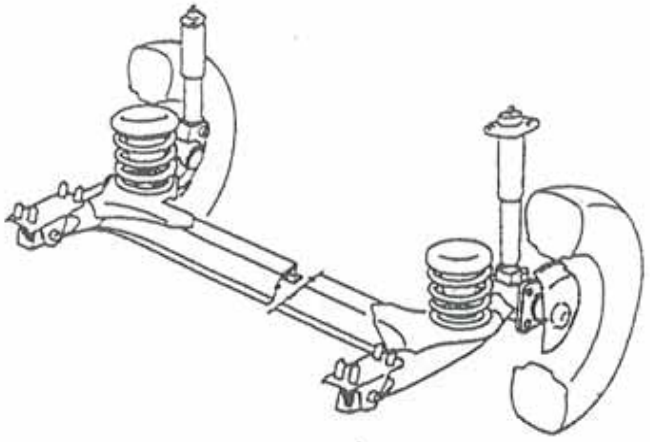
TWIST AXLE SUSPENSION

ADVANTAGES

- Small vertical dimension
- Camber gain
- Change in rolling condition

DISADVANTAGES

- Large transversal dimension
- Complexity and high cost



BASICS OF VEHICLE DYNAMICS
Module H3
Suspension Characteristics

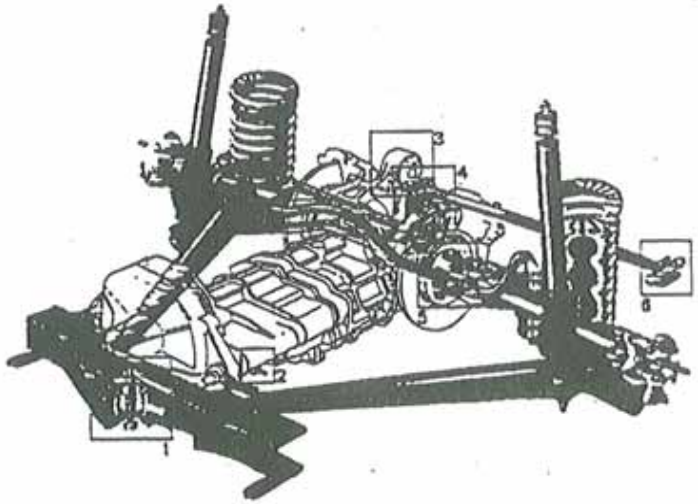
DE DION SUSPENSION

ADVANTAGES

- Good handling on flat road
- Reasonable control of compliance effects
- Low unsprung mass
- Total camber gain

DISADVANTAGES

- Large dimension
- Complexity and high cost



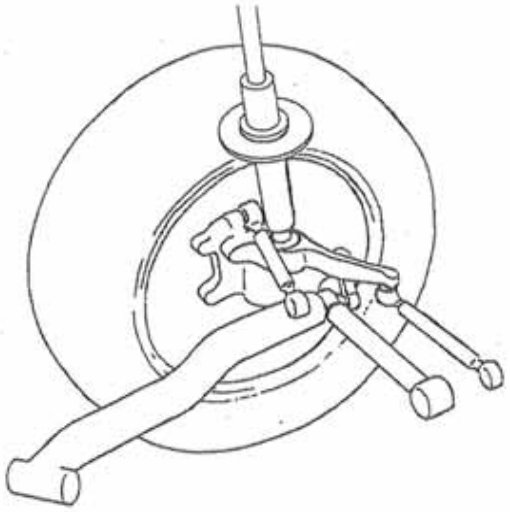
MULTILINK SUSPENSION

ADVANTAGES

- Full control of kinematic parameters
- Good compliance control
- Low unsprung mass
- Longitudinal and transversal compliance without toe effects

DISADVANTAGES

- High cost
- High geometrical sensitivity
- Sophisticated design



BASICS OF VEHICLE DYNAMICS
Module H3
Suspension Characteristics

Suspension Model

AIM OF MODEL

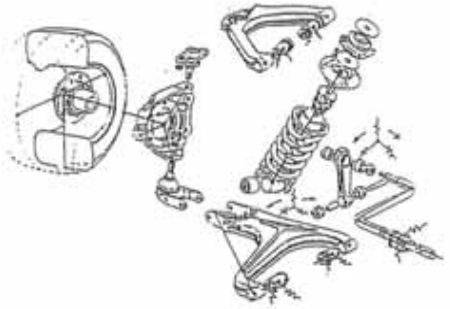
SUSPENSION HANDLING BEHAVIOUR
NUMERICAL SIMULATION
that is
WHEEL-CAR BODY
RELATIVE POSITION DEFINITION
IN OPERATIONAL CONDITIONS

- *VERTICAL WHEEL DISPLACEMENT*
- *STEERING*
- *GROUND FORCES*

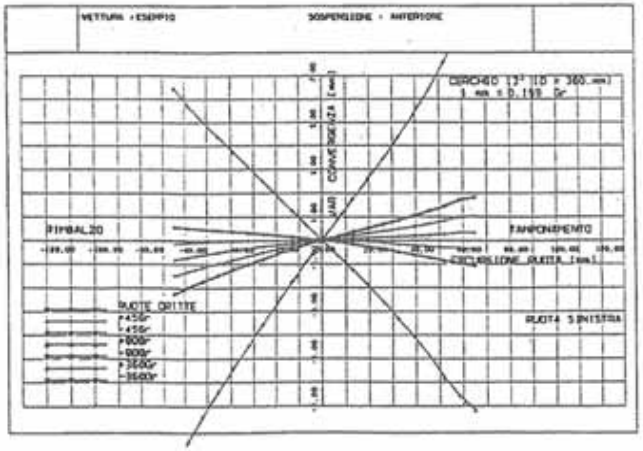
BASICS OF VEHICLE DYNAMICS
Module H3
Suspension Characteristics

MODEL TYPES

1) PHYSICAL Suspension behaviour simulation by suspension physical characteristics (geometry, elasticity, ecc.)



2) INTERPOLATION Suspension behaviour simulation by interpolation of the functional characteristics obtained by experimental tests or physical models



ABAQUS CODE

- Non linear F.E.M. code
- Problems solving with geometrical and material non linearity
- Particularly efficient in suspensions kinematic and structural analysis

The code allows:

- *Large displacements elasto-kinematic analysis*
- *Linear and non linear lumped elasticities simulation*
- *Kinematic/structural analysis of systems deformable components*

BASICS OF VEHICLE DYNAMICS
Module H3
Suspension Characteristics

ADAMS CODE

- Mechanical systems kinematics and dynamics problems solving code
- Kinematic and elastic behaviour simulation of suspensions with linear and non linear lumped elasticities or consistent simple elasticities (linear beams)
- Vehicle suspensions dynamic vibrations simulation

The code allows:

- *Large displacements elasto-kinematic analysis*
- *Linear and non linear lumped elasticities simulation*
- *Rigid bodies mechanical systems dynamic analysis*