# Basics of Vehicle Dynamics

## Module H4

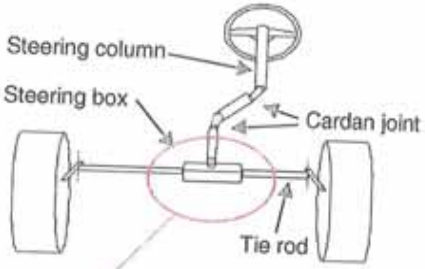
## Steering Systems Characteristics

- King pin axis geometry
- Ackerman error
- Steering wheel systems

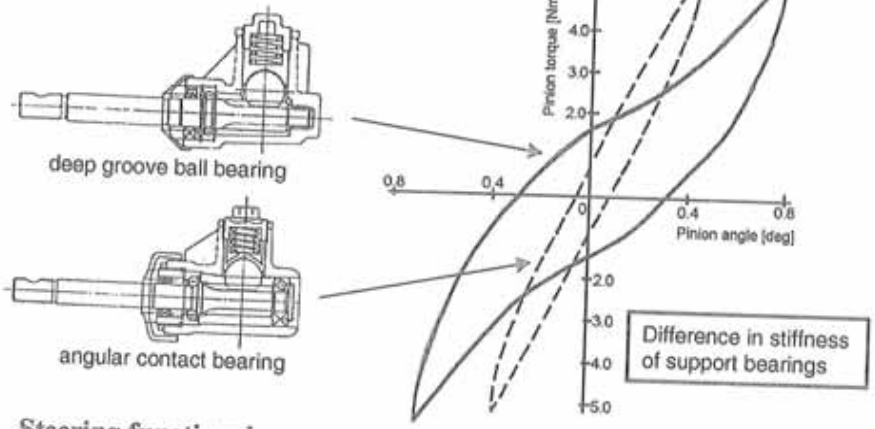


## INTRODUCTION

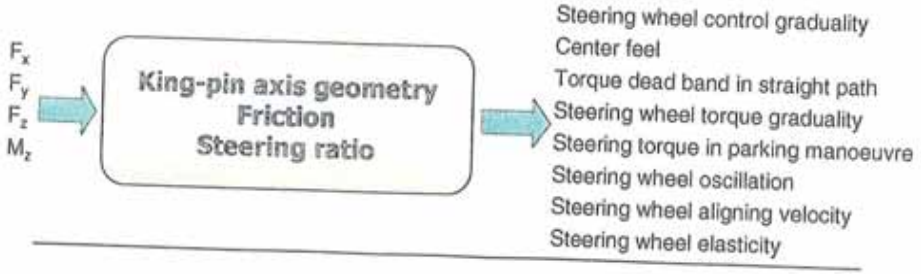
### Structural arrangement :




### Pinion support bearings:



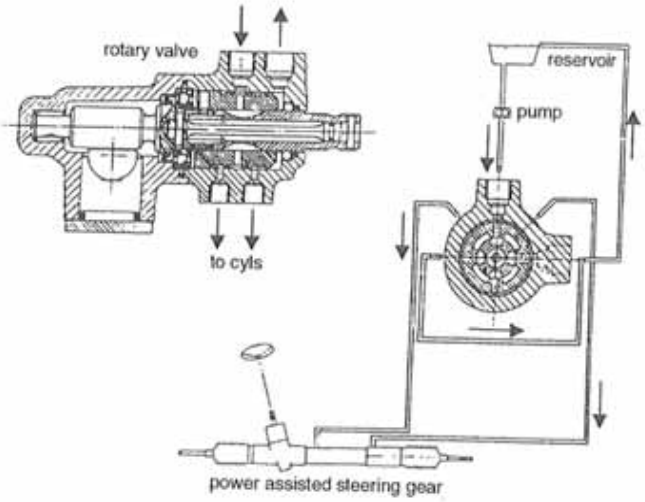

### Steering functional map :

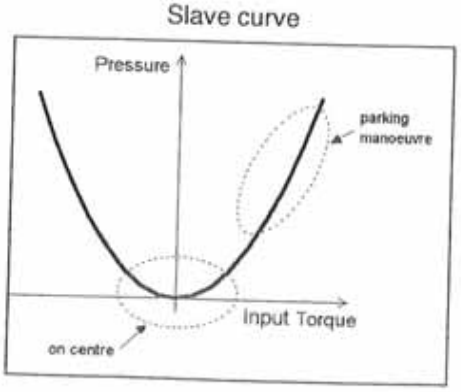


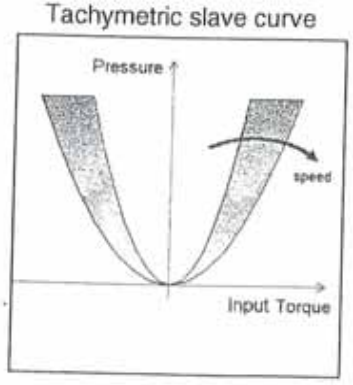
# POWER STEERING

- Hydraulic
- Electric

## Hydraulic power steering



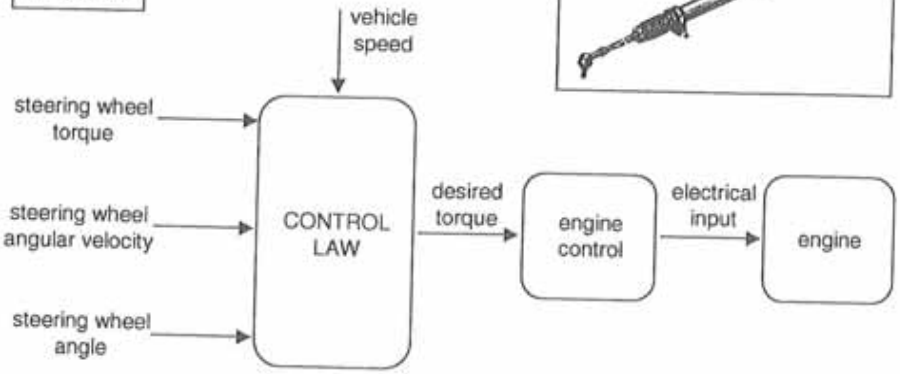



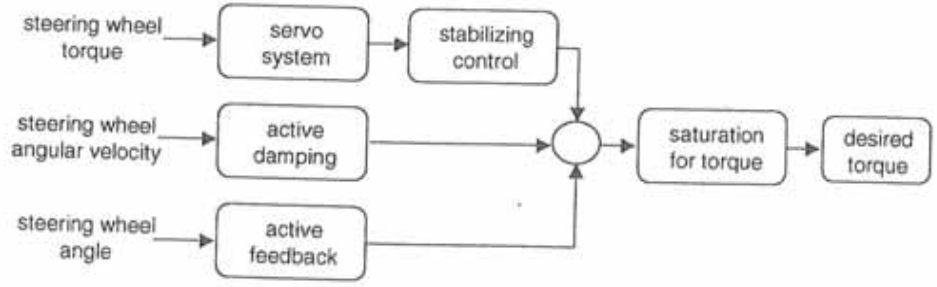



## Electric power steering

SYSTEM



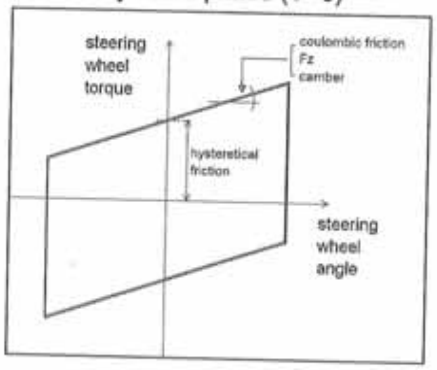

CONTROL LAW



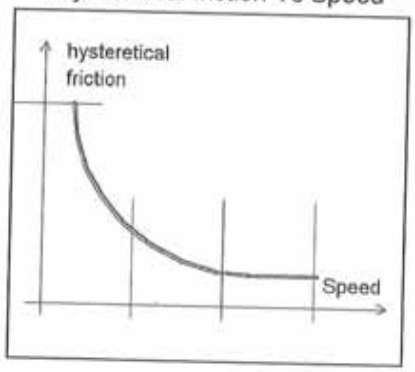
## FRICTION

- Hysteretical ⇒ Steering column, steering box, suspension links
- Viscous ⇒ Steering box
- Coulombic ⇒ Steering box, suspension links

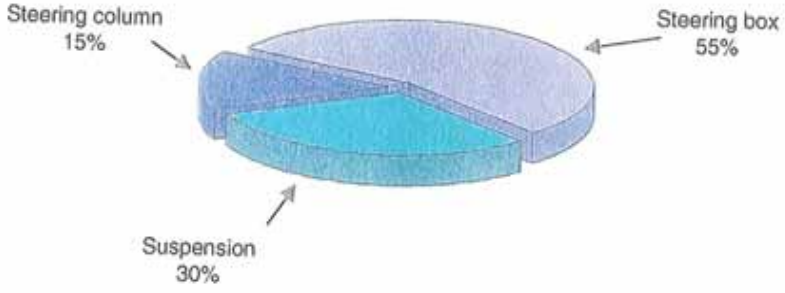
Cycle on plates (V=0)




Hysteretical friction Vs Speed



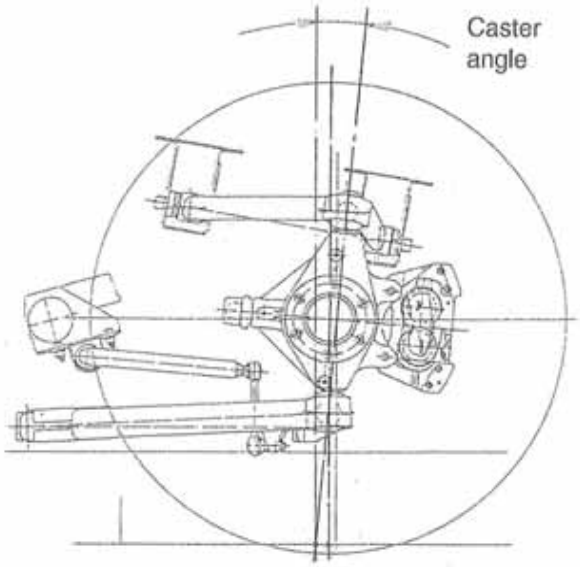

Hysteretical friction distribution in cycles on plates

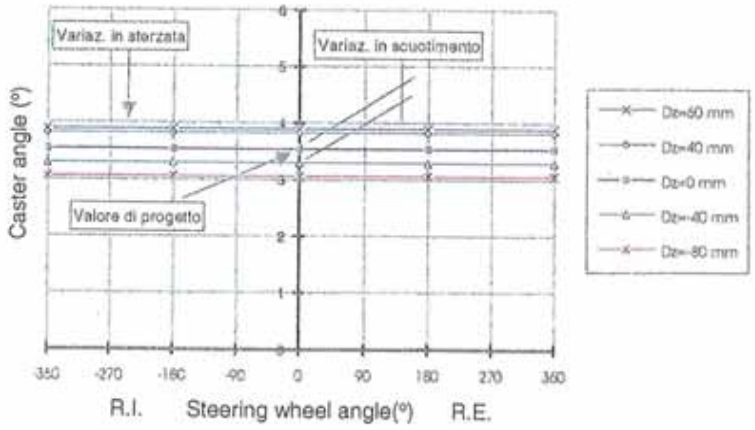





# King-pin axis geometry

# CASTER ANGLE




BASICS OF VEHICLE DYNAMICS
Module H4
Steering Systems Characteristics

# CASTER ANGLE

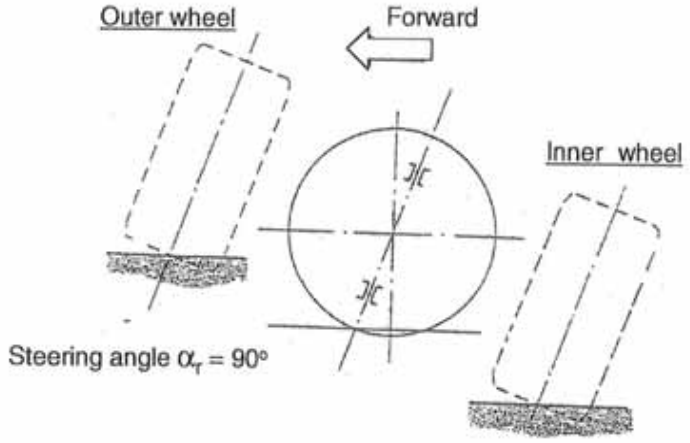
## CASTER ANGLE INITIAL VALUE INFLUENCES:

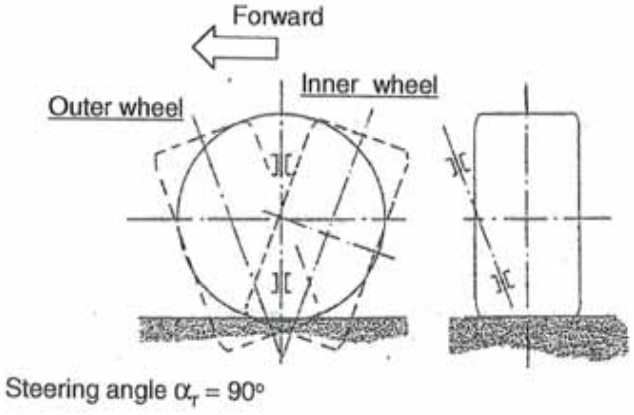
- Steering camber change and king-pin inclination negative effect compensation
- Mechanical trail value

## VARIATION IN KINEMATIC RIDE HEIGHT INFLUENCES:

- Mechanical trail variation
- Bump toe variation
- Comfort and stability due to the dynamic reactions of moving masses
- Suspensions - ABS compatibility
- Braking quality in uneven ground

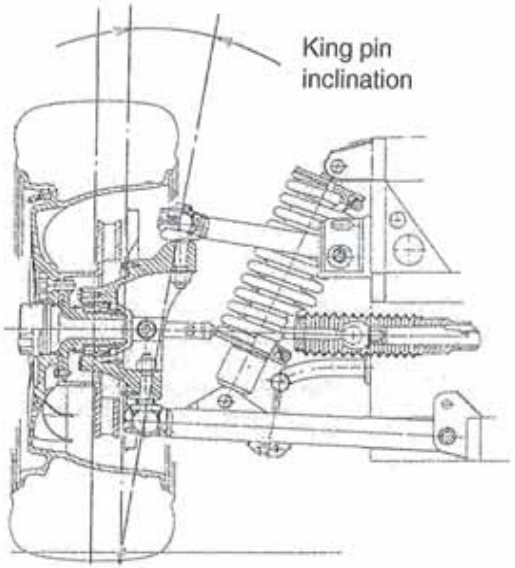
## STEERING CAMBER COMPENSATION

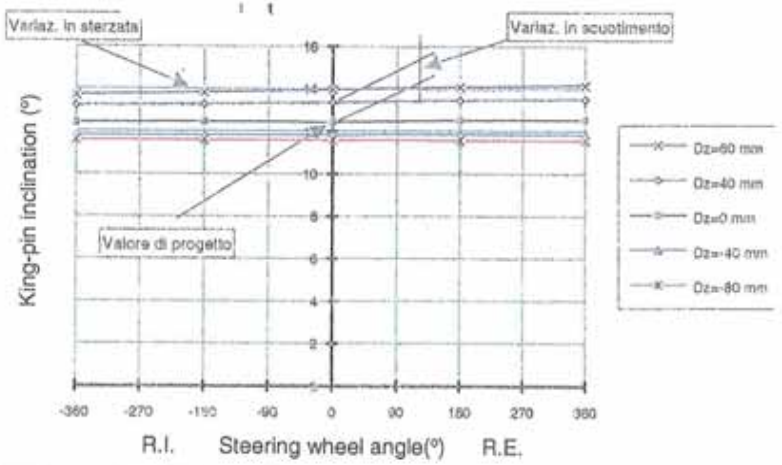




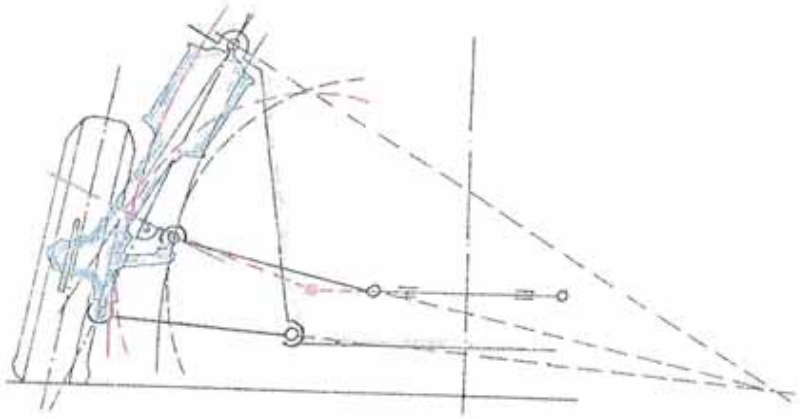

## KING-PIN INCLINATION

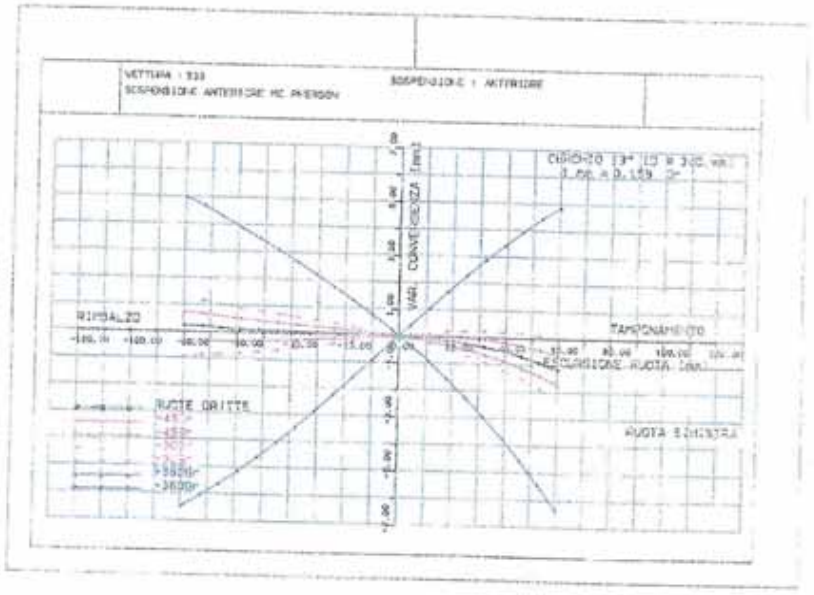


## KING PIN INCLINATION

### TOE CURVES vs WHEEL TRAVEL






BASICS OF VEHICLE DYNAMICS
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## KING PIN INCLINATION

KING PIN INCLINATION INITIAL VALUE INFLUENCES:

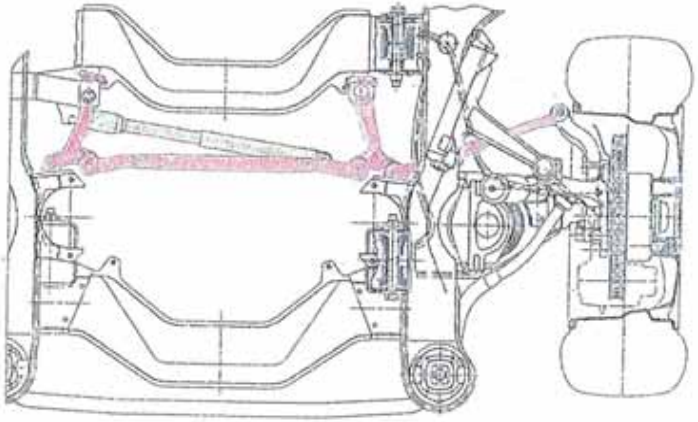
- Scrub radius value
- Bump toe variation curves amplitude
- Steering wheel back at low lateral acceleration due to the vertical load

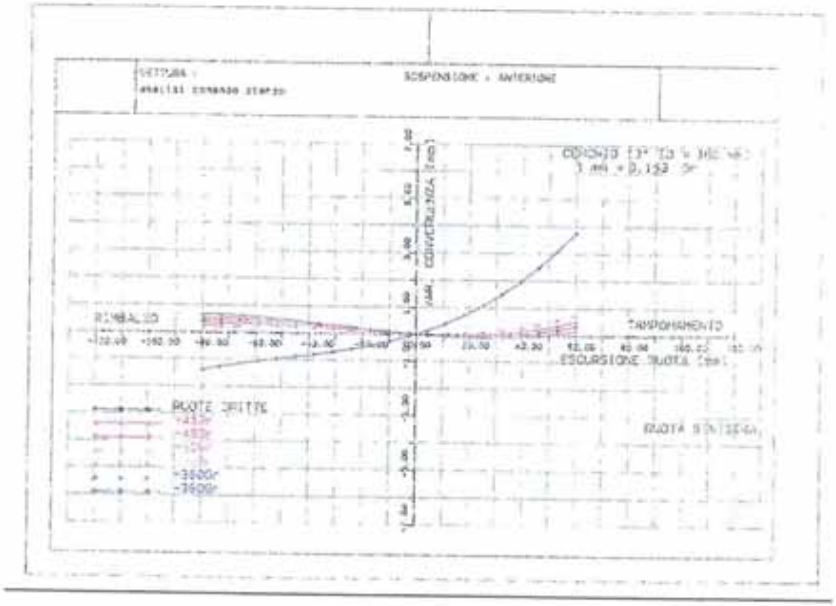
VARIATION IN KINEMATIC RIDE HEIGHT INFLUENCES:

- Scrub radius value variation
- Braking steering wheel force

# KING PIN INCLINATION

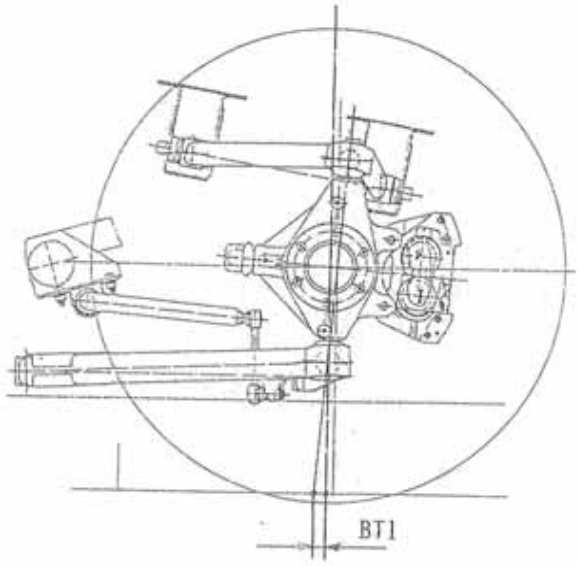
## STEERING WHEEL SYSTEM INFLUENCE ON TOE CURVES

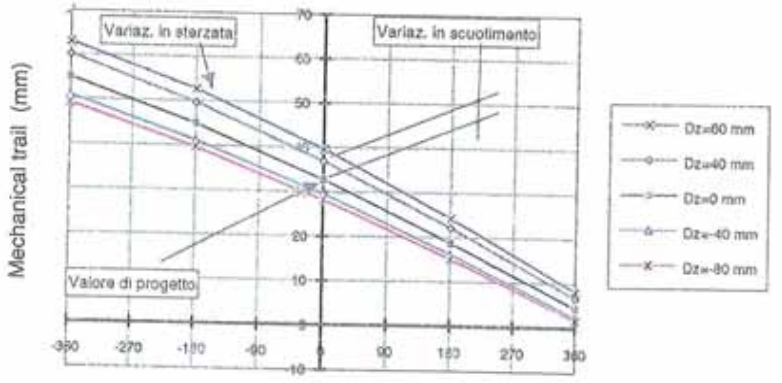







# MECHANICAL TRAIL




R.I. Steering wheel angle (°) R.E.

# MECHANICAL TRAIL

MECHANICAL TRAIL INITIAL VALUE INFLUENCES:

- Wheel stability in straight path
- Lateral load contribution to the steering wheel trim force

VARIATION IN KINEMATIC RIDE HEIGHT AND IN STEERING INFLUENCES:

- Ground adhesion level sensor system quality
- The variable to be monitored by steering wheel trim force (lateral force or aligning torque)
- Wheels different contribution to steering wheel trim force (external/internal)
- Steering wheel trim force value on curves with variable radius

BASICS OF VEHICLE DYNAMICS
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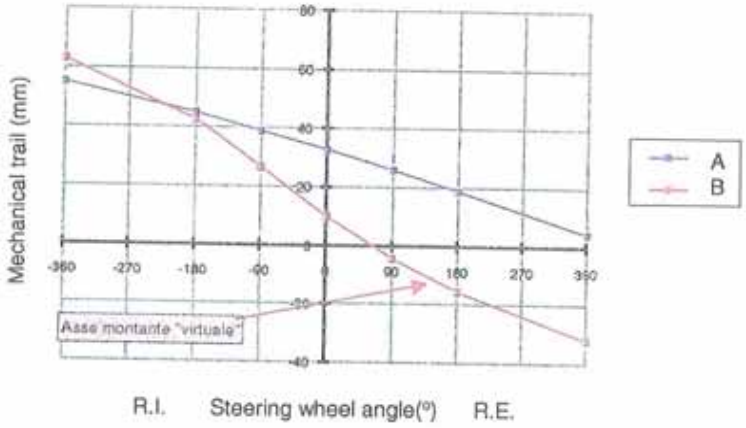
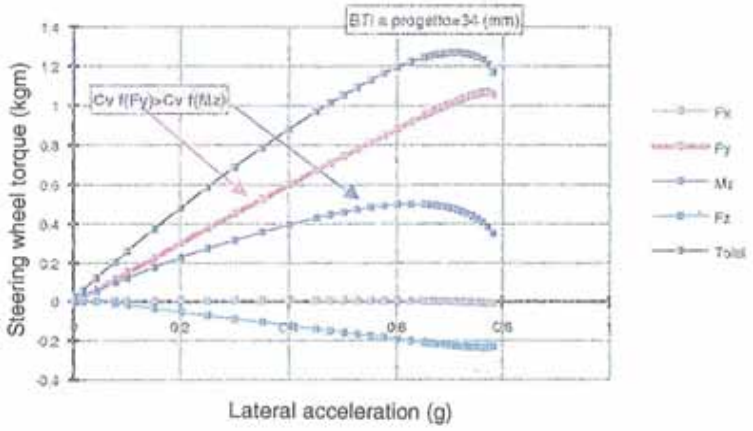
Steering Systems Characteristics

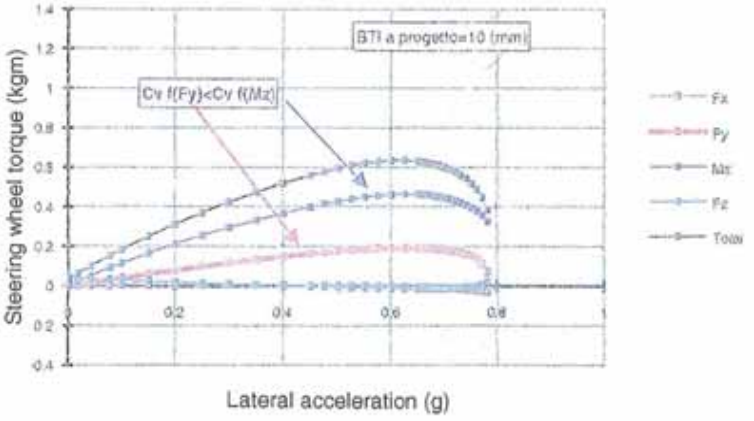
# MECHANICAL TRAIL VARIATION



# MECHANICAL TRAIL EFFECT ON THE STEERING WHEEL TORQUE

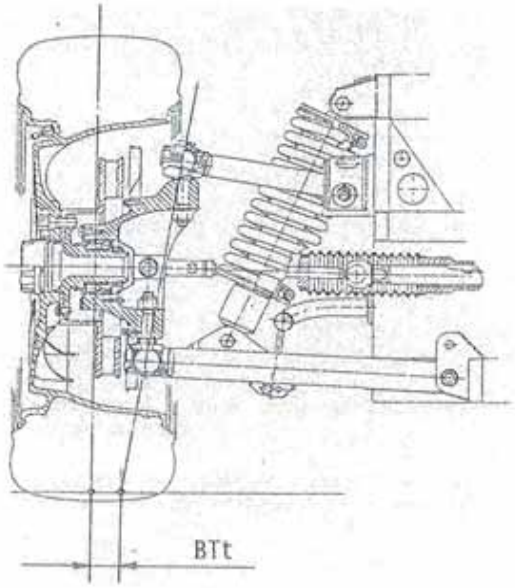
## STEERING-PAD Radius = 100 m

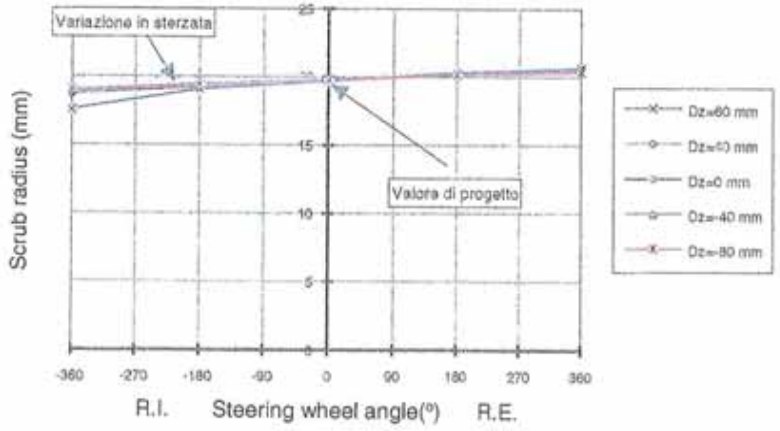





# SCRUB RADIUS



## SCRUB RADIUS

SCRUB RADIUS INITIAL VALUE INFLUENCES:

- King-pin axis torque value in bracking, i.e. steering system components loads value
- Steering wheel torque value and versus in cornering braking
- Car stability in braking in split condition or with crossed braking system circuit in breakdown

VARIATION IN KINEMATIC RIDE HEIGHT AND IN STEERING INFLUENCES (virtual king-pin axis):

- Steering wheel torque value and versus in cornering braking

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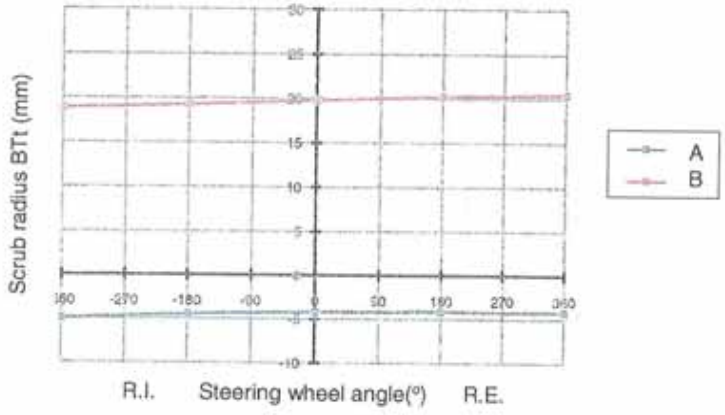
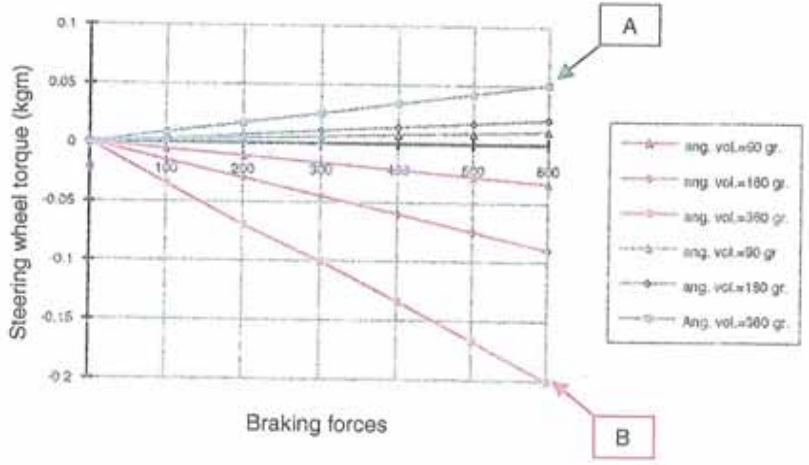
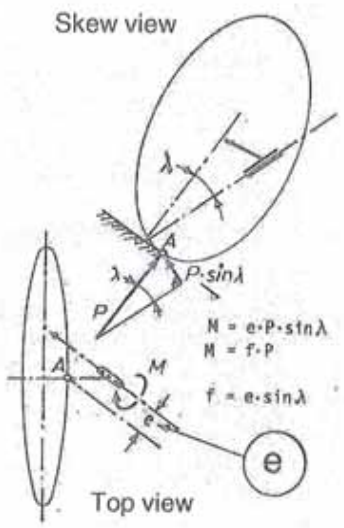
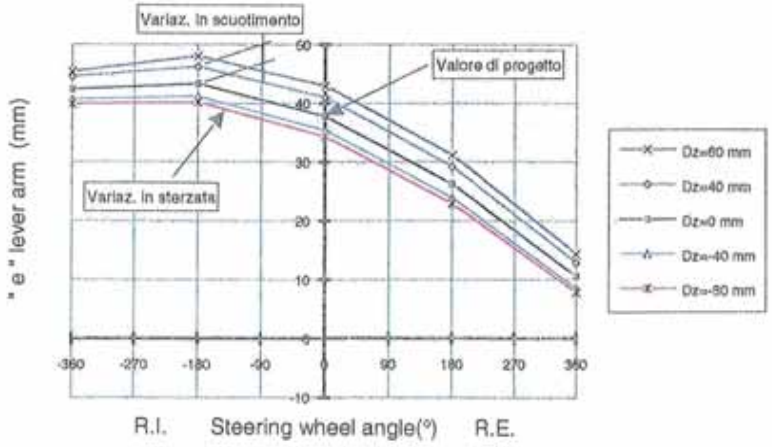
## STEERING WHEEL TORQUE IN CORNERING BRAKING



# " e " LEVER ARM




BASICS OF VEHICLE DYNAMICS
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Steering Systems Characteristics

# " e " LEVER ARM

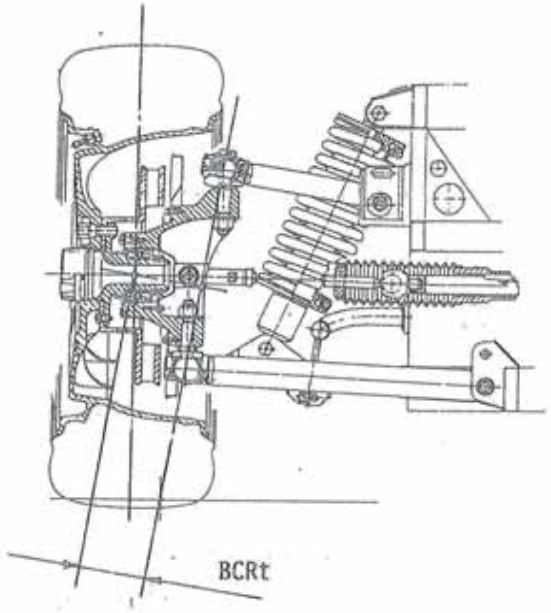
## "e" LEVER ARM INITIAL VALUE INFLUENCES :

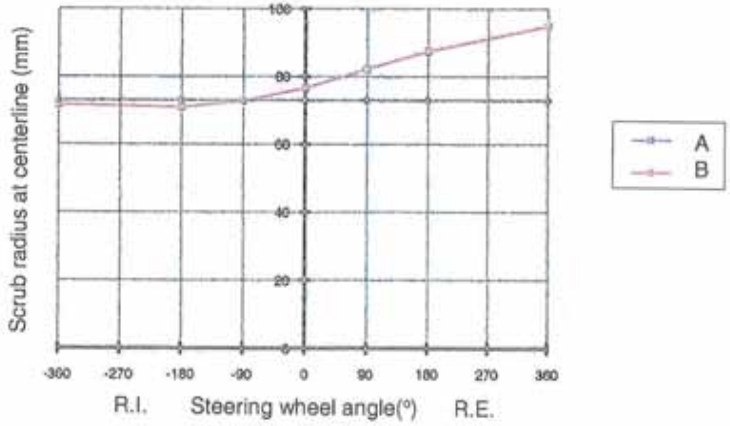
- Steering wheel torque value due to load transfer between the axle wheels in straight path

## VARIATION IN KINEMATIC RIDE HEIGHT AND IN STEERING INFLUENCES :

- Steering wheel torque evolution with steered wheels (steering cone)
- Steering wheel torque evolution due to load transfer

## SCRUB RADIUS AT CENTERLINE




BASICS OF VEHICLE DYNAMICS
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## SCRUB RADIUS AT CENTERLINE

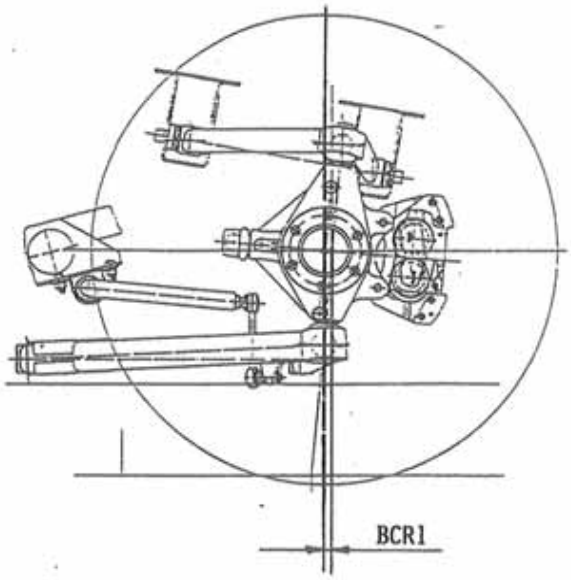
INITIAL VALUE OF SCRUB RADIUS AT CENTERLINE INFLUENCES:

- King-pin axis torque value in traction, therefore steering system components load value
- Variation of steering wheel torque in fast start and grip loss
- "kick-back" effect when the wheel pass over an obstacle
- Steering wheel vibration, called "flutter", usually due to tyre unbalance

VARIATION IN KINEMATIC RIDE HEIGHT AND IN STEERING INFLUENCES (virtual king-pin axis):

- Steering wheel back due to traction

## KING-PIN OFFSET




KINGPIN OFFSET INFLUENCES:

- longitudinal ground arm value independently of caster angle value
- axle shaft pumping in cornering
- king-pin axis torque due to lateral acceleration applied to steering masses

BASICS OF VEHICLE DYNAMICS
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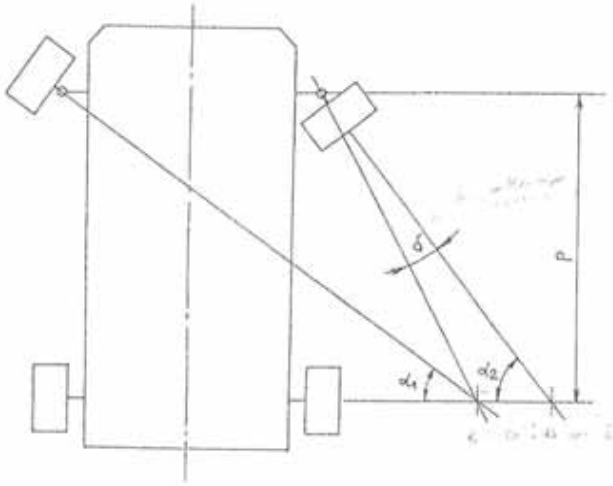
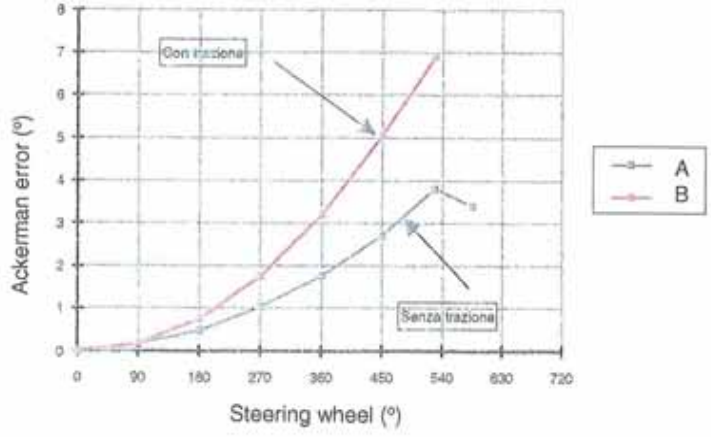
Steering Systems Characteristics

# Ackerman Error

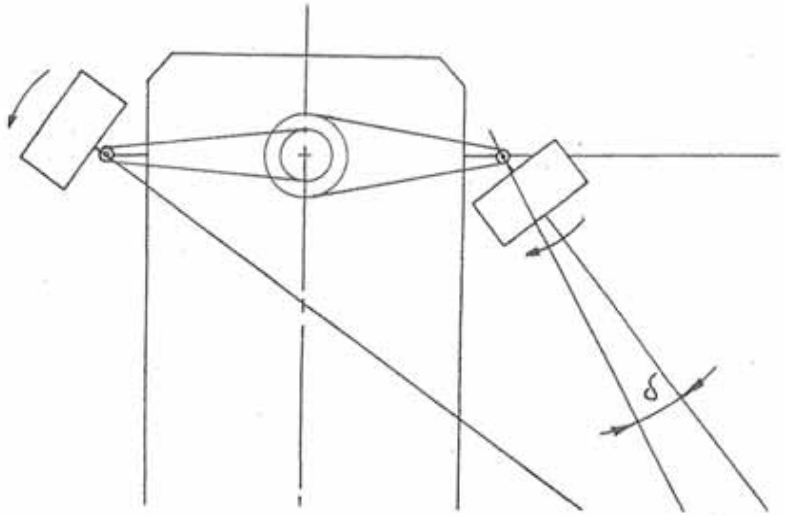
## ACKERMAN ERROR

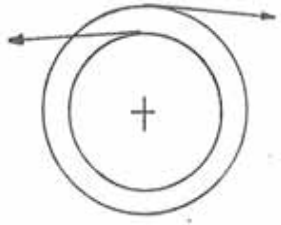





## ACKERMAN ERROR EFFECT ON STEERING WHEEL TORQUE



## ACKERMAN ERROR

ADVANTAGES RELATED TO LOW ACKERMAN ERROR:

- Reducing wheels sliding on the ground during the manoeuvres
- Reducing lateral forces which lighten steering wheel force on small radius curves
- Making easier steering wheels back related to vertical and longitudinal traction loads

DISADVANTAGES:

- At high lateral acceleration, the inside front tire is forced to higher slip angle, causing tire wear
- With positive scrub radius, self-steering effect occurs under braking longitudinal load

BASICS OF VEHICLE DYNAMICS
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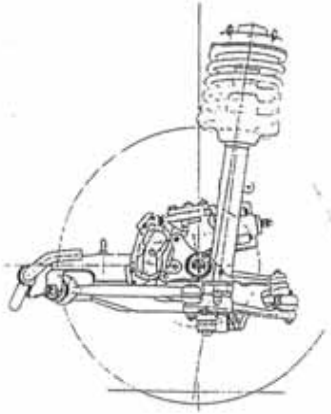
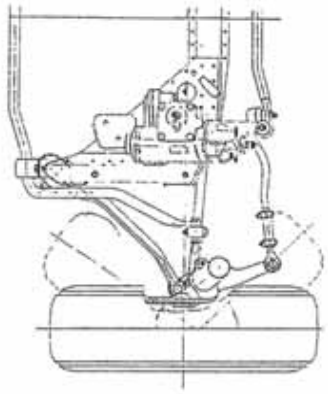
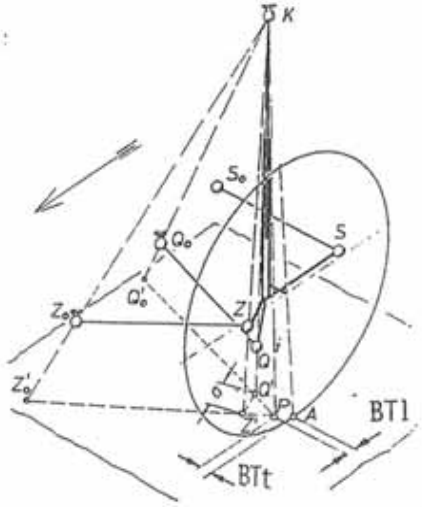
# Steering Wheel Systems

## "SEMI-VIRTUAL" KING-PIN AXIS

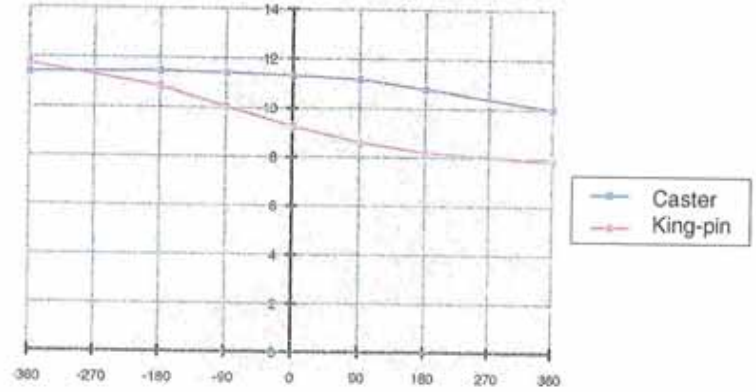




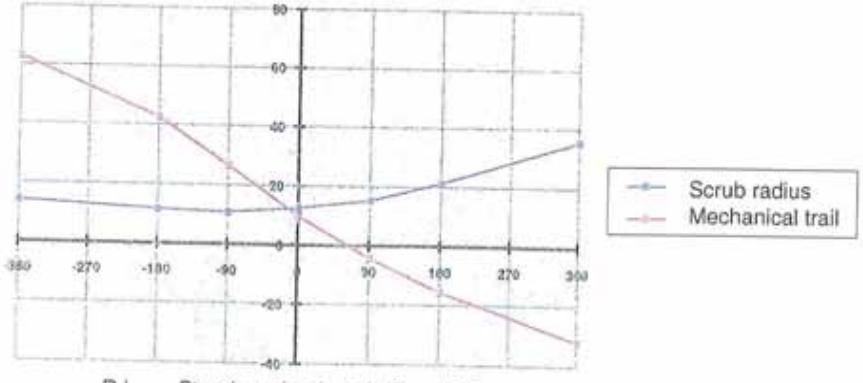





## KING-PIN GEOMETRY

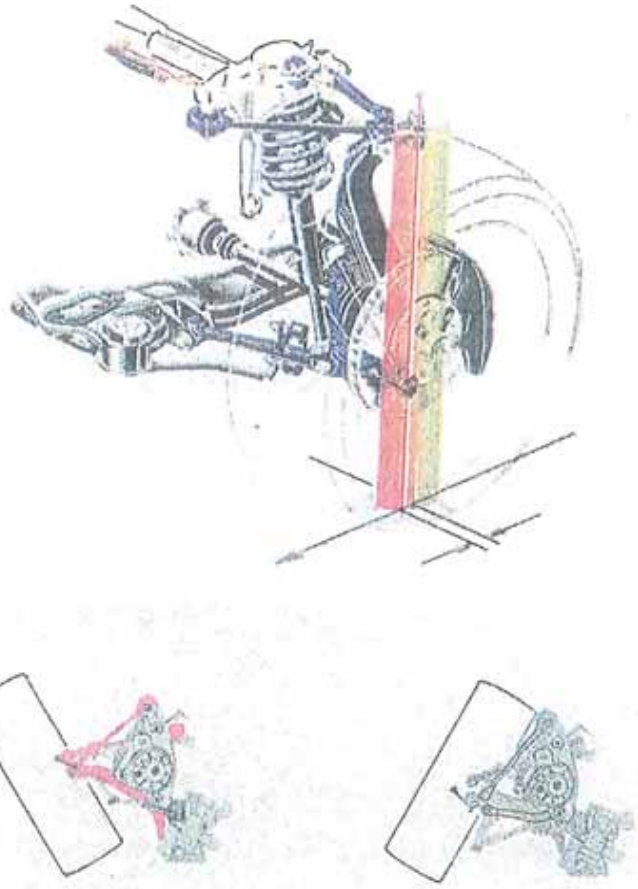



R.I. Steering wheel angle(°) R.E.



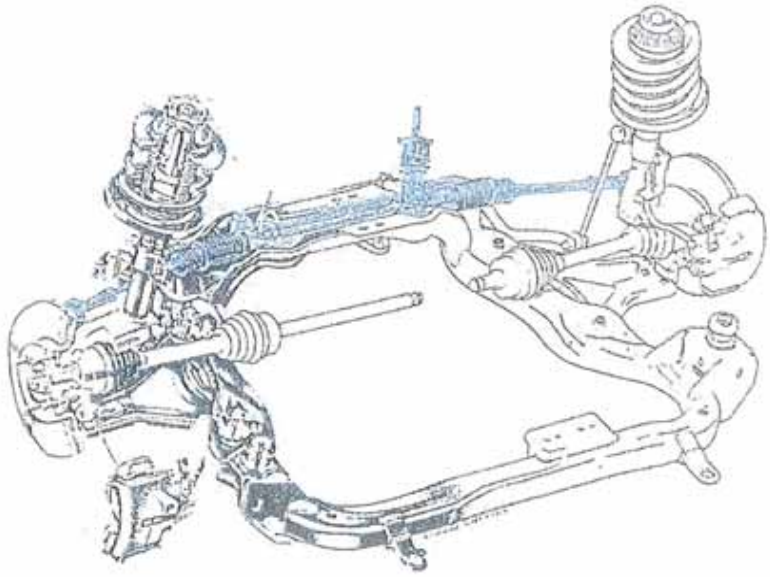

R.I. Steering wheel angle(°) R.E.

## "VIRTUAL" KING-PIN AXIS





## RACK WITH LATERAL EXIT



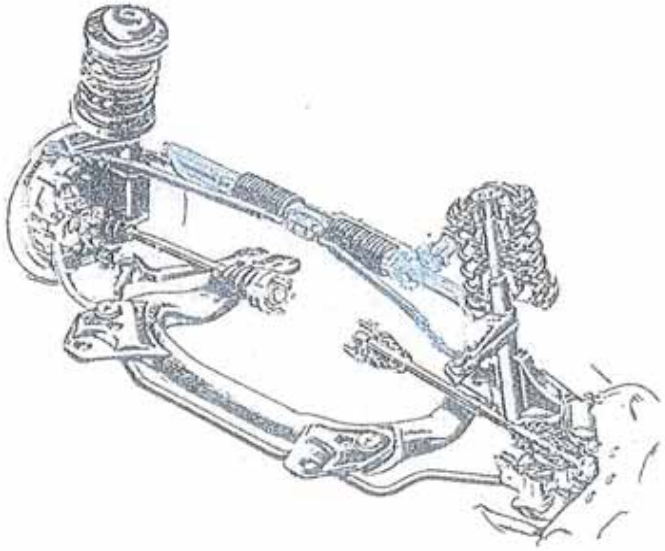
### ADVANTAGES:

- Easy manufacturing
- Small dimensions suitable for transversal engine

### DISADVANTAGES:

- Compliance and imprecisation of the command
- Large toe variation with steered wheels in kinematic ride height

## RACK WITH CENTRAL EXIT



### ADVANTAGES:

- Good adaptability for longitudinal engine
- Good toe variations control with steered wheels in kinematic ride height
- Structure suitable to keep constant displacements

### DISADVANTAGES:

- More complex to manufacture with respect to the lateral exit solution

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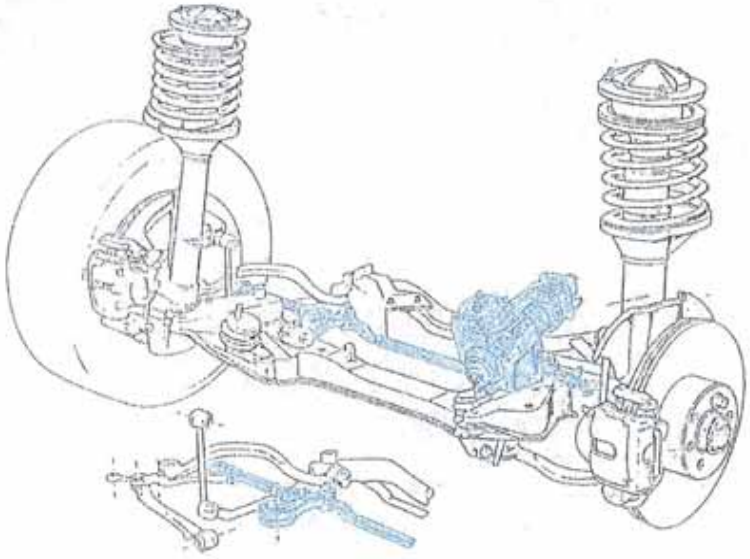
## PARALLELOGRAM WITH WORM SCREW



### ADVANTAGES:

- Good toe variation control with steered wheels in kinematic ride height
- Good reversibility control

### DISADVANTAGES:

- Cost element
- Large dimensions