Basics of Automotive Engineering

Part 1:

Basics of Vehicle Construction

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Basics of Vehicle Construction

Goals of the course:

• Introduction and analysis a modern vehicle concept
• Explanation of main vehicle systems (cars only)
• Chassis and main mechanical components (without engine and systems for comfort, lighting...)

Purpose of the course:

• To introduce basics of automotive engineering
• To explain main vehicle systems through examples and real models
Basic overview

Contents of today’s course

- Vehicle concepts (position of main systems)
- Transmission
  - Main clutch
  - Manual gearbox
  - Automatic gearbox (fundamentals)
  - Final drive and differential
  - Wheels and tyres
- Suspension system
- Steering system
- Braking system
- Test
At first ...

- Complex system
- Many individual parts
- Real engineering problems
- Mixed study fields: mechanical, electrical, ergonomics, control engineering ...
Main vehicle systems

1. Engine (black box)
2. Transmission (drivetrain)
3. Suspension system
4. Steering system
5. Braking system
## Drivetrain configurations

<table>
<thead>
<tr>
<th>Type of drive</th>
<th>Engine position</th>
<th>Powered axle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard drive</td>
<td>Front</td>
<td>Rear axle</td>
</tr>
<tr>
<td>Front-wheel drive</td>
<td>Front, lateral</td>
<td>Front axle</td>
</tr>
<tr>
<td>All-wheel drive</td>
<td>Front (mostly), Rear</td>
<td>Front and Rear axle</td>
</tr>
<tr>
<td>Rear-wheel drive</td>
<td>Rear</td>
<td>Rear axle</td>
</tr>
</tbody>
</table>
1. Main clutch
2. Gearbox
3. Drive-shaft
4. Final drive and differential
5. Half drive-shaft
6. Drive-Wheels
Drivetrain elements

Drivetrain elements must perform the following functions:

✓ Keep the vehicle stationary even with the engine running
✓ Achieve the transition from stationary to mobile state
✓ Convert torque and rotation speed
✓ Provide for forward and reverse motion
✓ Changing drive-wheel speed when cornering
✓ Secure minimum fuel consumption, exhaust emission and high efficiency
Main clutch

**Purpose:**
- Connect the engine and rest of the drivetrain
- To enable smooth engaging of drivetrain
- Interrupt power flow between engine and drivetrain
- Damping of torsional vibrations and impacts from engine to drivetrain

**Main types:**
1. Dry single plate friction clutch
2. Dry multi plate friction clutch
3. Wet multi plate friction clutch (e.g. Motorcycle)
4. Hydrodynamics torque converter
Main clutch

Dry single plate friction clutch

Engaged Clutch = Power transfer enabled
Disengaged Clutch = Power transfer disabled
Manually shifted gearbox

- Part of vehicle drivetrain
- Main purpose: to change parameters of power flow (torque and angular velocity) from engine to drive-wheels
- Changing vehicle direction (reverse direction)
- Discontinuation of power transfer between engine and drive-wheel in situation when the main clutch is engaged (neutral gearbox position)

Why we need transmission...?

\[ P = T \cdot \omega = \text{constant} \]

**Graph of output engine power** (what we have)

**Graph of vehicle traction** (what we need)
Manually shifted gearbox - *construction*

- Type of the manual gearbox depends on the vehicle construction which is used
- Gearboxes for lateral and *longitudinal* oriented vehicle engine

**Principle of work ...**

- Main parts
- Controlling speed and torque from engine for different drive conditions
- Constant gear ratio
- One gear has directly power flow direction
Manually shifted gearbox

Synchronizator (gearbox clutches)

Purpose:
- Connection the parts in the gearbox
- Speed synchronization between elements

Summary video
Semi-automatic transmission

- Same construction as manually transmission
- Manually shifted transmissions on which all operations normally performed by the driver are carried out by electrically controlled actuator system
- It works without main cluch pedal
- Gear change always with discontinuation of power flow

Fully-automatic transmission

- Change gear under a load, i.e. To continuously transmit the power to the driving wheels during a gearshift operation
- Makes gears ratio by planetary set (or sets)
- Uses Hydrodynamics Torque Converter
- Complex management with hydraulic or pneumatical devices
- Full control by ECU (Electronic Control Unit)
- Has own oil pump
- There are many wet multi-plate clutches and brakes for control the planetary set/s
Drive Shafts

- Part of every vehicle configuration
- Transmit the torque from the transmission system through the final-drive unit to the driven-wheels
- Can be tubular or solid in design
- Low weight
- High resistance to misalignment, especially sag
- Low resistance (low inertia) to changes in angular speed
- Main part: Joint

### Types of Joints

<table>
<thead>
<tr>
<th>Hooke-type</th>
<th>Rubber-type</th>
<th>CV-type (Rzeppa)</th>
</tr>
</thead>
</table>
| - Has two yokes set at 90° to each other  
- Yokes are joined to each other by a cross-shaped block  
- Contact between two parts is made by needle roller bearings  
- Variable velocity per a revolution | - Absorption of torsional shocks and driveline vibrations in transmissin  
- Used shape of rubber bushings to transmit the drive between the trunnion and yokes | - Drive from the inner to outer race is by means of longitudinal, elliptical grooves, which hold a series of steel balls (normally six), that are held in the bisection plane by a cage  
- Maximum angle of about 45°  
- Lubrication by grease |
Final-Drive gears

Purpose and construction

- To transmit the drive through an angle of 90°
- To gear down the engine revolutions so that a ’direct top’ gearbox ratio may be employed
- Final-drive ratio of approximately 4:1
  - Has two friction cones – the crown wheel and the pinion
  - Typical layout with Bevel gears

**Spiral bevel gear**

**Hypoid bevel gear**
Differential

Why we need differential...?

- Picture shows that the outer wheel must travel a longer distance when the vehicle is cornering
- **Problem:** If the wheels are interconnected, the tyres will have to ’scrub’ over the road surface and tend to keep the vehicle moving straight ahead

![Diagram showing differential](image)
Differential

Principle of work

- The drive is applied to the cross pin and push the planet gears forward to exert an equal torque on each sun wheel irrespective of the speed.
- When the vehicle turns a corner, the inner wheel will slow down and cause the planets to rotate on their own axis to speed up the outer wheel.
- Straight-ahead motion of the vehicle will allow that all units rotate at the same speed.

Two main laws of differential

1. Torque law
   Torque from differential cage is distributed half to the right axle shaft and half to the left axle shaft.
   \[
   T_{cage} = \frac{T_{LEFT\ WHEEL}}{2} = \frac{T_{RIGHT\ WHEEL}}{2}
   \]

2. Speed law
   Average speed of the right and the left wheel have to be at the same speed as the cage.
   \[
   \omega_{cage} = \frac{\omega_{LEFT\ WHEEL} + \omega_{RIGHT\ WHEEL}}{2}
   \]
Wheel

Function and requirements:

- Transfer of dynamic forces between the vehicle and road surface
- Transfer the rotary motion of the axles to the tyres
- Wheel = Rim + Tyre

<table>
<thead>
<tr>
<th>Tyre</th>
<th>Rim</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Only component of a vehicle that comes into contact with the road</td>
<td>• The radially part of the wheel which holds the tyre</td>
</tr>
<tr>
<td>• Perform many functions in everyday driving applications (e.g. Steer, acceleration, brake, comfor...)</td>
<td>• In a <em>tubeless</em> tyre it provides the air seal</td>
</tr>
<tr>
<td></td>
<td>• Made from steel or light materials (e.g. Aluminium)</td>
</tr>
</tbody>
</table>

*Tubeless – Pneumatic tyre without inner tube*
Tyre construction

- Complex construction with many individual parts
- Tread and Sidewall are the most important parts
- The Tread pattern ensures low rolling resistance, water expulsion, good grip and high mileage
- The Sidewall is thin and highly flexible rubber flank forms and the area of the tyre that is most sensitive to damage

Tyre designation

- Nominal Section Width
- Normal Aspect Ratio (Section Height/Section width)
- Construction (R-Radial)
- Rim Diameter
- Load Index
- Speed Symbol
SUSPENSION

Purpose:
- The suspension system has a influence on the vibration characteristics and therefore on both comfort (ride quality) and driving safety (vehicle handling / roadholding)

Construction

Main subsystems:
1. Elastic elements
2. Damping elements
3. Suspension mechanism (linkage)
Elastic elements – Body springs

- Parts of the chassis system that provide most of the vertical return forces between the wheel and body
- Protects the vehicle structure and the vehicle’s passengers
- Maintain wheel contact with the roadway

<table>
<thead>
<tr>
<th></th>
<th>Coil Spring</th>
<th>Leaf Spring</th>
<th>Torsion-Bar Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Image</strong></td>
<td><img src="image1.png" alt="Coil Spring" /> <img src="image2.png" alt="Leaf Spring" /> <img src="image3.png" alt="Torsion-Bar Spring" /></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Description</strong></td>
<td>The most common type of spring, heavy-duty torsion bar coiled around an axis</td>
<td>This type of spring consists of several layers of metal bound together to act as a single unit</td>
<td>This type of spring use the twisting properties of a steel bar</td>
</tr>
</tbody>
</table>
| **Advantages** | ✓ Low cost  
 ✓ No inner damping  
 ✓ Lower space requirement  
 ✓ Low weight  | ✓ Good transfer of forces to chassis (trucks)  
 ✓ Low cost  
 x Maintenance requirement  
 x Acoustic influences | ✓ Wear free, maintenance free  
 x Long springs |
| **Disadvantages** | x Spring characteristic curve is non-variable | | |
**SUSPENSION**

*UNDER THE HOOD*

**Damping elements – Shock absorbers**

- Shock absorbers are required to dampen the vibrations
- In use hydraulic telescopic shock absorbers
- Convert the kinetic energy of the vehicle body and wheel vibrations into heat
- Primarily requirements for comfort and driving safety

**Types of Shock Absorbers**

1. Mono-tube shock absorber
2. Dual-tube shock absorber
**Suspension Mechanism - Linkage**

- Vehicle wheels and the vehicle body are connected via suspension mechanism
- Suspension mechanism has a function of leading the wheel in relation to the vehicle body
- There are a large number of different suspension mechanism

<table>
<thead>
<tr>
<th>Rigid axles</th>
<th>Semi-rigid axles</th>
<th>Independent Suspensions</th>
</tr>
</thead>
</table>
| • The wheels of an axle are firmly interconnected by a rigid axle body, which leads to mutual influences on the wheels  
• Used as both driven and non-driven rear axles on heavy vehicles with high ground clearance | • The elasticity of the coupling profile that is used enables relative movements between the wheels  
• The coupling profile forms a cross-connection between two trailing links to which it is firmly connected | • Most modern vehicles have independent axles where each wheel is individually connected to the vehicle body according to the wish degrees of freedom of movement |

- [McPherson](image1)
- [Multilink](image2)
General requirements

- The steering system converts the driver’s rotation input at the steering wheel into a change in the steering angle of the vehicle’s steered road wheels
- The steering train must be highly rigid
- Light, safe steering of the vehicle must be facilitated

Types of steering box
1. Rack-and-pinion steering
2. Recirculation-ball steering (for trucks and heavy vehicles)
   Power-assisted steering systems
## STEERING

### Rack-and-pinion steering
- The rack-and-pinion steering consists of a steering pinion and a rack
- The steering ratio is defined by the ratio of pinion rotation to rack travel

### Power-assisted steering
- The steering forces exerted by the drive are boosted by a hydraulic or electric servo system
- Basically for weight vehicles

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### Rack and pinion steering video

### Power assisted steering video
BRAKING

Purpose of a system
• Reduce vehicle speed or bring the vehicle to a stop or to hold the vehicle stationary if already stopped
• All parts have to be regulated via various directives
• Motor vehicles must have at least two separate brake systems, one must be lockable

Types of vehicle’s brake devices:

1. Service-brake system (main brake application)
• Allow the driver to reduce with graduable effect the speed of a vehicle during normal driving
• Normally modeled as energy-assisted brake system
• Force by driver is trasmitted to the wheel brakes via the tandem brake master cylinder to two independent hydraulic tranmission devices
BRAKING

Types of vehicle’s brake devices:

2. Parking-brake system (handbrake)
   • Independent brake system which holds the vehicle stationary
   • The holding-stationary mechanism is integrated in the wheel brake
   • Usually activated by a handbrake lever
### BRAKING

#### Wheel brakes

<table>
<thead>
<tr>
<th>Disk brakes</th>
<th>Drum brakes</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fixed calipers</strong></td>
<td><strong>Floating calipers</strong></td>
</tr>
<tr>
<td>- Are defined as calipers which have a fixed housing and brake pinions on either side of the brake disc</td>
<td>- Usually feature a one-piece floating housing which moves on two rail-like arms extending from a fixed frame</td>
</tr>
<tr>
<td>- Has two pistons which are hydraulically connected either by fluid drills into the housing</td>
<td>- Both brake pads are pressed evenly onto the brake disk</td>
</tr>
<tr>
<td>- Less noise is generated</td>
<td></td>
</tr>
</tbody>
</table>

**Fixed caliper:** (1) brake disc, (2) brake piston, (3) hydraulic connection, (4) bleed screws

**Fully-floating caliper:** (1) brake disc, (2) brake piston, (3) hydraulic connection, (4) bushings, (5) mounting body, (6) frame

**Brake cylinder**

**Brake shoe**

**Brake lining**

**Brake drum**
Revision of today’s course

- Vehicle concepts (position of main systems)
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  - Automatic gearbox (fundamentals)
  - Final drive and differential
  - Wheels and tyres
- Suspension system
- Steering system
- Braking system
THE END

THANK YOU FOR YOUR ATTENTION