

(see also the mid-terms of the previous semesters in the same directory)

HISTORY OF VEHICLE AERODYNAMICS

- List the periods in history of vehicle aerodynamics development. Main characteristics of the periods, with sketches of example cars, with names of the most famous aerodynamicists / designers.
- Explain the main findings of the period I. (borrowed shapes) with sketches of characteristic car bodies & vehicle examples!
- Explain the main findings of the period II. (streamlining) with sketches of characteristic car bodies & vehicle examples!
- Explain the main findings of the period III. (detail optimisation) with sketches of characteristic car bodies & vehicle examples!
- Explain the main findings of the period IV. (shape optimisation) with sketches of characteristic car bodies & vehicle examples!

INTRODUCTION TO FLUID DYNAMICS / BASICS OF AERODYNAMICS

- Aerodynamic force acting on a body in case of non-viscous and viscous fluid flow. Pressure (form) drag and viscous drag from wall friction.
- Definition of streamlined and bluff bodies. Sketch the flow field around them. What is the physical quantity that dominates in the drag force acting on these bodies?
- Derive the equation for the aerodynamic force (F) acting on a body in case of viscous fluid flow. Define and explain the pressure coefficient and the wall friction coefficient!
- Euler's equation in normal coordinate system. Connection between parallel straight / curved streamlines vs. pressure gradient in normal direction. Consequences of local pressure distribution on vehicle body surface based on the curved streamlines.
- Bernoulli's equation, Venturi-channel flow, continuity, total, static and dynamic pressure.
- Attached and separated flows around bodies. Laminar / turbulent boundary layer (BL), BL separation, reattachment. Conditions for BL separation. List some methods to favour and to inhibit or postpone BL separation.
- Evaluate the role of separation bubbles, reattachment zones, trailing vortices in vehicle aerodynamics.
- How and where does a passive separation bubble form? List the characteristics of a passive/2D separation bubble with the help of a sketch. What does the pressure inside the bubble depends on and how?
- How and where does an active separation bubble form? List the characteristics of an active separation bubble with the help of a sketch. What are its characteristics?
- Describe the formation of the drag force on a prismatic body with sharp edges. Sketch the flow field and pressure distribution! Estimate the magnitude of each component of the drag force (front, sides, rear).
- Describe the formation of the drag force on a prismatic body with rounded-up edges. Sketch the flow field and pressure distribution! Estimate the magnitude of each component of the drag force (front, sides, rear). How does the rounding-up of the leading edges reduce the drag force?
- What are the consequences of ground proximity in terms of pressure distribution on vehicle body?
- List (with help of sketches) some alternative methods to reduce the drag force forming on the front face of a prismatic body (other than rounding up the leading edges.)
- Sketch the coordinate system in vehicle aerodynamics with main (x;y;z) axes. Define the various forces and moments and their coefficients!
- What does it mean: side-wind condition in terms of relative flow field? Sketch the relative flow velocity profile $\underline{v}=f(z)$ vector for no-wind and for side-wind conditions! Effect of side-wind on stability in function of yaw angle (side forces and moments in function of yaw angle).

PASSENGER CARS

- Describe the formation of the lift /drag force for a passenger car body! List methods to decrease the lift / drag!
- List and explain (with sketch) methods to decrease the front drag / lift!
- List and explain (with sketch) methods to decrease the rear drag / lift!
- Explain typical pressure coefficient distribution in the symmetry (vertical) mid-plane (upper and lower part) of the vehicle contour body-line.
- Rounding-up of the edges. How does it effect on the drag / lift? Explain its mechanism with the help of a sketch.

- Effect of closed / open front grille. How does it effect on the drag / lift? Explain its mechanism with the help of a sketch.
 - Boat-tailing. How does it effect on the drag / lift? Explain its mechanism with the help of a sketch.
 - Changing slant angles (front, hood, windows, sider, rear, underbody). How does it effect on the drag / lift? Explain its mechanism with the help of a sketch.
 - Wings, spoilers (front, rear). How does it effect on the drag / lift? Explain its mechanism with the help of a sketch.
 - Methods for changing of the position of the front stagnation point. How does it effect on the drag / lift? Explain its mechanism with the help of a sketch.
 - Rear diffuser. How does it effect on the drag / lift? Explain its mechanism with the help of a sketch.
 - Underbody coverings. How does it effect on the drag / lift? Explain its mechanism with the help of a sketch.
 - Stationary / rotating wheels with partially open rim in wheel housing. How does it effect on the drag / lift? Explain its mechanism with the help of a sketch.
 - List and explain methods for aerodynamic optimisation of flow field around rotating wheels.
 - Describe the flow field forming at the rear of a fast-back / square-back / notch-back car, and show the lift force acting on it in function of the angle relative to the horizontal plane of the rear windshield.
 - With the help of a sketch show the working mechanism of the front and rear spoilers / wings placed on a passenger car. How do they affect the drag and lift coefficients?
 - How do interact the front spoiler and the rounding up of the top leading edge of a passenger car? How does this interaction influence on the drag force?
 - List - without explanation - at least eight methods to reduce the drag force acting on a passenger car.
 - List - without explanation - at least eight methods to increase the negative lift force acting on a passenger car.
 - How do wheels and wheel housings affect the drag and lift coefficient acting on a car? Explain the mechanism with the help of a sketch of the pressure distribution around the stationary / rotating wheel.
 - Side-wind effect, directional stability. Show (with the help of a sketch) how the side wind changes the pressure distribution on the body surface in the horizontal plane.
 - List methods to increase the directional stability!
 - Describe how the add-on devices (excrescences) influence on the drag / lift forces and moments.
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Additional: in mid-term these will not be included

+on COMPETITION CARS (high performance race cars)

- Explain the role of the lift-to-drag ratio (L/D) in case of competition cars.
- List methods to increase downforce!
- Describe the functioning of a diffuser and side skirt in case of race cars. What parameters should be taken care of? What is the disadvantage of a diffuser and how can it be moderated?
- Explain how side fin and Gurney flap influences on efficiency of a wing? Sketch a diagram of the drag / lift coefficient in function of the incidence angle
- Explain what aspects should be considered when installing a rear wing on a race car (wing profile, height, cord length, distance from rear wheels, wing profile, end-plate).
- Explain how ground clearance (underbody gap) influences on drag & lift!
- Explain the role of the side skirt height in underbody flow, how skirt influences on drag & lift!
- Explain how underbody Venturi-effect (rear diffuser) influences on drag & lift!
- Explain how divided diffuser influences drag & lift!
- Explain how vortex generators on underbody and wings influences on drag & lift!

+on HEAVY VEHICLES (BUSES & TRUCKS)

- Ratio of aerodynamic and rolling drag. Explain the diagram of increasing aerodynamic drag relative to the total vs. vehicle speed.
- Main aims of aerodynamics developments in case of buses & trucks.
- Describe the main characteristics of the flow field around typical body types of buses & trucks! What are the main aims and key elements for aerodynamic optimisation in case of buses& trucks?
- List and explain the flow field of main areas of aerodynamic losses (front, side, rear, gap, underbody, wheels)
- List and explain methods for drag reduction for buses & trucks.

+ on WIND TUNNEL MEASUREMENTS..., + on CFD SIMULATIONS...

- Wind tunnel types, blockage ratio, pressure gradient, moving ground simulation, Reynolds-number, Mach-number, measurement of pressure distribution, flow visualisation techniques
- The role of CFD in vehicle aerodynamics, 2D / 3D simulation cases, meshing, simplifications