Statistical modelling of the influence of turbulent flow separation control devices

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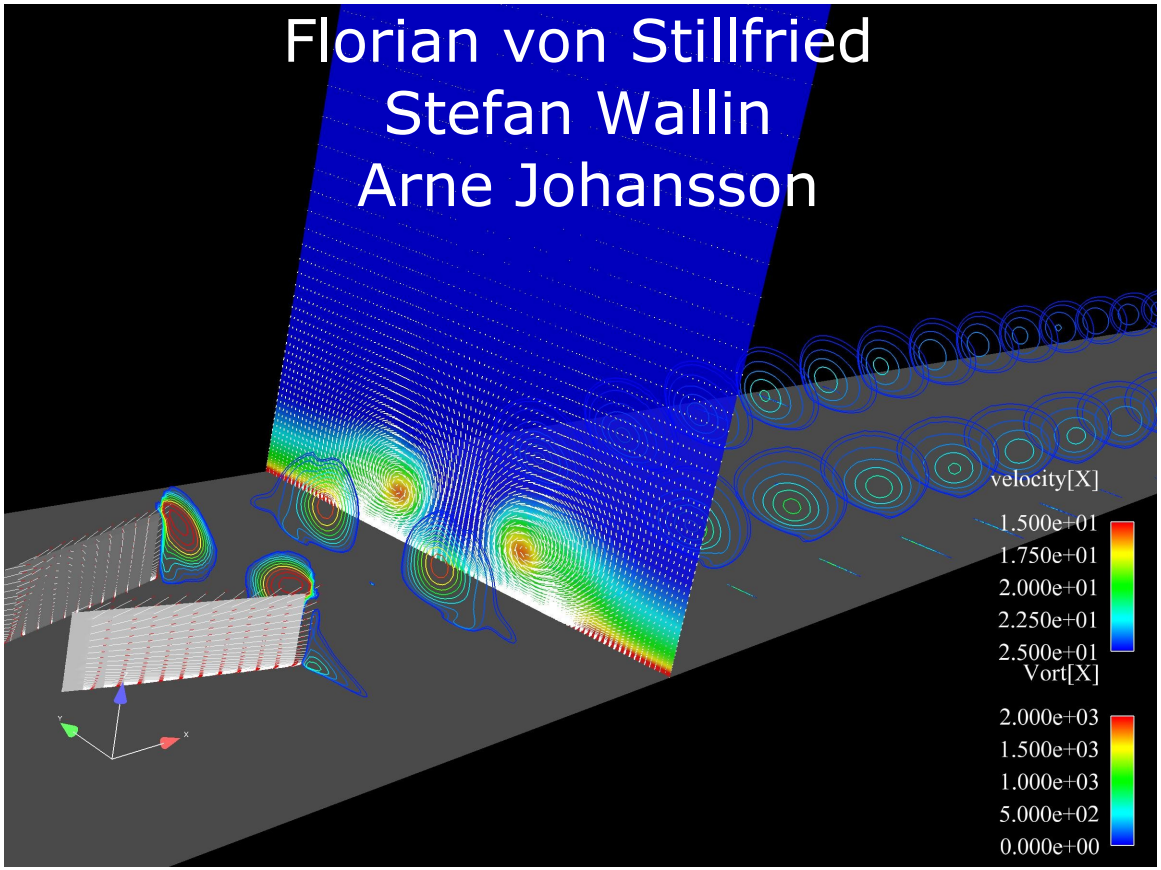


Use of vortex generators

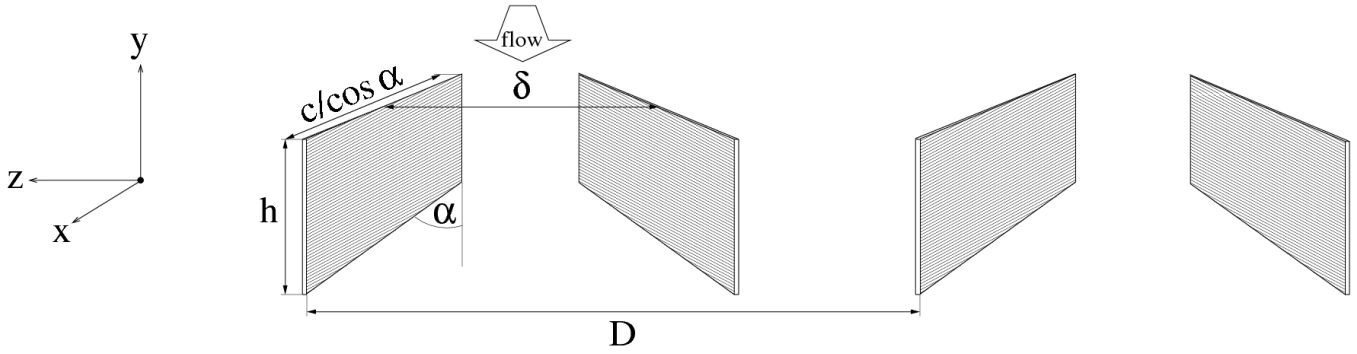
- Found in many engineering applications, e.g.
  - Aircraft wings
  - Diffusers, inlets
- General purpose
  - Enhance boundary layer mixing
  - Flow separation control device
- Sub-boundary layer vortex generators
  - Typically 10% - 50% of local boundary layer thickness
  - Parasite drag reduction for regular flight regimes

Use of vortex generators

- Example: vortex generators on a wing, B737

VG experiments at KTH

- Ola Lögdberg (2006):
  - Experimental data used for detailed validation of vortex modelling results
  - Flat plate: L = 4.5 m, U_∞= 26.5 m/s $\rightarrow Re_L \approx 8 \cdot 10^6$
  - VGs at: $Re_\theta \approx 6000$, $\theta \approx 3.37$ mm, $h/\delta \approx 0.65$



Blade size	N [−]	α [^{o}]	h [mm]	δ [mm]	c [mm]	D [mm]	AR [−]
large	5	15	18	37.5	54	150	0.64

VG - CFD methods

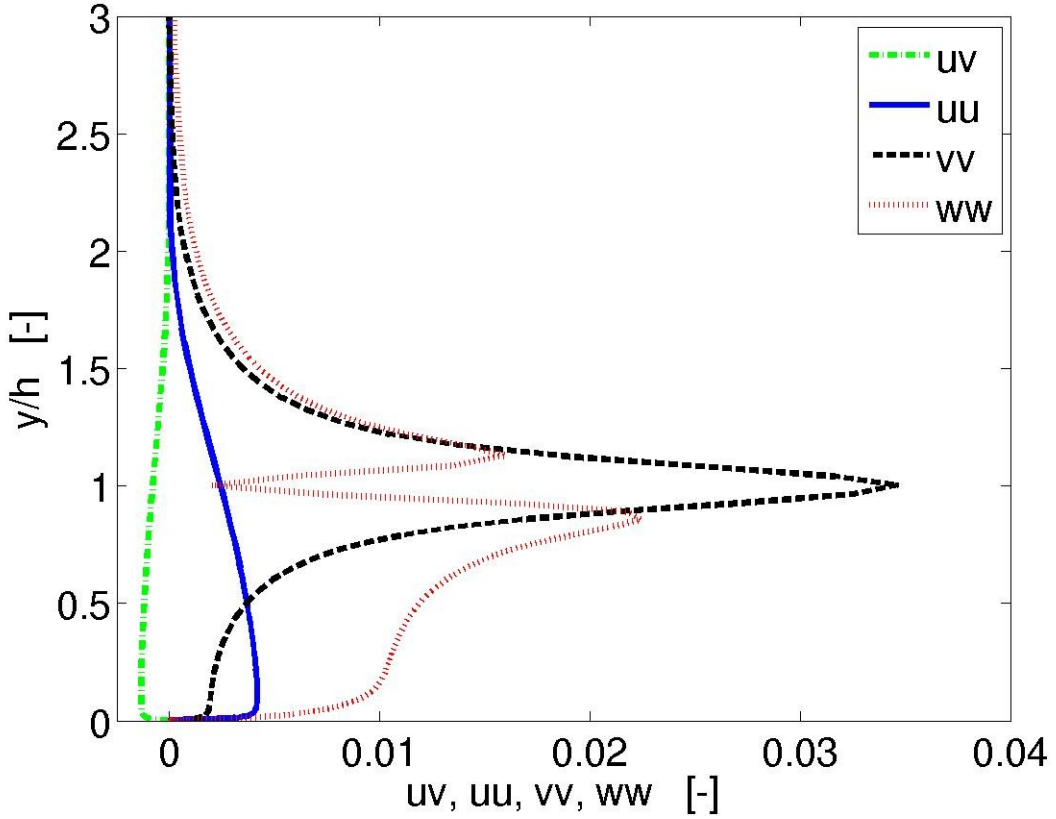
- Fully resolved
  - Fully resolved within mesh, new mesh for new VG size
  - Computational expensive
- Partly resolved (Adam Jirásek 2004)
  - Devices modelled by surface and volume forces
  - Generated structures resolved within 3D mesh
  - Not as expensive
- Represented by RANS model
  - Statistical description, RST modelling
  - No structures to resolve, no mesh refinement
  - Same computational costs as for RANS

Vortex modelling

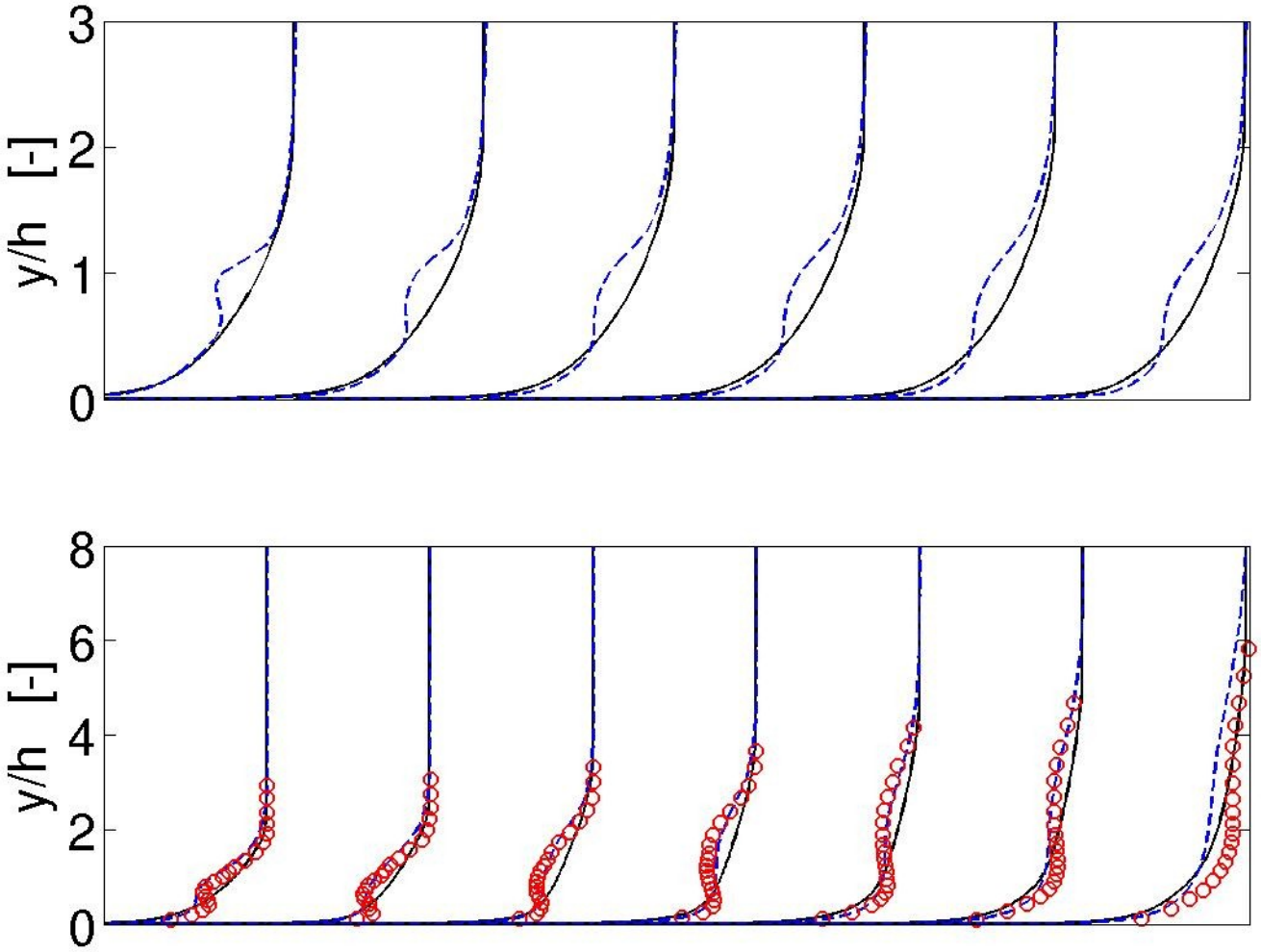
- Olle Törnblom (2006)
  - VGs modelled by lifting-line theory (LLT) and vortex theory
    - ➔ Circulation distribution Γ(y) from LLT
    - ➔ Vortex velocity field $u_\Phi(r)$ from Lamb-Oseen vortex
  - Resulting 2D vortex velocity field (y-z plane) uncorrelated to turbulent fluctuations in forcing region
  - Additional velocity correlations act as Reynolds stresses
  - Spanwise averaging of second order statistics necessary for BL solver input file

Vortex modelling

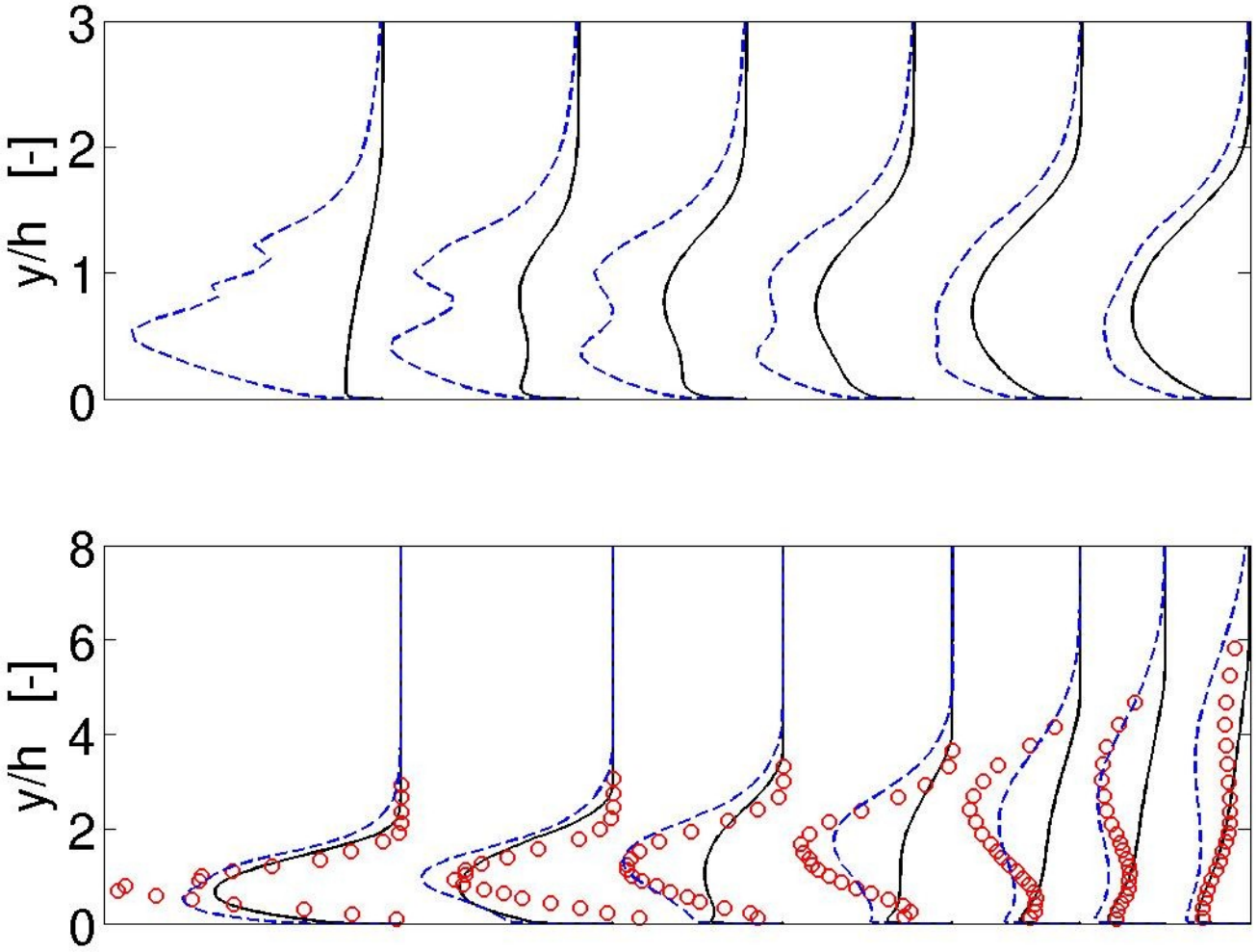
- Total turbulent stresses at VG plane



Results – velocitiy field



Results – turbulent u'v' stresses



Conclusions

- Vortex modelling results provide a first good description of the turbulence and velocities downstream of the VGs
- Reasonable interaction between the different stress components
- 2D vortex model should be expanded
- Vortex structures persist much longer in experiments than in computations
- Computational time is heavily reduced