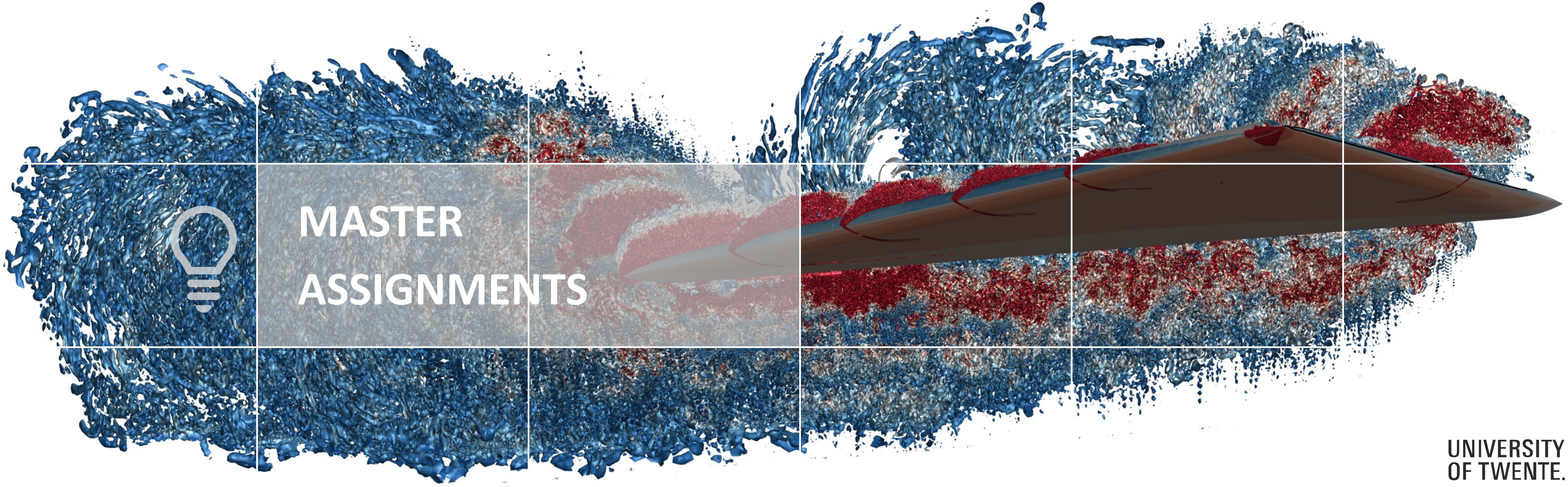
Transition-Transport Modelling:

2) Implementation, Comparison and Validation of Transition-Transport Modells for different CFD codes



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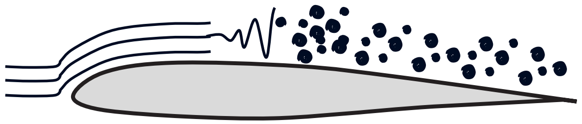
LAMINAR-TURBULENT TRANSITION AND ITS PREDICTION

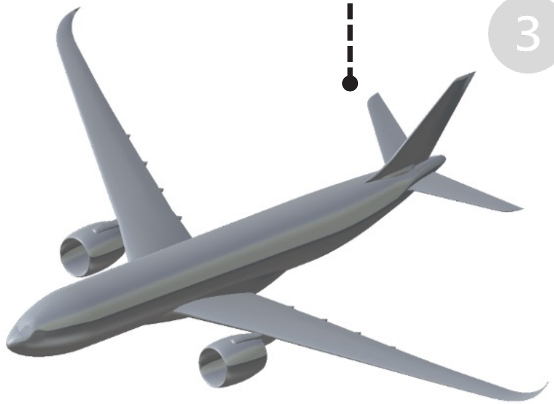


1

The laminar-to-turbulent transition is the process of a **laminar flow becoming turbulent.** Depending on the mechanism this process is caused by instabilities growing exponentially and eventually turning the flow into a chaotic, turbulent state.

2

For many applications in aerodynamics it is essential to consider the laminar-to-turbulent transition and to know in which region this transition is happening. For this purpose, a wide range of methods exists that enable the **prediction** of the transition at different levels of fidelity.



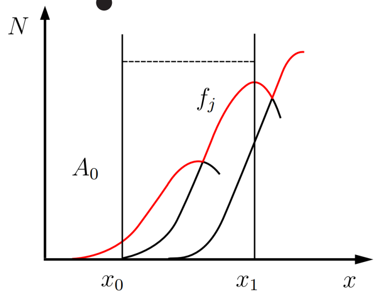
$$\frac{\partial(\rho\phi)}{\partial t} + \nabla\cdot(\rho\,\boldsymbol{u}\phi) = \mathcal{P}_\phi + \nabla\cdot((\mu+\mu_t)\sigma_\phi\,\nabla\phi)$$

3

A class of methods pioneered by Menter and colleagues in the early 2010s are known as local (correlation-based) transition-transport models [1]. They adhere to the principal of being fully compatible with modern computational fluid dynamics software, offering additional advantages such as robustness and user-friendliness. However, a drawback of these methods is that they may sacrifice accuracy in pursuit of these benefits.

4

The first model of this class was carried out by Menter and colleagues leading to the so-called γ−Re_θ model [1]. The model is based on empirical data using the so-called Abu-Ghanam and Shaw transition criterion. Models that are based on linear stability theorey + e^N method have been developed e.g. by Coder et al. [2] and Ströer et al. [3,4].



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ASSINGMENT 2 *Implementation, Comparison and Validation of Transition-Transport Modells for different CFD codes*

Research questions:

How do different Transition Models perform for different CFD codes?

Problem description:

- *If a physical model is implemented in two* ***different Computational Fluid Dynamics (CFD)*** *codes that solve the same sets of equations and use comparable numerical methods, one would anticipate* ***very similar results for identical test cases****.*
- *To achieve this, conducting an intercomparison among different codes is crucial and provides valuable insights for* ***verifying the implementation of models****.*

ASSINGMENT 2 *Implementation, Comparison and Validation of Transition-Transport Modells for different CFD codes*

Research questions:

How do different Transition Models perform for different CFD codes?

- This assignment covers the implementation, intercomparison and validation of different transition models and validation for generic test cases into the flow solvers SU2 and DLR-TAU (cf. slide in the appendix “CFD Software”)

- **Tasks in this assignment:**

  ✓ Comparison of $\gamma - Re_\theta$ [1] implementation in SU2 and TAU for relevant test cases.

  ✓ Implementation of the AFT 2019 model by Coder et al. [6] in SU2 and TAU
  or
  ✓ Implementation of the 1-Equation model by Ströer et al. [5] in SU2 and TAU

  ✓ Comparison and validation of these models for relevant test cases.

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Piqued your interest?

Reach out!

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CFD SOFTWARE

- **SU2**
  - ✓ *Open Source C++ code*
  - ✓ Unstructured Compressible Finite-Volume (FV) Solver
  - ✓ Unstructured Incompressible Density-Based FV solver
  - ✓ First version of DG-FEM solver
  - ✓ RANS and (Hybrid) Scale-Resolving Capabilities
  - ✓ Adjoint Solver

- **DLR TAU**
  - ✓ *Commercial C code (German Aerospace Center)*
  - ✓ Unstructured Compressible Finite-Volume Navier-Stokes Flow Solver (Low Mach-Number Preconditioning)
  - ✓ RANS and (Hybrid) Scale-Resolving Capabilities
  - ✓ Adjoint Solver
  - ✓ "Transition Module", Stability Solver

REFERENCES

[1] Langtry, R. B., and Menter, F. R., "Correlation-based transition modeling for unstructured parallelized computational fluid dynamics codes," AIAA Journal, Vol. 47, No. 12, 2009, pp. 2894-2906.

[2] Coder, J.G., andMaughmer,M.D.,"Computational Fluid Dynamics CompatibleTransition Modeling Usingan Amplification Factor Transport Equation," AIAA Journal, Vol. 52, No. 11, 2014, pp. 2506–2512. doi: 10.2514/1.J052905.

[3] Ströer,P.,Krimmelbein,N.,Krumbein,A.,and Grabe,C.,"Stability-Based Transition Transport Modeling for Unstructured Computational Fluid Dynamics Including Convection Effects", AIAA Journal, Vol. 58, No. 4, 2020, pp. 1506-1517. doi: 10.2514/1.J058762.

[4] Ströer, P., Krimmelbein, N., Krumbein, A., & Grabe, C., "Galilean-invariant stability-based transition transport modeling framework," AIAA Journal, Vol. 60, No. 7, 2022, pp. 4126-4139.

[5] Coder, J. G. "Further development of the amplification factor transport transition model for aerodynamic flows," In: AIAA Scitech 2019 Forum, 2019.