

# Anisotropic Inflow Turbulence

## Investigation of the Influence of Anisotropic Inflow Turbulence on the Prediction of Scale Resolving Turbine Cascade Simulations

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### In Short

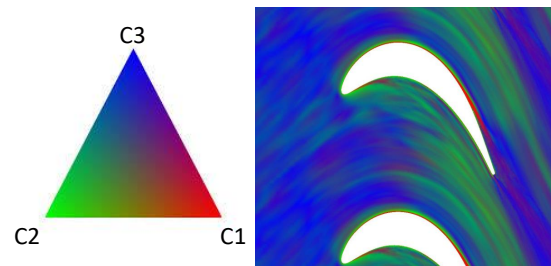
- Large Eddy Simulations (LES) of turbine cascades
- Discontinuous Galerkin method
- Influence of anisotropic turbulence on flow physics

The performance, efficiency, and longevity of turbomachinery components are significantly affected by the turbulent flows they encounter. Turbulence itself is inherently complex, but this complexity is further compounded by anisotropy, which refers to turbulent structures and stress distributions being direction-dependent. This anisotropy has a profound impact on flow physics. Current low-fidelity simulation methods, such as the Reynolds-Averaged Navier-Stokes (RANS) equations, often lack the precision needed to accurately predict turbulence anisotropy, leading to reduced accuracy in simulations of complex flow phenomena [1].

In contrast, high-fidelity simulations, like Large Eddy Simulations (LES), are capable of predicting anisotropic turbulence accurately. However, a typical assumption as an inflow condition for numerical investigations of cascade test cases is isotropic turbulence — where turbulence is uniform in all directions. Although these ideal conditions are straightforward to describe and may represent experimentally conducted cascade test cases [3], real-world turbomachinery operations of multi-stage configurations usually involve highly anisotropic turbulence.

Large eddy simulations of a low-pressure turbine cascade (Fig. 1) show the transition of isotropic inflow turbulence (blue) into a direction-dependent anisotropic turbulence state. In the passage between the blades, a two-component turbulent state develops from the passage entry plane until the passage exit plane (green colored). This anisotropic turbulent state is then further convected. In multi-stage turbomachinery, the outflow condition of one blade row enters the downstream blade row. The direction dependence of the inflowing turbulence is, therefore, important for replicating the flow physics in these configurations.

This research project aims to explore how anisotropic inflow turbulence influences aerodynamic predictions in cascade flows by using LES



**Figure 1:** State of Reynolds stress anisotropy tensor in terms of barycentric weights of principal states in low-pressure turbine cascade

with the discontinuous Galerkin method in the flow solver TRACE [2]. The study will focus on the development and decay of anisotropic turbulence in turbomachinery flows. Turbulence anisotropy in both the core flow between blades and the wake of blades will be examined as representative conditions. Based on these conditions, the research will further investigate how anisotropic turbulence affects overall performance metrics and the specific aerodynamic characteristics of linear blade cascades.

### WWW

<http://www.tfd.uni-hannover.de>

### More Information

- [1] N.F. Afshar, D. Kozulovic, S. Henninger, J. Deutsch, P. Bechlars, *Journal of the Global Power and Propulsion Society* doi: <https://doi.org/10.33737/jgpps/159784>
- [2] <https://www.trace-portal.de/userguide/trace/index.html>
- [3] C. Morsbach, M. Bergmann, A. Tosun, B.F. Klose, E. Kügeler, M. Franke, doi: <https://doi.org/10.1007/s10494-023-00502-6>

### Funding

### DFG Subject Area

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