

DLR-Project CeraFlex: Ceramic hot gas stator for hydrogen and fuel flexible propulsion systems

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This presentation offers a comprehensive overview of a multidisciplinary DLR project, which is characterized by its numerous facets and the employment of diverse methodologies in the development of a disruptive engine. The objective of the DLR Project CeraFlex is to enhance the efficiency of gas turbines by employing innovative materials, novel hybrid designs and advanced manufacturing technologies, whilst concurrently minimizing the environmental impact. The development of a cooled and hybrid 1st HPT-nozzle guide vane incorporates two distinct materials: Silicon carbide (SiC)-based ceramic matrix composites (CMC) and 3D-printable high-temperature metal alloys. In this project, the manufacturing challenges and the degree of difficulty associated with fiber-reinforced ceramics with environmental barrier coatings (EBC) are significantly increased. In addition to material characterization, the application scenario is being further specified as test data are expanded.

To this end, the project team will investigate metal-ceramic bonding technology, the improvement of cooling effectiveness through the use of innovative cooling geometries, including additive manufacturing, and the development of high-resolution large-eddy simulations (LES), including surface roughness and film cooling approaches. The state-of-the-art NG-Turb wind tunnel will be redesigned for the experimental investigation and verification of the CMC and metallic additive manufactured hybrid vanes. Additionally, the HBK1 combustor test rig will be expanded to include an optically accessible secondary zone and the combustor-turbine interface. This will make it possible to investigate the influence of different fuels on combustion chamber outflow conditions and provide inlet boundary conditions for the turbine.

The advantages of alternating stator vanes manufactured from metallic and CMC materials, depending on the combustor outflow temperature profile, are to be demonstrated. Furthermore, multiphysical multiscale models for predicting the service life of the designs are to be developed and validated. The present project aims to investigate the influence of hydrogen combustion and water vapor corrosion on EBC-coated CMCs and additively manufactured metal components, as well as the joining interface. The results of this study will highlight the future potential for new hybrid designs with regard to the use of hydrogen or other alternative fuels (e.g. Sustainable Aviation Fuel, SAF) in the field of aviation propulsion.

Through interdisciplinary cooperation along the process chain, critical questions about the potentials and challenges for CMC applications in turbines and the influence of fuel and design decisions on the combustor-turbine interface will be addressed. The project results include the design and build of new stator vanes for use on the TRL5 test bench NG-Turb, in hybrid design, which are mutually adapted to the manufacturing possibilities of the selected materials and the joining technologies. To this end, numerical simulations with LES, AI methods, multiphysical service life prediction models and coupled strength verifications are used to develop a deeper understanding of materials and manufacturing processes. In addition, the further developed LES methods take into account the special features of additive manufacturing, and the CMC demonstrator stator vanes manufactured at the end of the project.