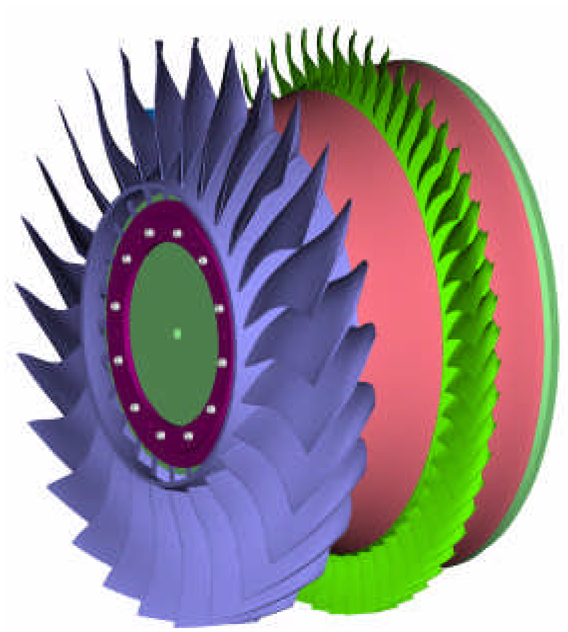
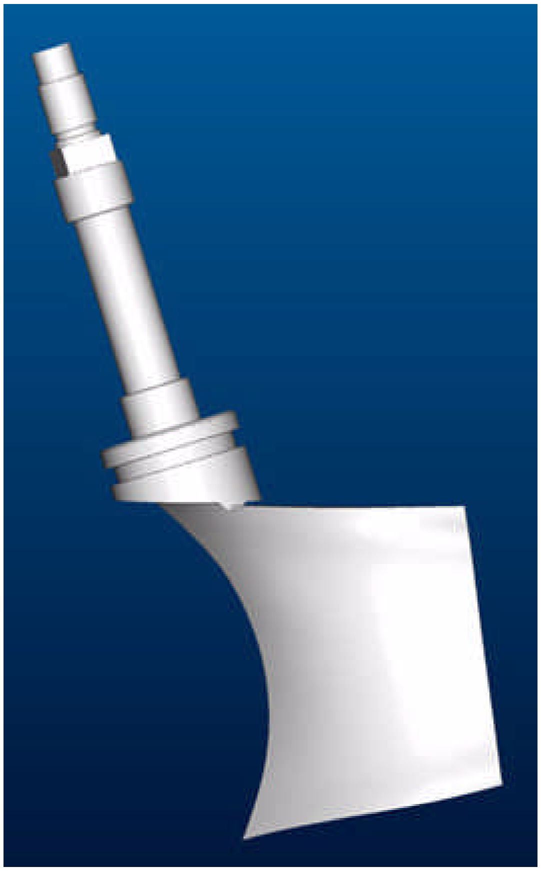
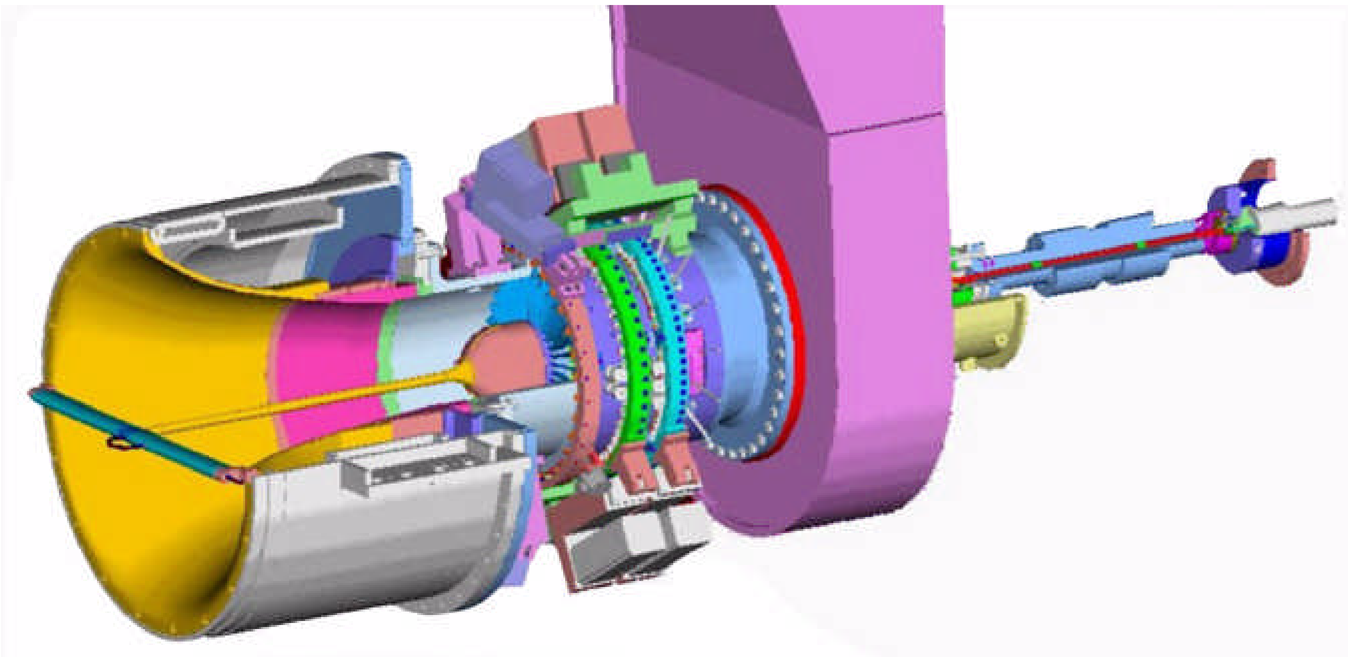
Two-Stage Axial Compressor Rig Designed To Develop and Validate Advanced Aerodynamic Technologies



Solid model of rotor assembly for the two-stage axial compressor rig. The transonic rotor blades are swept forward to achieve a beneficial spanwise loading balance.



Side view of variable stagger stator. The variable stagger is employed to rematch the stages at off-design operation.



Computer-aided design (CAD) drawing of a two-stage rig planned to be manufactured and assembled by end of fiscal year 2003.

Future aeropropulsion gas turbine engines must be affordable in addition to being energy efficient and environmentally benign. Progress in aerodynamic design capability is required not only to maximize the specific thrust of next-generation engines without sacrificing fuel consumption, but also to reduce parts count by increasing the aerodynamic loading of the compression system. To meet future compressor requirements, the NASA Glenn Research Center is investigating advanced aerodynamic design concepts that will lead to more compact, higher efficiency, and wider operability configurations than are currently in operation.

Preliminary aerodynamic design studies of highly loaded multistage axial compressors were conducted in-house to establish the level of technical advancements to be expected if rational enhancements are made to key aerodynamic technology elements of the current design systems. A four-stage research configuration with a compression ratio of 12:1 was conceived to evaluate how much efficiency could be improved at high loading levels by the use of turbomachinery computational fluid dynamics (CFD) and the latest aerodynamic design concepts. The objective was to configure a technology demonstrator compatible with anticipated future multistage core compressors for high-bypass-ratio turbofans. Although a specific application was not defined, the design was constrained by current aeromechanical and manufacturing practices. Three-dimensional blading and spanwise tailoring of vector diagrams guided by CFD were employed in an attempt to manage the aerodynamics of the high-loaded endwal l regions. Multistage CFD simulations of the preliminary four-stage configuration indicated that efficiency was better than the state of the art. To advance the technology significantly beyond this preliminary design baseline, we identified performance-limiting fluid dynamic features, such as leakage-vortex-dominated endwall action and/or reaction and strong shock-boundary-layer interactions.

Further performance gains require design methods that effectively extend the custom-tailored blading philosophy into the endwall regions and allow adequate matching of blade rows in the multistage environment. The first two stages of the four-stage configuration were extracted to serve as a proof-of-concept vehicle. A blade inverse aerodynamic design method developed by Dang (ref. 1) was coupled to the multistage CFD code of Adamczyk (ref. 2) to refine the aerodynamics of the two-stage configuration. An efficiency potential significantly higher than the state of the art was projected on the basis of engineering analysis supported by CFD. Glenn's Engineering Design and Analysis Division has transformed the aerodynamic definition of the two-stage configuration into a mechanical design of a rig to be manufactured and assembled for research and development by the summer of 2003. This rig will serve three main purposes: (1) verification and calibration of design methods, (2) pr ovision of a testbed for new aerodynamic design concepts, and (3) elucidation of the performance-limiting issues in this class of compressor.

Find out more about this research:
Glenn's Compressor Branch http://www.grc.nasa.gov/WWW/5810/
Ultra-Efficient Engine Technology Program
http://www.ueet.nasa.gov/techareas/Turbomachinery.html

References

1. Dang, T.Q.: A Fully Three-Dimensional Inverse Method for Turbomachinery Blading in Transonic Flows. Trans. ASME J. Turbomachinery, vol. 115, no. 2, 1993, pp. 354-361.

2. Adamczyk, John J.: Aerodynamic Analysis of Multistage Turbomachinery Flows in Support of Aerodynamic Design. Trans. ASME J. Turbomachinery, vol. 122, no. 2, 2000, pp. 189-217.

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