

# **Design, optimization, and analysis of highly loaded multi-element compressor blades**

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## **Abstract**

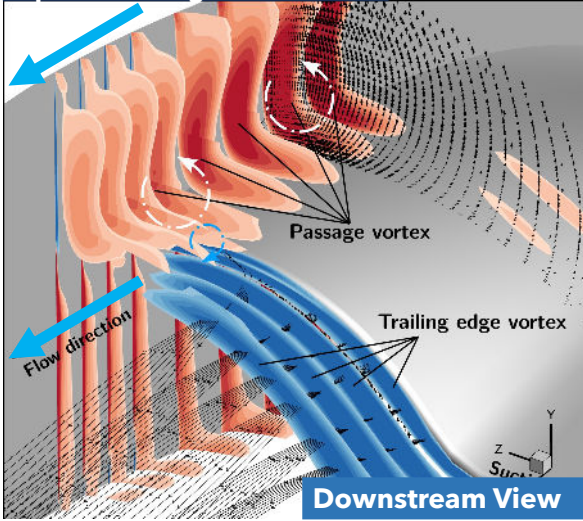
Since the introduction of jet engines, significant efforts have been made to increase the stage pressure ratio of the low-pressure compressor while maintaining high performance. The multi-element tandem blade concept was introduced in the 1960s during the development of supersonic compressors to achieve high flow turning without separation, by re-energizing the boundary layer on a second blade before flow detachment occurs on the first blade. The concept has been experimentally and numerically explored throughout 70 years of research, providing a general idea of the underlying flow mechanisms.

Leveraging state-of-the-art advancements in numerical flow simulation and shape-optimization techniques, this thesis re-examines the tandem blade concept through a gradient-based automated optimization framework and documents each design step leading to experimental validation. The conventional single blade and the tandem blade are optimized and compared in two-dimensional space to assess their benefits for large flow turning applications. Although the tandem blade performs better than the single blade using a novel gap geometry, the latter provides, nonetheless, a 50° flow turning with good performance at the cost of a higher solidity. Subsequent analysis of the flow around the tandem-blade gap highlights the influence of mass flow and flow curvature on the aerodynamic performance of the front and aft blades, offering new insights into the tandem effect. The gradient-based automatic optimization method demonstrated the ability to produce a novel tandem design by circumventing the complexity of the tandem blade design space.

Multi-element concepts, such as three-element and four-element configurations, were designed and optimized to assess whether the tandem effect can be extended over multiple airfoil gaps. Such a configuration was found to be effective for applications with large incidence variations, where the two-element tandem configuration becomes limited.

The optimized tandem airfoil was then prepared for linear cascade experimental tests by optimizing the near-wall region to reduce secondary flow pollution on the midspan flow measurements. The latter was achieved by unloading the profiles near the end wall through increasing the solidity, minimizing the generation of three-dimensional flows in the experimental setup. Due to the complex geometry, the structural performance during wind tunnel operation is assessed, providing design recommendations to prevent structural failure and ensure reliable measurements.

**Optimized Single Blade**



**Optimized Tandem Blade**

