Structural Design and Aerodynamic Validation of Morphing Compressor Blades Concepts

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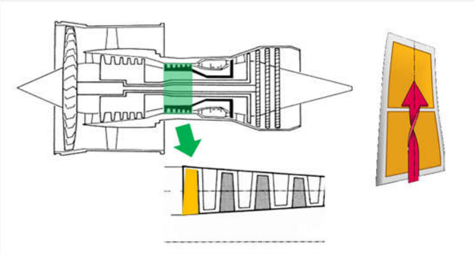
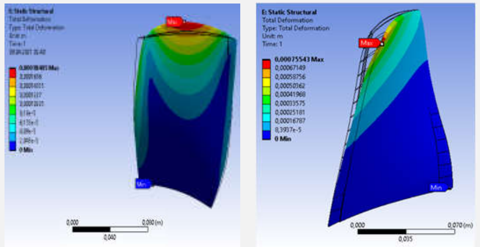
Motivation

In order to make aviation more environmentally friendly and comply to current international environmental goals aiming to reduce polluting emissions, it is necessary to improve aircraft performance. Since today's aircraft are designed by following a single design point development process, one way to improve efficiency is to realize high performance during all or most flight phases. For this, it is necessary to proceed towards a development process that can adapt to different flying conditions and requirements and that can also cover multidisciplinary aspects. Since an engine's performance and therefore the compressor performance is crucial for an aircraft's overall efficiency, it is possible to increase performance by designing compressor blades capable of adapting themselves to different flying conditions, such as cruise and take-off or climbing.



Structural Design Approach

The use of structurally integrated actuators made of piezo-electric materials or shape memory alloys, which are embedded onto compressor blades for modifying their shapes, is being investigated. The goal of this study is to increase the aerodynamic performance of the blade by structurally changing its shape, so that it offers an optimal geometry under diverse flow conditions. By expanding or contracting surface integrated actuators, it is possible to achieve different blade geometries that correspondingly satisfy the necessary design and off-design operating conditions. Possible geometric changes include but are not limited to modifications of camber, spanwise turning and stagger.

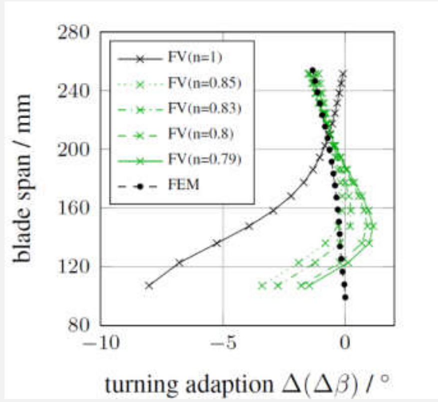


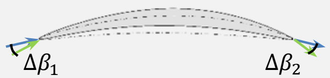
The figure above, left, illustrates an example for the total deformation that can be achieved for a blade with two integrated large surface Macro Fiber Composite (MFC) piezo-actuators, one on the pressure side and one on the suction side, both actuating in the chordwise direction, the one on the pressure side set on compression mode and the one on the suction side on expansion mode and maximizing camber.

The figure on the right shows the effects on twist of two surface integrated MFC piezoactuators, set at 45° and 135° degrees, for compression and expansion at the pressure and suction sides respectively.

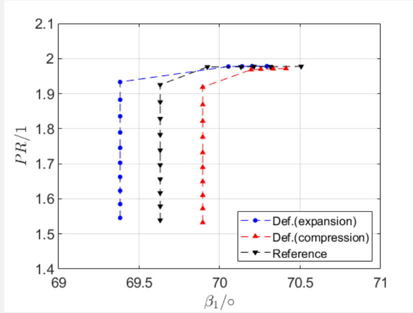
Aerodynamic Analysis & Validation

In order to analyze the effects of shape adaption of the morphing blades, it is necessary to study the aerodynamic sensitivity of the deformed rotor blade geometries. To illustrate this process, this work first presents the results for two piezo-actuated morphing blade cases, the first focusing on an increment in the maximum camber of the blade and the second on a change in the blade's twist angle. The aerodynamic validation for these morphing configurations compares the resulting structurally morphed shapes with the aerodynamic pre-design adaption expectations. The figure below presents the results for the spanwise deformation distribution for the maximum camber configuration.





The results of such comparisond enable the analysis of the aero-structural discrepancies and serve to optimize the blade design. For achieving these results and performing the necessary aero-structural analysis, the morphing blade structure is studied with the help of FEM simulations allowing to calculate the morphed shapes. The adaption results are then transferred to the aerodynamics and further analyzed with the help of stationary 3D RANS CFX simulations, also focusing on the suitability of different turbulence models.



First results show that even small deformations at the blade's tip can lead to a positive influence on the blade's performance under transonic conditions.

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