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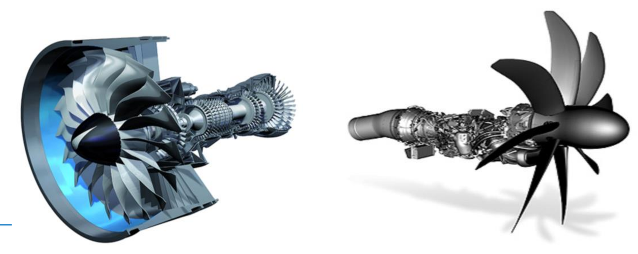


Rotor Tip Desensitisation

Introduction

Tip Leakage Flow is a phenomenon that leads to high instabilities and increases the risk of compressor stall. This project aims to reduce its impact and increase the surge margin. Many ways of achieving this have been investigated in the past, mainly focusing on the casing of the compressor. However, these methods cause a significant reduction of the efficiency. For that reason, the objective of this work is to develop new methods of limiting the sensitivity of the rotor tip while having a decreased impact or no negative impact on the compressor efficiency. Various geometrical modifications will be applied to the rotor tip and casing and tested numerically to investigate their contribution to this secondary flow phenomenon.

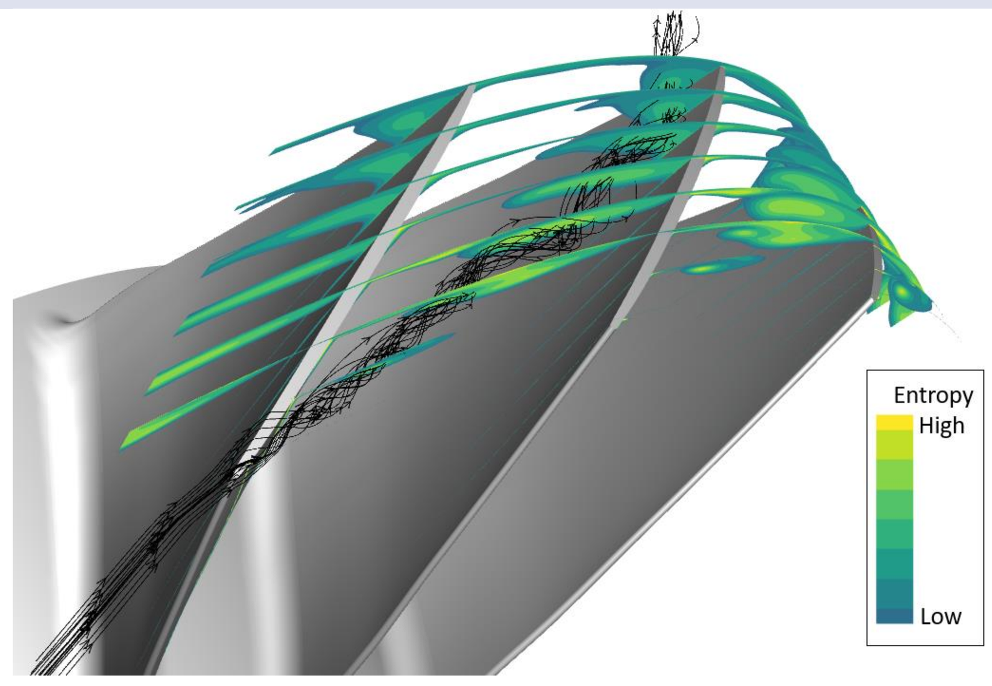
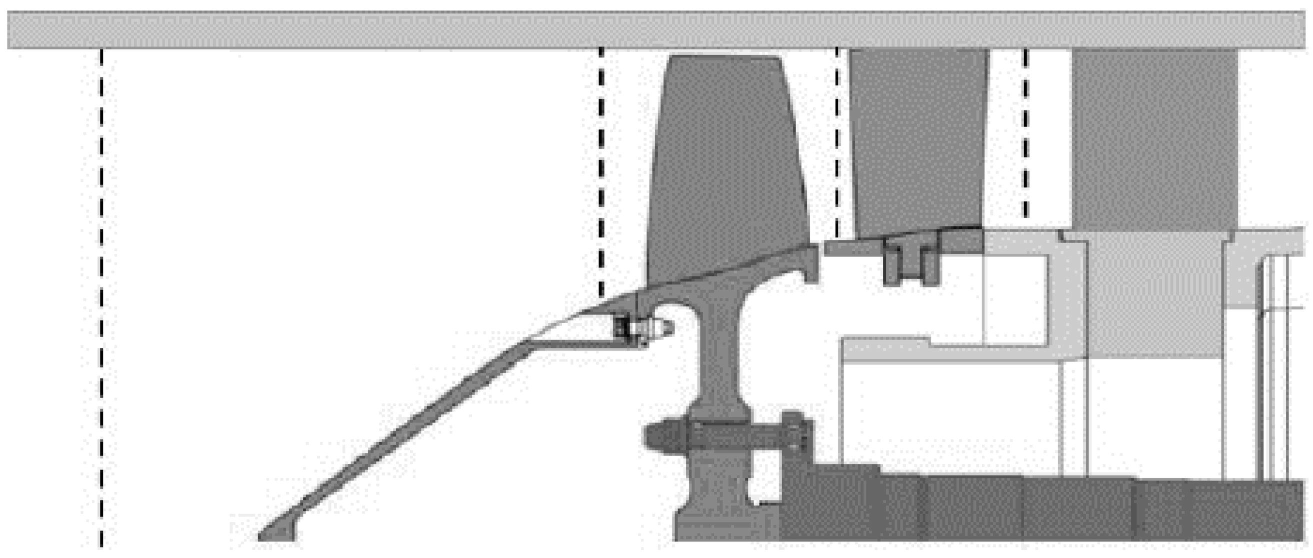


Fig. 1 Tip Leakage Vortex and static entropy in the rotor of the reverse engineered Transonic Compressor Darmstadt

Reference Case

Transonic Compressor Darmstadt

TUDa-GLR-OpenStage is a 1.5-stage axial compressor designed by the Technical University of Darmstadt in collaboration with MTU Aero Engines and the German Aerospace Centre (DLR). This test rig represents the front stage of a high-pressure compressor of a turbofan engine.



Blade Count	Design Speed	Max. Power	Design Mass Flow	Tip Gap
16 (Rotor), 29 (Stator), 5 (OGV)	20000 RPM	800 kW	16.0 kg/s	0.8 mm

Fig. 2 Meridional view and main specifications of TUDa-GLR-OpenStage

Reverse Engineered Compressor

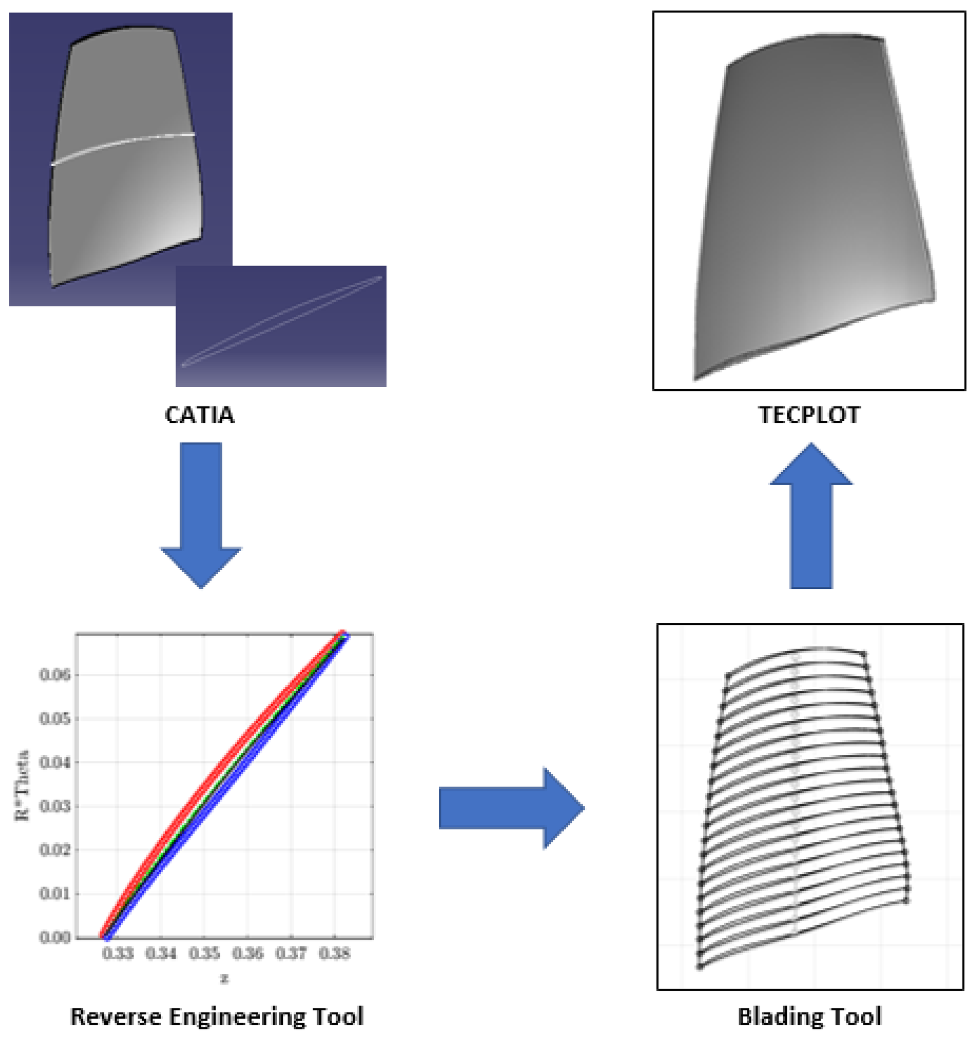


Fig. 3 Blade reverse engineering process

The Institute of Turbomachinery and Flight Propulsion (LTF) has developed a blading tool that offers flexibility in implementing complex modifications on the rotor tip. To that end, the reference compressor was regenerated by extracting blade profiles from the original CAD file and reverse engineering them with another tool, which was also developed at LTF. The reverse engineering tool calculates the main characteristics of an airfoil (chord, angles, etc.) by fitting the camber distribution to the original one. At the end of the process, the blading tool recreates each blade based on the reverse-engineered profiles.

Concepts for Desensitisation

Slotted or Tandem Tip

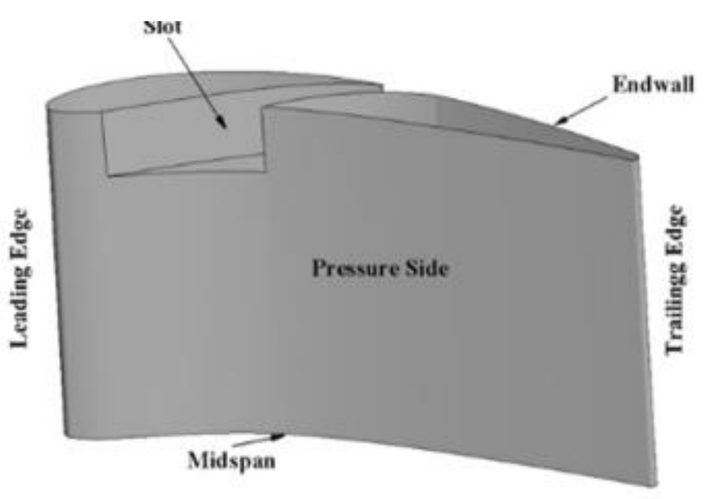


Fig. 4 Slot on blade tip

The addition of a slot on the rotor tip, shaped as a converging channel, could modify the pressure distribution on the pressure side of the blade and, thus, affect the tip leakage flow. The slotted tip could even have the form of a tandem configuration, as the tip leakage vortex would break into two weaker ones. It is worth examining the interaction between them and their impact on losses and efficiency.

Vortex Generators

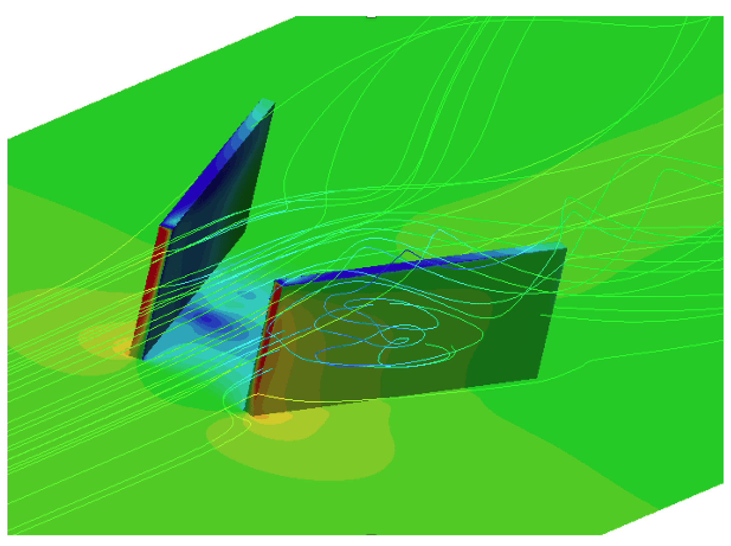


Fig. 5 The impact of vortex generators on flow behaviour

Vortex generators are passive flow control methods that energise the boundary layer and increase its momentum by creating vortices. In that way, the boundary layer becomes less prone to separation. The application of vortex generators on the casing in front of the rotor could weaken the boundary layer's interaction with the tip leakage flow and reduce blockage.

Pressure Side Tubercles

The application of tubercles has been investigated in various fields of aerodynamics over the last decades. The most common position, where they are usually implemented, is the leading edge, resulting in several advantages. However, placing tubercles on the pressure side of the blade tip could also be beneficial. Each tubercle generates a pair of counter-rotating vortices, which could alter the pressure distribution on the pressure side of the rotor tip and compartmentalise the tip leakage flow to smaller sections. Investigating the interaction of a leakage flow of this form with the incoming boundary layer may lead to interesting results.

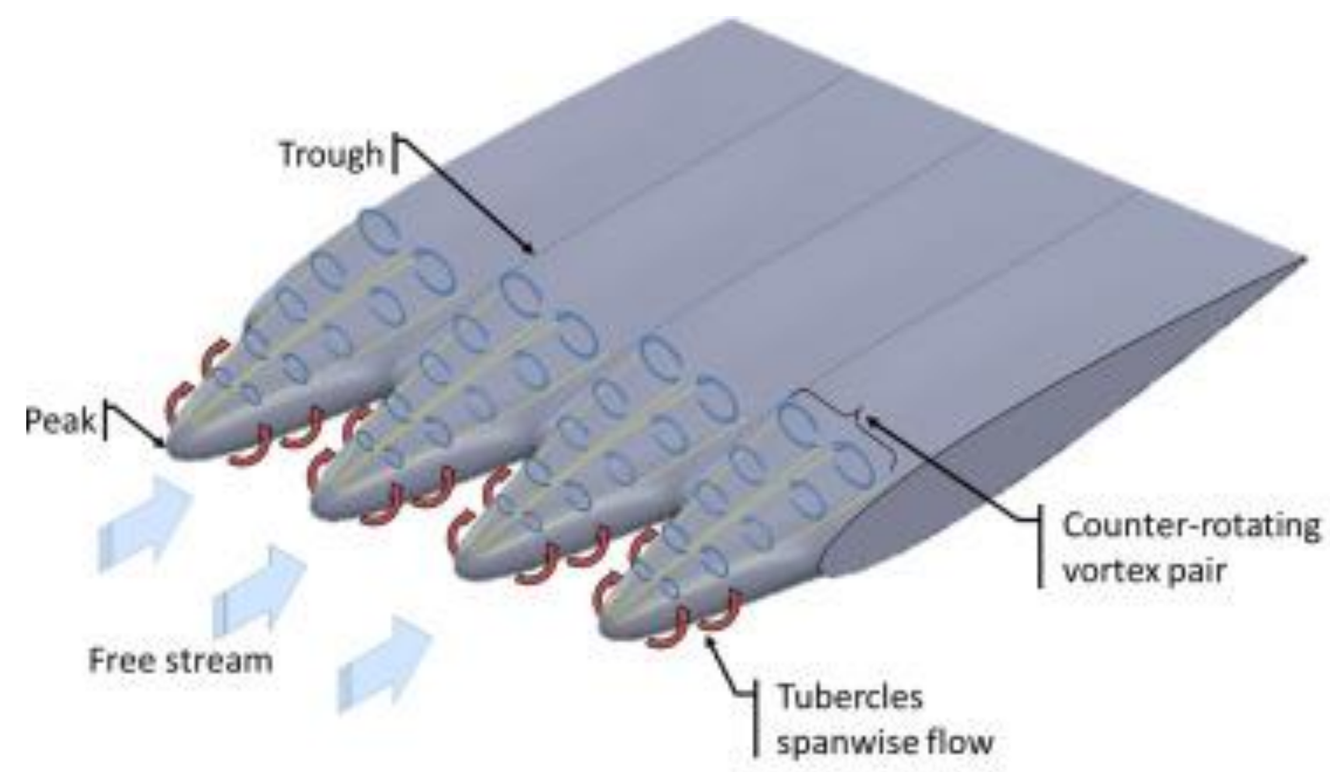


Fig. 6 Generation of counter-rotating vortices by tubercles

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