Effect of Twisted Vanes on Leakage Losses in Variable Geometry Radial Turbines.

Ariane Emmanuelli, Xavier Carbonneau, Yannick Bousquet, Nicolas Binder
Department of Aerodynamics, Energetics and Propulsion, University of Toulouse, ISAE, Toulouse, France

Long Abstract

Introduction

Radial turbines are primarily found in turbocharger applications, but are also used for aircraft cooling systems or auxiliary power units. A variable geometry nozzle is used to extend the operating range of the stage, while maintaining an acceptable peak efficiency. However, this necessarily leads to additional losses due to stator leakage flows.

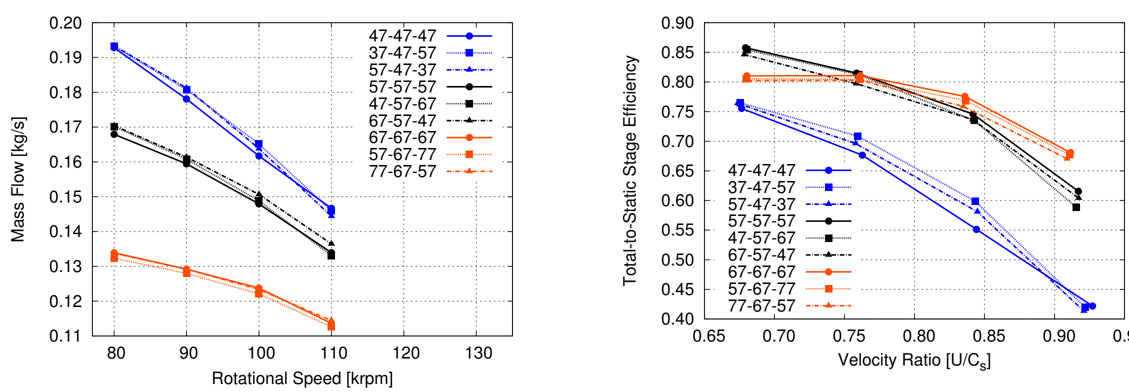
Blade loading affects leakage vortex intensity, which twisted nozzle vanes should reduce as they locally modify the incidence. The aim of the present study is to identify and understand the mechanisms related to these twisted geometries in order to comprehend their capacity to improve performance, especially regarding leakage losses. Preliminary investigations are presented, followed by the methods used in this study and its results.

1. Background

The effect of stator vane clearance was examined in several researches, such as reference [1]. The current study further investigates this flow, notably by determining the effect of stator blade loading.

Moreover, the performance of different nozzle geometries remains identical at equal stator reduced sections [2]. Taking this into account, a preliminary article established symmetrical twisting of a nozzle with no clearance didn't deteriorate the performance of the stage [3].

The global performance of different configurations with nozzle clearance was calculated using steady RANS simulations, for a first assessment of the effect of nozzle clearance and twist. The mass flow and total-to-static efficiency of straight and twisted configurations with nozzle clearance are exposed in figure 1.



(a) Mass flow **(b)** Total-to-static efficiency

Figure 1. Performance of geometries with nozzle clearance.
Ref. case, 47_57_67 : 47° from radial direction at hub, 57° mid-span and 67° at shroud.

2. Methods

In this study, twist was applied symmetrically along the nozzle blades, with $\pm 10°$ at the hub and shroud and the average stagger angle mid-span. Configurations with three different average stagger angles were examined, so that most of the range normally covered by this nozzle was investigated. Cases with and without nozzle clearance were studied for four rotational speeds.

The phenomena associated with nozzle clearance were analyzed in a first instance, followed by those induced by twist. The flow was studied both in the stator and the rotor. To this end, unsteady phase-lagged and harmonic nonlinear [4] methods were used for the most pertinent cases, which were identified using the database of stationary simulations introduced in the previous section. The global performance resulting from these different numerical methods coincided. Line integral convolutions of the skin friction were used to analyze the flow, as well as contours and averaged quantities in key positions.

3. Results

The open configurations, presented in blue in figure 1, displayed the best results with up to five points increase in total-to-static efficiency with twisted blades, and were investigated in particular detail. The effect of nozzle clearance and twist was described using parameters such as nozzle loading, clearance vortex intensity and detachment position (Figure 2) or incidence at rotor inlet. These were compared with the performance of the configuration in order to determine the impact of twist. A twisted nozzle's potential to reduce leakage losses was characterized, both regarding its effect at different stagger angles and rotational speeds, and its greater effectiveness at the hub or shroud.

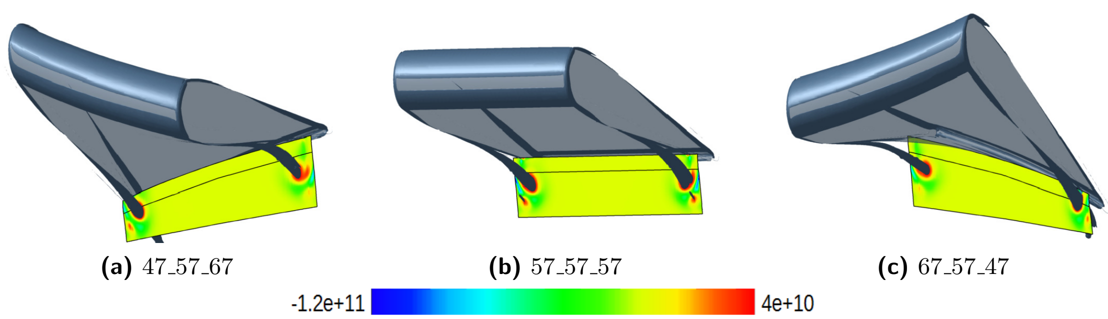


Figure 2. Visualisation of clearance vortices - isosurface at 5.10^{10} and contour of the Q criterion for configurations based on the nominal case.
Ref. case, 47_57_67 : 47° from radial direction at hub, 57° mid-span and 67° at shroud.

References

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