About Subsonic Compressor Tandem Aerodynamics - A Fundamental Study

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Long Abstract

Introduction

The arrangement of airfoils in a tandem configuration is well known for increasing the deflection and static pressure ratio in an axial compressor stage. Furthermore an extension of the design space for compressors due to the stage matching can be achieved. In this context, different approaches can be found in the literature how to arrange the blades. In the work of Weber and Steinert [1] the development and experimental investigation of a transonic tandem cascade with a deflection of 60 deg. is presented. This cascade concept is characterized by a blade ratio of 1:2, without axial overlap of the blades. The study of Hoeger and Müller et al. [2, 3], about a transonic tandem cascade shows that with a tandem configuration of 19 percent chordwise blade overlap a 10 percent increase of turning and a loss reduction by 30 percent was achieved, compared to a wide chord single blade. Additionally, Hertel et al. [4] investigated the loading limit of a subsonic cascade tandem and found a dependency between the incidence angle and the loading distribution of the blades. An increase of the incidence angle leads to an increase in loading of the first blade and a decrease of the incidence angle leads to higher loading of the second blade. A more detailed 3D design of a tandem cascade seems to be necessary to achieve further improvements. In the study of McGlumphy et al. [5] a tandem blade arrangement for a rotor application was numerically investigated. It is shown that such a configuration could enable more work loading on the rotor and should replace three conventional rotors. It becomes apparent, that the design of a tandem cascade is specific and depends on the application and the used design philosophy. In this context, the question is: It is possible to define fundamental design recommendations for the arrangement of a compressor tandem cascade. Hence, the current study is focused on the development of such recommendations for a subsonic compressor tandem cascade.

1. Approach

Nowadays, the modern compressor design is based on advanced CFD and optimization methods. Hence, in this study the following approach is used. In the first step an application of a subsonic tandem cascade is defined. An optimization is carried out in order to create a database of more than 1900 subsonic tandem configurations. Within this process, the parametrization of the tandem arrangement take the fundamental aerodynamic effects into account and in addition to that, the use of an optimization process provides not only the possibility to find an optimal configuration for a single application but also offers the chance to understand the aerodynamic behavior by a detailed evaluation of the database generated. Therefore second step includes the detailed analysis of the optimization database and the development of design recommendations. The database enables the

assessment of defined geometry parameters due to their direct link to the aerodynamic and performance parameter of each cascade configuration.

2. Setup

An inlet Mach number of 0.5 is used as boundary condition for the optimization. Furthermore three operating points are defined in order to ensure a maximum working range of 15 deg. The optimization process was conducted using the optimization tool “AutoOpti” which has been developed at the DLR Institute of Propulsion Technology. The optimizer is based on an asynchronous multi-objective genetic algorithm. The numerical simulations are carried out with DLR’s 3D-RANS flow solver TRACE, using a k-w turbulence model. 41 optimization parameters are used in the optimization. For each blade 17 parameters define the blade shape. Figure 1 shows the definition of the blade as well as cascade parameters.

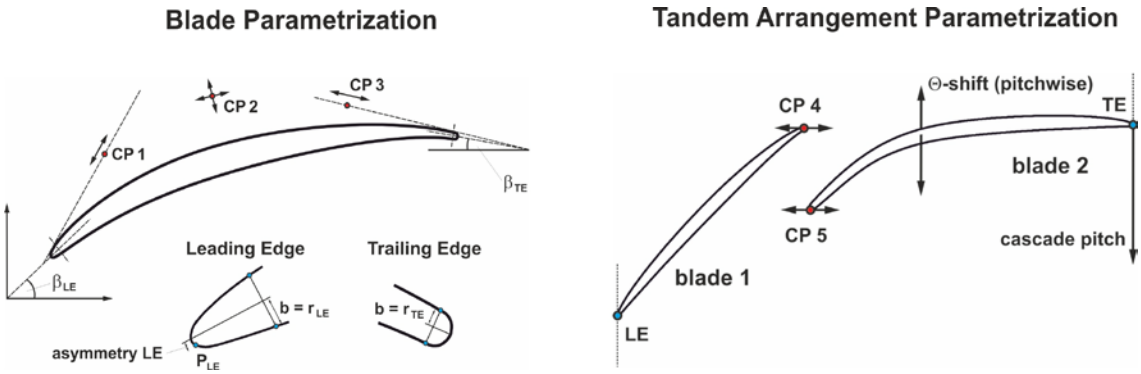

Figure 1. Cascade Parametrization

Furthermore, three objective functions are used, which are focused on the minimization of the losses at the three operating points and the enhancement of the cascade performance in terms of pressure rise

3. Results

Three design recommendations are stated in the study. The chord length of blade 1 should be 30 % longer than the chord length of the second blade in order to achieve an optimal load balancing between the blades. The axial overlapping of the tandem blades should only be within the range of 1 up to 2 % axial chord. The variation of the pitchwise position of the second blade can be used to adjust the nozzle flow between the both blades. The pitchwise distance between the blades should be 15 % of pitch.

References

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