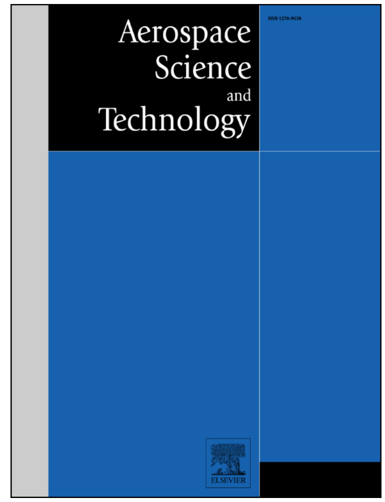


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# Improvement of Aerodynamic Performance of a Low Speed Axial Compressor Rotor Blade Row through Air Injection

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**Abstract**

This paper reveals that air injection at tip region of an axial compressor rotor blade row is an effective technique for enhancing its aerodynamic performance. Method of investigation is based on solution of the Navier-Stokes equations exploiting shear stress transport (SST) $k$-$\omega$ turbulence model. This model attempts to predict the turbulence by two partial differential equations for two variables of turbulence kinetic energy ($k$) and specific rate of dissipation ($\omega$). Initially, computational performance curves of the proposed rotor blade row for no-injection case are compared with available experimental data, which show reasonable agreement. Then, effects of air tip injection on flow field and general aerodynamic performance of the rotor blade row are studied in detail. Results are presented in terms of the blade row span-wise distributions of total pressure rise coefficient and diffusion factor for no-injection and injection cases. Flow patterns at the blade row tip region are also carefully demonstrated. Six pseudo static pressure taps were mounted along the blade chord line within the blade tip gap region for detection of the flow fluctuations. So, it was possible to extract frequency spectrum of the fluctuating flow in this region. Numerical simulations confirmed that injection of air flow at the blade row tip region boosts the flow momentum and reduces blockages due to the flow separation from the blades surfaces. Results showed that air injection as small as of only 0.5% of the whole annulus mass flow rate causes the stall margin of the rotor blade row to increase by 15.5%.

**Keywords:** Axial compressor, Flow unsteadiness, Blade tip injection, Blade tip leakage flow

## 1. Introduction

Axial compressors are exposed to adverse pressure gradients within their air passages which may lead to flow separation and amplification of instabilities. These flow instabilities may appear in the form of rotating stall or surge. Under some circumstances, a few stages of a compressor may be allowed to work under rotating stall conditions, even though going along with reduction in its efficiency. However, surge must be completely avoided; because it is usually irreversible and may be accompanied by considerable mechanical destructive effects. Stall inception mechanism is itself investigated by many researchers either experimentally or numerically (see for example [1-5]).

Design point of a compressor is set at a specified rotational speed and pressure ratio, where the efficiency is a maximum. Compressor designers are always interested in employing techniques to maximize the pressure ratio. On the other hand, the maximum pressure occurs to a certain extent, close to the stall point. Under some circumstances, for example downstream throttling or inlet distortions, stall phenomenon may occur in some blades passages. Consequently, the compressor efficiency reduces and its performance point gets closer to the surge line. Obviously, seeking techniques for avoidance or alleviation of the stall and surge phenomena would be essential and vital.

Commencement of instabilities, their growth and propagation are processes which may occur after several blade row rotations. So far, several methods are presented either to avoid formation or to alleviate the rotating stall. All these methods, either of passive or active types, try in introducing strategies which can expand the stable operating range of the compressor. Casing treatment, as a passive method, is the most widespread technique in alleviation of the flow unsteadiness. Up to now, various configurations are presented for casing treatment, among which, can be referred to circumferential grooved [6-9] and slotted types [10, 11].

General primary idea of the active control method was introduced by Epstein et al. in 1989 [12]. Nearly one decade later, discrete air injection method was brought into instability control perception [13, 14]. Suder et al. have studied effectiveness of the air jet injection on the performance of a transonic compressor in both the steady and unsteady

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