Passive Flow Separation Control in Linear Compressor Cascade

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Abstract*— Losses reduction is one of the main targets in modern compressors. In this article, the passive separation-controlled technique has been used to reduce the losses through six NACA 65-009 linear compressor cascade blades. Among passive techniques, the arced diverge -converge slot passes were grooved from the blade pressure side (P-S) to its suction side (S-S). Here, the slot height in the span-wise direction was selected to be 0.08 of the blade heights from End- wall side. The current work was performed experimentally and numerically at inlet flow conditions of Reynolds number $R_{ec} = 2.98 \times 10^5$ and incidence angle $i = 4^{\circ}$. The experimental work was done to get the inlet velocity profile needed to initiate the solution of the numerical work. The five-hole probe was used to measure the flow parameters in the experimental part. The accuracy and the mesh independent were tested for numerical work. There was good agreement in results about velocity profiles and total pressure in the blade downstream between experimental and numerical solutions, even the numerical using K-ω-SST turbulence model provided higher values of total pressure losses. It was concluded that the use of a slotted blade able to reduce the total pressure losses coefficient by 40.5%, increasing the flow turning angle by 20.3% and increase the static pressure coefficient by 8.7 % near the end-wall.

Keywords*— *Passive flow control, Compressor cascade, Flow separation, K-ω-SST turbulence model

I. INTRODUCTION

The design of modern compressors in gas turbine engines aims to be at greater efficiency and smaller weight. The challenge is how to increase the compressor pressure ratio with lower stage number so increasing blade loading. The problem is that at increasing flow turning angle there more adverse pressure gradient occurs and more corner separation occurs at blade suction side and near the end- wall. The boundary layer separation has an adverse pressure gradient and low velocity or low momentum flow, so the reversed flow occurs; flow separation. The separated flow in compressors leads to blockage, instability as surge and stall, and energy losses. Correspondingly there is a reduction in efficiency and performance of compressor [1]–[4]. The sources of these aerodynamics loses in compressor cascade can be summarized as (i) profile losses which occur due to the blade wall shear stress and the wake formation after trailing edge, and (ii) secondary flow which occurs due to the leading edge horseshoe vortex, end-wall cross flow, passage vortex, End-wall boundary layer separation, tip vortex, corner vortex [4]. Corner separation is the interference of the end wall separation and the suction side separation and 3-D separation which has a different structure than 2-D separation [5]. Many research efforts have been carried out to control the flow separation targeted to reduce these losses and/or improve compressor aerodynamic performance. Flow separation control techniques re-energize the low momentum zone by increasing the flow velocity in this zone and suppress/delay the occurrence of flow separation.

From deep research, the flow separation reduction can be performed by active and passive methods [6]–[15], as collected in Fig. 1. Active Flow Control method (AFC) can add energy to fluid from external source, while Passive Flow Control method (PFC) add energy to fluid from itself without using external energy source. The PFC techniques are popular than AFC one because of its simplicity of design at a cheap cost [16]. Moreover, the PFC methods would be recommended in the rotor rather than in stator as it is easy to implement with low cost

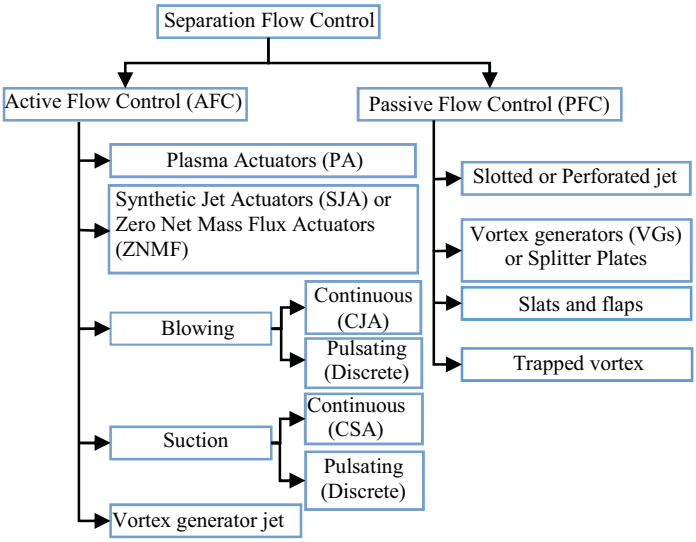

Fig. 1. Flow separation control techniques

One of the promising PFC methods recently received great attention is the use of slight slots at the roots of end-walls. In this technique, air from the pressure side is allowed to flow to the low-pressure side just before the separation zone to

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