Experimental Investigation of Flow Control Using Blade End Slots in a highly loaded Compressor cascade

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Long Abstract

Introduction

Three-dimensional (3D) corner separation is identified as an inherent flow feature formed by the blade suction surface and endwall in axial compressors [1]. The 3D corner separation has large impact on compressor performance, such as passage blockage, limiting on blade loading and static pressure rise, considerable total pressure loss, efficiency reduction and eventually stall or surge especially for highly loaded compressor [2]. Hence, the 3D corner separation should be effectively controlled.

Over the last several decades, many efforts have been made and various flow control methods have been used to control the 3D corner separation [3–10]. Some active control methods, such as boundary Layer suction [3], plasma actuator [4], synthetic and continuous jets [5] and vortex-generator jets [6], show effectiveness. However, passive control methods remain preferable because of their simplicity and cost effectiveness. Some passive control methods, such as blade center slots [7], groove on the sidewalls [8], and vortex generator [9] were studied and show some effectiveness. Recently, Liu et al. [10] numerically studied the effect of blade end slots in a low-speed PVD compressor cascade and the cascade performance can be significantly improved by the slot.

In this paper, the purpose is to evaluate the effectiveness of blade end slots to control 3D corner separation in a high-speed highly loaded compressor cascade. Based on our previous study and numerical optimization, blade end slots are designed for the cascade. Then flow fields are experimentally investigated for both cascades with and without slots. The comparisons show that the blade end slots can effectively suppress the 3D corner separation and significantly improve the performance in the high-speed highly loaded cascade.

1. Methods

The experimental investigation is carried out in a high-speed linear compressor cascade tunnel at Dalian Maritime University in China. The cascade tunnel is a consecutive with air drivering by a high-pressure radial compressor. The driven air is supplied to the test section after cooling and via inflowing values, a silencer, a diffusor, a settling chamber and a nozzle by steps.

The investigated cascades with and without slots consist of 8 blades. The inlet mental angle is 41.91˚ and the stagger angle is 21.70˚. The camber angle is up to 52.94˚. The aspect ratio is 1.82 and the solidity is 1.52 with a chord length of *c*=55mm. The design diffusion factor is 0.52. The inlet mach number is 0.59 and the Reynolds number is up to 0.72×10^6 based on inlet velocity and balde chord. Based on our previous study and numerical optimization, blade end slots are designed for the cascade, as shown in Fig.1.

In the experiment, a three-hole probe is emplaced upstream to monitor the incoming flow Mach number and real flow angle. Measurements are made by a five-hole pressure probe reticulated with 21 points pitchwise and 16 points spanwise in the measured plane at 60% chord length behind the trailing edge. The experiments for both the datum cascade and the slotted cascade are conducted under various of incoming flow conditions. The good states of periodicity of the cascade are validated by the outlet total pressure losses.

2. Results

Based on the five-hole pressure probe measurements, total pressure loss, static pressure rise and velocity vectors at 60% plane chord length behind the trailing edge, can be compared for the cascade with and without slots. Figure 2 shows the total pressure loss contours at the 60% plane under incidence 0˚. It can be seen that the high total pressure loss region is reduced by the slot. This indicates the 3D corner separation is suppressed by the slot. Similar obvious improvement can be found under other incidences from -1.69˚ to 7˚. Furthermore, the static pressure rise can be increased and deviation angle can be reduced under these incidences.

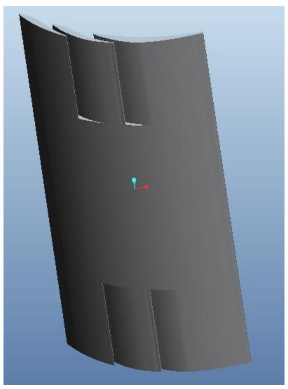
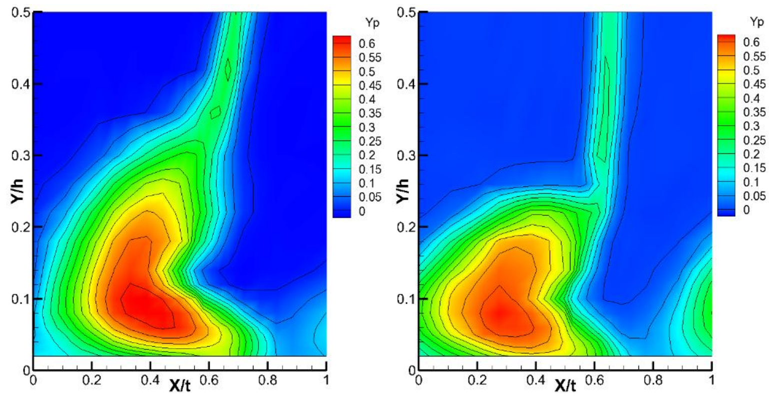


Figure 1. Slot geometry



(a) without slot (b)with slot

Figure 2. Total Pressure Loss Contours at 60%

The mass-weighted averaged total pressure loss of the measured plane is calculated and compared for cascade with and without slots under different incidence angles. From the comparison of the total pressure loss versus incidence angle (not shown here due to page limits), it can be seen that obvious loss reduction by blade end slots over the incidence -1.69˚ and the loss keeps very low under incidences from -1.69˚ to 4˚. Under incidences -6˚ and -8˚, the total pressure loss is just slightly larger with slots than without slots. In a word, the control method using blade end slots can effectively suppress the 3D corner separation and improve the cascade performance. It can significantly extend the operating range of the compressor.

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