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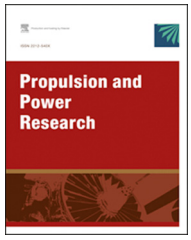

ORIGINAL ARTICLE

Stability management of high speed axial flow compressor stage through axial extensions of bend skewed casing treatment

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Abrupt

Abstract This paper presents the experimental results to understand the performance of moderately loaded high speed single stage transonic axial flow compressor subjected to various configurations of axial extensions of bend skewed casing treatment with moderate porosity. The bend skewed casing treatment of 33% porosity was coupled with rectangular plenum chamber of depth equal to the slots depth. The five axial extensions of 20%, 40%, 60%, 80% and 100% were used for the experimental evaluations of compressor performance. The main objective was to identify the optimum extension of the casing treatment with reference to rotor leading edge which results in maximum stall margin improvements with minimum loss in the stage efficiency. At each axial extension the compressor performance is distinctive. The improvement in the stall margin was very significant at some axial extensions with 4%–5% penalty in the stage efficiency. The compressors stage shows recovery in terms of efficiency at lower axial extensions of 20% and 40% with increase in the peak stage efficiency. Measurements of flow parameters showed the typical behaviors at near stall flow conditions. Hot wire sensor was placed at the rotor upstream in the tip region to capture the oscillations in the inlet axial and tangential velocities at stall conditions. In the absence of casing treatment the compressor exhibit abrupt stall with very high oscillations in the

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inlet axial and tangential velocity of the flow. The extents of oscillations reduce with bend skewed casing treatment. Few measurements were also performed in the plenum chamber and salient results are presented in this paper.

1. Introduction

High speed axial flow compressors are integral parts of aero-engines because of their ability to produce relatively higher pressure ratio per stage with reasonably good efficiency. The main drawback of these machines are relatively lower operating range because of the instabilities like rotating stall and surge in the absence of control tools. These instabilities are normally triggered at off-design conditions and will be catastrophic in nature if they are not controlled and allow growing. Bend skewed casing treatment with 33% porosity coupled with plenum chamber is designed and used for evaluating the performance of single stage axial flow compressor with stage total pressure ratio of 1.36 at 12,930 rpm, corrected speed was used for the experimental analysis. Casing treatments is the powerful old techniques used for controlling the instabilities in tip strong rotors. Researcher across the globe [1–24], designed several types of casing treatment ranging from simple honeycomb, circumferential grooved, axial grooved and recently bends skewed casing treatments to improve the stall margin of the compressor. However, the criterion for the selection of casing treatments for the tip critical rotors was proposed given by Greitzer et al. [1]. Venzel and Moss [2] studied the effect of circumferential grooved and slotted casing treatment on the performance of multistage compressors. They found the stall pressure ratio was slightly lower than the baseline and the overall compressor efficiency with the grooved casing was not appreciably differs from the baseline, but it was 1 to 2 points lower with the slotted casing. In case of radial tip distortion stall pressure ratio was slightly improves with both the casing treatments. The casing treatment used was not effective in extending the stall margin of the compressor. Donald Urasek [3] studied the effect of circumferential grooved casing treatment on the performance of two stage high pressure ratio fan and found stall margin improvement without affecting the efficiency. Slotted casing was more effective in enhancing the stall margin of the compressor at the cost of efficiency penalty which is confirmed by Guruprasad [5] through experimental results. He also confirmed that higher stall margin gains with minimum efficiency penalty can be achieved by optimizing various geometric parameters of casing treatments. Parametric studies on the axial slot casing treatment was carried out by many researcher [6–12] to understand its potential benefits numerically and experimentally on low speed as well as high speed compressors. Almost everyone confirm the benefits of this type of casing treatment but at the cost of degradation in the efficiency. Axial skewed slotted casing treatment was then modified to give birth to another very interesting casing treatment called bend skewed casing treatment by Junqiang Zhu et al. [12–16]. This type of casing treatment has a combinations of axial as well as bend slots. Experimental and numerical results of an isolated rotor showed considerable improvement in the stall margin without efficiency penalty. The axial skewed casing treatment improves the stall margin by 27.66% and degrades the compressor efficiency by 3% whereas the bend skewed groove achieves 18.09% improvement with negligible loss in the compressor efficiency at lower axial extensions. The bend skewed casing treatment weakens the circulation in the tip region because of the rear skewed slot. Gourdain et al. [17], Schnell et al. [18,19], Voges et al. [20] studied bend skewed casing treatment numerically and experimentally and confirm the positive benefit of this type of casing treatment in enhancing the stall margin by periodical injection of energized fluid out of the casing slots and stabilizing the tip clearance vortex.

From the above literatures it is clear that the bend skewed casing treatment has a potential to improve the stall margin with minimum penalty on the efficiency. However, the research does not give the substantial understanding of behavior of this type of casing treatment with plenum chamber in the high speed compressor stage environment. Experimental data presented by Junqiang Zhu et al. [12–16] is on subsonic compressor with the isolated rotor environment, in which effect of presence of stator will not be highlighted. The rotor stator gap also plays significant role with casing treatment retrofitted above the rotor as reported by Gourdain et al. [17]. Also, the casing treatment geometry used by Junqiang Zhu is having higher porosity of 67%. There is a gap in the research to understand the behavior of lower porosity bend skewed casing treatment in the transonic environment which is very close to the real engine applications. This fact motivated us to take the rigorous experimental research on the lower porosity bend skewed casing treatment and understand the compressor stage performance with different geometrical parameters. Dilipkumar Alone et al. [21–24], generated exhaustive experimental data to understand off-design unsteady behavior of the transonic compressor stage and also evaluated an impact of various geometrical parameters of bend skewed casing treatments like porosity, axial locations, and an un-explored parameter