Accepted Manuscript

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PII: S1270-9638(17)30971-9
DOI: http://dx.doi.org/10.1016/j.ast.2017.05.036
Reference: AESCTE 4049

To appear in: *Aerospace Science and Technology*

Received date: 29 March 2016
Revised date: 4 May 2017
Accepted date: 26 May 2017

Please cite this article in press as: T. Pan et al., Effects of axisymmetric arc-shaped slot casing treatment on partial surge initiated instability in a transonic axial flow compressor, *Aerosp. Sci. Technol.* (2017), http://dx.doi.org/10.1016/j.ast.2017.05.036

Draft

Effects of axisymmetric arc-shaped slot casing treatment on partial surge initiated instability in a transonic axial flow compressor

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Academic Editor:
Received: date; Accepted: date; Published: date

Abstract: Instability initiated by rotating stall and surge limits the normal operating range of compressors, and seriously deteriorates the efficiency of gas-turbines. Partial surge is a new type of instability inception observed in a transonic axial flow compressor; it occurs in the form of axisymmetric low-frequency disturbances localized in the hub region and finally grows into rotating stall. For energy saving purposes, it is necessary to enhance the operating margin or stall margin of compressors. In this paper, a new design of casing treatment (axisymmetric arc-shaped slot casing treatment) is investigated to enhance the stall margin of a transonic compressor whose instability is initiated by partial surge. Both compressor performance and instability evolution before and after treatment are analyzed. The stall margin is successfully enhanced by 19.88% with the casing treatment, but the total pressure ratio only drops by 0.3% and the adiabatic efficiency does not quite change (increases by 0.15%), compared with the original solid wall case. The results of instability evolution present that partial surge occurs at nearly the same mass flow rate as the stall point of the solid wall case. As the compressor is further throttled, partial surge disappears. Then, rotating stall cells suddenly appear and trigger the formation of partial surge. In the presence of rotating stall cells and partial surge, the compressor suddenly and substantially turns into the final instability (substantial drop of compressor performance). The reasons for why the stall margin can be enhanced with this casing treatment are discussed, and the functions of the casing treatment are also discussed.

Keywords: stall inception; partial surge; transonic compressor; casing treatment; arc-shaped slot; stall margin enhancement

1. Introduction

Rotating stall and surge are two well-known manners of the breakdown of orderly flow in a compressor, which have been described as the most unfortunate occurrence to befall an aero-engine compressor [1]. They could appear when an axial compressor is throttled and the instability limit is reached [2]. Rotating stall behaves as a disturbance of the flow in the circumferential direction, while surge is flow disturbance in the axial direction. Consequently, in the stalled operating mode, the average mass flow rate through a compressor is steady, but in the surge operating mode, the flow rate fluctuates. It is the length and volume scales of the entire compression system that determine which form of instability will be dominant [3, 4].

Stall inceptions

Previous studies found that rotating stall might be initiated by two types of initial perturbation in pressure/velocity: large-scale "modal" inception and small-scale "spike" inception. The former is characterized by small-amplitude disturbances with wavelength on the order of the annulus