PhD Dissertation Defense Announcement
Mechanical and Aerospace Engineering Department
University of Texas at Arlington

DYNAMICS OF SEPARATED FLOWS IN DIFFUSERS WITH VORTEX GENERATORS

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12:30 PM, Tuesday, July 16, 2024

Woolf Hall 200

Abstract

Flow through curved diffusers is complicated due to the possibility of flow separation and secondary flows. Vortex generators (VGs) are a class of passive flow separation control devices used to improve the flow quality in curved diffusers by suppressing flow separation. Thus, understanding the flow physics and performance of VGs is crucial. The chosen geometry for this study is a well-documented asymmetric diffuser exhibiting mild flow separation. The present numerical study examines the effect of two families of vanes and a swept ramp on flow control. The VGs are placed upstream of the diffuser, and the downstream flowfield is analyzed through skin friction topology to identify flow features. Subsequently, performance parameters such as overall drag, pressure recovery, flow distortion, and diffuser efficiency are presented and discussed.

A pair of vanes that has demonstrated effective performance—namely, reduction in separation region, improvement in pressure recovery, and reduction in distortion index was selected for further analysis. The flowfield downstream of the VGs was studied using large eddy simulations to gain insights into the underlying flow physics of flow separation control. Two modes of momentum transfer were identified: 1) downwash from the trailing vortices shed by the VGs and 2) an increase in velocity fluctuation due to the breakdown of the trailing vortices. From the literature review, the effect of vortex breakdown on flow separation control is relatively unexplored in the context of confined flows. This study aims to detect vortex breakdown and analyze its associated effects, such as the increase in turbulent kinetic energy (TKE) production.

The trailing vortices emanating from the VGs were found to break down immediately after the diffuser entrance. At the breakdown location, a drastic increase in the vortex size was observed along with heightened TKE production. The location of peak TKE production spreads in the spanwise and wall-normal direction. This increases the mode-2 momentum transfer, which is beneficial in suppressing the flow separation. Additionally, investigating the influence of different vortex breakdown modes on the flow separation control could provide further insight into the underlying flow physics of VG-induced flow separation control.