Embedded Flow Control for High Work / Low Reynolds Number Turbines

Turbomachinery and Heat Transfer Laboratory

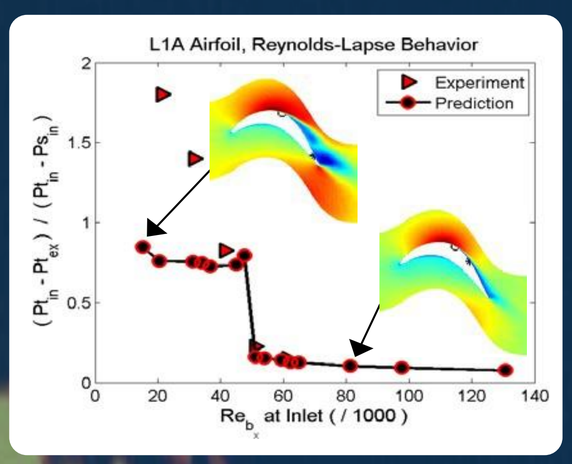
Technion – Israel Institute of Technology

Acar Celik, Assoc. Prof. Beni Cukurel

This work is the result of a joint effort with other members of the research group: *Tapish Agarwal, Abhijit Mitra*

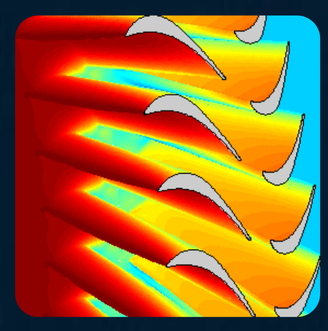
MOTIVATION

- Engines for future platforms require significantly increased performance
- Turbine airfoils are known to suffer severe performance degradation at off-design conditions
- Flow control technologies can mitigate performance degradation if implemented in practical designs
- The effort could yield robust on- and off- design performance for future engines



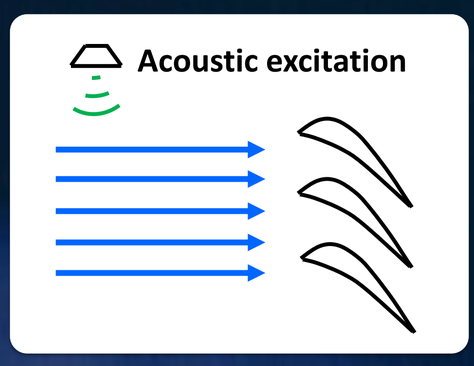
PROJECT OBJECTIVES

- Design high work / low Reynolds turbine components that are relevant to future engine cycles
- Develop novel flow control strategies that are suitable for embedding in rotating turbomachinery
- Understand the fundamental physics of acoustic flow control
- Evaluate candidate flow control methods in linear cascades, annular cascades, and potentially both part- and full-scale rotating stages
- Demonstrate effectiveness of embedded flow control strategies for integration into future engine demonstrators

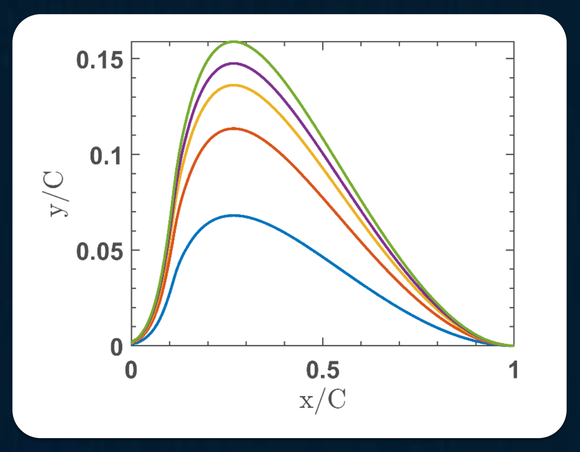


INTRODUCTION

- Global flow control strategies are more effective to reach optimal benefit for turbomachines



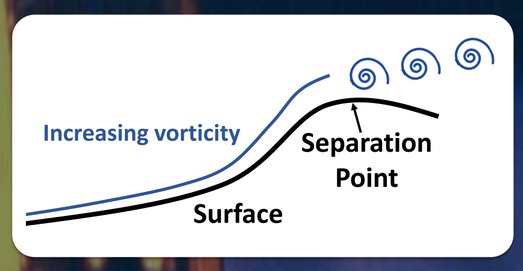
GEOMETRY SELECTION

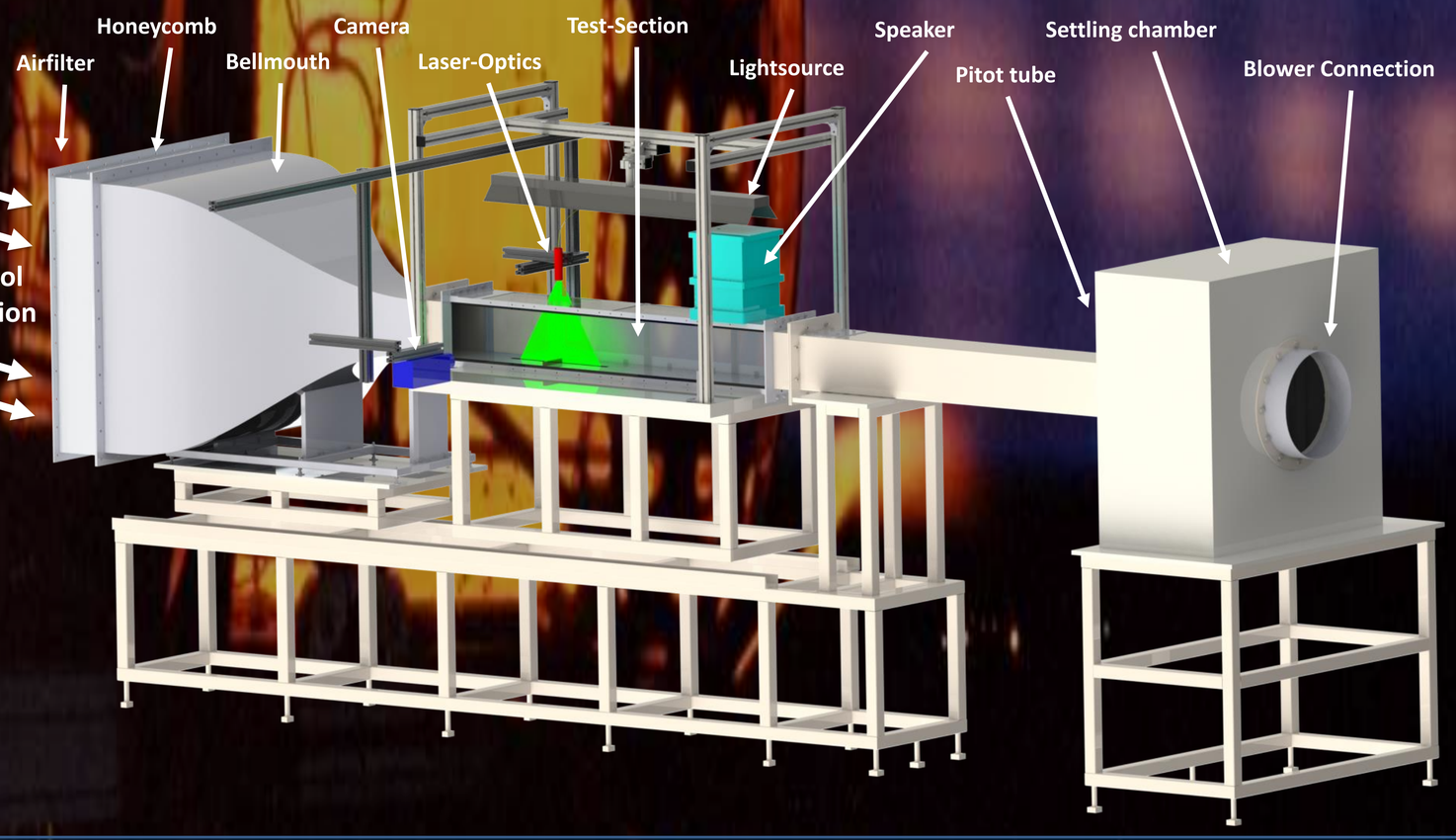


TEST SECTION

- Velocity: up to 25 m/s
- Test-section: 1500 mm [length]
- Cross-section: 200 mm * 200 mm [height*width]
- 2MP high-speed (up to 100kHz) camera
- 70W continuous NIR laser
- LaVision seeding generator
- Davis image processing software

KH VORTICES AND LOSSES





Unexcited case measurements

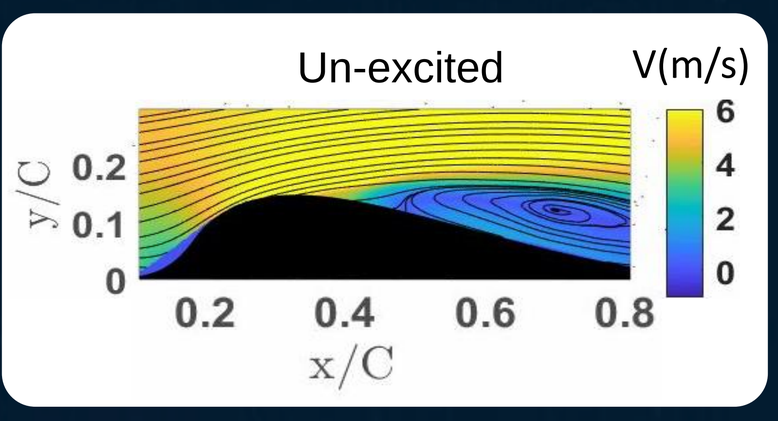
FFT of velocity fluctuations in separated region → **Finding KH frequency of vortices**

Excited case measurements

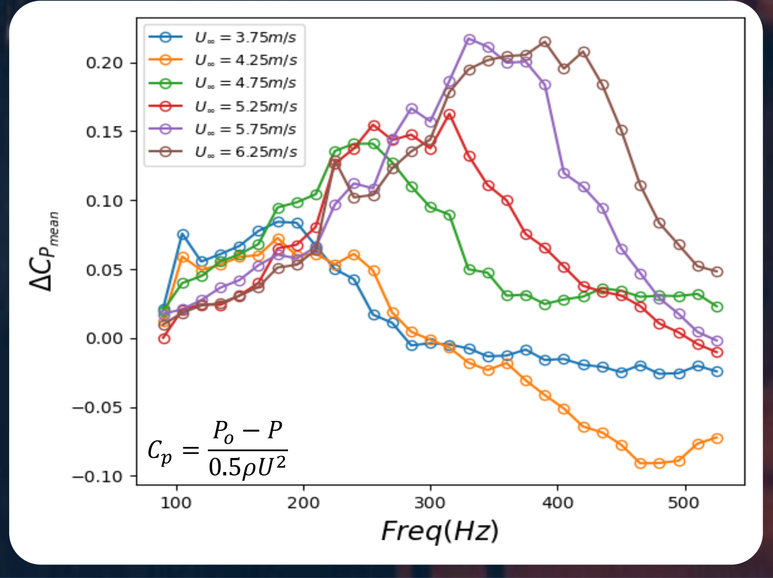
- Effect of frequency
- Effect of Reynolds number

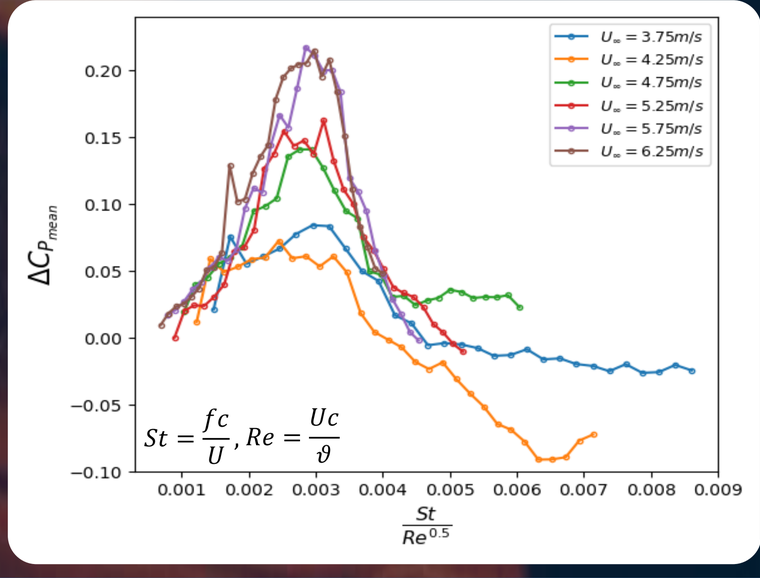
ΔC_p vs. f and Zn

UNEXCITED VELOCITY FIELD

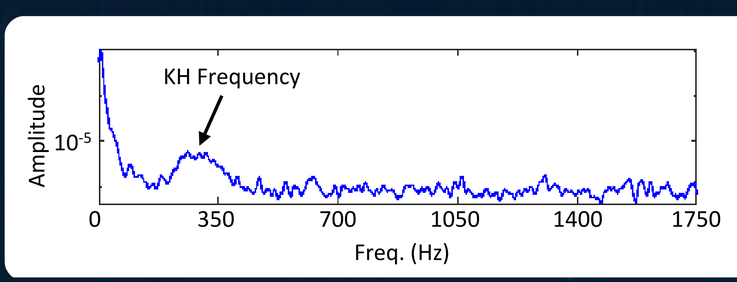


RESULTS OF EXCITED CASES





FFT FOR UN-EXCITED KH FREQUENCY



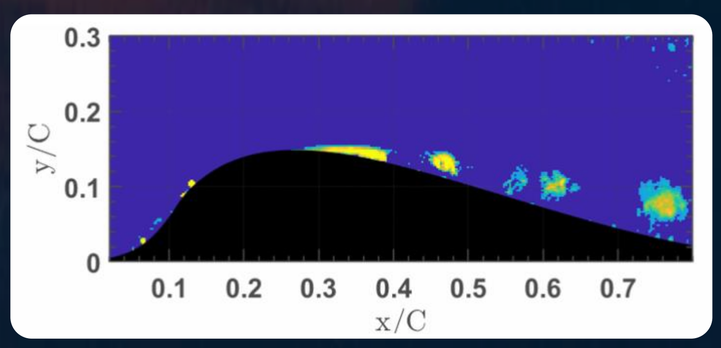
SUMMARY

- $St \sim \sqrt{Re}$ indicates KH
- Excitation causes accumulation and shedding of coherent vortices

FUTURE WORK

- Closer understanding to interaction of acoustic waves and shear layer
- Investigation into role of attached boundary layer in the control process
- Water tunnel PIV measurements
- Schlieren and PIV experiments of turbine blades in transonic linear cascade

ACCUMULATION OF COHERENT VORTICES



EXCITED VELOCITY FIELD