Poznań University of Technology

Doctoral Thesis

Method for direct noise analysis of NASA R67 axial compressor blade

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A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy. Engineer.

in the

Faculty of Work Machines and Transportation
Chair of Thermal Engineering

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Declaration of Authorship

I, MSc. Eng. Jędrzej Mosiężny, declare that this thesis titled, 'Method for direct noise analysis of NASA R67 axial compressor blade' and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for a research degree at this University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

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Abstract

This thesis proposes a method of assessing flow generated noise in transonic flows by direct formulation.

First a steady state Reynolds Averaged Navier-Stokes analysis of NASA R67 transonic axial compressor is performed as a validation study of the mesh and numerical setup. The result of the steady state analysis is then used as an initialization for transient DDES analysis performed on high quality, 11 million cells hexagonal mesh. The transient analysis covers 0.05s of physical flow time, which corresponds to about 800 revolutions of the rotor. Both steady state and transient simulations are performed on PL-Grid HPC infrastructure.

Transient results are analyzed with an in-house build program. The program uses information about static pressure, transient particle velocity and vorticity from each timestep. This data is then postprocessed into sound pressure levels, sound frequency and effective sound power level.

Information on generation of sound phenomena occurring in the blade passage are gathered from direct formulation and may be used as a validation case for FW-H or other computational aeroacoustic analogies dealing with flows in transonic regimes in rotating machinery.

Acknowledgements

In this place I would like to thank the Chair of Thermal Engineering of Poznań University of Technology, with special recognition to MSc. Eng. Bartosz Ziegler and PhD Eng. Przemysław Grzymisławski for thorough scientific and personal support during this project.

A big recognition goes to the owners and maintainers of the PLGRID - Polish HPC infrastructure, especially team in HPC Cyfronet center in AGH University of Science and Technology in Kraków. Being able to use the state of the art HPC clusters for analyses made this project possible.

Contents

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Abbreviations

CAA	**C**omputional **A**ero **A**coustics
CFD	**C**omputional **F**luid **D**ynamics
DDES	**D**elayed **D**etached **E**ddy **S**imulation
DES	**D**etached **E**ddy **S**imulation
HPC	**H**ight **P**ower **C**omputing
LES	**L**arge **E**ddy **S**imulation
N-S	**N**avier **S**tokes
SRS	**S**cale **R**resolving **S**imulation

Physical Constants

Speed of Light $c = 2.997\ 924\ 58 \times 10^{8}\ \mathrm{ms}^{-\mathrm{S}}$ (exact)

Symbols

a	distance	m
P	power	W (Js^{-1})
ω	angular frequency	$rads^{-1}$

To my wife. For limitless patience...

Chapter 1

Introduction

1.1 Main Section 1

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Chapter 2

Current research on Computational Aeroacoustics

2.1 Main Section 1

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Chapter 3

Approach and direct formulation noise analysis

3.1 Nasa R67 - zmienić tytuł

Direct noise formulation method as described in chapter **??** is applied on a single blade of the test compressor. NASA R67

3.2 Research approach

A following approach is used to obtain data describing sound propagation in the acoustic near-field. Each step is described in detail in further chapters of this work

First a simplified CFD project is performed. A number of simplified cases is run. The simplified case is a steady state, density based, RANS (k-omega SST) on a coarse mesh with cell count under 500k elements. The goal of this simplified calculation is to get a stable numerical scheme that reaches convergence while delivering the results correlating with the experiment. Also a number of methods for efficient gathering of data are tested.

Based on the initial results, a number of calculations is performed in order to estimate proper mesh sizing, boundary layer thickness and time step.

A coarse mesh is refined to desired cell sizing. The cell count of a refined mesh is around 11.5 million. A steady state RANS case with numerical setup obtained from simplified project is performed. The reason for this case is to estimate the amount of postprocessing data to be generated.

Once a converged steady state solution is reached and the results are validated, the setup is switched to a pressure based, SIMPLE algorithm, DDES (LES and k-omega SST) calculation. This setup is then computed for around 38 thousand timesteps. The reason for this intermittent calculation is to generate a flowfield that resembles random movement of turbulent boundary layer. This run is also used to test the data aquisition from the case.

Finally, the transient setup is left to generate 50150 timesteps. Static pressure, velocity magnitude, temperature and density is exported from blade surfaces and conical design surfaces for each timestep and stored for further analysis

As for postprocessing of the data, the files

3.2.1 Geometry

First, a geometry of the single blade is created. Studies by NASA (tutaj referencja) provide a

Chapter 4

Test case

4.1 NASA Rotor 67 description

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4.1.1 Efficiency figures

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4.2 CFD

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Chapter 5

RANS Analysis

5.1 Main Section 1

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Chapter 6

DDES Analysis

6.1 Main Section 1

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Chapter 7

Results of flowfield noise analysis

7.1 Main Section 1

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Chapter 8

Conclusions & Further work

8.1 Main Section 1

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Appendix A

Code for direct formulation of noise analysis

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Appendix B

Code for discrete Fourier analysis

Write your Appendix content here.

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