INVESTIGATION OF THE TURBULENT FLOW AROUND A RAF-6E AIRFOIL WITH MEASUREMENT, VISUALIZATION AND SIMULATION

by

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/B6W1A5/

Submitted to the
Department of Fluid Mechanics of the
Budapest University of Technology and Economics
in partial fulfillment of the requirements for the degree of
Master of Science in Mechanical Engineering Modelling

on the 7th of December, 2012

MSc Thesis

Final Project /BMEGEÁTMWD2/

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ASSIGNMENT

MSc FINAL PROJECT (BMEGEÁTMWD2)

Title:	**Investigation of the turbulent flow around a RAF-6E airfoil with measurement, visualization and simulation**
Author's name (code): Curriculum :	**Dávid VIRÁG (B6W1A5)** MSc in Mechanical Engineering Modelling / Fluid/Solid Mechanics
Supervisor's name, title: Affiliation, address:	László NAGY, assistant lecturer Department of Fluid Mechanics / BME H-1111 Budapest, Bertalan L. 4-6.
Handed out / Deadline:	**3rd of September 2012. / 7th of December 2012.**
Curriculum subjects (code):	1. Computational Fluid Dynamics (BMEGEÁTMW02) 2. Flow Measurements (BMEGEÁTMW03) 3. Building Aerodynamics (BMEGEÁTMW08) 4. Aerodynamics and its Application for Vehicles (BMEGEÁTMW09)
Title of the Major Project (BMEGEÁTMWD1):	Post-processing Fluent simulation and measurement results in case of a RAF6-E airfoil
Description / refinement of the Major Project (BMEGEÁTMWD1):	1. Draw conclusions from a BSc and MSc thesis discussing the same topic in measurement techniques, in the theme of RAF6 airfoil. 2. Prepare pressure measurements on the airfoil surfaces in the NPL wind tunnel. 3. Use visualization techniques to show vortices along and behind the airfoil in the NPL wind tunnel. 4. Post-process and compare Fluent simulation results with the measurement. 5. Summarize the project results.
Description of the Final Project (BMEGEÁTMWD2):	1. Investigate the possibilities in the Department using of high-speed camera in the NPL wind tunnel for airfoil. 2. Post-process and compare Fluent simulations. 3. Draw conclusions from the given results. 4. Summarize the Final Project.

Budapest, 3rd of September 2012.

(L.S.)

…….
Dr. János VAD, associate professor
Head of Department

Approved by:
Budapest, 3rd of September 2012.

(L.S.)

…….
Prof. Tibor CZIGÁNY
Dean of Faculty

Received by:
Budapest, 3rd of September 2012.

The undersigned declares that all prerequisite subjects of the Final Project have been fully accomplished. Otherwise, the present assignment for the Final Project is to be considered invalid.

…….
student

Supervisor's declaration of acceptance:	The submitted Thesis fulfils all requirements of the Department of Fluid Mechanics, Budapest University of Technology and Economics. The Thesis is accepted for review process and public defence.
Supervisor's proposal for final grade of the thesis:	The proposed final grade* of the MSc Thesis: …….... * Please, select one: excellent (5), good (4), medium (3), acceptable (2), fail (1)
Date:	Budapest, 7th of December, 2012.
Name / Signature:	…… supervisor

Reviewer's proposal for final grade of the thesis:	The proposed final grade* of the MSc Thesis: …….... * Please, select one: excellent (5), good (4), medium (3), acceptable (2), fail (1)
Date:	
Name / Signature:	…… reviewer

DECLARATION

Full Name (as in ID):	Dávid VIRÁG
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University:	Budapest University of Technology and Economics
Faculty:	Faculty of Mechanical Engineering
Department:	Department of Fluid Mechanics
Major/Minor:	MSc in Mechanical Engineering Modelling Fluid Mechanics major / Solid Mechanics minor
Thesis title:	Investigation of the turbulent flow around a RAF-6E airfoil with measurement, visualization and simulation
Academic year of submission:	2012 / 2013 - I.

I, the undersigned, hereby declare that the Thesis submitted for assessment and defence, exclusively contains the results of my own work assisted by my supervisor. Further to it, it is also stated that all other results taken from the technical literature or other sources are clearly identified and referred to according to copyright (footnotes/references are chapter and verse, and placed appropriately).
I accept that the scientific results presented in my Thesis can be utilised by the Department of the supervisor for further research or teaching purposes.

Budapest, 7th of December, 2012

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(Signature)

FOR YOUR INFORMATION

The submitted Thesis in written and in electronic format can be found in the Library of the Department of Fluid Mechanics at the Budapest University of Technology and Economics.
Address: H-1111 Budapest, Bertalan L. 4-6. „Ae" building of the BME.

ABSTRACT

The main goal of the thesis is an investigation of a turbulent flow around a RAF-6E airfoil with measurement, visualization and simulation.

The main aim of the measurement is to determine the pressure coefficient distribution along airfoil (both at the suction side (SS) and at the pressure side (PS)) by measuring the static pressure distribution. Further task was to compare the measured pressure coefficient values with other, earlier made measurement and simulation results. Furthermore the effect of the angle changing was investigated also. With the help of it the stall of the airfoil can be determined.

First of all the goal of the visualization is to get acquainted with the available and used devices, gain experiences, discover the possibilities and limitations. Furthermore give recommendations for future researches. Meanwhile the aim is to investigate the developing phenomena around the airfoil.

Aim of the simulation part is to post-process and evaluate earlier performed Fluent simulations (3D, LES) in Tecplot software. Comparisons were prepared and also conclusions were drawn of these results (they differ only in the mesh densities).

KIVONAT

A diploma célja egy RAF-6E típusú szárny körüli turbulens áramlás vizsgálata különböző módszerekkel, többek között méréssel, vizualizációval és szimulációval.

A mérés során a fő cél a statikus nyomás- és nyomástényező eloszlás meghatározása a szárny mentén, a szívott és nyomott oldalon. Feladat továbbá a nyomástényező összehasonlítása, validálása, más korábban elvégzett mérési és szimulációs eredményekkel. A vizsgálat tárgya volt még az állásszög változtatásának hatása a nyomásra, ill. nyomástényezőre. Ennek segítségével továbbá meghatározható és összehasonlítható irodalmi adattal a szárnyprofil úgynevezett átesése.

A vizualizáció célja elsősorban a tapasztalatszerzés, a lehetőségek, nehézségek, korlátok megismerése, tanszéki eszközök használata. Továbbá a jövőbeli vizsgálatok megalapozása, javaslatok megfogalmazása. Mindeközben pedig az alapvető, szárny körül kialakuló jelenségek tanulmányozása, gyakorlatban való megismerése.

A szimuláció rész célja, korábban Fluentben elvégzett 3D LES szimulációk post-processzálása, kiértékelése Tecplot szoftverrel. Ezen eredmények egymással való összehasonlítása, következtetések levonása (csak a hálósűrűség a különböző).

CONTENTS

NOMENCLATURE

c	chord length [m]
L	length of the investigated domain [m]
p	pressure [Pa]
p_0	ambient pressure [Pa]
p_{dyn}	dynamic pressure [Pa]
p_{st}	static pressure [Pa]
p_{tot}	total pressure [Pa]
R	gas constant of air [J/kgK]
T_0	ambient temperature [$°C$]
t_{flow}	time elapsed during the simulatin [s]
U_{ref}	flow velocity [m/s]
$u*$	friction velocity [m/s]
x	distance of the bores [m]
y	distance of the boundary layer at a given point from the wall [m]

GREEK INDEX

α	angle of incidence [°]
Δp	pressure measurement range [Pa]
$\delta\Delta p$	accuracy of pressure measurement [Pa]
δp	absolute pressure measurement error [Pa]
ΔT	temperature measurement range [$°C$]
$\delta\Delta T$	accuracy of temperature measurement [$°C$]
δT	absolute temperature measurement error [$°C$]
Δt	time step [s]
Δx	size of the cell in the x direction [m]
ν	kinematic viscosity [m^2/s]
ρ	density of air [kg/m^3]

DIMENSIONLESS QUANTITIES

c_p	pressure coefficient
L_z	spanwise extension
N	number of cells
N_z	number of spanwise cells
Re	REYNOLDS-number
y^+	wall distance