



# **LARGE-EDDY SIMULATION OF AIRFOIL FLOW USING OPENFOAM**

by

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## DECLARATION

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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, 16<sup>rd</sup> of December, 2011

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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. „Ac” building of the BME.

## ABSTRACT

The goal of this thesis was simulating turbulent flow around airfoil RAF-6E. As first steps, two dimensional simulations were performed by both OpenFOAM and FLUENT. Then their results were compared to each other.

Then several numerical schemes were selected in OpenFOAM and they were compared to FLUENT and measurement. The goal of this part of the project was finding the proper numeric settings for the LES. As the necessary computation time is long for 3D LES simulation, these simpler, faster 2D cases were suitable for testing several possible numeric settings.

After performing mesh-dependence examination in 2D, the former mesh turned out to be coarse. A new, refined mesh generation was necessary, which meant new challenges and extra working time on preparing the LES case for simulation. From the refined 2D mesh a 3D one was generated in OpenFOAM with extrusion.

Finally, a Large-Eddy Simulation (LES) of the airfoil in OpenFOAM was performed in 3D.

## KIVONAT

A dolgozat célja a RAF-6E típusú szárny körüli turbulens áramlás vizsgálata. Első lépésként két dimenziós szimulációt futtattunk OpenFOAM-ban és FLUENT-ben, majd az eredményeket összehasonlítottuk egymással.

Később számos különböző numerikus sémát választottunk ki OpenFOAM-ban, melyek eredményeit összevetettük a FLUENT-es szimuláció, illetve tanszéki mérések eredményeivel. A cél ebben az részben az volt, hogy a megfelelő numerikus sémákat ki lehessen választani a LES számára. Mivel a 3D LES szimuláció számítási igénye jelentős, ezek az egyszerűbb, gyorsabb, 2D-s esetek alkalmasak voltak több lehetséges numerikus séma tesztelésére.

Hálófüggetlenségi vizsgálat elvégzése után (2D) kiderült, hogy a korábban használt háló nem volt elég finom felbontású. Egy új, jobb felbontású háló készítésére volt szükség, ami új kihívásokat és többlet munkaigényt jelentett a LES-eset beállításában. A finomított 2D hálót OpenFOAM-ban kihúзва hoztuk létre a 3D hálót.

Végül nagy örvény szimulációt (LES) végeztünk OpenFOAM-mal 3D-ben.

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## NOMENCLATURE

Mark	Name	Unit			
$c$	chord length	m			
$C_D$	drag coefficient	1	$v_{RMS}$	normal direction root mean square of velocity in wall-normal direction	m/s
$C_L$	lift coefficient	1	$w$	instantaneous velocity spanwise direction	m/s
$FTN$	flow through number	1			
$N_x$	cells in streamwise direction	1			
$N_y$	cells in wall-normal direction	1			
$N_z$	cells in spanwise direction	1			
$p$	static pressure	Pa			
$p_{mean}$	mean of static pressure	Pa			
$p_{RMS}$	root mean square of static pressure	Pa			
$u_{mean}$	mean velocity in tangential direction	m/s			
$u_{RMS}$	root mean square of velocity in tangential direction	m/s			
$U_{ref}$	reference velocity	m/s			
$v$	instantaneous velocity in wall-normal direction	m/s			
$v_{mean}$	mean velocity in wall-	m/s			

  

GREEK INDEX		
Mark	Name	Unit
$\alpha$	angle of attack	°
$\Delta_t$	time step	s
$\Delta_x$	step size of the grid in x direction	m
$\Delta_y$	step size of the grid in y direction	m
$\Delta_z$	step size of the grid in z direction	m
$\tau_{w,x}$	x component of wall shear stress	Pa
$\tau_{w,x,mean}$	mean of x component of wall shear stress	Pa