

INTRODUCTION TO LARGE EDDY SIMULATIONS

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OBJECTIVE

Several papers on LES for turbomachinery appear each year in Turbo Expo. These are usually of the results, and not of the method. In industrial settings, RANS is the common approach, though the larger organizations have been using LES for some components where the benefits have been convincing. This tutorial is to provide an introduction for attendees who may wish to begin analysis using LES. A second reason is to discuss newer approaches that can be more efficient than methods that are typically available in commercial codes.

TUTORIAL OUTLINE

Slide	Topic summary
1	Contents 1. LES for prediction of turbulent flows 2. Equations and models Equations for LES fields and the need for modeling Typical LES models Numerical methods for LES 3. Example 1: A compressor cascade with transitional boundary layers 4. Example 2: Separation in a diffuser 5. Flows with shocks, with examples 6. Assessment of LES 7. Explicit filtering method 8. Expectations of LES: reliability, accuracy, convergence, spectra
2	Turbulent flow computations RANS: Mean flow field DNS: Unsteady, 3-d, turbulent flow field
3	RANS is affordable, often sufficient, not always <i>reliable</i> DNS is reliable, but not practical <i>LES is reliable and affordable</i> complement to routine RANS
4	Basis for LES Large scale organization of turbulence Most energy and flow-surrounding interaction is by large scale part

- 5 **LES definition**
- Why is it **necessary**? Why is it **sufficient**
- 6, 7 **LES equations and *need for modeling***
- Arises when approximating a nonlinear equation
- Functional model. Structural model**
- 8, 9, **LES models**
- A. **Eddy viscosity models**
- Smagorinsky, Dynamic Smagorinsky
- 10 B. **Structural models**
- Scale similarity (Bardina)
- Approximate Deconvolution (Stolz & Adams)
- SGS velocity estimation (Domaradzski)
- 11 C. Other models
- Mixed, Spectral, SGS k.e, ILES**
- D. **Explicit Filtering**
- 12, 13, **Example 1: Compressor cascade**
- 14,
- 15,16, 17 Experiment
- Simulations
- Blade surface pressure
- Improvement provided by LES and 3-equation transition sensitive RANS
- Flow structure revealed by LES/DNS
- Higher Re cases
- 18, 19 **Example 2: Separation in a diffuser**
- Experiments
- RANS has qualitative errors
- 20, 21, **LES of Cherry Diffuser**
- 22, 23,
- 24 Three LES of increasing sophistication and improving results
- 25 **LES of flows with shocks**
- Transonic, tandem blade
- Impinging supersonic jet
- 26 **Obtaining reliable LES**
- 27 **Practical issues**
- Grid
- Inflow turbulence
- Simulation times
- 28 **Explicit Filtering Method for LES**
- Method
- Experience
- on flow types
- User groups
- 29 **Fundamental test 1:**
- Compressible, homogeneous, isotropic turbulence
- Spectral extension at small scales
- 30, 31 **Fundamental test 2:**

Subsonic round jet
Re=11 000 and 1 100 000
LES grids are not very large!

- 32 **Expectations of an LES**
- 33 **Reliability**
- 34 **Eddy viscosity models and Explicit Filtering**
- 35 **Summary**

References

Turbulence

Pope, S.B., 2000. *Turbulent flows*. Cambridge University Press.

LES

Books:

Sagaut, P., 2006. *Large eddy simulation for incompressible flows: an introduction*. Springer Science & Business Media.

Garnier, E., Adams, N. and Sagaut, P., 2009. *Large eddy simulation for compressible flows*. Springer Science & Business Media.

Reviews:

Georgiadis, N.J., Rizzetta, D.P. and Fureby, C., 2010. Large-eddy simulation: current capabilities, recommended practices, and future research. *AIAA journal*, 48(8), pp.1772-1784.

Examples

Compressor cascade

S A H Rizvi & J Mathew, Large eddy simulation of transitional flow in a compressor GT2017-64279

Separation in diffuser

A Shende, M Verma, VT K ashist & J Mathew, Simulations of 3-d separation in a diffuser GT2012-9555

Tandem blades

P Mitra, J Kantharaju, R Rayan, & J Mathew
Large eddy simulation of tandem blade stator cascades. GT2017-64286

Explicit filtering

Proposal:

Mathew, J., Lechner, R., Foysi, H., Sesterhenn, J. & Friedrich, R. 2003 An explicit filtering method for LES of compressible flows *Phys. Fluids* 15(8), 2279--2289.

Interpretation:

Mathew, J, Explicit filtering for large eddy simulation as use of a spectral buff er.
<http://arxiv.org/abs/1610.01738>