EUROPEAN MECHANICS SOCIETY

Colloquium Final Report Form

Please send this report in electronic form to the Secretary General of EUROMECH, within one month after your Colloquium. As an example, please consult the Report of Colloquium 443 (available at www.euromech.org/colloquia/after.htm).

Title Quantification of uncertainties in modeling and predictive simulation of fluids
Colloquium No 543 Dates and location Oct. 10-11, 2013, Munich, Germany
Chairperson …*Prof. Dr. Nikolaus Adams* …………………………….………………
Co-Chairperson …*Prof. Dr. Wolfgang Schröder*……………………………………..

Is there need of another Colloquium on the same or a related subject? Which year?

…yes – probably 3-4 years later …………………………………………………

Full registration fee …*324 €*…………………………………………………………

What other funding was obtained? …*none*……..……………………………………

What were the participants offered? …coffee break, conference dinner, lunch (2x) book of abstracts and conference kit ..………………………………………………

Number of members of Euromech (reduced registration fee) …*6*..…………………...

Number of non-members of Euromech (full registration fee) …*15*…………………...

Number of participants from each country:

Austria		United Kingdom		Slovakia	
Belgium		Greece		Slovenia	
Bosnia		Hungary		Spain	
Byelorussia		Ireland		Sweden	
Bulgaria		Italy	1	Switzerland	
Croatia		Latvia		Ukraine	
Czech Republic		Lithuania		Serbia	
Denmark		Netherlands	2	Montenegro	
Estonia		Norway		Turkey	
Finland		Poland		Others	
France	1	Portugal		Israel	1
Georgia		Romania		USA	2
Germany	14	Russia		Total	

List names of Applicants to EUROMECH…*see attached last 2 pages* ....

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Scientific Report
Please type your report on the following pages. Use additional pages if required. Put the date and your signature at the end.

Colloquium No 543 Scientific Report

Uncertainty Quantification (UQ) is a relatively new approach to investigate and evaluate the unknown fidelity in numerical and experimental investigations in fluid mechanics. The mathematical approach helps to identify the sensitivities and the possible systematic error propagation in complex fluid dynamic systems. As numerous sources of errors are to be accounted for, a large number of experiments or simulations would be necessary to identify the influence of a single error source on the quality of the result. UQ can help to reduce the number of simulations/experiments to get a hand on the sensitivity of the result on the different error sources (i.e. unknown inflow conditions, unknown parameters, …) and on the overall error of the investigated system. On top of that, optimization strategies can benefit from the knowledge of the level of uncertainty in the final result.
The colloquium brought together researchers from various countries to exchange ideas and concepts on 'Uncertainty Quantification' in fluid mechanics.
Among the applications, 14 presentations were selected which drew 22 participants from 6 different countries in Europe, Israel and the USA. The colloquium took place the TU München at the Institute of Aerodynamics and Fluid Mechanics. The two day event together with a social event on the evening of the first day brought forth fruitful ideas and saw intense discussion on the details of the presented subjects.
Prof. Moser from UT at Austin, Texas, gave the invited lecture on the topic of UQ as a means to build confidence in predictive simulations at the example of atmospheric re-entry vehicles.

The coollquium presentations can be grouped in four different main topics: turbulence, experimental data uncertainty, supersonic flows with shocks, miscellaneous, which shall be presented here in short:

Turbulence: Three presentations dealt with UQ in a turbulent environment with RANS,
The first authors estimated the error in Reynolds-Averaged Navier-Stokes (RANS) simulations due to the turbulence closure model. The method of UQ was applied to the unknown model parameters and their influence on wall-bounded flows at a variety of favourable and adverse pressure gradients. The second presentation dealt with uncertainty in low-dimensional models of the Navier-Stokes equations. To reduce the uncertainties here to treat turbulent flows at high Reynolds numbers not accessible to DNS of NSE it is necessary to study the fundamental the rich direct and bidirectional coupling between large/resolved and small/unresolved scales. The third authors show a practical application with trailing edge noise influenced by synthetic turbulence. The application of porous material at the trailing edge leads to a reduction in emitted noise of up to 6 dB. The influence of the uncertainties on the CAA simulations was shown.

Experiments: Three presentations gave insight into UQ in the processing of experimental data and the effects on the experimental setup.
The first group showed that the formulation of accurate inflow data

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in numerical simulations depend on experimental knowledge which is in general inaccessible in the require detail. UQ can help to identify the regions which are responsible for the largest error propagation in the inflow data. The subsequent presentation showed the accuracy of heat transfer measurements and implications on data interpretation in natural convection. The error propagation for the calculation of the Nusselt number and its related data interpretation from the measurements was discussed. The next group presented a very instructive method to UQ in particle image velocimetry (PIV). The contribution of individual particle images to the correlation peak is evaluated and the measurement uncertainty is retrieved from the ensemble of particle image disparities.

Supersonics/ flows with shocks: Shocks are extremely sensitive to the exact numerical and experimental initial conditions. In many cases, the problem depends on many known and unknown influence factors. The work presented in the third session of the colloquium mostly dealt with the quantification of the uncertainty of these known initial errors. The first talk showed the uncertainty of a shock/bubble interaction in comparison with published experimental results. The investigations could identify the most plausible cause for disparities in numerical and experimental work. The second talk dealt with Polynomial Chaos methods applied to a scramjet intake with uncertain inflow Mach number and uncertain angle-of-attack. The UQ investigations lead to a better understanding of the sensitivities in the problem with various different flow regimes (shock/boundary-layer interaction, separation regions, etc.). For the same flight regime, the next group looked at simulations at the design stage of the scramjet combustion chamber flow. The early stages of the design process are often dominated by low fidelity design tools, which are used to calculate system level metrics on flight envelopes or during parameter studies. UQ can lead to a significant decrease in parameter permutations as one can quantify the uncertainty propagation due to errors in the modelling parameters of the combustion and the flow simulation. The final presentation in this session was given on the quantification of initial-data uncertainty on a shock-accelerated gas cylinder.

Miscellaneous: The combination of an inverse approach and UQ showed an impressive iteration on the initial conditions of an interface in a shock-tube setup. The exact experimental setup of the two media interface is extremely difficult to measure accurately enough for the exact representation in numerical experiments. Thus, the problem is looked at reversely developing the initial conditions from the non-linear evolution of the interface hit by the shock. In a second contribution in this session, the interaction of wakes of two cylinders in proximity depending on the uncertainty of the cylinder shape and distance was presented explaining the difference in the global wake behaviour and cylinder movement. In a more fundamental presentation on the formulation of the polynomial chaos expansions, the role of incomplete statistical input information was detailed. In the last presentation of this session the error quantification of passive scalar transport in the context of large eddy simulation using implicit filtering was presented. Most LES codes for engineering applications

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rely on the implicit filtering approach, where grid convergence studies in the sense of Richardson extrapolation cannot be performed. A method to overcome this difficulty was proposed including the assessment of the uncertainty of the first and second order moment of a passive scalar embedded in a LES flow field.

The colloquium gave insight into various applications of uncertainty quantification in different aspects of fluid mechanics applications. The better understanding of error propagation in experiments and the quantification of the direct impact of initial errors on the final result in non-linear environments was clearly shown. The colloquium showed that UQ can deliver a deeper insight into the uncertainties and their propagation in complex environments. This leads to an increase in confidence in the experimental measurements and the numerical predictions. It also shows the need to work hand in hand. The discussions showed the constructive awareness among the participating scientists. The organizers and the participants express their gratitude towards EUROMECH to host the meeting under their auspices.