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: Immersed Boundary Methods: Current Status and Future Research Directions

Colloquium No: 549

Dates and location: 17-19 June 2013, Leiden (The Netherlands)

Chairperson: Dr. W.-P. Breugem, Delft University of Technology, The Netherlands

Co-Chairperson: Prof. R. Verzicco, University of Rome “Tor Vergata”, Italy

Is there need of another Colloquium on the same or a related subject? Which year? The workshop was a success and it was decided to have a follow-up colloquium on the same topic in 2016. Prof. R. Mittal and Prof. R. Verzicco agreed to organize this in the USA this time.

Full registration fee: 409 Euro (non-members), 385 Euro (members of EUROMECH)

What other funding was obtained? We requested some funding from the JM Burgerscentrum, the Dutch research school for fluid mechanics, but this was not needed in the end and we therefore decided not to make use of it; all costs could just be covered from the colloquium fees paid by the participants.

What were the participants offered? The participants were offered the following: (1) A plastic bag with a hardcopy of the book of abstracts, a note block and pen, a leaflet from EUROMECH and a map of the city of Leiden; (2) A boat tour on the canals of Leiden with drinks and snacks on the first day of the colloquium; (3) A colloquium dinner on the second day of the colloquium; (4) A closing reception with drinks and snacks on the third day of the colloquium; (5) A lunch every day; (6) coffee/tea during breaks. Everything was included in the registration fee and free of charge.

Number of members of Euromech (reduced registration fee): 16

Number of non-members of Euromech (full registration fee): 39

Number of participants from each country:

Austria		United Kingdom	2	Slovakia	
Belgium		Greece		Slovenia	

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Estonia		Norway		Turkey	
Finland		Poland		**Others:**	
France	11	Portugal		USA	6
Georgia		Romania		Japan	4
Germany	10	Russia	2	Canada	2
				Taiwan	1
				Total	55

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EUROPEAN MECHANICS SOCIETY

Colloquium No. 549. Immersed Boundary Methods: Current Status and Future Research Directions
Scientific Report

Over the past 10 years, so-called Immersed Boundary Methods (IBMs) have seen a rapid development. Characteristic for IBMs is that the flow geometry is ‘immersed’ in a simple computational, often Cartesian, grid. The boundary conditions are fulfilled in good approximation by imposing additional forces on the flow field in the immediate vicinity of boundaries (direct-forcing and continuous-forcing IBMs) or by building exceptional cell forms near boundaries (cut-cell methods). The flexibility and cost-effectiveness of these methods (for instance in case of moving boundaries and finite-sized particles) have made these methods very popular.

After the very successful Euromech colloquium 507 with the same title held in Amsterdam in 2009, it was thought it was time to hold a follow-up colloquium to see the progress made in this rapidly developing field. Thus, a new Euromech colloquium on these methods was organised in Leyden, The Netherlands, from June 17-19 2013. The new colloquium addressed currently interesting subjects such as theory, error analysis, applications, implementation issues and best-practice.

The colloquium was supported by three organisations: Euromech, Ercoftac and the J.M. Burgerscentrum (the Dutch research school for fluid mechanics). Three very well-known researchers in the field accepted our invitation to give a keynote lecture, namely R. Mittal (Johns Hopkins University, Maryland, USA), T. Kempe (Technical University of Dresden, Germany) and J.J. Derksen (University of Aberdeen, UK). The public was of a widely varying background (as intended), including developers who showed the last progress in for instance error analysis but also users from science and industry.

All aspects of IBMs mentioned above have been addressed in the lectures. For instance, the number of fields in which IBMs are used is ever growing. Moreover, special attention was given to the order of spatial accuracy that can be attained (can the order of accuracy be arbitrary?) and stability (energy conservation). A short summary, including a comparison with the former colloquium, is given below.

We had in the former colloquium in 2009 many applications, using Peskin’s original IBM, the direct-forcing method of Verzicco et al., the LS-STAG (cut-cell) method in 2D and the method of Prosperetti (Physalis). We saw many examples with Fluid-Structure Interaction (FSI), usually with rigid moving parts, and simulations with finite-sized particles. Analysis of IBMs was going on. Items deserving attention that were noticed were: the finite penetration velocity at immersed boundaries (except for LS-STAG methods), conservation properties (except for LS-STAG), order of accuracy of the flow near boundaries and the grid-locking phenomenon, which occurs when an immersed boundary moves over grid cells.

In comparison with the previous colloquium, this time applications shown were more complicated, combining several different parts of physics at the same time (a beating heart with FSI and platelets, Peskin's method with Marangoni effects). Many FSI applications included deforming obstacles in this workshop. The finite-sized particle

applications used much more modeling for unresolved features, such as the very thin fluid layer between two colliding particles just before impact.
The problem of non-zero penetration velocity at the wall is still an issue for direct-forcing methods. One work-around is the so-called direct discretisation method, which adapts the discretisation scheme locally, however leading to more expensive matrix solvers.
The grid-locking problem is not yet entirely solved for the direct-forcing method and LS-STAG. It can be alleviated for the direct-forcing method by an extrapolation procedure for the pressure or smoothing. For LS-STAG it can be alleviated by smoothing, however at the expense of the conservation properties.
Higher-order applications are coming up, combining spectral and spectral element codes with IBM. However, the order of accuracy near the boundary is still lower than spectral.
Analysis of the IBM by studying the properties of the resulting discrete system of equations is progressing, but unfortunately there was only one talk on this subject this time.
A novel method is BDIM (Boundary Data Immersion Method), in which the continuous equations are smoothed and blended near the boundary. Grid locking is absent, higher-order treatment should be possible, and the issue of conservation is under study.
Much work was done on compressible flow around deformable obstacles, adapting the Riemann solver to impose the boundary conditions. Work is in progress on LS-STAG to go higher order and 3D. Wall-law type modeling for high Reynolds number flows also received attention.
Summarizing, work has been done on conservation, grid locking, higher order of accuracy of the methods near the boundary and wall treatment for high Reynolds number flow. Work is still in progress, and results are to be expected in the follow-up colloquium. The program and proceedings of the colloquium are available at: http://www.pe.tudelft.nl/~wim/euromech549.
The colloquium was a great success, and it was decided to have a follow-up colloquium on IBMs in 2016. R. Mittal and R. Verzicco agreed to organize it in the USA this time.
Finally, the organisers wish to thank Euromech, Ercoftac and the JM Burgerscentrum for making possible this event.

The organising committee consisted of the following persons:
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On behalf of the organising committee:

Wim-Paul Breugem (chairman) & Mathieu Pourquie (co-organiser)
Delft, November 14 2013

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