Report on the Workshop

Mathematical challenges and modelling of hydroelasticity

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Organisers:
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Short report

Hydro-elasticity is concerned with deformations of elastic bodies responding to hydrodynamic excitations which themselves depend on elastic deformations. Problems of hydro-elasticity are coupled, which implies that elastic deformations of the body are dependent on hydrodynamic forces and vice versa.

The mathematical theory of hydro-elasticity and mathematical methods of solving complex hydro-elastic problems are not well-developed at present. This is viewed as a major obstacle to adequate and successful treatment of problems of hydro-elasticity both in academic research and applications.

The aim of the workshop was to identify and to outline mathematical problems of modern hydroelasticity, to review recent developments in this rapidly advancing field, to specify directions to solving hydroelastic problems and to establish contacts between international leaders and young researchers, which may lead to joint international and national projects on mathematical hydroelasticity. In order to achieve this aim, the invited speakers were from four main areas: Mathematics, Fluid Mechanics, Engineering Science and Industry. Papers in the mathematical theory of hydro-elastic waves, floating elastic plates, very large flexible ships, biomechanics, and marine hydrodynamics were presented. Several young researchers made contacts with leading experts in the field and new collaborations were established.

Detailed report

Structure:

There were 38 participants, as originally planned, 14 from the UK, 15 from the EU/EEA, 4 from New Zealand, 2 from Russia, 1 from Ukraine, 1 from Israel, 1 from USA. Five of the participants were PhD or postgraduate students. Four of the participants were from Industry, the other thirty-four being applied/pure mathematicians and engineers. The programme consisted of one 1-hour talk, two 45-minute talks and twenty-nine 30-minute talks. Each day one of the talks was given by a speaker from Industry. Each half-day concluded with an open discussion session. One of the talks was streamed live from New Zealand. There were no significant deviations from the original accepted proposal.

Topics covered:

The talks covered a wide range of aspects of hydroelasticity, which reflected the different research areas of the participants. The talks can be divided into the following topics, with the understanding
that some presentations can be classified within more than one topic:

**-Fluid-structure interactions.** Interactions between fluids and flexible structures occur in many areas of the energy industry. Interactions of water waves with floating plates and beams, self-excited vibrations of cantilever pipes aspiring water were discussed. (Peake, Schulkes, Eatok Taylor, Khabakhpasheva, Makasyeyev, Metrikine)

**-Slamming problems.** Very large elastic ships on oceans were discussed. Hydroelastic issues related to the global springing & whipping vibratory response of ships and local hydroelastic effects related to the sloshing impacts in the LNG tanks were also discussed. Water entry problems, slamming loads on the bow part of the ship and wave impact onto a flexible wall were covered. (Kapsenberg, Malenica, Hirdaris, Oliver, Tassin, Korobkin)

**-Hydroelastic waves generated by moving loads on ice sheets.** Reviews of the ocean waves/sea ice interactions were presented. Boundary integral methods used to solve the nonlinear problems and new results obtained when nonlinear effects are present were discussed in two and three dimensions. An infinite family of periodic solutions was demonstrated with dimples on the wave profile, overhanging waves and generalised solitary waves were discussed in two dimensions. In three dimensions, new forced waves and solitary waves were computed. (Squire, Hosking, Vanden-Broeck, Parau)

**-Scattering of hydro-elastic waves.** An experimental programme with artificial “sea ice” was described. Different methods on solving the scattering of waves by cylinders, vertical and floating elastic plates or random inhomogeneities were presented. (Meylan, Peter, Martin, Avital, Bennett, Brocklehurst)

**-Mathematical theory of hydroelastic waves and related problems.** Existence theorem and stability proofs for different problems of hydroelasticity were presented. (Plotnikov, Haragus, Iooss)

**-Hydroelasticity in biological and other flows.** Simulation of elastic capsules in channels and swimming mechanics, storage of CO2 at the bottom of the oceans, negative damping with possible applications in ice engineering, modelling of solid-fluid interfaces were covered. (Smyth, Blyth, Eloy, Tucsnak, Kalisch, Gudnestad, Gavryliuk )

**Outcomes:**

At the end of the Workshop, the expected outcomes have been attained: people working in different fields of hydroelasticity became aware of the theoretical development and the mathematical aspects in this field, and mathematical problems of modern hydroelasticity have been identified.

Some ideas for further work and future directions which resulted at the end of the discussion session are:

- Stronger interaction between theoretical and experimental researches;
- Better collaboration between computational and analytical scientists;
- CFD approaches should be extended;
- Experiments on FSI of increasing complexity are needed;
- More extensive analysis of non-linear waves in infinite elastic plates over a fluid;
- Finite length plate effects within non-linear dynamics;
- Behaviour of complex structures under transient loads/motions;
- Melting / freezing of ice for different volumes of ice and water;
- Identification of further relevant effects, which need to be incorporated in models;
- Stability of hydroelastic interactions;
- Modelling of flows over composite materials and porous elastic plates;
- Interaction ice-structure and damping effect of the an ice sheet;
- Modelling the heterogeneity of the ice sheet;
- Moving away from linear formulations in hydroelasticity;
- Extension of simple models to more complex and realistic geometries;
- Motion of elastic shells and membranes in compressible fluids;
- Whipping and sloshing;
- 2nd order 2D/3D models of water impact for elastic bodies;
- Rigorous mathematical theory of liner and nonlinear hydroelasticity;
- New practical problems of high speed water transport;
- Problems of takeoff and landing on water;
- Nonlinear dynamics of complex liquid/solid systems;
- Problems of Arctic engineering;
- Mathematical methods to give simple understanding for complex physical systems;
- Self-propulsion of elastic micro-capsules in a collapsing vessel;
- Scattering of water waves by random elastic objects;
- Nonlinear problems of hydroelasticity;
- Hydroelastic problems with complex rheology;
- Efficient fluid/structure calculation coupling.

A number of new collaborations were mentioned by the participants in their feedback. Young PhD students have made contact for the first time with some of the most important researchers in the field of hydroelasticity.

**Highlights:**

All the participants have appreciated the important role of the discussion sessions. Also, the fact that the workshop brought together applied and pure mathematicians, engineers, people from industry was mentioned by many participants as something new and positive.

One of the review talks on floating plates was streamed live from New Zealand, using the facilities at ICMS. This went very well, showing an important feature which can be used in other meetings hosted by ICMS.

**Dissemination:**

Most of the presentations are available for the general public at the ICMS website. A theme issue of the Philosophical Transactions of the Royal Society A with the title “Mathematical challenges and modelling of hydroelasticity” will appear in 2011, where some of the invited speakers to the ICMS workshop have agreed to contribute.

**Organisation:**

All the participants found the Workshop very well organised and expressed great satisfaction with the IMCS venue and the help from the local staff, with a special mention for Helene Frossling.