EHITUSTEADUSKOND
MEHAANIKAINSTITUUT
TEADUS- JA ARENDUSTEGEVUSE AASTAARUANNE 2013

1. Struktuur

Mehaanikainstituut / Department of Mechanics, direktor Aleksander Klauson

- Tehnilise mehaanika õppetool, Chair of Engineering Mechanics, Aleksander Klauson
- Hüdro- ja aeromehaanika õppetool, Chair of Fluid and Aeromechanics, Tiit Koppel
- Rakendusmehaanika õppetool, Chair of Applied Mechanics, Andrus Salupere
- Hüdromehaanika teadus- ja katselaboratoorium, Laboratory of Fluid Mechanics, Ivar Annus
- Tugevuse teadus- ja katselaboratoorium, Laboratory of Strength of Materials, Hendrik Naar

2. Teadus- ja arendustegevuse (edaspidi T&A) iseloomustus

2.1 Struktuuriüksusesse kuuluvad uurimisgrupid *(kõik uurimisgrupid näidatakse aruandes eraldi, järgides alltoodud ülesehitust).*

2.1.1 Dünaamilised protsessid veesüsteemides / Dynamic processes in water systems, research group leader prof. Tiit Koppel

Research work description
The research of the group focuses on water dynamics and boundary interactions in the hydraulic systems: unsteady flow, transient flow, stratified flow, two-phase flow, etc. Engineering applications focus on energy efficiency analysis and optimization of hydraulic systems.

Water quantity modelling in water distribution systems

The aim of this investigation is to correct water flow fluxes in a water distribution system (WDS) on the basis of pressure measurements. The number of these parameters in this problem is usually quite large. Even the Levenberg–Marquardt Algorithm (LMA), which works quite fast, requires comparably long computer time. Decreasing of computer time is especially significant when estimating the real-time water fluxes in case of accidental or natural contaminations of WDS.

Water quality modelling in rivers

Evaluation of the contribution of the nitrogen leaching from the peat soils to nitrogen load coming from the watersheds and possibility to model this process.

Main results obtained in 2013
The stratified flow dynamics in the rotating system was experimentally analysed. Mixing intensity and buoyancy fluxes were quantified for the bottom gravity current in the submerged channel with adverse wedge-shape bottom slope having background constant vorticity.
The development of accelerating pipe flow starting from rest was analysed, 1D and 2D models describing the development of accelerating pipe flow were verified using new experimental results gained in a large scale pipeline system.
A semi-empirical method was developed to estimate pressure losses in complex pipeline systems.

Parametrization of the air-water interactions in the rapid filling and emptying processes of the hydraulic system has been performed.

Water quantity modelling in water distribution systems

Results showed that the optimization procedure can be used to find real-time water fluxes in WDS on the basis of pressure measurements. Minpack software (with our modifications) works quickly and gives quite stable results even with 20 parameters. Computer time was less than 1 min on the computer with eight processors for operational WDS containing more than 2000 pipes for one simulation time.
Calculations showed also that the stability of results depends on the steps along the parameters when calculating Jacobian. Therefore it is necessary to repeat the calculations 3–4 times with different steps. However, even in this case computer time is applicable for evaluation of the propagation rate of contaminated zones in case of deliberate or accidental chemical or biological threats.
Hydraulic power capacity of the water distribution network was analysed, and energetically optimal flows in pipes and networks were determined.
Full water network model of Tallinn City was calibrated using industry standard tools. Some calibration results were compared with research group's in-house tools. Conclusions were made in respect of algorithm's easiness of use, calibration speed and calibration results (in respect of errors that satisfied water company).

Water quality modelling in rivers

Results showed that the drained peat soils must be regarded as a noticeable diffuse source of nitrogen in Estonia.
The leaching of nitrogen from drained peat soils can be modelled by SOIL and SOILN models at the watershed scale using several modifications proposed. This provides a possibility to simulate nitrogen leaching from the drained peat soils in a longer perspective (for several decades).

Research group publications

1. Koppel, T.; Vassiljev, A. (2013). Estimation of real-time water fluxes in water distribution system on the basis of pressure measurements. Advances in Engineering Software, 66, 19 - 23.
2. Vassiljev, A.; Blinova, I. (2013). Overview of water quality problems in Estonia with the focus on drained peat areas as a source of nitrogen. Berit Arheimer (Toim.). Understanding Freshwater Quality Problems in a Changing World (69 - 76). IAHS Press, CEH Wallingford, Oxfordshire OX10 8BB, UK: IAHS
3. Annus, I.; Koppel, T.; Sarv, L.; Ainola, L. (2013). Development of Accelerating Pipe Flow Starting From Rest. ASME Journal of Fluids Engineering, 135(11), 111204-1 - 111204-10, DOI:10.1115/1.40255256.
4. Cuthbertson, A.; Lundberg, P.; Davies, P.; Laanearu, J. (2013). Gravity currents in rotating, wedge-shaped, adverse channels. Environmental Fluid Mechanics, DOI 10.1007/s10652-013-9285-4.

2.1.2 Laevaehituse töörühm / Maritime engineering research group, Senior Reseacher Kristjan Tabri

Research work description

Scientific work concentrated on the development of Accidental Damage Assessment Model (ADAM) combining structural damage assessment model, oil spill model and ultimate strength model. The model allows time-efficient analysis of maritime accidents and is suitable to analyse the maritime transportation risks in certain sea regions. ADAM model was used to evaluate large

number of collision and grounding scenarios based on the traffic flows in the Gulf of Finland. The effects of different risk control options were studied. ADAM model was also used to simulate possible grounding accidents close to Muuga harbour. The oil spill data was then used in SmartResponseWeb to evaluate possible oil spill trajectories. Web-based application of ADAM was generated and is linked to the SmartResponseWeb.

Main results obtained in 2013

Development of Accidental Damage Assesment Model (ADAM) and its simplified web-based applications. Finalizaton of risk analysis for the maritime transportation in the Gulf of Finland within the framework of Interreg IV A MIMIC project.

Research group publications

1. Heinvee, M., Tabri, K., Kõrgesaar, M. A simplified approach to predict the bottom damage in tanker grounding (2013) Collision and Grounding of Ships and Offshore Structures - Proceedings of the 6th International Conference on Collision and Grounding of Ships and Offshore Structures, ICCGS 2013, pp. 161-169.
2. Sergejeva, M., Laanearu, J., Tabri, K. Hydraulic modelling of submerged oil spill including tanker hydrostatic overpressure (2013) Analysis and Design of Marine Structures - Proceedings of the 4th International Conference on Marine Structures, MARSTRUCT 2013, pp. 209-217.

2.1.3 Mittepurustav kontroll ja allvee akustika / Non-destructive evaluation (NDE) and acoustics research group, prof. Aleksander Klauson

Research work description

Non-destructive evaluation

NDE research is aiming to elaborate new ultrasonic testing techniques and to develop effective algorithms for defect detection. A challenge is to increase the performance of such systems which can generate high resolution defect maps of a large inspection area such as plate and pipe structures. It is important to improve detection techniques and algorithms in order to increase the performance of the transducer array technology. NDE methods are used to characterize adhesively bonded joints. A clear need exists for the development of non-destructive testing techniques to monitor long term performance of adhesive joints.

Underwater acoustics

Underwater noise caused by human activities is becoming an important issue as the density of ship traffic and off-shore construction is increasing. The evaluation of sound pressure levels produced by submerged structures is a part of regulations on underwater noise pollution. Different measurements and modelling are required to evaluate actual underwater noise pollution levels. Underwater sound field of a submerged structure can be also interpreted in terms of elastic waves generated in the structure and radiated into the surrounding medium. The information about structural vibrations is important for the realistic directivity pattern of source.

Main results obtained in 2013

Non-destructive evaluation

The orthogonality relation-based method is developed for post-processing Finite Element (FE) predictions in order to separate Lamb modes at a plate edge. The reflected wave field from the free edge is assumed to be a superposition of all the eigenmodes of an infinite plate. The eigenmode

coefficients of the reflected wave field are determined by adapting the orthogonality-based method that was used to determine the reflection coefficients of Lamb modes at a plate edge. Overlapping wavepackets of Lamb modes at a plate edge are simulated by using the FE model of the incident S0 mode in a plate with a crack. Time-domain signals of propagating, non-propagating and complex modes are extracted.

Underwater acoustics.

The study of the underwater acoustic radiation of a stainless steel tube subjected to vibrations generated by a shock obtained by using a hammer is carried out. The vibrations of the tube, placed successively in air and in water, are measured by using accelerometers. In water, the acoustic radiation measurements are performed by using a hydrophone. Results are presented as frequency spectra and are confronted with results of the elastic theory.
Acoustic data-loggers have been tested, calibrated and deployed in the Baltic Sea in frames of BIAS project.

Research group publications

1. Van de Loock, J.; Decultot, D.; Leon, F.; Chati, F.; Maze, G.; Rajaona, R.; Klauson, A. (2013). Acoustic radiation of a submerged cylindrical shell in low frequency. Journal of the Acoustical Society of America, 133(1), EL26 - EL32.
2. Ratassepp, M; Klauson, A; Chati, F; Leon, F; Maze, G (2013). Separation of Lamb modes at a plate edge by using orthogonality relation. Estonian Journal of Engineering, 19(4), 283 - 291.
3. Ratassepp, M.; Chati, F.; Klauson, A. (2013). Using orthogonality-relation for the separation of Lamb modes at a plate edge. *In: OAS 2013 Proceedings of the 2nd International Conference of Optimization and Analysis of Structures : 2nd International Conference of Optimization and Analysis of Structures . (Toim.) J. Lellep, E. Puman.*, 2013.

2.3 Loetelu struktuuriüksuse töötajatest, kes on välisakadeemiate või muude oluliste T&Aga seotud välisorganisatsioonide liikmed.

- Janek Laanearu, IAHR liige (International Association for Hydro-Environment Engineering and Research)

- Janek Laanearu, EUROMECH liige (European Mechanics Society)

- Janek Laanearu, SGF liige (Svenska Geophysica Föreningen)

- Aleksander Klauson, ASA liige (Acoustical Society of America)

- Tiit Koppel, IAHR liige (International Association for Hydro-Environment Engineering and Research)

- Kristjan Tabri, ISSC Eesti correspondent (International Ship and Offshore Structures Congress) and is a member of Accidental Limit State committee

- Anatoli Vassiljev, Nordic Association for Hydrology liige

- Anatoli Vassiljev, ICWQ liige (International Commission on Water Quality)