EHITUSTEADUSKOND
MEHAANIKAINSTITUUT
TEADUS- JA ARENDUSTEGEVUSE AASTAARUANNE 2014

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, Ivar Annus
- 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 / Senior Researcher Ivar Annus

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 including the development of optimal pumping schedule and comparative studies of various calibration algorithms' performance on real network data.

Reduction of risks and energy consumption in hydraulic systems

The aim of the investigation was to elaborate new methods to reduce energy consumption in water distribution systems (WDS). The development of optimal pumping schedule was formed into a simple graphical visual tool that finds all possible working points for a given pump set. It allows to compare any pump station performance with real measurements and can be easily applied in engineering applications. Comparative studies for various calibration algorithms were carried out to evaluate their performance when available data is limited.

Hydraulic power capacity of the water distribution network (WDN) was analysed, and energetically maximum flows in pipes and networks were determined. The concept of hydraulic power for the analysis of WDN characteristics was presented. A capacity reliability indicator called the surplus power factor was introduced for individual transmission pipes and for distribution networks. A case study was conducted in order to determine the network resistance coefficient and hydraulic capacity in the water network in service. The influence of the new energy efficiency index (EEI) on the pumps performance in order to reduce energy consumption and carbon dioxide (CO_2) emission in hydraulic systems was analysed.

Unsteady and stratified flow in hydraulic systems

Stratified flow mixing in the hydraulic systems, where the water originates from different sources was experimentally investigated. The gravity current propagation and the critical flow conditions due to the effects of boundary friction and interfacial shear was studied.
Two-phase unsteady flow in pipes where liquid flows along the bottom and gas flows above was experimentally investigated. It was determined that during the pipeline filling and emptying two-phase flow can reveal different dynamics due instability and mixing e.g. when mixing between liquid and gas is absent and flow reveals open-channel like dynamics and when the fluids (e.g. water and air) are mixed and flow reveals dynamical effects due to compressibility.

Main results obtained in 2014

Reduction of risks and energy consumption in hydraulic systems

It was shown that a novel procedure can be used to optimize the operation of pumps with the same and with different characteristics. An algorithm to regulate the pumps switching on/off in a pumping station in order to save energy was developed. It was found that a simple tool to evaluate optimal pumping schedules can be a first trigger to find optimal solutions for energy use.
A water distribution system in service was analysed to demonstrate the surplus power factor values under different demand conditions. In order to calculate the factor for WDNs, a network resistance coefficient C was determined. A theoretical approach to determine the coefficient C through matrix equations was introduced. This approach was found to be the most accurate in estimating the networks hydraulic capacity in a real water network case study. It was shown that the energy consumption of new energy efficient pumps compared to old models can be reduced in laboratory conditions up to 59 % and electricity cost by around 50 %.

Unsteady and stratified flow in hydraulic systems

It was found that in the case of relatively steeply inclined submerged channel, the dense-water bottom current can be frictionally-controlled. For the mildly sloped channel, the dense water outflow can be hydraulically-controlled, with internal flow dynamics characterised by increasing isopycnal separation in the along-channel direction. Analysis of the gradient Richardson number Ri_g of the flow confirmed that hydraulically-controlled flows dilute the active bottom water due to interfacial mixing.
It was found that the pipeline emptying dynamics is similar to the filling dynamics in respect of the two-phase flow front dynamics. It was demonstrated that the water-air front that enters into the large-scale pipeline splits into two water-fronts during the filling process. The along-flow pressure gradient in the case of filling corresponds to the rigid-column motion. Thus the pressure changes are different in the pipeline emptying and filling processes.

Research group publications

1. Vaabel, J; Koppel, T; Ainola, L; Sarv, L. (2014). Capacity reliability of water distribution systems. Journal of Hydroinformatics, In press.
2. Laanearu, J.; Cuthbertson, A.J.S.; Davies, P.A. (2014). Dynamics of dense gravity currents and mixing in an up-sloping and converging vee-shaped channel. IAHR Journal of Hydraulic Research, 52(1), 67 - 80.
3. Hou, Q.; Tijsseling, A. S.; Laanearu, J.; Annus, I.; Koppel, T.; Bergant, A.; Vučković, S.; Anderson, A.; van 't Westende, J. M. C. (2014). Experimental Investigation on Rapid Filling of a Large-Scale Pipeline. ASCE Journal of Hydraulic Engineering, 140(11), 1 - 14.

4. Puust, R., Koor, M., Vassiljev, A. (2014). Water distribution model for decision-making with updatable data links. Journal of Water Supply: Research and Technology - AQUA, In Press, doi:10.2166/aqua.2014.038
5. Puust, R; Vassiljev, A. (2014). Real Water Network Comparative Calibration Studies Considering the Whole Process from Engineer's Perspective. Procedia Engineering, 89, 702 - 709.

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

Research work description

Collision analysis model was developed further by including the effects of the level ice on the collision dynamics. The ice load model is based on the Crossdale 2D model that allows to evaluate the ice interaction as a linear load. Ice load module was added to the time domain collision simulation model. Additionally a simplified version of the model was developed based on the conservation of the liner momentum.
Development of the simplified numerical model for the assessment of ship collision and grounding resistance was started by Martin Heinvee. The model is based on the idealization of ship bottom and side structures via larger structural elements, which are capable of considering the element bending, stretching, buckling and fracture within the element.
Accidental Damage Assessment Model (ADAM) combining structural damage assessment model, oil spill model and ultimate strength model was developed further to allow more logical structure for the input parameters

Main results obtained in 2014
Ice load module was added to the collision analysis tool. Model was used to conduct a parametric study on the ice effects on different collision scenarios. One journal article was submitted and three conference papers were prepared.

Research group publications
1. Montewka, J.; Ehlers, S.; Goerlandt, F.; Hinz, T.; Tabri, K.; Kujala, P. (2014). A framework for risk assessment for maritime transportation systems - a case study for open sea collisions involving RoPax vessels. Reliability Engineering & System Safety, 124, 142 - 157.

2. Kõrgesaar, M.; Tabri, K.; Reinhold, E.; Naar, H. (2014). Ship Collision Simulations Using Different Fracture Criteria and Mesh Size. *In: Proceedings of 3rd International Conference on Ocean, Offshore and Arctic Engineering (OMAE2014): 3rd International Conference on Ocean, Offshore and Arctic Engineering (OMAE2014).* ASME (American Society of Mechanical Engineers), 2014.

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

Lamb modes are widely used for non-destructive evaluation of plate-like structures. One of the principal difficulties to a robust, rapid and accurate defect localization technique based on wideband, multi-mode guided waves is the multimodal response signal. Even if the incident wave is a pure Lamb mode, the interaction of a wave with a defect or structural feature can result in a complicated multimode signal due to mode conversions, since there may exist at least two propagating modes in a plate at any chosen testing frequency. It is important to separate wave-packets of different modes, as the relative amplitude of each received mode is dependent on the geometry and location of the defects. This provides more information about the defect and is vital for the development of inverse procedures for the defect characterization.

Composite pressure vessel approval can also be carried out according to the principles of structural reliability. The first step in this approach is establishing an annual probability of failure which can be viewed as acceptable for this structure. Experience from similar applications, which are already in widespread use, can be used as helpful guidance. Once the probability of failure is decided, safety factors can be calculated for all design/failure criteria. However, an acceptable probability of failure needs to be estimated before calculating the safety factors.

Underwater acoustics

Anthropogenic underwater noise 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 shipping in the Baltic Sea is performed in frames of EU project Baltic Sea Information on Acoustic Soundscape (BIAS). Obtained recordings should be treated in order to produce estimates of the sound pressure levels (SPL) in third-octave bands of 63Hz and 125Hz, which are considered as the most representatives for noise generated by ships. As the shipping noise is a part of ambient noise, it is important to reveal the influence of other factors contributing in it, as wave noise, Also the influence of the annual variations of the sound speed profiles and the bottom structure must be analysed.

Main results obtained in 2014

Non-destructive evaluation

A numerical and experimental procedure based on the Lamb mode orthogonality to separate various modes at a plate edge in a plane strain condition is developed. Overlapping wavepackets of S0 and A0 Lamb modes arriving at a plate edge are simulated by using the FE model and generated in the experiment of an incident S0 mode in a plate with a notch. The required wave field displacement components for the experimental procedure are measured with a 3D SLDV. It was demonstrated that it is possible to extract the signals of several propagating and non-propagating modes in time-domain. The proposed approach is attractive for NDT research because it provides new ways of analysing the signals and is much faster than the classical spatial two-dimensional Fast Fourier transform for mode separation.

Acceptance of different methods of calculation of annual probability of failure is discussed. Annual probability 10^{-8} is recommended to use for the annual probability of failure for all CGH2 pressure vessels, large or small, provided that the societal risk for the whole system remains acceptable.

Underwater acoustics.

Acoustic recordings have been obtained in frames of BIAS project. The analysis of the preliminary results has shown that apart from general signal processing needed by project, additional tools are

necessary for effective SPL analysis, such as AIS and acoustical data synchronisation, sound propagation modelling nearby the recorder. To reveal the presence of the shipping noise the statistical analysis is applied.

Research group publications

1. Ratassepp, M.; Klauson, A.; Chati, F.; Léon, F.; Décultot, D.; Maze, G.; Fritzsche, M. (2015). Application of orthogonality-relation for the separation of Lamb modes at a plate edge: Numerical and experimental predictions. Ultrasonics, 57, 90 - 95.
2. Echtermeyer, A. T.; Lasn, K. (2014). Safety approach for composite pressure vessels for road transport of hydrogen. Part 2: Safety factors and test requirements. International Journal of Hydrogen Energy, 39(26), 14142 - 14152.
3. Lasn, K.; Echtermeyer, A. T. (2014). Safety approach for composite pressure vessels for road transport of hydrogen. Part 1: Acceptable probability of failure and hydrogen mass. International Journal of Hydrogen Energy, 39(26), 14132 - 14141.

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)

- 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)