EHITUSTEADUSKONNA MEHAANIKAINSTITUUDI TEADUS- JA ARENDUSTEGEVUSE AASTAARUANNE 2011

1. Instituudi struktuur

Instituudi direktor Tiit Koppel

- 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. Instituudi teadus- ja arendustegevuse (edaspidi T&A) iseloomustus
(NB! punktid 2.1- 2.6 täidab struktuuriüksus)

2.1 struktuuriüksuse koosseisu kuuluvate uurimisgruppide
    2.1.1 teadustöö kirjeldus *(inglise keeles)*;

A simplified ship collision and grounding simulation model was developed further and partially validated. The model uses precise numerical simulations for its calibration and can be used for time efficient simulation of large number of collision and grounding accidents. The simplified model is being used in MIMIC project to conduct a risk analysis for the oil transportation in the Gulf of Finland. In the field of strength of structures in the liquid the coupled beam method has been developed further for strength assessment of multi-deck ships.

Ultrasonic guided waves have the advantage of propagating over large distances in plates and pipes, thus allowing the fast and efficient detection of defects in large structures. Despite the rapid progress in the field, describing the interaction of guided waves with structural features remains a complex task, which needs a priori modelling and understanding. Last year the focus was directed on the studies of the interactions of symmetric Lamb mode S0 with a through-thickness straight-edge notch. The scattered wave-fields at a notch were examined using finite element simulations and experimental measurements. Secondly, the possibility to detect axial defects in cylindrical pipes by using synthetic focusing method via finite element modelling was investigated. The software based on global optimization algorithm is developed to determine elastic properties of composite plate by inverse problem solution.

Water network modelling tasks (modelling & optimization) are complex and heavily dependent on data availability. Real time data streams demand efficient ways to read/evaluate it and also for processing tasks. In 2011 two main directions were taken to improve data processing procedures as well as incorporating today's hardware for optimization (processing) tasks. First, water network modelling development directions were searched, analysed and optimized based on Tallinn 80'000 pipe model. Secondly, graphical processing units (GPUs) suitability for water network modelling tasks was researched. Optimizations in general are very compute-intensive. Therefore finding new, approved ways, to quicken data processing, shortens the time-frame that is needed to make decisions.

The energy transfer has been investigated theoretically and experimentally in pipe systems (networks, water hammer, two-phase flow, cavitation), and the analysis of the efficiency and hydraulic reliability in water systems has been studied. Hydraulic modelling is used to analyse net and internal flows in environmental systems and numerical model is under development, considering contaminants dynamics.

Conventional test methods for measuring elastic constants are often destructive and require several kinds of sophisticated tests to obtain all data. Non-destructive methods to determine the effective elastic constants of composite plates can be based on static measurements, vibration testing or on the measurements of ultrasonic wave velocities. The last group of methods is most suitable to be used in guided wave non-destructive examination (NDE) system for the automated inspection of a component in a structure. Lamb waves, dispersive by nature, are frequently used with an inverse procedure to determine the elastic constants of a homogenous anisotropic plate. Dispersion curves characterizing wave propagation in different directions are traced from experimental data obtained with an excitation of the glass-fiber composite plate by piezoelectric transducer and displacement measurements with laser interferometer. A sensitivity analysis of the elastic constants to the phase velocity in orthotropic composite plate is made to choose better initial data. A hybrid optimization procedure consisting of genetic algorithm with simplex method is applied to the experimental dispersion curves to determine the effective elastic constants of an orthotropic composite plate.

The interaction of the axisymmetric Lamb type mode S1 (called also L(0,4)) with a resin deposit coupled to the wall of a stainless steel pipe is studied. The considered deposit has a shape of axisymmetric ring. The purpose of this work is to analyze in detail the damping of the mode S1 as function of the variation of the deposit width.

2.1.2 aruandeaastal saadud tähtsamad teadustulemused *(inglise keeles).*

Rigid water-column model was developed to investigate the water-air front motion during filling of pipe. Gradual changes of inflow rate of water column, advancing into the empty or partially filled domain of the pipe, were analyzed. Fluctuations of the flow due to free-surface waves and air mixing were observed during the filling of stratified pipes. An optimization procedure was proposed to obtain the proportions of real and apparent leakages in calibration of a water distribution system (WDS). Nonlinear optimization with linear constraints was used for the redistribution of leakages over a WDS. The methodology proposed allowed to exclude the influence of systematic errors on the result of calibration. A uniformly accelerated laminar flow in pipe, initially at rest, was analyzed. It has been shown that in pipes with large diameters and at modest acceleration rates the transition to turbulence takes place at different time steps over the pipe length. From experimental results obtainable, it follows that the logarithms of the time of transition is the linear function of the logarithms of the acceleration.

Hydraulic modelling is used to analyse mixing conditions for net exchange flows in environmental systems and dense-water bottom gravity currents in laboratory rotating systems. The model has been developed for simulation of nutrient concentrations in a river system.

Simplified ship collision model was partly validated with numerical simulations. This validation proves the feasibility of such simplified approach.

The study of S0 Lamb mode interaction with a notch showed that the orientation of the notch is an important parameter describing the defect detection sensitivity. The strongest sensitivity was obtained by measuring straight reflection from a notch. In the pipe study the dependence of the reflection coefficient on crack length was measured for both through thickness and part depth axially aligned defects, at a range of frequencies, using the torsional guided wave family. The results show that the reflection coefficient is increased when focusing is employed, compared to the sensitivity for unfocused fundamental torsional waves. However the sensitivity is still very low, so in practise this approach could only be used to find severe defects.

A test plate specimen (30x30cm glassfiber/epoxy crossplied laminate) was produced and uniformly damaged (saturated cracked state artificially created) with tensile loading. It was measured afterwards in Le Havre for Lamb wave propagation in principal directions and in TUT for free vibration frequencies. Experimental data has been collected and it is to be processed and published in the near future. Genetic algorithm procedures (SGA, mGA) were developed and applied to inverse problems based on Lamb wave propagation and free vibration measurements. Results from these two methods agreed well and also were close to results from simple static testing. These results were presented in two international conferences. Uncertainty estimation for the elastic constants is required in order to quantify fatigue damage in the future. Uncertainty in the ply moduli measurement was evaluated from simple static tests for cross-plied laminates.

The attenuation of axisymmetric guided waves caused by a circular shape deposit placed on the pipe wall is studied. For this, the mode S1 is generated on the section of the tube by a piezoelectric transducer at a frequency corresponding to an axial phase velocity Cz equal to the velocity of bulk longitudinal wave. The reception of this wave is realized by means of a flexible comb transducer wrapped around the tube. The attenuation of the experimental echo amplitude related to the mode S1 is after compared to the attenuation of the theoretical echo amplitude of this wave. This echo is obtained by using the finite element method and a basic simulation of the comb transducer. A strongly axial wave is used for a tube filled with water because the S1 wave, at some particular frequency is able to distinguish the deposit, independently of the presence of the fluid. It appears, experimentally and theoretically, that the attenuation of this wave can be characterized by an exponential law when the tube filled or not with water. It must be noted that the evolution of the attenuation of the mode S1 versus the width is quasi linear. This wave can be used to estimate the width of a deposit.

2.2 Uurimisgrupi kuni 5 olulisemat publikatsiooni läinud aastal.

Cuthbertson, A.; Laanearu, J.; Wahlin, A.; Davies, P. (2011). Experimental and analytical investigation of dense gravity currents in a rotating, up-sloping and converging channel. Dynamics of Atmospheres and Oceans, 52, 386 - 409.

Lasn, K.; Klauson, A.; Chati, F.; Décultot, D. (2011). Experimental determination of elastic constants of an orthotropic composite plate by using Lamb waves. Mechanics of Composite Materials, 47(4), 435 - 446.

Annus, I; Koppel, T. (2011). Transition to Turbulence in Accelerating Pipe Flow. J. Fluids Eng.-Trans. ASME, 133(7), 071202-1 - 071202-9.

Pill, I; Tabri, K. (2011). Finite element simulations of ship collisions: A coupled approach to external dynamics and inner mechanics. Ships and Offshore Structures, 6(1-2), 59-66.

2.3 Loetelu struktuuriüksuse töötajate rahvusvahelistest tunnustustest.

- dotsent Janek Laanearule määrati Suurbritannia Kuningliku Inseneriakadeemia stipendium (Royal Academy of Engineering Distinguished Fellowship, London, UK) koostöö raames toimuvaks uurimistööks Dundee Ülikoolis (oktoober 2011.a.)

2.4 Loetelu struktuuriüksuse töötajatest, kes on välisakadeemiate või muude oluliste T&A-ga 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)

- Anatoli Vassiljev, Nordic Association for Hydrology liige

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

2.5 Aruandeaasta tähtsamad T&A finantseerimise allikad.

- T072, Vedeliku ja konstruktsiooni koostoime mehaanika
- AP072, Vedeliku ja konstruktsiooni koostoime mehaanika
- VIR519, Minimizing risks of maritime oil transport by holistic safety strategies
- Lep11010, Tallinna linna veevõrgu mudeli kaasajastamine reaalajas juhitavate toimingutega
- ETF7900, Tõenäosuslik prao avastamise modelleerimine mittepurustavas kontrollis
- ETF7646, Vedeliku voolamise dünaamika survetorudes
- ETF8718, Laeva karilesõidul tekkivate vigastuste modelleerimine arvmeetodite abil arvestades liikumisdünaamikat

2.6 Soovi korral lisada aruandeaastal saadud T&A-ga seotud tunnustusi (va punktis 2.3 toodud tunnustused), ülevaate teaduskorralduslikust tegevusest, teadlasmobiilsusest ning anda hinnang oma teadustulemustele.

- doktorant Kaspar Lasn viibis kevadsemestril Norras NTNU-s doktorikooli ja DoRa projekti toetusel. Uurimistöö NTNU toimus komposiitide/polümeeride laboratooriumis

- vanemteadur Madis Ratassepp, Heinrich Laulu stipendium, SA TTÜ Arengufond

2.7 Instituudi teadus- ja arendustegevuse teemade ja projektide nimetused *(Eesti Teadusinfosüsteemi, edaspidi ETIS, andmetel)*

- Haridus- ja Teadusministeerium
sihtfinantseeritavad teemad:
  - T072, Vedeliku ja konstruktsiooni koostoime mehaanika, Tiit Koppel

baasfinantseerimise toetusfondist rahastatud projektid (sh TTÜ tippkeskused):
riiklikud programmid:

- <u>Teiste ministeeriumide poolt rahastatavad riiklikud programmid:</u>

- <u>Uurija-professori rahastamine:</u>

- <u>SA Eesti Teadusfond</u>

grandid:
- ETF7900, Tõenäosuslik prao avastamise modelleerimine mittepurustavas kontrollis, Aleksander Klauson

- ETF7646, Vedeliku voolamise dünaamika survetorudes, Tiit Koppel

- ETF8718, Laeva karilesõidul tekkivate vigastuste modelleerimine arvmeetodite abil arvestades liikumisdünaamikat, Kristjan Tabri

ühisgrandid välisriigiga:
järeldoktorite grandid (SA ETF ja Mobilitas):
- MJD110, Coupled approach for numerical modelling of accidents in maritime transportation, Kristjan Tabri

tippteadlase grandid (Mobilitas):

- <u>Ettevõtluse Arendamise SA</u>

eeluuringud:
arendustoetused:

- <u>SA Archimedesega sõlmitud lepingud</u>

infrastruktuur (nn „mini-infra“, „asutuse infra“):
- AP072, Vedeliku ja konstruktsiooni koostoime mehaanika, Tiit Koppel

Eesti tippkeskused:
riiklikud programmid:
muud T&A lepingud:

- <u>SA Keskkonnainvesteeringute Keskusega sõlmitud lepingud:</u>

- <u>Siseriiklikud lepingud:</u>
- Lep11010, Tallinna linna veevõrgu mudeli kaasajastamine reaalajas juhitavate toimingutega, Raido Puust

- <u>EL Raamprogrammi projektid:</u>

- <u>Välisriiklikud lepingud:</u>
- VIR519, Minimizing risks of maritime oil transport by holistic safety strategies, Kristjan Tabri

2.8 Struktuuriüksuse töötajate poolt avaldatud sihtfinantseeritava teadusteema taotlemisel arvestatavad eelretsenseeritavad teaduspublikatsioonid *(ETIS klassifikaatori alusel 1.1, 1.2, 1.3, 2.1, 2.2, 3.1, 3.2, 3.3, 4.1 ja 5.1).*

<u>1.1</u>

Lasn, K.; Klauson, A.; Chati, F.; Décultot, D. (2011). Experimental determination of elastic constants of an orthotropic composite plate by using Lamb waves. Mechanics of Composite Materials, 47(4), 435 - 446.

Cuthbertson, A.; Laanearu, J.; Wahlin, A.; Davies, P. (2011). Experimental and analytical investigation of dense gravity currents in a rotating, up-sloping and converging channel. Dynamics of Atmospheres and Oceans, 52, 386 - 409.

Chati, F.; Léon, F.; El Moussaoui, M.; Klauson, A.; Maze, G. (2011). Longitudinal mode L(0,4) used for the determination of the deposit width on the wall of a pipe . NDT&E International, 44(2), 188 - 194.

Annus, I; Koppel, T. (2011). Transition to Turbulence in Accelerating Pipe Flow. J. Fluids Eng.-Trans. ASME, 133(7), 071202-1 - 071202-9.

Pill, I; Tabri, K. (2011). Finite element simulations of ship collisions: A coupled approach to external dynamics and inner mechanics. Ships and Offshore Structures, 6(1-2), 59-66.

<u>1.2</u>

Ratassepp, M.; Fletcher, S.; Klauson, A. (2011). Axial defect imaging in a pipe using synthetically focused guided waves. Estonian Journal of Engineering, 17(1), 66 - 75.

Laanearu, J.; Vassiljev, A.; Davies, P. A. (2011). Hydraulic modelling of stratified bi-directional flow in a river mouth. Engineering and Computational Mechanics, 164 (EM4), 207 - 216.

<u>3.1</u>

Romanoff, J.; Remes, H.; Bralic, S.; Naar, H.; Niemelä, A.; Jelovicam, J.; Klanac, A.; Varsta, P. (2011). Hull/superstructure-interaction in optimized passenger ships. Advances in Marine Structures. Proceedings of the 3rd International Conference on Marine Structures: 3rd International Conference on Marine Structures.. (Toim.) Guedes Soares; W. Fricke. Taylor & Francis, 2011, 625 - 632.

Tabri, K.; Broekhuijsen, J. (2011). Influence of ship motions in the numerical prediction of ship collision damage. In: Advances in Marine Structures. Proceedings of the 3rd International Conference on Marine Structures: 3rd International Conference on Marine Structures. (Toim.) C. Guedes Soares; W. Fricke. Taylor & Francis, 2011, 391 - 397.

Koppel, T.; Vassiljev, A. (2010). Calibration of water distribution network for BWCN. In: Proceedings of the 12th International Conference: Water Distribution Systems Analysis 2010. ASCE, 2010, 9 pp. doi:10.1061/41203(425)142

<u>3.2</u>

Laanearu, J.; Annus, I.; Raidmaa, M.; Koppel, T. (2011). Transient flow during filling of horizontal pipe containing water. In: Urban Water Management: Challenges and Opportunities: Eleventh International Conference on Computing and Control for the Water Industry (CCWI2011), University of Exeter, 5-7 September. (Toim.) Dragan A. Savić, Zoran Kapelan, David Butler. Exeter, UK: Centre for Water Systems, University of Exeter, 2011, 913 - 918.

Koppel, T.; Vassiljev, A. (2011). Correction of Demand Patterns on the Basis of Pressure Measurements. Thirteenth International Conference on Civil, Structural and Environmental Engineering Computing. (Toim.) B.H.V. Topping Y. Tsompanakis. Civil-Comp Press, Stirlingshire, Scotland:, 2011, 1 - 9.

Cuthbertson, A.; Davies, P.; Laanearu, J.; Wåhlin, A. (2011). Dense Gravity Currents in Rotating, Up-sloping and Converging Channel. In: Proceedings of VII International Symposium of Stratified Flows: ISSF2011, Sapienza Universita Di Roma, Rome 22nd-26th of August, Italy. (Toim.) Antonio Cenedese, Stefania Espa, Roperto Punini., 2011.

Laanearu, J.; Cuthbertson, A.; Davies, P. (2011). Dense-Water Overflow in A Converging and Up-sloping Channel. In: Proceedings of VII International Symposium of Stratified Flows: ISSF2011, Sapienza Universita Di Roma, Rome 22nd-26th of August, Italy . (Toim.) Antonio Cenedese, Stefania Espa, Roperto Punini., 2011.

Puust, R.; Maddison, M.; Laanearu, J. (2011). Reviewing the effectiveness of GPU power when used for water network optimization problems. In: Urban Water Management: Challenges and Opportunities: Eleventh International Conference on Computing and Control for the Water Industry (CCWI2011), University of Exeter, 5-7 September. (Toim.) Dragan A. Savić, Zoran Kapelan, David Butler. Exeter, UK: Centre for Water Systems, University of Exeter, 2011, 3 - 8.

Vassiljev, A.; Koppel, T.; Saare, A. (2011). Sensitivity of calibration results to uncertainties in input data: case of operational water distribution system. In: Urban Water Management: Challenges and Opportunities: Eleventh International Conference on Computing and Control for the Water Industry (CCWI2011), University of Exeter, 5-7 September. (Toim.) Dragan A. Savić, Zoran Kapelan, David Butler. Exeter, UK: Centre for Water Systems, University of Exeter, 2011, 713 - 718.

2.9 Struktuuriüksuses kaitstud doktoriväitekirjade loetelu *(NB! struktuuriüksus lisab struktuuriüksuse töötaja juhendamisel mujal kaitstud doktoriväitekirjade loetelu)*

Kert Tamm, mehaanikainstituut ja Küberneetika Instituut
Teema: Wave Propagation and Interaction in Mindlin-Type Microstructured Solids: Numerical Simulation (Lainelevi ja interaktsiooni numbriline modelleerimine Mindlini tüüpi mikrostruktuursetes tahkistes)
Juhendaja: prof. Andrus Salupere
Kaitses: 27.04.2011
Omistatud kraad: filosoofiadoktor (rakendusmehaanika)

Toomas Liiv, mehaanikainstituut
Teema: *Experimental Analysis of Boundary Layer Dynamics in Plunging Breaking Wave* (Sukelduva murdlaine piirikihi dünaamika eksperimentaalne analüüs)
Juhendaja: prof Aleksander Klauson
Kaasjuhendaja: emeriitprof Klas Cederwall
Kaitses: 24.05.2011
Omistatud kraad: filosoofiadoktor (ehitus ja keskkonnatehnika)

Ivar Annus, mehaanikainstituut
Teema: *Development of Accelerating Pipe Flow Starting from Rest* (Paigalseisust algava kiireneva voolamise areng torus)
Juhendaja: prof Tiit Koppel
Kaitses: 8.11.2011
Omistatud kraad: filosoofiadoktor (ehitus ja keskkonnatehnika)

2.10 Struktuuriüksuses järeldoktorina T&A-s osalenud isikute loetelu *(ETIS-e kaudu esitatud taotluste alusel)*

MJD110, Coupled approach for numerical modelling of accidents in maritime transportation, Tabri Kristjan

2.11 Struktuuriüksuses loodud tööstusomandi loetelu

3. Struktuuriüksuse infrastruktuuri uuendamise loetelu

- Avasängis vee kvaliteedi mõõtekomplekt, 10.01.2011, 3 611 €
- Vooluhulgamõõtur Promag 53W40, 13.01.2011, 2 422 €
- Avasängi vooluhulga ja sademete mõõtur,1 1.02.2011, 18 049 €
- Impulssgeneraator DPR300, 7.04.2011, 3 200 €
- Mõõtetulemuste salvestussüsteem, 3.05.2011, 9 074 €
- Arvuti HP Workstation z600 -MT, 18.07.2011, 2 230 €

4. Struktuuriüksuse poolt korraldatud seminarid

- Ehituse ja keskkonnatehnika doktorikooli raames toimus 9-12. september 2011.a. TTÜ-s intensiivkursus „Optimaalsed lahendused veemajanduses". Välislektoritest osalesid kursusel prof. Angus Simpson, Adelaide Ülikool, Austraalia ja prof. Zoran Kapelan, Exeteri Ülikool, Suurbritannia. Koolitusel osalesid loengutega samuti hüdro- ja aeromehaanika õppetooli õppejõud ja teadlased.
- Komposiitmaterjalide seminar toimus 10. november 2011.a. Loengutega esines prof. Andreas Echtermeyer Norra Teaduse ja Tehnoloogia Ülikoolist (NTNU), prof. Urve Kallavus, vanemteadur Jüri Majak, doktorand Kaspar Lasn ja doktorand Georg Allikas.

5. Arvamused ja ekspertiisid

- Süstmördi kasutamisest torustiku renoveerimisel sujutusmeetodil. Arvamus Tallinn-Muuga vee- ja kanalisatsiooniühendustorustike baasil. AS Nordecon tellimus.
- Eksperthinnang HPDE kile kasutamiseks Kohtla-Järve tööstusjäätmete ja poolkoksi prügila sademevee ärajuhtimiseks. AS Pöyry Entec tellimus.
- Püssi peapumpla torustiku keevisühenduse vigastus. Arvamuse tellija AS K&H.
- Veepuhastusjaama osooni kompressori (rootorpuhuri) arvutused. Tellija AS Tallinna Vesi.