

# MEHAANIKATEADUSKONNA MEHHATROONIKAINSTITUUDI TEADUS- JA ARENDUSTEGEVUSE AASTAARUANNE 2011

## 1. Instituudi struktuur

Instituudi direktor Mart Tamre

- Mehhatroonikasüsteemide õppetool, Chair of Mechatronics Systems, Mart Tamre
- Masinaelementide ja peenmehaanika õppetool, Chair of Machine Elements and Fine Mechanics, Priit Põdra
- Masinamehaanika õppetool, Chair of Machine Mechanics, Merle Randrüüt
- Kvaliteeditehnika ja metroloogia õppetool, Chair of Quality Engineering and Metrology, Andres Kiitam
- Mehhatroonika-, masina- ja mõõtesüsteemide teadus- ja katselaboratoorium, Laboratory for Mechatronics, Machine and Measurement Systems

## 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*);

#### **Metrology and Quality Engineering**

The metrology group was recreated to strengthen and enhance competence in metrology at TUT and Faculty of Mechanical Engineering. The main focus of research is in development of measurement methods for establishment of metrological traceability to SI units with growing and/or emerging needs. Amongst the others, measurement techniques in traceability dissemination of possible re- definition in terms of photons of unit of luminous intensity, the *candela* have been improved by participation in international as well as in national collaboration. It was found that with the implementation of a special attenuator consisting of ten photodiodes, the uncertainty in calibration of SPAD (*Single Photon Avalanche Detector*) can be approximately 0,3 %. Another area of research is in development of fully characterized method for electrical conductivity, both in DC and AC methods. It was shown that with the use of equipment of moderate accuracy, the calibration relative uncertainty of samples can be achieved 0,2 %-0,3 %. Also, special coil-type calculable electromagnetic sensors were designed for further studies in covering the gap between measurement accuracy with DC and AC measurement techniques. Study of accurate methods for measurement of electrical conductivity of reference standards has been a focus of the activity too. Instruments designed for conductivity measurements are widely exploited by research and industry. The modern devices operate at frequencies up to 1 MHz with the relative expanded uncertainty of about 1 % of the measured value. Accuracy of the measurement instruments is ensured by use of external measurement standards. In close collaboration with AS Metrosert the methods for traceable measurements of the conductivity standards have been investigated: Van der Pauw method (dc current) and eddy-current method (ac current). Investigations of the eddy-current method for characterization of the conductivity standards at the alternative current have been started. For this purpose a set printed-circuit-board (pcb) planar sensors has been designed. Impedance of the sensors above a conductive medium will be measured by a calibrated impedance meter and substituted to the mathematical model developed by Dodd, C.V. and Deeds, W.E.

The results have been published in four scientific papers (incl *Measurement, Metrologia*) and presented in international conference *11th Int. Conf. on New Developments and Applications in Optical Radiometry* (NEWRAD 2011, Maui, HI, 19–23 September 2011). Two scientific papers have been submitted for publications and two conference presentations are prepared.

Therefore it could be concluded that despite of the unfavourable situation for the metrology research at the Faculty it was succeeded to start a serious research.

### **Machine Elements and Machine Mechanics**

The focus in the research is on multibody system dynamics and vibration analysis and monitoring targeted on modeling and optimization of systems and materials behavioral characteristics. People from the chairs of Machine Elements and Machine Mechanics are participating on many projects of which main are Mechatronic and Production Systems Proactivity and Behavioural Models and Advanced multiphase tribo-functional materials and Hard coatings and surface engineering and therefore consolidation of the research into one focus has been difficult.

One focus of the research is to extend the theoretical analysis methods of free vibration of grillages (skeletal structures) that consists of uniform beams with one axis of symmetry and to study the sensitivity of grillages by numerical examples. Main objective in case of thin-walled beams is to study the effect of warping onto the natural frequencies of grillages in two cases: I) when longitudinal members and crossmembers of grillages are adjoined at the nodes in plane and II) when beam members of grillages are adjoined at the nodes on each other. Therefore it is aimed to extend a simplified alternative approach for calculation of forced vibration of grillages under the action of repeated loading in the presence of hysteretic damping and to develop the simplified alternative approach for calculation of natural frequencies and corresponding mode shape of grillages in case, when reinforcing effect of the covering plate cannot be excluded from the dynamic analysis.

The second activity is focused on the testing activities on the tribometer Wazau 500 and developing consulting services for companies in the areas of strength and reliability of machines.

Third focus is on investigation of nonlinear evolution equation for wave propagation in bubbly liquids, taking into account viscosity and heat transfer, has been derived by Kudryashov and Sinelshchikov. In the case of no dissipation the authors have provided analytical solutions representing undistorted waves. These results are cast into a simpler form and studied in more detail. In addition to the wave profiles the corresponding phase curves are presented. Depending on some parameter the solutions represent solitary or periodic waves. Some of the periodic waves exhibit peaks or cusps. From the periodic waves a new type of “meandering” solutions is constructed.

### **Mechatronics Systems**

The research is focused on proactive smart machine and robotic and production systems, models and optimization for production and service system automation

Activity of is concentrated on two main subfields: Proactive decision support in networked collaborating enterprises of special tooling and machining clusters and modeling and design of proactive autonomous service and technology components. Intelligent prediction of manufacturing capability in enterprises cluster for preventing management failures enables achieving of near-zero down-time and the best possible quality of a product. Proactive hardware components will be able to react autonomously and flexibly to changing environments and configuration of the networked system structure according to the software control whereby service and industrial system components especially industrial or service robots and their component design are under investigation. Intelligent prediction of manufacturing capability in enterprises cluster for preventing management failures has been tested utilizing smart grid technology and several production models that enable achieving of greater efficiency. Proactive system behaviour have been investigated on the example of the whole production chain of wood product chain where the energy consumption in wide sense and environment impact is used as a driving parameters in a technology process. This kind of tests were performed for whole wood production chain where a subtask was automatic

building a sensor network in very beginning of operating materials for production of the artificial objects up to sensor systems at the endproduction, considering time and space separation and distribution of the information and decision/control processes. In parallel reconfigurable robot control algorithms have been investigated in case of modifying sensor network and multy-robot collaboration (UGV and UAV case) where the control optimization and mission planning from the safety critical and energy consumption wiewpoint is of interest.

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

Main achievements in research:

#### **Metrology and Quality Engineering**

- It was found that with the implementation of a special attenuator consisting of ten photodiodes, the uncertainty in calibration of SPAD (Single Photon Avalanche Detector) can be approximately 0,3 %.
- It was shown that with the use of equipment of moderate accuracy, the calibration relative uncertainty of samples can be achieved 0,2 %-0,3 %. Also, special coil-type calculable electromagnetic sensors were designed for further studies in covering the gap between measurement accuracy with DC and AC measurement techniques.

#### **Machine Elements and Machine Mechanics**

- Developed a set of models for multibody system dynamics and vibration analysis applicable for reliability analysis and non-destructive control of machine structures

#### **Mechatronics Systems**

- Developed patented marking technology for automated traceability of materials and products.
- Developed a set of machine vision algorithms for service and industrial robot control and navigation and visual servoing applications based on PTAM and SLAM algorithms.
- Developed a mission critical service robot path planning methodology

## 2.2 Uurimisgrupi kuni 5 olulisemat publikatsiooni läinud aastal.

- Kübarsepp, Toomas; White, Malcolm (2011). Characterization of the throughput beam of a ten-photodiode transmission trap detector. *Metrologia*, 48, 359 - 364.
- Vendt, Riho; Juurma, Madis; Vabson, Viktor; Jaanson, Priit; Kübarsepp, Toomas; Noorma, Mart (2011). Effects of Environmental Conditions on the Performance of Thermal Imagers. *International Journal of Thermophysics*, 32, 248 - 257.
- Randrüüt, Merle (2011). On the Kudryashov–Sinclshchikov equation for waves in bubbly liquids. *Physics Letters A*, 375(42), 3687 - 3692.
- Laaneots, Rein; Mathiesen, Olev (2011). *An Introduction to Metrology*. The second, thoroughly completed edition. Tallinn: TUT Press
- Hudjakov, R.; Tamre, M. (2011). Ortophoto analysis for UGV long-range autonomous navigation. *Estonian Journal of Engineering*, 17(1), 17 - 27.

## 2.3 Loetelu struktuuriüksuse töötajate rahvusvahelistest tunnustustest.

**2.4** Loetelu struktuuriüksuse töötajatest, kes on välisakadeemiade või muude oluliste T&A-ga seotud välisorganisatsioonide liikmed.

- Toomas Kübarsepp - Euroopa regionaalse metroloogiaorganisatsiooni EUROMET Eesti Vabariigi delegaat
- Tiia Tammaru - European Organization for Quality (EOQ), asepresident
- Rein Laaneots - Rahvusvahelise Standardimisorganisatsiooni (ISO) tehniliste komiteede ISO/TAG 004, ISO/TC 30 ja ISO/REMCO liige
  - Euroopa Standardimiskomitee (CEN) tehniliste komiteede CEN/TC 92, 176, 237, 290, 294 ja 332 liige
- Mart Tamre - Robotics Industries Association Eesti esindaja

**2.5** Aruandeaasta tähtsamad T&A finantseerimise allikad.

- Sihtfinantseerimise teema T113B
- Baasfinantseerimise toetusfond B04

**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.

- Raivo Sell - International Engineering Educator “ING-PEAD IGIP”
- Mart Tamre - ASME ja AUVERSI liige
- Külalisdoktorant MH instituudi juures Mikhail Larin (ITMO St.Peterburg), juhendaja M.Tamre

Üldhinnang teadustulemustele - hea

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

- Haridus- ja Teadusministeerium

sihtfinantseeritavad teemad:

- T113B, Mehhatroonika- ja tootmissüsteemide proaktiivsus ja käitumismudelid, Tamre, Mart

baasfinantseerimise toetusfondist rahastatud projektid (sh TTÜ tippkeskused):

- B04, Metroloogia kaasagsetes teadustes, Toomas Kübarsepp

riiklikud programmid:

- Teiste ministeeriumide poolt rahastatavad riiklikud programmid:

- Uuriija-professori rahastamine:

- SA Eesti Teadusfond

grandid:

- ETF7475, Pinna geomeetriat iseloomustavate suuruste mõõtemetodid, mõõtekompleksi arendus ja mõõtmiste jälgitavus, Laaneots Rein
- ETF8652, Mudelitel baseeruv manussüsteemide projekteerimine ja autonoomne navigatsioon, Raivo Sell

ühisgrandid välisriigiga:

järel doktorite grandid (SA ETF ja Mobilitas):

tippteadlase grandid (Mobilitas):

- Ettevõtluse Arendamise SA

eeluuringud:

arendustoetused:

- SA Archimedesega sõlmitud lepingud

infrastruktuur (nn „mini-infra“, „asutuse infra“):

Eesti tippkeskused:

riiklikud programmid:

muud T&A lepingud:

- SA Keskkonnainvesteeringute Keskusega sõlmitud lepingud:
- Siseriiklikud lepingud:
- EL Raamprogrammi projektid:
- Välisriiklikud lepingud:

**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*).

### 1.1

Kübarsepp, Toomas; White, Malcolm (2011). Characterization of the throughput beam of a ten-photon transmission trap detector. *Metrologia*, 48, 359 - 364.

Vendt, Riho; Juurma, Madis; Vabson, Viktor; Jaanson, Priit; Kübarsepp, Toomas; Noorma, Mart (2011). Effects of Environmental Conditions on the Performance of Thermal Imagers. *International Journal of Thermophysics*, 32, 248 - 257.

Randrüüt, Merle (2011). On the Kudryashov–Sinelnshchikov equation for waves in bubbly liquids. *Physics Letters A*, 375(42), 3687 - 3692.

Sergejev, F.; Peetsalu, P.; Sivitski, A.; Saarna, M.; Adoberg, E.. (2011). Surface fatigue and wear of PVD coated punches during fine blanking operation. *Engineering Failure Analysis*, 18(7), 1689 - 1697.

### 1.2

Penkov, I., Aleksandrov D. (2011). Axial Displacements in Ball Screw Mechanisms with Two and Four Contact-point . *International Review of Mechanical Engineering*, 5(7), -

Aleksandrov, D.; Penkov, I. (2011). Fluid flow optimization on semiautomatic code marker base. Journal of Energy and Power Engineering, xx - xx. [ilmumas]

Penkov, I.; Strizhak, V. (2011). Increasing of Durability of Responsible Threaded Joints by Improvement of Geometrical Parameters of the Nut. Machines, Technologies, Materials, 5, 31 - 32.

Hudjakov, R.; Tamre, M. (2011). Ortophoto analysis for UGV long-range autonomous navigation. Estonian Journal of Engineering, 17(1), 17 - 27.

Väljaots, E.; Laaneots, R.; Sell, R. (2011). Uncertainty in ground vehicle dynamic measurement system. Системи обробки інформації, 1(91), 52 - 56.

### 1.3

### 2.1

### 2.2

Laaneots, Rein; Mathiesen, Olev (2011). An Introduction to Metrology. The second, thoroughly completed edition. Tallinn: TUT Press

### 3.1

Shvarts, D.; Tamre, M. (2011). The map merging approach for multi-robot monocular SLAM . Recent advanced in mechatronics (21 - 32).Springer [ilmumas]

Hudjakov, Robert; Tamre, Mart (2011). Aerial Imagery Based Long-Range Path Planning for Unmanned Ground Vehicle. In: 7th International Conf. Mechatronics Systems and Materials MSM 2011 Abstracts book and full papers CD: Mechatronic Systems and Materials (MSM 2011) 7th International Conference, Kaunas, Lithuania, 7 - 9 July, 2011. (Toim.) Skiedraite, I., Baskutiene, J., Dragašius, E.. Lithuania: Kaunas University of Technology Press, 2011, 1 - 7.

Hiiemaa, Mairo; Tamre, Mart (2011). Assisting Control Algorithms for Simplified Operation of Remotely Controlled Unmanned Ground Vehicle. In: 7th International Conf. Mechatronics Systems and Materials MSM 2011 Abstracts book and full papers CD: Mechatronic Systems and Materials (MSM 2011) 7th International Conference, Kaunas, Lithuania, 7 - 9 July, 2011. (Toim.) Skiedraite, I., Baskutiene, J., Dragašius, E.. Lithuania: Kaunas University of Technology Press, 2011, 1 - 5.

Kübasepp, T., White, M., Jaanson, P. (2011). Beam properties of trap detectors. In: Proceedings of NEWRAD 2011: NEWRAD 2011 Conference, Maui, Hawaii, 18-23 September 2011. (Toim.) Park, S. (KRISS), Ikonen, E. (MIKES)., 2011, 233.

Aryassov, G.; Barashkova, T.; Gornostaiev, D.; Petritsenko, A. (2011). Development of the Improved Method of Grids . In: Annals of DAAM for 2011 & PROCEEDINGS of the 22 st International DAAM Symposium " Intelligent Manufacturing & Automation:Focus on Interdisciplinary Solutions" : 22 nd International DAAM Symposium, November 2011, University of Vienna, Vienna, Austria. (Toim.) B.Katalinic. Vienna, Austria: DAAAM International Vienna, 2011, 00565 - 0566.

Sell, Raivo; Seiler, Sven (2011). Integrated Concept for Embedded System Study . In: Mechatronic Systems and Materials: 7th International Conference of Mechatronic Systems and Materials. (Toim.) I. Skiedraite, J. Baskutiene, E. Dragasius. Kaunas Technologija, 2011, 14 - 15.

Manoocheri, F et al (2011). Predictable Quantum Efficient Detector (PQED). In: Proceedings of NEWRAD 2011: NEWRAD 2011 Conference, Maui, Hawaii, 18-23 September 2011. (Toim.) Park, S. (KRIS), Ikonen, E. (MIKES)., 2011, 13 - 15.

Sildoja, M. et al (2011). Predictable Quantum Efficient Detector I: Photodiodes and Design. In: Proceedings of NEWRAD 2011: NEWRAD 2011 Conference, Maui, Hawaii, 18-23 September 2011. (Toim.) Park, S. (KRIS), Ikonen, E. (MIKES)., 2011, 227 - 228.

Müller, I. et (2011). Predictable Quantum Efficient Detector II: Characterization Results. In: Proceedings of NEWRAD 2011: NEWRAD 2011 Conference, Maui, Hawaii, 18-23 September 2011. (Toim.) Park, S. (KRIS), Ikonen, E. (MIKES)., 2011, 209 - 210.

Seiler, Sven; Sell, Raivo (2011). Semantics on Mobile Robot Algorithms Development. In: Mechatronic Systems and Materials: 7th International Conference of Mechatronic Systems and Materials. (Toim.) I. Skiedraite, J. Baskutiene, E. Dragasius. Kaunas: Kaunas Technologija, 2011, 52 - 53.

Gran, J., Kübarsepp, T., Sildoja, M., Manoocheri, F., Ikonen, E., Müller, I. (2011). Simulations of Predictable Quantum Efficient Detector with PC1D. In: Proceedings of NEWRAD 2011: NEWRAD 2011 Conference, Maui, Hawaii, 18-23 September 2011. (Toim.) Park, S. (KRIS), Ikonen, E. (MIKES)., 2011, 263 - 265.

Laaneots, R.; Kulderknup, E.; Riim, J. (2011). Surface roughness measurement uncertainty estimation using random function. 15 International Congress of METROLOGY, Paris-France. 03.-06. October 2011. (Toim.) Sandrine Gazal. Paris: Collège Français de Métrologie, 2011.

Brida, G. et al (2011). Toward Traceable Few Photon Radiometry. In: Proceedings of NEWRAD 2011: NEWRAD 2011 Conference, Maui, Hawaii, 18-23 September 2011. (Toim.) Park, S. (KRIS), Ikonen, E. (MIKES)., 2011, 293 - 294.

Pölder, Ahti; Juurma, Märt; Tamre, Mart (2011). Wood products automatic identification based on fingerprint method. In: 7th International Conf. Mechatronics Systems and Materials MSM 2011 Abstracts book and full papers CD: Mechatronic Systems and Materials (MSM 2011) 7th International Conference, Kaunas, Lithuania, 7 - 9 July, 2011. (Toim.) Skiedraite, I., Baskutiene, J., Dragašius, E.. Lithuania: Kaunas University of Technology Press, 2011, 1 - 11.

### 3.2

Juurma, M.; Pölder, A. (2011). Energy Efficiency Aspects in Wood Production Value Chain. 10th International Symp Topical Problems in the Field of Electrical and Power Engineering, Pärnu. Tallinn: Estonian Society of Moritz Hermann Jacobi, 2011, 183 - 186.

Hiiemaa, M.; Tamre, M. (2011). Using Wireless Sensor Network Components in Practical Assignments. 10th International Symp Topical Problems in the Field of Electrical and Power Engineering, Pärnu. Tallinn: Estonian Society of Moritz Hermann Jacobi, 2011, 193 - 196.

### 3.3

Laaneots, R.; Kulderknup, E.; Lillepea, L.; Odrats, I.; Orav, M. (2011). EVS 912:2011. Mitteautomaatkaalud. Taatlusmetoodika.

Laaneots, R.; Kulderknup, E.; Lillepea, L.; Odrats, I.; Orav, M. (2011). EVS 913:2011. Kütusetankurid. Taatlusmetoodika.

4.1

5.1

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

**Jürgen Riim**, mehhatroonikainstituut

Teema: *Calibration Methods of Coating Thickness Standards* (Pindepaksusetalonide kalibreerimismeetodid)

Juhendaja: emeriitprof Rein Laaneots

Kaitstes: 16.06.2011

Omistatud kraad: filosoofiadoktor (mehhatroonika)

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

**2.11** Struktuuriüksuses loodud tööstusomandi loetelu

### **3. Struktuuriüksuse infrastruktuuri uuendamise loetelu**

- Quanser mootorite juhtmoodul,22.07.2011,2 478 €
- Quanser mootorite juhtmoodul,22.07.2011,2 478 €
- Quanser pöördpendli ja Vernier,22.07.2011,3 832 €
- Quanser HVAC ja FPGA moodulid,22.07.2011,2 810 €
- Mehhatroonika sensorite moodul,22.07.2011,2 520 €
- Mehhatroonika sensorite moodul,22.07.2011,2 520 €
- Laser kaugusmõõtja LM-200,18.10.2011,2 000 €
- Liugehõörde stand,8.12.2011,1 728 €
- Laser 1550nm toiteallikaga,16.12.2011,4 117 €
- Mõõtesensor elektrijuhtivusele,29.12.2011,2 055 €