



TALLINNA  
TEHNIKAÜLIKOOL

## MASINAEHITUSE INSTITUUT

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Läbi vaadatud:

*Masinaehituse instituudi nõukogus*

*Instituudi direktor Kristo Karjust*

*01.märts 2012*

# TEADUS- JA ARENDUSTEGEVUSE AASTAARUANNE

# 2011

TALLINN  
2012

**SISUKORD**

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## 1. INSTITUUDI STRUKTUUR

Instituudi direktor Kristo Karjust

- Autotehnika õppetool, Chair of Automotive Engineering, Jüri Lavrentjev
- Tootmissüsteemide õppetool, Chair of Manufacturing Systems, Jüri Riives
- Tootearenduse õppetool, Chair of Product Development, Martin Eerme
- Tootmistehnika õppetool, Chair of Production Engineering, Tauno Otto

**Tabel 1** – ME Instituudi töötajad 31.12.2011 seisuga

Jrk	Perenimi	Eesnimi	Nimetus	Hõive	Õppetool
1	Eerme	Martin	professor	1	Tootearenduse õppetool
2	Hermaste	Aigar	lektor	1	Tootmistehnika õppetool
3	Herranen	Henrik	tehnik	0,75	Tootearenduse õppetool
4	Jürves	Erik	direktori abi	0,5	Tehnilised töötajad
5	Karaulova	Tatjana	teadur	1	Tootmistehnika õppetool
6	Karjust	Kristo	dotsent, direktor	1	Tootmistehnika õppetool
7	Kirs	Maarjus	insener	1	Tootearenduse õppetool
8	Kivima	Gerth	lektor	0,5	Tootearenduse õppetool
9	Kulbas	Ruth	sekretär	1	Tehnilised töötajad
10	Kõiv	Risto	lektor	0,5	Autotehnika õppetool
11	Lavrentjev	Jüri	professor	1	Autotehnika õppetool
12	Lend	Henri	tehnik	0,75	Tootearenduse õppetool
13	Luppin	Janek	lektor	1	Autotehnika õppetool
14	Majak	Jüri	vanemteadur	1	Tootmistehnika õppetool
15	Maruste	Kristjan	insener	0,5	Autotehnika õppetool
16	Napp	Andres	tehnik	1	Tehnilised töötajad
17	Otto	Tauno	professor	1	Tootmistehnika õppetool
19	Pohlak	Meelis	vanemteadur	1	Tootearenduse õppetool
20	Pääsuke	Kaarel	assistent	0,25	Tootmistehnika õppetool
21	Randmaa	Merili	assistent	0,5	Tootmissüsteemide õppetool
22	Riives	Jüri	professor	0,5	Tootmissüsteemide õppetool
23	Rämmal	Hans	vanemteadur	1	Autotehnika õppetool
24	Sarkans	Martinš	haridustehnoloog	0,5	Tehnilised töötajad
25	Semeniuk	Mykola	insener	0,5	Tehnilised töötajad
26	Sonk	Kaimo	lektor	1,0	Tootearenduse õppetool
27	Ševtšenko	Eduard	teadur	1	Tootmistehnika õppetool
28	Tähemaa	Toivo	dotsent	0,75	Tootearenduse õppetool
29	Veldi	Ilje	asjaajaja	0,5	Tehnilised töötajad
30	Vene	Karl-Kristo	tehnik	0,5	Tootearenduse õppetool

Tootearenduse-, tootmistehnika- ja tootmissüsteemide õppetoolide juurde kuuluvad järgmised laborid:

1. Prototüüpide kiirvalmistamise labor
2. Toodete modelleerimise ja materjalide dünaamilise- ning vibrokatsetuste labor

3. Tootmise automatiseerimise labor
4. Hüdro- ja pneumoseadmete labor

Olulisemad seadmed:

Kiirprototüüpimise masinad - Zprinter 310 ja Formiga P 100.

Optilised skännerid GOM ATOS, GOM TRITOP, GOM ARAMIS ja GOM ARGUS.

Olulisemad tarkvarad:

ANSYS Professional V12.1. Ansys on LEM programmipakett, mis võimaldab sooritada erinevaid toodete simulatsioone (tugevusarvutus, voolamise ülesanded jne). On olemas programmi kommerts- litsents tööstusprojektide tegemiseks. Varem kasutati programmi vaid õppetöös.

#### **Autotehnika õppetooli laborid:**

1. Sisepõlemismootorite labor
2. Akustikalabor

Mootorilabori kõige kaasaegsemateks seadmeteks on:

- väljaheitegaaside 4-komponendiline analüsaator (Bosch),
- endoskoop (Karl Storz),
- 2-kanaline digitaaltermomeeter,
- 8-kanaliline analoog-digitaal andmeloger (NI)
- mootorite tehnilise diagnostika seade Automotive Kit.

Akustikalabori olulisemateks seadmeteks on:

- dünaamiline kuumade gaaside mõõtestend (kiirus kuni 100 m/s, temperatuur kuni 200 C)
- 2-kanaliline pieso-elektriline mõõteseade koos vedelikjahutusega dünaamiliste rõhuanduritega (Kistler),
- 4-kanaliline D/A andmeloger (National Instruments) kiirete protsesside mõõtmiseks arvuti abil,
- 4 mõõtemikrofoni koos eelvõimenditega (PCB).

Instituudi liikmed osalevad aktiivselt arenduskeskuse IMECC töödes.

## **2. INSTITUUDI TEADUS- JA ARENDUSTEGEVUSE ISELOOMUSTUS**

Masinaehituse instituudi põhilised teadussuunad 2011 aastal:

- Teooria ja meetodid jätkusuutlike tootmisprotsesside ja toodete arendamiseks (Vanemteadur Jüri Majak)
- Mehhatroonika- ja tootmissüsteemide proaktiivsus ja käitumismudelid (Prof. Tauno Otto)
- E-tootmise kontseptsioon väike- ja keskmise suurusega ettevõtetele (Prof. Tauno Otto)
- Materjalide ja konstruktsioonide optimeerimine arvestades elastset ja/või plastset anisotroopiat (Vanemteadur Jüri Majak)

- Kõrgtemperatuursete gaaside voolu akustika eksperimentaalsed uurimismeetodid (Prof. Jüri Lavrentjev).

## 2.1 Struktuuriüksuse koosseisu kuuluvate uurimisgruppide kirjeldus ja tulemused

### 2.1.1 Teadustöö kirjeldus (inglise keeles)

#### **a) The e-manufacturing and production systems proactivity concept for small and medium-sized enterprises (T213B, ETF7852 ).**

Persons: Prof. Tauno Otto, Prof. Jüri Riives, researcher Eduard Ševtšenko, lector Aigar Hermaste, assistant Kaarel Pääsuke, lektor Kaimo Sonk, assistant Merili Randmaa, Martins Šarkans

The e-Manufacturing research group is focused on elaboration of concept for SME. Small and medium sized enterprises where orders (and their nature) changes, technological processes might vary in relatively great extent, need flexible and easily adoptable integrated systems, reaching over the single enterprise and covering whole cluster if needed. In scientific matter use of embedded systems (smart dust) enables to link enterprise information systems in a new way. Web-enabled and information technologies play indispensable roles in supporting and enabling the complex practices of design and manufacturing by providing the mechanisms to facilitate and manage the integrated systems. Proactive solutions are major pillars that support the success of the integration of e-Manufacturing and e-business. Machinery enterprises in Estonia are mainly SME. There are over 400 small and medium sized enterprises in the machinery apparatus and metal engineering sector. Estonia is a good testing and implementation region such models as here is needed www infrastructure, Internet using habits and interest toward novel e-solutions. Integrating order handling system and ubiquitous computing gathering manufacturing data through "smart dust" (motes) network and analysing it by data mining tools is possible discover alerting situation by decision support system and enable enhanced productivity through in-time order handling and resource sharing network implementation.

This is connected to a interdisciplinary research of mechatronics and production systems proactivity and behavioural models. Activity of the research group is concentrated on proactive decision support in networked collaborating enterprises of special tooling and machining. Intelligent prediction of manufacturing capability in enterprises cluster for preventing management failures thus following the Predict and Prevent Bottleneck manufacturing paradigm enables achieving of near-zero down-time and the best possible quality of product in comparison with the currently prevalent Fail and Fix paradigm mirrored in reactively addressing and fixing the manufacturing problem once it occurs.

#### **b) Theory and tools for development of sustainable manufacturing processes and products (B05)**

Persons: senior researcher Jüri Majak, senior researcher Meelis Pohlak, professor Martin Eerme, associate professor Kristo Karjust, technician Henrik Herranen, technician Henri Lend.

The primary goal of the project was study of the aspects of manufacturing engineering including the development of novel methods and tools for optimal product development and manufacturing planning in industry.

Main activities:

1. Development of methods and tools for structural analysis and optimal design of products and manufacturing processes.
2. Design, simulation and processing with advanced materials

#### **c) Design of Materials and Structures with elastic and/or plastic anisotropy (ETF 8485)**

Persons: senior researcher Jüri Majak, senior researcher Meelis Pohlak, professor Martin Eerme, associate professor Kristo Karjust, technician Henrik Herranen, technician Henri Lend.

Project contains two main research areas:

1. Optimal design of composite structures
2. Structural analysis and design of sheet metal forming processes

Development of the multistage optimisation strategy combining FEA, function approximation and global optimisation algorithms is planned in order to solve engineering design problems considered. Treatment of discretization methods for particular problem cases has been foreseen.

#### **d) Experimental methods for acoustic studies of hot gas flows (ETF7913)**

Persons: Prof. Jüri Lavrentjev, senior researcher Hans Rämmal.

The investigations of the acoustic group have been mostly concentrated on investigations of acoustics of ducts and duct systems, including internal combustion intake and exhaust systems. Research group has a unique hot flow test-rig, which includes set of dynamic pressure transducers and multi-channel data acquisition device and dedicated software to determine complete flow, temperature and acoustic characteristics of a hot flow duct system. One of the important tasks have been experimental investigations of plane acoustic wave reflections at duct openings where a hot high speed jet flows into relatively cold surrounding media. The other tasks deal with acoustic characterization of different automotive gas exchange devices.

### **2.1.2 Aruandeaastal saadud tähtsamad teadustulemused**

#### **a) The e-manufacturing and production systems proactivity concept for small and medium-sized enterprises (T213B, ETF7852 )**

From the research group of e-Manufacturing Birthe Matsi defended successfully Doctoral thesis "Research of Innovation Capacity Monitoring Methodology for Engineering Industry" (supervisors L.Roosimölder, T.Otto), where e-manufacturing was analysed as essential possibility to speed up

product development process thus increasing innovation capacity of SME. The methodology of technological resources and competence management evaluation in terms of manufacturing system ontology are analysed in pre-order and post-order fulfilment stages. The results are published in peer-revised journal and in implementation at competence centre IMECC. Smart dust was used at CNC machine tools for measuring vibration, noise and other essential parameters. Implemented experiments were made using wired solutions, but wireless solutions are proposed. The proposed solution helps to detect changes in shop floor and predict possible problems, thus avoiding unplanned pauses in production. It was shown that different working modes can be detected using in-process monitoring.

#### **b) Theory and tools for development of sustainable manufacturing processes and products (B05)**

Project was focused on the study of composite materials and structures, including the following subtopics:

1. Design of new composite recycled from glass fibre reinforced plastics. The mechanical properties of the new material, time and material resources have been considered as optimality criteria.
2. Design of light weight sandwich panels. Design of trailer panels has been performed as practical application.
3. Sustainable manufacturing. Stability and reliability of the manufacturing processes.

These subtopics are related to development and adaption of optimal design strategies and methods. The methodology proposed include combined use of global optimization techniques and artificial neural networks. Study of the two traditional research topics of the Institute of Machinery: new acoustic materials and design of sheet metal structures has been kept going. New research topic introduced is study of mechanical properties and constitutive behaviour of nanomaterials and nanostructures. Main attention is paid to structural analysis of nanoplates and graphene sheets.

#### **c) Design of Materials and Structures with elastic and/or plastic anisotropy (ETF 8485)**

Study of the main research topic of the project was continued - solving optimal material orientation problems. Attention was concentrated on development of methodology for solving optimal material orientation problems of linear elastic 3D general non-orthotropic material. Decomposition method based approach has been proposed. An advantage of the such an approach is dividing original problem into several simpler subproblems, which can be solved separately. Study sheet metal forming processes was concentrated on practical application – design of car frontal protection system. New research topics included are design of new composite recycled from glass fibre reinforced plastics and design of light weight sandwich panels. These topics are studied in cooperation with department of Materials Engineering.

**d) Experimental methods for acoustic studies of hot gas flows (ETF7913)**

A dedicated facility has been designed to perform the experiments on the flow acoustics of duct and duct terminations in hot subsonic flow conditions. A new 3-microphone method has been developed and verified to test the reflection properties of the open duct end. The measurements were carried out for air jet velocities up to Mach 0.4, doubling the speed range compared to earlier studies and also covering the full plane wave range, Helmholtz numbers up to 1.8. An experimental investigation on engine catalytic converters treated as acoustic two-ports is carried out. The acoustic behavior of the catalytic converters is investigated in detail by analyzing the scattering matrix elements. It has been discovered that the flow resistance in the narrow tubes in the catalytic converter element results in frequency dependent dissipative effects on the transmitted sound. The first systematic experimental investigation on the sound transmission in the complete turbocharger (the compressor and turbine) working at realistic operating conditions has been performed.

**2.2 Uurimisgrupi kuni 5 olulisemat publikatsiooni läinud aastal**

- Herranen, H.; Pabut, O.; Eerme, M.; Majak, J.; Pohlak, M.; Kers, J.; Saarna, M.; Allikas, G.; Aruniit, A. (2011). Design and Testing of Sandwich Structures with Different Core Materials. *Journal of Materials Science of Kaunas University of Technology*, 17(4), 1 - 6.
- Aruniit, A., Kers, J., Goljandin, D., Saarna, M., Tall, K., Majak, J., Herranen, H. (2011). Particulate Filled Composite Plastic Materials from Recycled Glass Fibre Reinforced Plastics. *Materials Science (Medžiagotyra)*, 17(3), 276 - 281.
- Tiikoja, H.; Rämmal, H.; Åbom, M.; Bodén, H. (2011). Investigations of Automotive Turbocharger Acoustics. *SAE International Journal of Engines*, 4(7), 2531 - 2541.
- Sahnö, J.; Polyantchikov, I.; Pribytkova, M.; Shevtshenko, E. (2011). Model based enterprise manufacturing capacity definition and product cost estimation for SME. *JOURNAL OF MACHINE ENGINEERING*, 11(1-2), 23 - 34.
- Aruväli, T.; Serg, R.; Preden, J.; Otto, T. (2011). In-process determining of the working mode in CNC turning. *Estonian Journal of Engineering*, 17(1), 4 - 16.

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

Jüri Lavrentjev – Society of Automotive Engineers (SAE)

Jüri Lavrentjev – International Institute of Acoustics and Vibration (IIAV)



## 2.4 Aruandeaasta tähtsamad T&A finantseerimise allikad

Sihtfinantseerimine:

- T213B, Mehhatroonika- ja tootmissüsteemide proaktiivsus ja käitumismudelid, Otto Tauno

Baasfinantseerimine:

- B05, Teooria ja meetodid jätkusuutlike tootmisprotsesside ja toodete arendamiseks, Jüri Majak

Grandid:

- ETF7913, Kõrgtemperatuursete gaaside voolu akustika eksperimentaalsed uurimismeetodid, Lavrentjev Jüri
- ETF8485, Materjalide ja konstruktsioonide optimeerimine arvestades elastset ja/või plastset anisotroopiat, Majak Jüri
- ETF7852, E-tootmise kontseptsioon väike- ja keskmisega suurusega ettevõtetele, Otto Tauno

## 2.5 Instituudi teadus- ja arendustegevuse teemade ja projektide nimetused

- Haridus- ja Teadusministeerium

sihtfinantseeritavad teemad:

- T213B, Mehhatroonika- ja tootmissüsteemide proaktiivsus ja käitumismudelid, Otto Tauno

baasfinantseerimise toetusfondist rahastatud projektid (sh TTÜ tippkeskused):

- B05, Teooria ja meetodid jätkusuutlike tootmisprotsesside ja toodete arendamiseks, Jüri Majak

- SA Eesti Teadusfond

grandid:

- ETF7913, Kõrgtemperatuursete gaaside voolu akustika eksperimentaalsed uurimismeetodid, Lavrentjev Jüri
- ETF8485, Materjalide ja konstruktsioonide optimeerimine arvestades elastset ja/või plastset anisotroopiat, Majak Jüri
- ETF7852, E-tootmise kontseptsioon väike- ja keskmisega suurusega ettevõtetele, Otto Tauno

- Välisriiklikud lepingud:

- VIR478, Development of Innovative Business Models for Ensuring Competitiveness (INNOREG), Otto Tauno
- VERT498, Research Based Competence Brokering (REBASING ), Otto Tauno

## 2.6 Struktuuriüksuse töötajate poolt avaldatud sihtfinantseeritava teadusteema taotlemisel arvestatavad eelretsenseeritavad teaduspublikatsioonid

### 1.1

Herranen, H.; Pabut, O.; Eerme, M.; Majak, J.; Pohlak, M.; Kers, J.; Saarna, M.; Allikas, G.; Aruniit, A. (2011). Design and Testing of Sandwich Structures with Different Core Materials. Journal of Materials Science of Kaunas University of Technology, 17(4), 1 - 6.

Aruniit, A., Kers, J., Goljandin, D., Saarna, M., Tall, K., Majak, J., Herranen, H. (2011). Particulate Filled Composite Plastic Materials from Recycled Glass Fibre Reinforced Plastics . Materials Science (Medžiagotyra), 17(3), 276 - 281.

### 1.2

Kabral, R.; Rämmal, H.; Lavrentjev, J.; Auriemma, F. (2011). Acoustic Studies on Small Engine Silencer Elements. SAE Technical Paper Series, 2011(0514), 1 - 8.

Velsker, T.; Eerme, M.; Majak, J.; Pohlak, M.; Karjust, K. (2011). Artificial neural networks and evolutionary algorithms in engineering design. Journal of Achievements in Materials and Manufacturing Engineering, 44(1), 88 - 95.

Bashkite, V.; Moseichuk, V.; Karaulova, T. (2011). Combination of end-of-life strategies for extension of industrial equipment life cycle. JOURNAL OF MACHINE ENGINEERING, 10(4), 76 - 88.

Lõun, K.; Riives, J.; Otto, T. (2011). Evaluation of the operation expedience of technological resources in a manufacturing networ. Estonian Journal of Engineering, 17(1), 51 - 65.

Aruväli, T.; Serg, R.; Preden, J.; Otto, T. (2011). In-process determining of the working mode in CNC turning. Estonian Journal of Engineering, 17(1), 4 - 16.

Tiikoja, H.; Rämmal, H.; Åbom, M.; Bodén, H. (2011). Investigations of Automotive Turbocharger Acoustics. SAE International Journal of Engines, 4(7), 2531 - 2541.

Sahno, J.; Polyantchikov, I.; Pribytkova, M.; Shevtshenko, E. (2011). Model based enterprise

manufacturing capacity definition and product cost estimation for SME. JOURNAL OF MACHINE ENGINEERING, 11(1-2), 23 - 34.

Tiikoja, H.; Rämmal, H.; Åbom, M.; Bodén, H. (2011). Sound Transmission in Automotive Turbochargers. SAE Technical Paper Series, 2011-01-1525, 1 - 12.

Majak, J.; Pohlak, M. (2011). Stationary Of The Strain Energy Density In Anisotropic Solids . World Journal of Engineering, 8(1), 765 - 766.

Lavrentjev, J.; Rämmal, H.; Tiikoja, H. (2011). The Passive Acoustic Effect of Automotive Catalytic Converter. SAE Technical Paper Series, 2011-24-0219 , 1 - 8.

Siano, D.; Auriemma, F.; Bozza, F.; Rämmal, H. (2011). Validation of 1D and 3D Analyses for Performance Prediction of an Automotive Silencer. SAE Technical Paper Series, 2011-24-0217, 1 - 14.

### 3.1

Sonk, K (2011). Automatic creation of a company model using functional requirements. In: Proceedings of the 22nd DAAAM International World Symposium: The 22nd DAAAM International World Symposium, Viin, Austria. 23-26 november 2011. DAAAM International Vienna, 2011, 1453 - 1454.

Karaulova, T.; Pribytkova, M.; Sahnó, J.; Shevtshenko, E. (2011). Design of reliable production route system. In: Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium: Vienna, Austria: DAAAM International Vienna, 2011, 539 - 540.

Sarkans, M.; Eerme, M. (2011). Programming time estimation and production planning steps on welding robot cells in SME-s. In: Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium: 22nd DAAAM International World Symposium, Austria, Viin, 23.11 - 26.11.2011. (Toim.) Katalinic, Branko. Vienna, Austria: DAAAM International Vienna, 2011, 1485 - 1486.

### 3.2

Bashkite, V.; Zahharov, R. (2011). Modularization impact to product end of life. Lahtmets, R. (Toim.). 10th International Symposium "Topical problems in the field of electrical and power engineering. Doctoral school of energy and geotechnology". II : Pärnu, Estonia, January 10-15, 2011 (213 - 218). Estonian Society of Moritz Hermann Jacobi

Tsinjan, A.; Klaasen, H.; Kübarsepp, J.; Adoberg, E.; Talkop, A.; Viljus, M. (2011). Performance of tool steels strengthened by PVD coatings in adhesion and cyclic loading wear conditions. Proceedings of EURO PM 2011 Congress & Exhibition, October 9-12, 2011, Barcelona, Spain (1 - 6). Shrewsbury, UK: European Powder Metallurgy Association [ilmumas]

Pribytkova, M.; Polyantchikov, I.; Karaulova, T. (2011). Design of Experiments for Processes Reliability Management. In: Publication of the 10th International Symposium „Topical Problems in the Field of Electrical and Power Engineering\* Doctoral school of energy and geotechnology II" Proceedings: 10th International Symposium „Topical Problems in the Field of Electrical and Power Engineering“ Pärnu, Estonia, January 10-15, 2011. (Toim.) Rein Lahtmets. Estonian Society of Moritz Hermann Jacobi, 2011, 203 - 208.

Aruväli, Tanel; Otto, Tauno; Serg, Risto (2011). In-process vibration monitoring on CNC lathe . In: 10th International Symposium "Topical problems in the field of electrical and power engineering": 10th International Symposium "Topical problems in the field of electrical and power engineering", Pärnu, Estonia, January 10-15.2011. (Toim.) Lahtmets, Rain. Pärnu: Estonian Society of Moritz Hermann Jacobi, 2011, 174 - 178.

Sonk, K.; Otto, T. (2011). Online CAD library applications and pitfalls. In: 10th International Symposium “Topical Problems in the Field of Electrical and Power Engineering” and “Doctoral School of Energy and Geotechnology II”, Pärnu, Estonia, January 10 - 15, 2011: (Toim.) Rein Lahtmets. Tallinn,: Eesti Moritz Hermann Jacobi Selts, 2011, 179 - 182.

Sahno, J.; Polyantchikov, I.; Shevtshenko, E. (2011). Preparation and estimation methods for transformation Small enterprise to Medium-size . In: Publication of the 10th International Symposium „Topical Problems in the Field of Electrical and Power Engineering\* Doctoral school of energy and geotechnology II" Proceedings: 10th International Symposium „Topical Problems in the Field of Electrical and Power Engineering“ Pärnu, Estonia, January 10-15, 2011. (Toim.) Rein Lahtmets. Estonian Society of Moritz Hermann Jacobi, 2011, 197 - 202.

## 2.7 Struktuuriüksuses kaitstud doktoriväitekirjade loetelu

**Birthe Matsi**, masinaehituse instituut

Teema: *Research of Innovation Capacity for Estonian Engineering Industry* (Innovatsiooni võimekuse monitooring Eesti töötlevale tööstusele)

Juhendaja: prof Lembit Roosimölder

Kaasjuhendaja: prof Tauno Otto

Kaitses: 2.09.2011

Omistatud kraad: filosoofiadoktor (tootearendus ja tootmine)

## 2.8 Struktuuriüksuses kaitstud magistritööde loetelu

Tabel 2 – Kaitstud magistritööd

	2011
	M
Tootearendus	11
Tootmistehnika	16
Transporditehnika	10
MARM	9
Laevaehitus	1
Kokku	47

## 3 STRUKTUURIÜKSUSE INFRASTRUKTUURI UUENDAMISE LOETELU

- Mõõteseade NI Compact DAQ, 15.12.2011, 2 090 €