Measurements Quality Assurance In Technical Universities

Edi Kulderknup

Institute of Mechatronics, Tallinn University of Technology, Tallinn, 19086, Estonia, edi@eak.ee

***Abstract* -** Technical universities have some other involvements additionally to the task to teach students and to generate competent engineers, who shall be able work in the wide area. Universities have great specialists capability and know-how to carry out research work and this allows to solve various applied science task for the industrial infrastructure. Above two tasks have in some moments contrary application, especially to give the widely accepted assurance of the testing result, including measurements, is under suspicion. Now-a-days assurance of testing is mainly in the form of the accreditation or the certification from the third parties. In some cases other principles, like proficiency testing, can be used.
Main goal of this study work was to find testing and measurements assurance main rules in technical universities and give some conclusions, what shall be done to give more assurance to the test results. Study work includes the estimation of possibilities for measurements quality assurance for universities testing and calibration laboratories, analyse of the accreditation assessments results and the found non-conformities. Given conclusions, which can help better to solve the quality problems by measurements in practice.

I. Introduction

Main goal of this study work was to find testing and measurements assurance main criteria and give some conclusions what shall be done to give more assurance to the test results in technical universities.
This includes the estimation of possibilities for measurements quality assurance in universities testing and calibration laboratories, analyse of the accreditation assessments results and the found non-conformities and conclusions which can help better to solve the quality problems by measurements in practice.
Technical universities additionally to teach the students and generate competitive engineers, who shall be able work in wide area of infrastructure, have some other involvement. Universities main task is to give for state infrastructure progressive and well-qualified specialists. This task is bound with next assignments [1].
First, it is necessary to prepare itself for tough international competition and adapt to its requirements. The role of the university is to ensure that there is sufficient number of well-trained competitive specialists and develop solutions for the economy.
Secondly, the development of new ides and knowledge has little value for the society if they are not properly implemented. To ensure that innovative solutions developed by university staff reach companies. The university needs to become notably more effective in promoting its knowledge and its research potential.
Thirdly, in order to uphold socio-economic independence and identity the university more then ever needs to think of ways of how to earn money and use it for development in the most feasible way.
By reason that technical universities have great specialists capability and know-how to carry out research work, this allows to solve various applied science task for the industrial infrastructure.
Above tasks have same main goal but in some moments contrary application. Mainly, to give the widely accepted assurance of testing including measurements is under question. Shall be used complementary methods to assure the test results.
Now-a-days assurance of testing, which includes plenty of various measurements, is mainly in the form of the accreditation or the certification from the third parties. In some cases other principles, like proficiency testing, can be used.

II. Need for measurements and testing

A. Research and industry needs for testing and measurement

Estonian industry is more developed in next areas:
- oil shale processing technology;
- building materials production, including cement quality;
- energetical power plants technology;
- environmental research, including investigation of the ecosystem of the Baltic Sea;

- infotechnology, including PC production;
- machinery technology;
- some other topics.

Depending on above main areas also testing and measurement possibilities are developed in the research bodies. For example according to policy of Tallinn University of Technology (TUT) [1], who is the only university of technology in Estonia, is committed to high level research and development in the broad fields of engineering, technology, science and management. The University aims at enhancing its contribution to Estonia's science policy, based on key international trends and local industry needs and on the social and economic changes in the society. TUT promotes domestic and international scientific co-operation through strengthened contacts with business, business associations, other higher education and research institutions and public sector authorities

Throughout several years TUT has carried out contract research on behalf of large infrastructure companies: AS Narva Elektrijaamad (subsidiary of Eesti Energia, an electricity production and distribution company) and Eesti Põlevkivi (an oil shale mining company). TUT has been holding close co-operation also with technology supplier companies for the energy sector such as Foster Wheelers OY, Alstom Power Estonia AS and ABB Eesti AS. In the field of telecommunication, TUT has started long-term co-operation with the Estonian Mobile Telephone Company (a subsidiary of Estonian Telecom) and Ericcson Eesti AS. A testing and training laboratory for GPRS applications has been launched in the framework of this co-operation. This initiative is partially financed by Ericsson Eesti AS, and partially by Swedfund.

In the area of manufacturing different co-operation examples can be highlighted. TUT co-operation with Elcoteq Eesti AS and JOT Eesti AS is mainly devoted to training and re-training activities. In the area of signal processing TUT is engaged in contract research for AS Tarkon, a medium-sized electronics and machinery sub-contracting company. In the field of electrical equipment and power electronics TUT is engaged in co-operation with Estel Pluss in the field of applied research and development of electro-technical equipment. TUT also carries out contract research for Norma AS (now a subsidiary of Autoliv concern), supplier of sub-components for automotive industry.

In chemical technologies TUT has co-operation with AS Silmet Grupp, manufacturer of rare earth metals, this co-operation includes mainly technical consultation and technical information exchange, but will be extended to contract research in coming years.

B. Testing centres of universities

In Estonia 2 biggest universities have testing centres which co-ordinate also its university other testing laboratories activity.

To illustrate the testing capabilities of the Estonian universities, the accredited laboratories data were used. Data are given in Table 1.

No	Area of activity	Most used methods	Quantity of accred. labs
1	Building materials testing: cement, concrete, sand aggregates, timber – content, strength	EN, ISO, GOST	2
2	Water analyses: drinking, surface and waste water – content, quality	EN, ISO	1
3	Chemical analyses: content	Well-known	1
4	Occupational health measurements: noise, light density, particles content, air quality	EN, ISO	2
5	Liquid and solid fuels: oil shale, coal, petrol products, ash	EN, ISO, GOST	2
6	Metal and its products: structure, hardness, strength, coatings quality	ISO, EN, DIN, GOST	1

Table 1. Accredited area of universities testing laboratories

As a general remark concerning accredited areas of testing laboratories of universities is – tests are suitable for industry customer and not for research work. Above tests and measurements are carried out based on large amount of the methods and procedures. Some methods are used through long years and based on regional requirements and some on international standards.

C. Best measurement capability of calibration laboratories

Estonian 2 biggest universities have also measuring instruments calibration laboratories. In Table 2 are given data of the calibration capabilities there. Shown data expresses that calibration laboratories accuracy level is not high and they can satisfy general customers needs.

No	Calibration object	Range	Best measurement capability
1	Length measuring instruments	Up to 300 mm	6,3 µm
2	Measuring instruments for thickness of coatings	(0 ÷ 100) µm	0,8 µm
3	Hardness gauges	(165 ÷ 800) HV	1,5 %
4	Thermocouples	(400 ÷ 1100) ^{o}C	0,6 ^{o}C
5	Non-automatic weighing instruments	5 mg ÷ 3 kg	OIML class II
6	Pressure gauges	Up to 6 MPa	0,5 %
7	DC voltage	1 µV ÷ 1000 V	0,01 %

Table 2 Universities calibration laboratories main data

In near future is possible to get some national level standards in Tallinn University of Technology and in Tartu University. This make possible to carry out more serious scientific research work in metrology field.

D. Teaching of students in metrology area

For the students exist lections in the field of measurement only in 2 biggest Estonian universities. Lections in the Tallinn University of Technology are has follows:
- basics of metrology – mainly for the students of mechanical department;
- physics, include basics of the measurements for all technical areas;
- electrotechnical measurements - mainly for the students of electrotechnical department;
- geotechnical measurements – for the students studying geotechnics;
- chemical measurements – for the students of chemical department;
- some specific topics – mainly specific lections for master students.

This shows that students can have various lections related to the measurements. Problem is, that many of above lections were carried out by lectures who don't have metrology training and often was forgotten such term like the uncertainty of measurement.
Lections in the Tartu University are has follows:
- basics of metrology – mainly for the students of physics department;
- physics, include also basics of measurement, for all;
- chemical measurements – for the students of chemical department;
- some specific topics – mainly specific lections for master students including measurements for the sport.

As general unpleasant remark is, that initial courses teaching only errors of the measurements and later courses deal with the measurement uncertainties.

III. Quality assurance of measurements and accreditation

A. General data

In Estonia was up to 01.06.2004 accredited 160 testing laboratories and 20 calibration laboratories. This quantity includes 8 testing laboratories (includes also 2 laboratories, which performs measuring instruments calibration) and 1 purely calibration laboratory of the universities.
In Figure 1 is shown growth of quantity of the accredited universities laboratories depending on year.

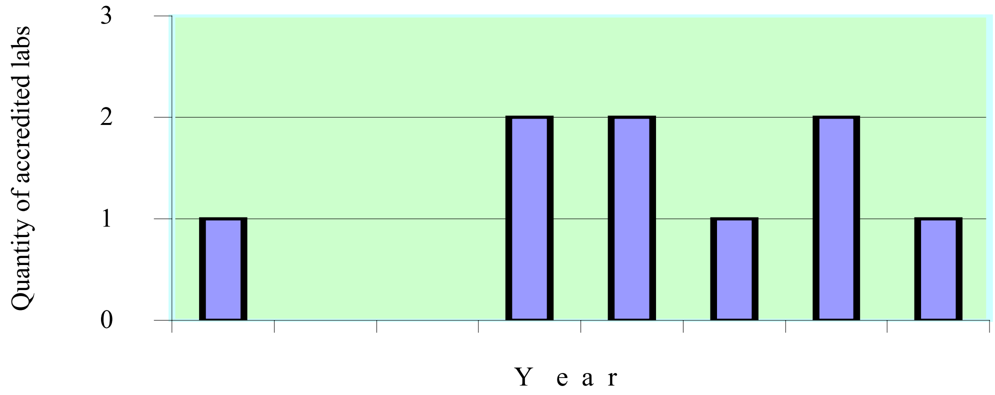

Figure 1 Quantity of firstly accredited universities testing and calibration laboratories (shown is period 1997 up to 2004) in Estonia

Practice shows, that more suitable was testing activities accreditation on the requirements of the standard EN ISO 17025 for the technical universities measurements assurance.
To become aware of the critical points of the measurements quality assurance in the universities testing laboratories were analysed findings of the accreditation process of 9 Estonian universities laboratories.
In the same time period only 1 purely calibration laboratory was accredited and its scope involve not wide area and not high accuracy level.
Shortly giving found non-conformities were as follows:
- management of laboratories has very various tasks and quality assurance task was one of the last;
- lack of practical use of some methods;
- some measuring instruments were jointly used for the students teaching process and for the testing;
- measuring instruments were not traceably calibrated, but confirmed in so called „scientifical way";
- to the testing personnel was not presented the quality system.

During initial assessments found non-conformities, related to ISO 17025, quantity was minimum 6 and maximum 20 for the case. Through accreditation period above non-conformities were corrected and only in one case accreditation was not given.
Practical accreditation process shows also how above non-conformities were easiest way corrected:
- the structure of testing laboratory was regulated, more or less, on the level of highest management of university and for each laboratory was appointed quality system responsible person;
- separated and marked was equipment for testing and research work;
- the quality system was explored by personnel and concrete job descriptions were issued;
- accreditation scope was restricted only for such area were practical activity was needed and exists;
- understanding of measuring equipment traceable calibration was applied;
- specified were rules for use and maintenance of measuring equipment;
- were taken part from proficiency schemes.

B. Proficiency testing

For the assurance its technical level of laboratory the most suitable are interlaboratory comparisons.
Estonian university laboratories can took part from comparisons schemes, which are organised:
- by international bodies (most case for chemical and building material testing);
- in some areas by Estonian reference laboratories (water and food analyses);
- by accreditation bodies (some specific areas);
- by group of laboratories themselves.

To have the accreditation acceptance the level and requirements of comparisons shall be those, which are given in [2]. Especially object stability and homogeneity, logistic of object, data statistical handling, reference values selection, confidentiality and integrity shall be assured.
Particularly difficult for comparisons schemes which did not have wide tribute is to assure the similarity and stability of the measurement object for the all participants.
Result of comparisons showed that ordinary level of the best measurement capability for laboratories is satisfactory. Laboratories used correction procedures if those were needed.

C. Use of ISO 9001:2000

Quality system shall give more stability for the laboratories measurements. More common was to built up the quality assurance system on EN-ISO 17025:1999 requirements, but also ISO 9001:2000 standards requirements can be used for testing laboratories. Firstly mentioned is more suitable for the testing, including measurements laboratories and second for measurement service.

Next articles of EN-ISO 17025:1999 are not replaceable for measurements:

- measuring instruments requirements;
- measurement procedures;
- traceability to the SI measuring unit;
- measurement accuracy estimation (uncertainty);
- proficiency testing and intercalibration

Depending on main goal of the universities laboratories and especially if this includes also some consultation service the ISO 9001 may be chosen successfully.

For this purpose next articles of ISO 9001:2000 are fitting:

- quality planning;
- internal information exchange;
- designing and development of services;
- procedures with customers;
- correction procedures.

IV. Specific metrological aspects

A. Measurement traceability

In Estonia significant measuring instruments have calibration possibilities in the accredited calibration laboratories. If measuring instrument is calibrated in the accredited calibration laboratories then is assured the competent traceability to SI units. Estonian Accreditation body is signed MLA of EA for calibration and testing laboratories. The traceability of some specific measurements shall be brought from other states, for example vibration, air velocity and so on.

B. Measurement uncertainty estimation

In the university testing laboratories measurements accuracy magnitude was estimated using uncertainty of measurement based on GUM [3] principles or repeatability and reproducibility based on standard ISO 3754 or in the rare cases on errors based on GOST standards. Accreditation process showed that accredited university laboratories used mainly uncertainty estimation according to GUM in practice. If test method describes repeatability or reproducibility, then those were used. This was case especially for building materials and chemical testing. According to [4] both above principles are valid.

Uncertainty estimation of measurements using GUM principles were carried out as follows. Uncertainty calculation was carried out on the level of standard uncertainty using sensitivity coefficients giving final result on measurement unit, which was typical for the given measurement.

Account were taken standard uncertainty components which can be calculated using statistical techniques, A-type components, and standard uncertainty components found by others methods, B-type components.

Combined standard uncertainty can be found by equation:

$$u = \sqrt{u_{\mathrm{A}}^2 + u_{\mathrm{B}}^2}\,. \qquad (1)$$

Standard uncertainty component u_{A} is suitable to calculate in the most cases through well-known equation, presuming that repetitions are more than 10 and they are non-correlated:

$$u_{\mathrm{A}} = \sqrt{\frac{1}{n(n-1)}\sum (x_i - \bar{x})^2}\,, \qquad (2)$$

where n is repetitions quantity, x_{i} value of measurement and $\overline{x}$ is arithmetical mean of measurement results.

Combined standard uncertainty u_{B} is formed from the influence of measuring instruments, measurement object, method and environment and if possible it can include the pooled uncertainty.

Combined standard uncertainty from the measuring instrument u_{MI} includes next components:

- combined uncertainty estimated through calibration of measuring instrument;
- possible drift;
- various parts connection and its mutual influence and co-operation;

- reading of indication.
Combined standard uncertainty from the measurement object u_{OBJ} includes mainly next components:
- dimensional parameters of the object;
- accuracy of the determination of measurement actual place;
- distance between measured object and measuring instrument;
- object shape and specific characteristics.
Combined standard uncertainty from the environment influences u_{EN} includes next main components:
- natural level;
- industrial disturbances and "noises";
- sudden change of conditions and its non-stability;
- object unstable power supply and its deviations.
Uncertainty component from the method u_M includes next components:
- pooled uncertainty;
- influence of specific requirements which demand exact set up of the measurement;
- influence from the calculation of the result to the other conditions.
Combined uncertainty u of measurement result is calculated by an equation:

$$u = \sqrt{u_{MI}^2 + u_M^2 + u_{ENV}^2 + u_{OBJ}^2}\ , \qquad (3)$$

where all components are expressed in same measurement units, this mean sensitivity coefficients are equal to 1. Expanded uncertainty U has coverage factor k = 2 and this gives the level of confidence approximately 95 %.

V. Positive effects of quality assurance

Most positive effect of the quality assurance of measurements and testing was case that laboratories personnel and laboratories management got the experience in this area and this experience was carried out also for students.
Secondly the measuring equipment was metrologicaly controlled and this allows more correctly carry out also research work.
Troubling was case that only 50 % - 60 % of accredited laboratories the testing activity more or less was financially on the self standing.
By above problem laboratories personnel was contracted only for the estimated period and often they would be not involved for the next time period.

VI. Conclusions

As conclusions of the study work can be given:
- accreditation of testing/measurement and calibration laboratories of technical universities can be used for assurance of quality;
- accreditation gives some positive effects also for the other activity of technical universities;
- accreditation gives understanding of a need to have measurement instruments metrological control and traceability of measurement unit;
- accreditation is reasonable only in the field were exists concrete practical need from clients.

References

[1] Policy of Tallinn University of Technology, www.ttu.ee (01.06.2004) (in Estonian)
[2] ISO Guide 43 Proficiency testing by interlaboratory comparisons, Geneva, 1997
[3] ISO et. al. Guide to the expression of uncertainty in measurement, Geneva, 1995
[4] EA Draft Guideline on the expression of uncertainty in quantitive testing, rev.15, 09.2003