The group expert evaluation of the state of metrological assurance of capacitance measurements

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Abstract
The measurement of the impedance of devices and transmission lines is a practical problem in technology and other fields. Measurements of capacity are used in metallurgical and mining industry. The results of group expert evaluation of metrological assurance of capacitance measurements with evaluated expert's competence are considered. Special and universal statistical software is used for processing of expert data obtained. Priority problematic questions for improvement of the metrological assurance of capacitance measurements are established.
Key words: MEASUREMENT, IMPEDANCE, CAPACITANCE, METROLOGICAL ASSURANCE, GROUP EXPERT EVALUATION, EXPERT COMPETENCE

The scope and application of a measurements are dependent on the context and discipline. In the natural sciences and engineering, measurements are not applied to nominal properties of objects. Measurement is a cornerstone of science, technology, trade, and quantitative research in many disciplines. Measurement of electrical quantities may be done to measure electrical parameters of a system. Applied measurements are required every day in industrial practice.

Electrical impedance is the measure of the opposition that a circuit presents to current when voltage is applied. The measurement of the impedance of devices and transmission lines is a practical problem in technology and other fields. A capacitor has purely reactive impedance, which is inversely proportional to the signal frequency. A capacitor consists of two conductors separated by an insulator, also known as dielectric.

Measurements of such electrical quantity as capacity are used at the high-fidelity measurement of change of geometrical sizes of wares from a metal to the coefficient of specific temperature expansion of substance (capacity dilatometer), high temperature measuring of level of liquid metal in stoves, express controls of quality of the inflicted coverages from a metal and thickness of metal-roll, properties of intermetalloids and alloys, level of cooling and lubricating liquid in a flatting mill and others like that.

The increase of requirements to quality of eventual products of metallurgy envisages the increase of requirements to exactness of measuring instruments that, in turn, envisages the presence of national standard base of certain physical quantities, and also row of measures from providing of the metrological traceability measurements from international standards to every measuring instruments.

Metrological assurance (MA) of capacitance measurements should be considered in two approaches:conventional approach (verification and calibration of measuring instruments with the definition of the metrological characteristics) [1] and non-conventional approach (group expert evaluation of state of MA). The group expert evaluation (GEE) is widely used in various fields [2-10]. They are intended to resolve problematic issues concerning certain activities to find solutions (or ways of solving them). In this case, it is expedient to consider the opinions of qualified experts with special skills or knowledge in particular field [5, 8-10]. Considering the practical competence, each expert is involved for GEE taking into account their objective professional data allows increasing the reliability and accuracy of such GEEs. MA is the establishment and application of metrological rules and regulations and also the development, production and application of technical means needed to achieve the necessary unity and accuracy of certain measurements [1]. Authentic knowledge of the real status of MA of certain physical quantity measurements is very important. GEE involves experts on metrology, i.e. highly qualified metrology specialists can be one of the useful means of solution of noted issue.

The main aim of GEE in metrological activity is to assess the quality of a metrological work and specialists on metrology. This aim is implemented by the method of GEE, the essence of which is to set out a quality level on the basis of common criteria for quality evaluation and expert questionnaires (prepared for the particular measurements).

1. National standard base of electrical capacitance measurements

National Standard of the unit of capacitance and loss factor (Figure 1) is the most precision measurement standard of the unit of capacitance in Ukraine (DETU 08-06-01), which is kept in State Enterprise "Ukrmetrteststandard" (Kyiv).

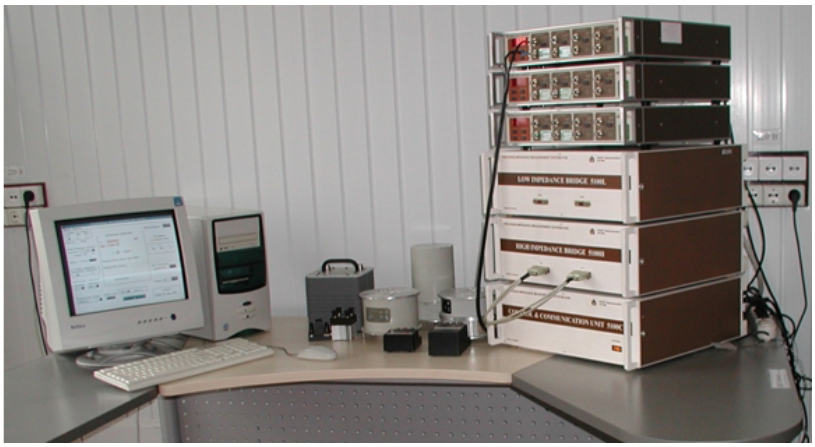


Figure 1. General view of National Standard of the units of capacitance and loss factor

Transfer of the unit of capacitance is performed by the State verification scheme in accordance with national standard GOST 4064. Each year from 40 to 70 working standards (measures of capacitance and loss factor, RLC-meters) are verified and calibrated by using National Standard DETU 08-06-01.

The evaluation of state of MA of capacitance on national level is of extreme importance. An important issue for calibration of measuring instruments of capacitance is provision metrological traceability to National Standard DETU 08-06-01. Ukraine has internationally recognized calibration and measurement capabilities (CMC) for calibration of measuring instruments of capacitance. This CMC on measurement of capacitance were obtained by positive results of international comparisons of National Standard DETU 08-06-01 in project of Euro-Asian regional metrology organizations (COOMET.EM-S13).

2. Main results of expert competence evaluation

In [11], there suggested methodology of evaluation of expert competence taking into account descriptions of data uncertainties that belong to the sphere of comparative evaluation of level of expert competence in various fields of activities. For implementation of suggested methodology, corresponding criteria are set for the numerical score of expert competence of certain field.

Within the framework of realization of GEE of the metrological assurance of capacitance measurements on the specially worked out criteria, the evaluation of competence was also conducted for 14 attracted experts on issues of metrology. Quantitative descriptions of competence of these experts were appraised by means of universal (Microsoft Excel 2010) and special (Competence ND 1.1) statistical software. All evaluations were done on the same criteria: K1 – education; K2 – total work experience; K3 – experience in field of metrology; K4 – experience of expert work in field of metrology; K5 – work status.

Windows of the marked special software with final evaluation results are shown in Figure 2 (Competence ND 1.1).

Figure 2. Appraised expert competence with the use of the software Competence ND 1.1

On the basis of all present results, it is possible to talk about a rejection on the whole 3 experts (declined even by one of the program). Percent of the declined experts on evaluation results folds these programs: 29 % (4 experts out of 14 for software Microsoft Excel 2010) and 21 % (3 experts out of 14 for software Competence ND 1.1). In general, it is possible to establish the high consistency of evaluation results.

The values of the obtained evaluation results of expert competence in the rationed average values (in a range from 0 – minimum to 1 – maximal) for all 14 experts are presented in Table 1.

Table 1. Competence coefficients for all experts

Expert	01	02	03	04	05	06	07
Relative average value	0.72	0.67	1.00	0.92	0.74	0.90	0.90
Expert	08	09	10	11	12	13	14
Relative average value	0.87	0.97	1.00	0.90	1.00	0.97	0.77

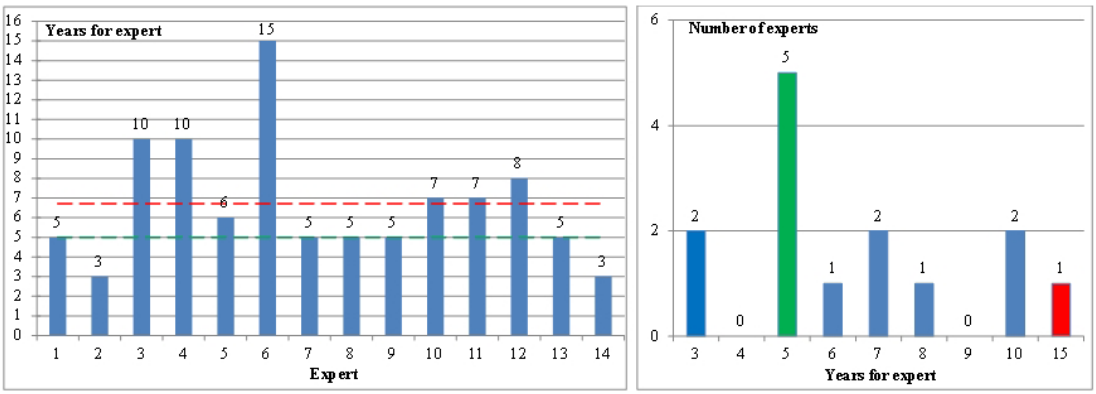
These coefficients were obtained by using the methodology described in [11]. Also experts were asked to make their own assessment of their competence during conducting mentioned questionnaire.

In framework of the carried out questionnaire, questioning took place also in relation to work experience in the field of metrology. Mostly there was the answer (mode) – 5 years (5 experts, 36 %), following by the amount of the answers – 3, 7 and 10 years (2 experts, 14 %), and all the rest – 22 % (3 experts), and less than (Figure 3, reference value is 6.71 and mode is 5.00). The results obtained allowed specifying some quantitative evaluation on the criterion of "K4 – experience of expert in field of metrology".

3. Main results of group expert evaluation

Group expert evaluation (GEE) of MA conducted by the methodology described in [11]. For GEE involved a group of 14 experts in field of metrology whose competence was previously estimated (Table 1).

Evaluation was carried out for 6 problematic questions of MA: personnel involved in metrology works (X1); conditions of implementation of metrology works (X2); normative and methodical documents (X3); standard base and adjuvant equipment (X4); procedures and documents for implementation of metrology works (X5); metrological traceability (X6), which contain 38 sub-questions total, taking into account the established grade evaluations. It was calculated by using universal (Microsoft Excel 2010) and special (Competence ND 1.1) statistical software taking into account the competence of experts.



a) b)

Figure 3. Results of exper's level estimation

(a – years for each expert estimation; b – number of experts by years)

Statistical data of a group of 14 experts in the field of metrology is shown in Figure 4. Special software (Expertise CE 1.0) and universal software (Microsoft Excel 2010) were used to process the obtained data.

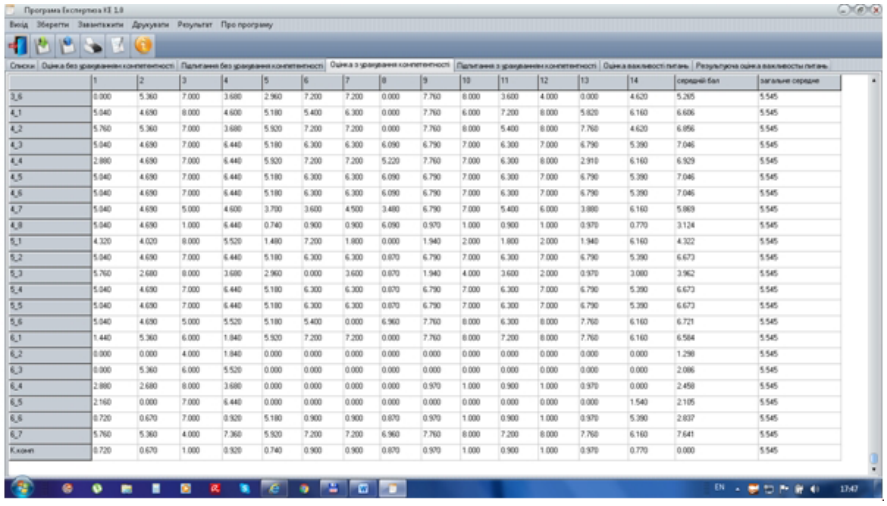


Figure 4. Statistical data of group of 14 experts in the field of metrology (horizontal – expert number; vertical – sub-question number)

The view of these software windows is shown in Figures 5 (Expertise CE 1.0) with evaluated results for sub-questions. Reference values of expert evaluations (evaluated average grade is 5.55) are shown as dashed lines in Figure 5 as well.

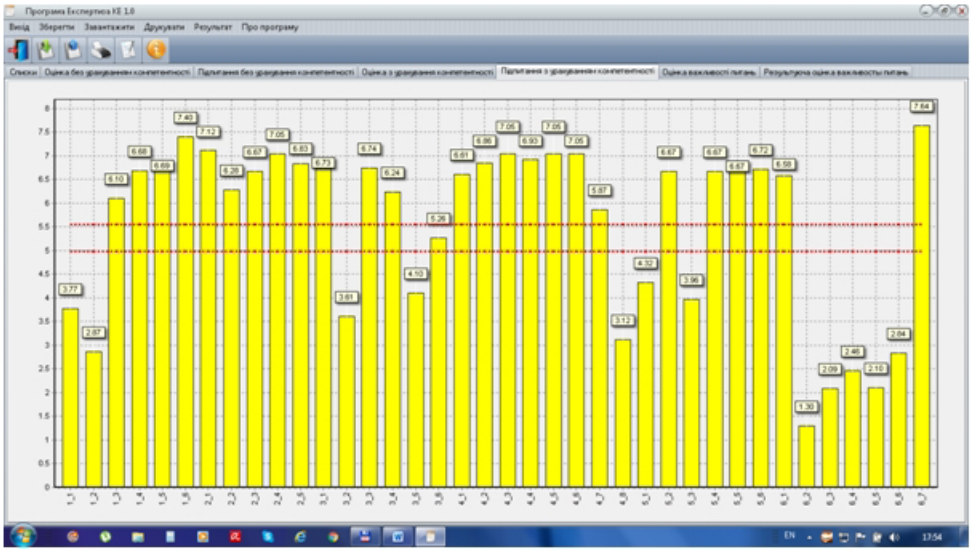
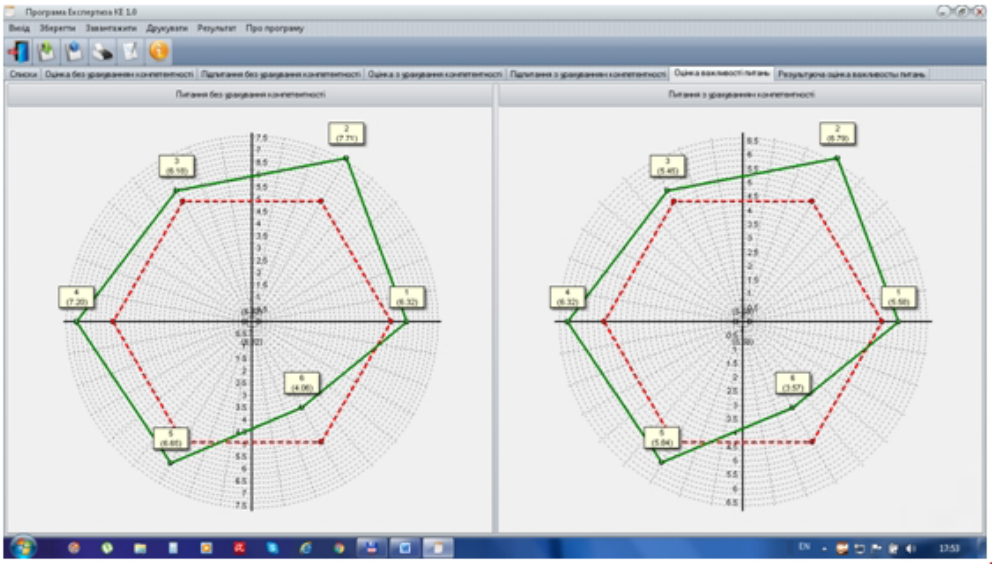


Figure 5. Evaluated average grades by using special software (Expertise CE 1.0) taking into account the competence of experts

Also analysis of these results showed that in all cases 12 sub-questions (32 %) were priority for further detailed analysis in order to take necessary decisions. But 26 sub-questions (68 %) did not have priority or matter at all for their further analysis.

By the results of analysis of resulting evaluation of the importance of questions there was built chart for average grades of expert evaluations with and without taking into account the competence of experts by using universal (Microsoft Excel 2010) and special (Competence ND 1.1) statistical software (Figure 6).

Overall analysis of these results showed that the least important questions for consideration are the following: X2 (average grade with/without taking into account the competence of experts are 7.71/6.79); X4 (7.20/6.32); X5 (6.65/5.84); X1 (6.32/5.58); X3 (6.18/5.45). However, the most important question is X6 (4.06/3.57).



a) b)

Figure 6. The chart for average grades of expert evaluations by using special software (Expertise CE 1.0)

(a – without taking into account the competence of experts; b – with taking into account the competence of experts)

The total evaluation results of the importance of questions are shown in the Table 2.

The results obtained show small variation of average grades of expert evaluation for questions (X1–X6) that testifies to its quite good consistency. Considering competence coefficient of experts did not influence the result of evaluation on problematic questions that were discussed.

Table 2. The total evaluation results of the importance of questions

Question	Without taking into account the competence of experts			With taking into account the competence of experts		
	Average value	Reference value	Degree of deviation	Average value	Reference value	Degree of deviation
X2	7.71	6.30	1.41	6.79	5.55	1.25
X4	7.20		0.89	6.32		0.77
X5	6.65		0.35	5.84		0.29
X1	6.32		0.02	5.58		0.04
X3	6.18		-0.12	5.45		-0.10
X6	4.06		-2.24	3.57		-1.97

4. Priority problematic questions for improvement of the metrological assurance of capacitance measurements

Only the problematic question of MA (X6) is attributed for further more detailed researching by the results of GEE on problematic questions of MA of capacitance.

The following sub-questions are attributed for further more detailed researching by the results of GEE (in order of importance):

- calibration of working standards (X6_2);
- correlation between the number of verified and calibrated measuring instruments by the enterprise (X6_3);
- status of evaluation uncertainty during calibration of measuring instruments (X6_5);
- the use of calibration methodologies of measuring instruments (X6_4);
- estimation of suitability of software for the automated collection and processing of the obtained data at the verification (calibration) of measuring instruments (X6_6);
- number of experts who conduct or participate in testing (X1_2);
- availability on the enterprise of the movable laboratories manned by working standards, measuring instruments and equipment (X4_8);
- used methodologies of verification of measuring instruments (X3_2);
- total amount of specialists that work in metrology (X1_1);
- use of verification protocol forms (X5_3);
- availability of methodologies that require development or review (X3_5);
- authority or accreditation of enterprise on implementation of metrology activities (X5_1).

The other problematic questions of MA are referred to the ones that have no primary importance.

Conclusion

The increase of requirements to quality of eventual products of metallurgy envisages the increase of requirements to exactness of measuring instruments. The capacitance measurement is a practical problem in metallurgical and mining industry. The group expert evaluation with evaluated expert competence for establishment of the real state of metrological assurance for specific measurements is very useful tool in different fields of industry. Special and universal software can be used for mathematical processing of obtained expert data.

The status of metrological assurance for capacitance measurements by the results of group expert evaluation can be stated generally. Some problematic questions should be established which need take into account calibration of working standards; correlation between the number of verified and calibrated measuring instruments by the enterprise; status of evaluation uncertainty during calibration of measuring instruments; the use of calibration methodology of measuring instruments.

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