МИНИСТЕРСТВО НАУКИ И ВЫСШЕГО ОБРАЗОВАНИЯ
РОССИЙСКОЙ ФЕДЕРАЦИИ
Федеральное государственное автономное
образовательное учреждение высшего образования
«РОССИЙСКИЙ УНИВЕРСИТЕТ ДРУЖБЫ НАРОДОВ»

GREEN–2022

СТУДЕНЧЕСКИЕ ИССЛЕДОВАНИЯ В ОБЛАСТИ ЭКОЛОГИИ, ИНЖЕНЕРИИ И ПРИРОДЫ — 2022

СБОРНИК НАУЧНЫХ ТРУДОВ

**Молодежной научно-практической конференции
на иностранных языках с международным участием**

Москва, 28 ноября 2022 г.

В двух частях

ЧАСТЬ 1

GREEN–2022

GRADUATE RESEARCH IN ECOLOGY, ENGINEERING AND NATURE — 2022

**Proceedings of the International
Youth Scientific Conference**

Moscow, November 28, 2022

In Two Parts

PART 1

**Москва
2022**

УДК 574:62:502/504(063)
ББК 20.1+3/4
Г85

Утверждено
РИС Ученого совета
Российского университета
дружбы народов

Г85 **GREEN–2022. Студенческие исследования в области экологии, инженерии и природы = Graduate Research in Ecology, Engineering and Nature** : сборник научных трудов Молодежной научно-практической конференции. Москва, 28 ноября 2022 г.: в 2 частях. — Москва : РУДН, 2022.

ISBN 978-5-209-11676-9

Часть 1. — 482 с. : ил.
ISBN 978-5-209-11677-6

Сборник содержит материалы научных трудов Молодежной научно-практической конференции на иностранных языках с международным участием «Студенческие исследования в области экологии, инженерии и природы» (Москва, 28 ноября 2022 г.). В работе конференции принимали участие ученые, докторанты, аспиранты, магистранты и студенты российских и зарубежных вузов, сотрудники научно-исследовательских учреждений и производственных предприятий.

ISBN 978-5-209-11677-6 (ч. 1)
ISBN 978-5-209-11676-9

2. Transport strategy of the Russian Federation until 2030 with a forecast for the period up to 2035. Approved by order of the Government of the Russian Federation of 27.11.2021 № 3363-r. Available at: https://mintrans.gov.ru/ministry/targets/187/191/documents (Accessed 20.10.2022).
3. GOST R 52051-2003. Power-driven vehicles and trailers. Classification and definitions.
4. GOST R ISO 14067-2021. Greenhouse gases. Carbon footprint of products. Requirements and guidelines for quantification.
5. Argonne GREET Model. Available at: https://greet.es.anl.gov (Accessed 20.10.2022).
6. Emissions Gap Report 2021. Available at: https://www.unep.org/resources/emissions-gap-report-2021 (Accessed 20.10.2022).
7. The National Report of the Russian Federation on the Inventory of the Anthropogenic Emissions and Sinks of Greenhouse Gases Not Controlled by the Montreal Protocol for the years 1990–2020. Available at: https://unfccc.int/documents/461970 (Accessed 20.10.2022).
8. Analytical agency in the field of statistics and analytics of the automotive business “Avtostat”. Available at: https://www.autostat.ru (Accessed 20.10.2022).
9. The hydrogen economy — a path towards low carbon development. Available at: https://eenergy.media/wp-content/uploads/2019/06/SKOLKOVO_EneC_Hydrogen-economy_Rus.pdf (Accessed 20.10.2022).
10. CNG Market: Global Development Experience and Lessons for Russia // EY. Available at: https://assets.ey.com/content/dam/ey-sites/ey-com/ru_ru/topics/oil-and-gas/ey-cng-market-world-development-experience-and-les sons-for-russia.pdf (Accessed 20.10.2022).
11. Science-based forecast of adaptation of the road transport sector to the likely impacts of climate change and possible scenarios for its decarbonization in the Russian Federation (2022). Available at: https://sk.skolkovo.ru/storage/file_storage/b013d3a4-d719-43e1-a27b-1732879abe9a/SKOLKOVO_EneC_RU_Transport.pdf (Accessed 20.10.2022).

METHODOLOGY FOR CALCULATING UNCERTAINTY OF MEASUREMENT ON THE EXAMPLE OF AN ELECTRONIC TACHOMETER

D.M. Kokurina

Master’s student, Institute of Environmental Engineering
RUDN University, Moscow, Russia
1132227539@rudn.ru

Abstract: This article presents the results of calculating uncertainty of measurement on the example of an electronic tachometer

Key words: metrological control, tachometer, uncertainty of measurement, verification procedure

1. INTRODUCTION

Under the conditions of accelerated scientific and technological development and the rapid growth of industrial production, metrological control of technological and measuring processes becomes an important argument in favor of ensuring the efficiency and safety of both production as a whole and its environmental component.

One of the most important devices in the control of industrial engines is a tachometer — a device for measuring the shaft speed (angular velocity). Tachometers can be used for various types of equipment in various settings such as conveyors, windmills, rotary feeders, shredders, dryers, cooling equipment, augers and elevators. The list of industries that use these devices includes power plants, processing plants, chemical plants, automotive plants, material handling, food/beverage plants, paper mills, and many more.

To ensure and confirm the suitability of tachometers in production, a verification operation is used — a set of operations performed in order to confirm the compliance of measuring instruments with metrological requirements. However, when developing a verification procedure for a given measuring instrument, it makes sense to calculate the uncertainty of its measurements.

2. METHODOLOGY

Uncertainty (of measurement) is a parameter associated with a measurement result that characterizes the spread of values that could reasonably be attributed to the measurement quantity. Uncertainty makes it possible to compare the results of different measurements of the same measured quantities with each other or with reference values [1].

There are 2 main types of uncertainty estimation:

- *Type A* — a method for estimating uncertainty by statistical analysis of a series of observations.
- *Type B* is a method for estimating uncertainty in a manner other than statistical analysis of a series of observations.

3. RESULTS

The measured quantity Y is not directly measurable, but depends on other variable quantities $X_1, X_2, \dots X_n$. These influencing quantities act on it and convert its "true" value into the value indicated by the tachometer. Therefore, the measured value Y should be expressed through a functional dependence, which in general is formula (1):

$$Y = f(X_{ind}, X_1, X_2 \dots, X_N). \quad (1)$$

The Y value is the output value in the verification process and is defined as the error of the measuring instrument. The values X1, X2, X3, X4 and X5 are sources of uncertainty, since most of them are not constant and their values can be determined with different errors over time:

X1 — the value of the standard sample (tachometric installation UT-05-60);

X2 — air temperature;

X3 — relative humidity of the air;

X4 — atmospheric pressure;

X5 — power supply of verification tools from the AC mains with frequency.

In order to compose a system of equations, it is necessary to move from conditional equations to normal ones. We get a system of equations that needs to be solved to find the coefficients:

0,0103a+6,45b+20,15c+29,58d+14,57e=0,035;

6,45a+5040b+15892c+22911d+11258,7e =26,1;

20,15a+15892b+50399c+72548d+35636,1e =80,7;

29,58a+22911b+72548c+104669d+51416,2e =117,5;

14,57a+11258,7b+35636,1c+51416,2d+25260,88e =57,79.

Therefore: a=-0,965; b=0,0192; c=-0,0114; d=0,00354; e=0,00317.

For each quantity, an estimate and standard uncertainty must be determined. Each estimate of the input quantity Xi and its associated standard uncertainty u(Xj) is obtained from the probability distribution of the input quantity Xi.

Type B uncertainty assessment:

1. The error of the standard sample (tachometric installation):

$$U = \frac{0.05}{2\sqrt{3}} = 0.014\,.$$

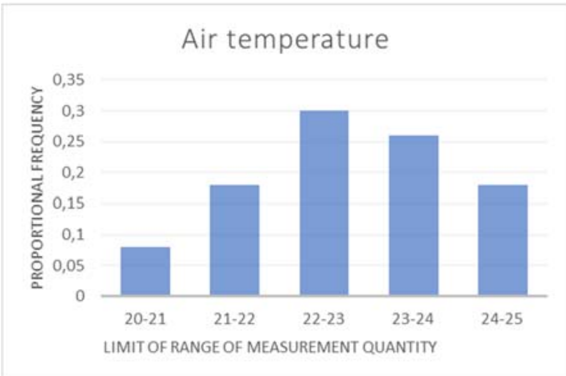
2. Power supply of verification tools from the AC mains with a frequency:

$$U = \frac{0{,}5}{2\sqrt{3}} = 0{,}144\,.$$

For factors assigned to type A (air temperature, relative air humidity, atmospheric pressure), it is necessary to conduct an experiment of multiple measurements in order to determine the type of distribution and calculate the RMS. To measure factors of type A, the following measuring instruments are used:

For type A factors, the following measuring instruments are used: a thermometer for the air temperature, a moisture meter for the relative humidity of the air, and a barometer for atmospheric pressure.

$$\bar{X} = 22{,}32°\text{C}\,;\; S = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{X})^2}{n(n-1)}} = 0{,}179°C\,;$$



Histogram 1. Fir temperature

Analyzing the above histogram, we can conclude that the histogram has a bell-shaped shape, similar to the normal distribution. It is asymmetric and has a scatter slightly larger than that of the normal distribution.

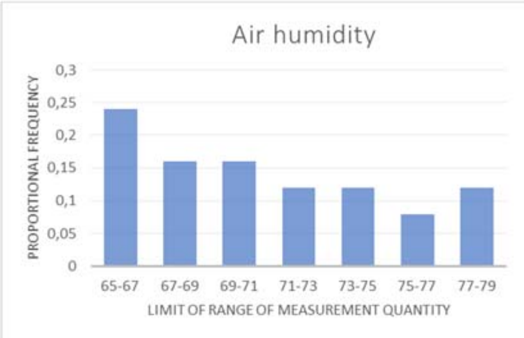
Similar measurements were made for relative air humidity and atmospheric pressure.

Results for air humidity:

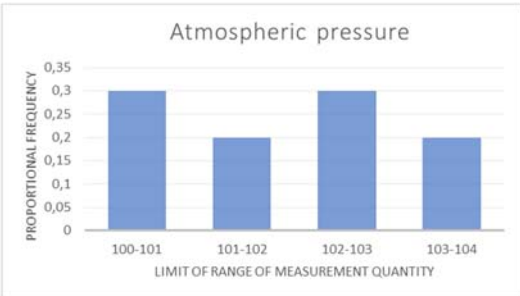
$$\bar{X} = 70{,}32\% \; ; \; S = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{X})^2}{n(n-1)}} = 0{,}598\% \; ;$$

Results for atmospheric pressure:

$$\bar{X} = 102{,}3 \text{ kPa} \; ; \; S = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{X})^2}{n(n-1)}} = 0{,}181 \; kPa \; ;$$



Histogram 2. Air humidity (left)



Histogram 3. Atmospheric pressure (right)

When analyzing the air humidity histogram, we can conclude that the histogram has a shape similar to a uniform distribution and is also asymmetric. When analyzing the atmospheric pressure histogram, we can conclude that the histogram has a shape similar to a uniform distribution, and is also asymmetric, with a spread within two values.

The concept of uncertainty refers to a “logical” correlation, not a mathematical one. To what extent the correlation effect should be taken into account depends on the specifics of the measurement, on knowledge about the measurement method and on the evaluation of the interdependencies of the input quantities.

Since the input quantities are independent of each other, we can say that there is no correlation.

An estimate of the output quantity Y, denoted y, is the result of measuring the quantity whose value is to be set when the measurement is taken. This estimate is obtained from the regression equation (model) by replacing the input values Xi with their estimates xi.

$$y = (-0{,}965) * 0{,}05 + 0{,}0192 * 22{,}32 + (-0{,}0114) * 70{,}32 + 0{,}00354 * 102{,}3 + 0{,}00317 * 3 = -0{,}0497\,.$$

We calculate the standard uncertainty of the output quantity, which is the standard deviation of the estimate of the input quantity or measurement result and characterizes the spread of values that can be reasonably attributed to the measured quantity Y.

$$\mathrm{U}_c(y) = \sqrt{0{,}000183 + 0{,}00000118 + 0{,}0000465 + 0{,}000000411 + 0.000000209} = 0{,}0156\,.$$

The expanded uncertainty U is obtained by multiplying the standard output uncertainty u(y) by the coverage factor k:

$$U = ku(y) = 2\ \cdot 0{,}0156 = 0{,}0312\,.$$

In general, in practice, take k = 2 for an interval with a 95% confidence level or k = 3 for an interval with a 99% confidence level.

When specifying the expanded uncertainty, the result should be expressed as Y = y ± U.

$$Y = \ 0{,}2 \pm 0{,}0312\, rpm.$$

This means that the best estimate of the value attributed to the measurand Y is y, and that the interval from y — U to y + U contains, one would expect, most of the distribution of values that can reasonably be attributed to Y.

4. CONCLUSIONS

Metrologists are not as far from ecology as it seems at first glance. After all ecology and environmental control cannot do without measuring instruments for various purposes. For example, one of the functions of metrological departments at enterprises is to ensure the correctness and efficiency of technological processes, which are closely related to industrial environmental control. Compliance with environmental legislation and the implementation of environmental protection measures is the main task of every person working in the industry.

REFERENCES

1. *Zayats N.I.* Evaluation of the uncertainty of measurements: textbook-method. manual for students of the specialty “Physical and chemical methods and devices for quality control of products” N. I. Zayats, O.V. Stasevich. Minsk: BSTU, 2012. 91 p.
2. ISO/IEC Guide 98-3:2008 Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)
3. ISO 3534-1:2006 Statistics — Vocabulary and symbols — Part 1: General statistical terms and terms used in probability
4. JCGM 100:2008 Evaluation of measurement data — Guide to the expression of uncertainty in measurement