Engineering experiment as an underlying tool for training research engineers

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Abstract: The paper analyzes the contribution of the engineering experiment to professional skills of research engineers. The discussion is based on the educational programs and methodology of the disciplines taught at the Engineering Institute of Kazan Federal University.

In a contemporary context, the engineering progress leads not only to an increase in the complexity of test objects, but also it constantly steps up the requirements for the depth of penetration into the essence of the performance of the industrial equipment components, the compatibility with them and their interaction, as well as the measurement accuracy of recorded values. Therefore, the importance of the experiment in modern science, technology and industrial activity is not in doubt. This is the essential and most important method of obtaining new knowledge, innovative technologies and products. Even where the scientific research is theoretical and present in the form of mathematical models, a need always arises to confirm the compliance of the models constructed with real processes, and this is only possible by means of experiments [1, 2].

The training of research engineers has been carried out at the Engineering Institute of Kazan Federal University since 2013 based on the principal undergraduate and master’s degree programs in specialized departments «Technical physics and energy», «Quality management», «Biomedical engineering and innovation management».

The training of bachelors-to-be is performed in the following subjects:
Applied physics;
Quality management (Quality Management and Robotics).

The training of masters-to-be is performed in a variety of disciplines:
Measurement and certification;
Biomedical devices, systems and facilities;
Medical and clinical equipment;
Innovation studies: Intellectual property.

In all of the above subjects and focuses of educational programs, the engineering experiment is present either as a basic discipline or as a variable discipline, or is implemented in the form of
laboratory studies and independent R&D activity performed under the guidance of experienced teachers.

In obtaining professional competencies, students are aware of scientific research purpose in terms of engineering: identify objective patterns that determine the workflow processes in machines, apparatuses, technological systems and facilities, etc.; study the physical and physico-chemical phenomena that make up these processes; use the obtained scientific results to create innovative designs that are optimal in terms of efficiency, economy, metal consumption, service life, or any other data [1, 3].

They are also aware of the issues facing them as researchers of a fundamentally new equipment, materials, and structures. One of these issues is caused by the fact that often the characteristics of test objects that need to be experimentally determined are increasingly becoming inaccessible for direct measurement. Because of this, the performance indicators used to evaluate the test object or to take organizational and design decisions usually do not coincide with the object parameters determined by the results of a full-scale experiment.

Another issue is the arrangement for testing of objects that have a complex dynamic behavior of performance and are subject to significant influences of changing environmental conditions.

In addition, testing sophisticated facilities enhances the importance of the effects that the test, recording and control equipment has on the running of the test object.

In this regard, the most important challenge of arranging the training of research engineers in the field of design, planning and implementation of the engineering experiment is to master a systematic approach, which involves considering all the tools involved in the experiment as a single system described by the corresponding mathematical model [4]. Thus, mathematical modeling becomes an integral element of research activity applicable to the engineering experiment. Without building a model, today it is impossible to imagine either the design of the experiment, or its performance, nor the processing and analysis of the results [5]. Only the availability of ratios linking the desired technical and economic data of the test object with its parameters allows reasonable judgments about the requirements for the accuracy of measurements, the frequency of registration of recorded data, etc. The same ratios serve to determine the estimates of the desired characteristics that satisfy the relevant statistical requirements (bias, minimum dispersion, etc.)

Complex research problems are associated with the need to analyze the interrelation of many factors[6]. For studying processes and phenomena in order to further manage them, it is necessary to find out what purpose each factor individually serves in this process or phenomenon. This is possible only with careful design of a series of experiments and an adequate assessment of the scope of experimental activity. Too small amount of experimental data may not allow to establish a pattern or function, and the researcher may get low accuracy of constant values or not notice a weak effect, which, nevertheless, has great theoretical value. But on the other hand, with an excessively large amount of data, experimental studies take a long time, and data processing can take long, it becomes very time-consuming, complicated, confusing to analyze and obtain calculated engineering dependencies. At the same time, there is a challenge of an obstacle to the detection of relevant effects, the signs of which are literally blurred in giant data sets. This implies the importance of students gaining skills and competencies for self-planning of the experiment.

The methodology of setting the discipline “Design of experiment”, which is on the list of basic disciplines of the “Quality management” and “Robotics”, includes the development of students' professional skills in the implementation of the following components of the engineering experiment:

1. Statement of the problem of experimental research.
2. Design of experiment
3. Analysis of experimental data and their conversion into a form convenient for engineering calculations.

The statement of the research problem implies the acquisition by students of skills in choosing independent variables which influence will be studied; substantiation of the assumptions made that facilitate the problem; selection of measuring equipment; assessment of required accuracy; identification of effects that are not capable to direct measurement [7].

The design of the experiment is considered from the point of view of the conventional one-and multi-factor experiment and a randomized experiment. The student acquires skills in determining the required scope and sequence of research work, compiling mathematical models for processing experimental data and describing them.

Analysis of the research results implies the acquisition by students of professional skills in collecting and managing experimental data, maintaining experimental reports, processing (including automated processing) data and their generalization [8,9]. Currently, specialized programs make it possible to display experimental data in the graphical form and even as multidimensional surfaces, nevertheless, the engineering practice urges to obtain simple criteria dependencies that would allow the calculation of similar processes without significant time costs with satisfactory accuracy. In light of this, the «Experiment planning» discipline includes among others: «Similarity theory in engineering research» and «Dimension analysis».

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