EXPERIMENTAL MECHANICS

Educational Support for Students
Brno University of Technology

Experimental mechanics and its benefit

If the product has to succeed in the demanding global market, where the supply usually exceeds the demand, it is dependant (besides its price and availability) on its high technical level and quality. In order to achieve this aim it is very necessary to coordinate and also systematically ensure series of processes and activities resulting in products with high-level added value. These processes affect the quality in all stages of the product life cycle (research, development, production, use, reconstruction, liquidation, etc.). The product capabilities, which a designer, constructor, calculating staff, can most significantly influence, are mainly reliability (in the broad sense of the word) involving failure-free operation, safety and service life. According to their knowledge, skills, possibilities and many other factors having impact on their activities, the staff „breathes into" the product a certain rate of inherent reliability. The success of this process is to a considerable extent affected by the quality of applied experimental work in connection with solving mechanical engineering problems that can occur during designing and examination of the product. The cost value is shown in a balance sheet, which, however, cannot reflect the above-mentioned benefits because it is very difficult to express their value in money. Therefore higher management is sometimes not aware of them and it can make somebody think that the experimental department is not productive.

Experimental mechanics in the system of engineering education

From the above mentioned reasons is clear that the importance of experimental mechanics is indisputable, as well as the quality of special training of technical university graduates. In this respect, the existing state can be regarded as not very satisfactory. Within the basic studies the students can be provided with only limited information about experimental mechanics and its possibilities. Situation is becoming better in some specializations, curriculum of which includes subjects specializing on this or related topics. Unfortunately, some departments still do not take into consideration the role and importance of experimental mechanics. Generally speaking, the best conditions are being created within specializations of applied mechanics at faculties of mechanical engineering. Due attention to technical experiments is paid also within the postgraduate study programs. However, the situation should improve. The whole mechanism and its behavior should be properly evaluated, possible problems should be detected and their cause remedied. Good workers engaged in experimental mechanics have to work on the intellectual background – on the deep knowledge of interrelationship in inanimate structures. They also have to extend and improve their professional knowledge through lifelong learning. The quality of the training is closely connected with the available equipment and quality of school laboratories. A close cooperation of our departments with world companies and firms prove effective in this respect.

Basic characteristics of the existing experimental methods

When describing the basic characteristics it is possible to say the following:

- the meaning of classical methods of experimental mechanics remains the same (except for e.g. transmission photoelasticity);
- renaissance, or even a huge development in the sphere of optical methods;
- the experiment is:
    - automated
    - computer aided,
    - interactively controlled,
    - system oriented,
    - requiring hi-tech software equipment – i.e. requirements on its reliability, openness, balancing between its universality and specialness.

Constantly growing variety of experimental measuring systems equipped with high computer technology bring about particular level of danger: spectacular colorful graphs and almost immediately computed results can hide e.g. mistakes in the measured places or wrong units of measurement.

Applying the methods of experimental mechanics

Nowadays, the experimental mechanics can be applied in different spheres of interest, such as:

- Fracture mechanics
- Biomechanics
- Composite materials
- Modal analyze
- Residual stresses
- Experiment
- Diagnostics of technical objects
- Experiment in the product quality assurance.

Main tasks of experimental mechanics

- Input data acquisition for computational modeling
- Verification of the results from computational and mathematical modeling
- Compensation of computation
- Monitoring and Diagnostics
- Obtaining new information, and others.

Summary of the most significant methods in experimental mechanics

Main attention is paid to the investigation of strains, stresses, displacement, movement parameters, and the relevant action of forces, such as forces, pressures, twisting moments etc. At the present time, especially electrical and various optical methods are the most commonly used. Therefore, they are considered hereinafter more in detail. Other methods will be characterized much briefly.

The summary:

- Electrical methods
  - Evaluation of the electrical methods
  - Transducers
  - Adjustment, processing and setting of electrical signals
- Optical methods
  - Standard optical methods
  - Holography
  - Holographic interferometry
  - Coherent-granularity methods
- Brittle paints
- Radiography
- Acoustic emissions
- Ultrasonic methods
- Hybrid methods

Big attention paid also to the Uncertainties and Errors in Measurement, Stochastic Processes and Electric Resistive Strain Gauges.

Uncertainties and Errors in Measurement

When reporting the result of measurement of a physical quantity, it is obligatory that some indication of the quality of the result be given so that those who use it can assess its reliability. Without such an indication, measurement results cannot be compared, either among themselves or with reference values given in specification or standard. It is therefore necessary that there be a readily implemented, easily understood, and generally accepted procedure for characterizing the quality of a result of measurement, that is, for evaluating and expressing its uncertainty.

The following terms are included and explained in detail:

- Standard uncertainty
- Type A evaluation of standard uncertainty
- Type B evaluation of standard uncertainty
- Combined standard uncertainty
- Expanded uncertainty
- Random error
- Systematic error, etc.

Stochastic Processes

The analysis of the dynamic system includes analysis of its dynamical properties as a complex, as well as the analysis input and output quantities. In the mechanical engineering, the input quantities are the forces, force couple, pressures and the like. As the output quantities are regarded the loading, deformations, deviation, and acceleration, whereas most of these quantities are a function of time. All the given effects can be expressed by a common term *process*.

The processes can be divided into:

a) Deterministic
b) Stochastic (random)
c) Hybrid
d) Inhomogeneous.

The following terms are included and explained in detail:

- Frequency analysis
  - Fourier sequence
  - Fourier transformation
- Classification of stochastic processes
  - Stationary process
  - Ergodic process
- Characteristics of ergodic processes
  - Characteristics in the time domain
  - Characteristics in the frequency domain
- Characteristics of a system with two ergodic processes
- Characteristics of non-stationary process

Resistance Strain Gauges

The strain gauges have undergone significant evolution and they achieved a considerable high level of perfection. However, the development still continues. The strain gauges are most commonly used in the sphere of experimental analysis focused on stresses, forces, pressures and twisting moments. Of course they can be used to measure also displacements, shifts and acceleration of oscillating motion.

The strain gauges:

- enable measured data transfer in long distance;
- enable easy further data processing;
- enable measuring of static and dynamic loads up to high frequency. The maximum measured frequency is usually determined by the characteristics of the measuring device, not by the gauge;
- have low weight and there is only small influence on the measured object;
- enable measuring on various curved surfaces;
- provide possibility of measuring at high and low temperatures.

The following chapters are included as well:

- History of the resistance strain gauges
- Division and typical characteristics
- Types of strain gauges
- Technical characteristics
- Installation of gauges
- Connection problems
- Instruments
- Methods of particular connections of gauges, etc.