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Kuzinovski, M., Trajčevski, N., Cichosz, P.

AUTOMATION OF EXPERIMENTAL RESEARCHES OF PHYSICAL PHENOMENA IN CUTTING PROCESS BY MACHINING WITH TURNING

Abstract: *The study presents procedure performed at projection and realization of experimental scientific-researches. Special accent is placed on the introduction of automation thereby increasing experimental research effectiveness and quality through integration of measuring and control systems by application of computer technique. Automation is described through a created automated monitoring system for experimental researches of temperature and forces in cutting process by machining with turning.*

Key words: *automation; forces; temperature; cutting; turning.*

AUTOMATIZACIJA EKSPERIMENTALNIH ISTRAŽIVANJA FIZIČKIH POJAVA U PROCESU REZANJA PRI OBRADI STRUGANJEM

Rezime: *U ovom referatu predstavljeni su postupci koji se izvode pri projektovanju i realizaciji eksperimentalnih naučnih istraživanja. Uvođenjem automatizacije u svim fazama proektovanja i realizacije naučnih istraživanja uvećava efikasnost i kvalitet eksperimentalnih istraživanja integrirajući merne i upravljačke sisteme sa primenom kompjuterske tehnike. Automatizacija je opisana na realizovanom automatiziranom monitoring sistemu za eksperimentalna naučna istraživanja temperature i sile u procesu rezanja pri obradi struganjem.*

Ključne reči: *avtomatizacija, sile, temperatura, rezanje, struganje.*

1. INTRODUCTION

High scientific development stage nowadays contributes to intensifying and expansion of scientific researches, increase of number of engaged researchers and cost increase for their implementation. Experimental scientific researches have significant meaning in comparison with theoretical scientific researches. Theoretical researches are characterized with a large number of approximations and difficulties at defining limit conditions and precise description of changes in the research process by means of mathematic models [2]. Thereof outcomes the justification for automation implementation for experimental researches whereof is expected: saving of time, necessary for performing scientific researches; presentation of experiment results in a form suitable for fast implementation in the industry; cost reduction for performing scientific experimental researches; cost reduction for power supply, compressed air and other sources by means of automation of management of output values at given regime; cutting down engaged personnel in experimental researches, creating possibilities for performing new types of experimental researches, finding optimal solutions for given task, creating economically justified technologies, machines with high technical properties, high quality materials, etc.; high system safety for performing experimental researches, provision of conditions for gaining precise and secure information at minimum number of experiments and excluding the possibility for occurrence of an undesired break of experimental project until the moment of gaining necessary information; easy adjustment towards modified conditions in next researches and multiple use of equipment for performing various experimental researches as result of structural flexibility of system for automation; multiple time saving, necessary for experiment performing as result of the large informativenes of automatic systems; creating conditions for larger creativity as result of time saving and raising quality level by automation of all processes that are characterized with large manual engagement and full release of manual activities [5].

2. POSSIBILITIES FOR AUTOMATION OF EXPERIMENTAL SCIENTIFIC RESEARCH STAGES

Stages of experimental scientific researches are shown on Fig. 1 [3]. First activity is adoption of correspondent language with strictly defined terms, stage (1), which serve for describing the problem analyzed. Defined language terms provide performing quantitative measurements at certain quantities, which are not always directly measurable. For defining the numerical values of those quantities, it is necessary to find the relations that provide their intermediate quantitative interpretation. In following stage, the experimenter selects correspondent methods and measurement technique (2). The experimenter then has an ability to act on the subject and perform measurements of correspondent output quantities. Output and input quantities are concrete values of physical quantities. In third stage (3) the experimenter has a possibility to determine the research aim, recording it in the form of a function and also defining input and output quantities. Analysis of experiment hyperspace that represents real mathematical model of input and output in terms of input and output quantities follows. This is realized by application of dimensional analysis. The requirements for dimensional independence of input variables are fulfilled then selected function can be considered as quantitative-qualitative function (4). In stage (5), the function form is selected as: - function with given form; - function selected of the function menu; - differential equation with given form and differential equation selected of the equation menu. Follows determination of the domain interval of independent variables where the experimenter reaches decisions based on own experience, consultations with experts and literature (6).

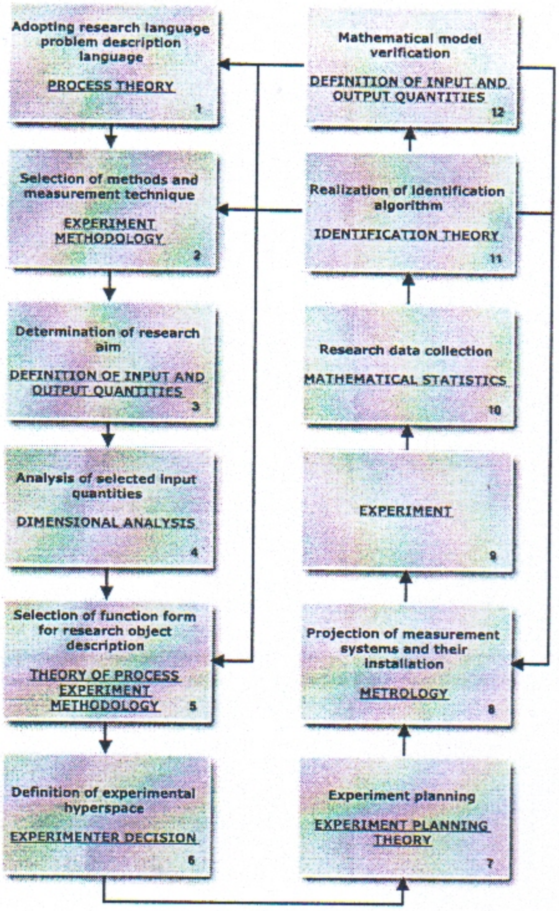


Fig. 1. Stages of activities of the experimenter at projection and realization of experimental scientific researches

In defined hyperspace measurement points are determined i.e. experiment is planned (7). Experiment planning is possible to be performed in two modes. First mode is plan issue prior experiment performing and its realization against plan, independent of received information. Second mode is so called planning in real time, when plan modifications are forecasted, even modifications to its strategy, dependent on gained information in measurement process. This mode requires higher automation level of whole experiment and application of fast computers with large memory. Functions for data collecting, planning, commanding control systems and data transforming have to be linked and performed mutually. Such planning is rather more rational. Taking into account information gained of (2) and (7), measurement systems are selected and installed (8). Whole project of measurement system is possible to be performed against experiment planning, since then the number of necessary accessories is known. Selection of accessories, measurement systems and methods and measurement techniques that influence the value of evaluated parameter in the model is crucial for measured values accuracy. Prior experiment performing, the experimenter knows required accuracy for process description and permitted error, as well as the form of the condition against which the gained mathematical model shall be verified. Then, the experimenter applies correspondent algorithms, programs and technical means. Automation of all activities is not possible, if specifics of the task and the significant portion of heuristic procedures are taken into account. Here welcomed is the dialogue of the experimenter with the computer, which is supplied with programs and correspondent units for input and output. Experiment projection, actually, represents a whole of experimenter activities till the moment when he/she can perform the experiment; these are the activities from (1) to (8). Technical realization is performed by connecting measurement systems and control systems to a computer. During experiment performing, signal transfer from measurement systems onto computer is necessary all with the purpose of data memorizing and providing transfer of numerical signals from computer towards control units with executive organs. For the purpose, most applied are analogue-digital and digital-analogue converters. By program support and correspondent technical systems installation realization of following functions is provided: transforming and transferring of recorded measurement results; experiment management, including experiment planning as well as management of technical means of experimental apparaturs, providing experiment automation; dialogue of the experiment with the system, which provides interventions during research and its results transforming. Once these activities are performed, experiment realization is possible to be performed (9). Measurement data are collected in a certain mode, when two possibilities exist, collection of statistically unverified data and collection after correspondent statistical processing (10). Experiments are necessary to be made, which shall inform us at which stage and in which case the experiment is possible to be trusted. Based on certain statistical procedures, whole program libraries are built that serve for measured values verification. Those programs can be used at measurement result transforming, which measurement results are recorded by means of a computer, and also can be applied for measurement management at recurrence of statistical measurements in order to gain the estimators of average values and the dispersion with correspondent characteristics. In such cases, it is more suitable only to memorize estimators of required quantities, not the measurement results. Further on, measurement results are processed in compliance with the algorithm of the identification theory (11). Algorithm of identification is performed by application of correspondent programs. After each change of function degree within the frames of its class, for example, class of polynomes, it is checked whether number of adopted measuring points during planning is larger than the number of required parameters in the function. If this non-equation is not met, than planning is repeated. If possible function degrees and measurement basis are spent and the gained mathematical model accuracy requirements are not thereby met, then it is returned to procedure (5), selecting another function form. If identification procedure with a return path does not lead to reaching "correspondently accurate" model, then have to return to procedures (2) and (8), analyzing measurement methods and measurement technique, or to the activities (1). In the last case, the experimenter concludes inadequacy of process describing with reality, and mostly that it misses some dimension in the description that significantly influences the experiment trend. In the end, reached mathematical model is verified and accuracy against which it describes experiment results in defined experiment hyperspace is checked, but not only in the measuring points (12). In cases when accuracy is smaller than prescribed one further procedure is identical as in stage (11).

3. PROPERTIES OF CREATED SCIENTIFIC-RESEARCH EXPERIMENTAL SYSTEM

Stages of experimental scientific researches found full verification by practical realization of automated scientific-research monitoring system for investigation of force and temperature in cutting process by machining with turning. Monitoring system is created at the Mechanical Faculty in Skopje, Fig. 2 [6]. It includes:

- Personal Computer (PC) interface, intended for adjustment and acquisition of signals, concluded of 5-component amplification unit and data acquisition card, Fig. 3;
- MS Windows based software package for PC, Fig. 4;
- modernized analogue inductive dynamometer for force value measurement;
- two paths for temperature measurement that use the method of natural thermo-couple, made by an device designed by professor D-r Mikolaj Kuzinovski [4] and an device of the program *Hottinger Baldwin Messtechnik GmbH*, which are placed on the workpiece side and the contact on the cutting tool through specially designed cutting tool holder.

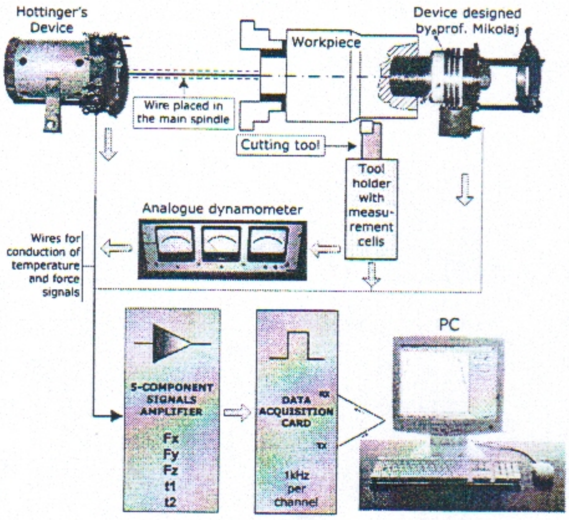
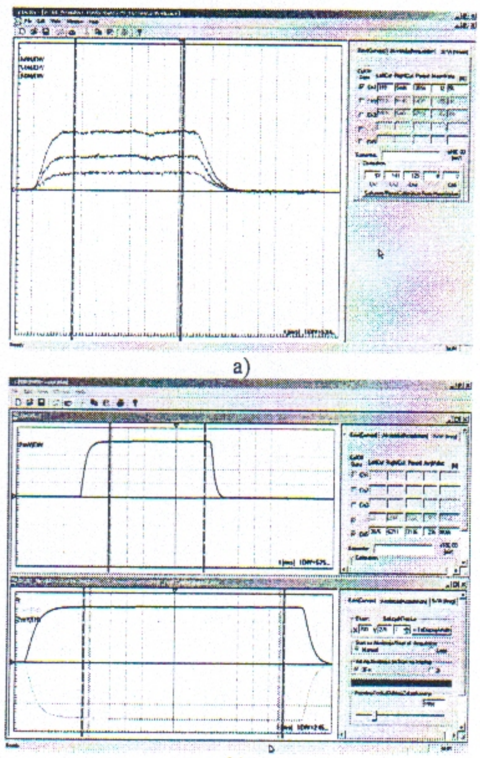


Fig. 2. Scheme for element connection of the forces and temperature monitoring system

For force measuring, the monitoring system uses an analogue inductive dynamometer type FISHER MESSTECHNIK TYP EF2 D3 NR 24570, which consists of cutting tool holder with inductive measurement cells for transforming forces into voltage. For temperature measurement the method of natural thermo-couple is used, which consists of workpiece and cutting tool. The generated thermo-voltage is possible to be conducted against two paths. One path, for signal conducting from workpiece, uses a device designed by prof. d-r Mikolaj Kuzinovski, which is applied in cases when signal can not be conducted from the side of the clamping head through main spindle. Other path for signal conducting from machined part uses Hottinger's device and is applied when having a concave main spindle. The interface between signal source and (PC) consists of 5-channel signal amplification unit and an data acquisition card. Signal amplification unit has three roles as part of the interface. Initially, amplifies thermo-voltage that is generated of natural thermo-couple workpiece-cutting tool and dynamometer signals till necessary level. Second role is galvanic separation of circuits with thermo-couples from circuits that exists on the acquisition card and PC. The role of galvanic separation is protection of circuit power surges that can damage this part of measurement system. Third role is removal of circuit effect between acquisition card and the circuit with thermo-couples and dynamometer. Acquisition card integrates a microchip microcontroller with code PIC 16F877 and accompanying electrical components for support. Microcontroller has a built in 10-bite A/D converter and the generator frequency of 20 MHz is used. Microcontroller contains an installed module for serial synchronic and asynchrony communication in both directions simultaneously with a possibility for easier adjustment of communication speed. Communication speed of 115200 bps is used for communication with PC. The frequency of sample taking is 1 kHz for each channel individually.

Fig. 3. Prototype version of the PC interface

Software that we developed for monitoring system has abbreviated code FORTMON (full version. ***FORce & Temperature MONitoring***), Fig. 4. Left part is intended for graphic interpretation of forces and thermo-voltage dependent on time, while as right part contains dialogue window with many controls. It provides: real time-monitoring, software calibration, acquisition management, multi-tasking, resolution adjustment, more analysis simultaneously, operations over curves, opened code, data recording, adjustments recording, graphics exporting, selection of value of axis divisions, etc.



a)

b)

Fig. 4. Application FORTMON a) determining average value of force components b) determining average value of temperature

Force measurement system calibration is performed in a way that it is loaded with established force in direction of certain component action and monitoring system results are read, Fig. 5. After table issue with correspondent values, same are graphically analyzed and the model of force dependence of monitoring system readings is created. After model implementing in the software package, readings can be expressed in force measurement units.

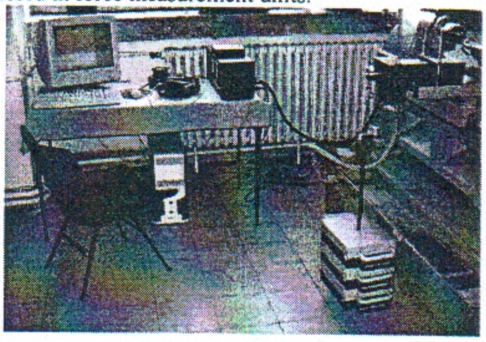


Fig. 5. Measurement system calibration by loading with established force

For experiment planning automation and results processing, until mathematic model creation the tool *Model-Based Calibration(MBC) Toolbox Version 1.1*, is used, which is part of the software package of *Matlab* and is intended for experiment design and statistical modeling. Fig. 6 shows example of gained mathematical model that resulted of statistical processing of gained results of the experiment by use of MBC in the scope of presented input parameters.

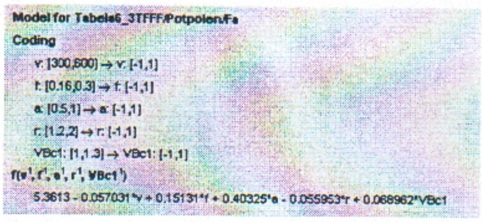


Fig. 6. Presentation of gained mathematical model - MBC

Use of MBC possibilities provides significant advantages in experimental researches in this field [1]. MBC provides also graphical interpretation of results, Fig. 7.

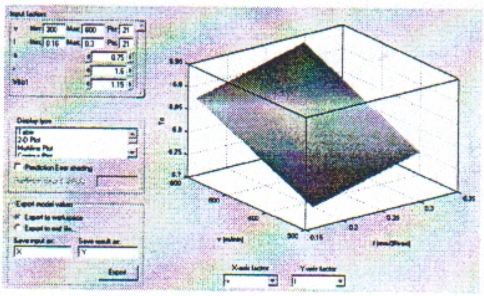


Fig. 7. Graphical interpretation of mathematical model - MBC

4. CONCLUSIONS

1. Application of automated monitoring system in experimental researches wholly justifies the idea of its creation, especially due to the fact that during research by application of newly created monitoring system many output quantities in real time, which describe the subject of research, are simultaneously identified. In this case, these are the temperature and resulting force in cutting process expressed through tangent, axial and radial component. This provides performing more creative activities by the experimenter as analysis of applied methods for experiment planning, analysis of gained results, definition of experiment error, analysis of gained mathematical models for description of subject of research and verification of same.

2. Created monitoring system characterizes by opened access towards software and hardware components, thereby providing analysis of adequacy of selected hardware components and software solutions in function of signal acquisition.

3. It is determined that it is appropriate to perform upgrade and modernization of old systems by adding electronics and software.

4. Verification of experimental methods and applied methodology for experimental research showed coinciding of gained results of researches with results gained from researches performed at Wroclaw University of Technology, Poland, against same conditions.

5. Computer aided process of physical phenomena investigation in cutting process makes the informative database creation easier with information for processing of various machined materials and various cutting materials. In this way, pre-conditions are created for optimum selection of processing parameters and management of mechanical and heat model for creation of residual stresses that affect the surface layer properties.

6. Automation contributes for reduction of uncertainty of results gained from performed measurements and determination of the effect of certain factors, for the purpose of reduction or elimination of their negative influence on research hardware equipment and software.

7. Possibilities are created for performing continuous monitoring system development activities.

5. REFERENCES

[1] Jurković, Z., Jurković, M.: *Modeling and simulation of the cutting force using experimental data*, 7-th International Research/Expert Conference "Trends in the Development of Machinery an Associated Technology", TMT 2003, pages 81-84, Lloret de Mar, Barcelona, Spain, 15-16 September, 2003.

[2] Kuzinovski, M., Pavlovski, V., Zebrovski, H.: *Automation of experimental research in science and technics*, Proc. Fac. of Mech. Eng., 12, pages 5-12, Skopje, 1992.

[3] Kuzinovski, M., Pavlovski, V., Zebrovski, H., Cichosz, P: *Development of methods and laboratory equipment for performing analytic-experimental researches in the field of machining process*, Ministry of Science of Republic of Macedonia, 1995-1997.

[4] Kuzinovski, M.: *Device for signal conduction during temperature measurement*, Patentno rešenie br.62/96, delovoden broj 09 6287/1, od 27.12.1996. PATENT MKP B23Q 11/14, G01K 13/08, 900602 od 30.09.2000, pages 2-58, Glasnik IPPO, 7/3, Skopje, September 2000.

[5] Ордынцев, В. М.: *Системы автоматизации экспериментальных научных исследований*, Машиностроение, Москва, 1984.

[6] Trajčevski, N.: *Monitoring system in experimental investigation in machining with turning*, Master thesis, Skopje, February 2008.

Authors: **Prof. Kuzinovski Mikolaj, PhD,** University "Ss. Cyril and Methodius", Faculty of Mechanical Engineering, Skopje, Republic of Macedonia. **Trajčevski Neven, MSc,** Ministry of defence, MP4420 Skopje, Republic of Macedonia. **Prof. Cichosz Piotr, DSc**, Institute of Production Engineering and Automation of the Wroclaw University of Technology, Wroclaw, Poland.

E-mail: mikolaj@mf.edu.mk
neven.trajchevski@gmail.com
piotrc@itma.pwr.wroc.pl

Univerzitet u Novom Sadu
FAKULTET TEHNIČKIH NAUKA
DEPARTMAN ZA PROIZVODNO MAŠINSTVO
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