

TEACHING SOFTWARE FOR DESIGNING OF EXPERIMENTS (DOE) IN WOODWORKING PROCESSES

Wilhelm LAURENZI

Transilvania University of Brasov, Faculty of Wood Engineering
Str. Universitatii nr. 1, 500068 Brasov, Romania
Tel: 0040 268 419581, Fax: 0040 268 419581, E-mail: willy@unitbv.ro

Abstract

This paper presents a teaching software that allows students and researchers to understand how passive and active experiments can be made, without making real experiments. The software generates experimental data for a wooden milling process based on an experimental design for two factors, $y=f(x_1, x_2)$. The data pass through different modules which simulate a data acquisition system that convert the analog simulated data into digital data which are recorded into text files. The software has five modules: a process module, a current transformer module, a power transducer module, a data acquisition module and a file saving module. The interface of the software follows these modules and allows the user to set very easily the input and output values of every module. After simulation of all experiments and processing the recorded data, the experimental design can be completed with the measured values. With this information and with adequate software, a mathematical model of the process can be obtained very easily.

Key words: design of experiments; simulation of experimental data.

INTRODUCTION

A general definition of scientific research is given by Martyn Shuttleworth (2008) - "In the broadest sense of the word, the definition of research includes any gathering of data, information and facts for the advancement of knowledge". Another definition given by Creswell (2008) is more precise "Research is a process of steps used to collect and analyze information to increase our understanding of a topic or issue. It consists of three steps: "Pose a question, collect data to answer the question, and present an answer to the question". The collection of data can be realized only by experiments". These experiments can be passive (classic) or active experiments (DOE). Experimental research consists of the following general steps:

1. Establishing the design of the experiment;
2. Performing the experiment and gathering the experimental data;
3. Processing the collected data
4. Interpreting the experiment results.

Because the second step of experimental research requires different experimental stands, materials and complex scientific equipments, it is useful for researchers to improve their experimental skills with simulation software. In order to fulfill this aim, this paper presents a software which can simulate and collect experimental data for every experiment based on an experimental design. This design can be elaborated manually or computer assisted (Laurenzi 2013), considering the information for designing experiments from the relevant literature. For processing the collected data, different software packages can be used - like Datafit, Statistica or the software developed by the author (Laurenzi 2014).

OBJECTIVE

The main objective of this paper is to present a simulation software which can be used in designing the process of an experiment, without making any real experiment.

MATERIAL, METHOD, EQUIPMENT

Before starting experimental research, the researcher must realize the design of the experiment. This design can be established manually or computer-assisted, using different DOE (design of experiments) methods (Kiesling, Laurenzi 2013, 2014). Fig. 1 illustrates an example with two designs, a passive (classic) design (Fig. 1,a) and a active design (1,b) for two factors. The passive design has 25 experimental points with 1-5 tests in every point (total 25 – 125 tests) and the active design has 9 experimental points, with total 13 tests (5 test in the center of the experiment) and 1 test in 8 different points of the experiment.



Fig. 1.

Example of an passive (classic) and an active experimental design with two factors

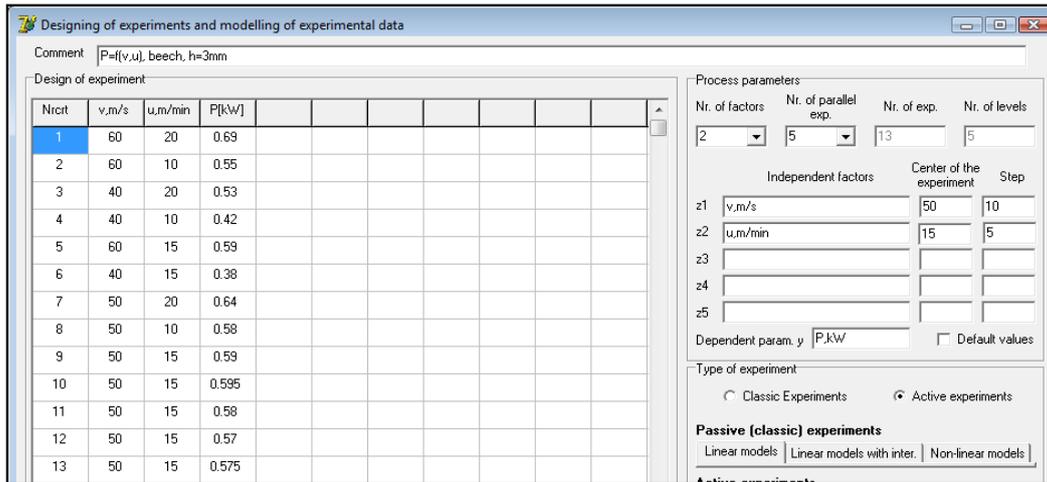


Fig. 2.

Example of an active experimental design with two factors for a milling process

In Fig. 2 is presented an active experimental design with real values for a milling process with two factors $P=f(v, u)$, where: P – milling power [kW]; v – cutting speed [m/s] and u – feed speed [m/min]. In order to perform a real experiment on base of this experimental design, it is necessary to set up a data acquisition system like the system presented in Fig. 3.

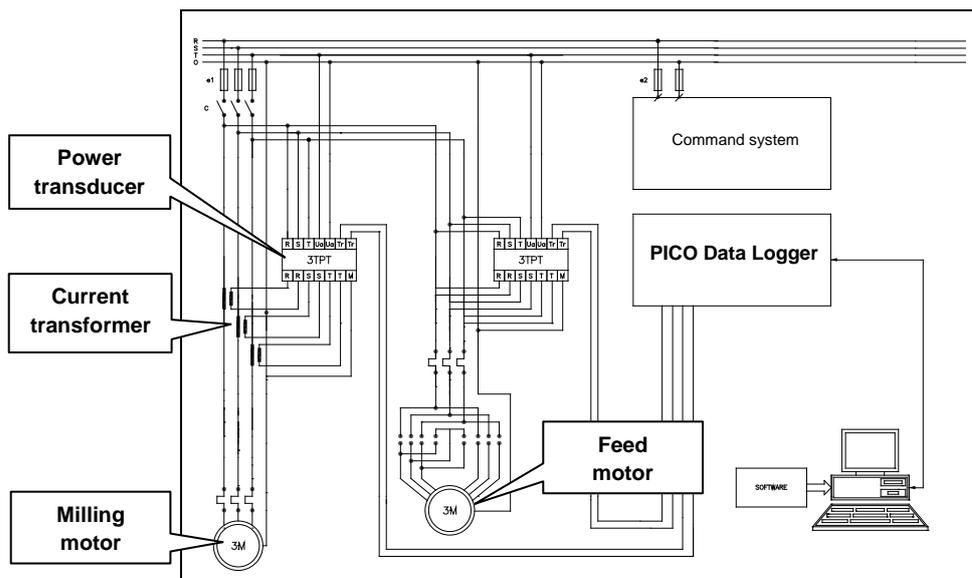


Fig. 3.

Data acquisition system for a milling process

The diagram contains two electrical motors, the milling motor and the feed motor, three current transformers for the milling motor, one power transducer for the milling motor and for the feed motor, a data acquisition system and a personal computer. Fig. 4 presents an example of experimental data recorded from a real wooden milling process. Fig. 5 illustrates the content of the text file with the same data.

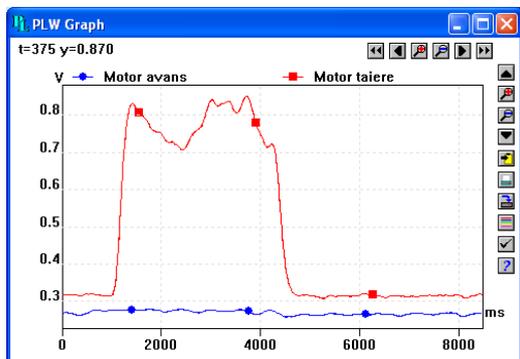


Fig. 4.
Graphic of recorded experimental data

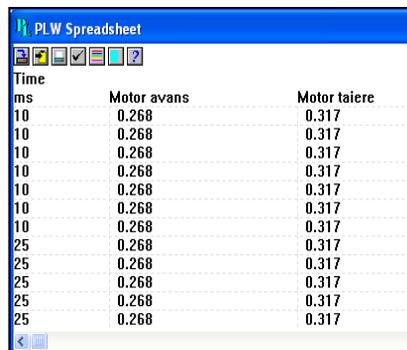


Fig. 5.
Text file with recorded experimental data

RESULTS AND DISCUSSION

Based on the diagram presented in Fig. 3, the simulation software presented below was developed. The software allows to establish the input and output values of every module, to establish the values of the process factors, to simulate the cutting power as it happens in real cutting processes, to display the graphic of the cutting power and to save the simulated values. In order to perform an experiment, the user must modify the process factors for every test and start the simulation process and save the simulated values in the data base. The number of files depends on the type of experiments.

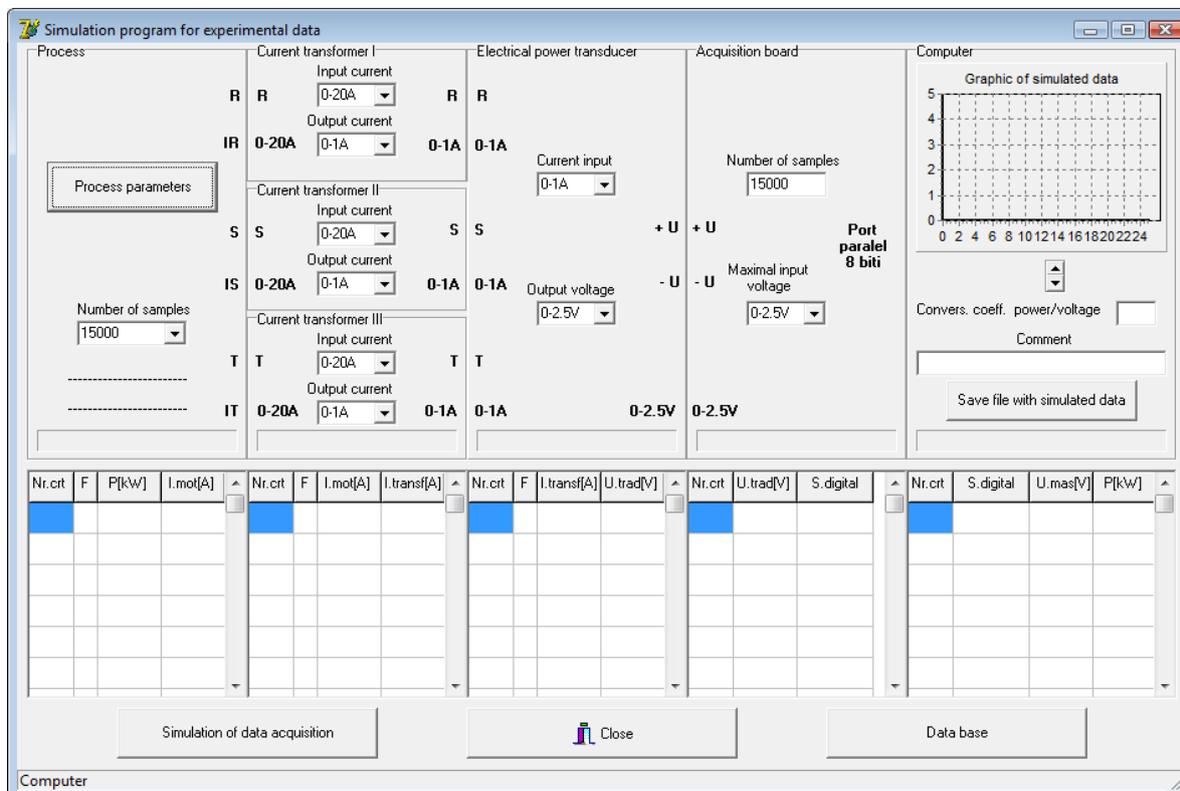


Fig. 6.
Main menu of the simulation program for experimental data

The simulation software has 5 modules which respect the functions of the diagram presented in Fig. 3.

1. The first module named **“Process”** establishes the process parameters based on the experimental design. Pressing the **“Process parameters”** button opens the menu presented in Fig. 7, where the user can establish the values of the independent factors. Also, in the process module the number of the generated samples can be set.

2. The second module named **“Current transformer I,II,III”** reduces the current for all three phases of the main motor to values which can be measured by the power transducer.

3. The third module named **“Electrical power transducer”** converts the currents from the three current transformers into analog voltage, which can be the input value for the data acquisition board.

4. The fourth module named **“Acquisition board”** converts the analog voltage into a digital value.

5. The fifth module named **“Computer”** allows the graphic representation and recording of the experimental data in a text file. For every test of the experiment, a text file is created, which contains information about the test and several simulated samples.

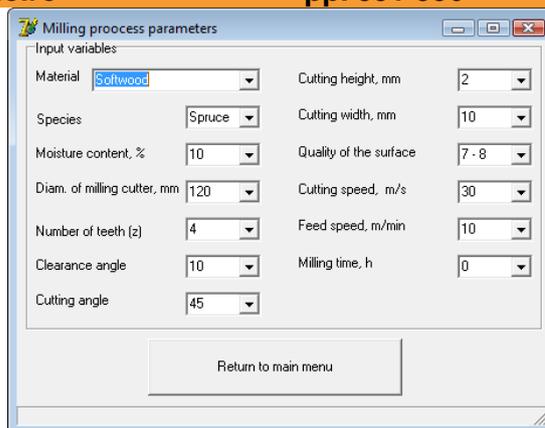


Fig. 7.
Process parameters of the milling process

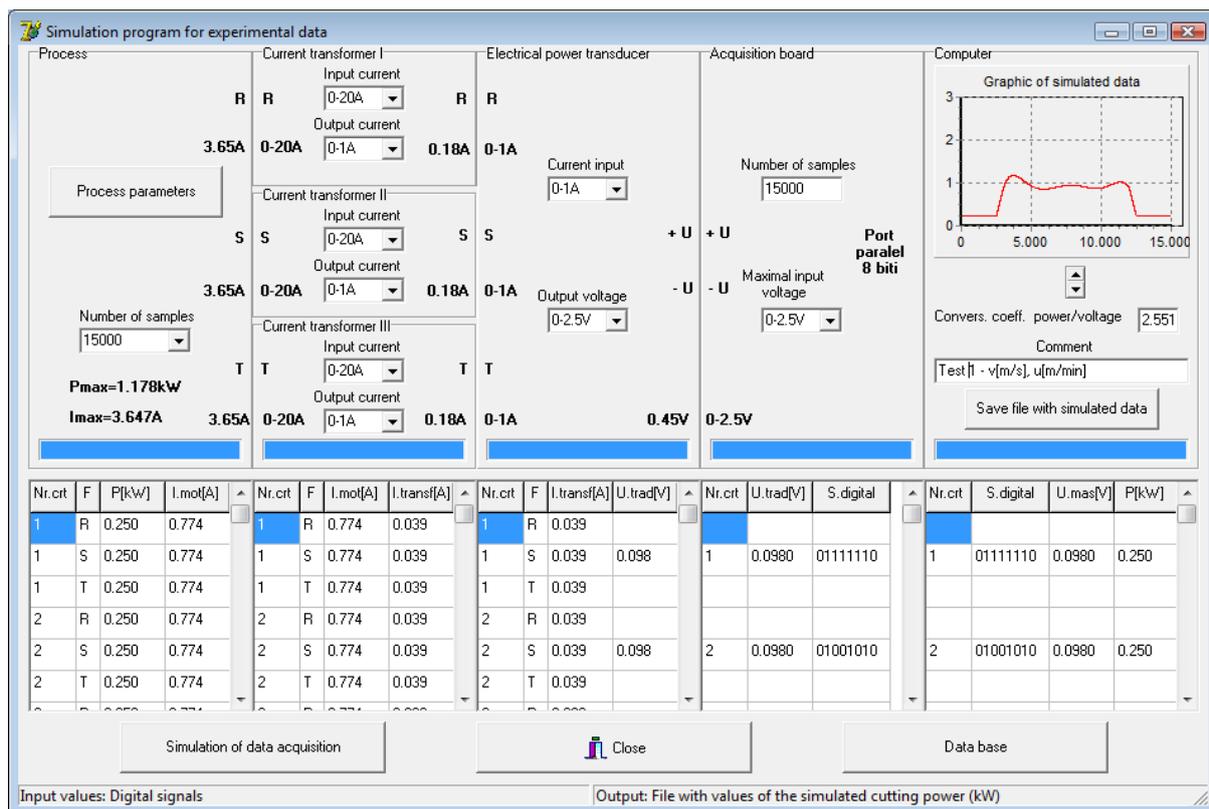


Fig. 8.
Example of a simulation and generation o experimental data

After finishing the experiment, the values of the cutting power P[kW] are determined with another software (Laurenzi 2013) presented in Fig. 9. Every text file of the experiment is loaded into the software module and by selecting the desired area with two mouse clicks, the cutting power is displayed on the status bar of the main menu. With these values the experimental design presented in Fig. 10 is completed.

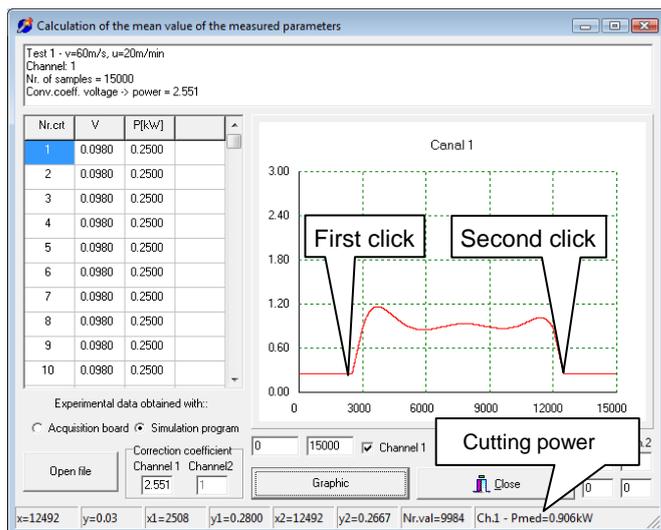


Fig. 9.
Calculation of the average value of the cutting power

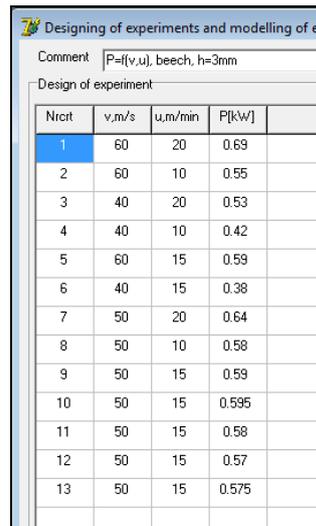


Fig. 10.
Design of experiments completed with average values of the cutting power

With the completed experimental design, it is possible to obtain the mathematical model (Fig. 11) and the graphic (Fig. 12) for the dependence of the cutting power $P[kW]$ from the cutting speed, $v[m/s]$ and the feed speed, $u[m/min]$, $P=f(v,u)$. Therefore it is possible to use the software (Laurenzi 2013) presented in Fig. 11.

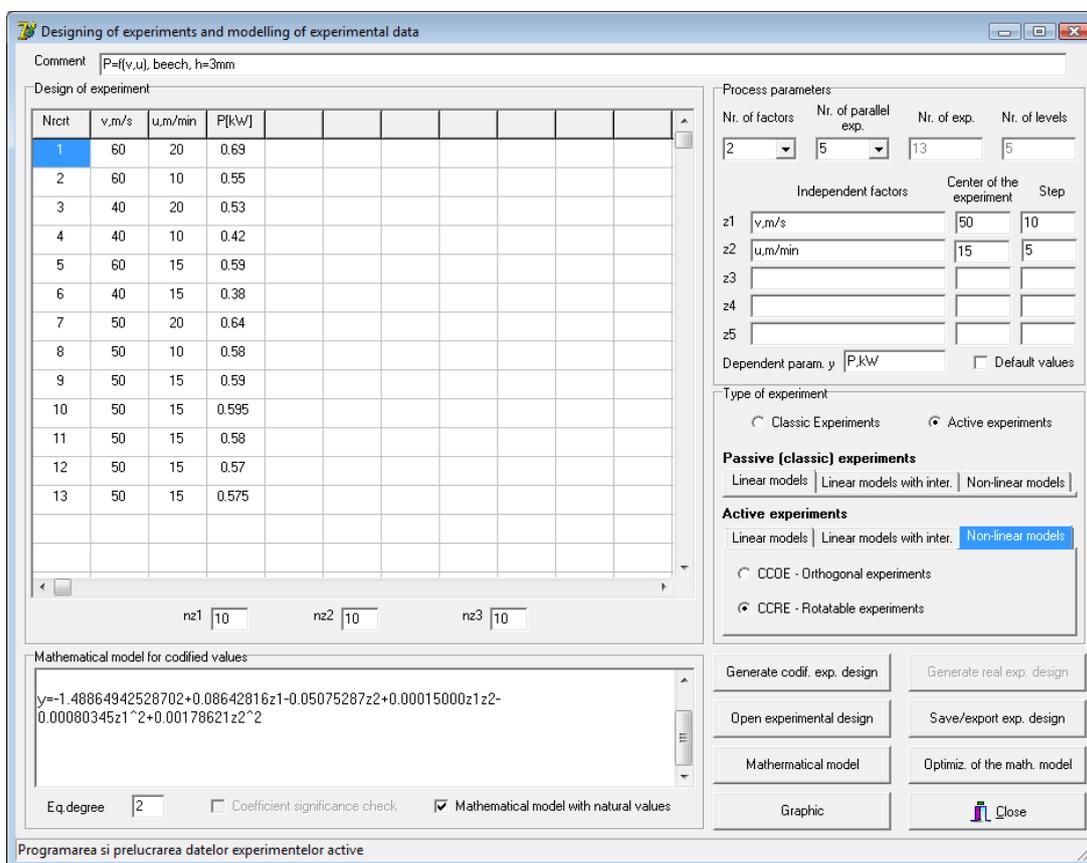


Fig. 11.
Software module for modeling the experimental data

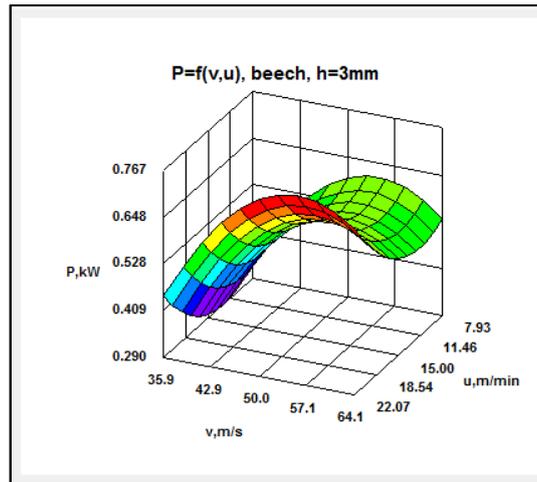


Fig. 12.
Graphic of the cutting power $P=f(v,u)$

After the graphical representation of the mathematical model, it is possible to analyze the influences of the factors on the cutting power and gather conclusions about the cutting process.

CONCLUSIONS

The simulation software presented in this paper is a very useful tool in the teaching process of experiments in order to understand how experiments can be done. Because the software replaces the real acquisition process, it is possible to simulate an experiment offline – from designing the experiment and gathering the data to processing and interpreting them. This software can be used by students and researchers in their scientific activity.

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