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CAN ACTIVE EXPERIMENTS BE USED IN WOODWORKING PROCESSES?

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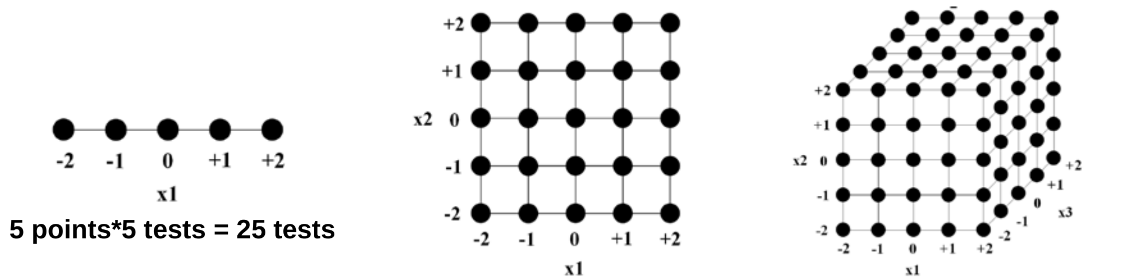
Abstract:
The experiments conducted during scientific research can be very simple or very complex. It is widely known that the classic (passive) experiments, consisting of 5 tests at every point of the experiment, are the most precise, but also expensive experiments. In order to reduce the cost of experiments, many researchers use different types of active experiments. These experiments are cheaper than the classical experiments, but no so precise (up to 95%). The number of tests that are necessary can be reduced by designing the experiments (DOE experiments). If we take into account that the structure of wood (depending on its type) is non-uniform, it is possible that the results of the experimental research conducted with active experiments are inaccurate. In order to confirm or invalidate these hypothesis, this paper presents a simulation program that allows simulations of a milling process for different types of experiments.

Key words: *simulations of experimental plans.*

INTRODUCTION

Scientific research is often conducted through experiments. These experiments can be classic, i.e. passive experiments, where 5 tests are made in every point of the experiment, or they can be active experiments, named DOE experiments (Wikipedia, Taloi 1987, Czitrom 1999, Jiju 2003, Cavazzuti 2013), where fewer tests are made, but based on a designed experimental plan. Classic experiments are more expensive, but also more precise. If a lower precision is acceptable (up to 95%), active experiments can also be used. These experiments are less expensive than passive experiments. Fig. 1 and 2 show some examples of classic and active experiments (Laurenzi 2013).



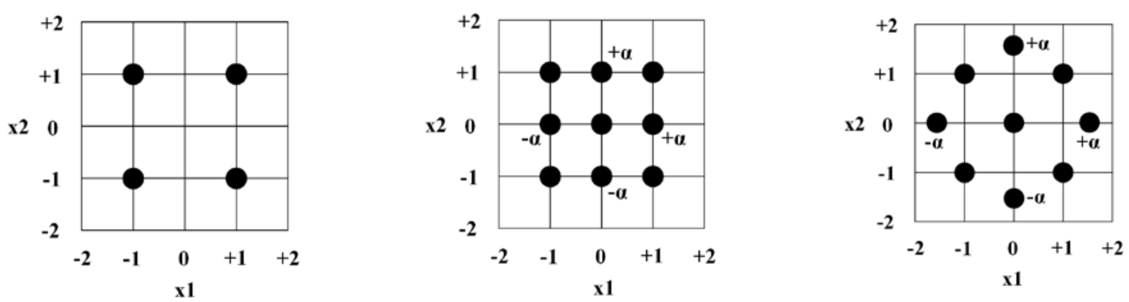
5 points*5 tests = 25 tests

25 points*5 tests = 125 tests

125 points*5 tests = 625 tests

a **b** **c**

Fig. 1.
Examples of classic (passive) experiments:
a – one factor, y=f(x1); b – two factors, y=f(x1,x2); c – three factors, y=f(x1,x2,x3).



4 points*1 test = 4 tests

a

8 points*1 test +
1 centerpoint*5 tests=
13 tests
b

8 points*1 test +
1 centerpoint*5 tests=
13 tests
c

Fig. 2.
Examples of active experiments with two factors y=f(x1,x2).

If we are interested in using these type of experiments in woodworking processes, at first, we must know that there are very few information about active experiments in woodworking processes and also we must put following question: "Can active experiments be used in these processes?". We must ask this question because wood has an uneven structure, depending on the type of wood and also on the cutting direction. An answer to this question can be found by making a large number of classic and active experiments – which also means destroying many wooden samples. In order to avoid this, we can try at first to simulate these types of experiments by using a simulation program.

OBJECTIVE

This paper has three main objectives:

- to present a simulation program developed on the basis of information obtained from speciality literature on experiment design and wood milling processes;
- to simulate and compare different classic and active experiments;
- to formulate conclusions regarding the question if the active experiments can be used in woodworking processes.

METHOD

In order to fulfil the above-named objectives, we will first present the simulation program (Fig. 3), then we will illustrate a series of different graphics of the simulated experimental plans and finally we will formulate the conclusions resulted after the comparative study.

Presentation of the simulation program

The simulation program was developed on base of other programs for simulation of woodworking milling processes (Laurenzi 2011) and experimental data processing (Laurenzi 2013). The simulation program has four modules which can be accessed very easily from the main menu (Fig. 3).

The first module (Fig. 4, Fig. 5) is used to generate classic or active experimental plans for two different factors, for 1 to 5 tests only for the checked points on the experiment.

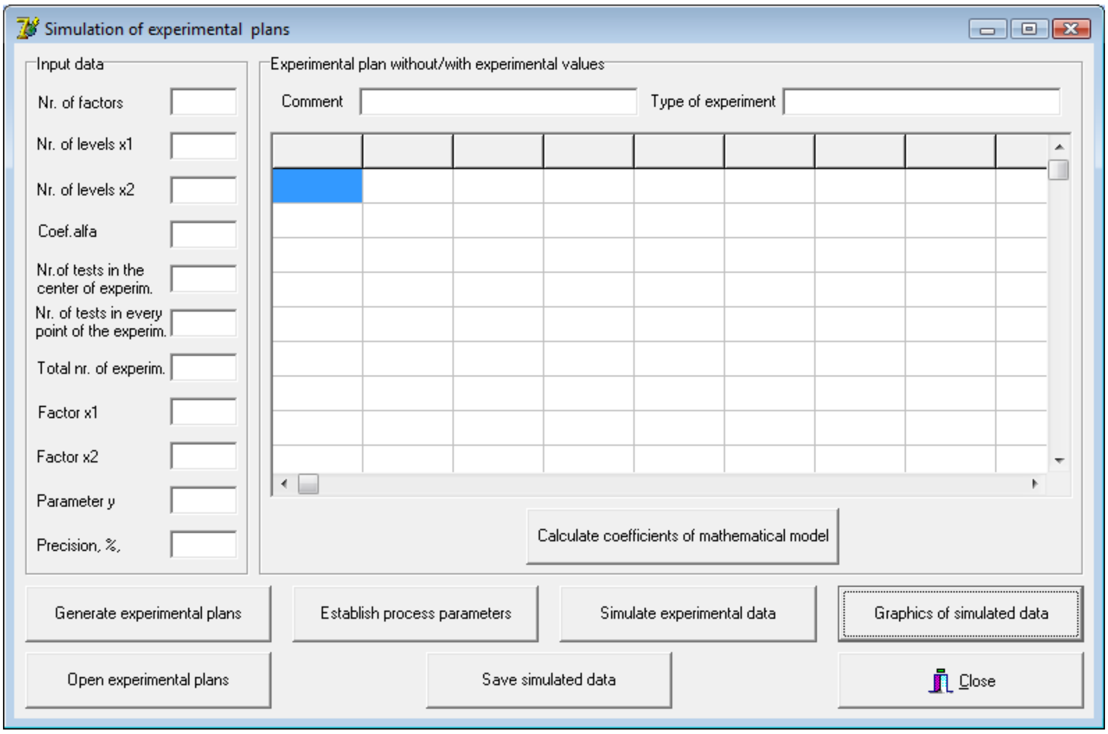


Fig. 3.
Main menu of the simulation program.

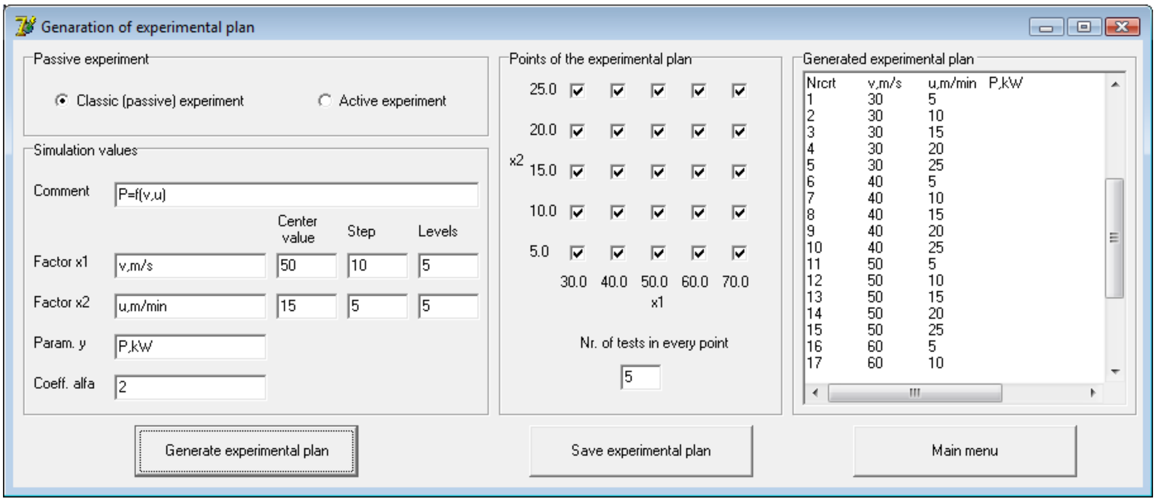


Fig. 4.
Generation of classic experimental plans.

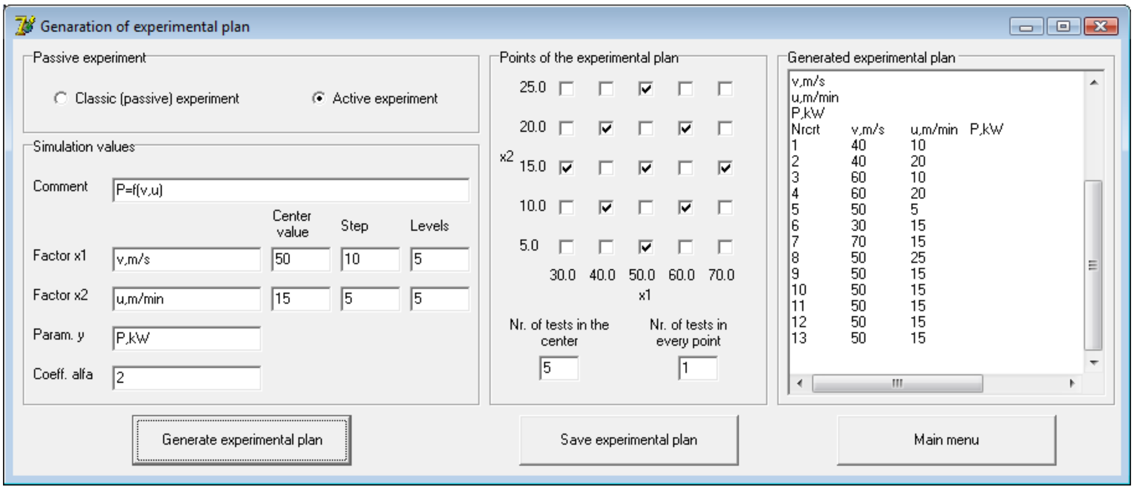


Fig. 5.
Generation of active experimental plans.

The second module (Fig. 6) is used to establish the milling process parameters.

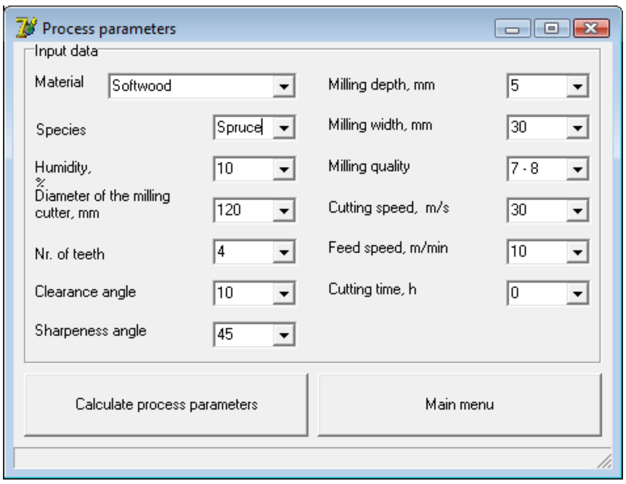


Fig. 6.
Establishing the process parameters.

The third module (Fig. 7) is used to simulate the experiment on base of the experimental plan established with the first module and the process parameters established with the second module. In this version of the program, the simulation module generate only values for the cutting power in function of the cutting and the feed speed. Because the wooden structure is variable, the simulation module generates randomized values around the calculated values of the cutting power. The size of this intervals can be set by the user, respectively 0%, ±15% and ±30%.

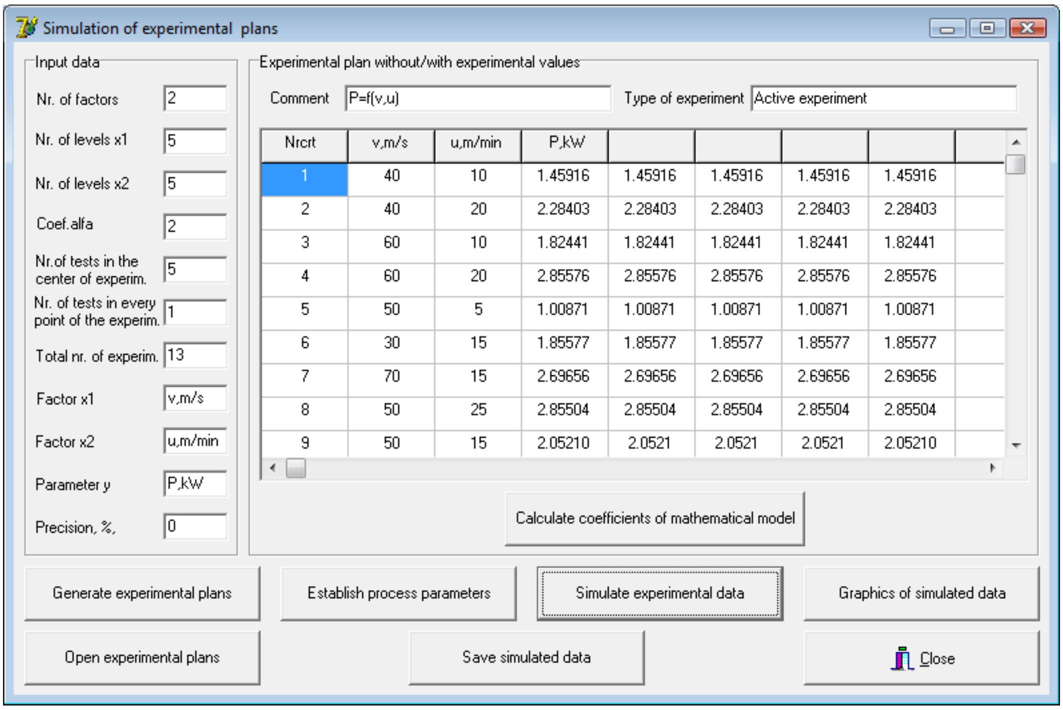


Fig. 7.
Simulation of the experimental plan.

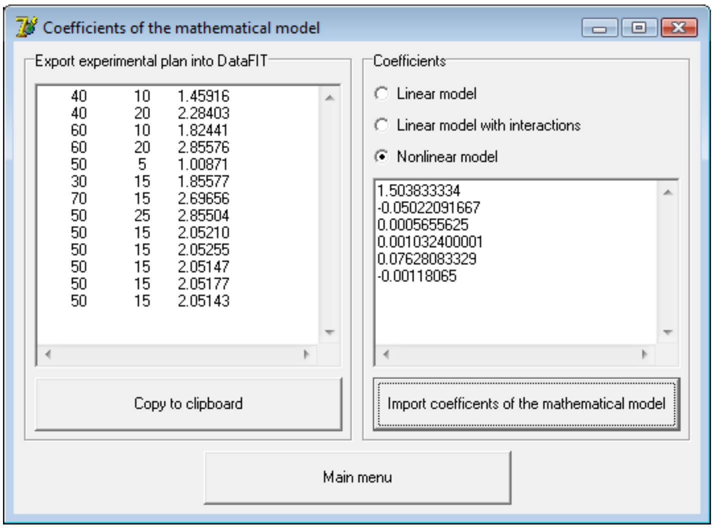


Fig. 8.
Export experimental data into a regression software and import coefficients of the mathematical model.

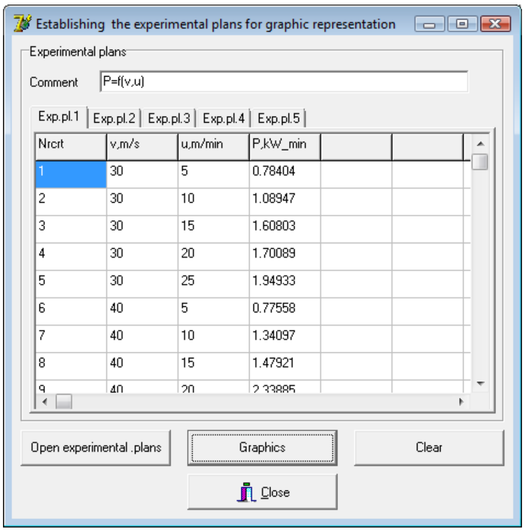


Fig. 9.
Establishing which graphics are displayed.

For active experiments, the experimental plan with the simulated values must be exported to a regression program, like DataFit, in order to calculate the coefficients b0, b1, b12, b2, b11 and b22 for the linear or non-linear mathematical model (Fig. 8):

- linear models with interactions: y(x1,x2) = b0+b1*x1+b2*x2+b12*x1*x2; (1)
- nonlinear models: y(x1,x2) = b0+b1*x1+b2*x2+b12*x1*x2+b11*x1*x1+b22*x2*x2 (2)

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After the coefficients are determined, the simulation process with the new mathematical model must be repeated, because the first simulation was only with values from the simulated experimental plan. After simulation, the experimental plan must be saved. Automatically are saved three files with the minimum, medium and maximum values depending on the random intervals.

The fourth module (Fig. 9) is used to represent graphics of the experimental plans for classic and active experiments. In order to compare these graphics, every file with experimental data must be loaded into a page named Exp.pl. 1 – Exp.pl.5 (maximum 5 pages). Thus can be compared the simulated values for different types of experiments (Fig. 10).

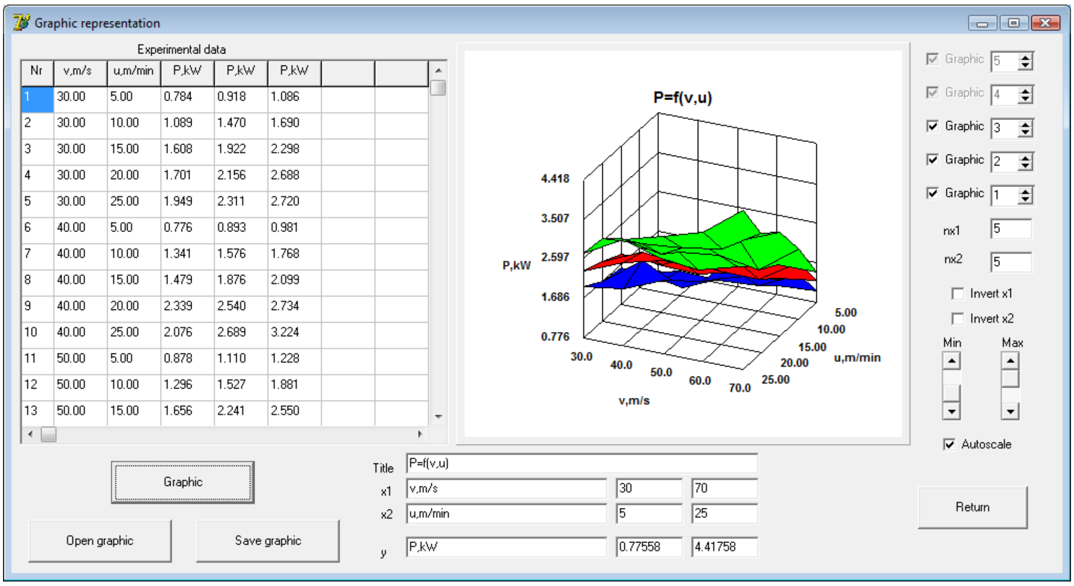
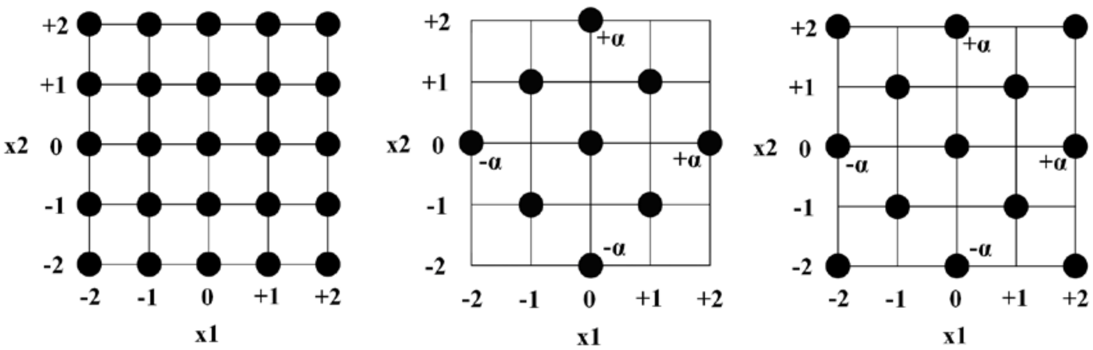


Fig. 10.
Simulation of classic and active experiments.

RESULTS & DISCUSSION

In order to determine if active experimental plans can be used in woodworking processes, for example in milling processes, there are simulated four different types of experiments. In this paper are presented only simulations of the cutting power P[kW] in function of the cutting speed v(m/s) and the feed speed u(m/min), P=f(v,u). The other factors of the cutting process are maintained constant (Fig. 6). The simulations are based on the experimental plans presented in Fig. 11. Every experiment has two factors, x1 and x2 with 1 to 5 points (levels). In every point of the experiment, 1 to 5 tests can be performed. Every experiment has a center point (noted 0) and two points downward (noted -2 and -1) and two points upward (noted +1 and +2). The values of all points (Table 1) depends on the central values of the factors $x1_0$ and $x2_0$, the values of the steps for every factor and a coefficient α which depends on the type of experiment (Taloi 1987, Laurenzi 2009).



a ***b*** ***c***

Fig. 11. Experimental plans.
a – classic plan; b – active plan; c - completed active plan (I and II);

Table 1 presents the equations which are used to calculate the real values of the factors for the chosen experimental plan.

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Table 1

Codified and real values of the factors

Code	Codified factors		Real factors	
	x1	x2	x1 v(m/s)	x2 u(m/min)
Δ	Δx1	Δx2	10	5
-2	$x1_0$-α*Δx1	$x2_0$-α*Δx2	30	5
-1	$x1_{-1}$= $x1_0$-Δx1	$x2_{-1}$= $x2_0$-Δx2	10	10
0	$x1_0$	$x2_0$	50	15
+1	$x1_{+1}$= $x1_0$+Δx1	$x2_{+1}$= $x2_0$+Δx2	60	20
+2	$x1_{+2}$= $x1_0$+α*Δx1	$x2_{+2}$= $x2_0$+α*Δx2	70	25

The figures below illustrate the simulated linear and nonlinear mathematical models P=f(v,u) for:

a - classic experimental plans (Fig. 11a) with 125 tests (5 tests in every point of the experiment).

b - active experimental plans (Fig. 11b) with 13 tests (5 tests in the center and only 1 test in every point of the experiment)

c - completed active experimental plans I (Fig. 11c) with 17 tests (5 tests in the center and only 1 test in every point of the experiment)

d - completed active experimental plans II (Fig. 11c) with 65 tests (5 tests in every point of the experiment)

The experimental plans were simulated with three different deviations +/-0%, +/-15% and +/-30% in order to take into account the variable wooden structure.

In the figures presented below (Fig. 12 – 17), the graphics can be recognized by there colours: classic experiments with 125 tests (blue); active experiments with 13 tests (red); completed active experiments I with 17 tests (green); completed active experiments II with 65 tests (yellow).

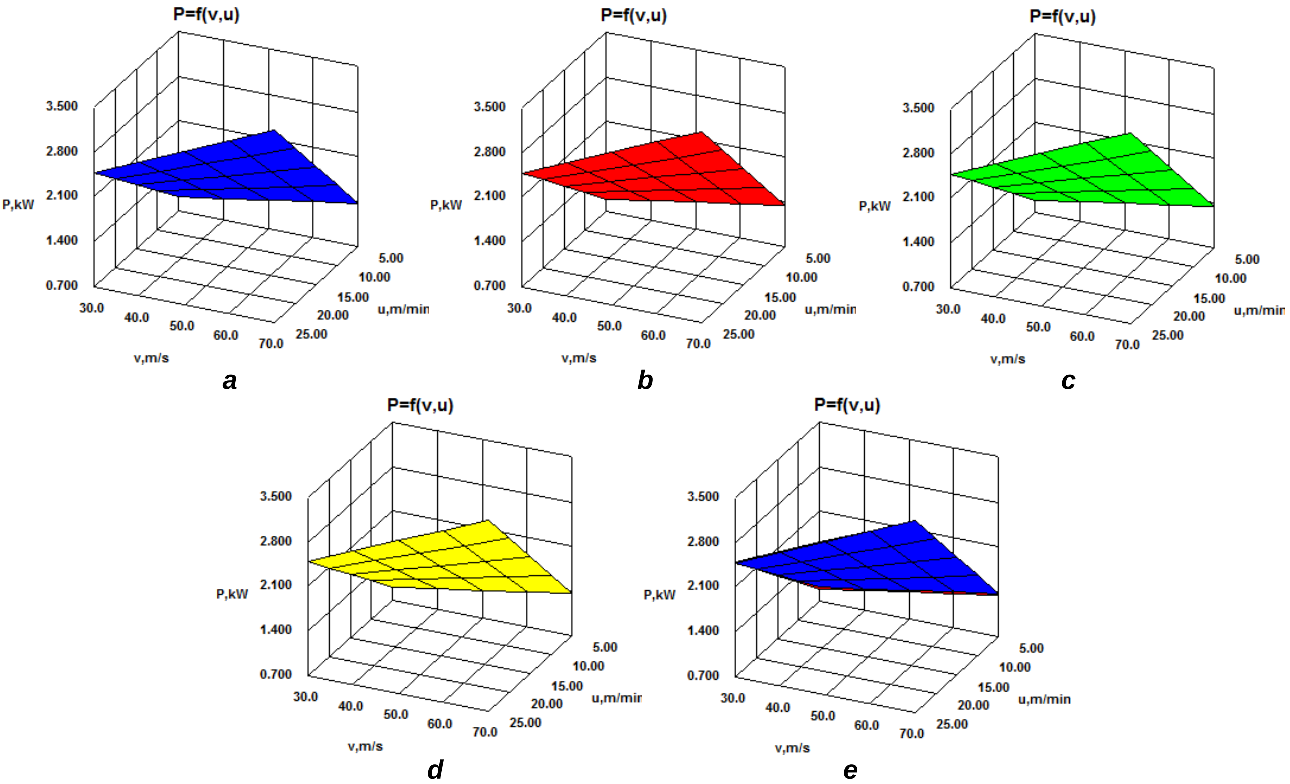

Fig. 12.
Simulations of linear classic and active experiments (+/- 0%):
a – classic; b – active experiment; c – completed active experiment I;
d - completed active experiment II; e - overlapped graphics.

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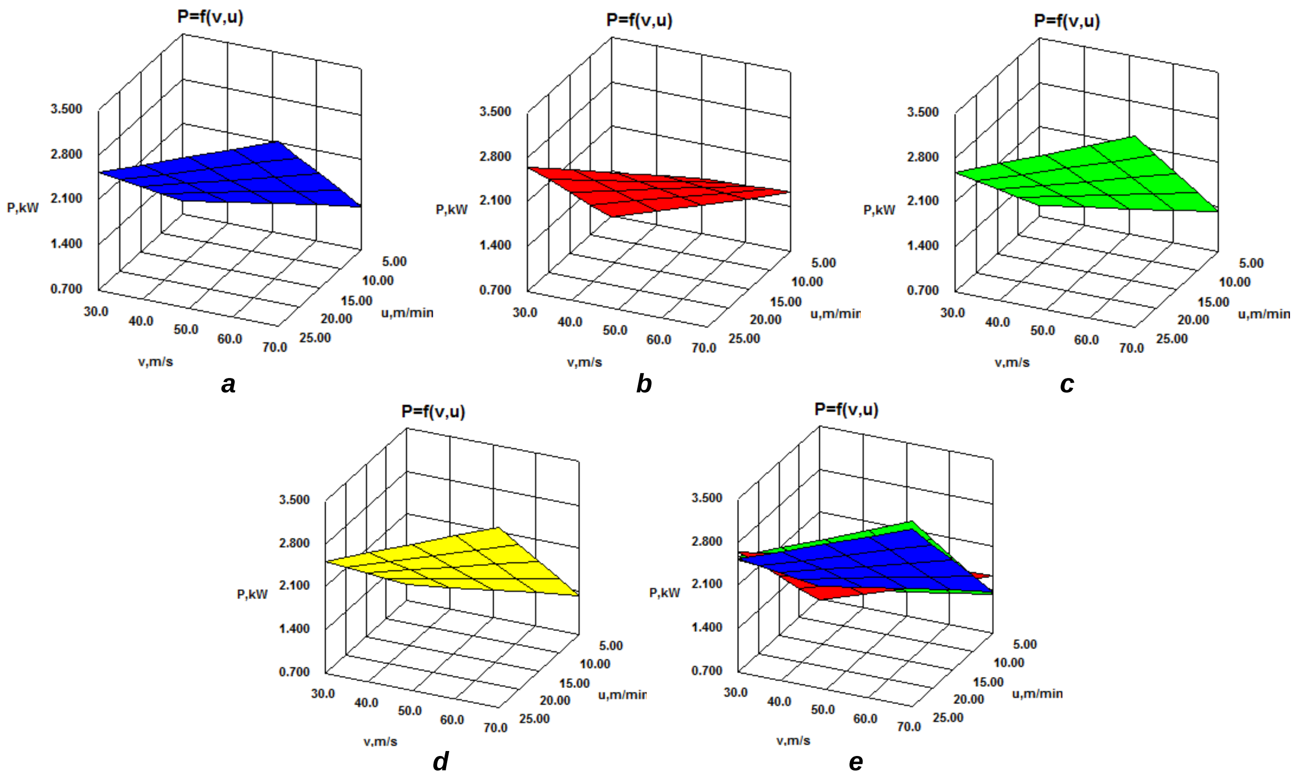

Fig. 13.
Simulations of linear classic and active experiments (+/- 15%):
a – classic; b – active experiment I; c – completed active experiment II;
d - completed active experiment III; e - overlapped graphics.

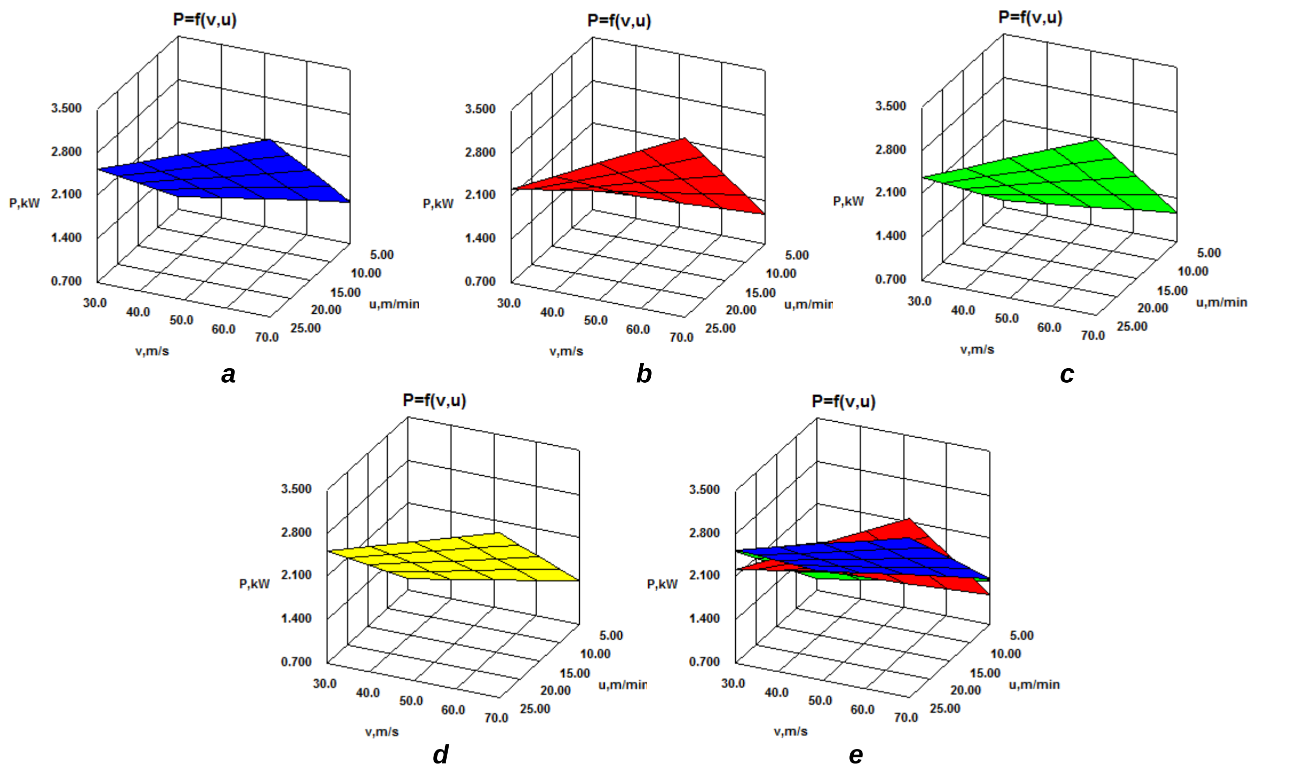

Fig. 14.
Simulations of linear classic and active experiments (+/- 30%):
a – classic; b – active experiment; c – completed active experiment I;
d - completed active experiment II; e - overlapped graphics.

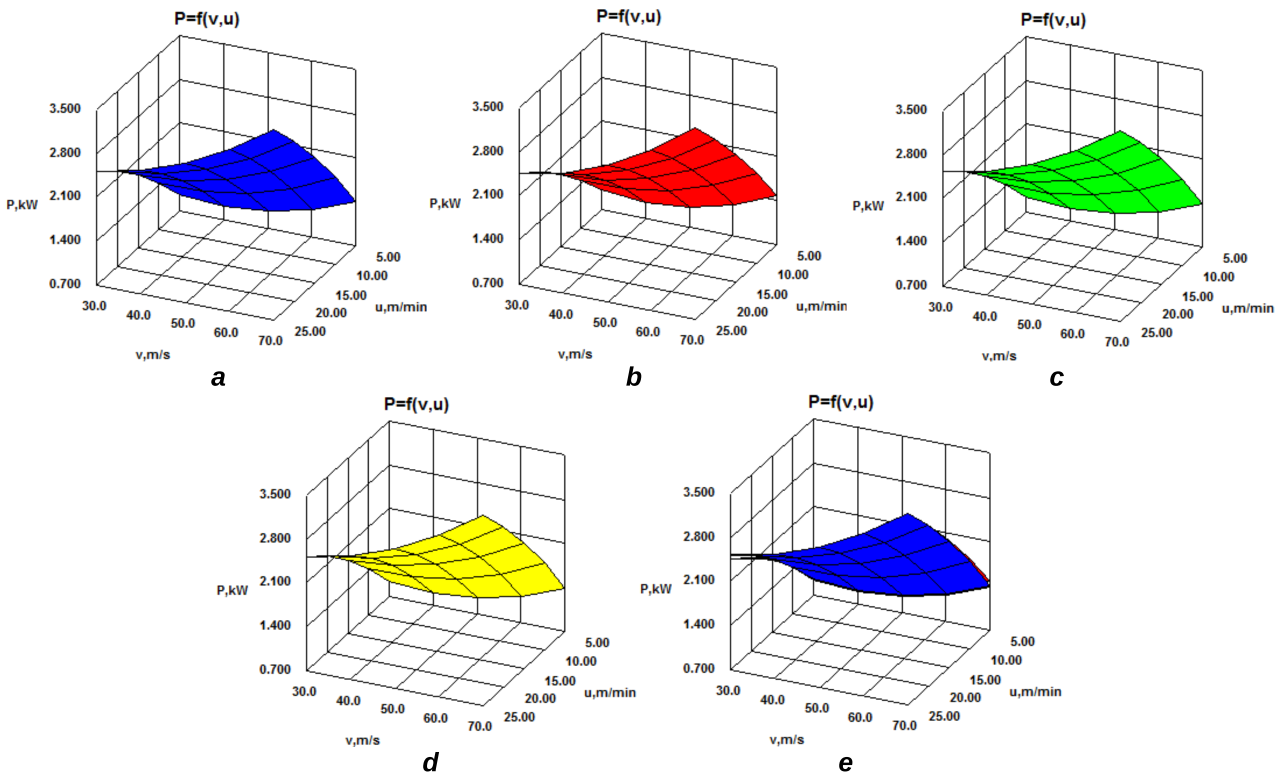

Fig. 15.
Simulations of nonlinear classic and active experiments (+/- 0%):
a – classic; b – active experiment; c – completed active experiment I;
d - completed active experiment II; e - overlapped graphics.

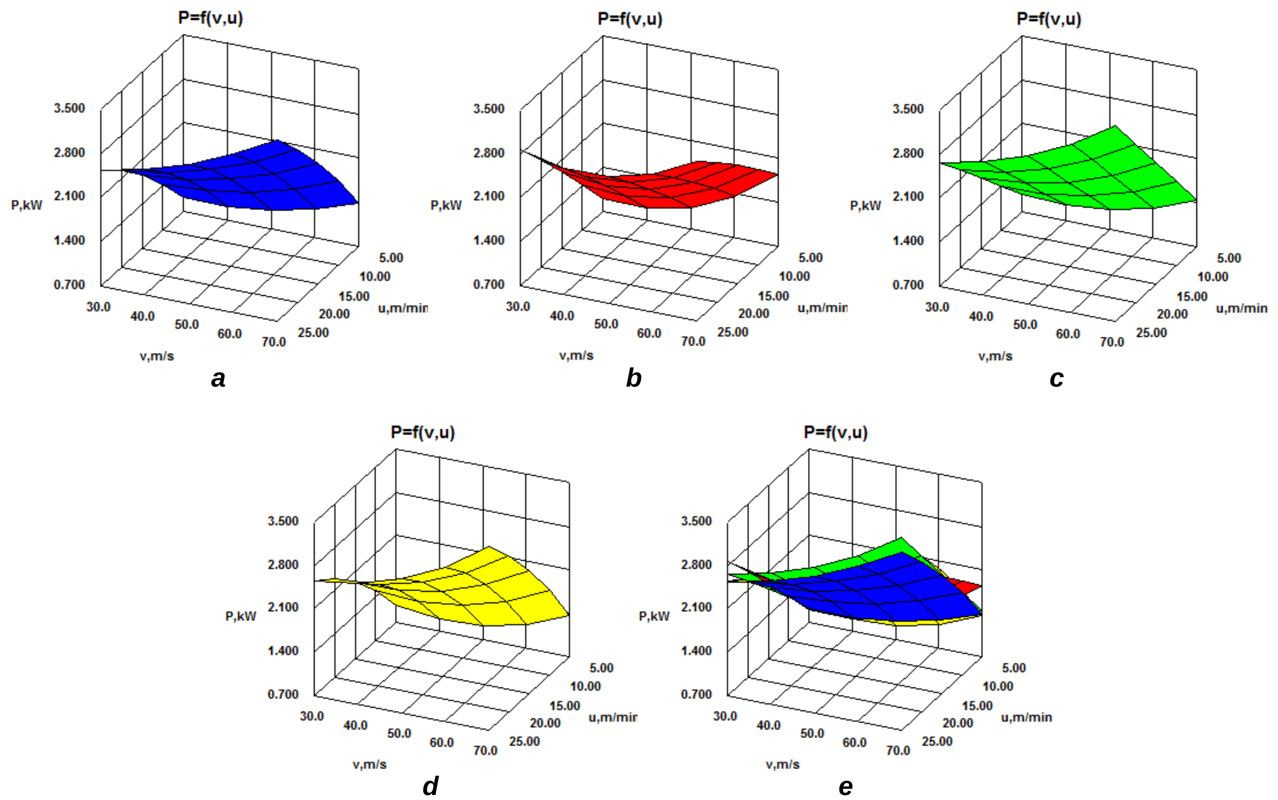

Fig. 16.
Simulations of nonlinear classic and active experiments (+/- 15%):
a – classic; b – active experiment; c – completed active experiment I;
d - completed active experiment II; e - overlapped graphics.

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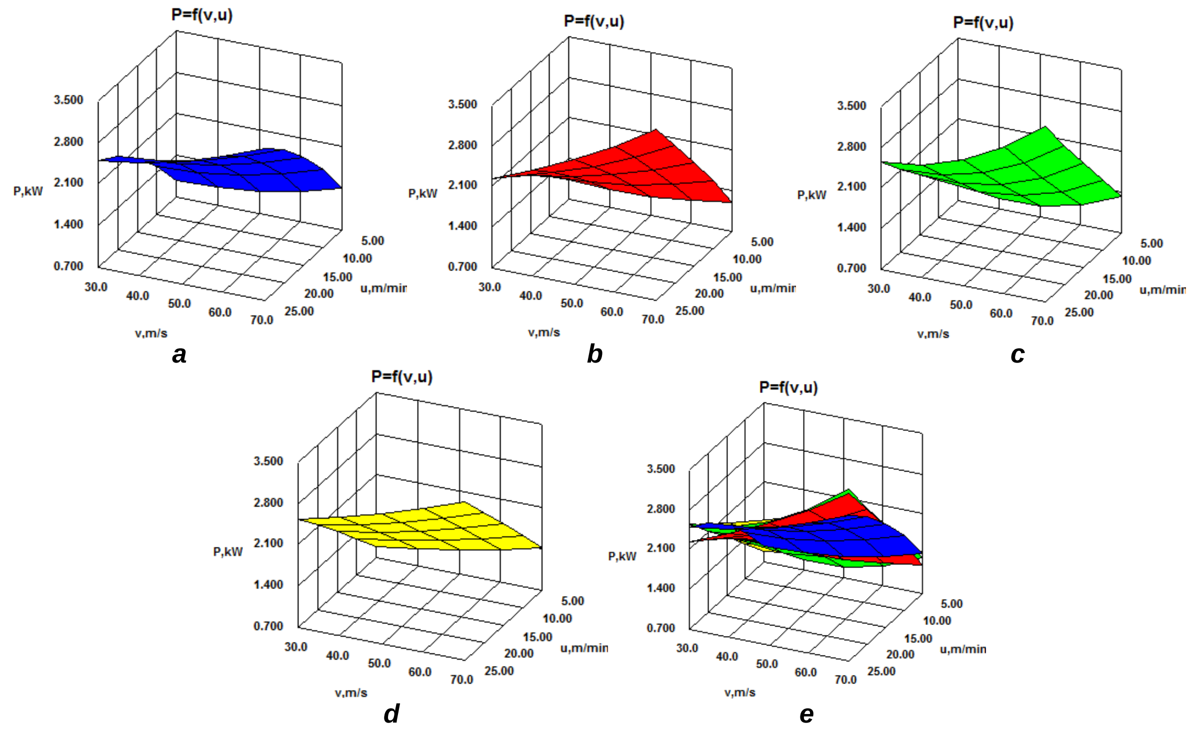

Fig. 17.
Simulations of nonlinear classic and active experiments (+/- 30%):
a – classic; b – active experiment; c – completed active experiment I;
d - completed active experiment II; e - overlapped graphics.

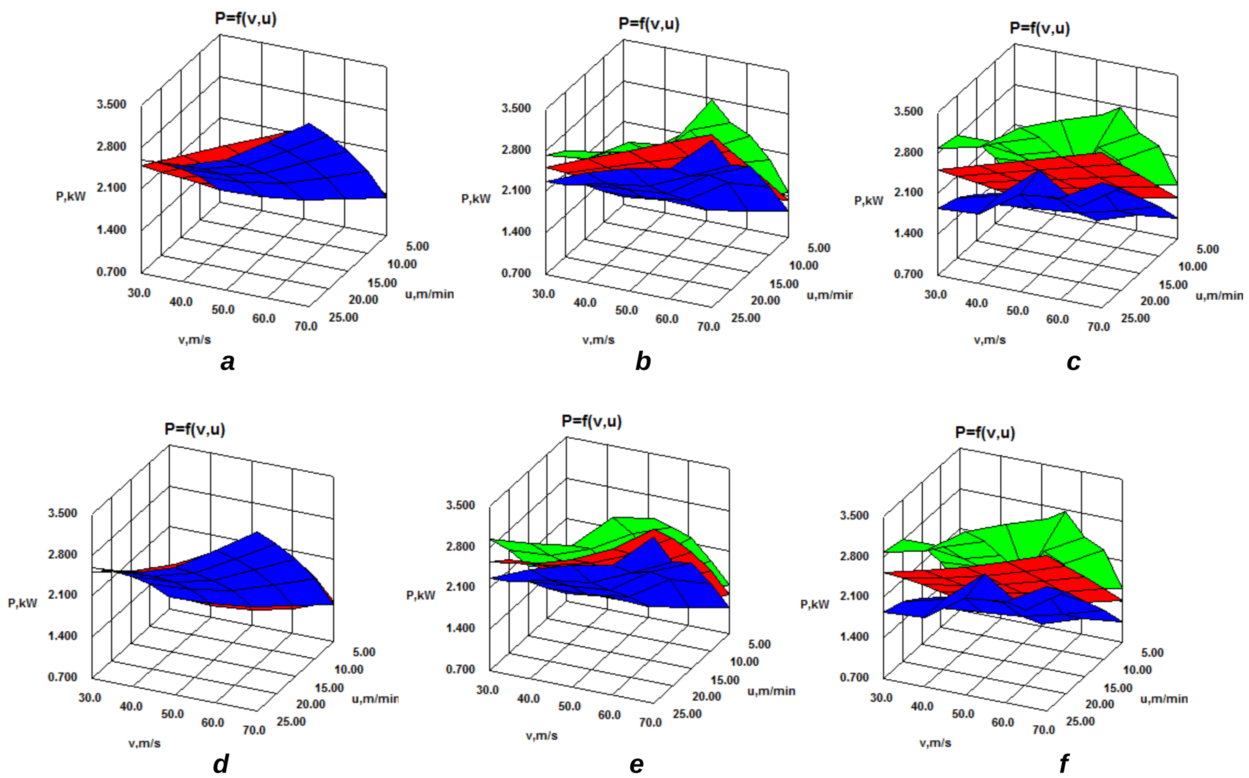

Fig. 18.
Simulations of classic and linear completed active experiments:
blue – minimum values (classic experiment); green – maximum values (classic experiment);
red – linear (a, b, c) and nonlinear model (d, e, f) completed active experiment II;
a – 0%; b = +/- 15%; c - +/- 30%.

The analysis of the simulation process and the simulated graphics lead to the following conclusions:

- the active experiments with 13 tests (5 tests in the center of the experiment and 1 test in each point of the experiment) can be used very well in woodworking processes when the wooden structure is uniform.
- when the wooden structure is slightly irregular, i.e. when the variations are smaller then +/-15%, it is possible to use completed active experiments with 17 tests, or better even, 65 tests.
- when the wooden structure is very non-uniform, respectively the variations are greater then +/30%, it is recommended to use classic experiments with 125 tests.
- the linear models appear to be better than non-linear models.
- because this study is only a theoretical approach there are necessary other real experimental studies in order to answer to the question: Can active experiments be used in woodworking processes?

CONCLUSIONS

There are two ways of studying whether active experimental plans can be used in woodworking processes: one way is to perform simulations based on information from literature, and the other way is to find out through experiments. Because the second way is very expensive, the simulation program allows to simulate different types of experiments in variable conditions. The results of these simulations are very helpful in identifying the correct type of experiment to be conducted. A certain answer to the question put in this paper can only obtained by real experimental studies for all types of species and woodworking processes.

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