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MODELING OF THE PRESSING FORCES USING GENETIC PROGRAMMING

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ABSTRACT
In this paper, for the research of the models of genetically programed pressing forces, experimentally given values of pressing forces of axial symmetric stratified wood were used, given by the procedure of bending and simultaneous sticking while being warmed up by high frequency electricity. Namely, during the experiment the pressing forces were measured as output values, with variable parameters which determine the conditions of the experiment that are defined by independent varying input process variables. Those are: contact pressure, tangent voltage and strains determined by the thickness of the workpiece. For research purposes, special tools were made by using necessary measurement devices, and for the production of the models a software package for genetic programing called GPdotNET was used. This program was developed for modeling and optimization by using genetic programing. Based on the results given by the GP model, the coefficient of multiple regression was calculated thus implying that the GP model exquisitely describes the interpretation process.
Key words: genetic programing, GP model, pressing forces, axial symmetric workpieces

1. INTRODUCTION
The conducted experimental studies are based on a theoretical analysis of the problem of modeling layered-laminated wood, in order to clarify and further define the influence of frequently important input variable parameters to the output value of the pressing force of the processing axisymmetric pieces from layered wood, which makes the process of shaping easier and more efficient in the future. Experiments and experimental measurements are planned in accordance with scientific settings and implemented in real-world conditions of the production process. The obtained results are pressing force values (Table 1), based on input variables: the contact pressure (p), the thickness of the molded part deformation (φ) and the shear stress (τ), as important factors of the process, and they have underpinned findings of the mathematical regression model with the method that with satisfactory accuracy describes the process of creating axially symmetric workpieces from layered-laminated wood. To check the reliability of the resulting mathematical model with regression method, the method of genetic programming (GP) was performed. Since the results obtained by the GP model for the pressing force show a high degree of compatibility with the experimental results, it is considered that they confirm its reliability. A method of obtaining GP model is described later in this work.

2. MODEL CALCULATION USING GENETIC PROGRAMMING (GP)
Genetic programming is a modification of the method of genetic algorithm whereby chromosomes are represented through computer programs. To achieve that the computer solves a problem, without having to be instructed, is in fact the basic idea of solving any problem. The most important contribution, starting from the 70s of the 20th century until today, in genetic programming was given by an American John Koza. At least 36 problems are known today [1] for which the genetic programming produced a better solution than the best already known solution, most of which are

related to the areas of electrical circuits, molecular biology, scheduling, etc. Genetic programming has many similarities, but also some important differences from genetic algorithms. The basic idea is the same: to create a population of initial solutions (in this case the program to solve the problem). Then, through a number of generations to find the optimal solution, with the activity of genetic operators and reviewing the extent to which individual solution meets our needs. Modeling of the pressing forces, in the processing of axially symmetric workpieces of plywood, with genetic programming (GP) begins by defining the data obtained by experimental measurement. Data obtained by experimental measurement of pressing forces with the varied three input independent variables (p-contact pressure; φ-deformation in thickness and τ-tangential stress), and in accordance with the plan of the experiment are given in Table 2-left. To calculate the mathematical model using genetic programming, it is necessary to define the parameters by which to execute the algorithm of genetic programming. For the application of this engineering process to genetic programming, GP parameters are defined in the Table 1.

Table 1. GP parameters for the process application

Functions used in GP		
+	Summation	
-	Subtraction	
*	Multiplication	
Add(4) x1+x2+x3+x4	Addition of 4 parameters	
X^2	Quadratic function	
1/x	Hyperbolic function	
Sin	Sine function	
Cos	Cosine function	
Sqrt	Root function	
Exp	Exponential function	
log	Natural logarithm	

After defining the GP parameters, the evolution of computer programs is started, which means that the process of genetic programming operators activity is initiated. Selection of arithmetic operations that can be found in the mathematical model depends on the type of the process and requires several tests with different sets of operations. It's required to initiate the algorithm for calculations multiple times in an effort to obtain more reliable genetically programmed model. For the purpose of this calculation, the genetic programming software package GPdotNET was used, which has been developed for modeling and optimization using genetic programming. The calculated mathematical model is shown by the following expression:

$$
\begin{aligned}
&(((R3 * R5) * (((R5 - X2) * R6) + X1)) \\
&\quad + ((R1 * ((R5 - X1) * R6)) * (sin((\frac{1}{X2 * X1})))) \\
&\quad + (((sin((Exp(X1)))) + ((R1 * R1) * (sin(X3)))) \\
&\quad + (((R5 - X1) + (sin(R3))) * (sin((X1 * R3))))) \\
&\quad + (sin((((X1 - X2) * (R3 + X2)) + ((R3 - X1) + (sin(X3))))))) \qquad (1)
\end{aligned}
$$

Thus, in algebraic form, the displayed GP model (1) is equivalent to the display via graphic representation, the so-called wood structure, Figure 2.1.

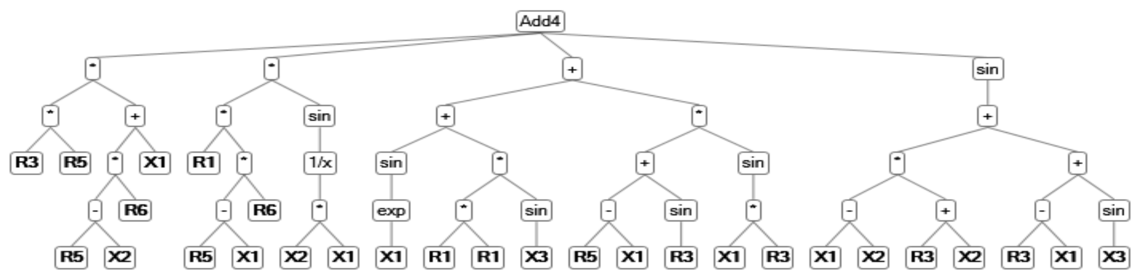


Figure 2.1. GP model shown by the structure of wood

In Figure 2.1., the parameters X_1, X_2 and X_3 correspond to the input parameters: *p*, *φ* and *τ*, respectively, and the letters R_1, R_2, R_3, R_4, R_5 and R_6, correspond to the randomly generated constants at the beginning of the genetic programming calculation of the model. Population size: G = 3,000 specimens, Figure 2.2., and the best solution was found in 2147 generation, Figure 2.3.

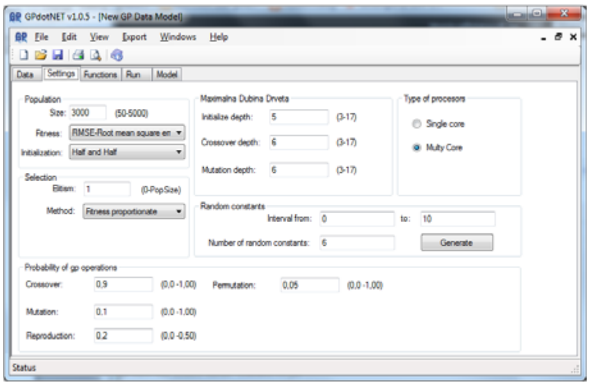


Figure 2.2.The population size and parameters

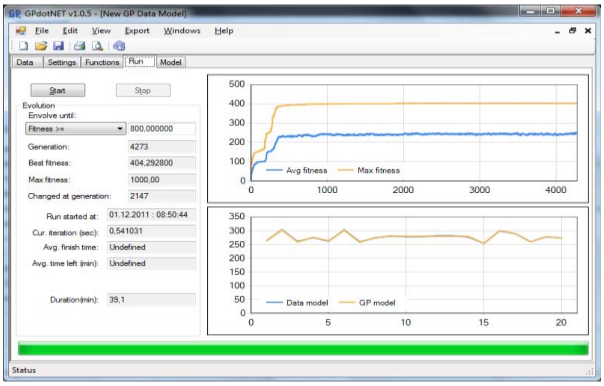


Figure 2.3. The best found solution of GP model

Results obtained using genetic programming (Y_{gp}) are shown in Table 2. The criterion function of the chromosomes validity tests (of the computer programs) is defined by multiple regression and multiple regression coefficient is calculated using the formula:

$$R = \sqrt{1 - \frac{\sum (Yi - \tilde{\tilde{Y}}i)^2}{\sum (Yi - \bar{Y}i)^2}} \qquad (2)$$

where the: Y_i – is the value of experimental data; $\bar{Yi}$ - medium value of experimental data and $\approx{Yi}$ - value according to GP model,

According to equation (2) and based on the results obtained from the GP model (1) the coefficient of multiple regression is calculated:

$$R = \sqrt{1 - \frac{43,4214}{3.911,75}} = 0,9944344 \qquad (3)$$

For the R = 0.9944344, it can be concluded that the GP model (1) perfectly describes processing operation.

3. COMPARISON OF THE EXPERIMENTAL AND GP MODEL RESULTS

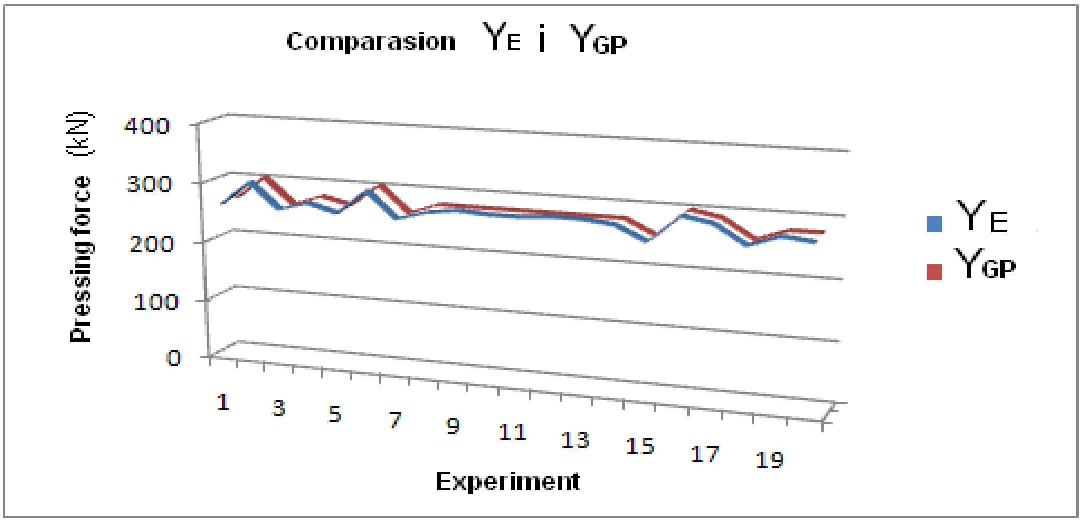
The results obtained by experimental measurements and the results of the GP model, as well as their comparison are given in Table 2.

Table 2. Results according to the experiments and GP model

Ordinal number	*p* (N/mm^2)	*φ* (mm)	*τ* (N/mm^2)	Y_E (kN)	Y_{GP} (kN)	Residual ($Y_E - Y_{GP}$)
E1	0,38	0,66	0,17	264	264,6772	0,6722
E2	0,84	0,66	0,17	304	302,9245	1,0755
E3	0,38	1,0	0,17	261	259,4112	1,5888
E4	0,84	1,0	0,17	275	276,8007	1,8007
E5	0,38	0,66	0,29	262	265,0356	3,0356
E6	0,84	0,66	0,29	303	303,1616	0,1616
E7	0,38	1,0	0,29	260	259,6579	0,3421
E8	0,84	1,0	0,29	274	277,2020	3,2020
E9	0,61	0,83	0,23	281	276,8661	4,1339
E10	0,61	0,83	0,23	278	276,8661	1,1339
E11	0,61	0,83	0,23	278	276,8661	1,1339

E12	0,61	0,83	0,23	282	276,8661	5,1339
E13	0,61	0,83	0,23	282	276,8661	5,1339
E14	0,61	0,83	0,23	277	276,8661	0,1339
E15	0,22	0,83	0,23	254	252,8211	1,1789
E16	1,00	0,83	0,23	299	298,7197	0,2803
E17	0,61	0,54	0,23	290	288,6494	1,3506
E18	0,61	1,12	0,23	260	258,4063	1,5937
E19	0,61	0,83	0,13	278	276,5490	1,4510
E20	0,61	0,83	0,33	273	277,1831	4,1830

The calculated results (Y_{GP}) according to the GP model (1) show very good compatibility with respect to the experimental results (Y_E) as shown in Table 2 and 3D diagram, Figure 3.1.



Slika 3.1. 3D diagram of experimental and GP model results

From Table 2 the residual of experimental data and data obtained by the GP model ($Y_E - Y_{GP}$) are also indicating a very good compatibility, what is also possible to display with 2D and 3D charts.

4. CONCLUSION

The results of experimental measurements are adequate and represent a good basis for the calculation of the mathematical model. Also, experiments confirmed the hypothesis that change of values of the input parameters also changes the intensity of the pressing force. With the regression analysis in the previous work, and based on the same experimental results, the mathematical model which describes the process very well was obtained and as such is applicable in practice. In addition, the resulting regression model, with good compatibility with experimental results, was confirmed using genetic programming, which was the purpose of this paper. Also in addition to confirming the regression model, it was observed that the model obtained by using genetic programming more specifically describes the effect of friction and relative deformation of the thickness on the intensity of the pressing force, especially compared to some analytical models in the literature given in cases of pressing axially symmetric pieces of layered-laminated wood.

5. REFERENCES

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