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FEED-FORWARD NEURAL NETWORK MODEL VERIFICATION AND EVALUATION

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Abstract: *The paper deals with laser micro-machining of polymer material. The experimental data are processed and modelled by artificial neural network (multilayered feed-forward neural network). Furthermore, the new set of experiments was performed to test and verify the obtained neural model. The acquired results are graphically displayed and evaluated.*
Key words: *artificial, neural, network, laser, micro-machining*

1. INTRODUCTION

Compared to traditional computing methods the artificial neural networks (ANNs) are robust and global (Freeman & Skapura, 1991). Because of this, artificial neural networks are widely used for system modelling, function optimization, image processing, and intelligent control (Groze et al., 2007). Artificial neural networks give an implicit relationship between the input(s) and output(s) by learning from a data set that represents the behaviour of a system. Artificial neural networks consist of a large number of processing elements, called neurons that operate in parallel. Computing with artificial neural networks is non-algorithmic. The ANNs are trained through examples rather than programmed by software.

The task of the laser micro-machining has very extensive usage in industrial applications. The system development and introduction of these technologies is very attractive. Micro-machining belongs to the group of production processes, in which undersized products are made. Production specifications trend to continual minimization of product's dimensions (Yilbas, 2001). The laser is optimal tool for its features in this development. Results of the laser micro-machining – surface quality of product and his utility in specific application – depend on the laser parameters and the polymer material type (Al-Sulaiman et al., 2006). In order to interpret complicated dependencies between technological characteristics of laser micro-cutting and output parameters artificial neural networks (ANNs) can be used (Karazi et al., 2009).

This paper is organized as follows. In the next chapter, the practical experiments on the laser machine Laser Pro Mercury L 30 are described. Then, the artificial neural model is designed and trained using Matlab software. Furthermore, the obtained model is verified by new set of experiments. The results of the verification are presented and discussed in the following chapter. The contribution is finalized by some concluding remarks and summary.

2. METHODOLOGY

All experiments have been done on the CO2 laser machine Laser Pro Mercury L 30 which is widely used for laser scribing and laser micro-machining. This machine uses two main input parameters that have key influence to machining results – laser power *P* (W) and feed rate *f* ($mm \cdot s^{-1}$). As the most important output parameters of this laser micro-machining were chosen depth of the groove *d* (mm), surface roughness characteristics *Ra* (µm) and *Rz* (µm). The task of the ANN model is to suggest correct settings (*P*, *f*) of the laser machine for required depth (*d*) and surface quality (*Ra*, *Rz*) to the operator.

In the following text are power *P* and feed rate *f* expressed in percents (related to the maximum power and maximum feed date of the laser machine Mercury L 30). As the tested material the PMMA was selected. All simulations and computations were done using Matlab and Neural Network Toolbox.

This experimental study can be divided into the two following steps:

- Neural model preparation - Experiment on the laser machine, measurement of surface roughness and depth, training data preparation, modelling (=training of artificial neural network)
- Neural model verification – obtaining the settings of the laser machine using neural network, new experiments that tests the suggested setting, data comparison and evaluation

3. NEURAL MODEL PREPARATION

There have been done hundreds of the experiments with various combinations of settings of both input parameters. The surface roughness was measured on all specimens by Mitutoyo Surftest SJ-301, while the depth was obtained by Mitutoyo Linear Height Gage LH-600B.

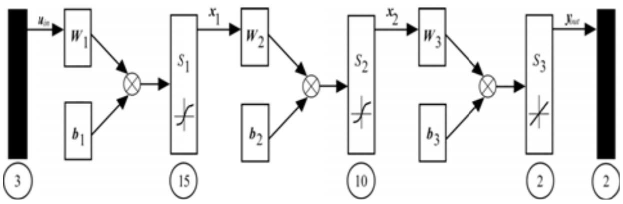

Fig. 1. Structure of predictor based on ANN

Measured data were processed and modelled in Matlab. After few experiments with various types of artificial neural networks, the three-layered feed-forward neural network was selected as the best predictor for the particular nonlinear system.

As can be seen from the figure 1, the network has 3 neuron in the input layer (corresponds with *d*, *Ra*, *Rz*), 15 and 10 neurons with hyperbolic tangent transfer function in the hidden layers and 2 linear neurons in the output layer (corresponds with *P* and *f*). As the training method the Levenberg-Marquart algorithm was used.

4. NEURAL MODEL VERIFICATION

In the verification phase the ANN based model was used for predicting the optimal parameters (power of laser *P* and feed rate *f*) of the laser machine. The number of the settings was 36, as is shown in Table 1. Then, these parameters were used for micro-machining new set of specimens. Again, there was prepared one hundred specimens for the each setting. After the machining, the specimens were measured by same techniques as in the first step. The obtained data were processed in Matlab and arithmetic averages were compared to the original data (the goal of the ANN model). The differences between the goal and real data are presented in figures 2 and 3.

No.	1	2	3	4	5	6
P (%)	30	40	50	60	70	80
f (%)	30	30	30	30	30	30
No.	7	8	9	10	11	12
P (%)	30	40	50	60	70	80
f (%)	40	40	40	40	40	40
No.	13	14	15	16	17	18
P (%)	30	40	50	60	70	80
f (%)	50	50	50	50	50	50
No.	19	20	21	22	23	24
P (%)	30	40	50	60	70	80
f (%)	60	60	60	60	60	60
No.	25	26	27	28	29	30
P (%)	30	40	50	60	70	80
f (%)	70	70	70	70	70	70
No.	31	32	33	34	35	36
P (%)	30	40	50	60	70	80
f (%)	80	80	80	80	80	80

Tab. 1. Verification data (goal settings of the laser machine)

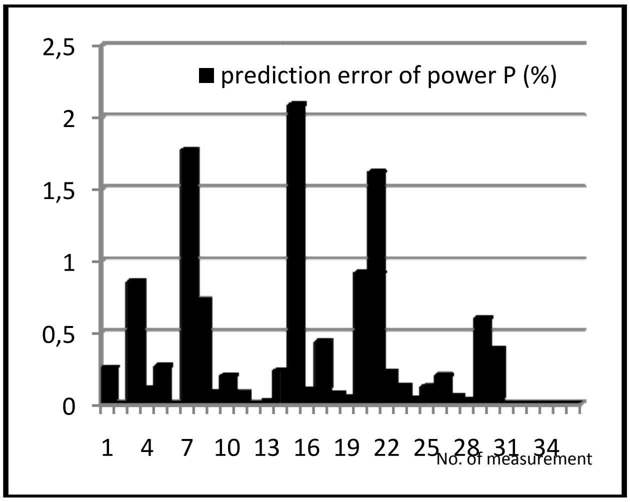

Fig. 2. Prediction error of power *P*

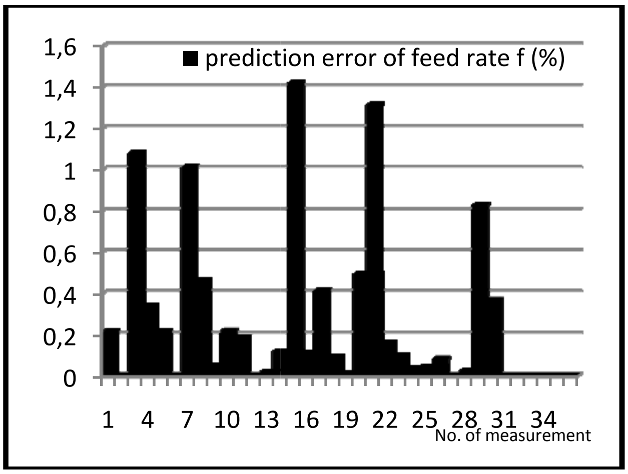

Fig. 3. Prediction error of feed rate *f*

5. DISSCUSION

As can be seen from figures 2 and 3, the artificial neural network proved its quality. The displayed error is mostly under 1 percent (relative to the absolute value of the goal). Interesting behaviour could be observed in the last 6 points. All errors are almost zero for the settings feed rate f = 80%. This feature is probably caused by the shape of nonlinear dependences of *Ra*, *Rz* and *d* on the laser power *P* and feed rate *f* (Jaksik, 2006). In other words the level of functional nonlinearity is much lower for higher feed rates than for low feed rates.

6. CONCLUSION

The artificial neural network was successfully used for modelling of highly nonlinear function. The advantage of presented methodology lays in the fact that other modelling methods such as polynomial models do not offer such simple and powerful tools for modelling and identification of multi input – multi output systems. What is more, artificial neural networks are nonlinear in nature (when nonlinear transfer functions are utilised) and they provide interesting results in case of complex systems.

Of course, this approach has some drawbacks too. One of the most important disadvantages is the fact that the selection of the proper type of artificial neural network and the following design of the network structure is not simple and basic knowledge from the field of artificial neural networks is necessary.

The significance of the presented method lays in practical application of the predictor. The ANN model is ready to be used for obtaining optimal settings of the laser machine Laser Pro Mercury L 30. This method enables to achieve required depth of the machined groove in desired surface quality.

The further research will be focused on the economic aspects of laser micro-machining because the costs of the manufacture in the large-scale productions are the key features. Therefore, it is planned to extend the developed ANN model to economical expenses.

7. ACKNOWLEDGEMENTS

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