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PLASTIC DEFORMATION INITIATION IN SLIDING IDENTATION CASE

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Abstract: *Sliding indentation is obtained by association between normal forces with tangential ones. This generate a specific type of plastic deformations, channel shaped, with track width depending on the normal force's value. If this value is constant thus the track width is constant, otherwise the is variable. In the last situation, the correlation between the width of the channel and the corresponding forces values is difficult to make. This is the reason of constant forces usage. The paper proposes, based on experimental results obtained for a limited range of forces values, a prediction methodology for the track width in sliding indentation case, taking into account the tested material hardness, roughness and normal force values. The proposed methodology uses a neural network simulator, trained with experimental tests results, in order to analyze the tested material characteristics, taken as inputs and delivers as output the track width values. In this way, the predicted values can be used for material characterization.*

Keywords: *plastic deformation, sliding indentation,track width prediction, neural networks*

1. INTRODUCTION

When two bodies interact and the pressure exceeds a certain values, plastic deformations are generated. In the general case the reciprocal forces are normal coupled with tangential ones [1]. In the paper this association is called sliding indentation. As result a specific type of plastic deformations, channel shaped, are generated. Their width and depth depend on the normal force's value and other mechanical characteristics of the tested material. The plastic deformation is distributed into a layer, located in the immediate vicinity of the surface of the bodies, generically called superficial layer. It determines the subsequent behaviour of the two bodies and cause modifications of the hertzian distributions of the pressure [2]…[9]

The paper tried to determine the influence of the roughness, hardness and normal forces upon the track width. For this purpose it was used an especially designed test rig and a neural network simulator, trained with experimental tests results.

2. THE TRIBOMODEL

In order to develop the experimental researches, a ball-plane tribomodel was used, providing a point contact, Figure 1a. For practical design the solution of fixed ball in a mobile mounting was choose, with a flat sample as second body of the tribomodel, Figure 1b.

In Figure 2 the test rig used for experimentally measurements is presented [10], [11].

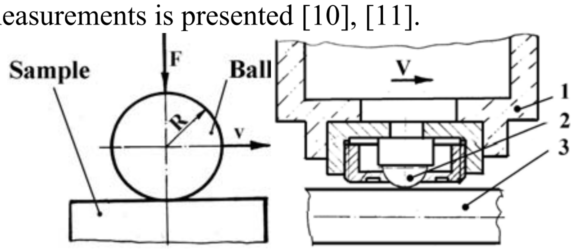


Figure. 1. Tribomodel
a) conceptual representation; b) practical design

The tested samples were made from romanian 41MoCr11 alloyed steel, similar to 4140 – SAE steelgrade, with the composition presented in table

1. The material choice was determined by its general use for all kind of machine elements.

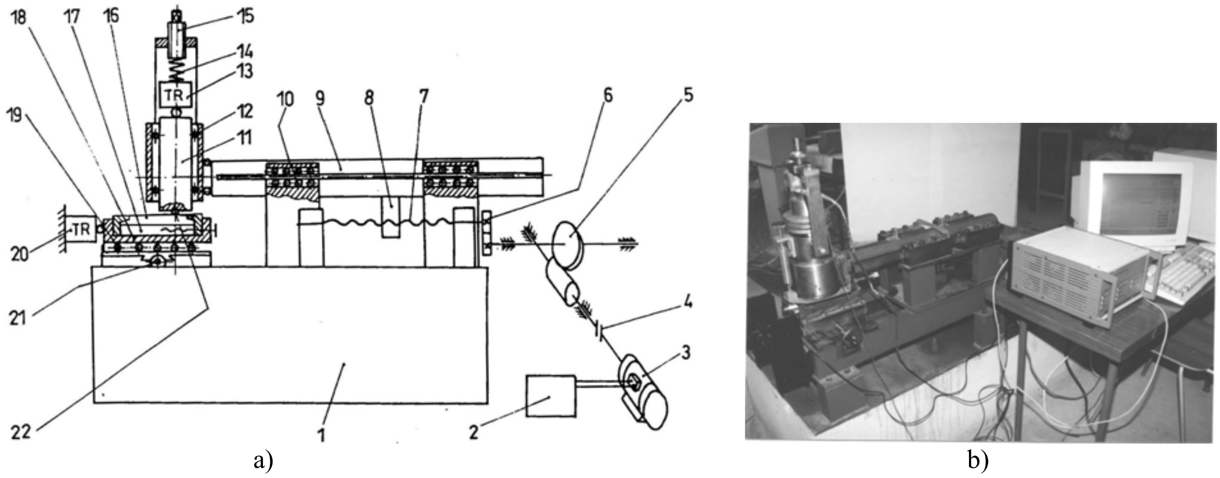


Figure 2. Test rig
a) test rig draft (1-cradle, 2-variator, 3-electric drive, 4-sleeve connection, 5-worm gear reducer, 6- cylindrical gear reducer, 7,8-screw-nut transmission, 9-mobile beam, 10-bearings, 11-ball's holder, 12-vertical holder, 13-force transducers, 14-elastic element, 15-loading screw, 16-sample, 17-sample's holding, 19,21-positioning system, 22-ball).
b) test rig

Three hardness values were choose (8, 30 and 55 HRC), combined with values for normal indentation force in range of 0.2 - 12 kN and roughness values into range of 0.08 – 6.3 µm.

Table 1. Alloyed steel 41MoCr11 composition

C [%]	Mn [%]	Si max [%]	Cr [%]	Mo [%]
0,38-0,45	0,40-0,80	0,17-0,37	0,50-1,30	0,20-0,30

Te researches were completed considering as variable parameters the hardness and the roughness. The last one measured with Surtronic 3+ device.

The results are graphically presented in Figure 3.

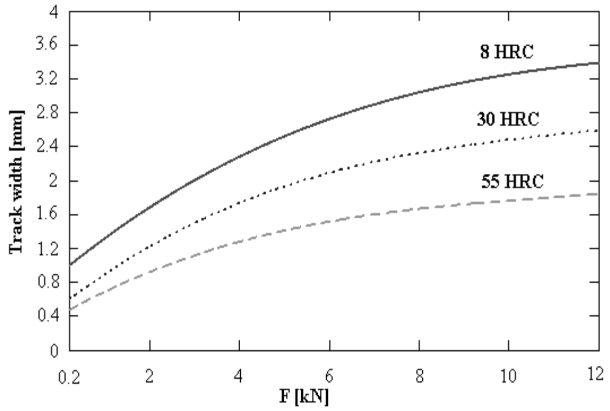


Figure 3. Track widths vs. force and hardness

It is obvious the non-linear dependence between the indentation force value and track width value, measured on the flat sample.

With the aim of establishing a prediction method of track width values, for a known hardness, roughness and normal forces set of values, was built a model based on neural networks.

3. NEURAL NETWORKS

Neural networks are data modelling tool able to capture and represent complex input/output relationships, performing "intelligent" tasks similar to those performed by the human brain. Like the human brain, neural networks:

- neural network acquires knowledge through learning.
- neural network's knowledge is stored within inter-neuron connection strengths known as synaptic weights.

The main advantage of neural networks lies in their ability to represent both linear and non-linear relationships and in their ability to learn these relationships directly from the data being modelled. Traditional linear models are simply inadequate when it comes to modelling data that contains non-linear characteristics.

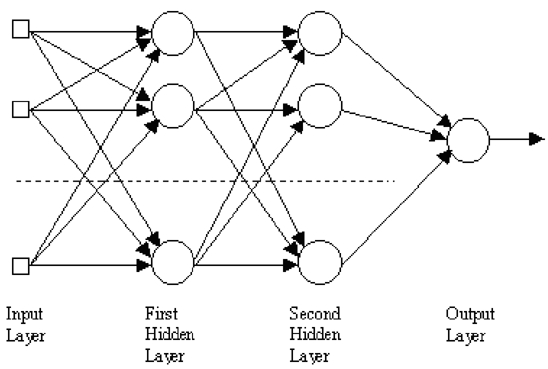


Figure 4. MLP neural network architecture

The most common neural network model is the multilayer perceptron (MLP), figure 4. This type of neural network is known as a supervised network because it requires a desired output in order to learn. The goal of this type of network is to create a model that correctly maps the input to the output using historical data so that the model can then be used to produce the output when the desired output is unknown.

The MLP networks are organized in layers, one for input data, other for output data and one or more between these two (the hidden layers). The information is passing through a neuron based a so called transfer function, which has as inputs the sum of weighted outputs of the neurons from previous layer and as output the function result.

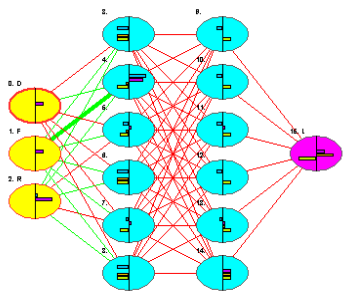
The steps used in building a neural network based model are:

- building the appropriate network's architecture
- train the network, using experimentally acquired data, until the desired error is obtained
- validate the network, comparing the results obtained for known inputs with the appropriate known results.

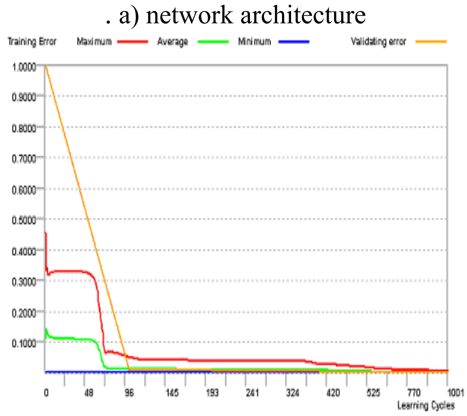
In order to build a neural network based model for sliding indentation, the EasyNN software was used. EasyNN can build, train and validate MLP networks [12], using experimental acquired data. The software also has an built-in module which can develop, by an optimizing algorithm, the best architecture for certain input data

4. SLIDING INDENTATION MODEL

Based on experimental data, an optimized network model with two hidden layers was built, figure 5.



. a) network architecture



b) training and validating error graphs

Figure 5. Neural network model

As inputs the hardness, normal force and roughness were used. The output is the track width. In figure 5 can be observed that after 1001 learning cycles the model reach the prescribed error (0.001%) and the validating tests are completed with a 2 % range error.

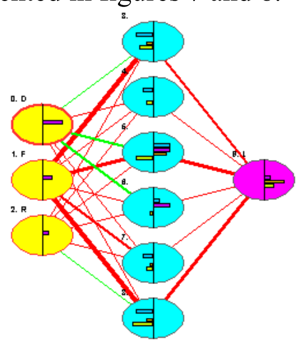
The model can be now used for predict [13] the average track width, for a known hardness-roughness values.

Other utility of the neural network model is to analyse the inputs' importance on output values. In figure 6 is presented the importance graph delivered by the model.

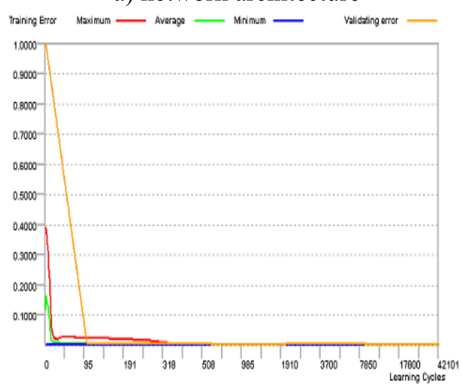
Figure 6. Importance of inputs on the output

It is obvious, in figure 6, that the main influence on track width has the normal force.

Taking into account that for different networks architectures the numerical outputs' values can be different [14], but fitting into the prescribed tolerances of course, one can ask if the importance are the same. For sure, as numerical values are not, but as hierarchy they are. In order to answer to this question, other models with one and three hidden layers respectively, were built up and tested. These ones are presented in figures 7 and 8.



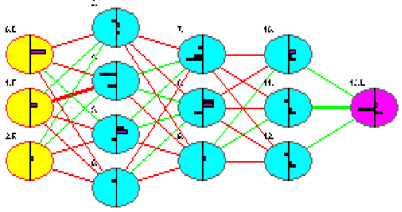
a) network architecture



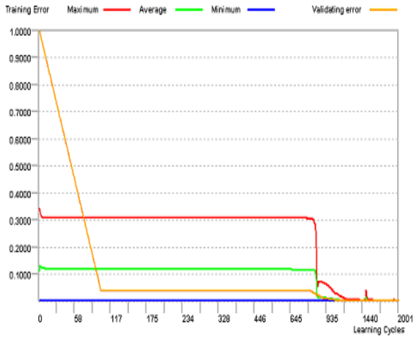
b) training and validating error graphs

Figure 7. One hidden layer architecture

From the figures 7 and 8 it an be observed that, for the same prescribed errors, the training cycles' number is increased: 42101 for the one hidden layered network and 2001 for the three hidden layered network.



a) network architecture

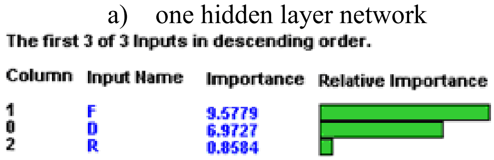


b) training and validating error graphs

Figure 8. Three hidden layer architecture

From the inputs' importance point of view, the results are presented in figure 9.

a) one hidden layer network



b) three hidden layers network

Figure 9. Importance of inputs on the output

As can be observed in figures 6 and 9, the importance of influence of the inputs on the output has different numerical values but the hierarchy is the same.

5. CONCLUSIONS

The sliding indentation tracks can be obtained using a specially designed test rig.

Samples with different characteristics (hardness, roughness) were tested for different normal indentation force values, allowing graphical dependencies representation.

Based on the experimentally acquired data neural network based models were built up, allowing track width prediction and importance of the inputs on output establishing [15].

The model's results are in good concordance with the experimental observations, allowing the use of this one for prediction of the track width for known hardness, roughness and normal forces values.

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