Estimation of the Heat Transfer Coefficient by Neural Network

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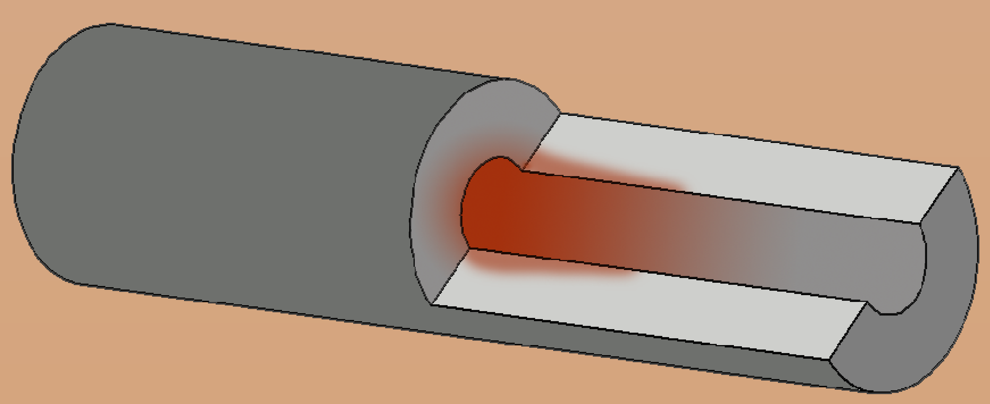
Introduction

•The heat transfer coefficient (HTC) has usually high uncertainty as its determination is quite difficult either by calculation or by measurement.

•The subject of the research work is to determinate the HTC between a gas and a long thick-walled tube from the measured transient temperature distribution by Neural Network (NN) from measured temperature plots. This is an Inverse Heat Conduction Ploblem.

• The hot gas flows trough the tube which also heats it up. The outer surface of the tube is adiabatic. A thermocouple is inserted into the wall which can measure the transient temperature during the heating process.



The problem solving method

•The subject of the present study is to establish a NN which can calculate the HTC from the measured transient temperature.

•For training and testing the NN a large number of coherent HTC-Temperature function pairs are needed which was generated by a finite difference method-algorithm. This means the solution of the direct problem.

•It is necessary to choose a suitable NN-type for the problem. In this study a Multilayer Perceptron (MLP) has been used.

• To solve the inverse problem, the MLP was trained with the coherent HTC-Temperature function pairs.

Solution of the direct problem

•The mathematical formula of the direct problem:

$$a \cdot \left(\frac{\partial^2 T(r,\tau)}{\partial r^2} + \frac{1}{r} \cdot \frac{\partial T(r,\tau)}{\partial r} \right) = \frac{\partial T(r,\tau)}{\partial t} \qquad T(r, \tau = 0) = T_0$$

$$-\lambda \cdot \left. \frac{dT}{dr} \right|_{r=r_2} = 0 \qquad -\lambda \cdot \left. \frac{dT}{dr} \right|_{r=r_1} = \alpha(\tau) \cdot \left(T(r_1,\tau) - T_\infty \right)$$

•By applying the finite difference method:

$$a \cdot \left(\frac{T_{i+1,h} + T_{i-1,h} - 2 \cdot T_{i,h}}{(\Delta r)^2} + \frac{1}{r} \cdot \frac{T_{i+1,h} - T_{i-1,h}}{2 \cdot \Delta r} \right) = \frac{T_{i,h+1} - T_{i,h}}{\Delta \tau}$$

The applied Neural Network

• The applied NN was a Multilayer Perceptron with one hidden layer. The structure of the network can be seen in Fig. 1.

•It consisted 21 neurons in the input layer, 30 neurons in the hidden layer and 21 neurons in the output layer.

• The neurons make a linear combination of the inputs then a non-linear activation function (sigmoid) transforms it to an output value.

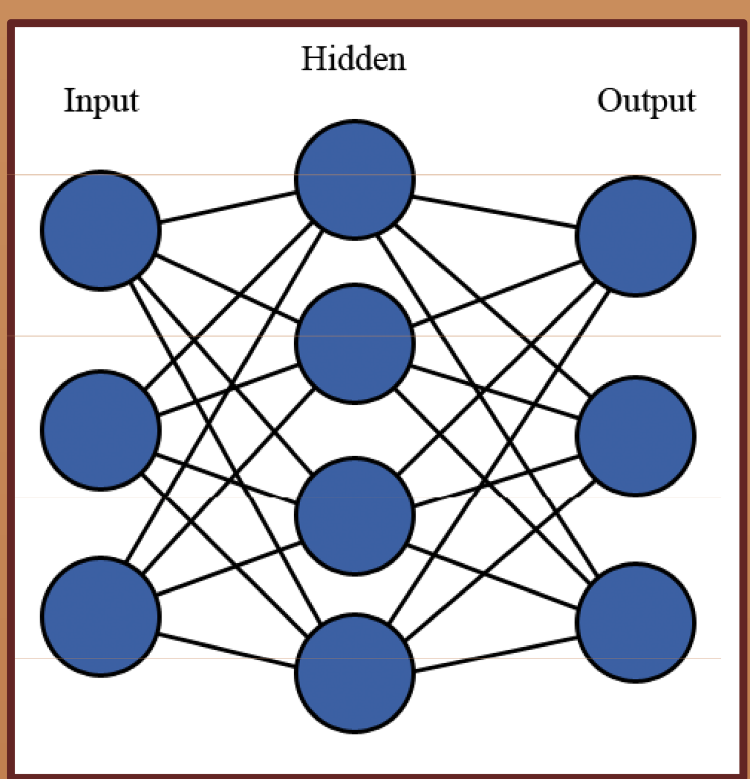


Fig.1. The structure of the MLP

Results

•The temperature and HTC history are described by 21-21 data points.

•In the following figures the results are shown with a learning function (Fig.2.), a random test function from the test set (Fig.3.), a sinus (Fig.4.) , a step (Fig.5.) and a triangle function (Fig.6.).

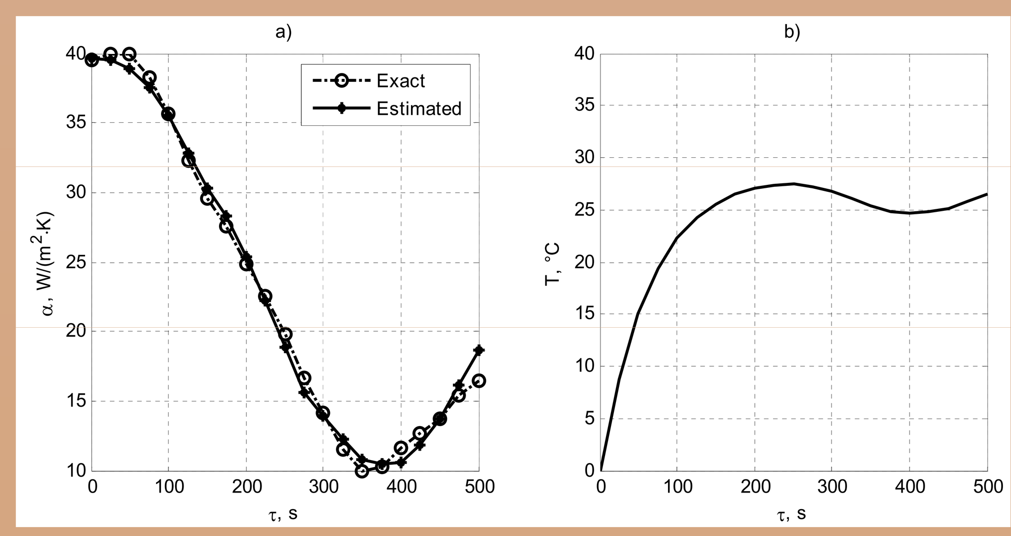


Figure2 – Sample from the training set
(a – HTC function, b – transient temperature of the sensor))

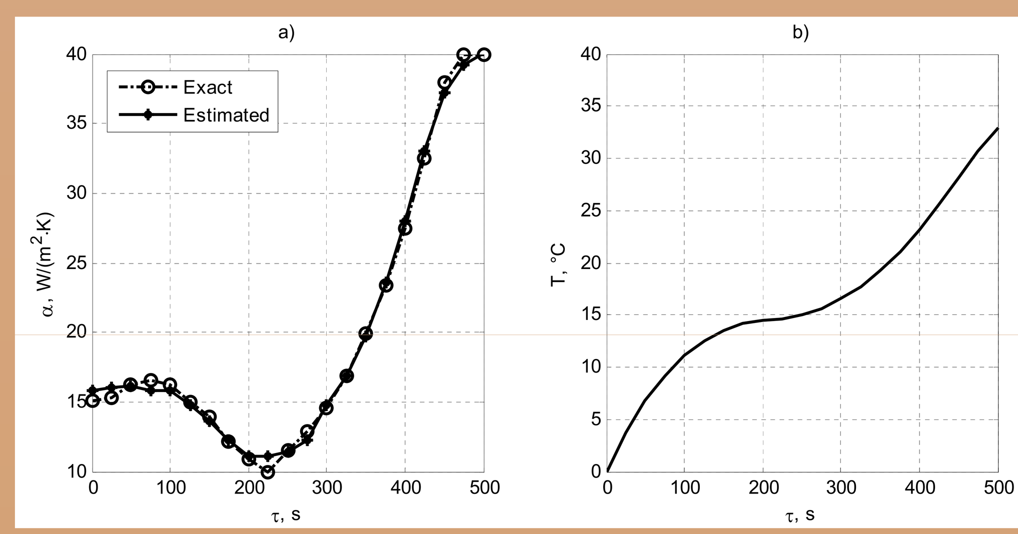


Figure 3 – Sample from the test set
(a – HTC function, b – transient temperature of the sensor)

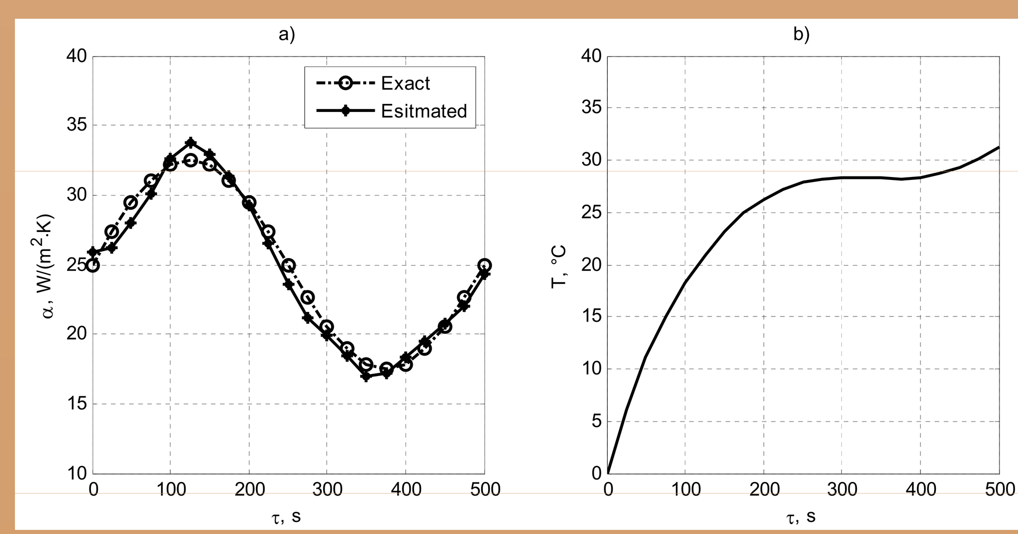


Figure 4 – Test with sinus function
(a – HTC function, b – transient temperature of the sensor)

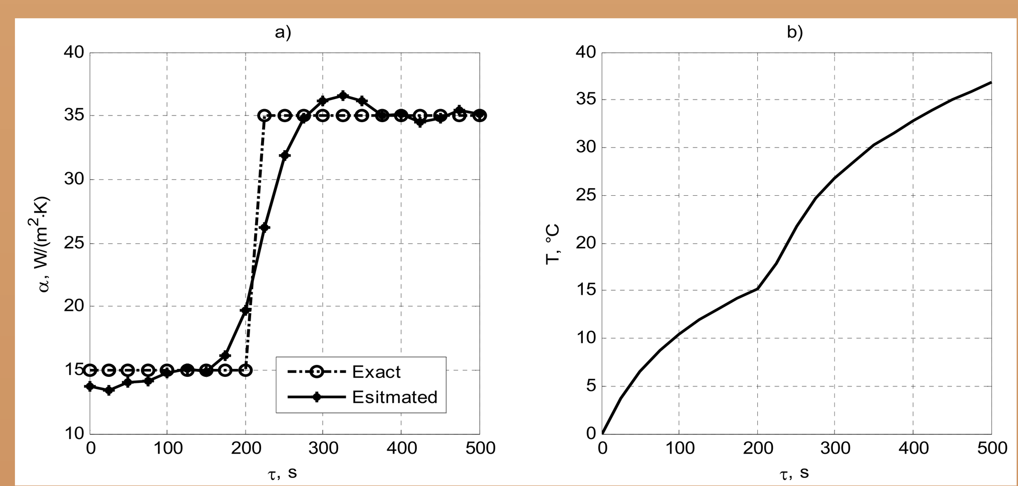


Figure 5 – Test with step function
(a – HTC function, b – transient temperature of the sensor)

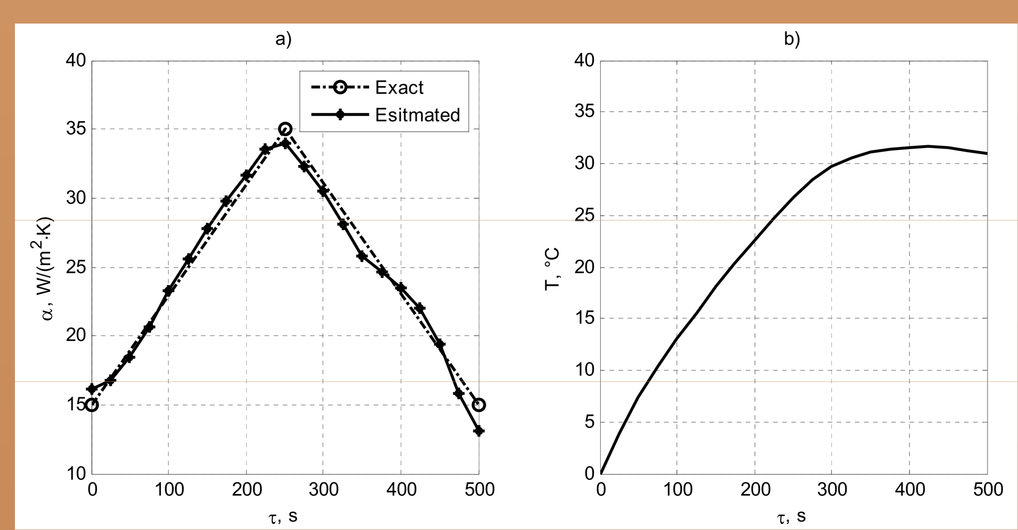


Figure 6 – Test with triangle function
(a – HTC function, b – transient temperature of the sensor)

Conclusion

The NN estimated the exact HTC functions very accurate in case of any kind of test functions. Based on the results presented in this paper the NNs seem to be a very effective tool in a great variety of inverse heat conduction problems.

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