Calculation of the heat power consumption in the heat exchanger using artificial neural network

by S. Dudzik*

* *Faculty of Electrical Engineering, Institute of Electronics and Control Systems – Częstochowa University of Technology, Częstochowa, Poland*

1. Introduction

In this paper a new method for calculation of heat power consumption in the heat exchanger is described. The method is based on the analysis of phenomena proceeding on the ambient side. The calculation of heat power consumption represents an inverse heat transfer problem [1, 2]. In the paper an artificial neural network, trained with data obtaining from infrared thermography measurements [3-6] and from the numerical model of the heat exchanger is used to calculate the heat power consumption in steady state. The experiments were carried out using measuring stand with open chamber [7].

2. Calculation of heat power consumption using artificial neural networks

The solution of coefficient inverse heat conduction problems was presented e.g. in [8, 9]. In this paper, an artificial neural network is used to calculate the heat power consumption of a radiator (e.g. in a central heating system). The input data for training networks, were obtained both from thermograms of considered radiator surface and from the numerical model of the heat exchanger. The output data (measured heat power consumption) were obtained using the measuring position with the open chamber equipped with a PC and suitable measurement devices. Ambient temperature was also measured using the position described above. The neural network, carries out the algorithm is shown in the figure 1.

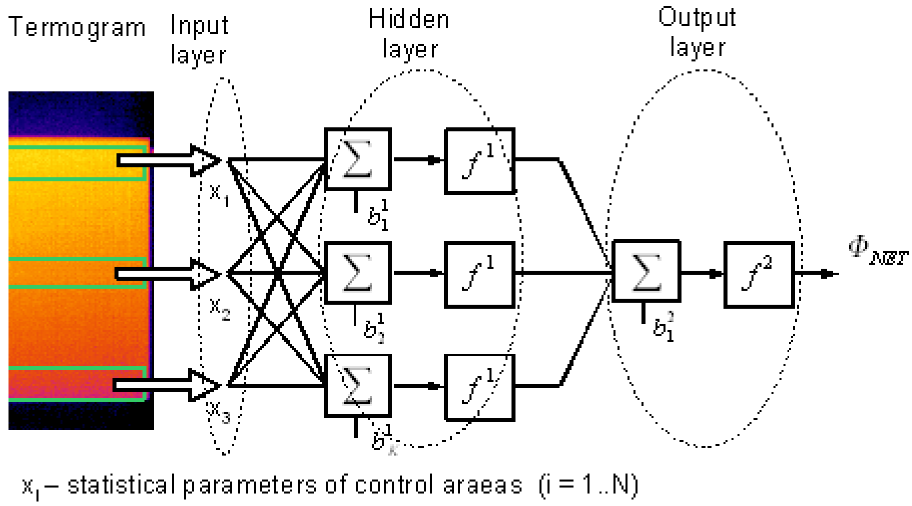

***Fig. 1.** Diagram of the algorithm for calculation of heat power consumption*

The following denotations were assumed in the figure 1:
x_1, x_2, x_3 – inputs of neural network (e. g. average temperature values of control areas);
f^1 – activation function of neurons in hidden layer (linear or tangent curve),
f^2 – activation function of neurons in output layer (as above),
b^1_K – biases of neurons in hidden layer,
b^2 – bias of neuron in output layer.
Φ_{NET} – measured power consumption in investigated heat exchanger.

3. The results of simulations

The simulations of the described algorithm were carried out in following stages:

1. Division of data set on the training, testing and validating data sets.
2. Normalization of data sets.
3. Training of networks using different optimization algorithms and different network architectures.
4. Simulation of neural networks, in particular for testing data.
5. Analysis of simulation results.

Some results of simulations were depicted in figure 2.

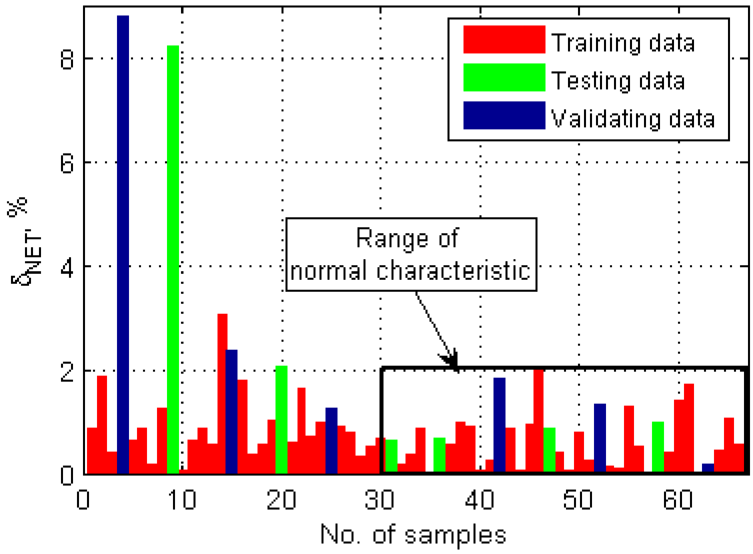

Fig. 2. *Exemplary simulation results of the described algorithm*

δ_{NET} - % – the relative error of calculation of heat power consumption, with the afore described algorithm.

4. Conclusions

- The application of the described algorithm, trained with thermovision data, allows for the calculation of heat power consumption in steady state.
- Use of neural network models, trained with thermovision data, gives the limiting error less or equal 2%, if the measured heat power consumption is contained in the range of the normal characteristic – as shown in figure 2.
- The best simulation results were obtained for networks trained with Levenberg-Marquardt optimization algorithm.

REFERENCES

[1] Beck J. V., Blackwell B., Clair JR, Ch. R. St.: „Inverse heat conduction", John Wiley & Sons Inc., New York 1985.

[2] Kreith F.: „The CRC Handbook of Thermal Engineering", CRC Press LLC, 2000.

[3] Minkina W., Dudzik S.: „Simulation analysis of uncertainty of infrared camera measurement and processing path", Measurement – Vol. 39, Issue 8, pp 758-763, Elsevier Ltd, 2006.

[4] Astarita T., Cardone G., Carlomagno G.M., Meola C.: „A survey on infrared thermography for convective heat transfer measurements", Optics & Laser Technology, Vol. 32 (2000) pp. 593-610, Elsevier Science Ltd, 2000.

[5] Minkina W.: "Thermovision Measurements – Methods and Instruments", Technical University of Czestochowa Publishers, Czestochowa 2004, ISBN 83-7193-237-5 (in polish).

[6] Bąbka R., Minkina W.: „Sub-pixel edge location in thermal images using a meansquare measure" 7th International Conference on Infrared Sensors & Systems (IRS²'2002), 14-16.05.2002, Erfurt, RFN, str. 213-218.

[7] DIN 4704-2: „Prüfung von Raumheizkörpern, Offene Prüfkabine", 1998.

[8] Islamoglu Y.: „A new approach for the prediction of the heat transfer rate of the wire-on-tube type heat exchanger–use of an artificial neural network model", Applied Thermal Engineering Vol. 23 (2003), pp. 243-249, Elsevier Science Ltd, 2003.

[9] Raudensky M., Horsky J., Krejsa J.: „Usage of neural network for copled parameter and function specification inverse heat conduction problem" International Communications in Heat Mass Transfer Vol. 22, No. 5 pp. 661-670, Elsevier Science Ltd. 1995.