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Active binder content as a factor of the control system of the moulding sand quality

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Abstract

One of the modern methods of the production optimisation are artificial neural networks. Neural networks are gaining broader and broader application in the foundry industry, among others for controlling melting processes in cupolas and in arc furnaces, for designing castings and supply systems, for controlling moulding sand processing, for predicting properties of cast alloys or selecting parameters of pressure castings. An attempt to apply neural networks for controlling the quality of bentonite moulding sands is presented in this paper. This is the assessment method of sands suitability by means of detecting correlations between their individual parameters. The presented investigations were obtained by using the Statistica 9.0 program. The presented investigations were aimed at the selection of the neural network able to predict the active bentonite content in the moulding sand on the basis of this sand properties such as: permeability, compactibility and the compressive strength. An application of the Statistica program allowed to select automatically the type of network proper for the representation of dependencies occurring in between the proposed moulding sand parameters. The most advantageous conditions were obtained for the uni-directional multi-layer perception (MLP) network. Knowledge of the neural network sensitivity to individual moulding sand parameters, allowed to eliminate not essential ones.

Keywords: Quality management; Green moulding sand; Artificial neural networks

1. Introduction

A large number of data which is being generated in foundry processes is usually not undergoing direct measurements and recordings, especially automatic. Even the data which are measured and stored are not used for an optimisation and computer aided quality control. The access to a higher number of reliable data requires purchasing of the proper measuring equipment and employing additional staff [1].

One of the modern methods of the production optimisation are artificial neural networks. They owe their popularity to the fact that they constitute convenient tools of investigations. Neural networks are able to represent complex functions. Their non-linearity should be specially emphasised. They are gaining broader and broader application in the widely understood foundry industry, among others for controlling melting processes in cupolas and arc furnaces, designing castings and supply systems, controlling moulding sand processing, prediction of properties of cast alloys or selecting parameters of pressure castings [2-7].

Modern control systems are utilising changes of the selected sand properties for controlling its quality, mainly the sand compactibility [8]. Studies determining the usefulness of sand property changes for the estimation the active binder content are available in the scientific literature [9].

2. Researches

The results concerning the neural networks application for the determination of the moulding sand moisture and bentonite content are presented in papers [10–12]. The results concerning the selected properties of moulding sands of the active bentonite content as well as neural networks models for the collected results, which constitute the continuation of the studies on the neural networks suitability in the process of the quality control of moulding sands, are presented below.

2.1. Influence of the active bentonite content on the selected properties of moulding sands

In order to determine the influence of the deactivation degree of the binder contained in the moulding sand on its properties, moulding sands of various contents of active and non-active binder were prepared (at the constant total amount of both binders, being equal to 8 parts by weight). Thus, part of the active binder was overheated at a temperature of 1223 K for 3 h. in a chamber furnace. Moulding sands containing a non-active binder being from 2 to 20% of the total binder content were tested.

This way of preparation of a circulating used sand is not taking into account a non-active binder which occurs in a form of the oolitized layer.

High-silica sand from Jaworzno Szczakowa was used as a matrix while bentonite from Zębiec as a binder. Investigations were carried out at a variable sand moisture being from 1 to 5%. Influence of the binder deactivation degree on the compressive strength is presented in Figure 1. As can be seen, when the active binder content is higher the strength is also higher.

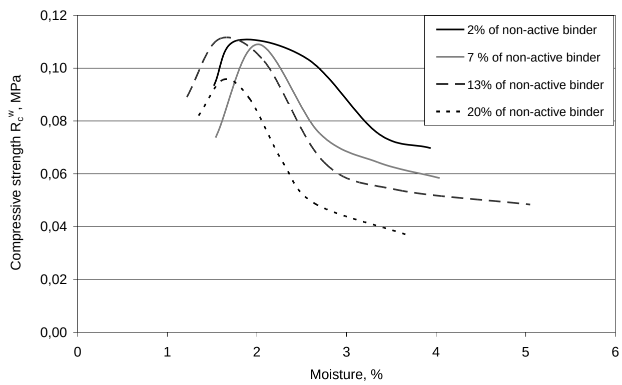

Fig. 1. The influence of water content on compressive strength R_c^w, for the moulding sands with different active bentonite content

The performed investigations of the influence of a non-active binder on moulding sand permeability did not reveal essential permeability changes as a moisture function.
The compactibility results are displayed in Figure 2. An increased sand moisture causes the increased compactibility, which obtains its maximum. An increased active bentonite content also causes the increased compactibility.

The Statistica 9.0 program with the automatic designer function, which enables an optimal selection of the network, was applied for designing the neural network models.

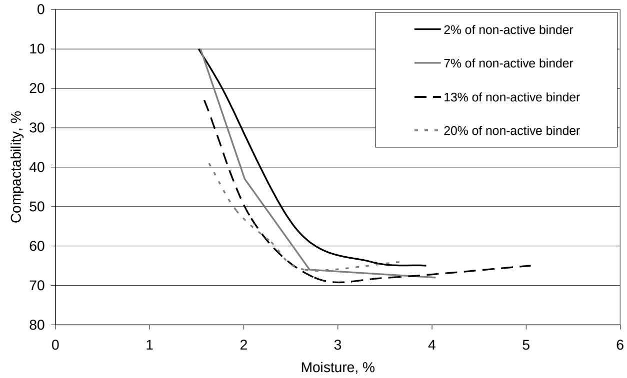

Fig. 2. The influence of water content on compactability, for the moulding sands with different active bentonite content

2.2. ANN modelling to determine the active bentonite content in moulding sands

The results obtained for the model providing the best representation of the experimental results of the compressive strength are shown in Figure 3. The continuous line exhibits real moisture values, while points indicate the data obtained as the deactivated bentonite input content. The presented diagrams concern representation achieved for the test sample, which shows the real quality of the neural network developed model.

The best representation was obtained for the MLP 1-72-1 network. However, in case of using compressive strength in order to estimate the deactivated bentonite content, one can notice that the distribution of data generated by the designed network significantly differs from the experimental values.

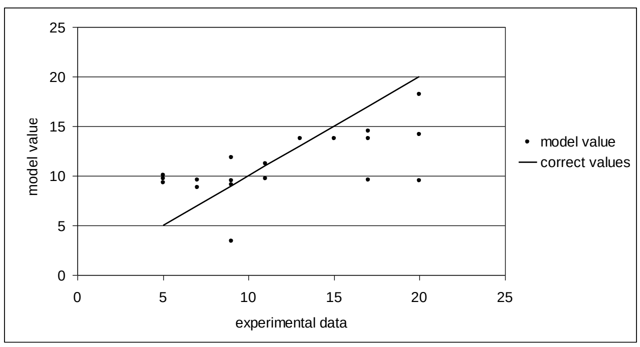

Fig. 3. Comparison of the distribution of data generated by the network and the experimental data (test data), input data: compressive strength, output data: non-active binder, the network model: MLP 1-72-1, model quality: 0, 6052

Figure 4 illustrates the distribution of data generated by network models, in which sand compressibility was applied as input data. Also in this case the representation accuracy is on a low level (0.5668), which indicates the worse suitability of models of such structure for the estimation of the deactivated bentonite content in moulding sands than for the estimation of their moisture [12].

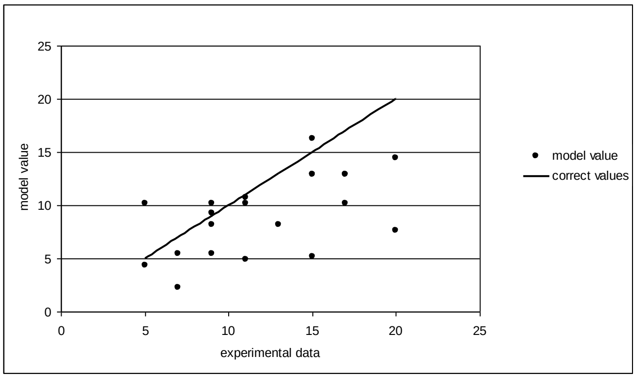

Fig. 4. Comparison of the distribution of data generated by the network and the experimental data (test data), input data: compactability, output data: non-active binder, the network model: RBF 1-24-1, model quality: 0, 5668

In the successive stage of the study the network models, in which the experimental results of strength and sand compactibility were simultaneously applied, were designed (Fig. 5). Using these parameters for training networks only slightly improved the model quality (in case of the model 2-24-1 presented in Figure 6 this quality is equal to 0.7002).

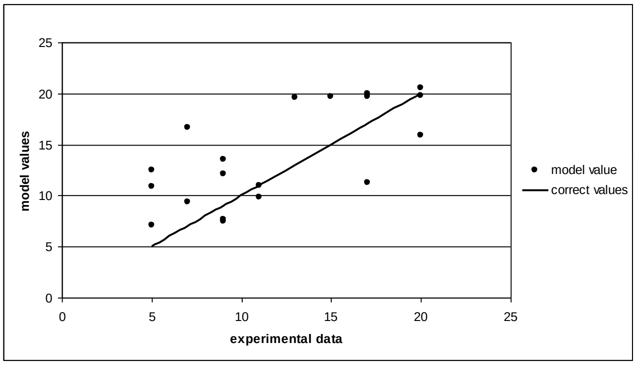

Fig. 5. Comparison of the distribution of data generated by the network and the experimental data (test data), input data: compressive strength, compactability, output data: non-active binder, the network model: RBF 2-24-1, model quality: 0, 7002

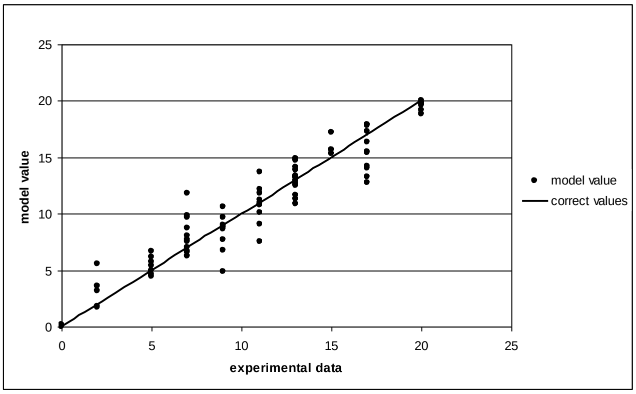

Fig. 6. Comparison of the distribution of data generated by the network and the experimental data (learning data set), input data: compressive strength, compactability, permeability. output data: non-active binder, the network model: MLP 3-8-1, model quality: 0,9619

Then, in order to improve the network models quality, the results of sand permeability were added to the input data. The data distribution results generated for the best model in relation to the experimental data are presented in Figure 6 (training sample) and Figure 7 (test sample). In both cases the network representation quality is above 0.96. An application of additional data in a form of the sand permeability results allowed to obtain network models of a good quality of predicting the needed values. The permeability experimental results indicated rather small influence of the active bentonite content on this parameter and its low usefulness for models designing. This proves that even such moulding sand properties, which weakly react for variable conditions - essential from the experimental point of view - can constitute an important element of modern prediction systems such as neural networks.

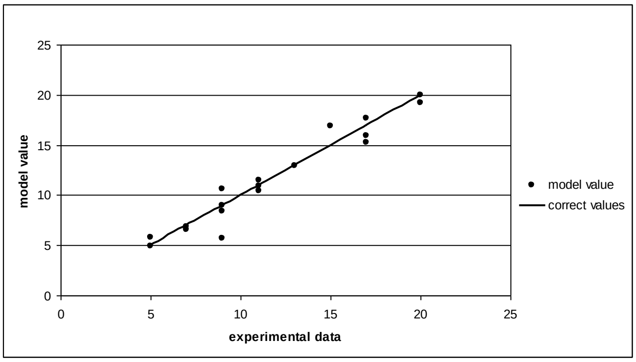

Fig. 7. Comparison of the distribution of data generated by the network and the experimental data (test data set), input data: compressive strength, compactability, permeability. output data: non-active binder, the network model: MLP 3-8-1, model quality: 0,9683

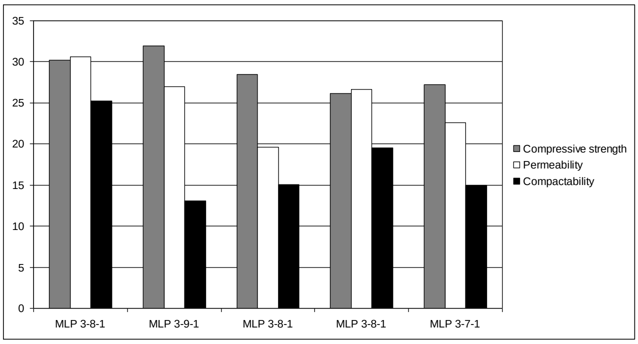

Fig. 8. Sensitivity analysis of a complex network

The results of the analysis of the network model - developed for the data concerning compressive strength, compactibility and permeability - sensitivity for individual parameters are presented in Figure 8.

These results indicate that regardless of the model, the networks exhibit the highest sensitivity to the data concerning compressive strength and permeability, while smaller to the compactibility data. However, in case of all three parameters taken into account the sensitivity is as much high that omitting any one of them at constructing the network models causes the quality worsening.

4. Conclusion

It was indicated that the application of artificial neural networks on the basis of the selected, individual properties for the estimation of the deactivated bentonite content in moulding sands provides weak results contrary to the estimation of moulding sand moisture or the total bentonite content [10, 11]. Using experimental data obtained for the several selected moulding sand properties enables constructing good quality models, however a long time of measuring individual values renders difficult a possibility of this solution application. Due to this fact, it is necessary to construct such model, which will be utilising - for the proper network training - the data collected in the foundry plant, whereas for the current predictions to apply such moulding sand property which can be tested in a short time, e.g. compactibility.

Acknowledgments

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