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Prediction of effective thermal conductivity of moist porous materials using artificial neural network approach

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ABSTRACT

An artificial neural networks (ANNs) approach is presented for the prediction of effective thermal conductivity of porous systems filled with different liquids. ANN models are based on feedforward backpropagation network with training functions: Levenberg–Marquardt (LM), conjugate gradient with Fletcher–Reeves updates (CGF), one-step secant (OSS), conjugates gradient with Powell–Beale restarts (CGB), Broyden, Fletcher, Goldfrab and Shanno (BFGS) quasi-Newton (BFG), conjugates gradient with Polak–Ribiere updates (CGP). Training algorithm for neurons and hidden layers for different feedforward backpropagation networks at the uniform threshold function TANSIG-PURELIN are used and run for 1000 epochs. The complex structure encountered in moist porous materials, along with the differences in thermal conductivity of the constituents makes it difficult to predict the effective thermal conductivity accurately. For this reason, artificial neural networks (ANNs) have been utilized in this field. The resultant predictions of effective thermal conductivity (ETC) of moist porous materials by the different models of ANN agree well with the available experimental data.

1. Introduction

Recently, complex multi-component systems as engineering materials have gained tremendous importance due to their industrial applications. Thermal conductivity is one of the major thermodynamic coefficients in the study of energy transport through complex systems due to its increasing importance in agronomy, geothermal and geo environmental engineering. The thermal conductivity values of complex materials are needed in thermal energy storages devices, weather control, artificial heating and cooling of buildings, in geothermal operations, thermal exchange in heat pumps and energy conservation in buildings. ETC has been investigated extensively using both experimental and theoretical approaches by various scientists in detail. Verma et al. [1] had used Hadley's geometry dependent resistor model to predict effective thermal conductivity of the three-phase systems, and obtained maximum deviation 30.1% and the average deviation 6.4% for calcareous sand stone/air/water system. Using resistor model, the constant of proportionality, B_0, in Equation $\tan\theta = B_0\psi^2F\phi^2(\lambda_s/\lambda_f)^{1/2}$, whose value dependents upon the mode of packing of the solid particles and the nature of the system, should be adjusted for various systems to perform estimation. Singh et al. [2] analyzed the effective continuous media approach and developed a model for the prediction of effective thermal conductivity of three-phase/unsaturated porous materials. The approach has been tested for different types of soils saturated with different liquids having variations in liquid content and temperature. Cosenza et al. [3] investigated the effects of water content and porosity on the thermal conductivity of the soil using numerical approach. Shabbir et al. [4] estimated the effective conductivity of porous rocks in terms of porosity and thermal conductivities of minerals constituents using transient plane source technique. Jiyu et al. [5] calculated the effective thermal conductivity of several porous materials using 2D Lattice-Boltzmann model. Wang et al. [6] predicted the effective thermal conductivity of multi-phase random porous media by three-dimensional mesoscopic method. Zhang et al. [7] developed a randomly mixed model for the prediction of effective thermal conductivity of a multi-phase system, which has been tested on several types of moist porous systems at various porosities and degrees of saturation. Wang et al. [8] developed a mesoscopic numerical tool for predictions of the thermal conductivities for microscale random porous materials. Hu et al. [9] derived a model for the thermal conductivity of unconsolidated porous medium based on capillary pressure saturation relation. Gori and Corasaniti [10] presented a theoretical model for effective thermal conductivity of unsaturated soils at moderately high temperatures by taking into account the special nature of the soil. Abu-Hamdeh et al.

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