APPLICATION OF EVOLUTIONARY ALGORITHMS IN IDENTIFICATION OF THERMAL PROPERTIES OF HARDENING CONCERTE

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1. Introduction

The proper determination of the thermal properties of hardening concrete plays a key role in the building the correct models of concrete structures. High temperature gradients associated with the exothermic chemical reactions of cement hydration may occur between the interior and the surface at the early age of concrete, when its strength is low. Cracks occur, when temperature gradients cause tensile stresses, which exceed the tensile strength of the young concrete. Thermal distortions have greater influence on stresses especially for massive structures [6].

Thermal characteristics of concretes described by: thermal conductivity, specific heat and heat of cement hydration, are evolving during hardening and depend on the maturity of concrete. Such parameters in practice can be determined by means of different experimental measurements, hot plate apparatus and several transient dynamic techniques. Thermal characteristics, identified in the paper, are performed on the basis of temperature measurements only [4,5].

In the paper [3] model of the hardened concrete sample specimen was considered as 2D. In present work axis symmetrical model is considered. The hardening of the concrete specimen is the long time process (up to 90 hours), so additionally, the heat losses have to be introduced in the model. In present paper appropriate the boundary conditions is introduced in the numerical model. The identification of the thermal properties is based on temperature measurements in the sensor points, which are located at the central axis of the thermally-isolated cylindrical mould. In order to solve identification task, an in-house implementation of the evolutionary algorithms (EAs) is used. EAs, as the global optimization technique for searching parameters, which describe thermal properties of hardening concrete are applied. Comparing to the use of conventional optimization methods, superiority of EAs manifest in many aspects, e.g. fitness function has not to be continuous, information about objective function gradient is not necessary, choice of the starting point may not influence the convergence of the method, regularization methods in no needed [1,2,3]

2. Formulation of the identification problem

From the mathematical point of view, the identification problem is expressed as the minimization of the functional. Following functional has been defined and implemented:

$$\min_{\mathbf{x}} \quad f(\mathbf{x}) = \sum_{i=1}^{n} \sum_{i=1}^{m} \left(T_{ij}(\mathbf{x}) - \hat{T}_{ij}(\mathbf{x}) \right)^2 \tag{1}$$

where: n is a number of sensors, m is a number of time intervals, T_{ij} and $\hat{T}_{ij}$ represent computed and measured temperature values in particular point in time and space, respectively, $\mathbf{x}$ is a vector of design variables.

Measured values of the temperature (T_{ij}) has been taken from real experiment during the proces of hardening concrete specimen, while computed values ($\hat{T}_{ij}$) has been simulated numerically.

The vector of design variables $\mathbf{x}$ contains parameters, which define heat of hydration, specific heat and thermal conductivity. The identification problem is solved by finding the vector of design variables **x**, by minimizing the functional (1). In-house implementation of EA, with the floating point gene representation is used (Fig. 1).

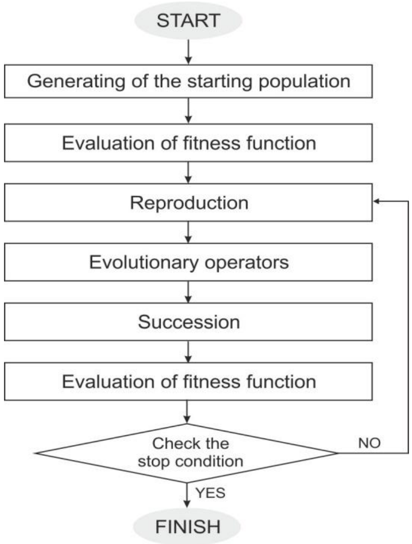

Figure 1: The flow chart of the applied Evolutionary Algorithm

In order to calculate temperature in time and space, unsteady heat conduction equation, including proper definition of internal heat sources is solved. Numerical model of the hardening concrete specimen was prepared and solved by means of the finite element method (FEM) [7].

The differentia equation of transient heat conduction problem in hardening concrete has following form:

$$\frac{\partial}{\partial x}\left(k\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(k\frac{\partial T}{\partial y}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)+q=\rho c_p\frac{\partial T}{\partial t} \tag{2}$$

where: T - temperature of concrete $[°\mathrm{C}]$, k - thermal conductivity, $[\mathrm{W/m\,K}]$, x, y, z – spatial coordinates, q- internal heat source $[\mathrm{W/m^3}]$, t- time [s], ρ – density of concrete $[kg/\mathrm{m}^3]$, c_p - specific heat of concrete $[\mathrm{J/kg\,K}]$.

Proposed identification algorithm was tested on an benchmark example, before it was used to identify thermophysical parameters on the basis of real experimental data. The identification tasks are performed for experimental data for different concrete mixtures.

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