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INVESTIGATION METHODS OF BUILDING INSTALLATION SYSTEMS' UNCERTAINTIES

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Abstract: *The real technical systems, such as building installation ones, have parameter uncertainties. These value fluctuations influence output parameters and power requirements of the systems. The aim of the presentation is to show the methodologies of system parametric uncertainties investigations which are based on sensitivity analysis. The essence of the sensitivity analysis is that the anomalies and variations of dependent (output) system parameters are simulated by changing of its independent (input and inner) variables. On the basis of the mathematical model of the investigated system can be determined how sensitive dependent system variables will be to simulated changes. To demonstrate methodologies mentioned above, case studies of easy building installation system will be used.*

Keywords: *uncertainty, modeling, system engineering*

1. INTRODUCTION

The main application of mathematics in the engineering is the mathematical modeling. During mathematical modeling of the real technical system we can meet any type and rate model and parameter uncertainty [3]. In case of geothermal pipeline (for example heating) systems, parametrical model (system) uncertainties mean the indetermination of physical parameters of the fluid. These characteristics influence the system parameters such as its head loss or pressure loss, therefore required pump power.

According to Macdonald and Strachan, the sensitivity analysis is an important technique to determine the effect that uncertainties or model variations have on the model predictions. The analysis can be carried out from a simple level to a comprehensive treatment. In practice, sensitivity analysis is used in an ad hoc way in a lot of practical modeling studies [2]. The author investigated effects of pipeline system's uncertainties using linearized sensitivity model [4].

The aim of this paper is to show the methodology of the sensitivity analysis and its possibility of use by an easy pipeline system model and discussions of results shortly. By these — basically theoretical — consequents and experiences can be used to investigate parametrical uncertainties of the fluid characteristic, such as indeterminations of water salinity in case of a geothermal pipeline system.

The rest of this paper is organized as follows: Sensitivity model is briefly showen in Section 2. Section 3. represents the result of sensitivity investigation in case of water silinity changing. Conclusions and future works are drawn in Section 4.

2. Sensitivity Model

In generally, the question of the sensitivity analysis is how sensitive the output parameter y is with respect to changing in any coordinate of the input parameter-vector **x**? Otherwise the question is: if any parameter of the system undergoes a change of 1 %, what a perceptual change occurs in the value of y? If we look at instead of y a function $f(x_1;\ x_2\ \dots\ x_n)$ the parameter vector **x**, the sensitivity coefficient $K_{y;xi}$ can be simply computed for y depending on x_i:

$$K_{y;x_i} = \frac{\partial f(x_1;x_2;\ldots x_k)}{\partial x_i}\frac{x_i}{f(x_1;x_2;\ldots x_k)} = \frac{\partial y}{\partial x_i}\frac{x_i}{y} \quad . \tag{1}$$

Using these coefficients, the relative changing depending on relative changing of vector's **x** elements of *y* can be determined by

$$\delta y = K_{y;x_1}\delta x_{y;x_2} + \ldots + K_{y;x_n}\delta x_n \tag{2}$$

equations, where:

$$\frac{d\eta}{\eta} \approx \frac{\Delta\eta}{\eta} = \delta\eta \tag{3}$$

equation, the following linear system can be achieved:

$$\delta y = K_{y;x_1}\delta x_{y;x_2} + \ldots + K_{y;x_n}\delta x_n \quad . \tag{4}$$

In this case study, the pressure loss and head loss of two main pipeline system structural elements (lineal pipe and pipe fitting) will be investigated. Therefore the illustrative system consists of only one lineal pipe and only one pipe fitting. The system was modeled in case of the stable laminar flow ($Re < 2320$).

The equation of investigated elements‘ model and their sensitivity functions are as folloving:

$$\nu = \frac{\mu}{\rho}, \qquad \delta\nu = \delta\mu - \delta\rho \tag{5}$$

$$c = \frac{4\dot{V}}{d^2\pi}, \qquad \delta c = \delta\dot{V} - 2\delta d \tag{6}$$

$$Re = \frac{cd}{\nu}, \qquad \delta Re = \delta c + \delta d - \delta\nu \tag{7}$$

$$\lambda_a = \frac{64}{Re}, \qquad \delta\lambda = -\delta Re \tag{8}$$

$$h'_{cs} = \frac{c^2}{2g}\frac{l}{d}\lambda, \qquad \delta h'_{cs} = 2\delta c + \delta l + \delta\lambda - \delta d \tag{9}$$

$$\Delta p_{cs} = \frac{\rho}{2}c^2\frac{l}{d}\lambda, \qquad \delta\Delta p_{cs} = \delta\rho + 2\delta c + \delta l - \delta d + \delta\lambda \tag{10}$$

$$h'_{sz} = \frac{c^2}{2g}\xi, \qquad \delta h'_{sz} = 2\delta c + \delta\xi \tag{11}$$

$$\Delta p_{sz} = \frac{\rho}{2}c^2\xi, \qquad \delta\Delta p_{sz} = \delta\rho + 2\delta c + \delta\xi \tag{12}$$

where:

μ	—	dynamical viscosity;
ρ	—	fluid density;
ν	—	kinematical viscosity;
c	—	average flow velocity;

$\dot{V}$ — volume flow rate;
d — internal diameter;
l — tube length;
Re — Reynolds-number;
λ — pipe loss coefficient;
h'_{cs} — head loss of pipe;.
Δp_{cs} — the pressure loss of the pipe;
h'_{sz} — the head loss of the pipe fitting;
Δp_{sz} — the pressure loss of the pipe fitting;
ξ — pipe fitting loss coefficient.

The parameters can be erranged into the vectors of independent

$$\mathbf{x} = [\mu \quad \rho \quad \dot{V} \quad d \quad l \quad \xi] \tag{13}$$

and dependent ones:

$$\mathbf{y} = [\nu \quad c \quad Re \quad \lambda \quad h'_{CS} \quad \Delta p_{CS} \quad h'_{SZ} \quad \Delta p_{SZ}] \tag{14}$$

Using these vectors, the sensitivity functions, mentioned above can be written by the following matrix form:

$$\mathbf{A}\delta\mathbf{y} = \mathbf{B}\delta\mathbf{x} \quad , \tag{15}$$

where **A** and **B** are coefficient matrices of external and internal parameters of the investigated system. Using the

$$\mathbf{D} = \mathbf{A}^{-1}\mathbf{B} \tag{16}$$

sensitivity coefficient matrix of investigated system, the equation

$$\delta\mathbf{y} = \mathbf{D}\delta\mathbf{x} \tag{17}$$

can be used for sensitivity and uncertainty investigations.

3. Result of the Sensitivity Analysis

Knowing the sensitivity coefficient matrix **D**, sensitivity of the system can be investigated by modification of independent variables' relative changing vector $\delta\mathbf{x}$. Results of sensitivity analysis can be used for conclusions to come about features of the given system and its behavior in case of simulated failures or parameter uncertainty (for example instability of geothermal water viscosity). It is important to mention, changes of independent variables cannot be more than about 1 or 5 %, depending on the intensity of the original model's nonlinearity.

In case of 1% water's salinity increasing, the density increases by 0,21 % and the dynamical viscosity of the fluid increases by 4,885 % [1]. Therefore the vector of the relative changing of independent variables will modified to

$$\delta\mathbf{x}^T = [4{,}885 \quad 0{,}21 \quad 0 \quad 0 \quad 0 \quad 0] \tag{18}$$

form. Results of the modeling are shown in the Figure 1.

The first conspicuous conclusion is: the dependent system variables have the most considerable sensitivities depend on the salinity of the water. Correspondingly with the result of the one parameter sensitivity analysis, the system is sensible in case of the stable laminar flow ($Re < 2320$).

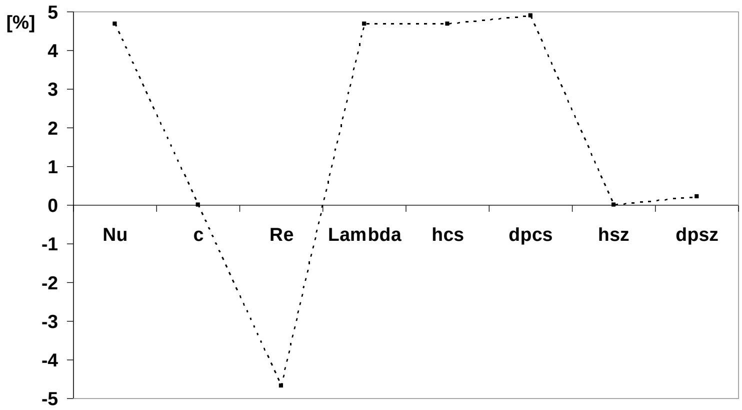

Fig 1. The Sensitivity of the System ($\delta\mu = +4{,}885\%$ and $\delta\rho = +0{,}21\%$)

4. Conlclusions

The author of this paper would like to arouse readers' interest in importance and possibilities of use of the mathematical model uncertainty analysis. This basically theoretical paper has shown the sensitivity analysis. Then the methodology of sensitivity test, which based uncertainty analysis, has been shown by the short and easy case study of an easy pipeline system.

During prospective scientific research related to this field of applied mathematics and technical system modeling the author would like to complete following tasks:

- analyzing of sensitivity of complex pipeline system and pipe-network;
- study of the parametrical pipeline system uncertainties by Mont-Carlo Simulation;
- adaptation of linear interval equations as a mathematical toll for pipeline system and pipe-network uncertainty analysis.

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