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TESTING A FLAT SOLAR WATER COLLECTOR MODEL FOR RELIABILITY

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ABSTRACT

The study deals with a test for reliability of processed data obtained by modeling mathematically the operation of a flat solar water collector. Applying the dispersion method examinations have been carried out to test the model.

The carried out analysis made proved the model reliability and confirmed its capability to describe precisely enough the processes and phenomena taking place during collector functioning.

Keywords: solar energy, heat transfer, test facility, simulation.

INTRODUCTION

Modern experimental studies are closely related to object mathematical modeling. A mathematical model is a function which determines the starting quantity dependence on various factors. Objects are affected by random disturbances. These are independent on each other and separately they weakly influence the object performance. According to the theory of probabilities, the joint influence of all disturbing effects is equivalent to that of one single random quantity of a normal distribution law. For that reason researchers do not measure the function real value each time but, usually, watch a random quantity. The function real value can not be measured in a given experiment because of random disturbances. In that case the mathematical model is formed through averaging the measured results. The overall investigation includes checking the correspondence between the results obtained in data processing and experimental data. That is called a test for adequacy [1, 2]. Using experimental results taken down in previous measurements of flat solar water collectors the adequacy of the realized mathematical model will be proved.

METHOD OF PROCESSING

The mathematical model has been realized for a water solar collector of the tube-rib (column) type. Experimental data are used in order to solve develop a mathematical model to be built. In order to assess more precisely different parameter influences a math description is made of the process dynamic and static characteristics and they are mathematically formulated. The process modeling concerns the heat carrier temperature gradient along the flow direction. The heat transfer processes in a solar water collector have bean mathematically modeled and described in a differential form. A system of partial differential equations describes heat transfer processes subsequently in the transparent cover, the absorber, the working fluid and the insulation. The fluid temperature along the collector and for each arbitrary selected moment is calculated. By iteration.

The experimental tests have been carried out on a solar water collector testing stand under a quasi - stationary regime in the period of astronomic noon, two hours about Sun noon. The incoming heat carrier flow and its temperature remain constant while the collector inlet temperature varies mainly due to changes of solar radiation intensity and ambient temperature. All quantitative measurements are taken down at each there minutes simultaneously for a twenty-seven-minute interval. Different temperature regimes are apriory set up at heat carrier forced continuous flow. For each collector type 13 tests have been made and each test includes 10 measurement.

Due to random disturbances the real quantity values are impossible to measure, so, their estimations are obtained. The model obtained allows for determining estimates of the real values of the goal function. These estimates are the predicted values of the initial quantity. The predicted initial quantity values must be close to the measured ones. As a criterion of closeness, the sum of the sguares of the deviation of predicted and measured values is used in the least squares method.

In order to check the correctness of the chosen model type the residual value of the dispersion S_R^2 should be found and compared with the value of the dispersion of the experimental results, obtained. As a basis of comparison the inlet fluid temperature is chosen. The outlet fluid temperature is taken as a boundary condition. The reliability of the is evaluated by applying the dispersion analysis method for eight different flat plate solar collectors [3].

The evaluation of the factor dispersion S_A^2 and the residual dispersion S_R^2 is made using the equations [2, 4]:

$$S_R{}^2 = \left\{ n.\sum \left[\left(\bar{t}_{ex} - \bar{t}_f\right)^2 + \left(\bar{t}_m - \bar{t}_f\right)^2 \right] \right\} / \nu_A \qquad (1)$$

$$S_R{}^2 = \left[\sum n \sum \left(\bar{t}_{ex} - \bar{t}_{ex.i}\right)^2 + \left(\bar{t}_m - \bar{t}_{m.i}\right)^2 \right] / \nu_R \qquad (2)$$

where: n is the number of experiments carried out;

k – number of ways to obtain the quality values;

ν_A – degreeS of freedom for evaluation of factor dispersion S_A;

ν_R – degree of freedom for the evaluation of the residual dispersion S_R;

$\bar{t}_{ex}$ – the experimentally measured value of incoming fluid temperature;

$\bar{t}_m$ – the value of incoming fluid temperature obtained through the mathematical model;

$\bar{t}_f$ - temperature of the incoming fluid.

Following are the formula used for calculating the values of $?t_{ex}$, $?t_m$ and $?t_f$:

$$\bar{t}_{ex} = \frac{1}{n}\sum_{i=1}^{k} \bar{t}_{ex.i} \qquad (3)$$

$$\bar{t}_m = \frac{1}{n}\sum_{i=1}^{k} \bar{t}_{m.i} \qquad (4)$$

$$\bar{t}_f = \frac{1}{k}\sum_{i=1}^{k} (\bar{t}_{ex} + \bar{t}_m) \qquad (5)$$

To check the model choice correctness a relation is written, the to called Fisher criterion (F) is used [4]:

$$F = S_R{}^2 / S_A{}^2 \qquad (6)$$

It is the ratio between assessment of factor dispersion S_A^2 and the residual assessment of dispersion S_R^2 [1, 2].

The requirement for model adequacy needs the following condition to be fulfilled:

$$F \le F_t \qquad (7)$$

where:

F_t is the value of the Fisher criterion for a certain level of significance α with the corresponding degrees of freedom ν_A and ν_R obtained for the particular case;

F - the calculated value for Fisher criterion.

Table 1. Tabular and calculated values of Fisher criterion.

Collectors	F_t	F
K1	4,26	1,50
K2	4,26	0,77
K3	4,26	1,26
K4	4,26	1,21
K5	4,26	1,15
K6	4,26	2,65
K7	4,26	0,99
K8	4,26	2,79

RESULTS AND DISCUSION

An experiment comprises n = 13 tests .The fluid temperature selected for comparison in measured in two ways: the one is the mathematical model; the other is by an experimental value. Hence, the ways for obtaining the quality values are k = 2. The degrees of freedom ν_A and ν_R for assessing the factor dispersion S_A^2 and the residual assess of dispersion S_R^2 can be calculated by using.

$$\nu_A = k - 1 = 2 - 1 = 1 \qquad (8)$$

$$\nu_R = n.k - k = (13.2) - 2 = 24 \qquad (9)$$

The degree of freedom for the evaluasion of factor dispersion on ν_A = 1, and the degree of freedom for the residual assess of dispersion ν_R = 24. For the case concerned the level of significance α = 0,05 with degrees of freedom ν_A = 1 and ν_R = 24.

The Fisher criterion value (F) can be calculated using equation (6). Its tabular value F_t is taken for a level of significance α = 0,05 and degrees freedom ν_A = 1 and ν_R = 24. Table 1 shows the calculated and tabular values of the Fisher criterion for all collectors (K1, K2, K3, K4, K5, K6, K7, and K8) probed.

A comparison is made between the Fisher criterion tabular and calculated values, since the requirement to model adequacy demands that the condition calculated Fisher criterion value is less than the tabular one is preserved. Otherwise, the hypothesis of adequacy should be rejected:

$$F \le F_t \qquad (10)$$

The adequacy of the mathematical model is proved, since the condition above has been fulfilled. Table 1 shows that calculated Fisher criterion values are less than the tabular ones for all the collectors studied.

CONCLUSIONS

In the present study a comparison is made between the results for a mathematically modeled flat solar collector and the experimentally obtained ones. Through the dispersion analysis method the model adequacy is proved comparing the results from experimental and numerical explorations. A statistical evaluation carried out proves the realized mathematical model as reliable and correctly describing the processes and phenomena taking place in all the solar collectors studied.

The realized mathematical model can be efficiently applied for calculating, designing and optimizing flat plate solar water collectors.

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