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STUDY OF THE PRESSURE AND DISTRIBUTION OF HEAT TRANSFER FLUID IN THE THERMOGENERATOR WITH PERMANENT MAGNETS AND EDDY CURRENTS

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Abstract: In the paper are presented the results of the study of heat transfer fluid pressure variation in the thermogenerator with permanent magnets and eddy currents. SOLIDWORKS Flow Simulation software was used to determine the dependence of the liquid pressure in the inlet pipe, of the thermogenerator, depending on the flow rate for its variation from 10 to 3500 l/h. The results obtained, will be used to design new permanent magnets thermal generators for domestic hot water preparation systems using wind energy.

Keywords: thermogenerator, heat transfer fluid, liquid pressure; simulation; SOLIDWORKS Flow Simulation

1. INTRODUCTION

The permanent magnet thermogenerator is a thermal generator for the direct conversion of mechanical energy generated by a wind turbine into thermal energy through eddy currents [1].

The basic purpose of the study is to develop a new construction scheme of the thermal generator with permanent magnets to produce thermal energy by direct conversion of wind energy.

For this, various constructive models of the permanent magnet thermogenerator have been developed for the study of the heat transfer fluid flow through the thermogenerator sleeves and, consequently, for the determination of a more efficient construction model. Thus, simulations were performed using SOLIDWORKS Flow Simulation software to determine the liquid pressure variation in the inlet pipe depending on the flow, which represents the local losses of hydraulic load caused by the so–called hydraulic resistances, such as local variations in shape and size of the pipe and the channel where the flow takes place. The passage of the liquid through these changes of form, determines the appearance of some variations of speed, variations of impulse, the local formation of vortices etc. [2].

The study, development and implementation of these technologies would contribute to improve-of the state in the rural sector in terms of hot water supply but would also lead to the achievement of the objectives of the Republic of Moldova on the use of renewable energies [3].

2. CONSTRUCTION SCHEME OF THE HEAT GENERATOR

The eddy currents wind thermogenerator, according to Figure 1, contains the glasses 1 and 2, which form the outer sleeve 12 and the inner sleeve 13 of the armature heat generator through which the heat transfer fluid flows. In the space formed between the sleeves 12 and 13, figure 2, the inductor 3 of the thermogenerator is concentrically oriented, being provided the air gaps 10 and 11, with a length of 1–2 mm.

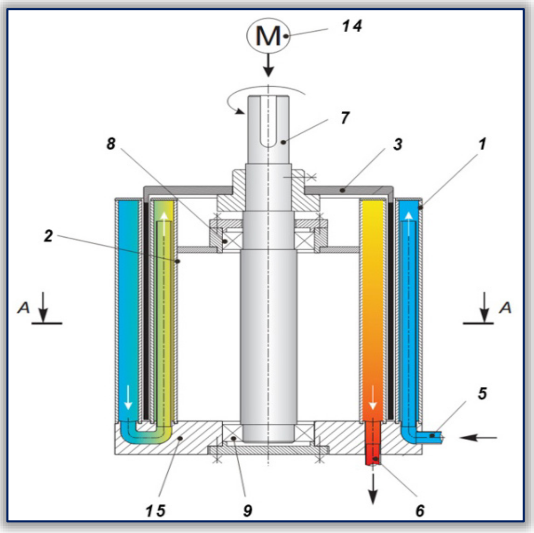

Figure 1. Overview of the thermogenerator in longitudinal section

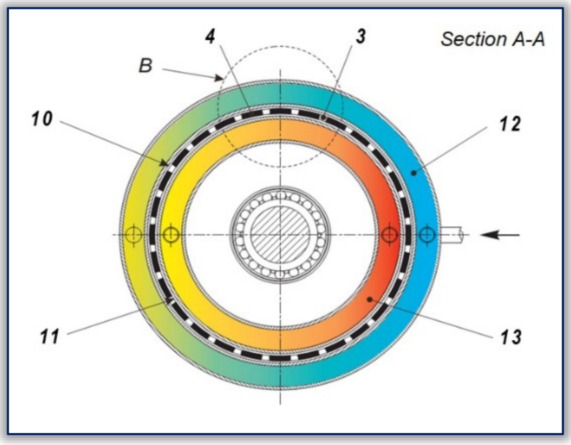

Figure 2. View of the thermogenerator in cross section

The inductor 3 is made of non–feromagnetic material, and in the longitudinal grooves, permanent magnets 4 are mounted. The heat transfer fluid, figure 1, which forms a closed circuit in the system for converting mechanical energy into thermal energy, enters the outer sleeve 12 of the thermogenerator through the inlet pipe 5 and exits the inner sleeve 13 through the discharge pipe 6. At the same time, the inductor 3 is mounted on the shaft 7, driven by the motor 14 and rotates freely in the bearings 8 and 9 fixed in the generator body 15 [1].

The eddy current thermogenerator works as follows: the motor 14, which can be a wind turbine, drives the shaft 7 on which the inductor 3 is mounted. When the inductor 3 rotates with the permanent magnets 4, the magnetic field intersects the walls of the solid ferromagnetic material of the armature. Thus, in the glasses 1 and 2 of the sleeves 12 and 13, are induced eddy currents and heated the material of glasses, which interacts the heat transfer fluid. As the heat transfer fluid, which circulates permanently in a closed system, is admitted into the sleeve 12 through the inlet pipe 5, it takes over some of the thermal energy generated and transports it to the consumer through the discharge pipe 6 at the outlet of the sleeve 13 [1].

3. SIMULATION OF HEATING FLUID FLOW CIRCULATION

In the context of the proposed study, three constructive models of the thermogenerator were developed, described in [4], using SOLIDWORKS software for the analysis of the flow of heat transfer fluid. The models have the same construction and operating principles described above, the difference is in the mode of intake and circulation of heat transfer fluid through the heat generator sleeves. SOLIDWORKS Flow Simulation software allows the simulation of the flow of liquids or gases using the typical physical models of liquids or gases to perform complex thermal calculations and create hydrodynamic or gas–dynamic and thermal models of technical devices [4].

The simulation of the heat transfer fluid flow through the thermogenerator sleeves performed in SOLIDWORKS Flow Simulation, aims to analyses the flow of liquid through the heat generator and determine the heat transfer fluid pressure variation in the inlet pipe depending on the flow, $P_1(Q)$, for each construction model.

Due to friction with solid walls and internal friction, some of the kinetic energy of the liquid is irreversibly transformed into heat, becoming an energy called hydraulic loss or pressure loss. Respectively, the total specific kinetic energy of the liquid decreases. Pressure losses depend on the shape, roughness of the pipe wall, flow rate and viscosity of the flowing liquid [2].

The required pressure in the inlet line for the developed models enable to estimate characteristics of the pump to maintain a constant flow of liquid through the sleeves of the heat generator.

The liquid flow circulation analysis was performed for the following conditions: the liquid temperature in the inlet pipe $T_1 = 11$ °C, the sleeves imposed temperature $T_0 = 20$ °C and the liquid flow variation through the thermogenerator sleeves from 10 to 3500 l/h.

In the Figures 3–8 are presented the flow of heat transfer fluid through the heat generator, at a flow rate of 1000 l/h and the liquid pressure in the heat generator, for each construction model.

According to the results, for the construction model with direct inlet and the model with direct inlet through the internal pipe, when sleeves is connected the in series and parallel, is observed that areas with low circulation of heat transfer fluid are formed in the sleeves, Figures 3–8. Regarding at the liquid pressure analysis in sleeves, is observed that in the constructive models with sleeves connected in series, the liquid pressure in outer sleeve is higher than in inner one, for the constructive models with sleeves connected in parallel, the liquid pressure in the outer sleeve is smaller than in the inner one. In the construction model with directioned inlet, when sleeves are connected in parallel, the liquid pressure through sleeves is more uniform.

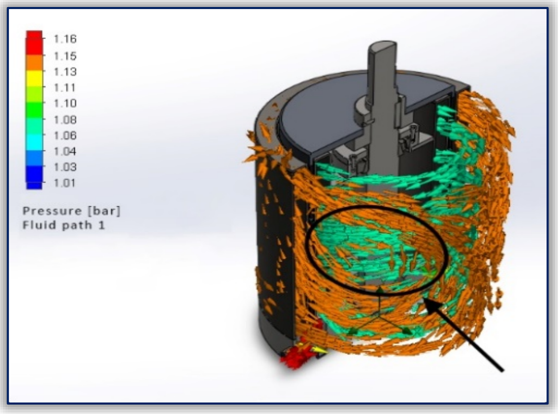

Figure 3. Liquid flow through the direct inlet thermogenerator and the sleeves connected in series

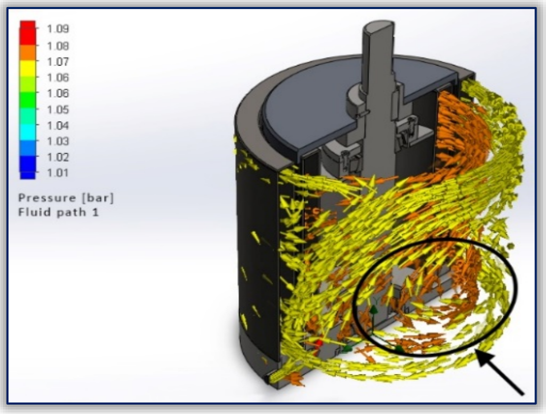

Figure 4. Liquid flow through the direct inlet thermogenerator and the sleeves connected in parallel

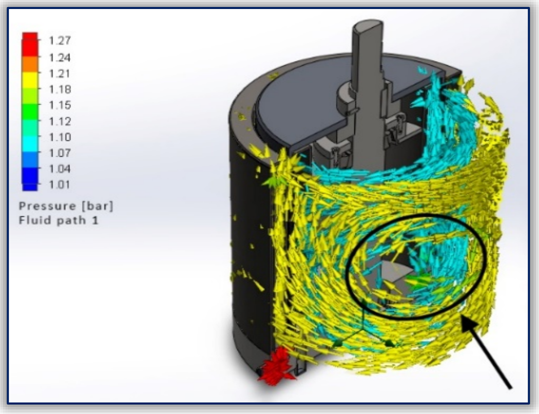

Figure 5. Liquid flow through thermogenerator with direct inlet through internal pipe with sleeves connected in series

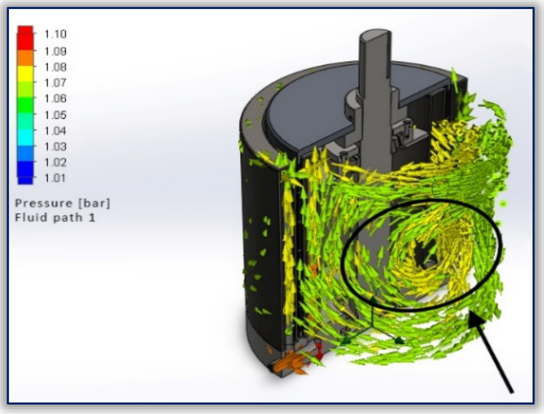

Figure 6. Liquid flow through thermogenerator with direct inlet through internal pipe with sleeves connected in parallel

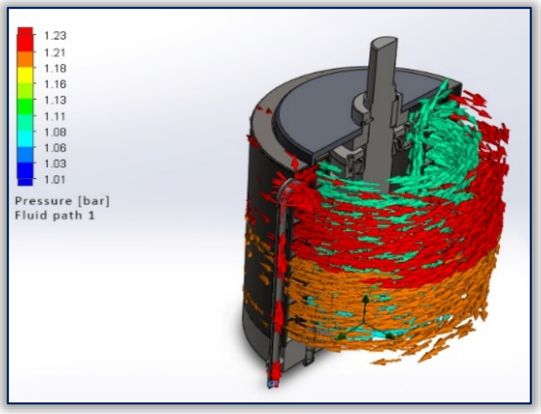

Figure 7. Liquid flow through the thermogenerator with directioned inlet and sleeves connected in series

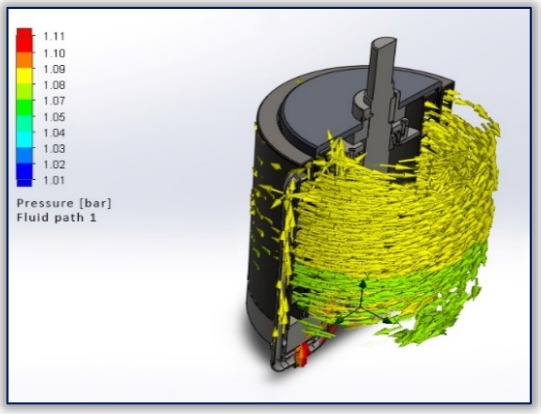

Figure 8. Liquid flow through the thermogenerator with directioned inlet and sleeves connected in parallel

4. RESULTS OF HEATING FLUID CIRCULATION SIMULATIONS

In the Table 1 are presented the results of simulations, regarding the circulation of heat transfer fluid through thermogenerator sleeves, for required temperature of the internal and external sleeves, equal to $T_0 = 20$ °C, the liquid temperature in inlet pipe – $T_1 = 11$ °C and the liquid flow variation through thermogenerator from 10 to 3500 l/h.

Table 1. The heat transfer fluid pressure variation in the inlet pipe depending on the flow rate $P_1(Q)$

Liquid pressure in the inlet pipe depending on the flow rate, for T_0=20 °C; T_1=11 °C						
Flow rate, l/h	Pressure P_1, bar					
	Model with sleeves connected in series			Model with sleeves connected in parallel		
	with direct inlet	with direct inlet through internal pipe	with directioned inlet	with direct inlet	with direct inlet through internal pipe	with directioned inlet
10	1,01	1,01	1,01	1,01	1,01	1,01
50	1,01	1,01	1,01	1,01	1,01	1,01
100	1,01	1,02	1,02	1,01	1,01	1,01
500	1,05	1,07	1,07	1,03	1,03	1,04
1000	1,14	1,25	1,23	1,07	1,08	1,10
1500	1,31	1,53	1,49	1,14	1,17	1,21
2000	1,54	1,93	1,85	1,25	1,29	1,36
2500	1,84	2,41	2,31	1,38	1,44	1,54
3000	2,20	3,03	2,86	1,53	1,63	1,77
3500	2,63	3,75	3,51	1,72	1,84	2,04

According to the simulation results, the pressure variation characteristic for all construction models, when the sleeves is connected in series and parallel, has the same shape of the curve, which can be characterized as follows: as the flow of liquid through thermogenerator increases, the pressure in the inlet pipe also increases, Figure 9. This represents energy losses of the fluid produced along the flow path and are due to viscous friction, turbulence effects as well as various hydraulic elements interspersed along the flow path, and the energy consumed to overcome these resistances and maintain a constant fluid flow, are compensated by increasing the fluid pressure in the inlet pipe.

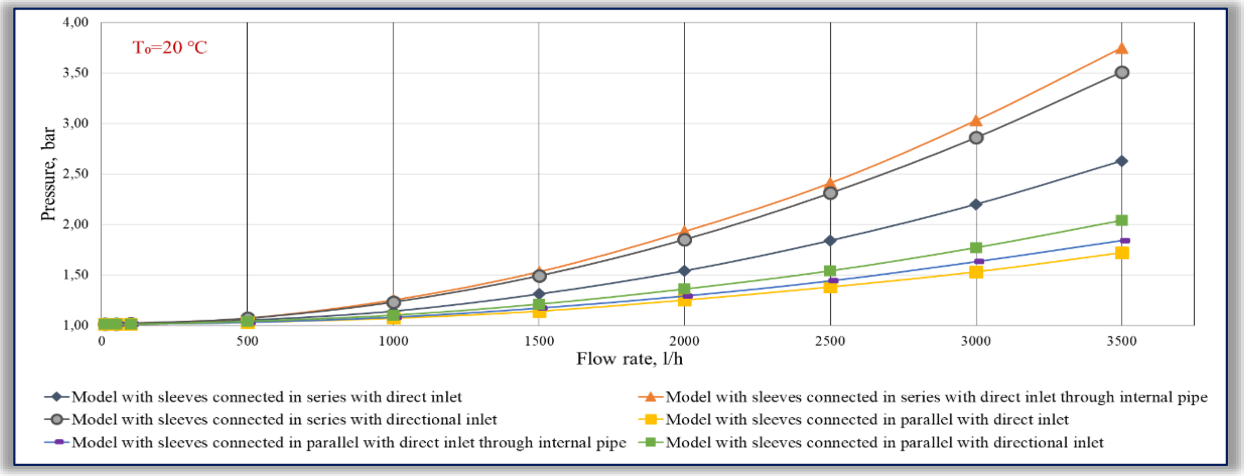

Figure 9. The heat transfer fluid pressure variation in the inlet pipe depending on the flow rate $P_1(Q)$

The following were found:

- According to the simulation results, is observed that in the construction model with directioned inlet, when sleeves is connected in parallel, the pressure in sleeves of the thermogenerator is distributed more evenly compared to the other models, Figure 8;
- For a constant flow rate of liquid through the thermogenerator sleeves, in the construction model with direct inlet and sleeves connected in parallel, are recorded the lowest values of pressure in the inlet pipe, Table 1.

5. CONCLUSIONS

Simulations were performed to determine the liquid pressure variation in the inlet pipe depending on the flow rate $P_1(Q)$ to its variation through the thermogenerator sleeves from 10 to 3500 l/h.

Based on the analysis of the simulation results, it was found that in the constructive model of the thermogenerator with directed inlet and the sleeves connected in series/parallel, the heat transfer fluid flow through the thermogenerator sleeves is more uniform, which determines that the active working surface in the thermogenerator is optimal.

At the same time is observed that for the constructive models with the sleeves connected in series, the liquid pressure in the outer sleeve is higher than in the inner one. For the constructive models with the sleeves connected in parallel, the liquid pressure in the outer sleeve is lower than in the inner one, Figures 3–8. This is explained by the fact that specific energy losses occur in the liquid circulation due to the sudden change of the section and the direction of the liquid circulation in the elbow between sleeves, which creates local hydraulic resistance.

It should be noted that in the constructive model with directioned inlet, when the sleeves in connected in parallel, the liquid pressure is more uniform through the thermogenerator sleeves.

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