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Experimentation and Simulation of Thermal Energy Storage System with Non-Phase Change Materials

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Abstract

This research a simulation study and experiment on the thermal energy storage system with non-phase change materials in the range of 50° - 150°C, this system is consisted of the storage tank size of 0.58 m in diameter, and 0.88 m in height, containing each set of the charging coil, and the discharging coil, embedded in the combination of 90% by volume of the used – engine oil, and 10% by volume of the river – water rocks. An electric heater is used as the heat source. The simulation of thermal-energy storage system with the mathematic modeling for the theoretical analysis of the system, and by using the Newton – Raphson method in the simulation process during the energy charging and discharging processes, The limitation of the charging oil temperature is maintained at 140°C with the flow rate in the range of 10 to18 l/min, whereas the inlet temperature of the discharge oil is maintained at 30°C with the flow rate of 6 to 14 l/min.

The computer simulation results with the charging time of 2 hours, and the oil flow rate of 14 l/min, The temperature of our storage media is increased by 60°C with the amount of heat gain by 23 MJ. And by our further simulation on discharging for 1 hour period, with the oil flow rate of 10 l/min, the storage temperature is decreased by 58°C, with the amount of heat removal of 23 MJ. It is found that results from the experiment are differed from the simulation by 3–5 %

Introduction

The Thermal energy may be stored as sensible heat. Sensible heat storage systems utilize the heat capacity and the change in temperature of the material during the process of charging or discharging - temperature of the storage material rises when energy is absorbed and drops when energy is withdrawn. One of the most attractive features of sensible heat storage systems is that charging and discharging operations can be expected to be completely reversible for an unlimited number of cycles. In the utilization of solar energy or waste heat from industrial, the storage of the energy received is of particular interest and importance because of the intermittent nature of solar energy. The energy storage system in this case must be able to retain the energy absorbed for at least a few days in order to be able to supply energy} as needed, on cloudy days when the energy input is small. For a small solar energy storage system time period of the variation is one day. Therefore, the storage system must be designed with both the energy input and the demand as important considerations.

S. Somasundaram, M.K. Drost, D.R. Brown, and Z.I. Antoniak.(1993), to study the "Intergrate thermal energy storage in power plant". There are committed to used the oil-rock storage or molten nitrate salt storage which to be better than anothers storage

T. Soontornchainacksaeng et al (1995) to study the water thermal energy storage system play an important role for continuous utilization of non-permanent existing energy source such as solar heating system. Storage tank can be separated into 3 parts which are ; 209 l – thermal storage tank containing 184 l of water, 30 cm-diameter charging coil made of 0.5 in. copper tube, and 30 cm-diameter discharging coil made of 0.5 in copper tube. The efficiency of thermal storage system while charging at all flow rate are nearly the same at 89% and the efficiency of the system while discharging at all flow rate are also the same of about 63%.

This paper considers the study and simulation of thermal-energy storage system with non-phase materials in the ranges of 50 to 150^{O}C. By using the Newton-raphson method in the simulation process during the energy charging and discharging processes.

Energy storage system principle

The study and simulation of thermal-energy storage system to be established and testing from the principle of the systems in fig. 1 shown the principle of energy storage system consist of ; storage tank is 0.58 m of diameters, 0.88 m of height and heating coils during charge and discharge. The heating coils are used copper tube, 0.016 m of outside diameter, includes the river-water rocks and used-engine oil test bed.

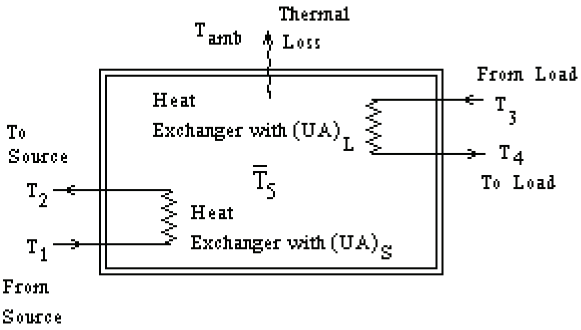

Fig. 1 principle of energy storage system

Assumptions of the system simulation are followings ; both of charge and discharge processes,

(1) The both of charge and discharge temperature are steady state conditions
(2) Non-stratified storage in the tank
(3) No mass transfer
(4) Constant temperature surroundings

Mathematical models of System

The energy storage system in fig. 1 can be to solved and show that in two cases, are consists in the case of charge and discharge temperatures following ;

(1) Charge the temperature into the systems

Heat losses during charge the energy into storage system have the relation as following ;

$$\Sigma Q_{loss} = \frac{1}{R_T}(\overline{T}_5 - T_{amb}) \tag{1}$$

Heat storage in the system to be calculated from equation(2)

$$\Sigma Q_{st} = m.c_m(\overline{T}_{5,fi} - \overline{T}_{5,ini}) \tag{2}$$

The outlet temperature of charge coils can be calculated form the equation(3) as following;

$$T_2 = \exp(\frac{-(U.A)_S}{\dot{m}_s.C_{f,s}})(T_1 - \overline{T}_5) + \overline{T}_5 \tag{3}$$

The average temperature are into the storage tank is given the relation as following ;

$$\overline{T}_5(t) = C_1 + C_2.\exp(x_1.t) \tag{4}$$

(2) Discharge the temperature from the systems

The discharge heat process are losses from the storage tank during these processes, may be calculated with the equation(5),

$$\Sigma Q_{loss} = \frac{1}{R_T}(\overline{T}_5 - T_{amb}) \tag{5}$$

The discharge temperature are calculated with equation (6) , So

$$\Sigma Q_{out} = m.c_m(\overline{T}_{5,fi} - \overline{T}_{5,ini}) \tag{6}$$

the outlet temperature are calculated with equation (7) , so

$$T_4 = \overline{T}_5 - \exp(\frac{-(U.A)_L}{\dot{m}_L.C_{f,L}})(\overline{T}_5 - T_3) \tag{7}$$

The average temperature are into the storage tank during these processes with the relation as following ;

$$\overline{T}_5(t) = C_3 + C_4.\exp(x_2.t) \tag{8}$$

These simulation are used the Newton – Raphson method and can be able to show that the relation of the variables of two cases that are charge and discharge processes.

Results of the system simulation

The parameters of the simulation systems are consisted of the flow rate of the oils in coils heat exchangers, ratio of rocks and oil by volume and the time used to charge and discharge in the storage system. The results of the simulations system are shown with the relations in Fig. 2 the average storage temperatures and heat storage,

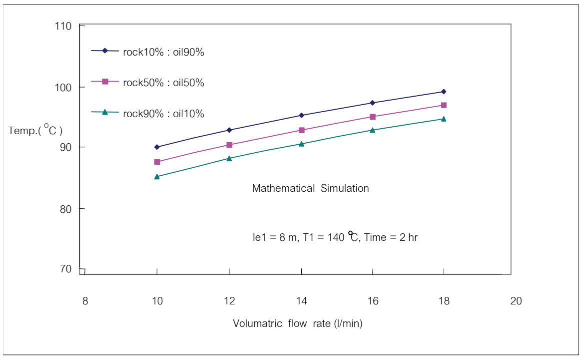

Fig. 2 The average temperatures in storage tank and volumetric flow rate (to charging 2 h)

In the Fig. 3, we found that when we choose the medium substance to collected heat with high heat capacity and high density as rock and oil respectively. It can be increased the heat storage to 4% approximately

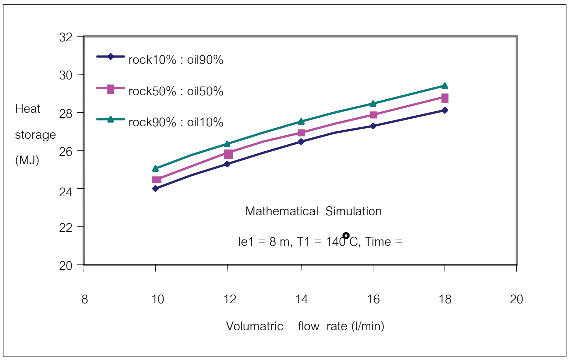

Fig. 3 Heat storage and volumetric flow rate (to charging 2 h)

In the Fig. 4 and 5 , when the thermal storage have high the heat capacity, It can be to discharged the heat from the storage system increase to 10% approximately

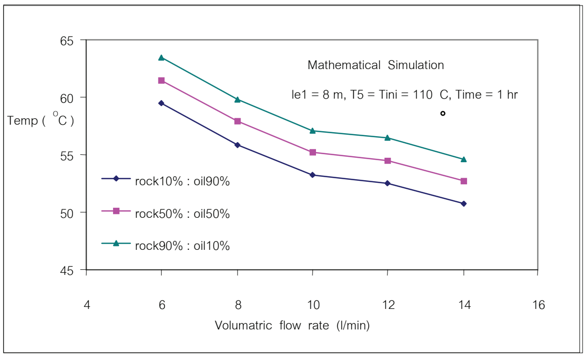

Fig. 4 The average temperatures in storage tank and volumetric flow rate (to discharging 1 h)

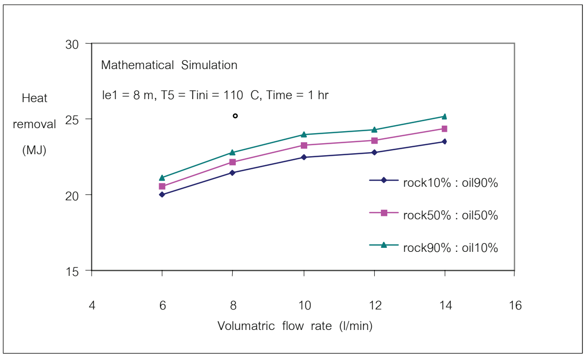

Fig. 5 Heat removal and volumetric flow rate (to discharging 1 h)

Experimental set-up

The experimental set-up is shown schematically in Figure 6 and 7. Its consisted of one storage and one water tank the two tanks which each of tank was 0.58 m diameters, 0.88 m high and 200 litres volume, gear pumps type GC-25 the inlet-out diameters was 1 inch, 55 l/min volumetric flow rate, electrically heated is 12 kW, water pump is 0.75 hp , flow controller, flow measurement tank, water tank and others accessories. So, the figure 6 is shown the schematic for charging systems and the figure 7 is shown the schematic for discharging systems respectively.

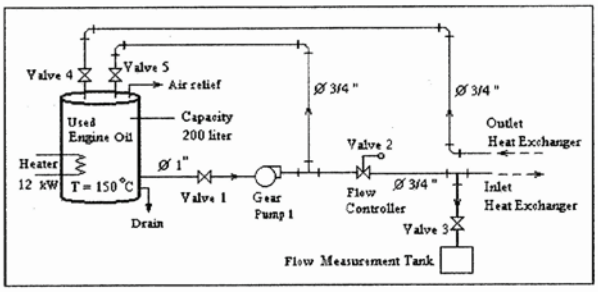

Fig. 6 Schematic representation of the experimental set-up in case of charging process.

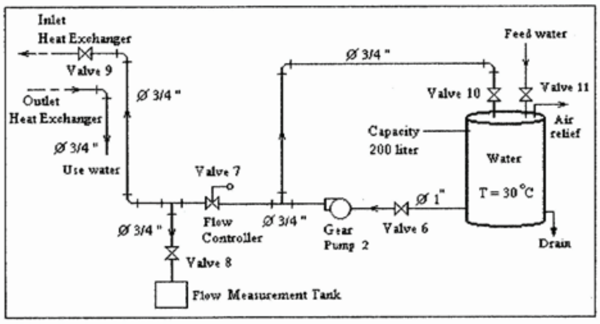

Fig. 7 Schematic representation of the experimental set-up in case of discharging process.

From the principle of this sensible heat storage system use materials that store energy as sensible heat. In this experimental; are used the engine-oil and rocks. The efficiency of thermal storage can be defined as the ratio of heat output to heat input, heat output being lower than the input by the amount of heat as in fig. 3 - 5. However, in the case of sensible heat storage the temperature of storage medium drops due to heat losses.

Experiment and simulation comparison

The Experiment and simulation comparison are shown schematically in Figure 8 and 11, these are consisted of two cases, the first case is the charging process and the another case is the discharging process, are shown in these followings,

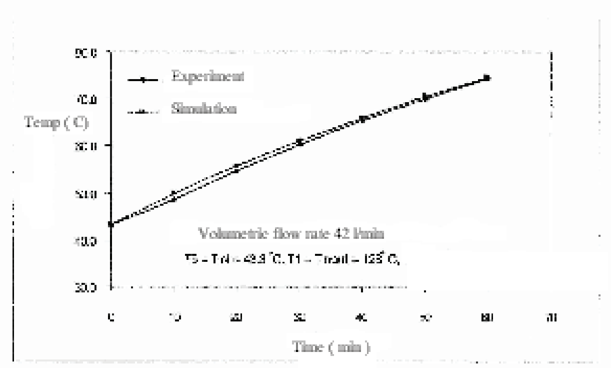

Fig. 8 The variations of the storage temperatures between experiment and simulations in case of charging systems

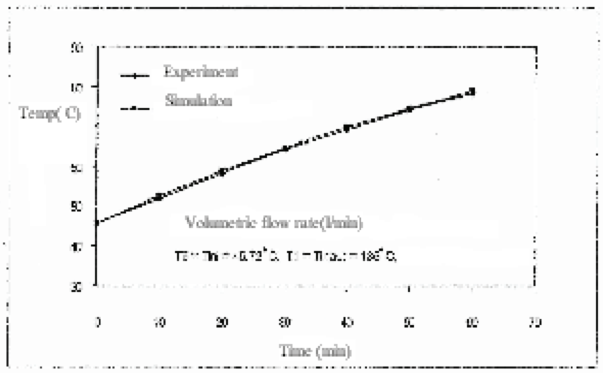

Fig. 9 The variations of the storage temperatures between experiment and simulations in case of charging systems

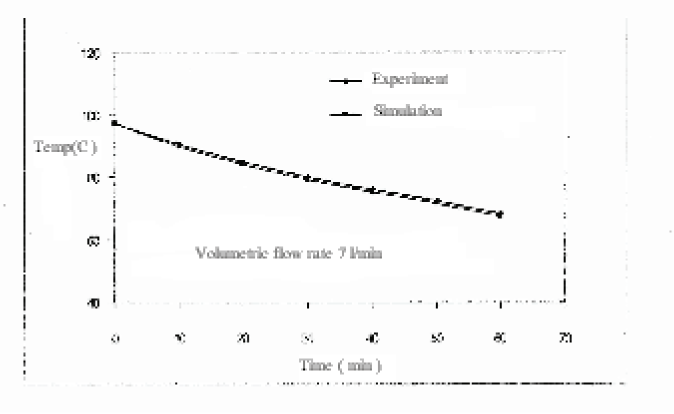

Fig. 10 The variations of the storage temperatures between experiment and simulations in case of discharging systems

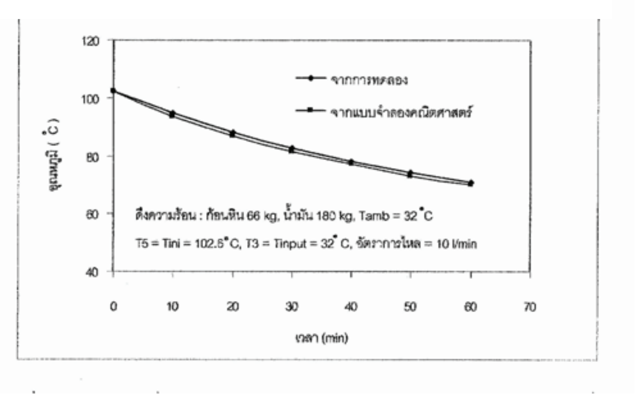

Fig. 11 The variations of the storage temperatures between experiment and simulations in case of discharging systems

Conclusions

Results of an experimentation and simulation on the our thermal energy storage systems which using the rocks and oil to be combined as storage materials in our system. We found that the ratio of rocks and oil have to be effect with the storage capacity. The computer simulation results with the charging time of 2 hours, and the oil flow rate of 14 l/min, The temperature of our storage medium is increased by 60° C with the amount of heat gain by 23 MJ. And by our further simulation on discharging for 1 hour period, with the oil flow rate of 10 l/min, the storage temperature is decreased by 58°C, with the amount of heat removal of 23 MJ. It is found that results from the experiment are differed from the simulation by 3–5 %

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