Chemical Technology, Control and Management

Volume 2020
Issue 5 *Special issue 5-6*

Article 27

11-20-2020

MODELING THE PROCESS OF HEAT EXCHANGE BETWEEN HEATERS AND THE MATERIAL TAKING INTO ACCOUNT HEAT EXCHANGE WITH THE ENVIRONMENT

J.E. Safarov
Department of mechanical building , Tashkent State Technical University, Uzbekistan, Address: str. University-2, 100095, Tashkent city, Republic of Uzbekistan, jasursafarov@yahoo.com

Sh.A. Sultanova
Department of mechanical building , Tashkent State Technical University, Uzbekistan, Address: str. University-2, 100095, Tashkent city, Republic of Uzbekistan

G.T. Dadayev
Department of mechanical building , Tashkent State Technical University, Uzbekistan, Address: str. University-2, 100095, Tashkent city, Republic of Uzbekistan

B.T. Jumayev
Department of mechanical building , Tashkent State Technical University, Uzbekistan, Address: str. University-2, 100095, Tashkent city, Republic of Uzbekistan

A.B. Saydullayev
Department of mechanical building , Tashkent State Technical University, Uzbekistan, Address: str. University-2, 100095, Tashkent city, Republic of Uzbekistan

Tashkent State Technical University, SSC «UZSTROYMATERIALY», SSC «UZKIMYOSANOAT», JV «SOVPLASTITAL», Agency on Intellectual Property of the Republic of Uzbekistan

ISSN 1815-4840, E-ISSN 2181-1105
Himičeskaâ tehnologiâ. Kontrol' i upravlenie
CHEMICAL TECHNOLOGY. CONTROL AND MANAGEMENT
2020, Special issue №5-6 (95-96) pp.157-162.
https://doi.org/10.34920/2020.5-6.157-161
International scientific and technical journal
journal homepage: https://uzjournals.edu.uz/ijctcm/
Since 2005

MODELING THE PROCESS OF HEAT EXCHANGE BETWEEN HEATERS AND THE MATERIAL TAKING INTO ACCOUNT HEAT EXCHANGE WITH THE ENVIRONMENT

J.E.Safarov[1], Sh.A.Sultanova[2], G.T.Dadayev[3], B.T.Jumayev[4], A.B.Saydullayev[5]

[1,2,3,4,5]Department of mechanical building , Tashkent State Technical University, Uzbekistan
Address: str. University-2, 100095, Tashkent city, Republic of Uzbekistan
[1]E-mail: jasursafarov@yahoo.com

Abstract: *The paper considers the modeling of the process of heat transfer between heaters and material, taking into account heat exchange with the environment. To solve this problem, an experimental drying unit was assembled. Paraffin, sand, salt and brick were selected as test materials. The research carried out with the use of paraffin shows the most optimal and economical result in relation to other materials. The efficiency of paraffin application reaches 51 ºC, and the cooling time takes much longer. In addition, the selected material and the selected temperature have a beneficial effect on the drying process of plant material. The article details the data and results of the heating process of the test materials and the selection justification. In the form of tables, the data of measurements of materials with high heat capacity at various temperatures from 20 to 51,5 °C are given. The process was observed with a thickness of 4 cm and for different durations from 1 to 120 minutes. The calculations of this procedure were also performed. This work can be useful for work where paraffin is used as a heating agent and, if necessary, for performing calculations.*

Keywords: *heat exchange, renewable energy, paraffin, heating.*

1. Introduction.

Currently, the main part of the world energy balance is covered by traditional fossil fuels, fossil fuels - 78% (coal, gas, oil) and nuclear energy - about 3%. The contribution of all types of renewable energy sources (RES) to global electricity production is about 22%, of which hydropower accounts for about 17% (other RES are slightly more than 5% [1]). Assessment of hydrocarbon reserves indicates that the global economy's supply of oil at the beginning of 2012 was 54 years, for natural gas this figure is 64 years, and for coal - 112 years [2].

According to the forecast of the International Energy Agency, by 2030 renewable energy sources will account for 29% of electricity production and 7% of motor fuel production [3]. In those regions where this is impossible due to the low potential of RES, it is necessary to develop nuclear energy, or rationally consume the available resources of organic raw materials [4,5,6,7].

One of the possible measures that allows more efficient use of thermal energy in various areas of the economy is the accumulation of heat through the use of different heat storage materials and heat accumulators of various designs [8,9,10,11,12,13].

2. Material and methods.

Classification of heat storage materials. The most important characteristics of the thermal energy storage system are [12]:

- capacity per unit of volume or weight;
- working temperature range, i.e. coolant temperature at the inlet and outlet from the system;
- ways of supply and extraction of heat and corresponding temperature drops;

- temperature stratification in the battery;
- power required for heat supply and removal;
- volumes of containers, tanks or other structural elements associated with the storage system;
- means for regulating heat losses of the accumulator;
- cost of manufacture and operation.

The creation of heat accumulators depends on the temperature level, the scale of the installation and the duration of heat accumulation [8].

When developing solar drying installations for drying specific materials in specific climatic conditions, the main requirements for the parts of the installation designed to impart thermal inertia are as follows [14,15,16,17]:

1. Large mass or volume of material, taking into account thermophysical properties.
2. Susceptibility to energy or intensity of heating.
3. Low rate of heat exchange with the environment.
4. Ease and compactness of installation design.

As a generalized criterion reduced to a unit of heat-insulating and accumulating material (HIAM), we take:

$$R = \frac{\mu_{21}}{\mu_{22}+\mu_{21'}+} \to max \qquad (1)$$

Where, μ_{21} – kinetic parameter characterizing the susceptibility to radiant energy; μ_{22} – exchange rate between HIAM and the environment; $\mu_{21} \to \mu_{21}$ while cooling.

An experimental setup was assembled to solve the problem. The experimental setup is shown in Fig. 1.

Paraffin, sand, salt and brick were selected as test materials. The experiments were carried out with materials 4 cm thick.

The beginning of the heating point was 20 ºC, the temperature of the tested materials was measured every 10 minutes for 120 minutes (2 hours). The heat source is an electric oven.

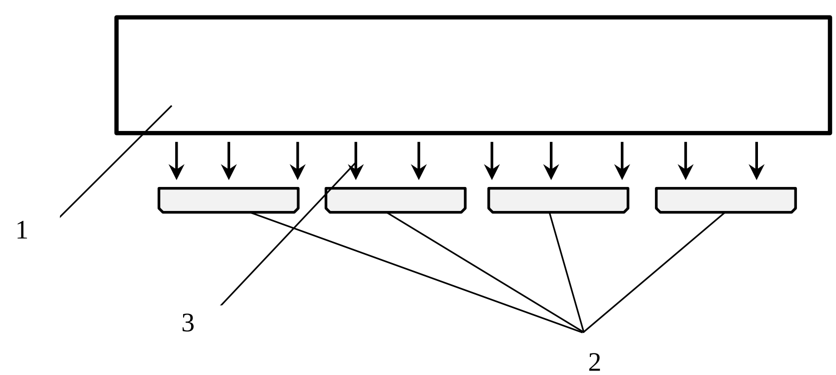

Fig. 1. ***Schematic of a setup for heating test materials:***
1-heat source; 2-tested materials; 3-heat flux.

The material temperature was monitored on the surface of the test material with an electronic thermometer.

3. Results and discussion.

The results of processing the experimental data by minimizing the sum of the squares of the deviations of the calculated data obtained by equation (2) from the experimental points are presented in Table 1. In Fig. 2 data are labeled 1-heater, 2-paraffin, 3-salt, 4-brick and 5-sand.

Table 1.

Kinetic parameters of heating mode.

№	Material	μ_{21}	μ_{22}
1	Paraffin	0,0718	0,010
2	Salt	0,0487	0,0128
3	Brick	0,0272	0,0155
4	Sand	0,0261	0,0155

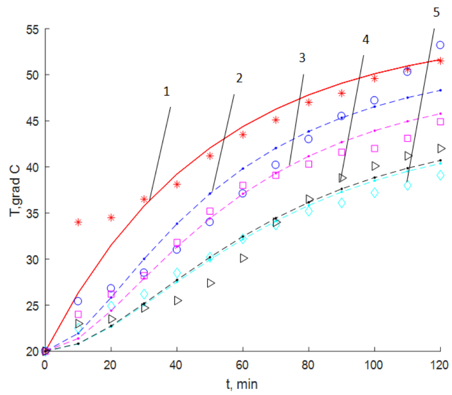

Fig. 2. ***Results of processing experimental data for heating mode.***
1-heater; 2-paraffin; 3-salt; 4-brick; 5-sand.

To quantitatively determine the parameters of interest to us, included in the expressions of criterion (1), we compose the equations of the kinetics of heat transfer between the heater and the material (HIAM), taking into account the heat exchange with the environment.

The heat flow diagram is shown in Fig. 3, where T_1 and T_2 are the temperatures in °C on the surface of the heater and HIAM.

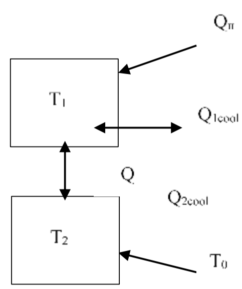

Fig. 3. ***Heat flow diagram.***

Where, $Q_н$ – heat flux to the heater from the source; Q_{1cool} – heat exchange flow between the heater and the environment; T_0 – ambient temperature; Q_{2cool} – heat flux between material and environment; Q – radiant flux from heater to material.

The kinetic equations of temperature change in the materials under consideration in time are drawn up in the form of a heat balance in dynamics.

$$\left\{\frac{dw_1}{dt} = Q_n - Q_{1cool} - Q\right. \qquad (2)$$

$$\frac{dw_2}{dt} = Q - Q_{2cool} \qquad (3)$$

For further calculations, these heat fluxes are expressed in the following form:

$$Q_{1cool} = \kappa_{1cool} \cdot S_1 \cdot (T_0 - T_1) \qquad (4)$$

$$Q_{2cool} = \kappa_{2cool} \cdot S_2 \cdot (T_0 - T_2) \qquad (5)$$

$$Q = q\, T_1\, S \qquad (6)$$

W= P C T – the amount of heat

The formulas indicate:

Where, к- heat transfer coefficient; S- heat exchange area; P- weight; C- heat capacity; q- the intensity of radiation from the heater to the material, referred to the radiation surface area.

After substituting equations 2, 3 into equations 4, 5, 6 and simple transformations, we get:

$$\frac{dt_1}{dt} = \mu_0 + \mu_{11}\,(T_0 - T_1) - \mu_{12}T_1 \tag{7}$$

$$\frac{dt_2}{dt} = \mu_{21}\cdot T_1 + \mu_{22}\,(T_0 - T_2) \tag{8}$$

The equations are solved under the following initial conditions:

$$T_1(0)=T_0$$

$$T_2(0)=T_0$$

Differential equations are solved by the method of operational calculus. For this equation, we transform according to Laplace:

$$\begin{cases} T_1\,(p)\cdot p - T_0 = \frac{a_0}{P} - a_1 T_1(p) \\ T_2\,(p)\cdot p - T_0 = \frac{\mu_{22}T_0}{P} + \mu_{21}T_1 - \mu_{22}T_2 \end{cases} \tag{9}$$

Here

$$a_0 = \mu_0 + \mu_{11}T_0;\;\; a_1 = \mu_{11} + \mu_{12} \tag{10}$$

We solve the obtained algebraic equations with respect to the relations:

$$\begin{cases} T_1\,(p) = \frac{T_0 + \frac{a_0}{P}}{p + a_1} = \frac{T_0 p + a_0}{p(p+a_1)} = \frac{T_0(p + \frac{a_0}{T_0})}{p(p+a_1)} \\ T_2\,(p) = \frac{T_0 + \frac{\mu_{22}T_0}{P} + \mu_{21}T_1}{p + \mu_{22}} = \frac{(T_0 + \mu_{21}T_1)p + \mu_{22}T_0}{p(p+\mu_{22})} \end{cases} \tag{11}$$

According to the values obtained from table 2, we obtain the solutions

$$T_1(t) = (A\cdot e^{-\alpha_1 t} + k)\cdot T_0;\;\; A = 1 + \frac{d}{a_1};\; k = -\frac{d}{a_1};\; d = \frac{a_0}{T_0} \tag{12}$$

In the second version of the analysis, the exchange between surfaces is expressed by the well-known formula of Stefan Boltzmann [18]

$$\mu_{21} = \left(\left(\frac{T_1 + 273{,}15}{100}\right)^4 - \left(\frac{T_2 + 273{,}15}{100}\right)^4\right) \tag{13}$$

Where, μ_{21} – coefficient that takes into account multiple reflections, as well as surface properties.

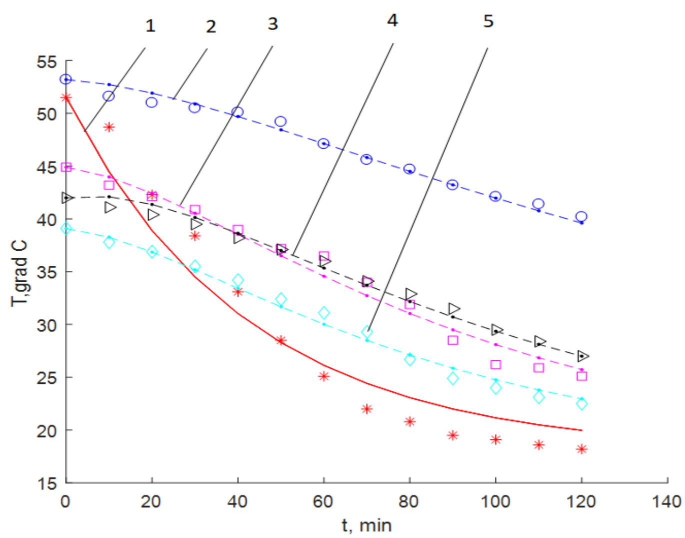

Fig. 4. ***Results of processing experimental data for the cooling mode.***
1-heater; 2-paraffin; 3-salt; 4-brick; 5-sand.

In the latter version, the kinetic equation can be solved numerically.

Further, in this case μ_0=0,7082 and μ_{11}=0,0200 (when obtaining the above results, the flows from the heater into the environment and towards the material are combined by one coefficient), measurements were made on the cooling of materials as a result of heat transfer. The results are shown in Fig. 4.

Table 2.

Kinetic parameters of the cooling mode.

№	Material	μ_{21}	μ_{22}
1	Paraffin	0,0048	0,0004
2	Salt	0,0108	0,0053
3	Brick	0,0110	0,0029
4	Sand	0,0102	0,0097

When processing the cooling mode, the initial conditions are taken equal to the last values reached in the heating mode.

In this case, μ_{11}=0,0236.

Now the values of the material selection criterion can be calculated according to the formula (1).

Table 3. A

Ccumulation of energy.

№	Material	Material selection criteria R
1	Paraffin	13,80
2	Salt	3,02
3	Brick	1,96
4	Sand	1,31

Table 3 shows that HIAM with number 1 (paraffin) best meets the formulated requirements for energy storage.

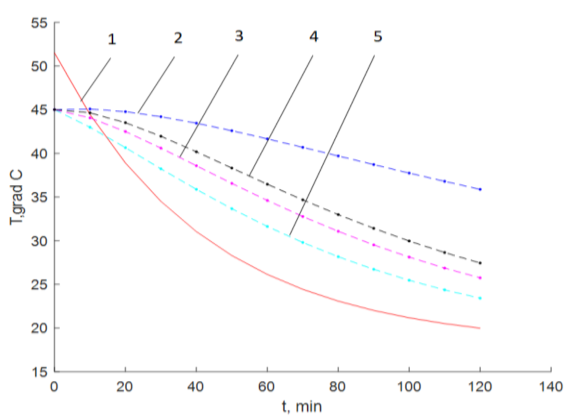

*Fig. 5. **Calculated graphs of temperature changes.***
1-heater; 2-paraffin; 3-salt; 4-brick; 5-sand.

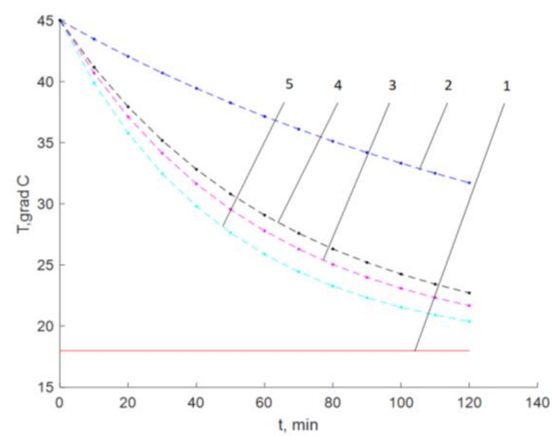

*Fig. 6. **Calculated graphs of temperature changes.***
1-heater; 2-paraffin; 3-salt; 4-brick; 5-sand.

In fig. Figures 5 and 6 show the calculated graphs of temperature changes at the same initial temperatures of the material and different temperatures of the heater $T_1(0)$=52 ºC and $T_1(0)$=18 ºC obtained according to equation (11).

4. Conclusion.

The nature of the change in the temperature curves, carried out under identical conditions, confirms the conclusions regarding the choice of material.

The laboratory studies and the results of experimental data processing show that the rate of wax warming (blue line in Fig. 2) and its efficiency are the highest. (the warming temperature reaches 51 ºC, and the cooling time is the greatest (Fig. 4)). Therefore, paraffin was chosen as a heat storage material, since the rate of heating and heat storage in it is the highest.

References

1. Renewables, Global status report. Renewable Energy Policy Network for the 21st Centure, [Electronic resource]. Rejim dostupa [Access mode] http://www.ren21.net, 2013.
2. «BP Statistical Review of World Energy, June 2012», [Electronic resource]. http://www.bp.com/assets/bp_internet/globalbp, 2012.
3. Official site of the company «International Energy Agency», [Electronic resource], http://www.iea.org, 2010.
4. S.M.Turabdjanov, H.Hasanov, A.Boboev, L.Yotova, "Effect of Hydrolysis products of different proteins of wheat on antioxidant enzymes", *International Journal BIOautomation*, no. 15(1), pp. 5-12, 2011.
5. N.R.Yusupbekov, A.R.Marahimov, Sh.M.Gulyamov, , H.Z.Igamberdiev, "APC fuzzy model of estimation of cost of switches at designing and modernizations of data-computing networks", *4th International Conference on Application of Information and Communication Technologies*, AICT 2010, 5612015, 2010, DOI: 10.1109/ICAICT.2010.5612015
6. N.Yusupbekov, F.Adilov, F.Ergashev, "Development and improvement of systems of automation and management of technological processes and manufactures", *Journal of Automation, Mobile Robotics and Intelligent Systems*, no. 11(3), pp. 53-57, 2012.
7. H.Z.Igamberdiyev, A.N.Yusupbekov, O.O.Zaripov, J.U.Sevinov, "Algorithms of adaptive identification of uncertain operated objects in dynamical models", *Procedia Computer Science*, no. 120, pp. 854-861, 2017.
8. B.Dj.Babayev, "Razrabotka i issledovaniye energosistem na osnove vozobnovlyayemykh istochnikov s fazoperekhodnym akkumulirovaniyem tepla" [Development and research of power systems based on renewable sources with phase-change heat storage]. Diss. dokt. tekhn. nauk., Makhachkala, 345 p. 2016 (in Russian).
9. G.Bekman, P.Gilli, *Teplovoye akkumulirovaniye energii [Thermal energy storage]*. Moskva: Mir, 1987, 272 p. (in Russian).
10. V.N.Bratenkov, P.V.Khavanov, L.YA.Vesker, *Teplosnabzheniye malykh naselennykh punktov [Heat supply to small localities localities]*. Moskva: Stroyizdat, 1988, 223 p. (in Russian).
11. V.A.Grigor'yev, "Razrabotka akkumulyatorov teploty s zernistym teplonositelem i metody ikh rascheta na osnove matematicheskogo modelirovaniya" [Developing batteries with a granular heat carrier, and methods of their calculation on the basis of mathematical modeling], dis. ... kan. tekhn. nauk., Moskva, RGB, 147 p. 2003. (in Russian).
12. Dzh.Daffi, U.Bekman, *Osnovy solnechnoy teploenergetiki [Basics of solar thermal power engineering]*. Dolgoprudnyy: Izdatel'skiy Dom «Intellekt», 2013, 888 p. 2013. (in Russian).
13. O.S.Popel', S.Ye.Frid, E.E.Shpil'rayn, i dr., "Solnechnyye i vetrovyye avtonomnyye energoustanovki s vodorodnym nakopitelem" [Solar and wind-autonomous power plants with hydrogen storage], *Perspektivy energetiki*, vol. 10, pp. 77 – 90, 2006 (in Russian).
14. J.E.Safarov, Sh.A.Sultanova, G.T.Dadayev, D.I.Samandarov, "Method for drying fruits of rose hips", *International Journal of Innovative Technology and Exploring Engineering*, vol. 9, Iss. 1, pp. 3765-3768, 2019.
15. J.E.Safarov, Sh.A.Sultanova, G.T.Dadayev, "Development of solar accumulating drying equipment based on the theoretical studies of solar energy accumulation", *Energetika. Proc. CIS Higher Educ. Inst. and Power Eng. Assoc*, vol. 63, no. 2, pp. 174–192, 2020.
16. J.E.Safarov, G.T.Dadayev, "Issledovaniye rezul'tatov po primeneniyu teploakkumulyatsionnykh materialov" [Invastigating the results of heat storage material use], *Problemy energo- i resursosberezheniya*, no. 3-4, pp. 223-227, 2017 (in Russian).
17. J.E.Safarov, G.T.Dadayev, "Issledovaniye protsessa nagrevaniya i okhlazhdeniya pri ispol'zovanii razlichnykh materialov dlya akkumuliyatsii teplovoy energii" [Investigation of the heating and cooling process using various materials for heat energy storage], *Universum: tekhnicheskiye nauki*, no. 11(44), pp. 16-18, 2017 (in Russian).
18. A.N.Tikhonov, A.A.Samarskiy, *Uravneniya matematicheskoy fiziki [Equation of mathematical physics]*. Moskva: Nauka, 1966, 724 p. (in Russian).