American Journal of Energy Engineering
2014; 2(3): 75-79
Published online April 30, 2014 (http://www.sciencepublishinggroup.com/j/ajee)
doi: 10.11648/j.ajee.20140203.11

Investigations of mathematical models in solar collectors

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To cite this article:
Nuru Safarov, Gurban Axmedov, Sedreddin Axmedov. Investigations of Mathematical Models in Solar Collectors. *American Journal of Energy Engineering.* Vol. 2, No. 3, 2014, pp. 75-79. doi: 10.11648/j.ajee.20140203.11

Abstract: There has been prepared the calculations methods of heat productivity of sun collectors which enables to determine the expedient of maintenance of polymers in sun collectors in the temperature mode given for different region and climate conditions. Show that, thermo endurance - T_0 maybe using as characteristic of thermo endurance of optic materials. If heating flow, destruction temperature and internal surface temperature is measured during test, it is possible to determine value T_0 and other necessity characteristics. As a result of the taking test was lead to comparison evaluation of considered materials. Working range of heating flow and up level heating embark have been determined.

Keywords: Solar Collectors, Polymer, Heat Transfer, Dynamic Model

1. Introduction

Majority of authors researching polymer collectors demand the comparative analysis and quantity estimation among the construction versions according the heat productivity in different climate conditions. There has been necessity of wide usage of report dependency as the most important period of technical preparation of solar system on the basis of sun collectors with new construction which are created [1,2].

In the investigations held up to the present time, the calculation methods of heat-productivity in sun collectors had been prepared in the calculation machines. At that time, the program maintenance had been written in Pascal language. But nowadays with the integration of high-speed computers to the science there has been appeared the necessity of correction to such kind of calculations and program maintenance. So, the program maintenance worked out by us is considered for modern new-generated computers. This program maintenance enables to create both, non-heat capacity and single -element_mathematical methods. According to the statistical data of direct and scattered sun-rays, the program maintenance also enables to get the distribution of sun-ray pressure getting onto the surface of sun collector for per hour. Besides, it helps to get the heat-productivity for the non-capacity and single-element models and also determines the total heat loss factor, the average temperature of heat transit, the ratio of convective heat-transfer factor and the temperature of transparent cover [3,4].

On the basis of numbers for per hour, the average heat-productivity of ratio of useful work and efficiency of sun panels are determined.

Except the modeling of work in sun collectors in a real climate conditions and the basis of its construction parameters, this prepared method enables the numeric investigation of efficiency of heat-capacity to its heat-productivity. All these estimations are held in the cooling and heating regime.

Obtaining knowledge about solidity and heating endurance of materials is tremendous important during material selection for preparation optical details which work under intense heating.

Lens and filters of projectors, heating equipment's of optic covered are considered as optical details. There isn't this information for many new materials. The reason of this situation is not only unique view to methodology of defining category of thermo endurance but also specifying of the materials. Comparatively low thermo endurance and solidity, weaker resistance to extraction rather than pressing include this specification. By this reason, traditionally extraction methods (for example: for various temperature) complicate process identification of characteristics for embedding optic materials [5,6]. In this situation direct test thermo endurance of optic materials become more important.

As mentioned above, specification of optic materials during their testing highly require heating base and method of their transferring. As specific factor base stable equal heating pollute additive and contactless with foreign substances, ordinary deformation and other similar requirements are demanded. In this view, it presents huge interest testing of one side heating of free placing flatness layers. As a source of heating, concentrating radiation and also solar radiation are utilized.

2. Data Collection and Analysis

Let's look at such a sun collector made of polymer in which heat-absorbing panel is consisted of two boards which are joined by sides themselves with heat-transferring channels. Such kind of construction has been considered as a basis by some investigators.

Non-heat capacity models can be explained like below [5]:

$$\frac{Q_u}{A} = F'[I(\tau\alpha) - U_L(T_m - T_a)] = 2Gc_p(T_m - T_i)/A \quad (1)$$

Here is Q_u – valuable heating, Wt

$(\tau\alpha)$ – optical ratio of useful work

(Gc_p) – water equivalent of circulated liquid, joule/kg

A – surface space of the collector, m^2

U_L – the total heat lost factor, Wt/(m^2xK)

T_m, T_i, T_a – the average temperature of heat transfer of solar collector, the temperature in the entrance of solar collector, and the temperature of the air in the environment

F' – the efficiency of solar collector

For the construction above one can be written:

$$F' = \frac{1/U_L}{1/U_L + 1/\alpha_{ds} + l/\lambda_p} \quad (2)$$

Here is a α_{ds}- heat-transfer ratio of inner space of panel to liquid, Wt/(m^2xK)

λ_p- heat transfer of panel material, Wt/mK

Heat-lost is composed of radiation on surface, radiation and convective based parts and heat-transfer lost in the back side part.

$$U_L = (q_L^t + q_L^b)/(T_m - T_a) \quad (3)$$

Heat-lost in the back side will be like this:

$$q_L^b = \frac{\lambda_t}{l_t} \quad (4)$$

Here λ_t- is heat-transfer of heat-isolations, Wt/(mxK) and l_t- is are thickness of heat-isolations, m.

The heat-lost of the outer surface $- q_L^t$ are determined by solving the heat balance of the system equations of absorbing surface and a transparent shells:

$$\begin{pmatrix} q_L^t - \left[\frac{\sigma(T_m^4 - T_g^4)}{1/\varepsilon_p + 1/\varepsilon_g - 1}\right] - \tau_t\varepsilon_p\sigma(T_m^4 - T_a^4) - \alpha(T_m - T_g) = 0 \\ q_L^t - \sigma\varepsilon_g(T_g^4 - T_a^4) - \alpha_h(T_g - T_a) = 0 \end{pmatrix} \quad (5)$$

Here is $\sigma -$ Stefan-Boltzmann constant, Wt/(m^2xK^4)

$T_g -$ the temperature of cover, K

$\tau_t -$ is a heat-releasing ability in infra-red diapason

$\varepsilon_p, \varepsilon_g -$ is a radiation ability of panel and cover

$\alpha, \alpha_h -$ heat convective coefficient between the panel and coating, between the coating and the environment panel, Wt/(m^2xK)

α and α_h - ratios, are calculated according the calculation dependence $U_L = (q_L^t + q_L^b)/(T_m - T_a)$.

Taking into account the temperature spreading along its length, the equation which explains the work of solar collector composes the basis of single element model.

$$c_a\frac{dT_m}{dt} = F'[I(\tau\alpha) - U_L(T_m - T_a)] - 2Gc_p(T_m - T_i)/A \quad (6)$$

$c_a -$ it's an imaginary heat-capacity characterizing the whole collector, kJ/(kgxK).

$c_a -$ quantity is defined with the correction of $U_L = (q_L^t + q_L^b)/(T_m - T_a)$ of the total heat lost ratio to the proportion of lost ratio out of the transferring cover to the environment.

In the numerical investigations of solar collectors there have been accepted two operating working modes. First mode coincides to 310 K (normal hot-water supply in the water reservoir), but the second mode to 330 K (hot-water supply in the mode of life). The reporting time was July. In that case there had been worked up Baku-Absheron climate and the initial data were taken since [7]. The thickness of panel walls was 0,001m, the thickness of an air lay was 0,04m, and the thickness of back-heat isolation was 0,03m.

Other quantities had been like this: $\tau\alpha - 0{,}85$; $\tau_t - 0{,}2$; $\lambda_p - 0{,}2$; $\lambda_t - 0{,}04$Wt/(mxK); $\varepsilon_p - 0{,}95$; $\varepsilon_g - 0{,}88$; $\alpha, \alpha_h -$ 1500Wt/m^2xK; G – 0,083kg/s; $c_a -$ 34400 kJ/(kgxK).

In this job, methods and some results of thermo endurance research are commented during heating optic materials in solar equipment's. Length of the equipment is based on parabolic concentrator which consists of 40 cm length and 30 cm focal distance organic glass. Thermocouple sample is located in focal zone of concentrator. Changing of heating parameters is implemented through breaking of sample focuses. This obtains with help of replacement of thermocouples sample by axis of mirror.

Sample which is provided with thermocouple and entire registration located on focal surface of concentrator. Replacement of heating parameters is obtained by breaking of focuses of sun ray which reflection on sample, because moving sample through mirror. Following concentrator of sun is implemented with help of azimuthally-zenithal photoelectric system which consist optic photo head, automat block and electric engine. Duration of experiment is registered via stopwatch.

Maximum capability of density of radiation on this equipment is 14KV/m^2. It is sufficient requirement for surplus practical cases. As sample for testing were using epoxy adhesive and optic glue materials. Elements are bordered by metal frames and provided complete and temperature sensors. Moreover, they registered separate moment and internal surface temperature of sample. Free settled sample surface happens with stretch-deformation during non-straight heating which characterize as whole bending. Its internal surface has extensibility tensions which undesirable issue [7].

Spreading of energy on focal surface and through concentrator axis is learned with help of colorimeter which cooled with water, imitated absolutely black matter.

Dependence of raying density from normal solar radiation for diaphragm with 200mm diameter on focal surface is presented in figure 1. Changing of radiation density through concentrator axis is exhibited in figure 2. Theoretically, the concentrator's focal shadow is guessed to be approximately 10 mm but it is 50mm in fact because it geometrically shape is non-precise. That is why maximal radiation density has had 200kkal/m^2 which is sufficient meet requirements of some practical cases. Using of focus breaching is seemed as correct method in regulation heating parameters because flow of heating less changed through concentrator axis.

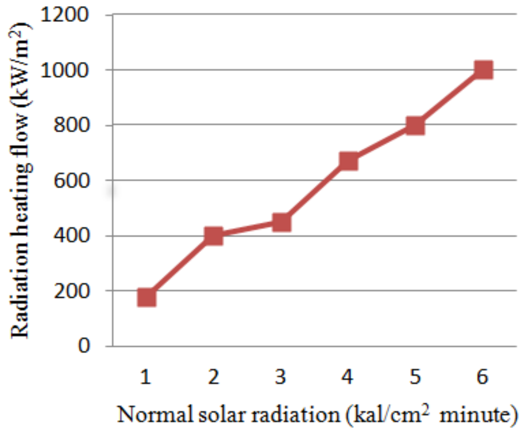

Figure 1. *Dependency of normal solar ray radiation from density of radiation on focal plane.*

Spreading of temperature on focal surface and its parallel surfaces per concrete case is implemented with help of thermo couple. Because used colorimeter type diaphragm is defined radiation density due to size. This measure is indicated that exceeding of temperature was not greater than 10% in whole researched diapason breaching of focusing in 40 mm shadow which is absolutely reasonable.

Figure 2. *Changing density of radiation energy through concentrator axis (q_0, ray – heating flow on focal plane)*

Circle samples have been tested which have been made by optic materials with 3-8 mm thickness and 30-50mm diameter. Layers made free settlements in metal frame. It provides with thermo couples and special completing registration which fix temperature of unheated inside layer and destruction moment of sample. Outside surface of sample was covered with swallow layer by 15 mkm thickness due to obstacle reflection radiation energy of sample. Obviously, during the period balanced heating of free settlement circle layer surface there happens tension-deformation case which is clear bend. This period happen pulling tensions in internal layer which cause serious danger.

It is presented that obvious accepting thermo-physic characteristic of material possible to define solid level from pulling due to heating flow of layer surface, temperature of internal surface and destruction period.

Indeed, thermo-flexibility theory of thin circle layer causes that given tensions, deformation of layer equal [8,9]:

$$\sigma = -\frac{\alpha E(t_U - t_i)}{1-\nu}, \varepsilon = \alpha t_U \tag{7}$$

$$t_U = \frac{1}{h}\int_0^h t(x)dx, \tag{8}$$

Here h – depth of layer

t(x) spread of temperature due to depth

t_i - temperature of unheated internal surface

E, α, ν – Yung module, linear enhancement coefficient and Poisson's ratio of layer material respectively.

It is not harsh to get expression for average integral temperature due to depth from thermal conductivity equation:

$$t_U = \frac{q\tau}{hc\rho}, q = \frac{1}{\tau}\int_0^\tau q(\tau)d\tau \tag{9}$$

Here q-heating flow direction to internal surface; c, ρ-heating capacity and density of material respectively; τ-time.

If during some period tension or deformation reach to own limited value then get from (7) and (8).

$$\frac{\sigma_0(1-\nu)}{E} = T_{kr} - \alpha t_i, \ \varepsilon_0 = T_{kr} \tag{10}$$

Here σ_0, ε_0 - solidity border to pulling top level deformation to pulling respectively. Temperature of the inner surface:

$$T_0 = \frac{\alpha q_0 \tau_0}{hc\rho} \tag{11}$$

From first approach of (10) resulted that

$$(T_0 - t_i)/\alpha = \sigma_0(1-\nu)/E\alpha \qquad (12)$$

So, T_0 may be using as characteristic of thermo endurance of optic materials. Resulted from (10) that T_0 is function of temperature. However, (11) and (12) following result: If heating flow, destruction temperature and internal surface temperature is measured during test, it is possible to determine value T_0 and other necessity characteristics.

As a result of the taking test was lead to comparison evaluation of considered materials. Working range of heating flow and up level heating embark have been determined.

Test result of enumerated before materials test result presented in table. Test has been accepted as average value in the result of checking 2-4 times same sample in the same heating flow.

Table 1. *Test results of samples.*

Material		Epoxy adhesive		Optic glue	
g, Vt/sm^2	Depth, mm	τ, sec	t_i, ^{0}C	τ, sec	t_i, ^{0}C
10	3	-	-	37	130
	5	-	-	42	145
20	3	23	285 130	54	145
	4	14	135	-	-
	5	-	-	15	60
25	8	9	70	-	-
30	3	6	120	-	-
	4	7	95	-	-
	6	4	50	-	-
	8	-	-	7	40

3. Results and Discussion

There had been given results of numeric modeling in figure 3. While according to the stationary -fixed-line model, the heat-productivity is higher than the dynamic one until the break point characterizing the transmitting of heating towards cooling the situation is changed back after the breaking point - the heat productivity in dynamic model becomes higher than stationary one.

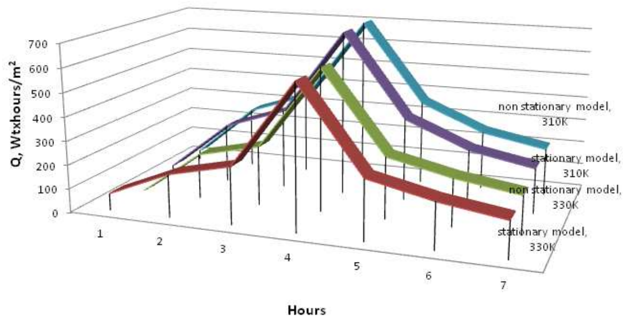

Figure 3. *The results of numeric modeling for the solar collectors.*

According the stationary and non-stationary -fixed-up model, there had been introduced the density of the total solar radiation onto the surface of the sun collector, heating and cooling intervals of the solar collector and heating productivity in the time-table below.

Table 2. *The characteristic parameters for collectors in various modes.*

Region	**Mode T=310K**			**Mode T=330K**			**I, Wtxhours/ m^2**
	Time, hours	**Qn, Wtxhours/m^2**	**Qnst, Wtxhours/m^2**	**Time, hours**	**Qn, Wtxhours/m^2**	**Qnst, Wtxhours/m^2**	
Baku-Absheron	7-13	2900	3020	8-13	1960	2075	6700
	14-18	1840	1735	14-17	1100	1034	
		4740	4755		3060	3109	

It can be seen from results of tests that optic ceramic is the best endurance to heating. It is important to note that curves which is showed in figure 1 allow to choose materials for develop of some thin wall details which work under one side intense heating (layers, semi spheres and cylinders). If T_0 which is calculated during concrete period for known heating flow during heating of internal detail's surface is placed on or above appropriate curve or then this material are not useful.

Some results of sample testing in 20W/cm^2 heating flow which is mentioned below:

- epoxy adhesive, depth is 3mm – 130 ^{0}C (test period τ = 23sec)
- optic glue, depth 3mm – 145 ^{0}C (test period τ = 54sec)

Consequently, T_0 would be used as thermo endurance characteristics of optic materials. If heating flow, splitting period and temperature of in internal surface is measured, and then T_0 indicator would be determined too. As a result of researches compared measures of thermo endurance for tested materials are found. Working diapason of heating has been determined.

4. Conclusion

Analyzing the received results, one can come to a conclusion that the working time-useful heat energy productivity is 9 to 11 hours. Ratio of useful work of collector for 24 hours is approximately 45%.

So, this prepared method enables to compare the mathematical model of static and non-element models of the solar collector. This method also determines the availability of supplying the solar collectors in the given temperature modes for different climate zones and regions.

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