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Study and Comparison Between Two Receivers of Parabolic Trough Collector

Ibrahim Bendjamaa[1*], Tayeb Allaoui[2], Younes Menni[1], Ali J. Chamkha[3], Giulio Lorenzini[4]

[1] Unit of Research on Materials and Renewable Energies, Department of Physics, Faculty of Sciences, Abou Bekr Belkaid University, B.P. 119, 13000, Tlemcen, Algeria
[2] Faculty of Applied Sciences, Department of Electrical Engineering, Tiaret University, P.B.78-Tiaret, Algeria
[3] Mechanical Engineering Department, Prince Sultan Endowment for Energy and Environment, Prince Mohammad Bin Fahd University, Al-Khobar 31952, Saudi Arabia
[4] Department of Engineering and Architecture, University of Parma, Parco Area Delle Scienze 181/A, 43124 Parma, Italy

Corresponding Author Email: bendjamaa_ibrahim@yahoo.fr

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ABSTRACT

In this paper, we studied in particular solar energy that recovers heat from solar radiation in a fluid, by converting the solar energy into thermal energy by the implementation of thermal solar collectors. This study is the modeling of heat transfer of the parabolic solar collector trough. The objective of this recent simulation is to determine the variation of the outlet temperature, the useful energy and the thermal efficiency of two different receivers. The fluid is water liquid. In order to determine these parameters, we simulate the different types of receivers by the MATLAB/Simulink. According to the simulation findings, using the second receiver leads to an increase of the fluid temperature at the output and the overall solar collector thermal efficiency.

1. INTRODUCTION

Solar concentration is one of the most techniques to enhance the performance of solar collectors. Many numerical and experimental studies have included this situation. Qu et al. [1] proposed and designed a spectral splitting concentrator for the achievement of cascading utilization of the full-spectrum solar energy. Barreto et al. [2] addressed the Computational Fluid Dynamics (CFD) modelling and thermal performance analysis of porous volumetric receivers coupled to solar concentration systems. Mahmoud et al. [3] presented the productivity and operational performance of a newly developed integrated solar still - two effects humidification-dehumidification desalination system (SS-HDH). Li et al. [4] demonstrated a high performance solar thermoelectric generator system combined with solar concentrators and carbon nanotubes absorber, which can greatly improve the solar-thermal conversion process. Lv et al. [5] developed and validated a mathematical model containing various heat losses ignored by previous studies to confirm the possibility of improved solar thermoelectric generator performance. de Sá et al. [6] addressed the most important issues regarding the two-phase flow in direct steam generation process in linear solar concentrators. Osorio et al. [7] analyzed the effect of the concentration ratio on the performance of parabolic trough and central receiver collectors with integrated transparent insulation materials. Teles et al. [8] focused on investigating the performance of a new version of evacuated tube solar collector with and without solar tracking system. Valera et al. [9] numerically investigated the feasibility of passive cooling mechanisms for microscale solar cells under ultra-high (UH) concentration levels, > 2,000 suns. Durth et al. [10] described the impact of the use of salts with higher sodium concentration salts in a commercial plant performance. Lungwitz et al. [11] developed a Ta-doped SnO_2 TCO on top of a BB as selectively solar-transmitting coating for high temperature CSP (concentrated solar power) technology. Arias [12] proposed and discussed an approach for solar concentration enhancement, called thermal conductive focusing. Cheng et al. [13] presented a new method to obtain the mother curves of the tailored non-imaging secondary (NIS) used for CPV system. Cook and Said Al-Hallaj [14] used film-based optical elements as a passive solar concentrator for Building Integrated Photovoltaic (BIPV) window applications. Delgado-Sanchez [15] described and contrasted a 2D model for Cu(In,Ga)Se_2 (CIGS) solar cells under low solar concentration with experimental data. Zhu et al. [16] proposed a novel light concentration and direct heating (LCDH) solar distillation device embedded underground. Wang et al. [17] described a multi-segment plate (MSP) concentrator for solar concentration photovoltaic (CPV) system. Wang et al. [18] demonstrated a modified one-step fabrication method for the band gap tuning of perovskite layer by designing iodide concentration gradient. Sagade et al. [19] defined effective concentration ratio (ECR) to assess the effectiveness of booster reflector. Ruelas et al. [20] incorporated an opt-geometric model to estimate the theoretical energy concentration performance of solar concentrators with offset parabolic satellite dishes (OPSDs). Li et al. [21] examined and reported different methodologies for effective energy concentration. They demonstrated the suitability of the developed approach by the theoretical analysis of several typical energy concentrator models. Other studies can be found in the literature as Gokhale et al. [22], Jafrancesco et al. [23], Tamaura et al. [24], Rabady and Andrawes [25], Eck et al. [26-32], Zarza et al. [33], and Lobón et al. [34, 35].

The objective of this recent simulation is to determine the variation of the outlet temperature, the useful energy and the thermal efficiency of two various receivers under consideration, using the MATLAB/Simulink.

2. MATHEMATICAL MODELING

In this study, considering two models of parabolic trough solar collector.

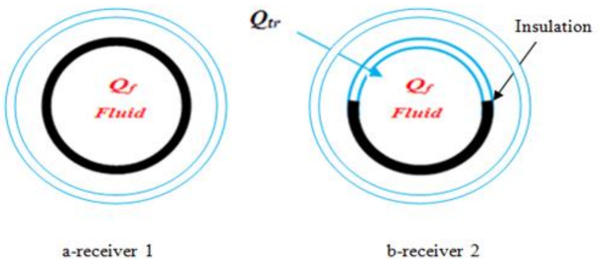

Figure 1. Cross-section view of the two receivers

A first absorber pipe with Glass Envelope is shown in Figure 1 (a) [36], and a second absorber (pipe-Glass) is reported in Figure 1 (b) [36]. We suggest the following hypotheses:

- Uniform repartition of the solar radiation in absorber tube;
- The ambient temperature is constant;
- The incidence angle modifier is neglected;
- Negligible absorber energy of glass envelop of second receiver
- The mathematical model of each part of the solar heat collection system is established based on the Matlab/Simulink platform. The physical properties of liquid water used in this simulation are shown in Table 1.

Table 1. Physical properties of liquid water and used in simulations [37]

Properties of HTF (Water) at 20 °C	
Density of fluid (ρ)	998.2 kg/m^3
Thermal Conductivity (k)	0.600 W/m K
Dynamic Viscosity (μ)	0.001003 kg/m-s
Specific heat capacity (Cp)	4.182 kJ/kg K

The characteristics of the PTC are reported in Table 2 [38].

3. RESULTS AND DISCUSSION

The climatic conditions are employed for a representative day with the inlet temperature and mass flow rate are equal to 25 and 0.02 kg/s respectively. The Absorber length equal (L=2m). According to the model, we can calculate the solar radiation intensity at any time and any region. Taking Ghardaïa as example, Ghardaïa city (32.4 °N, 3.8 °E); the sunshine duration is more than 3000 hours per year, which promotes the use of solar energy in various fields [39].

We take two days to represent two seasons of a year. N=31 represents January 31st, n=180 represents June 30 st. The simulation results are shown in Figure 2 and Figure 3, from which it can be seen that the start and stop time of solar radiation, are different. It's associated with the location and time of a year. The time of a day to reach the highest solar radiation is not very consistent, but it's basically between 12 and 14 clock. Global maximum solar radiation values are also different: June (GT=985w/m^2) is higher than January (GT=684 w/m^2). The average (ΔGT=301 w/m^2).

The outlet temperature of the collector is an important parameter to reflect collector performance. The dynamic simulation, of the pipe and glass absorber temperature and the outlet temperature of the first receiver is shown in Figure 4.

Table 2. Characteristics of solar PTC [38]

Module Size	7.8 m x 5 m
Absorber pipe outer diameter D_{ab2}	0.07 m
Absorber pipe inner diameter D_{ab1}	0.066 m
Glass envelop outer diameter D_{g2}	0.115 m
Glass envelop inner diameter D_{g1}	0.109 m
Absorber pipe thermal conductivity (k_{ab})	54 W/mK
Absorber pipe thermal absorptance (α_{ab})	0.906
Glass envelop thermal absorptance (α_g)	0.02
Glass envelop transmittance (τ_g)	0.95
Transmittance-absorptance factor (α_0)	0.864
Absorber pipe specific heat (C_{pab})	500 J/Kg.K
Glass envelop specific heat (C_{pg})	1090 J/Kg.K
Absorber pipe density (ρ_{ab})	8020 Kg/m^3
Glass envelop density (ρ_g)	2230 Kg/m^3
Absorber pipe emittance (ε_{ab})	0.14
Glass envelop emittance (ε_g)	0.86
Reflected surface reflectivity (ρ_0)	0.93
Shape factor (γ)	0.92

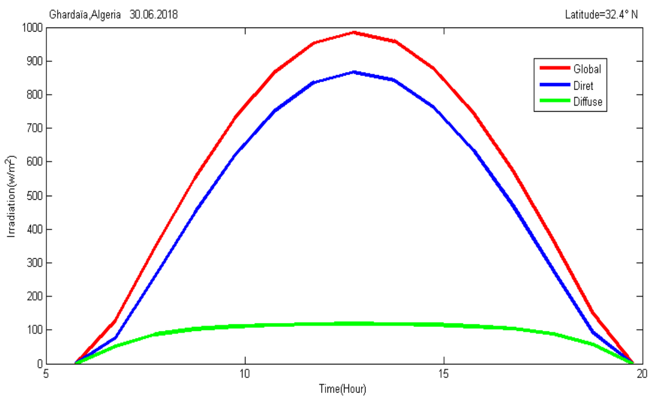

Figure 2. Global, direct and diffuse solar radiation versus time for the day

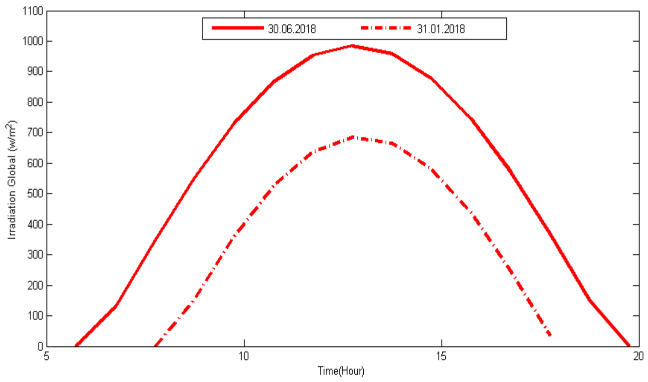

Figure 3. Global horizontal irradiation versus time for two different days

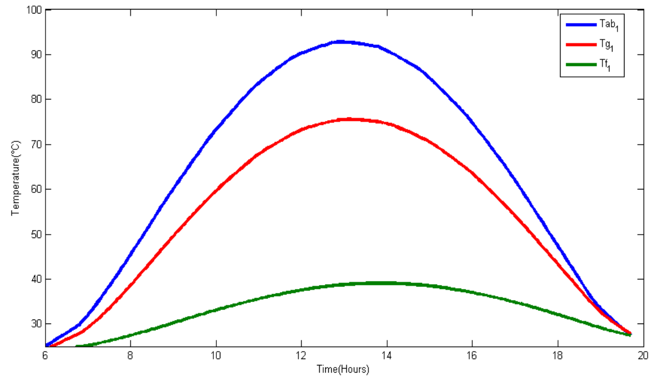

Figure 4. Temperature variation at the output of the First receiver versus time for the day

The collector does not work without solar radiation, so the collector outlet temperature is the lowest temperature. Only when the solar radiation energy is greater than the collector heat loss, the collector temperature will rise. With the gradual increase in solar radiation, the collector starts to work and the collector outlet temperature gradually increased. Taking the sun radiation value as input, Outlet temperature of the collector can reach to (76.04 °C) at about 13:00 pm, and the useful energy can reach to (4265 w), as shown in Figure 5. The efficiency is simulated and the results are shown in Figure 6, from which we conclude that the collector efficiency is basically stable at about 0.492 during the solar radiation.

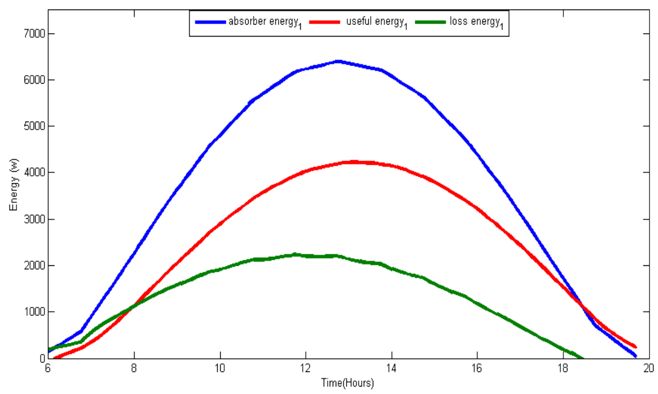

Figure 5. The absorber, loss and useful energy of the first receiver versus time for the day

It shows that the heat collection performance is stable. But, in summer, the collector efficiency is slightly lower with the increase of time. The reason is that the temperature of collector is so high that influence the heat radiation. The relationship between the thermal efficiency and the inlet temperature of the fluid is shown in Figure 7; the flow rate is (0.02 kg/s). It is noted that the thermal efficiency increases with the decrease of the inlet temperature, because in the case of low input temperatures the heat transfer fluid absorbs the maximum useful energy.

Figure 8 shows the comparison between the absorbed temperature and the fluid temperature of the two receivers. There is an increase in the order of a degree because of the increase in useful energy and the concentration factor which has an inverse relation with the surface of the absorber. The same thing with the useful energy and efficiency, there is an increase of (86 w) for energy and (1 %) for efficiency, as shown in the Figures 9 and 10, respectively.

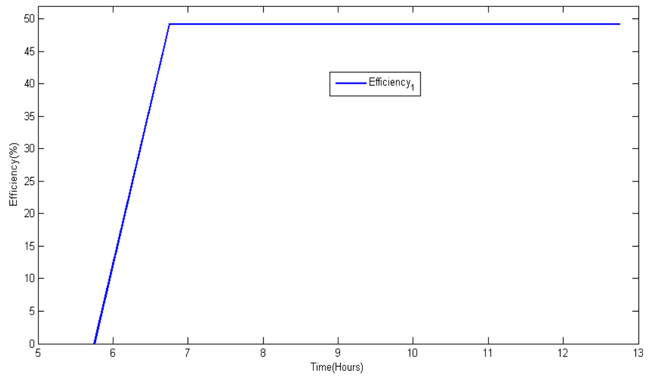

Figure 6. Efficiency of the first receiver versus time for the day

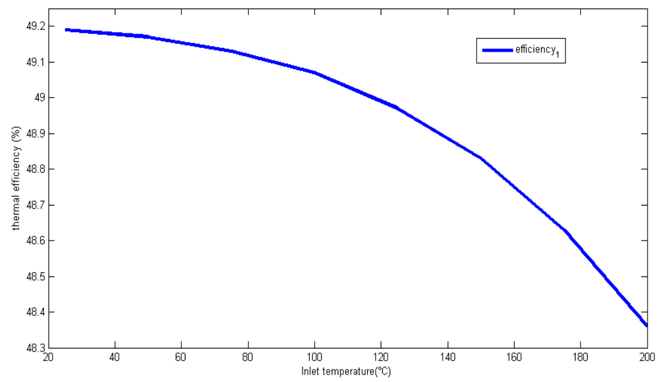

Figure 7. Effect of inlet temperature on thermal efficiency

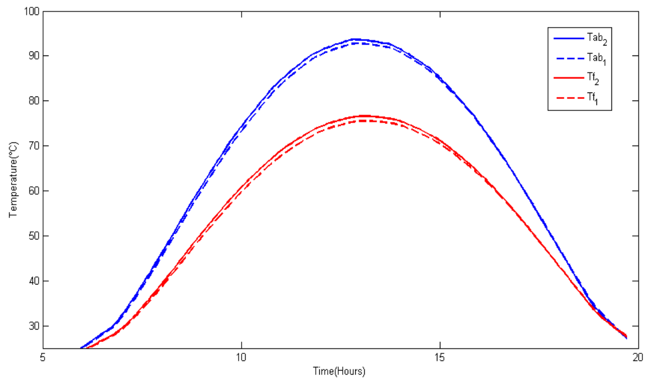

Figure 8. Comparison between the absorbed temperature and the fluid temperature of the two receivers versus time for the day

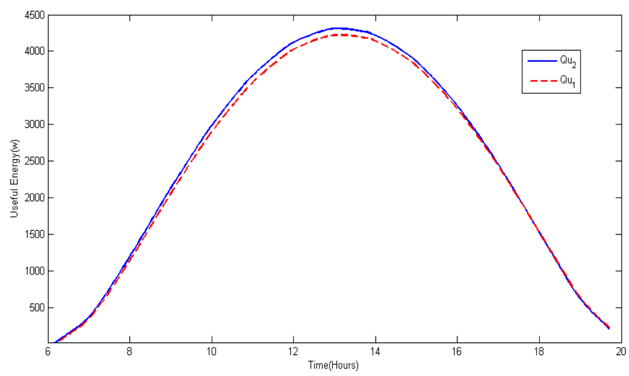

Figure 9. Comparison between the useful energy of the two receivers versus time for the day

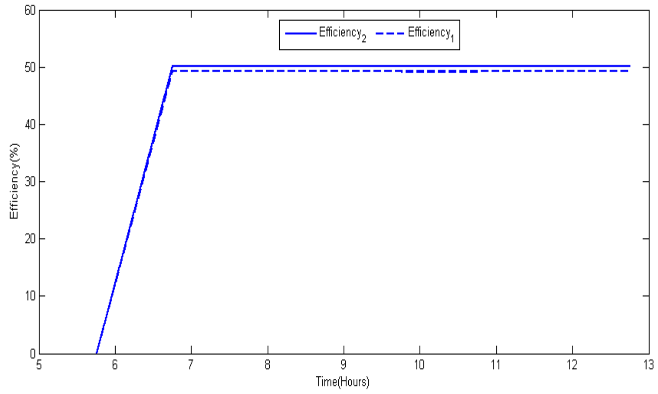

Figure 10. Comparison between the efficiency of the two receivers versus time for the day

4. CONCLUSION

We can deduce the following:

- The high useful energy is obtained with second receiver, equal to 4.351 kw.
- For the second receiver, we have high transmittance, high thermal efficiency and output fluid temperature compared with the first receiver.
- Base the obtained results, the coming years hold much promise for clean energies.
- Solar thermal electricity is a carbon-free source of electricity that is best suited to areas in the world with strong irradiation.

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