Improvement Design of Parabolic Trough

S. I. Ihsan\textsuperscript{1a*}, M. A. I. M. Safian\textsuperscript{1}, M. A. M. Taufek\textsuperscript{1} and A.K.M. Mohiuddin\textsuperscript{1}

\textsuperscript{1}Department of Mechanical Engineering,
Faculty of Engineering, International Islamic University Malaysia,
P.O.Box 10, 50728 Kuala Lumpur, Malaysia

E-mail: \textsuperscript{a}sihsan@iium.edu.my

**Abstract.** The performance of parabolic trough solar collector (PTSC) has been evaluated using different heat transfer working fluids; namely water and SAE20 W50 engine oil. New and slightly improved PTSC was developed to run the experimental study. Under the meteorological conditions of Malaysia, authors found that PTSC can operate at a higher temperature than water collector but the performance efficiency of collector using engine oil is much lower than the water collector.

1. **Introduction**

Energy production in Malaysia is based on fuels and natural gas. By using fuels or natural gas, it is easy to generate power or electricity for many purposes but it will cause big consequences to the environment such as air pollutants due to the production of carbon dioxide and carbon monoxide. These cases will lead to human made natural disaster such as greenhouse effect, thinning of the ozone layer, acid rain and many other bad effects. In order to conserve the environments, other alternatives must be taken into consideration such as renewable energy. For example, the main source of energy on earth which is from the sun can be converted to electricity by using solar thermal collector which is known as Parabolic Trough Solar Collector. Sun will produce the ultraviolet rays to earth. Despite of polluting the environment with many harmful gases, the energy from the sun can be used to generate electricity. This research will be focused on the usage of Parabolic Trough Solar Collector in these modern days in order to conserve the environments.

In understanding the working mechanisms of a parabolic trough collector, solar radiation coming from the will hit the parabolic trough’s mirror. In two dimensional (2-D), the incident rays will be reflected to one focus point due to the shape of a parabola. In three dimensional (3-D) views, the reflected rays from the solar radiation will produce one line which is called the focal line. The position where the focal line exists will be occupied with the heat collection elements consisting of receiver tube, heat transfer fluid (HTF) inside the receiver tube. The solar energy will be absorbed by the receiver tube and the heat collected is transferred to the HTF. This process is called the conversion of solar energy to thermal energy. Lastly, the HTF can be used for many application purposes such as generating electricity, production of hot water and many other applications.

According to Anam [1], “Parabolic trough is one of the most popular and demanding concentrated solar thermal technology available nowadays. It is efficient and environment friendly. But, the present
day parabolic trough holds some deficiencies which if solved can increase the efficiency more”. The parabolic trough consists of parabolic shaped trough frame, base that holds the trough, reflective coating or mirrors, heat collection tube, and fluids.

2. Parabolic trough design
A modified design of parabolic trough collector from the one developed by the previous student [2] is used for comparison in this work. Specifically, a tempered glass cover is added to the trough in order to trap solar radiation reflected from the surface to reduce heat losses. The designs are shown in Figure 1. The HTF is filled in the collector tube and the temperature and duration of exposure are measured. The process will be repeated for several times for several days. Two types of HTF are used in the experiment, which are water and engine oil. Their required properties are shown in Table 1. In the previous design, the instantaneous thermal efficiencies obtained were around 24% for water and 18-19% for engine oil [2]. With the introduction of the glass cover, the efficiency is expected to increase.

![Previous design](a) Previous design [2]

![Modified design](b) Modified design

**Figure 1.** Parabolic trough solar collector design

| Heat Transfer Fluid (HTF) | Water | SAE20 W50 engine oil |
|---------------------------|-------|----------------------|
| Specific Heat (kJ/kg °C)   | 4.167 | 2.34                 |
| Density (kg/m³)            | 1000  | 824                  |

3. Results and discussion
For each working fluid, the experiments were repeated five times on different days to ensure consistency of data. The experiments were conducted on the roof top of E3, Kulliyyah of Engineering building since the area is flat and unshaded. Solar irradiation is measured using pyranometer available in the lab. Figures 2 and 3 shows the temperature increase in the collector and the solar irradiation, for water and engine oil as the HTF, respectively.
Figure 2. Temperature rise and irradiation vs time for water based collector
As expected, the temperature in the working fluid increases as the parabolic trough is exposed to the sun. Complete data collected are summarized in Table 2 and 3 for both water and engine oil working fluid, respectively. The performance of parabolic trough solar concentrator was determined by obtaining values of instantaneous thermal efficiency, useful energy and the temperature of heat transfer fluid after being exposed to irradiation. The useful energy $Q_u$ is calculated from the measurement of initial and final temperatures and the fluid mass, $m_{fluid}$ as follows [4].

The useful energy, $Q_u = m_{fluid}c_p(T_f - T_i)$
The instantaneous thermal efficiency, \( \eta_{th} = \frac{q_u}{A_i l_b} \)

Table 2. Summary of experimental results using water as the HTF

| Experiment no | 1     | 2     | 3     | 4     | 5     |
|---------------|-------|-------|-------|-------|-------|
| Duration (s)  | 402   | 240   | 240   | 517   | 336   |
| Average Solar Irradiation (W/m\(^2\)) | 801.2 | 891.7 | 860.2 | 624.5 | 675.2 |
| Initial Temperature (°C) | 36.7  | 35.9  | 39.4  | 33.3  | 36.9  |
| Final Temperature (°C) | 100   | 100   | 100   | 100   | 100   |
| Temperature inside PTSC (°C) | 65.7  | 64.5  | 68.3  | 64.4  | 66.7  |
| Useful Energy Collected (kJ) | 126.3 | 127.9 | 120.9 | 133.1 | 125.9 |
| Total Solar Energy (kJ) | 322.1 | 214.0 | 206.4 | 322.9 | 226.9 |
| Instantaneous Thermal Efficiency (%) | 39.2  | 59.8  | 58.6  | 41.2  | 55.5  |

Table 3. Summary of experimental results using SAE20 W50 Engine oil as the HTF

| Experiment no | 1     | 2     | 3     | 4     | 5     |
|---------------|-------|-------|-------|-------|-------|
| Duration (s)  | 505   | 492   | 545   | 525   | 543   |
| Average Solar Irradiation (W/m\(^2\)) | 652.4 | 692.7 | 755.2 | 782.2 | 883.8 |
| Initial Temperature (°C) | 36.9  | 36.5  | 35.8  | 36.3  | 35.4  |
| Final Temperature (°C) | 144.6 | 143.1 | 142.3 | 144.3 | 145.3 |
| Temperature inside PTSC (°C) | 62.4  | 63.6  | 62.5  | 63.7  | 67.9  |
| Useful Energy Collected (kJ) | 120.7 | 119.4 | 119.3 | 121.0 | 123.1 |
| Total Solar Energy (kJ) | 329.5 | 340.8 | 411.6 | 410.7 | 479.9 |
| Instantaneous Thermal Efficiency (%) | 36.6  | 35.0  | 29.0  | 29.5  | 25.7  |

It can be observed from the tables that, even though the value varies from one experiment to another, trough with water as the HTF has consistently higher instantaneous efficiency compared to engine oil indicating that water is more suitable for low temperature thermal recovery application. Comparing to the performance obtained by the previous student [2], results also indicate significant thermal efficiency improvement is obtained by using the modified parabolic trough. This is mainly attributed to the fact that heat losses to the surrounding through convection is prevented by using the glass cover.

4. Conclusions
The study found that for low temperature thermal recovery application, water is more suitable HTF compared to SAE20 W50. Significant increase in the instantaneous efficiency from the previous results by Mohd Taufek [2] was obtained through glass cover by reducing as much as possible heat losses to the surroundings.

Acknowledgements
The work is funded by the International Islamic University Malaysia (IIUM) Research Initiative Grant Scheme (RIGS). The authors would like to acknowledge the support from the Department of Mechanical Engineering, IIUM for the support to carry out this work.

References
[1] Anam, K. (2012). An Improved Model for Solar Parabolic Trough. *International Conference on Informatics, Electronics & Vision (ICIEV)*, 2012, 420-423.
[2] Mohd Taufek, M. (2015). Design and Analysis of Performance Trough Thermal Collector Performance. Final Year Project Report.

[3] Thermophysical Properties: Engine Oil, Unused. (2011, November 13). Retrieved from Thermal - Fluids Central: https://www.thermalfluidscentral.org/encyclopedia/index.php/Thermophysical_Properties:_Engine_Oil,_Unused

[4] Cengel, Y. A., Ghajar, A. J., & Kanoglu, M. (2011). Fundamental of Thermal Radiation. Heat and Mass Transfer Fundamentals and Applications. New York: Mc Graw Hill.

[5] Iqbal, S., Iqbal, U., Khan, M. U., Saeed, M., & Waqas, A. (2014). Design, Fabrication and Analysis of Solar Parabolic Trough Collector for Steam Engine. Robotics and Emerging Allied Technologies in Engineering (iCREATE), 2014 International Conference on, 296-299.

[6] The Basics of Synthetic Oil Technology. (n.d.). Retrieved from Machinery Lubrication: http://www.machinerylubrication.com/Read/28671/basics-of-synthetic-oil-technology