Development of a thermal water pump with steam-air for agriculture

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Abstract:
This research purpose is to design and construct an automatic thermal water pump (TWP) with steam-air and study the appropriate amount of air added to a steam working fluid for use within the system. Direct contact cooling was employed. The system consisted of feed water tank, liquid piston tank, heating tank, storage tank and well tank. The objective is a feasibility study of the air quantity in the LT was set at 0%, 10%, 20%, 30% and 40% with a constant discharge head of 1 m, a constant suction head of 0.8 m and 1 hours test time. However, in this research we uses heater as a substitute of renewable energy. Thermal energy input was supplied by an electric heater as a substitute of renewable energy. An operation of the pump consisted of 5 stages: heating, pumping, vapor-flow, cooling and water suction. Results of the experiment use air in conjunction with system the maximum pumping efficiency 0.01903% at quantity of air 10% the maximum pumped water 96.4 l at quantity of air 0% the maximum numbers of pumping cycles 17 cycles at quantity of air 40%. As the quantity of air increased, the numbers of pumping cycles increased but the pumped water could be reduced accordingly, which affected the pumping efficiency. However, HT temperature could be further reduced. Using air in conjunction with the steam working fluid could lower the working temperature suitable to solar application.

Keywords: *Quantity of Air; Steam-Air; Thermal Water Pump*

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1. Introduction

A thermal water pump (TWP) is powered by waste heat or other energy sources. It employs a vapor of a low boiling point liquid as a working fluid produced in a flat plate collector system to supply pumping power for lifting water. A subsequent condensation provides essential water suction from a deep well. Sometimes a working fluid is water. While a photovoltaic pump employs some visible part of solar energy, TWP employs the rest. Various developments of such pumps were reported in literatures (Jenness Jr, 1961; Sumathy, 1999; Liengjindathaworn et al., 2002; Roonprasang et al., 2009; Wong and Sumathy, 1999; Pytlinski, 1978; Picken et al., 1997).

Jenness Jr (1961) proposed a solar water pump of Savery type that used steam power for pumping directly. It had a great simplicity such as easy pump maintenance, reliability and low expenses. However, it was air cooled which was very time-consuming. Based on the basic principles of steam pumps, Sumathy (1999) did an experiment on a solar thermal water pump, which comprised a one m^2 solar collector (SC), had overall efficiency of 0.12-0.14% for 6-10 m discharge heads and performed 12-23 cycles a day. The water mass of 15 kg was lifted for each cycle. Liengjindathaworn et al. (2002) presented the experimental and theoretical studies of a pulsating-steam water pump. The pumping system used an electric heater as an energy source to produce a working water vapor at low temperature (90-120°C). The experimental pump efficiency was around 0.005-0.03% for the pumped water of 1-8 l/cycle and suction heads of 1-2.5 m. However, the system was manually operated. Cooling time was still long. Roonprasang et al. (2009) invented a thermal water pump for circulation of water in solar water heating system using an electric heater as thermal power source. Air-water vapour was a working fluid.

The essential process is the irrigation which utilizes power from oil or electricity grid. An automatic thermal water pump may have great importance in arid regions where there is greater village dispersion over remote areas. For this problem, the pump may use power from solar energy, wind and biogas as renewable energy. Using a heat pump to heat sources, using the suitable geographical areas both in the local or distant prosperity in the city to select the source of heat and a slim design to suit the pump.

Air-steam was used as a working fluid within the system. Air addition could lower vapor temperature suitable to solar application (40-95°C). This saved energy.

2. Material and methods

2.1 Experimental setup

2.1.1 A Feed water tank (FT) was a cylinder tank of 40 cm height and 30 cm diameter with air vent above and no insulation. It had a check valve (CV) to supply 300 cc water at 30 °C to liquid piston tank (LT).

2.1.2 Liquid piston tank (LT) was a cylinder tank of 30 cm height and 20 cm dia. made from 2 mm stainless. It is well insulated with a 2.54 cm aeroflex. It could pump water to the storage tank (ST) by vapor from the water heat tank (HT). Max pumped water a cycle was 9.5 l.

2.1.3 The storage tank (ST) was a cylinder tank of 90 cm height and 54 cm dia. made from 5 mm plastic, without insulation. It was open to the air outside and used to store water from the LT. It should be located at the same level of the FT in order to prevent siphon. In this study it was placed at a lower level via the air vent.

2.1.4 The heat tank (HT) of 0.3 x 0.2 x 0.05 m^3 made from 2 mm stainless sheet, with 2.54 cm aero flex insulation. It was closed and contained 2.5l water. It had 3 kW heater installed inside to produce vapor at 105°C to supply the LT.

2.1.5 Well tank (WT) was a well that stored water to be pumped.

2.1.6 A Check valve (CV) was used to control direction of fluid flow.

2.2 System operation

2.2.1 Heating stage (Fig. 1(a)): During this step, the water in HT gets hot from electric heater. Water within the tank, there is a higher temperature and vaporization flows to the LT heat continuously until the pressure high enough to drive the water from LT through the check valve.

2.2.2 Pumping stage (Fig. 1(b)): When the steam pressure in the LT than height the discharge head of the water pressure to drive water through the check valve in the liquid piston tank to the discharge head of the opening to the atmosphere and flows into the storage tank with gravity (Fig.1(b)).

2.2.3 Vapor flow stage (Fig. 1(c)): After that, when the water level in the Liquid piston tank lower than the hose. Steam can open atmospheric pressure at Air vent because Floating pressure. Vapor flow to the atmosphere until pressure is less than the pressure caused by the height of the feed water tank.

2.2.4 Cooling stage (Fig. 1(d)): The water Cooling 300 cc at 30°C from the tank top will flow through the check valve the Liquid piston tank automatically, because the force of gravity of the Earth. When water flows out of float in the Feed water tank will close, The CV then closes temporarily due the blockage by a floating ball within the FT

2.2.5 Suction stage (Fig. 1(e)): The mixing of hot air-steam and cool water caused condensation and then vacuum in the LT. The water was suctioned from the WT. When the suction stage is complete one full pump working cycle of the system and the system will start in the next cycle.

3. Equations

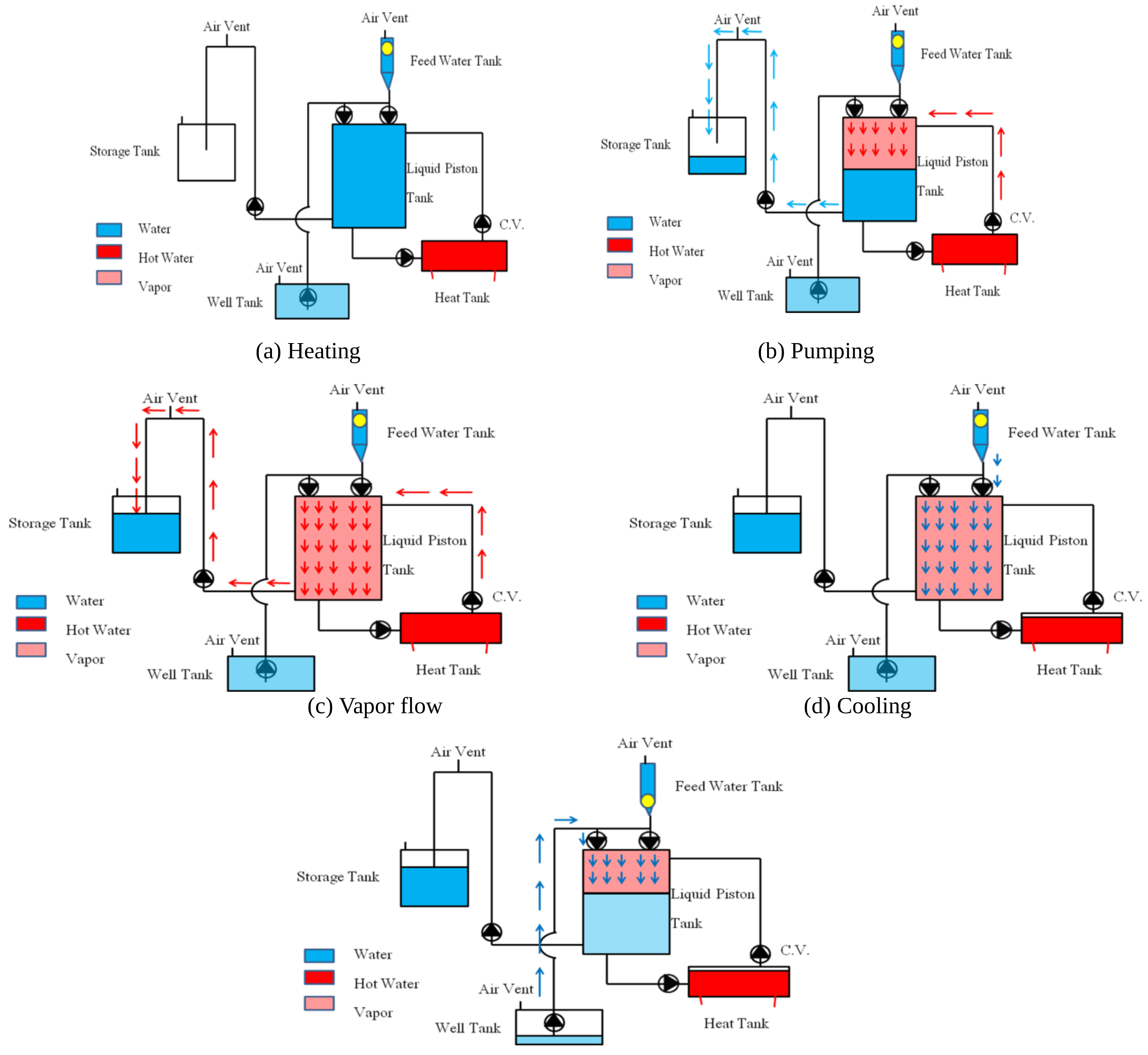
Thermodynamic analysis of efficiency η_p is the ratio of the energy stored by the pump to total energy input to the pump.

$$\eta_p = \frac{NW_h}{E_{tot}} \times 100\% \qquad (1)$$

Where N is total number of water pumping cycles, E_{tot} is the total energy input W_h the required hydraulic work per cycle is expressed by:

$$W_h = V_c\, \gamma \cdot h \qquad (2)$$

Where V_c is the pumped water volume per cycle, γ is the specific weight, and h the overall head of the system.



(a) Heating

(b) Pumping

(c) Vapor flow

(d) Cooling

(e) Suction

Fig. 1 The operation of the thermal water pump with steam-air.

4. Discussion

From Fig. 2, As the quantity of air increased, the numbers of pumping cycles increased but the pumped water could be reduced accordingly, which affected the pumping efficiency. However, HT temperature could be further reduced, this saved energy about 6%.

As a result the number of rounds in pumping more because air will expand when heated. As a result, the pressure used in driving is more than water pressure. The system takes less pressure to build. Use a lower temperature in the heating. When the air to replace the volume of water in LT as a result, the higher temperature in LT because the mass of water in fewer LT.

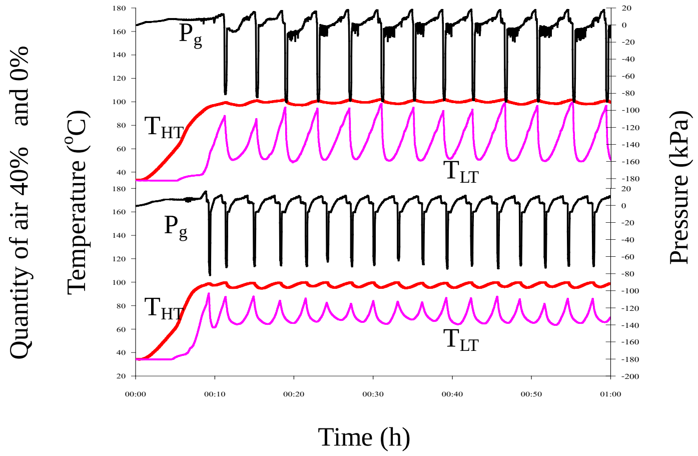


Fig. 2 Temperatures in the heat tank)T_{HT}), the liquid piston tank (T_{LT}) and gage pressure (P_g).

5. Conclusion

The optimum quantity of air where the pump efficiency was the highest. Conclusions when using air in conjunction with the working fluid (water) affect the pumping efficiency increased but if there is too much air quantity the pumped water is reduced affect the pumping efficiency reduced.

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7. References

Jenness, J.R. Jr. 1961. Some consideration relative to a solar power savery water pump. Sol. Energy 5(2): 58-60.

Liengjindathaworn, S., Kirtikara, K., Namprakai, P., and Kiatsiriroat, T. 2002. Parametric studies of a pulsating-steam water pump. Int. J Ambient Energy 23(1): 37-46.

Picken, D.J., Seare, K.D.R., and Goto, F. 1997. Design and development of a water piston solar powered steam pump. Sol. Energy 61(3): 219-224.

Pytlinski, J.T. 1978. Solar energy installations for pumping irrigation water. Sol. Energy 21(4): 255-262.

Roonprasang, N., Namprakai, P., and Pratinthong, N. 2009. A Novel thermal water pump for circulating water in a solar water heating system. Appl. Therm. Eng. 29(8-9): 1598-1605.

Sumathy, K. 1999. Experimental studies on a solar thermal water pump. Appl. Therm. Eng. 19(5): 449-459.

Wong, Y.W. and Sumathy, K. 1999. Solar thermal water pumping systems: a review. Renewable Sustainable Energy Rev. 3(2-3): 185-217.