International Journal of Advanced Culture Technology Vol.3 No.2 58-66 (2015)
http://dx.doi.org/10.17703/IJACT.2015.3.2.58

IJACT 15-2-7

A comparing on the use of Centrifugal Turbine and Tesla Turbine in an application of Organic Rankine Cycle

Kosart Thawichsri[1], Wanich nilnont[2]

[1]*Siam Technology College, Bangkok, Thailand*
kosartpikpik@yahoo.com.sg
[2]*Rajamangala University of Technology Suvarnabhumi, Nonthaburi, Thailand*
emnil@live.com.

ABSTRACT

This paper aims to compare the use of Centrifugal Turbine and Tesla Turbine in an application of Organic Rankine Cycle (ORC) Machine using Isopentane as working fluid expanding. The working fluid has boiling point below boiling water and works in low-temperature sources between 80-120 ℃ which can be produced from waste heat, solar-thermal energy and geothermal energy etc. The experiment on ORC machine reveals that the suitability of high pressure pump for working fluid has result on the efficiency of work. In addition, Thermodynamics theory on P-h diagram also presented the effect of heat sources' temperature and flow rate on any work. Thus, the study and design on ORC machine has to concern mainly on pressure pump, flow rate and optimized temperature. Result experiment and calculate ORC Machine using centrifugal Turbine efficiency better than Tesla turbine 30% but Tesla Turbine is cheaper and easily structure. Further study on the machine can be developed throughout the county due to its low cost and efficiency

Keywords: *centrifugal turbine, Tesla turbine, organic Rankine cycle, low-temperature sources, flow rate, high pressure pump.*

NOMENCLATURE

q_H	heat transfer at moment [W]
$\dot{m}$	mass flow rate [kg/s]
c_p	specific heat capacity [kJ/kg K]
T_{in}	temperature inlet [°C]
T_{out}	temperature outlet [°C]
h_e	specific enthalpy at exit [kJ/kg]
h_i	specific enthalpy sy[kJ/kg]
W	work [W]
η_{th}	thermal efficiency

Manuscript Received: Jun. 20, 2015 / Revised: Sep. 18, 2015 / Accepted: Nov. 10, 2015
Corresponding Author: kosartpikpik@yahoo.com.sg
Tel: +66 2 878 5000-5, Fax: +66 2 878 5002
Siam Technology College, Bangkok, Thailand

1. INTRODUCTION

At present, people in all around the world are concerned with Energy and Environment issues since various countries are entering into the age of energy shortage and climate change. The main reason is from an excess consumption on fossil fuel for developing infrastructure and urging economic growth. Anyway, people those recognizing the critical problems have tried on their efforts to find the solution which promote a sustainable development. One of the most effective solutions is using renewable energy that is friendly to environment. [1], [2]

Solar energy is, therefore, developed to generate electricity because of its low cost and efficiency.[3] The use of organic Rankine cycle with thermal energy storage system produces of electricity will decrease the expense on conventional oil. In addition, the design and test of Organic Rankine Cycle with thermal powerplants using turbine expander can save much more cost since its source can derive from within country.

The Organic Rankine Cycle (ORC) is Rankine cycle with organic working fluid that has boiling point below water boiling point and it works in low-temperature sources between 80-120 °C. Thus, it is produced from various natural and renewable sources such as geothermal energy, waste heat, solar-thermal energy etc. to generate electricity. The Organic Rankine Cycle consists of solar collector, thermal energy storage system and organic Rankine cycle power system with Isopentane [4] as working fluid and turbine expander for shaft work.

2. THEORY

The actual heat transfer may be computes by calculating either the energy lost by hot fluid or the energy or the cold fluid, as show in equation (1). [5], [6]

$$q_H = \dot{m}c_p(T_{in} - T_{out}) \tag{1}$$

2.1Rankine Cycle: The iedeal Cycle for vapor power cycle

Many of the impracticalities associated with the Carnot cycle can be eliminated by superheating the steam in the boiler and condensing it completely in the condenser, as shown schematically on a T-s diagram and a P-h diagram in Fig.1. The cycle that results is the Rankine cycle, which is the ideal cycle for vapor power plants. The ideal Rankine cycle does not involve any internal irreversibility and consists of the following four processes: [5]

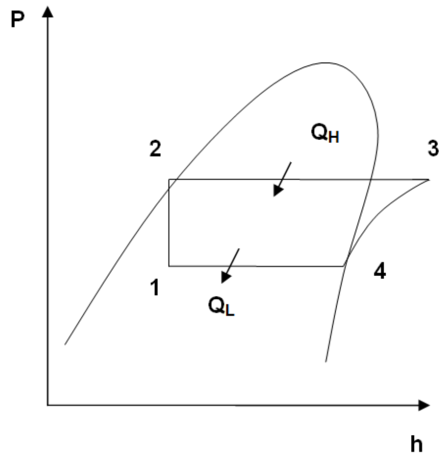

Figure 1. P-h diagram of the Rakine cycle

1-2 Isentropic compression in a pump
2-3 Constant pressure heat addition in a boiler
3-4 Isentropic expansion in a turbine
4-1 Constant pressure heat rejection in a condenser

2.2Energy Analysis of the Ideal Rankine Cycle

All four components associated with the Rankine cycle (the pump, boiler, turbine, and condenser) are steady-flow devices, and thus all four processes that make up the Rankine cycle can be analyzed as steady-flow processes. The kinetic and potential energy changes of the steam are usually small relative to the work and heat transfer terms and are therefore usually neglected.[5] Then the steady-flow energy equation per unit mass of steam reduces to

$$(q_{in} - q_{out}) + (W_{in} - W_{out}) = h_e - h_i \tag{2}$$

The boiler and the condenser do not involve any work, and the pump and the turbine are assumed to be isentropic. Then the conservation of energy relation for each device can be expressed as follows:

Pump $$(q = 0): \quad W_{pump,in} = h_2 - h_1 \tag{3}$$

Boil $$(W = 0): \quad q_{in} = h_3 - h_2 \tag{4}$$

Turbine $$(q = 0): \quad W_{turbine,out} = h_3 - h_4 \tag{5}$$

Condenser $$(W = 0): \quad q_{out} = h_4 - h_1 \tag{6}$$

The thermal efficiency of the Rankine cycle is determined from

$$\eta_{th} = \frac{W_{net}}{q_{in}} = 1 - \frac{q_{in}}{q_{out}} \tag{7}$$

Where

$$W_{net} = q_{in} - q_{out} = W_{turb} - W_{pump,in}$$

3. EQUIPMENT AND EXPERIMENT

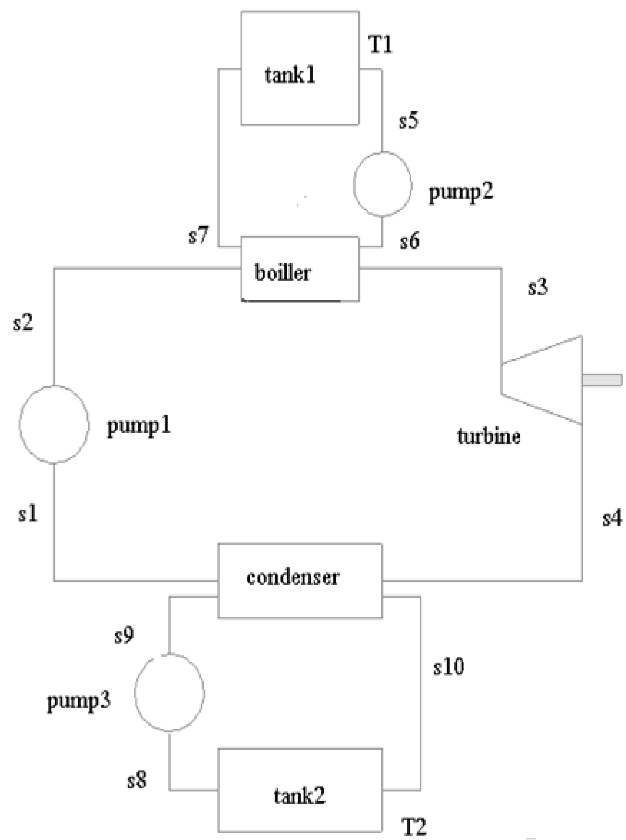

Figure 2. The diagram of Organic Rankine Cycle system and data collecting position. [8]

From the paper "A study and design of Organic Rankine Cycle"[8] Organic Rankine Cycle (ORC) Machine using Isopentane as working fluid expanding through turbine. Theory for calculate, Organic Rankine Cycle, using heat source at temperatures 90, 80 and 70 °C respectively, calculating by approximately from the experiment and comparison with P-h and T-s Diagram of a working fluid.

The experiments use a comparison on the use of Centrifugal Turbine and Tesla Turbine**;**

3.1 Experiment Methods (Centrifugal Turbine)

1. Preparing the water in a hot water storage tank at temperature 90 °C.
2. Open water valve the hot water storage tank sends the hot water flows to reach inside boiler.
3. Open working fluid valve expanded through Centrifugal Turbine

4. Recording data saving follow all position.
5. Starting step 1 to 4 again by change temperatures in the hot water storage tank at temperature 90, 80 and 70 °C respectively.

Correct data savings many times, for the data that is correct most accurate.

3.2 Experiment Methods (Tesla Turbine)

1. Preparing the water in a hot water storage tank at temperature 90 °C.
2. Open water valve the hot water storage tank sends the hot water flows to reach inside boiler.
3. Open working fluid valve expanded through Tesla Turbine
4. Recording data saving follow all position.
5. Starting step 1 to 4 again by change temperatures in the hot water storage tank at temperature 90, 80 and 70 °C respectively.

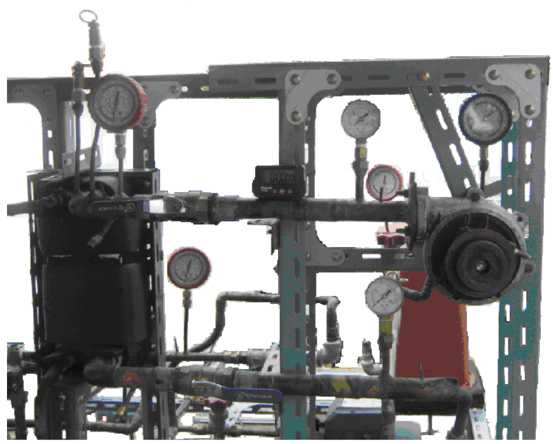

Figure 3. The Organic Rankine Cycle system and data collecting position. [8]

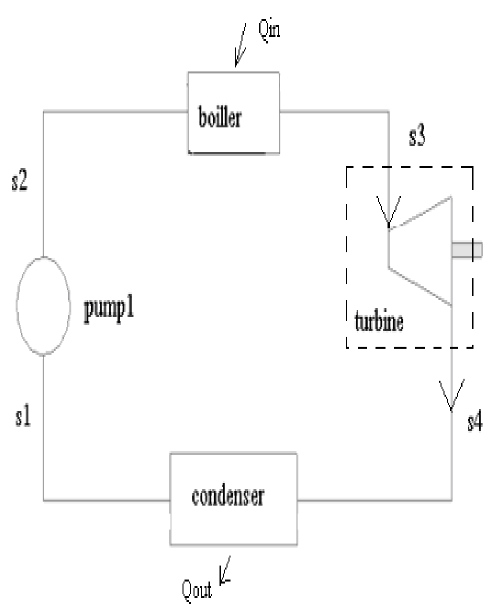

Figure 4. The diagram of Organic Rankine Cycle system and data collecting position change Turbine. [8]

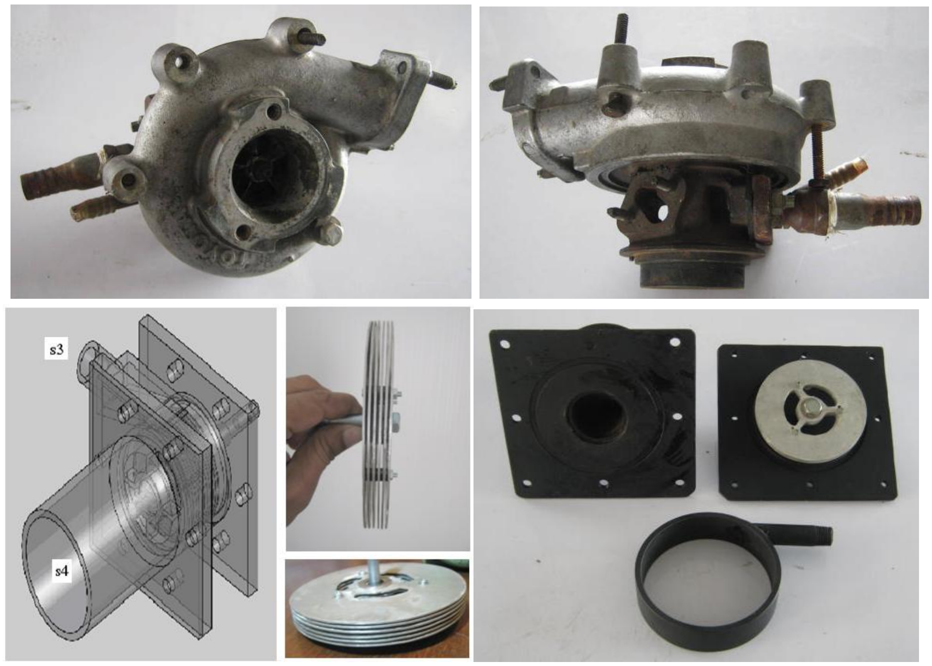

Figure 5. Comparing on the use of Centrifugal Turbine and Tesla Turbine.

4. RESULTS AND DISCUSSION

Theory for calculate, Organic Rankine Cycle, using heat source at temperatures 90, 80 and 70 °C respectively, calculating by approximately from the experiment and comparison with P-h and T-s Diagram of a working fluid, as follows.

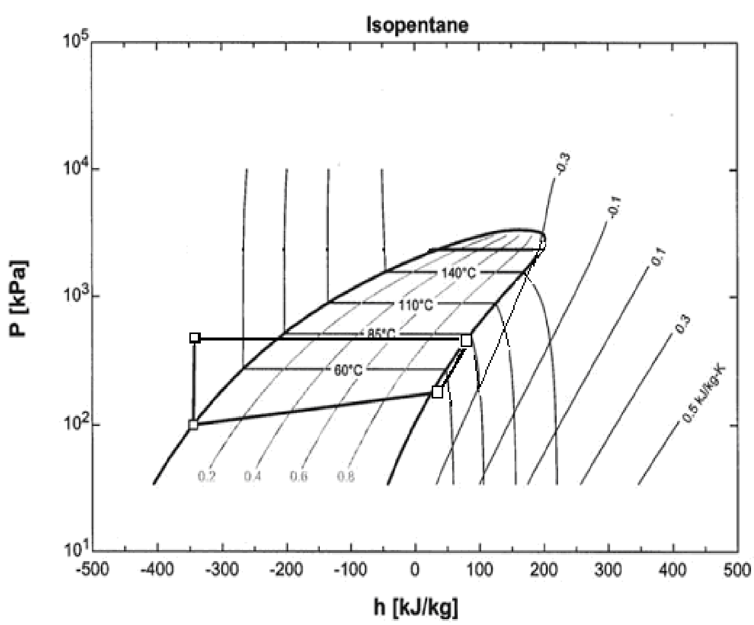

Figure 6. P-h diagram of isopentane application for Organic Rankine Cycle [8]

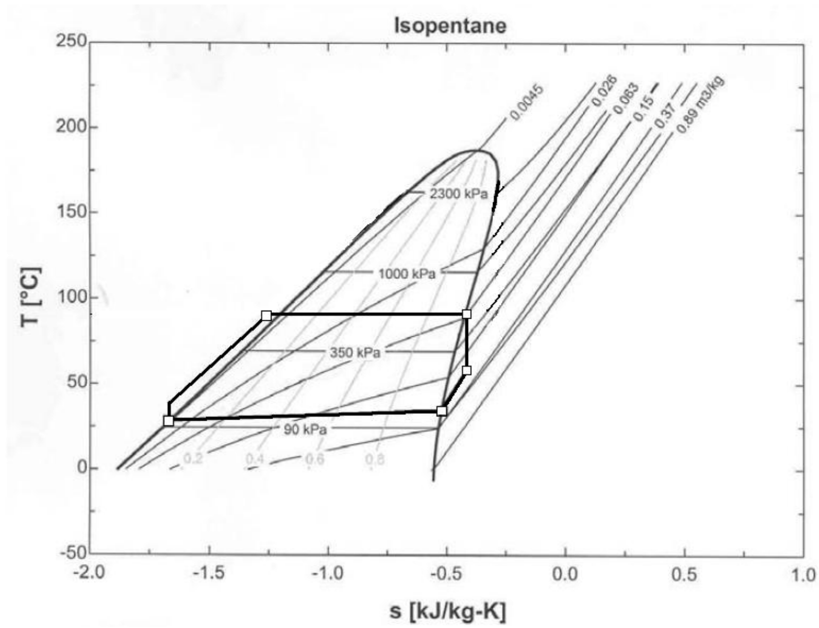

Figure 7. T-s diagram of isopentane application for Organic Rankine Cycle [8]

Results (Centrifugal Turbine)

Organic Rankine Cycle system, using heat source at temperatures 90 °C, result the working fluid through turbine at pressure and temperature inlet state 6 bar and 80 °C respectively, at pressure and temperature outlet state 1 bar and 30 °C respectively, output power 50 kJ/kg and The thermal efficiency equals 11.9%.

Organic Rankine Cycle system, using heat source at temperatures 80 °C, result the working fluid through turbine at pressure and temperature inlet state 5 bar and 70 C respectively, at pressure and temperature outlet state 1 bar and 30 °C respectively, output power 35 kJ/kg and The thermal efficiency equals 8.6%.

Organic Rankine Cycle system, using heat source at temperatures 70 °C, result the working fluid through turbine at pressure and temperature inlet state 4 bar and 60 °C respectively, at pressure and temperature outlet state 1 bar and 30 °C respectively, output power 20 kJ/kg and The thermal efficiency equals 5.1%.

Results (Tesla Turbine)

Organic Rankine Cycle system, using heat source at temperatures 90 °C, result the working fluid through turbine at pressure and temperature inlet state 6 bar and 80 °C respectively, at pressure and temperature outlet state 1 bar and 30 °C respectively, output power 35 kJ/kg and The thermal efficiency equals 8.3%.

Organic Rankine Cycle system, using heat source at temperatures 80 °C, result the working fluid through turbine at pressure and temperature inlet state 5 bar and 70 C respectively, at pressure and temperature outlet state 1 bar and 30 °C respectively, output power 24.5 kJ/kg and The thermal efficiency equals 6.2%.

Organic Rankine Cycle system, using heat source at temperatures 70 °C, result the working fluid through turbine at pressure and temperature inlet state 4 bar and 60 °C respectively, at pressure and temperature outlet state 1 bar and 30 °C respectively, output power 14 kJ/kg and The thermal efficiency equals 3.6%.

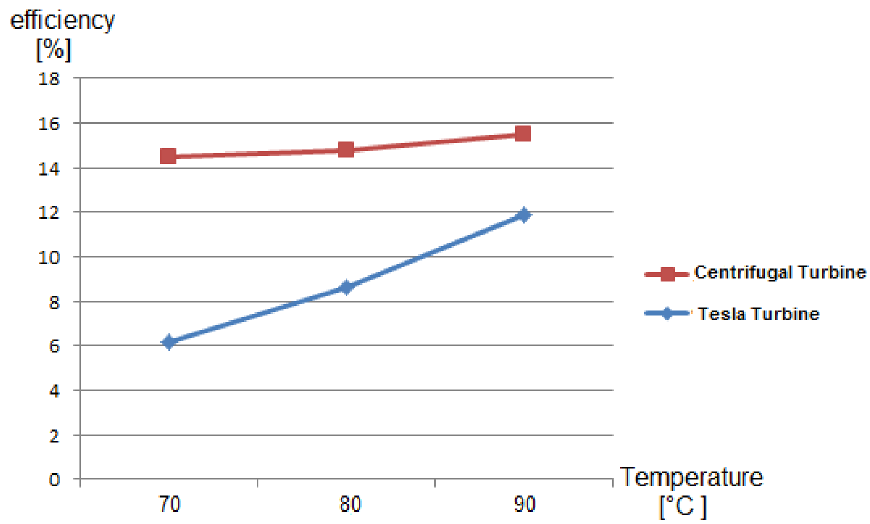

Figure 8. Result of comparison on Centrifugal Turbine and Tesla Turbine

Discussion

The study reveals that, low-temperature sources have low power output also. If we use low-temperature sources for suitable, it will appropriate make the interesting development, it is produced from various natural and renewable sources such as geothermal energy, waste heat, solar-thermal energy etc.

The suitability of high pressure pump for working fluid has result on the efficiency of work. In addition, Thermodynamics theory on P-h diagram also presented the effect of heat sources' temperature and flow rate on any work. Thus, the study and design on ORC machine has to concern mainly on pressure pump, flow rate and optimized temperature. Result experiment and calculate ORC Machine using centrifugal Turbine efficiency better than Tesla turbine 30% but Tesla Turbine is cheaper and easily structure. Further study on the machine can be developed throughout the county due to its low cost and efficiency.

5. CONCLUSION

From the experiment based on calculation theory, Organic Rankine Cycle using Isopentane as working fluid expanding through Turbine that has heat source at temperatures 90, 80 and 70 °C, result the working fluid through Turbine at pressure and temperature inlet state 6, 5 and 4 bar and 80, 70 and 60 °C respectively, at pressure and temperature outlet state 1, bar and 30 °C respectively, (Centrifugal Turbine) output power 60, 30 and 10 kJ/kg respectively, and the thermal efficiency equal 11.9, 8.6 and 5.1% respectively. and (Tesla Turbine) output power 35, 24.5 and 14 kJ/kg respectively, and The thermal efficiency equal 8.3, 6.2 and 3.6% respectively.

The study reveals that low-temperature sources have also low power output. If we use suitable low-temperature sources, it can be made interesting development. Generally, it is produced from various natural and renewable sources such as geothermal energy, waste heat, solar-thermal energy etc.

Thus, the study and design on ORC machine has to concern mainly on pressure pump, flow rate and optimized temperature. The results from experiment and calculation on ORC Machine using centrifugal Turbine present that its efficiency is 30% better than Tesla turbine even though the Tesla Turbine is cheaper and simpler structure. Further study on the machine can be developed throughout the county due to its low cost and efficiency.

REFERENCES

[1] Paper of Public Relations Department, Geothermal Power Plant, EGAT, Amphur Fang, Chiang Mai Province.

[2] Takashisa Yamamoto, Tomohiko Furuhata, Norio Arai, Koichi Mori, “Design and testing of the Organic Rankine Cycles,” *Science Direct*, Vol. 26, pp. 239-251, 2001. DOI:10.1016/S0360-5442(00)00063-3

[3] Organic Rankine Cycle:From Wikipedia, the free encyclopedi, 4 August 2009. *http://en.wikipedia.org/wiki/Organic_Rankine_Cycle*

[4] Bertrand Fankam Tchanche, George Papadakis, Gregory Lambrinos, Antonios Frangoudakiss, “Fluid selection for a low-temperature solar organic Rankine cycle,” *Applied Thermal Engineering*, Vol. 29, pp. 2468-2476, 2009. DOI:10.1016/j.applthermaleng.2008.12.025

[5] Cengel, Y. A., *Thermodynamics, 3rd ed*, New York: McGraw-Hill, 1998.

[6] Holman, J.P., *Heat Transfer, 8th ed*, Singapore: McGraw-Hill, 2001.

[7] Mohsen Taghaddosi, *Conceptual madelling of a power plant for the Sabalan geothermal area*, 2003, Iran.

[8] K. Thawichsri, V. Monyakul, S. Thepa, C. Jivacate and K. Sudaprasert, “A study and design of Organic Rankine Cycle Machine,” *GMSARN International Conference on Social-Energy-Environmental Development: SEED towards Sustainability*, 28-30 Mar., 2012.