ARPN Journal of Engineering and Applied Sciences

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THE DESIGN OF GEOTHERMAL FLUID WASTE UTILIZATION SYSTEM INTO ELECTRICITY USING ORGANIC RANKINE CYCLE WITH TURBOCHARGER

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ABSTRACT

The Lahendong Geothermal Area produces geothermal fluids with brine water with temperatures between 170°C to 140°C. Brine water heats the alternative working fluid (liquid R-134a) in the evaporator to be converted into pressurized steam which then drives an alternative turbine (turbocharge) connected to a power generator. The research was conducted by: studying literature / collecting related references, manufacturing process of model scale ORC systems (assembling ORC components), and conducting commissioning of water heater designs (brine water simulation) and turbines modified from Turbochager, with locations research in the workshop / laboratory of the Department of Mechanical Engineering, Manado State Polytechnic. The results of the operation test are as follows: Dimensions of the water heater box: (48.5 x 31 x 27.5) cm (L x W x H) with 4 heaters with a heating time of 36 minutes reaching 98.1 °C. The performance of the modified turbine with a pressure of 7 (bar) on the 4th data collection where the resulting torque = 0.15 (Nm) rotation n = 46000 (rpm) occurs Maximum power = 723 (Watt), indicating that the turbine can be used.

Keywords: geothermal waste, electricity, ORC, turbocharger, R-134a performance, screw turbine, power, efficiency.

INTRODUCTION

In the 35,000 MW power plant development acceleration program, there are 43 new geothermal field locations that have great potential as a small-scale PLTP market. Utilization of the potential for large-scale small-scale geothermal energy, especially in Eastern Indonesia, is very necessary and urgent to be carried out immediately, especially in the multiplication of energy diversification programs and the utilization of local energy (indigenous energy), as well as the PLTD substitution program to reduce electricity subsidies by the Government. , in Indonesia, there is currently no ready-to-use and proven technology for small-scale PLTP.

According to the results of an initial study by the Ministry of Research and Technology in 2009 which was conducted in 4 provinces in eastern Indonesia, namely NTB, NTT, Maluku, and North Maluku, there are more than 200 MW PLTPs with relatively small units of generating capacity (<5 MW) due to demand. in the area is also small. Utilization of small-scale geothermal energy (PLTP) to replace the existing PLTD is very urgent to do immediately because electricity subsidies are currently very burdensome to the Government. However, the construction of small-scale PLTP, especially in remote areas, is not in demand by private investors, so the development of small-scale PLTP is the responsibility of the Government.

Mastery of this small-scale PLTP technology is urgent to be realized because potential users (PLN, local government, geothermal developers, etc.) ask for proof that the PLTP is capable of operating properly. This is very important to provide a performance guarantee in further development. The Lahendong geothermal field is located in North Sulawesi Province. This field is one of the geothermal fields that has a two-phase system with a wetness level of 10% to 80%, a reservoir temperature between 250 °C to 350 °C, a reservoir pressure of 200 Ksc, relatively small permeability and a gas content of less than 1% by weight. The steam potential that can be produced by each well is relatively small, averaging 5 MW per well. There are quite a lot of Brine in Lahendong, because this field is a geothermal field with water domination.

EXPERIMENTAL METHOD

A. The Experimental Equipment Diagram

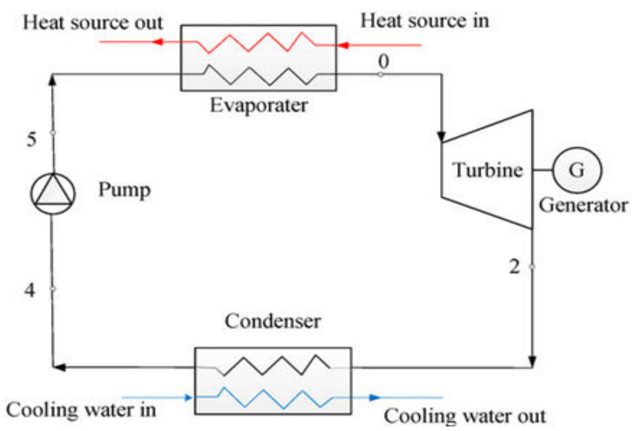

Figure-1. Organic rankine cycle system.

Figure-2. Turbine modified from turbocharger.

Figure-3. Laboratory Scale Organic Rankine Cycle (ORC) system design.

Caption:
1. Evaporator
2. Turbine (Turbocharger modification)
3. R-134a liquid circulation pump
4. Condenser
5. Water Heater Tub

Water Heating System Design

The water heating system is designed as a simulated geothermal brine water to support a laboratory scale ORC system (Figure-2. Design of a water heater system), this heating system functions to heat the evaporator where the liquid R-134a in the evaporator is converted into steam/gas

R -134a and has 4 heating elements with the dimensions of the water heater box: (48.5 x 31 x 27.5) cm (W x W x H). Table-1 shows the ability / time of heating water to reach a maximum temperature (100 ^{o}C).

Table-1. Water heating time to achieve temperature 100^{0}C.

Number of Heaters	Warm Up Time (minutes)	Temperature (^{o}C)
1	160	96,1
2	61	97,4
3	42	97,4
4	36	98,1

Turbocharge Modification to Turbine

The turbocharger has been modified into a turbine by removing the compressor casing and replacing it with a pulley for the power transmission system to the generator / power plant. The turbine is driven by R-134a and functions to rotate the electric generator through the transmission system.

To find out the performance, including rotation (rpm), torque (N-m) and power (Watt), the turbine has been tested for various pressures and loads, using several basic equations.

Where to get Turbine Power (P) is the torque T is directly proportional to the angular speed ω, the equation is:

$$P = T.\ \omega = T\ \text{(Watt)} \tag{1}$$

While the Tosi (T) on the shaft can be found by the formula:

$$T = w \times r\ \ \text{(Nm)} \tag{2}$$

Where:
T = is the engine torque (Nm)
w = is the load (N)
r = is the distance between the load and the center of rotation (m)

B. Experimental Design

To find out the performance which includes rotation (rpm), torque (N-m) and power (Watt), the turbine has been tested with varying pressures and loads, with air pressures of 6 (bar) and 7 (bar).

RESULT AND DISCUSSIONS

Following are the results of turbine performance testing with various variations of load (N), rotation (n), torque (T) and power (Watt) using compressed air (6 bar) and compressed air (7bar).

Table-2 is the data on the results of testing Turbine with compressed air 6 (bar), table-3 lists the results of testing Turbines with compressed air 7 (bar).

Table 2. Test results using compressed air 6 (bar).

No	P (bar)	W (N)	n (rpm)	r (m)	T (T.m)	Power (Watt)	ϖ
1	6	2.5	60,895	0.015	0.04	239.01	6,373.68
2		5	49,862	0.015	0.08	391.42	5,218.89
3		7.5	44,164	0.015	0.11	520.03	4,622.50
4		10	17,071	0.015	0.15	268.01	1,786.76
5		12.5	9,194	0.015	0.19	180.43	962.31
6		15	-	0.015	0.23		

The following is a graphical presentation of Table-2. between rotation n (rpm), torque (N.m) and power (Watt) with the number / sequence of data collection time.

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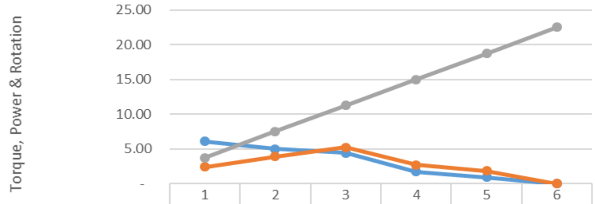


	1	2	3	4	5	6
n (rpm) (x 10000)	6.09	4.99	4.42	1.71	0.92	-
Pt (Watt) (x100)	2.39	3.91	5.20	2.68	1.80	-
T (N-M) (/100)	3.75	7.50	11.25	15.00	18.75	22.50

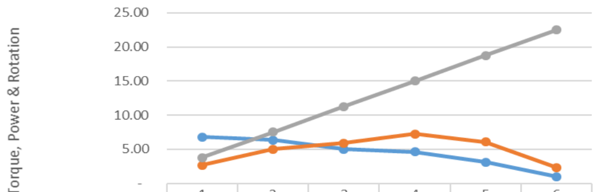
Figure-4. Graph between Torque, Power, Rotation with interval of data collection at pressure 6 (bar).

From Figure-4 is a graph of the performance trend of the turbine and it can be said that at the 3rd data collection with torque = 0.11 (Nm) rotation n = 44200 (rpm), the maximum power = 520 (Watt) occurs, while the data collection -6 with torque = 0.225 (Nm) rotation = 0 (rpm) and also Power = 0

Table-3. Test results using compressed air 7 (bar).

No	P (bar)	W (N)	n (rpm)	r (m)	T (T.m)	Daya (Watt)	ϖ
1	7	2.5	67,892	0.015	0.04	266.48	7,106.03
2		5	63,518	0.015	0.08	498.62	6,648.22
3		7.5	50,114	0.015	0.11	590.09	5,245.27
4		10	46,042	0.015	0.15	722.86	4,819.06
5		12.5	31,030	0.015	0.19	608.96	3,247.81
6		15	9,778	0.015	0.23	230.27	1,023.43

Next is the graphical presentation of Table-3 between rotation n (rpm), torque (N.m) and power (Watt) with the number / sequence of data retrieval time



	1	2	3	4	5	6
n (rpm) (x 10000)	6.79	6.35	5.01	4.60	3.10	0.98
Pt (Watt) (x100)	2.66	4.99	5.90	7.23	6.09	2.30
T (N-M) (/100)	3.75	7.50	11.25	15.00	18.75	22.50

Figure-5. Graph between Torque, Power, Rotation with time interval for taking data at pressure 7 (bar).

From Figure-5 is a graph of the performance trend of the turbine and it can be said that at the 4th data collection with torque = 0.15 (Nm) rotation n = 44600 (rpm), the maximum power = 723 (Watt) occurs, while the data collection to -6 with torque = 0.225 (Nm) rotation = 9800 (rpm) still produces Power = 230 (Watt).

CONCLUSIONS

The conclusions of this study are :

a) This research begins with preparation (literature study). The goal is to obtain reference information.
b) From the results of literature studies and field surveys, designs were made related to the development of the ORC system design that utilizes geothermal fluid waste into electrical energy using a turbocharger which is modified into a propulsion turbine.
c) After carrying out manufacturing work and assembling a laboratory scale ORC system, it is followed by a test of the ability of the modified Water and Turbine heaters with the following results:

- Water Heater: Dimensions of the water heater box: (48.5 x 31 x 27.5) cm (W x W x H) with 4 heaters with a heating time of 36 minutes reaching 98.1 ^{o}C
- The performance of the modified turbine with a pressure of 6 (bar) on the 3rd data collection where the resulting torque = 0.11 (Nm) rotation n = 44164 (rpm) occurs Maximum power = 520 (Watt),
- Turbine performance is modified with a pressure of 7 bar on the 4th data collection where the resulting torque = 0.15 (Nm) rotation n = 46042 (rpm) occurs Maximum power = 723 (Watt),

ACKNOWLEDGEMENT

Thanks to the Ministry of Research, Technology and Higher Education and the Manado State Polytechnic institution for helping to provide funding for this research and BPPT for allowing data collection.

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