AN EXPERIMENT ON PERFPRMANCE COMPARISON OF TWO-TYPE TESLA TURBINES APPLICATION IN ORGANIC RANKINE CYCLE

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ABSTRACT: This paper aims to study and design of Organic Rankine Cycle (ORC) using Isopentane as working fluid expanding through Tesla turbine. The study on ORC machine expanding through Tesla turbine has result on the efficiency of Tesla turbine. In addition, Thermodynamics theory on isentropic efficiency proved to be a successful method for overcoming the difficulties associated with the determination of very low torque at very high angular speed. By using an inexpensive experiment device and a simple method, the angular acceleration method, for measuring output torque and power in a Tesla turbine is able to predict a tendency of output work. The experiments using two-types Tesla turbine types, the first type is smooth disks, the second type is added small blades one. In comparison with the second type, it can produce power output more than 60% of the first type. Further study on the machine can be developed throughout the county due to its low cost and efficiency.

Keywords: Organic Rankine Cycle, Tesla turbine, high angular speed, inexpensive

1. INTRODUCTION

Authors are fully responsible for their papers, which should not have been published elsewhere. They must have taken necessary steps to obtain permission for using any material that might be protected by copyright. Due to the energy crisis, solar energy is developed to generate electricity as one of an alternative energy.[1,2] The use of organic Rankine cycle with thermal energy storage system to produce electricity will decrease the expense on conventional oil because of its low cost and efficiency. Thus, the design and test of Organic Rankine Cycle with thermal powerplants using tesla turbine expander [3] can save much more cost and its source is derived 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. 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.

In paper of Design of Tesla Turbine [5] reference to the change in speed the mechanism becomes very flexible [6]. Mr. Tesla claimed that the total effectiveness of his turbine could reach up to 98% [7]. Professor Warner Rice tried to renew Tesla's experiments. He used pressure air as a work substance. He reached a total effectiveness between 36% and 41% through his experiment [7]. Professor Rice published a mimeographed named "Tesla Turbomachinery" in 1990 [7], where he specified that by using analytic results the effectiveness of the rotor could be very high (up to 95%) with the effect of laminar flow [7].

The most important parameters that affect the performance and efficiency of disc turbomachinery,[5] as outlined by Cairns [6] and Rice [7], are as follows:

(a) spacing between the discs;
(b) characteristics of the fluid and the flow, such as velocity ratio;
(c) conditions of the surfaces of the disc and radius ratio;
(d) radial and axial clearances between the rotor and the housing.

2. THEORY

2.1 Determination of power from torque and angular speed [5]

Apart from the direct measurement of power, it can also be calculated from equation (1) once the torque and angular velocity are known

$$P=\tau\omega \tag{1}$$

In the following, a method for determining angular speed and several methods for determining the output torques that have been used in the present investigation are described.

2.2 Calculation Procedures [5]

A steady, adiabatic, compressible, quasi-one-dimensional flow of a perfect gas is assumed.

2.2.1 Inlet: mass flow and power input

The mass flow was estimated by means of the total and static pressures and total temperature readings at the inlet duct before the turbine. The Pitot tube at that position brings the fluid to rest, making it possible to obtain the total pressure. This process is considered adiabatic and reversible [8], i.e. isentropic. Then, knowing the static-to-stagnation pressure ratio and the stagnation temperature, the velocity of the fluid can be calculated. From the steady flow energy

equation it is obtained as

$$T_0 = T\left(1+\frac{\gamma-1}{2}M^2\right) \tag{2}$$

Since the process is assumed to be isentropic, the Mach number and the velocity of the fluid at the point where pressures and temperatures are being measured are respectively

$$M = \sqrt{\frac{2}{\gamma-1}\left[\left(\frac{p_0}{p}\right)^{(\gamma-1)/\gamma}-1\right]} = f(p_0, p) \tag{3}$$

and

$$V = \sqrt{2c_pT_0\left[1-\left(\frac{p}{p_0}\right)^{(\gamma-1)/\gamma}\right]} = f(p_0, p, T_0) \tag{4}$$

Finally, the mass flow can be obtained by introducing the equation of state of a perfect gas and equation (4) in the continuity equation for a one-dimensional steady flow

$$\dot{m} = \rho VA = \frac{p}{RT}VA = f(p_0, p, T_0) \tag{5}$$

With regard to the power input provided by the fluid, it can be defined [9] as

$$P_{input}=Q.p_{01} \tag{6}$$

Q being the volume flowrate calculated with the parameters measured at the inlet duct and p_{01} the total pressure obtained there.

2.2.2 The turbine as a whole: power and efficiency

The ideal power that should be developed by the turbine (isentropic power) is

$$\dot{W}_{isen}= \dot{m}c_P(T_{01}-T'_{03}) \tag{7}$$

where the ideal outlet temperature can be calculated by analysing the isentropic expansion in the rotor

$$T'_{03} = T_{02}\left(\frac{p_{02}}{p'_{03}}\right)^{(1-\gamma)/\gamma} = T_{02}\left(\frac{p_{02}}{p_{03}}\right)^{(1-\gamma)/\gamma} \tag{8}$$

The output power due to the actual enthalpy drop is

$$\dot{W}_{en}= \dot{m}c_P(T_{01}- T_{03}) \tag{9}$$

And then, the efficiency of the turbine defined as the ratio of the output power due to the enthalpy drop and the power involved in the corresponding isentropic process is

$$\eta_{en,isen} = \frac{\dot{W}_{en}}{\dot{W}_{isen}} = \frac{T_{01}-T_{03}}{T_{01}-T'_{03}} \tag{10}$$

Moreover, the efficiency can also be defined as the ratio of the actual power obtained by means of the angular acceleration method and the power involved in the corresponding isentropic process

$$\eta_{\Omega,isen} = \frac{\tau\omega}{\dot{m}c_p(T_{01}-T'_{03})} \tag{11}$$

A third way to define the efficiency of the Tesla disc turbine is as the ratio of the actual power obtained by means of the angular acceleration method and the power of the input stream (equation (6))

$$\eta_{\Omega,stream} = \frac{\tau\omega}{Qp_{01}} \tag{12}$$

2.3 Energy Aanlysis

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 (13). [10], [11]

$$q_H = \dot{m}C_P(T_{in}-T_{out}) \tag{13}$$

Rankine 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 irreversibilities and consists of the following four processes: [10]

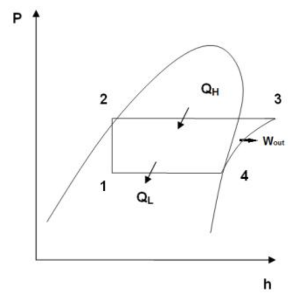

Fig. 1 P-h diagram of the Rakine cycle.

1-2 Isentropic compression in a pump

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

Energy 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 [10]. Then the steady-flow energy equation per unit mass of steam reduces to (14)

$$(q_{in}-q_{out})+(W_{in}-W_{out})=h_e-h_{in}) \quad (14)$$

The turbine is assumed to be isentropic. Then the conservation of energy relation for device can be expressed as follow:

$$W_{turbine,out}= h_3-h_4 \quad (15)$$

3. EQUIPMENT AND DATA COLLECTING POSITION.

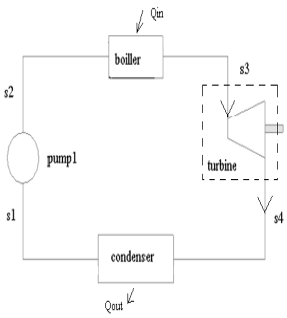

Fig. 2The diagram of Organic Rankine Cycle system and data collecting position.

Fig. 3 Tasla turbine plate of the first type**.**

Fig. 4 Tasla turbine plate of the Second type.

From the paper "A study and design of Organic Rankine Cycle"[12] 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 using two-types Tesla turbine types, the first type is smooth disks, the second type is added small blades one.

3.1 Experiment Methods

(the first type is smooth disks)

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 (smooth disks)
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 time, for the data that is correct most accurate.

3.2 Experiment Methods

(the second type is added small blades one)

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 (added small blades one)
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 time, for the data that is correct most accurate.

Fig. 5 comparison of two-type Turbines.

4. RESULT S AND DISCUSSION.

Calculation theory of Organic Rankine Cycle, using heat source at temperatures 90 °C which calculating by approximately from the experiment and comparison with P-h and T-s Diagram of a working fluid 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.

The experiments using two-types Tesla turbine types, the first type is smooth disks, the second type is added small blades one. In comparison with the second type, it can produce power output more than 60% of the first type.

The first type, an evaluation on Organic Rankine Cycle systerm, output power 50 kJ/kg, mass flowrate of working fluid 0.05 kg/s through Turbine claimed that the total effectiveness 36%, speed 3,000 r/min, we can calculate Torque equal 18 N.m. The use of heat source at temperatures 80 and 70 °C, result output power 35 and 20 kJ/kg, respectively, mass flow rate of working fluid 0.05 kg/s through Turbine claimed that the total effectiveness 36%, speed 3,000 r/min we can calculate Torque equal 12.6 and 7.2 N.m., respectively.

The second type, an evaluation on Organic Rankine Cycle system, output power 50 kJ/kg, mass flowrate of working fluid 0.05 kg/s through Turbine claimed that the total effectiveness 57.6%, speed 3,000 r/min, we can calculate Torque equal 28.8 N.m. The use of heat source at temperatures 80 and 70 °C, result output power 20.2 and 11.5 kJ/kg, respectively.

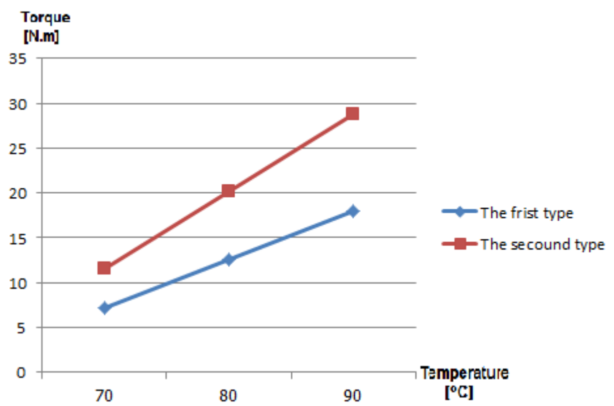

Fig. 6 Result of comparison of two-size Tesla Turbines.

The study reveals that low-temperature sources had low power output also. If we use low-temperature sources for suitable, it will get better development.

The most important parameters that affect the performance and efficiency of disc turbomachinery are as follows:

- spacing between the discs.
- characteristics of the fluid and the flow, such as velocity ratio.
- conditions of the surfaces of the disc and radius ratio.
- radial and axial clearances between the rotor and the housing.

In addition, Thermodynamics theory on isentropic efficiency proved to be a successful method for overcoming the difficulties associated with the determination of very low torque at very high angular speed. By using a simple method, the angular acceleration method, for measuring output torque and power in a Tesla turbine which experiment device must inexpensive but its can explain tendency for output work. Further study on the machine can be developed throughout the county due to its low cost and efficiency.

5. CONCLUSION

Thermodynamics theory on isentropic efficiency proved to be a successful method for overcoming the difficulties associated with the determination of very low torque at very high angular speed

The experiments using two-types Tesla turbine types, the first type is smooth disks, the second type is added small blades one. In comparison with the second type, it can produce power output more than 60% of the first type.

An evaluation on Organic Rankine Cycle systerm using heat source at temperatures 90, 80 and 70 °C, result the output power 50, 35 and 20 kJ/kg, respectively, mass flowrate of working fluid 0.05 kg/s through the first type Turbine claimed that the total effectiveness 36%, speed 3,000 r/min, we can calculate Torque equal 18, 12.6 and 7.2 N.m. respectively, and the second type , we can calculate Torque equal 28.8, 20.2 and 11.5 N.m., respectively.

A Tesla turbine which experiment device must inexpensive but its can explain tendency for output work. Further study on the machine can be developed throughout the county due to its low cost and efficiency

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 [K]
T_{out}	temperature outlet [K]
h_1	Specific enthalpy at the inlet state [kJ/kg]
h_2	Specific enthalpy at the exit state [kJ/kg]
h_3	Specific enthalpy at the inlet state [kJ/kg]
h_4	Specific enthalpy at the inlet state [kJ/kg]
c_p	specific heat capacity at constant pressure
M	Mach number
p	pressure
P	power
Q	volume flowrate
r	radius of the disc
R	gas constant distance between the centre of th e disc and the centre of the pole
T	temperature
V	absolute velocity
γ	ratio of specific heats
ρ	density
τ	torque
ω	rotor angular velocity

Subscripts

0	stagnation conditions
1	conditions at the inlet of the nozzle
2	conditions outlet of the nozzle/inlet of the rotor
3	conditions at the exhaust from the turbine
en	power due to enthalpy drop
isen	power of the isentropic process

stream power due to the input stream of fluid
out put from the angular acceleration method
i inner
o outer

Superscript

′ Ideal (isentropic) condition

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