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Novel Power Generation System for Low Temperature Heat Sources

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Abstract

Objectives: This research is about a novel power generation system for producing electricity from low temperature heat sources including renewable energy sources or waste heat from industrial process. Usage of renewable energy sources by current technologies has low efficiency and high investing costs. **Methods/Analysis:** Innovated system that is described in this paper consists of a reaction turbine as main part of the system, turbine shield, working fluid, heat exchanger, condenser, pump and electrical generator. Working fluid that gets energy from heat exchanger and increased its temperature enter to reaction turbine; exiting saturated working fluid from nozzles of turbine according to third law of newton cause rotation of turbine and thus produce electricity. **Findings:** In this research we could successfully design and test a novel power generation system with output power of around 1 KWe. Proving capability of application of a reaction turbine with an organic working fluid for use as power cycle to produce electricity from low temperature heat sources is the key finding of this research. This concept is simple and have low initial cost and less technical problems like corrosion and maintenance compared to thermodynamic cycle that use impulse turbines as expansion device. **Novelty/Improvement:** Power generation from low temperature heat sources such as solar and geothermal by means of a reaction turbine concept and an organic fluid as working fluid of the system is the main novelty of this work. This combination let us to generate power from low temperature heat sources simply and efficiently.

Keywords: Low Temperature, Power Generation, Reaction Turbine, Renewable, Waste Heat

1. Introduction

There is a continuing demand for clean renewable energy sources due to the depletion of the Earth's supply of fossil fuels and concerns over the contribution to global warming from combustion of fossil fuels. Renewable energy because of their sustain ability and clean nature is very attractive, but generating electricity from these sources with current technologies is less efficient and with high investing cost. Current power generation systems like traditional Rankin Cycle need high temperature heat sources, because energy conversion mechanism in such cycles need super heat steam[1] or have high technology and initial investment like sterling engine or ORC (Organic Rankin Cycle). Due to these barriers for the use of renewable energy sources, we need a system that can generate electricity from this energy sources efficiently and economically and has simple technology which is the aim of this research[2]. In this paper we describe a method for generating power from low temperature heat sources such as solar and geothermal by means of reaction turbine concept and an organic fluid as working fluid of the system. This combination lets us to generate power from low temperature heat sources simply and efficiently.

2. System Description

To generate power from low temperature heat sources economically, we must use reaction turbine in a closed cycle. This system consists of a reaction turbine as main part,

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turbine shield, working fluid (for example Cyclohexane), heat exchanger (depending on the heat sources, we could use different type of heat exchangers; for example in the case of solar energy it is the solar collector), condenser, pump and electrical generator. Hence parts of the system according to Figure 1. are: 1-Reaction, Turbine, 2-Heat Exchanger, 3-Pump and 4-Condenser. Parts of Reaction Turbine according to numbering in Figure 2. are: 1-Shaft, 2-Mechanism for connecting Shaft into Arms 3-Arms, 4-Convergent-Divergent Nozzle, 5-Turbine plate, 6-Turbine frame 7-Bearing, 8-Turbine Frame, 9-Structure for positioning of bearings.

In Figure 1. closed cycle of power generation from low grade heat sources by means of reaction turbine is shown.

Working fluid gets energy from heat exchanger (Figure 1.) and raised its temperature enter into reaction turbine (Figure 1). Exit of saturated liquid from reaction turbine nozzles (Figure 2.) according to third low of Newton cause rotation of turbine in opposite direction of fluid exit and this case rotation of shaft and connected generator and therefore producing electricity. Converging-diverging nozzle is shown in Figure 3.

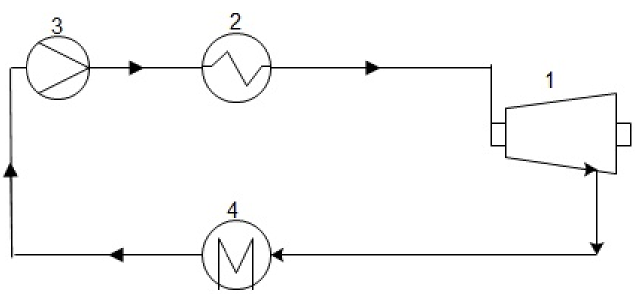


Figure 1. Low temperature power generation cycle.

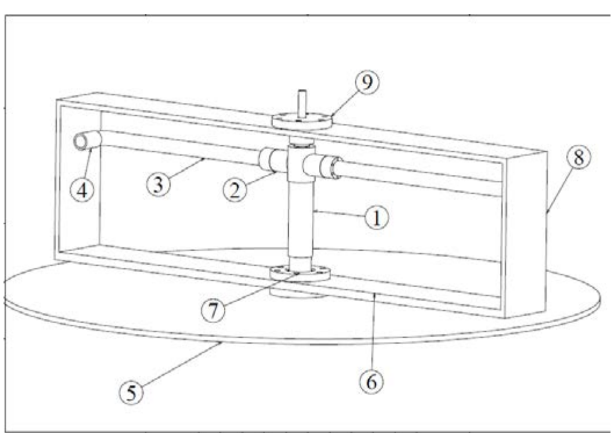


Figure 2. Designed reaction turbine.

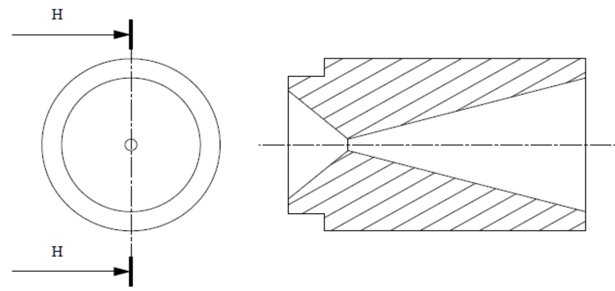


Figure 3. Converging-diverging nozzle.

Parameters for calculating output power of turbine is shown in Figure 4.; according to Figure 4. we have[3]

$$C_o = \sqrt{C_i^2 + 2\left(h_i - h_o\right)} \tag{1}$$

Where:

C_0 : Relative velocity of fluid.

$\dot{m}_0$: flow rate in nozzles.

$\dot{m}_1$: flow rate in arms.

ω : angular velocity.

h: enthalpy of fluid.

R: radius of arm.

From equation (1) for calculating relative velocity of fluid flowing in nozzles, if we assume fluid flow in nozzles adiabatically and process is isentropic, we have[4]

$$P = \dot{m}_i h_i - 2\dot{m}_o h_o - \frac{\dot{m}_i}{2}(C_o - \omega R)^2 \tag{2}$$

According to Figure 4. and equations (1), (2); we could calculate output power of turbine. Numbers that appear in Figure 4. refer to: 1-state 1, 2-state 2, 3-shaft, 4-angular velocity[5] We could use wide variety of working fluids in these systems but for better efficiency, we should use organic fluids like Cyclohexane, some chemical properties of these fluid is shown in Table 1[6].

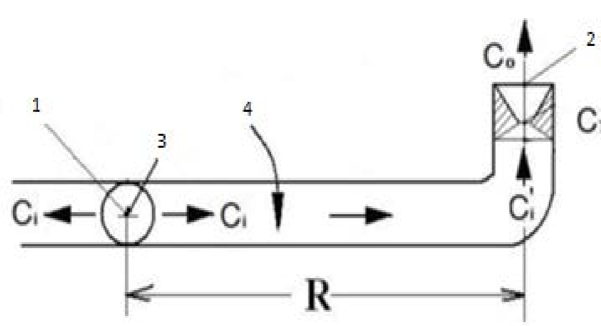


Figure 4. Parameters for calculating output power of turbine.

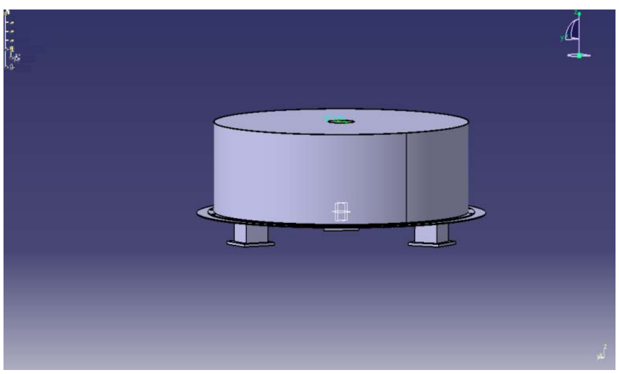
Table 1. Cyclohexane properties

Name	Cyclohexane
Formula	C^6H_{12}
Density	779.00 kg/m^3
Boiling point	80.74 °C
Molar mass	g/mol

3. Simulation and Prototype

For proven idea that described in this paper we built a prototype of reaction turbine and do some experiments on it. As first step of making a prototype of this idea we use some simulation software to better understand this concept and estimate its capabilities. Figure 5. shown Turbine shield software simulation. After simulation we start building turbine prototype, you can see in Figure 6. reaction turbine prototype.

Depending on heat source we could use different type of heat exchangers, for example if our heat source is sun, we connect reaction turbine into solar collector. (Figure 6).



(a)

(b)

Figure 5. (a) Turbine shield simulation. (b) Reaction turbine prototype.

Figure 6. Turbine prototype connected to solar collector.

4. Conclusion

Novel power generation system that is described in this paper has many application in use of low gradient heat sources especially for renewable energy sources. This concept is simple and have low initial costs and minimum technical problems like corrosion and maintenance compare to thermodynamic cycle that use impulse turbines as expansion device.

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