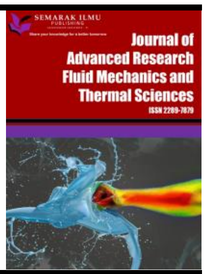
SEMARAK ILMU PUBLISHING
202103268166(003316878-P)

Journal of Advanced Research in Fluid Mechanics and Thermal Sciences

Journal homepage:
https://semarakilmu.com.my/journals/index.php/fluid_mechanics_thermal_sciences/index
ISSN: 2289-7879



Design and Construction of Steam Power Plant Prototype (Performance Analysis of Boiler System and Compress Cylinder)

Radhiah[1], Siti Amra[1], Zulfikar[1], Nelly Safitri[1,*]

[1] Electrical Engineering Department, Politeknik Negeri Lhokseumawe, Jl. Banda Aceh-Medan Km.280 Buketrata, Lhokseumawe Aceh 24301, Indonesia

ARTICLE INFO

Article history:
Received 19 November 2023
Received in revised form 31 March 2024
Accepted 14 April 2024
Available online 30 April 2024

Keywords:
Boiler system; compress cylinders; flywheel; van belt; kinetic energy; electrical energy

ABSTRACT

A steam power plant is a power production system that uses water as a working fluid to transform chemical energy into electrical energy. This STEAM POWER PLANT prototype is a power plant that uses linked equipment (components) such as boilers, compress cylinders, flywheel, generator, and load. A structural and functional approach was used in the investigation. Water is poured into the boiler and heated until it becomes steam. And the steam is channelled to the iron pipe by opening the boiler valve, then pressurized steam enters through the compress cylinder valve so that the compress cylinder moves and rotates the flywheel, then the pulley connected to the flywheel then also rotate and be connected to the generator via the van belt, so that the generator rotates causes the generator to work converting kinetic energy into electrical energy, to see changes in rotation, load vale to operate a compression cylinder without load, a pressure of 20 psi with a rotation of 466 rpm at a steam temperature of 113°C is required and takes 25 minutes to warm up.

1. Introduction

Fulfilling electricity needs in Indonesia is an urgent matter that must be addressed immediately if Indonesia does not want to experience an energy crisis in the next few years. The construction of primary power plants also needs attention if you want to continue to be able to support electricity needs in urban and industrial areas which incidentally are the centres of Indonesia's economic growth [1]. The usage of energy will continue to rise in tandem with economic expansion, and the growing population, as well as the high demand for everything, essentially depletes fossil energy supplies. Definitely this must be a concern for all parties involved in energy consumption because it is predicted that there will be energy scarcity. So, what should we do now? According to the law of energy conservation, which asserts that energy cannot be generated or destroyed. Only energy can be changed into another type of energy. As a result, several new innovations are required in

* *Corresponding author.*
E-mail address: nellysafitri@pnl.ac.id

https://doi.org/10.37934/arfmts.116.2.192199

developing and deploying new renewable energy sources in order to avoid the emergence of an energy crisis that then have far-reaching consequences and impact of human life.

According to references [2-6], the utilization of steam energy is one of the renewable energy sources with the most potential in Indonesia. Renewable energy power plants that use steam energy are often built on a massive scale. A Steam Power Plant is a steam power plant with up to 600 MW per engine. Technically, the power plant consists of numerous major components, including steam (energy source), either geothermal or coal, turbines, and generator [2]. The boiler in Figure 1 is a water tube type; the fireplace process occurs on the outside of the pipe, so the heat is absorbed by the water flowing into the pipe. The boiler is also known as a closed vessel since it has a feed water system, a steam system, and a fuel system. The heat of combustion from the fuel system is channelled into water until hot water is formed until the water produces steam or steam. Water vapor or steam at a certain pressure is then used to drain steam to another process. The steam turbine is a primary mover that turns the potential energy of steam into kinetic energy, which is subsequently converted into mechanical energy in the form of turbine shaft rotation. The turbine shaft is linked to the mechanism to be powered, either directly or via a reduction gear.

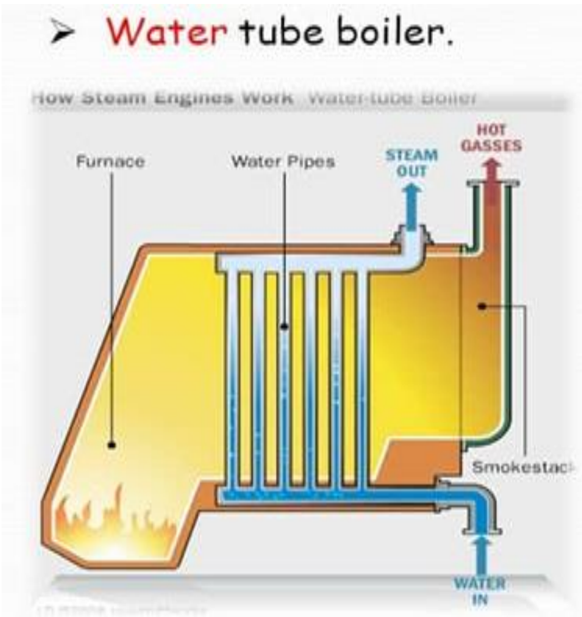


Fig. 1. Boiler [11]

Steam turbines can be employed in a variety of areas, including industrial, electric power generation, and transportation, depending on the type of mechanism used among the steam turbines on Figure 2. Compressed cylinders, also known as products used to provide linear or rotary motion and force to automated systems, machines and processes, for example in industrial applications [7]. When compressed air is forced into the cylinder or the actuator itself to move the piston placed in it. The 'work' is done by a mechanism mounted on the piston, converting the created energy into practical use. Compressed cylinders are goods that are used to give linear or rotational motion and force to automated systems, machinery, and processes, such as in industrial applications. When compressed air is pumped into the cylinder or the actuator itself in order to move the piston. A mechanism installed on the piston does the 'job,' putting the produced energy into practical use [8-10].

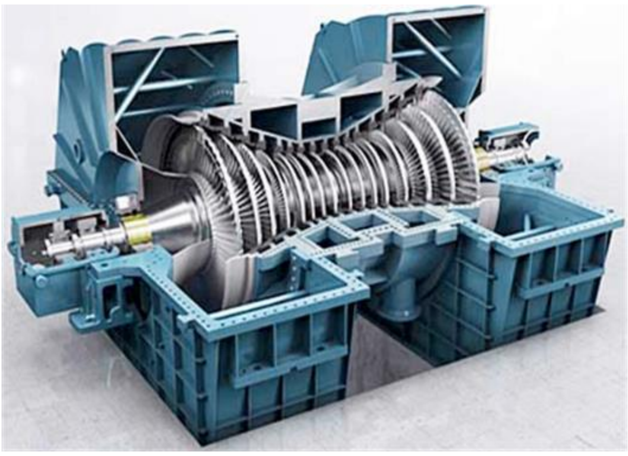


Fig. 2. Steam Turbine [11]

This study aims to plan, design and construct a prototype of steam plant power plant which specifically focus on the performance analysis of the boiler system and compressed cylinder. The design of the system is utilizing a tool making system, assessing and investigating the concept of a steam power plant based on existing components, and developing system [10].

2. Methodology

2.1 Steam Turbine

The steam turbine is a primary mover that turns the potential energy of steam into kinetic energy, which is subsequently converted into mechanical energy in the form of turbine shaft rotation. The turbine shaft is linked to the mechanism to be powered, either directly or via a reduction gear. Steam turbines can be employed in a variety of areas, including industrial, electric power generation, and transportation, depending on the type of mechanism used among the proposed steam turbines on Figure 3, the components are listed in Table 1.

The main element that must be determined is the fundamental concept of the design of the proposed prototype [8]. Boiler is the main component of most steam turbine power plant [12,13]. Additionally, the compressed cylinder is also the main component of the proposed prototype [14,15]. This fundamental concept represents the main idea towards which the prototype design is made. The prototype design concept taken the design of a steam turbine power plant, which is employing LPG gas as a boiler heater.

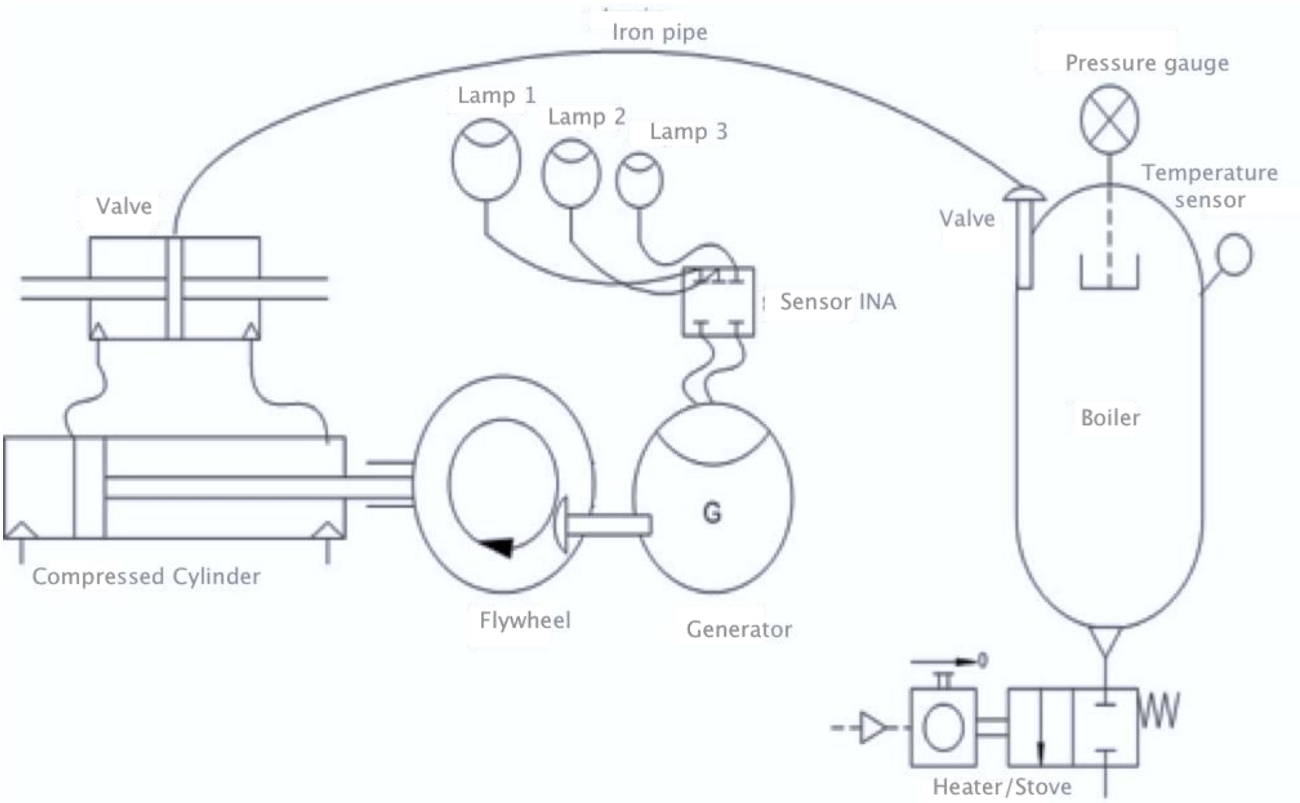


Fig. 3. Proposed steam turbine prototype

Table 1
Component of the proposed steam turbine prototype

Components	Descriptions
Steel Hollow	a size of 60x30, 1.5mm thick, 82cm wide, 105cm long, 54 high for construction and supporting tools
Acrylic	Acrylic with a size of 10 cm to place the load
Pneumatic Cylinder	1 compression cylinder (front shock of motorbike)
Flywheel	1 flywheel with a diameter of 25 cm
Generator	Permanent magnet generator with a power of 200 Watts
Battery	Lithium battery with a capacity of 7.5Ah
DC LED Lamp	3 LED lamps with the capacity of 5 Watts
Arduino Uno Atmega328	Microcontroller: Arduino Uno Atmega328 SMD
SMD	Sensor of Dc voltages (0-25V), watts and amperes
Fruit INA 219 Sensor	Pressure gauge with a size of 2.5 inches, pressure of 0-6 bars
Pressure Gauge	LPG cylinder used is in size of 12 kg
LPG	Which is made of flexible rubber that is circular without end
Belt Conveyor	

2.2 Steps of Designing and Running the Proposed Prototype

The research steps starting from planning the design of the steam turbine prototype to data collection and analysis can be seen in Figure 4, while the running process are as follow.

The stages for running a prototype of a steam power plant

i. Prepare portable gas for ignition in the water tube.
ii. Fill the boiler with 5 litres of water.
iii. The steam boiler or boiler that has been filled with water should be heated.
iv. Wait for the water to warm up and start to steam.

v. The pressure then is applied by the steam that is released from the little iron. Utilize the provided compression cylinder.
vi. The compression cylinder then moves after that in order to turn the flywheel, which is connected via the generator pulley's belt.
vii. The generator will then start spinning and start producing voltage.
viii. It then is provided to the load in the form of a lamp
ix. Thus, the lamp turns on as a result of the voltage on generator.

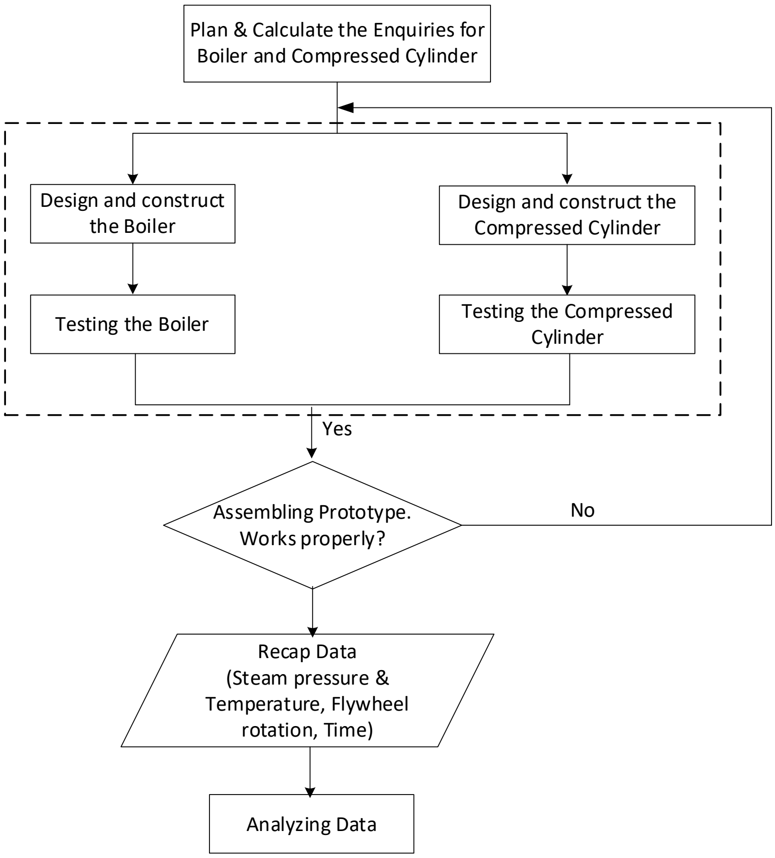


Fig. 4. Flowchart of the developed prototype

3. Results

3.1 Effect of Steam Pressure on Generator Rotation without Load

The no-load pressure test was carried out in 6 stages, starting from 10 psi to 60 psi, with an increase of 10 psi for each test. The test results are shown in Table 2. The findings of the no-load pressure test reveal that the pressure created by the boiler has a significant impact on variations in the generator's rotating speed. The more the pressure created, the faster the generator rotates, and vice versa. Data retrieval was performed six times, beginning with a pressure of 60 psi to generate a generator rotating speed of 886 rpm, then 50 psi to produce a generator rotational speed of 795 rpm, 40 psi to produce a rotational speed of 708 rpm, and 30 psi to produce.

Table 2
No-load condition

Steam Pressure (psi)	Generator Speed (rpm)	Indication
10	0	Not rotated
20	629	Rotated
30	682	Rotated
40	708	Rotated
50	795	Rotated
60	886	Rotated

Table 3
5-Watt load condition

Steam Pressure (psi)	Generator Speed (rpm)	Indication
10	0	Not rotated
20	307	Rotated
30	381	Rotated
40	435	Rotated
50	550	Rotated
60	614	Rotated

3.2 The Effect of Steam Pressure on Generator Rotation with Varied Loads

The no-load pressure test is carried out in 6 stages, starting from 10 psi to 60 psi, with an increase of 10 psi for each test, the test results can be seen in Table 3. Based on Table 3, the steam power plant prototype test is carried out every 10-psi pressure increase, starting from the initial pressure of 10 psi to the highest pressure of 60 psi. from the results of the table above, it can be concluded that testing the steam power plant prototype with a light load, namely the highest generator rotation produced at 614 rpm at a pressure of 60 psi and the lowest steam power plant prototype at a pressure of 10 psi where the generator rotation was at 0 rpm.

According to Table 4, the steam power plant prototype test is performed every 10-psi pressure increment, from the initial pressure of 10 psi to the maximum pressure of 60 psi. The lowest steam power plant prototype is at 10 psi pressure and 0 rpm generator speed. According to Table 5, the steam power plant prototype test is performed every 10-psi pressure increase, beginning with a pressure of 10 psi and up to a maximum pressure of 60 psi. According to the data above, the test of the steam power plant prototype with a light load, namely the greatest generator rotation generated 513 rpm at a pressure of 50 psi, was successful. The lowest steam power plant prototype is at 10 psi pressure and 0 rpm generator speed.

Table 4
10-Watts load condition

Steam Pressure (psi)	Generator Speed (rpm)	Indication
10	0	Not rotated
20	242	Rotated
30	365	Rotated
40	340	Rotated
50	490	Rotated
60	546	Rotated

Table 5
15-Watt load condition

Steam Pressure (psi)	Generator Speed (rpm)	Indication
10	0	Not rotated
20	227	Rotated
30	337	Rotated
40	322	Rotated
50	485	Rotated
60	513	Rotated

Table 6
20-Watt load condition

Steam Pressure (psi)	Generator Speed (rpm)	Indication
10	0	Not rotated
20	197	Rotated
30	258	Rotated
40	285	Rotated
50	340	Rotated
60	475	Rotated

4. Conclusions

The following conclusions may be drawn from the design and testing of the steam power plant prototype (study of the boiler system and compression cylinder work). The test findings reveal that as the pressure produced by the boiler increases, so does the temperature of the steam in the boiler, necessitating a longer heating time. Furthermore, the quicker the flywheel on the generator rotates, the higher the pressure created by the boiler. According to the test findings, the lowest pressure needed to rotate the flywheel and operate the generator is 20 psi, and the steam temperature reaches 113^{o}C. The greatest rotational speed obtained by the generator in the no-load test is 886 rpm.

Acknowledgement
This research was funded by a grant from Ministry of Higher Education of Indonesia.

References
[1] Apriandi, Riyki, and Aqli Mursadin. "Analisis Kinerja Turbin Uap Berdasarkan Performance Test Pltu Pt. Indocement P-12 Tarjun." *Scientific Journal of Mechanical Engineering Kinematika* 1, no. 1 (2016): 37-46. https://doi.org/10.20527/sjmekinematika.v1i1.26
[2] Aqsha, Biyan, Mas Sarwoko Suraatmadja, and Ekki Kurniawan. "Realisasi Pembangkit Listrik Mini Tenaga Sampah." *eProceedings of Engineering* 2, no. 2 (2015).
[3] Daneswari, Reza Gustarani. "RANCANG BANGUN PROTOTIPE PEMBANGKIT LISTRIK TENAGA UAP (Evaluasi Terhadap Sistem Thermal dan Kerja Turbin." PhD diss., Politeknik Negeri Sriwijaya, 2015.
[4] Huda, B. D. "Rancangan Bangun Safety Sistem Pada Prototype Steam Plant Untuk Pembangkit Listrik Tenaga Uap." *Doctoral dissertation, Institut Teknologi Sepuluh Nopember.* (2018).
[5] Anonim. "Buku Panduan Pengoperasian Pembangkit Listrik Sumbagut 2 Peaker Power Plant 250 MW P/1702. PT. Sumberdaya Sewatama" *ID Dokumen : DBAF456130.* (2020).
[6] Pranata, Supriyadi. "Pengoperasian Dan Perawatan Permesinan Bantu Generator Kapal Negara Trisula Di Kesatuan Penjagaan Laut Dan Pantai (Kplp) Tanjung Pinang." *Karya Tulis* (2019).
[7] Stevenson, William,Jr. "Analisa Sistem Tenaga Listrik." *Jakarta:Erlangga.* (2018).
[8] Soedjono, Denny Me, Joko Sarsetyanto, Dedy Zulhidayat Noor, And Lisa Andriani. "Kaji Numerik Ketel Uap Sederhana Berbahan Bakar Lpg Pada Industri Kecil Tahu Menggunakan Program Ansys 14.0."

[9] Rahman, Haidar. "Rancang Bangun Model Pembangkit Listrik Tenaga Uap Menggunakan Turbin Impuls." (2016).
[10] Boyce, Meherwan P. "Gas turbine engineering." (2012).
[11] Man Diesel & Turbo. "Power Plan Programme 2016/17." *Man Diesel & Turbo, Engineering the Future – Since 1978.* (2016).
[12] Anonim. "Mengenal Apa itu Ketel Uap (Boiler) dan Cara Perawatannya." (2021).
[13] Eonchemicals. "Komponen Boiler dan Fungsinya | Prinsip Kerja Boiler part 2." (2021).
[14] Office and Environmental Health and Safety, University of George Town. "Compressed Gas Cylinder." (2020).
[15] Anonim. "COMPRESSED GAS CYLINDER SAFETY." *Oklahoma State University* (2021).