# PERFORMANCE OF STEAM ENGINE AT DIFFERENT TEMPERATURES WITH VARIOUS LOADS

*Azna Ainatasya Athira Abdul Aziz*[1], *Ahmad Aizayuddin Abdullah*[1], *Mohamad Zamin Mohamad Jusoh*[1], *Helmisyah Ahmad Jalaludin*[1]

[1]*College of Mechanical Engineering, Universiti Teknologi MARA, Terengganu Branch, Bukit Besi Campus,23200 Dungun, Terengganu, Malaysia*
.
Corresponding Author: *helmisyah@uitm.edu.my*

## ABSTRACT

In a steam engine, vapor is supplied by a boiler, expands under pressure and a part of the heat energy is converted into mechanical work. However, the efficiency of the steam engine may reduce due to the different load weight. In this study, different temperature of steam relative to different load weight and different engine speed on a steam powered engine are analysed. Moreover, the engine torque and brake power are calculated. The pressure of steam is set to be at the range of 2 bars, and the load weights are ranging of from 0, 20, 30, 40, and 50 grams. As a result, the performance of steam engine increased along with higher temperature and lower load weight.

***Keywords:*** *Steam engine, loads, engine speed, torque, brake power*

## 1. INTRODUCTION

Energy demand is rising in tandem with economic growth. Increasing the effectiveness of energy utilization is one strategy to significantly lower global energy consumption (Wang et al., 2023). The current surge in economic growth has resulted in a notable rise in energy usage. To guarantee the affordable, effective, safe, and clean use of energy resources, swift action is required. The adoption of renewable energy sources has become a top priority for decision-makers due to the drawbacks of fossil fuels and their effects on the environment (Toledo-Paz et at., 2024). Efficiency in the nation's energy production, transmission, distribution, and consumption will become more and more important in determining the need to limit atmospheric emissions of greenhouse gases and other pollutants (Kaygusuz, 2009). Geothermal energy as an example has the potential to provide less waste and more reliable and constant electricity supply when compared to other renewable energy sources (Anderson & Rezaie, 2019). Referring dry steam power plants which uses high-temperature sources, the efficiency is usually higher than those of conventional geothermal power plants. One of the most straightforward and affordable concepts for geothermal power plants is the dry steam operation. Power is extracted from superheated steam that is directed straight into a steam turbine from the earth under high pressure (DiPippo, 2012; Zarrouk & Moon, 2014).

The organic Rankine cycle (ORC) offers a wealth of potential for research and practical implementation. It can be a sustainable, economical, and safe way to recover waste heat, which raises energy efficiency to conflate the economic significance of the steam engine with its early diffusion (Wang et al., 2023). In fact, the available shreds of evidence on the growth of steam power in the British economy in combination with data on the cost effectiveness of early steam engines indicate that steam power gave a only modest contribution to aggregate productivity growth until at least the 1830s (Tunzelmann, 1978). However, it is important to stress that these revisionist accounts concern the timing of the economic effects of the diffusion of steam power technology and do not intend to question the fundamental role played by this technology for economic growth over the long run. Thus, the views of Cipolla (1962) and Wrigley (1988, 2004) which regard steam power as a critical technological breakthrough that changed the energy budget of the British economy providing the opportunity for tapping into inorganic stocks of fossil fuels (coal).

The widely used reciprocating engine typically consisted as of a cast-iron cylinder, piston, connecting rod and beam or a crank and flywheel, and miscellaneous linkages. Steam has alternately been supplied and exhausted by one or more valves to the part. Speed control was either automatic, or by a manual valve. The cylinder is casting contained the steam supply and exhaust ports. Engines equipped with a condenser are a separate by the type than those that exhaust to the atmosphere. There are practical limits on the expansion ratio of a steam engine cylinder where it as increasing cylinder surface area tends to exacerbate the cylinder condensation and re-evaporation issues. Richard (1989) mentioned that this negates the advantages that are associated with a high ratio of expansion. The dominant efficiency loss in reciprocating steam engines is cylinder condensation and re-evaporation. As high-pressure steam is admitted into the working cylinder, much of the high-temperature steam is condensed as water droplets onto the metal surfaces, significantly reducing the steam available for expansive work. When the expanding steam reaches low pressure especially during the exhaust stroke, the previously deposited water droplets that had just been formed within the cylinder/ports may return to evaporize and this steam does no further work in the cylinder. Meanwhile, the compression phase where a cushion of steam is formed against which the piston does work whilst its velocity is rapidly decreasing which it would otherwise be caused by the sudden admission of the high-pressure steam at the beginning of the following cycle. (Marsden, 2004).

The fuel-energy efficiency of the engine largely depends on ambient parameters (Kornienko 2023; Konovalov, 2024). Uncontrolled heating may raise the steam pressure to a level high enough to cause the boiler to burst, and this may result in great damage to people. Then, the different temperature of the steam engine may reduce due to the different load weight. The pressure is drop in the steam line and produce the throttling effect of the valves. The result is pressure of the steam at entry is less than the boiler pressure and falls slightly until cut-off occurs. Then the valve closure is not instantaneous, therefore, cut off is not a definite point. At release stroke, the valve take time to open. The exhaust valves closed before the end of the stroke, trapping a quantity of steam in the cylinder. Criteria for performance can be calculated used below equations:

Engine torque,

$$T = F \times R \text{ [Nm]} \tag{1}$$

Engine brake power,

$$Bp = \frac{2\pi NT}{60 \times 1000} \quad \text{[kW]} \tag{2}$$

where,
N = engine speed [rev/min]
F = the load of spring [N]
R = radius of the pulley 0.056 [m]

This steam acts as a cushion thereby relieving stresses in the piston rod. The live steam is admitted before the end of the exhaust stroke. Therefore, this study is to analyse the effect and its performance of different temperature and load weight of steam powered engine.

## 2. METHODOLOGIES

This research was carried out using steam motor and energy conversion engine at the Universiti Teknologi MARA Cawangan Terengganu Kampus Bukit Besi as shown in Figure 1. The experiment was carried out at the engine speed up to 1400 rpm in steady condition and pressure of propane-fired boiler was set approximately at 2 bar. Different load weight ranging from 0, 20, 30, 40, and 50 grams were set at the end of spring scale using poly-brake load hanger. Boiler temperature, engine speed, and spring balance loads were recorded. The temperatures (ºC) at every engine speed (rpm) are recorded. Then, the engine torque and break power are calculated.

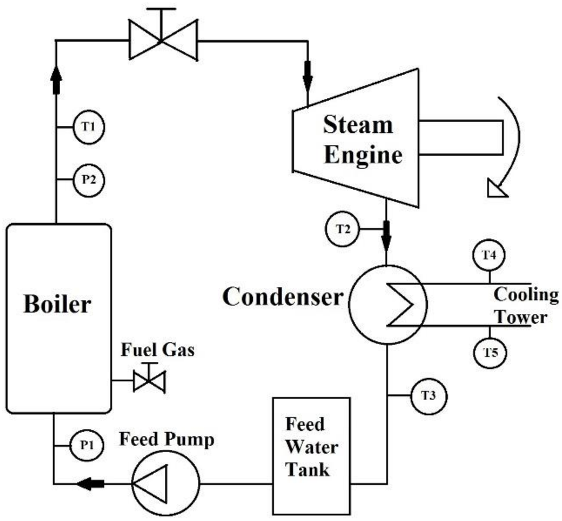


*Figure 1: Steam Motor and Energy Conversion Engine*

## 3. RESULTS

In a steam engine, the relationship between steam temperature and engine speed is quite significant and involves several key factors related to thermodynamics and mechanical operation. Higher steam temperatures generally result in higher thermodynamic performance at lower load, as they increase the energy available for conversion into mechanical work. The brake powers were increased along with engine speeds but slower down with higher load as shown in Figure 2. Moreover, the torques decrease as engine speed increases but the value increases along higher load. Obviously, zero load contributes to higher and longer duration on mechanical work on the engine with high speeds but zero brake power and torque. At 0 load, the maximum engine speed of 1301 rpm during the at 145ºC, the engine working duration was longer at temperature range of 105ºC to 145ºC. Compared to a higher load of 50g, the engine worked through a shorter life in between 135ºC to 145ºC. The brake power shows highest increment about 34% at 40g load compared to 16% at 50g because of energy loss. Brake power for 20g load was second lowest but achieved second higher of engine speed. According to the Carnot cycle, the efficiency of a heat engine depends on the temperature difference between the steam and the condenser. Thus, higher steam temperatures can improve efficiency and potentially allow the engine to operate at higher speeds. However, a working engine operating between two heat temperature limits can never exceed Carnot efficiency (Bhatia, 2014). Higher temperatures generally produce steam with less moisture (dry steam), which is preferable for efficient engine operation. Steam engines perform better with dry steam because it can expand more completely and effectively within the engine cylinders, leading to higher speeds.

The torque at 50g exhibited the highest value at 27.44Nm but lowest engine speed at 489 rpm compared to 20g load achieving 10.98Nm from 277 to 1054 rpm. Higher torque at lower speeds can be beneficial for tasks requiring more power, such as starting heavy loads. Generally, torque decreases as engine speed increases due to mechanical losses and changing dynamics within the engine.

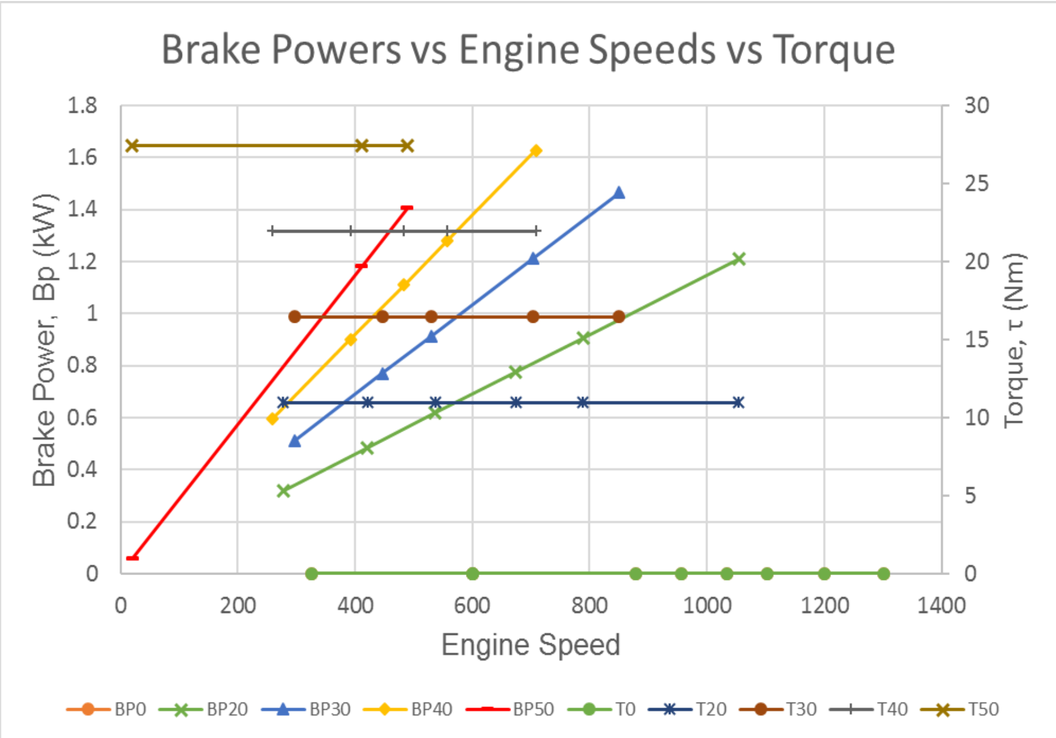


*Figure 2: Relationship Between Brake Power, Torque and Engine Speed of Steam Engine with Different Loads*

## 4. CONLUSIONS

In summary, the brake powers were increased along with engine speeds but slower down with higher load while the torques decrease as engine speed increases but the value increases along higher load. The brake power shows the highest increment about 34% at 40g load compared to 16% at 50g because of energy losses. The torque at 50g exhibited the highest value at 27.44Nm but lowest engine speed at 489 rpm compared to 20g load achieving 10.98Nm from 277 to 1054 rpm. Higher steam temperatures can increase steam engine performance and potential speed at lower loads, the actual engine speed also depends on other factors such as steam pressure, engine design, and mechanical limitations. Higher steam temperatures generally improve the efficiency and performance of steam engines, particularly under lower loads. However, the relationship between load, temperature, and efficiency is complex and governed by thermodynamic principles. Dry steam is preferable for optimal engine performance because it allows for more complete expansion and energy conversion.

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