Experimental Evaluation of Diesel Engine Performance using Producer Gas and Conventional Fuel: A Comparative Study

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ABSTRACT

This study empirically evaluated the performance of a downdraft biomass gasifier integrated with a diesel engine using a combination of biomass and diesel fuel. The employed downdraft gasifier consisted of two interconnected oil drums measuring 60×151 cm. A combustion chamber was installed in the conical steel drum with a central axis having a throat diameter of 31 cm. Rubberwood, tamarind wood, and sawdust were used as fuel sources. These woods were combusted to produce gas, which was subsequently channeled through a filtering and temperature-reduction apparatus before being blended with diesel fuel. A Nissan RD28 94 hp diesel engine was used for the experiments, with an airflow rate set at 0.226 m^3/s. The experimental results showed that burning a mixture of rubberwood and sawdust (7.5 kg each) produced gas for 61 minutes. Tamarind wood combustion (15 kg) resulted in 58 minutes of gas production. Burning pure rubberwood (15 kg) produced gas for 37 minutes. Combusting a blend of tamarind wood and sawdust (7.5 kg each) produced gas for 45 minutes. The gooseberry wood (15 kg) was burned for 57 minutes with gas formation lasting 48 minutes. Adjusting the air input to the gasifier combustion chamber to 100%, the rubberwood and sawdust mixture exhibited the highest gas production. Furthermore, engaging the RD28 engine at 978 RPM in gear L resulted in the gear halting at 99 RPM after gradually adding steel blocks. The torque required to cease the gear was measured at 10.68 N.m, highlighting the potential for stopping gear L within the low-speed range due to misalignment between the engine's end flywheel and the gear pulley spline.

Keywords-biomass; downdraft gasifier; diesel engine; rubberwood; tamarind wood; sawdust

I. INTRODUCTION

Currently, Thailand is one of the many countries affected by the energy crisis due to increasing oil demand and prices. Consequently, people are increasingly looking for alternative options to replace oil as an energy source. Thai officials propose separating talks on joint energy development from territorial disputes over the Gulf of Thailand's contested 27,000 km^2 area, rich in up to 11 trillion ft^3 of natural gas and significant oil deposits since the 1970s. Faced with declining domestic gas production and increased LNG imports, Thailand aims to prioritize energy needs over boundary issues, seeking for a pragmatic solution amidst its worsening energy security [1]. Consequently, people are searching for other solutions to replace oil as an energy source. The most suitable renewable energy source for this purpose is biomass energy. Biomass energy can be derived from various plant sources, such as wood charcoal, bagasse, or agricultural residues. Thus, the resources in the country to produce biogas are sufficient. Rubberwood chips and sawdust in three regions total 484,815 tons/year. This biomass is equivalent to 75.62 Kt/year of crude oil, which can provide 176,957,475 KWh/year of electricity and support approximately 21.07 MW of installed electrical power (20% efficiency, 350 days/year). This is used primarily for thermal energy: 40% (193,926 tons/year) in processing plants and 60% (290,889 tons/year) in other industries. All the wood chips and sawdust produced, totaling 484,815 t/year, are fully utilized, leaving none unused [2].

Burning biomass materials in a gasifier releases gases, such as carbon monoxide (CO), hydrogen (H_2), and methane (CH_4), which can be used as alternative fuels for internal combustion engines, such as gasoline and diesel engines. Gasifier engines can be utilized as prime movers for agricultural machines or as dispersed power sources to produce electricity and water pumps. This makes them suitable for rural areas where farmers can be self-reliant by employing locally available fuel resources. Many studies have investigated diesel engines powered by biomass fuel. In [3], a laboratory-scale downdraft gasifier was designed, constructed, and tested for the composition of the gas produced. The construction of the gasifier followed the design proposed in [4], incorporating key components such as the reaction chamber, the fuel hopper, the gas outlet, and the air inlet. Ignition was achieved using a flame torch, and the gas composition closely matched the desired specifications. In [5], experiments were carried out to evaluate the thermal efficiency, specific fuel consumption, and diesel substitution of a 5.25 kW, single-cylinder, four-stroke diesel engine. The tests were carried out using diesel alone and gas-cum-diesel (dual fuel mode) generated through a downdraft gasifier. The biomass moisture content varied between 8, 12, 16, and 21%, maintaining an engine speed of 1600 rpm with varying engine loads. The gas producer system, coupled with the diesel engine, demonstrated satisfactory performance using three biomass types: wood chips, pigeon pea stalks, and corn cobs. Although the thermal efficiency in dual fuel mode was slightly lower than in diesel mode, the specific diesel consumption was 60 to 64% lower in dual fuel mode for the same energy output. On average, diesel substitution in the diesel engine ranged from 62 to 64%, using three different biomass fuels.

In [6], the gasification of wood from a mill was studied, integrating it into a combined cycle for both power generation and fuel synthesis. This dual-purpose utilization optimizes the gasifier's efficiency. During the winter season, when electricity prices are high, the synthesis gas is employed to generate surplus electricity, whereas in other seasons, it is used for the production of transportation fuels. In [7], coffee husk was used as biomass for gasification, examining its impact on the performance of a diesel engine operating in dual fuel mode. This study achieved a maximum diesel replacement of 31%, mainly constrained by clinker formation and low biomass density. In [8], a comparative analysis of externally fired gas turbines was performed, using biomass fuel and natural gas. The findings demonstrated an 11.5% reduction in efficiency when biomass fuel was employed. In [9], the technical performance of the largest biomass gasifier-based power plant (500 kW) in India was evaluated. The sustainability of this power plant was evaluated by considering factors, such as diesel replacement, fuel wood supply, electricity generation cost, and environmental impact. The overall reported efficiency of the plant was approximately 19%, with a maximum diesel replacement of 64% achieved under optimal load conditions using wood chips. Several studies [10-13] explored the utilization of various biomass types as fuel in engines, contributing to a broader understanding of biomass-based energy systems. In [14], the performance of locally produced waste cooking oil biodiesel was evaluated and compared with conventional diesel fuel. Producer gas has also been used in normal diesel engines operating in dual-fuel mode, resulting in up to 85% savings in diesel fuel [15-18].

Diesel engines are more efficient due to their higher compression ratios, which typically range from 12 to 24 [19]. In addition, diesel engines are more durable than spark ignition engines and, in some situations, require less maintenance. Diesel engines using producer gas have only 15-30% derating due to their high compression ratio and low speeds. This is significantly better than the derating of SI engines. SI engines still derate between 40 and 50%, even when operated in dual fuel mode [20]. Additional components, such as a gas mixer, nonreturn valve, pressure regulator, and gas carburetor, must be added to the diesel engine system to enable dual-fuel operation. In spark ignition and diesel engines, producer gas and air are typically mixed in an intake manifold after which the air-fuel mixture, prepared for combustion, enters the engine cylinders. In [21], a high-efficiency downdraft gasifier was designed and optimized for gas production through dimensions and air control. With a capacity of 34 kW and a fuel feed rate of 15 kg/hr, key dimensions included a height of 166 cm, a stove diameter of 44 cm, a throat diameter of 13.80 cm, and an air pipe diameter of 1.56 cm. The gasifier achieved a steam production of 13.84 kg/hr with oxygen and air requirements of 2.68 m^3/hr and 13.99 m^3/hr, respectively, boosting 29.60% higher efficiency than conventional models. This study investigates the performance of a diesel engine fueled by three different types of biomass, rubberwood, tamarind wood, and sawdust, alongside conventional fuel. Through experimental evaluation, this study compares the efficiency of the diesel engine using these fuels. By analyzing combustion characteristics, energy output, and overall performance metrics, this comparative study endeavors to provide valuable insights into the potential of biomass as an alternative fuel for diesel engines, shedding light on its viability and effectiveness in real-world applications.

A. Diesel Engine

A diesel engine [22] is one type of internal combustion engine that converts fuel energy into thermal energy through combustion. Combustion occurs with the ignition of fuel, and the thermal energy is transformed into mechanical work. The diesel engine operates with a compression ignition system, where fuel is injected into a compressed air chamber. This compressed air undergoes ignition, resulting in combustion. The combustion process generates high pressure and temperature, causing the piston to move downward. This downward movement, in turn, drives the crankshaft. The efficiency of a diesel engine surpasses that of other internal combustion engines, such as gasoline engines. This superiority is attributed to its inherently higher lean burn and expansion ratio, allowing effective dissipation of heat through excess air. Originally employed in ships and submarines around 1910, diesel engines have since found applications in various sectors, including electricity-generating power plants, agricultural machinery, heavy equipment, trucks, and locomotives. Renowned for their longevity and durability, diesel engines are particularly acclaimed for their ability to produce substantial torque, which makes them well-suited for deployment in heavy-duty vehicles.

B. Downdraft Gasifier

A downdraft gasifier is designed to address the issue of tar in gasifier producers, commonly found in updraft gasifiers. In this type of gasifier, air is drawn downward from the top to the bottom through a nozzle. The combustion zone is in the nozzle area, where the gas from the combustion zone is reduced as it flows down through a layer of hot carbon above a small grate. Simultaneously, the upper layer of biomass in the combustion zone undergoes pyrolysis, flowing through the layer of hot carbon and causing diesel and oil to crack into gas. The gas produced in the downdraft gasifier has less than 10% of the diesel and oil content compared to the gas produced in the updraft gasifier. Therefore, the obtained gas is cleaner than that of the updraft gasifier. In crossdraft gasifiers, air is drawn through an injector located in a horizontal plane, followed by a combustion zone that is next to the injector, and further out is the gas reduction zone. The gas leaving the reduction zone exits through a grid surrounding the combustion and reduction zones. The reduction zone acts as an area for breaking down oil and crude oil, and the gas and crude oil obtained from this breakdown pass through the reduction zone before exiting externally. This results in gas and crude oil breaking down into gas before exiting, leading to gasifier gas with low amounts of oil and crude oil. All these types operate based on the chemical and physical properties of the fuel, while common issues encountered include slag formation and excessive pressure drop when the gasifier gas flows through. A fluidized bed gasifier has been proposed to address these challenges. In this design, air is drawn through a fuel bed. When the air velocity is increased to a certain value, the bed begins to exhibit fluid-like properties. Initially, the bed receives heat from the outside until the temperature increases to the ignition point of the fuel. Afterward, the fuel is continuously fed, and combustion occurs uniformly throughout the gasifier area. The fluidized bed gasifier, specifically the fluidized bed with a fluoride bed, can be further categorized into two main types: Circulating Fluidized Bed and Bubbling Bed.

C. Biomass Types [23]

Rubber wood, sourced from rubber trees, is valued for its eco-friendly attributes as a byproduct of the latex industry. It is a popular choice for furniture due to its light color, smooth texture, and sustainable nature. Rubber plants play a crucial role in Thailand's economy, involving approximately 1 to 6 million families through agriculture and related industries. Since 1991, Thailand has been the world's top exporter of rubber and rubber products. Rubber trees, tapped for natural rubber, lose efficiency with age and are traditionally burned after 25 years. These trees also supply the furniture industry, generating significant waste in the form of sawdust [24].

Tamarind wood [25], derived from the tamarind tree, is known for its durability and resistance to decay. It is often used in furniture crafting and construction due to its appealing grain and strength. The deciduous gooseberry tree [26] is highly valued for its attractive qualities in gardens and for its small sour berries. Gooseberry trees are grown for their resilient fruit and beautiful foliage. The gooseberry tree is prized for its aesthetic attributes in gardens and landscapes in addition to culinary purposes. It has a dense and bushy growth habit with branches that arch and are frequently covered with jagged thorns. The smooth and velvety leaves are lobed, and in the fall, they turn into vivid colors of yellow before dropping. The hardiness of the gooseberry tree is one of its main characteristics. It thrives in USDA hardiness zones 3 through 8, while it can withstand a wide range of conditions. The shrub is resistant to cold.

Sawdust is a waste product or by-product of woodworking processes, such as sawing, sanding, milling, and routing [27]. Sometimes, it is also called wood dust, as it is made from tiny wood chips. Sawdust is a notable biomass feedstock for gasifiers, offering a renewable energy source that can be converted into useful gases through the gasification process. This thermochemical process involves the partial combustion of biomass, such as sawdust, at high temperatures with a controlled amount of oxygen or steam, resulting in the production of a combustible gas mixture known as syngas.

Currently, Thailand is highly dependent on imported energy sources, involving natural gas and crude oil. Therefore, developing alternative energy sources can help reduce the dependence on foreign energy. Bioenergy and biomass are considered highly promising energy sources that can be utilized in various ways. Thailand has strong agriculture. Thus, numerous agricultural residues and by-products, previously disposed of or left without value, can be used in energy production processes, creating value from waste and generating income for farmers and communities. Furthermore, since Thailand's new energy development plan aims to generate 650 MW annually from energy plants, it is likely to require more biomass power plants and energy plants.

D. The Downdraft Gasifier System

The calorific value of the rubber wood residue biomass waste varies, but generally ranges between approximately 18 to 20 MJ/kg. This parameter guided the design decision for the downdraft gasifier, resulting in a diameter of 600 mm with a height of 1,510 mm. This gasifier operates on a downdraft design, with a single air entry opening and a throat diameter of approximately 310 mm. The system comprises a well-insulated cylindrical reactor, a fixed steel grate, and an induced draft fan. The reactor is a cylindrical steel shell externally insulated with 25 mm thick fiberglass and covered with steel. Supplementing the air drawn by the electrical blower, the air distribution unit features an air duct with 25.4 mm diameter and 383 mm length. The grate, constructed of iron steel, has an area of 0.10 m^2, designed based on a Specific Gasification Rate (SGR) of 119.352 $kg/h.m^2$ and a fuel input rate of 30 kg/h. The SGR is defined as the amount of biomass fuel used per unit time per unit reactor area, which is usually about 110-210 $kg/h/m^2$ [28]. The inside diameter of this gasifier is 565 mm. Ash generated during the process falls into the ash pit tank, made of 6 mm thick steel sheets. The ash pit volume (0.10 m^3) is ample, allowing for operation without the need for ash removal for an extended period (approximately 20 hrs).

The efficiency of a downdraft gasifier (η) can be calculated using [28]:

$$\eta = \frac{Q_g M_g \times 100}{LHV_f M_f} \quad (1)$$

where Q_g is the heat value of the fuel gas (MJ/kg), M_g is the gas production rate (m³/hr), and LHV_f is the lower heating value of the fuel (MJ/kg). The calculated efficiency is 62.6 %

Fig. 1. Constructed downdraft gasifier with combustion chamber.

The size or energy production capacity of the downdraft gasifier can be found with a fuel feed rate of 15 kg/hr and a stove efficiency of 62.60%. Given a fuel heat value of 13.08 MJ/kg, the size of the gasifier stove is 34 KW. Downdraft gasifiers exhibit adaptable gas production to biomass input and minimal susceptibility to charcoal dust and tar in fuel content. They demonstrate effective carbon conversion, manageable operation, high thermal efficiency, and economical initial investment.

E. Diesel Engine Performance

Calculating the performance of a diesel engine involves various parameters and measurements. Some key performance metrics and the corresponding calculations follow.

Brake Horsepower (*BHP*):

$$BHP = (2\pi NT) / 33{,}000 \quad (2)$$

where π is the mathematical constant (approximately 3.1416), N is the engine speed in revolutions per minute (rpm), and T is the torque produced by the engine.

$$Torque = (BHP \times 33{,}000) / (2\pi N) \quad (3)$$

Brake Specific Fuel Consumption (*BSFC*):

$$BSFC = Fuel\ Consumption / BHP \quad (4)$$

$$ThermalEfficiency = (BHP \times 2545)/FuelInput \quad (5)$$

where *FuelInput* is the rate at which fuel is consumed.

$$VolumetricEfficiency = \left(\frac{ActualAirFlow}{TheoreticalAirFlow}\right) \times 100 \quad (6)$$

$$MechanicalEfficiency = \left(\frac{BHP}{IHP}\right) \times 100 \quad (7)$$

where *IHP* is the indicated horsepower.

Indicated Mean Effective Pressure (*IMEP*):

$$IMEP = \frac{IHP \times 2\pi}{L \times A} \quad (8)$$

where L is the stroke length and A is the piston area.

Specific Fuel Consumption (*SFC*):

$$SFC = FuelConsumption/BHP \quad (9)$$

These formulas provide a basic overview of the calculations involved in evaluating the performance of a diesel engine. Specific parameters and units may vary depending on the measurement system used (e.g. metric or imperial). Additionally, actual testing and data collection are essential for accurate performance assessments.

II. MATERIALS AND METHODS

A. Material Preparation

Valaya Alongkorn Rajabhat University is located in Pathum Thani Province, the central region of Thailand, and has many types of tropical trees. Among these, three distinct varieties can be found: rubber wood, tamarind wood, and gooseberry tree wood. Each type of wood, totaling 15 kg, underwent meticulous processing. It began with the precise division of the wood into manageable 2×4 inch pieces to ensure optimal combustion within the downdraft gasifier's chamber. This methodical approach laid the groundwork for efficient utilization of these valuable biomass resources in sustainable energy production.

The gas produced from the pyrolysis process was ignited using a lighter to verify its formation. The syngas was then supplied to a diesel engine, which was initially started and operated using diesel fuel. A switch valve selector was opened to redirect the syngas to the diesel engine, aiming to reduce diesel fuel consumption. The temperature of the syngas was monitored and recorded throughout the experiment. To maintain optimal combustion conditions, an airflow rate of 0.325 m³/h was carefully regulated. The assessment of diesel performance took place at the Thermodynamics Laboratory of the Faculty of Industrial Technology Valaya Alongkorn Rajabhat University under the Royal Patronage Pathum Thani Province. A Nissan RD28 engine was used for evaluations, with detailed specifications shown in Table I.

TABLE I. DIESEL TEST ENGINE SPECIFICATIONS

Number of cylinders	4
Cooling system	Water cooled
Engine type	Horizontal
Piston size (bore)	85 mm
Displacement of piston (strokes)	83 mm (2,826cc 2.8L)
Compression ratio	20:1
Output torque/revolutions	18 kg.m /2,400 rpm
Output power/revolutions	93bhp/4,800 rpm(max)

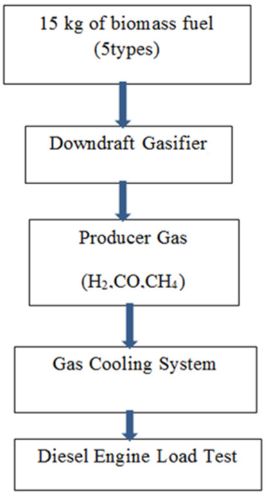

Fig. 2. Diagram of the experiment.

The gasification experiment was conducted in five steps:

- Step 1: 15 kg of rubber wood was prepared as a biomass fuel. Five thermocouples were strategically placed to measure temperatures at the external and internal furnace, the furnace exit pipe, the cyclone exit, and the cooling machine exit. Measurements were continuously recorded to monitor the system's thermal behavior. Accurate temperature data are crucial to ensure safety, optimize efficiency, and maintain gas quality. The precise weighing of biomass and detailed temperature monitoring help in analyzing and improving the gasification process, leading to better performance and yield of combustible gas.
- Step 2: 15 kg of biomass fuel was introduced into the gasifier and the combustion process was initiated by igniting the fire. Subsequently, the blower was opened to facilitate the introduction of air into the combustion chamber of the gasifier. This step initiates the gasification process, where the biomass transforms into combustible gas, setting the foundation for the subsequent phases of energy production. An electronic air supply blower with a capacity of 0.5 kW and an electric suction blower with a capacity of 0.7 kW were employed to initiate the gasifier. The suction blower was utilized to draw a flame torch to ignite wood chips within the gasifier. Once the gasification process was successfully established and the engine started running on producer gases, the suction blower was deactivated. However, the main air supply blower remained in continuous operation.
- Step 3: The valve was opened to allow the gas to flow through the heat exchanger, made from a car radiator and an electric fan, to cool the gas. This step involves the critical process of managing the temperature of the gas produced by the gasifier. This was achieved by directing the gas through the heat exchanger. The purpose of this step is to reduce the temperature of the gas before it is processed or utilized in the diesel engine.

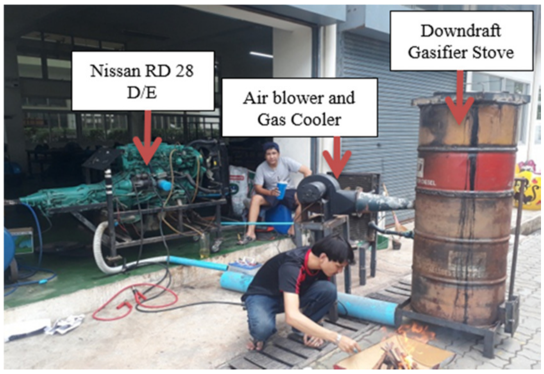

Fig. 3. Experimental setup of diesel engine and downdraft gasifier stove.

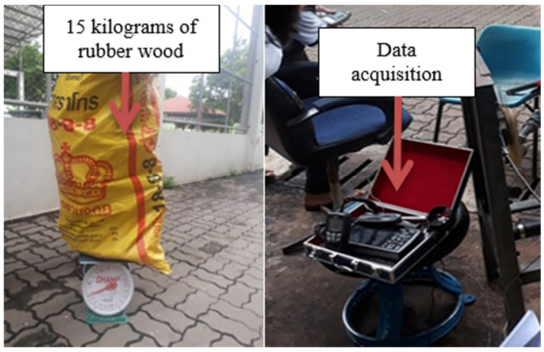

Fig. 4. 15 kg of rubber wood and temperature data acquisition.

Fig. 5. Fueling the gasifier with biomass.

Fig. 6. Gas cooling system configuration.

- Step 4: Verify whether any gas produced is escaping. When gas was detected, the gas pipe was connected to the Nissan RD28 engine. It is crucial to systematically connect the gas pipe from the gasifier to the diesel engine, as it acts as a conduit for transporting the generated gas. This step requires careful attention to detail to ensure a seamless flow of gas and an optimal performance of the diesel engine.

Fig. 7. Producer gases supply the test diesel engine.

- Step 5: When the gas was depleted, the remaining diesel fuel was recorded. Once the gas generation process was complete, the remaining resources were assessed. This involved weighing the remaining diesel fuel and the residue in which may include any byproducts or leftover materials from the experimental setup.

Fig. 8. Weighing the residue and diesel fuel following the test.

III. RESULTS AND DISCUSSION

The experiments involved burning various types of fuels, including a rubber wood sawdust blend, a tamarind wood sawdust blend, rubber wood, gooseberry wood, and tamarind wood. The fuel quantities used in each experiment were 15 kg, and the time was recorded while introducing the producer gas formed into the Nissan RD28 diesel engine. The goal was to determine how much the gas can contribute to reducing fuel consumption. The key parameters measured in the experiments were quantity, combustion time, gas formation time, and the quantity of oil consumed.

The results show that when using a blend of rubber wood and sawdust (15 kg), the combustion time was 90 minutes, gas formation took 61 minutes, and 0.8 l of fuel was consumed. For the tamarind wood-sawdust blend, the quantity was the same (15 kg) but the combustion time was shorter at 66 minutes, gas formation took 45 minutes, and fuel consumption was 0.6 l. Using pure rubber wood (15 kg), the combustion time was further reduced to 55 minutes, gas formation took 37 minutes, and fuel consumption was 0.5 l. The experiment using gooseberry wood (15 kg) exhibited a longer combustion time of 57 minutes, a gas formation time of 48 minutes, and oil consumption was 0.8 l. The test with tamarind wood (15 kg) resulted in an extended combustion duration of 97 minutes, a gas formation period of 58 minutes, and the fuel consumption was 0.8 l. In summary, the results illustrated in Table II suggest variations in the combustion time, gas formation time, and oil consumption based on the type of biomass used, highlighting the influence of biomass composition on the performance of the combustion process.

TABLE II. RESULTS OF EACH BIOMASS TYPE TESTED

Biomass type	**Quantity (kg)**	**Combustion time (min)**	**Gas formation time (min)**	**Quantity of fuel consumed (L)**
Rubberwood - sawdust blend	15	90	61	0.8
Tamarind wood saw dust blend	15	66	45	0.6
Rubberwood	15	55	37	0.5
Gooseberry wood	15	57	48	0.8
Tamarind	15	97	58	0.8

A comprehensive comparison of the gasifier performance characteristics encompasses several crucial factors. Efficiency measures how effectively biomass or other inputs are converted into usable gas, often quantified by energy-transfer efficiency. Gas quality assesses the composition of the produced gas to achieve higher purity, and so enhance combustion and energy generation. Feedstock flexibility assesses the gasifier's ability to efficiently process diverse biomass types. The tar content indicates the cleanliness of gas production, which affects downstream operations. The experiment also involved determining the heat content of the gas produced from burning biomass using the water boiling method. The goal was to evaluate and study the gas heat values from various types of wood for assessment purposes, as depicted in Figure 9. Among these options, the rubber and sawdust mix provided the highest heating value of 221.864 kJ when burned. Therefore, it had the highest heat value among the listed types of wood. Initial testing on a gasifier revealed that producer gas was initiated within 61 minutes, with a 90-minute burnout time. Engine testing on a dynamometer showed that increasing the engine speed decreased the torque and brake power. Dual syngas, fuel syngas mixed with diesel fuel, can compensate for torque and brake power, and at low engine speeds, it provides higher torque and brake power, as evidenced in Figure 10.

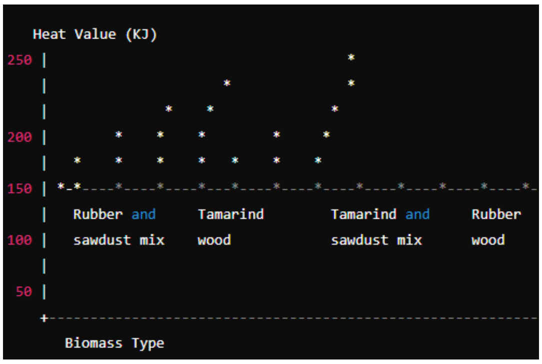

Fig. 9. Heat values (KJ) obtained from burning different types of biomass.

TABLE III. PRODUCER GAS COMPOSITION OF RUBBER WOOD SAWDUST BLEND

CO %	CO_2 %	CH_4 %	H_2 %	SGR
21.15	1.58	7.1	6.4	110

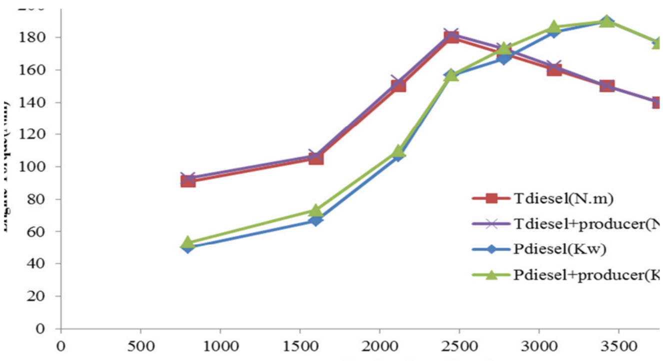

Fig. 10. Engine torque, power, and speed.

A. Engine Load Test

The rubberwood sawdust blend (7.5:7.5 kg) was selected for the diesel engine load test due to its efficiency. Critical engine performance metrics, such as speed, maximum load capacity, and torque generation, were examined. These tests provide valuable insights into the viability and efficiency of using rubberwood-derived producer gas as a renewable energy source for diesel engines. The experiment involved connecting a flywheel to the automatic gearbox of a Nissan RD28 diesel engine. After installing the engine, it was engaged in the lowest gear, and a weighted flywheel was deployed to stop the gearbox.

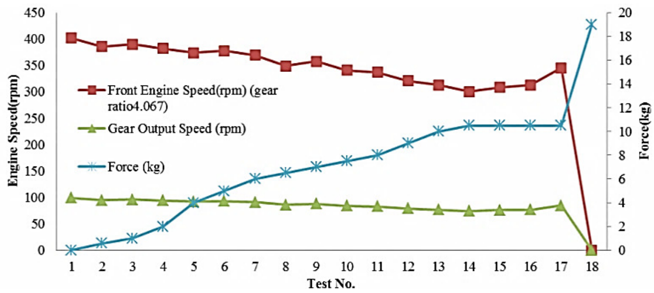

Fig. 11. Diesel engine speed, gear speed, and force during the test.

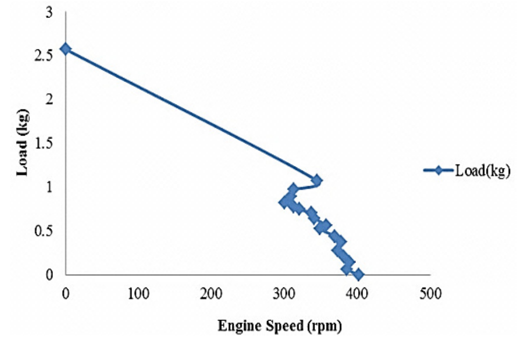

Fig. 12. Diesel engine speed and load during the test.

When the RD28 engine was engaged with a light running speed set at 978 RPM and shifted to gear L, the post-gear measurement yielded 99 RPM. Subsequently, steel blocks were incrementally added, starting from 65 g, until the flywheel, located after the gear, stopped rotating. The results indicate that the steel block needed to reach 2.573 kg. The weight recorded from the spring scale was 19 kg. The maximum torque obtained in the test was T_{max}=(19-2.573)×0.0663=1.08 kg.m or 10.68 N.m. The gear stops rotating due to the load force exerted by the steel block. Thus, it was feasible to stop gear L in the low-speed range of the RD28 engine. This was possible because the engine's end flywheel lacked alignment with the gear pulley spline, causing it to stretch.

However, the economic viability, scalability, cost-effectiveness, and practicality of combining biomass and gasifier technologies with diesel engines are important factors to consider. The potential advantages of this integration include the use of renewable, cheaper, and lower-emission biomass resources. Technical compatibility, operational effectiveness, investment costs, and the capacity to scale production to meet demand are all variables to consider when evaluating these factors. Achieving economic viability, maximizing system performance, and ensuring compatibility with current infrastructure are essential for a successful implementation that will be widely adopted. In [29], a single-cylinder Direct Injection-Compression Ignition (DI-CI) engine was examined, operating in dual fuel mode with syngas and using diesel as a pilot fuel. Syngas, composed of hydrogen (H_2) and carbon monoxide (CO), was blended in a gas mixer and introduced into the engine through a gas carburetor. This investigation focused on varying the H_2/CO ratio in syngas to assess its impact on engine performance and thermo-mechanical efficiency under load conditions from 20% to 100%. In contrast, this study presented an engine load test using a blend of tamarind wood and sawdust, a combination that has not been previously studied. Specifically, no former study has examined this mixture in a 4-cylinder engine, such as the Nissan LD-28. This study extends an earlier work conducted in a university in Pathum Thani province, aiming to evaluate the potential of biomass energy within an academic institution's context.

IV. CONCLUSION AND FUTURE SCOPE

According to the findings of this study, rubberwood was the most efficient fuel source in terms of oil usage, gas production time, and combustion time. Blends of sawdust with rubber or tamarind wood require longer periods for gas generation and combustion. Although these blends consume less oil than gooseberry wood, they use more oil than rubberwood. Gooseberry wood, despite producing gas quickly, has the longest combustion time and the highest oil consumption. Providing a practical and sustainable substitute for traditional diesel, biomass fuels support international initiatives aimed at lowering carbon emissions and dependency on fossil fuels. In Thailand, biomass waste is important. Addressing these challenges involves further investigation, including optimizing the supplied air flow rate for enhanced gasification efficiency and addressing concerns about the engine's efficiency. Achieving the necessary technological advances and support, biomass-powered diesel engines have the potential to be a major player in the shift to cleaner energy sources. The efficiency of employing rubberwood as a biomass fuel in contrast to other wood kinds such as tamarind and gooseberry wood is the novelty highlighted in this work.

With continuous research aimed at enhancing fuel processing methods, engine modifications, and supply chain logistics, biomass-powered diesel engines have a bright future. Genetic engineering and agricultural innovations can improve biomass yield and quality, which could further facilitate the switch to renewable diesel fuels.

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