Linking biofuel chemistry to engine performance: a study from Vietnam

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Abstract. The chemical composition of biofuels, determined by their biological origin, directly influences their combustion characteristics and, consequently, engine performance. This study focuses on developing a testing system to quantify the relationship between the biochemical properties of biofuels and the operational capacity of internal combustion engines. The platform enables precise measurement of how variations in fuel composition—affected by feedstock type and production process—impact engine parameters. Validated on a Mitsubishi 4G54 engine with over 90% accuracy, the system provides a critical tool for biochemists and bioengineers. It facilitates the screening and optimization of biofuels by linking their molecular-level properties to macroscopic engine behavior, thereby accelerating the development of efficient and environmentally sound biofuels tailored to the Vietnamese context.

1 Introduction

According to data from the Vietnam Register, as of September 2022, the total number of cars in circulation in Vietnam is 4.94 million. Thus, the number of cars per 1,000 people in Vietnam is about 50. The number of cars consumed in 2022 in Vietnam has reached about 510,000 cars. Also according to many forecasts, the Vietnamese automobile market can reach a scale of 700,000-800,000 vehicles/year by 2025 and over 1 million vehicles/year by 2030. Of the vehicles currently circulating in Vietnam, the majority is to use an internal combustion engine [1]. Therefore, research and testing of internal combustion engines in Vietnam is still developing. Internal combustion engines continue to develop in the world in the following directions: using hybrid technology, improving performance and environmental friendliness, and using alternative fuels. Leading the research and development of new generation internal combustion engines are Toyota, BMW,...

The engine test bed is a very important equipment system for the engine industry, thanks to which it is possible to evaluate indicators of economic and technical features, the level of emissions affecting the environment as well as durability and reliability of engine details [2-4].

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In Vietnam, engine power testbeds have long been of interest to many researchers, especially at research centers of universities and academies. However, no unit has designed and manufactured a complete commercial engine power test stand that can be supplied to the market, but mainly research to improve old test stands to improve their performance.

In Vietnam in particular, there are currently many devices to measure engine power such as: Weinlich and Land and sea,... The test bench systems of these companies are all very modern and meet the current test cycles to recognize the type. according to EURO standards. However, the cost of these test stands is very expensive and not suitable for Vietnam's conditions.

The engine test bed consists of the braking and measuring unit and the control unit (evaluation, display and control unit with MP Computer) (Fig.1) [5]. Often the control unit is swivelling mounted over the braking and measuring unit. In another design the control unit is contained in an operator's desk stand and the braking and measuring unit is connected by cables and plugs to the control unit.

The engine to be tested is connected to the brake by a special cardan shaft. Mobile supports (truck RWB or universal engine support) holding the engine are moved to the braking and measuring unit and fixed to it by one or two screws. While moving the engine on its support to the braking and measuring unit, the engine is connected to the brake by sliding together the multiple-spline parts of the cardan shaft. The cardan shaft is positioned in a solid protective housing fixed to the braking and measuring unit. The brake is protected against accidental contact by means of a protective grating. A foundation or fastening to the floor are not required, but an even floor surface.

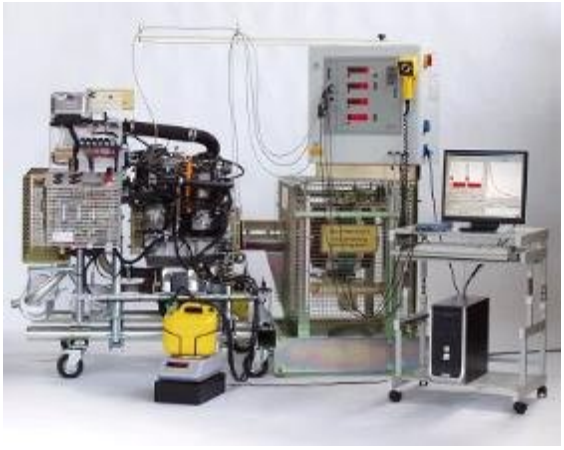


Fig. 1. MP 100S engine test bed

MAHA LPS 3000 truck dynamometer is for testing trucks and buses with axle weights up to 15 tons. The program can test manual or automatic transmission vehicles and reports engine power, drive wheel power and the difference between them. Furthermore, moments are measured and displayed at each time during the test (Fig. 2) [6].

Test driving of the vehicle takes place under actual loads and a series of different tests and measurements are performed to diagnose safety functionality. The road simulator includes a roller element to bear the load during operation and is equipped with a support roller to drive the direction shaft. The device also includes a PC-based communication console equipped with a 19" display, keyboard, printer, remote control, and more.

Fig. 2. MAHA LPS 3000 truck dynamometer

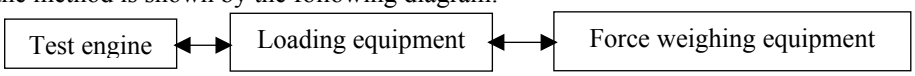
Figure 3 shows the engine power measurement system developed by Land & Sea, Inc [3]. This is one of the popular devices in the automotive engine testing industry, helping to accurately measure and evaluate the performance of internal combustion engines.

Fig. 3. DYNOmite™ Automotive Engine Dynamometer Systems

2 Methods and discussion

Currently, there are many methods and devices to determine engine capacity, but most of them are based on torque and rotation speed. For simplicity, it can be grouped as follows: Balanced type of useful capacity determination method; Method for determining unbalanced useful capacity; Method for determining capacity used in diagnosis.

Balance type power determination method: In this method the motor rotates a device whose rotor shaft is connected to the motor shaft. The device's stator can oscillate horizontally. When the motor works, it produces a torque that causes the device's rotor to rotate (ie, braking the motor's movement), requiring an intermediate medium. When the rotor acts on the intermediate medium, it causes the body (stator) of the device to rotate. To hold the body back, people try to apply a braking force (moment) to the body. The braking force (torque) is measured by another device called a force balance device. The principle diagram of the method is shown by the following diagram:



This method is widely used on test beds of engine factories and research agencies. This method essentially measures force (moment) and then calculates power according to the formula [2,3,7,8]:

$$N_e = \frac{\pi.n}{30}\left(M_x + M_{ms} + M_f\right) = \frac{\pi.n}{30}\left(P.l \pm M_{ms} + M_f\right) \quad (1)$$

where:

M_x - Torque is obtained through measuring equipment;

n - Motor rotation speed;

P - Force obtained on the measuring device;

l -The lever arm on the device exerts the load;

M_{ms} - The friction moment of the measuring device at the shaft bearings;

M_f - loss torque on the load-causing device.

Method for determining the power of unbalanced motors: Measuring devices of this type have the following characteristics: The motor needs to be determined to rotate the rotor of the device, while the body of the device is stationary, this device gives us the parameters on the meter (voltmeter, ammeter, pressure gauge...) from which to calculate the engine power.

These devices do not have force-balancing devices attached. This is a method of determining engine capacity at the place of use. Used in small capacity engines. It is especially important in the field of fishing vessels.

Method of measuring engine power used in diagnosis (usually used in diagnosing the technical state of cars):

Measuring active torque on wheels:

- Applicable to engines installed on transport vehicles;
- Use a device to measure the brake force on the wheel, thereby calculating the torque and engine power.

The main error of the method is not knowing the exact performance of the transmissions on the vehicle to be measured.

Measurement method without brakes: this is a simple method because it does not require removing the engine from the vehicle. People take advantage of the mechanical losses of non-working cylinders to load the cylinders. When measuring the rack in the maximum position (or the throttle is fully open), kill the cylinders used as load, leaving only one working cylinder to measure the engine speed, the measurement time is only about one minute. Change the other cylinders one by one and record the rotation measurements.

Measure power by acceleration method: based on the principle that the change in angular speed of the engine depends on the engine power, the greater the engine power, the greater the acceleration. The essence of the measuring tool is the acceleration time from low speed to rated speed when accelerating suddenly, the indicator will be engine power.

Measuring power using a power test brake: this is the most accurate measurement method but requires removing the engine from the car and placing it on the test brake. Loading the brakes can be by friction (mechanical brakes), water resistance (hydraulic brakes) or electromagnetic force (electric brakes). Engine power is calculated according to the formula:

$$N_e = M_{e.} = M_e.\frac{\pi.n}{30} \quad (2)$$

The chain balances the braking torque Mc.

The author proposes to build an engine power test stand with commercialized equipment. The construction of such a test stand is suitable for developing countries, especially Vietnam. The diagram of the engine power test bed is introduced in Figure 4. Main functions of the

test the capacity of internal combustion engines: determining engine power; determining fuel consumption output, …

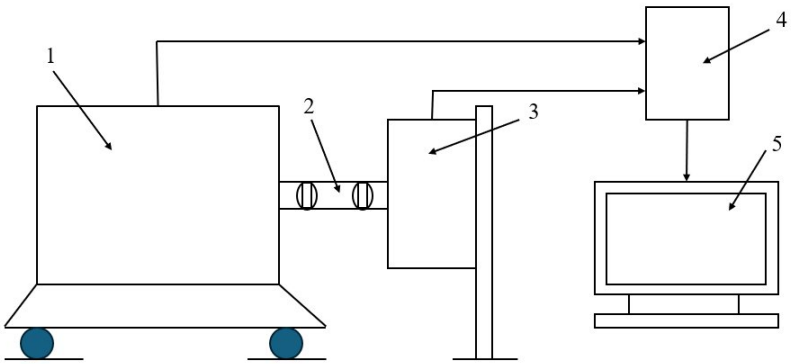


Fig. 4. Diagram of engine capacity test bed in Vietnam: 1 – engine under test; 2 – coupling; 3 – DYNOmite Dynamometers; 4 – Q.station 101; 5 – PC

Main technical parameters of the engine power test stand:
- Rated power: 150 KW;
- Rated rotation speed: 6000 (rpm),…

In the capacity test stand, the resisting moment generator is a very important structure in the test stand. This is the part that connects the test engine to the measuring sensor before the results are displayed on the computer. The accuracy of the measurement depends greatly on this structure. Therefore, the research team used the Dynometer load generator from Land and sea (Figure 5) [3].

Fig. 5. Land & Sea's DYNOmite Dynamometers

The Q Station 101 by Gantner Instruments is an advanced testing and data acquisition device that serves as the core component of the company's Q.series product line [9]. Designed to meet the measurement and testing demands across various domains, from industrial applications to research, this device stands out with its high-speed data acquisition capabilities, flexible programmability, and exceptional integration potential through multiple interface connections.

Fig. 6. Q Station 101 by Gantner Instruments

The Q Station 101 offers data acquisition capabilities at rates of up to 100 kHz per channel, an impressive benchmark in the field of measurement technology. The device can process multiple channels simultaneously without performance degradation, for instance, supporting 8 channels at 100 kHz or 128 channels at 10 kHz. This capability is particularly valuable in high-precision applications such as vibration analysis, acoustic measurements, and high-speed mechanical testing, where transient events must be captured in detail to ensure reliable results.

Equipped with multiple interfaces, including Ethernet, USB, CAN, and fieldbus options such as EtherCAT, the Q Station 101 seamlessly integrates into diverse environments, from laboratory settings to industrial production lines. The Ethernet interface enables high-speed data transmission over networks, facilitating remote monitoring and control.

Synchronization is a critical factor when working with multiple channels or distributed systems. The Q Station 101 employs advanced synchronization techniques, achieving an accuracy of up to ±1 μs, ensuring that all modules and systems operate in perfect coordination.

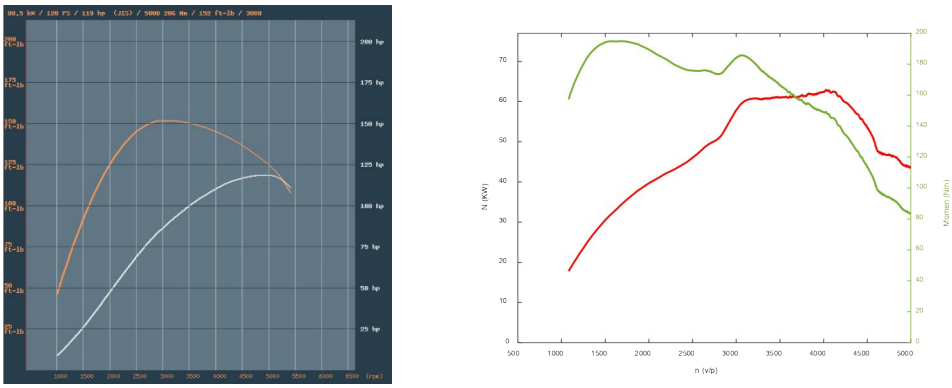
With 8 digital inputs and 4 digital outputs, the Q Station 101 can interface with external devices such as sensors, actuators, or signal indicators, enhancing its versatility in complex measurement and automation applications.

3 Result

The experimental engine is the Mitsubishi 4G54 engine, which is quite commonly used in Vietnam. Its technical specifications are presented in Table 1, and the test bench diagram is shown in Figure 7.

Specification	Value
Engine Type	Inline-4, SOHC, 2 valves per cylinder
Displacement	2,555 cc (≈ 2.6 L)
Bore × Stroke	91.1 mm × 98.0 mm
Compression Ratio	8.4 – 8.8 : 1 (depending on version)
Maximum Power	88.5 kW (≈ 119 hp / 120 PS) in 5000 rpm
Maximum Torque	206 N·m (≈ 152 ft·lb) in 3000 rpm
Fuel System	Carburetor
Balance Shaft System	Dual 'Silent Shaft' balance system for vibration reduction
Crankshaft Bearings	5 main bearings

Fig. 7. Testing mitsubishi 4G54 engine on design test stand



a – Specifications from the manufacturer b – Specifications from the experimental results

Fig. 8. Performance characteristics of the mitsubishi 4g54 internal combustion engine

The results of the external characteristic curve test show that the characteristic parameters are almost identical to the data published in the technical documents. The experimental graph matches >90% with the manufacturer's parameters, proving that the test platform and engine operate stably and according to the design. This shows that the experimental results are consistent with the theory and published data, and helps to verify the accuracy of the measurement and the actual operation of the engine.

4 Conclusion

Building an engine power test stand to become an important tool in the automobile industry, engine manufacturing and engine technology research and development in Vietnam:

The engine power test stand allows measuring the power produced by the engine under test conditions. This helps determine the engine's performance and working ability.

By measuring power and other parameters such as torque, one can evaluate the overall performance of the engine under different conditions.

When the engine is put on the test stand, it can help detect technical problems, poor performance, or failures during operation.

Before a new engine is installed in a vehicle or machine, a test run on an engine power meter helps ensure that it operates properly and meets technical requirements.

The engine power test stand provides a testing environment to adjust and check engine parameters, helping to ensure that it operates stably and efficiently.

- The built engine power test stand also serves as a load generating device with other research subjects not only for internal combustion engines.

The experimental results of the power and torque characteristics of the Mitsubishi 4G54 engine show that the engine test bench operates stably and meets measurement requirements effectively. The obtained characteristic curves exhibit trends consistent with the manufacturer's data, demonstrating that the load system, speed sensors, and torque sensors function accurately, with low latency and reliable continuous data acquisition. The deviations between experimental and theoretical results fall within acceptable limits, mainly due to actual operating conditions, engine wear, and environmental factors, rather than measurement equipment errors. This confirms that the test bench has high reliability in determining the speed, power, and torque characteristics of the engine, and it can be used for tuning, verification, or evaluating engine performance under various operating conditions.

Acknowledgments

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