Modification of Power Transmission by Electric Motor and Gasoline Engine in Small Hybrids Boat

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Abstract

Thailand often uses the small boats from internal combustion engine vehicles for transportation. It releases the pollute problem such the air and the sound. Therefore, the objective of this research is developing a small hybrid boat that uses both gasoline engine and electric motor. This research designs a small hybrid boat powered by an electric motor 1,500 W combined with a gasoline engine 6.5 HP. The result was that the electric motor combined with the gasoline engine could run independently and automatically switch to the engine if the battery died. The gasoline engine uses energy 83.85% more than the electric motor. The electric motor does not produce noise at high rpm, in contrast to using a noisy gasoline engine that complies with the required regulations. Gasoline engines can exacerbate the negative environmental effects of carbon monoxide emissions to communities, while using electricity will not release environmental pollution. However, if applied for commercial uses at speeds of more than 12 km/h, the new ratio must be modified in accordance with the intended use.

Keywords:
Small hybrid boat, Gasoline engine, Electric motor, Power Transmission

1. Introduction

Thailand has demand for energy has been rising in the past. The energy usage is switched to renewable energy sources. Thailand is still dependent on the importation of fuel. Thailand commercial energy demand in 2022 totaled 1,520 thousand barrels per crude oil equivalent, an increase of 9.3% from the demand in 2021. The demand increased for all energy types, especially natural and coal/lignite. The shares of commercial energy demand were the following: petroleum products 53%, natural gas 35.9%, coal/lignite 17.7% and electricity/import electricity 22% [1]. Therefore, the Thai Royal Government issued the Thailand Power Development Plan 2015–2036 (PDP2015) use energy consumption was 47 percent from oil, 33 percent from natural gas, 14 percent from coal, 2 percent from hydropower, and 4 percent from other sources, which also includes developing renewable energy [2]. In addition, the government has also become interested in promoting electric vehicles (EV) usage and building the EV manufacturing industry in Thailand. In 2015. That is one solution that aims to reduce air pollution and greenhouse gas emissions caused by internal combustion engine vehicles (ICEV). They created the national EV roadmap and set a target to create 1.2 million EVs by 2036 [3].

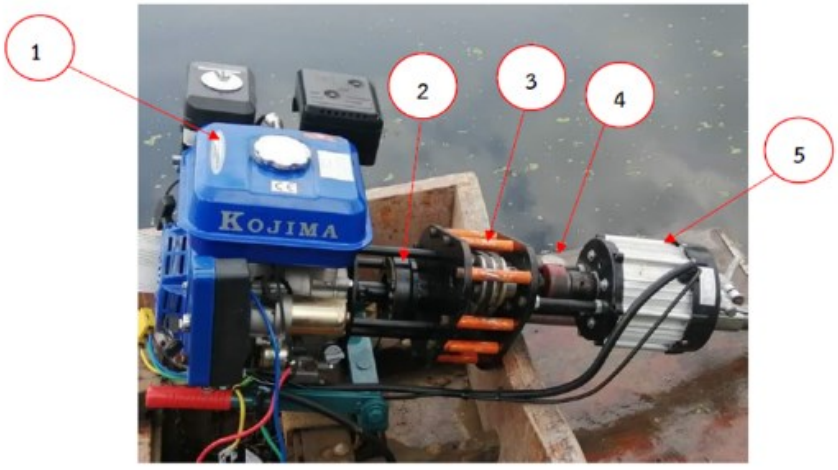
The small boats are internal combustion engine vehicles often used for transportation in Thailand. It releases exhaust gases that pollute the air when burning fossil fuel. There is no law regulating the amount of boat exhaust emissions, which results in environmental problem such as noise, water pollution, and air pollution. The fuel for engine use fossil fuel, which is expensive because crude oil prices change due to Thailand cannot manage independently [4]. In literature review was found gasoline

used in boat transportation was 1,357.80 L release CO_2 emissions 20,389.14 CO_2-eq in Kok Mak Island, Thailand [5]. In addition, the concentration was much higher than ambient concentrations at sites impacted by vehicular traffic. [6]. According to PDP 2015 and the EV roadmap of the Thai Royal Government, air pollution and greenhouse gas emissions must be decreased.

Therefore, the aim of this research is to develop a small hybrid boat that uses both electric power and gasoline engine to reduce air pollution, noise pollution, and fuel consumption. The modification was installed the electric motor with the gasoline engine, both components can run independently while still using the small boat to transfer power and produce all switch functions. It will automatically switch to the engine if the battery dies.

2. Experimental detail

The aim of this study is to design a small hybrid boat powered by an electric motor and gasoline engine. The boat is long (5 m), wide (0.8 m), and tall (0.5 m). A small hybrid boat component consists of a gasoline engine, a solenoid cluster, a set of speed reducer, a cluster of ventricle motor, and an electric motor shown in Fig 1. The gasoline engine used 6.5 HP with 12 Nm of torque at 2,500 rpm. The electric motor use 1,500 W working at 75% load. It has 1.5 Nm of torque at 60 rpm. The electric motor uses 4 batteries by PMF 50L of the 3K BATTERY brand, with a voltage of 13 V and a current of 50 A. The battery weighs total 48.12 kg. The mechanical hybrid transmission was designed with a set of speed reducers made of steel SS400 (thin at 6 mm). The steel sheets are in parallel, with a steel bracing in the middle between the two steel sheets, leaving the middle to install the pulley and belt. Driving a small boat by a propeller, its size was 19.05 cm and the pitch distance was 11 cm.



1. Gasoline engine
2.Solenoid cluster
3. Set of speed reducer
4. Cluster of ventricle motor
5. Electric motor

Fig. 1 Component of a small hybrid boat.

The experiment was testing the fuel and electricity consumption at each speed, noise pollution, and air pollution emissions. The fuel consumption is normally represented as the ratio of fuel consumed per distance travelled. Which given speed in kilometers per hour (km/hr), fuel consumption can be calculated as follows (1) [7]:

$$\text{Fuel Consumption (l/km)} = \frac{\text{Fuel Flow } (\frac{\text{l}}{\text{hr}})}{\text{Speed } (\frac{\text{km}}{\text{hr}})} \quad (1)$$

Energy consumption is measured by multiplying the number of power units consumed within the period over which it has been consumed. Hence, the energy consumption formula or the power consumption formula is given as equation (2), where P is power units in watts and t is time over which the power or energy was consumed [8].

$$\text{Energy Consumption (kWh)} = \text{P x } \frac{\text{t}}{1{,}000} \quad (2)$$

According to the Pollution Control Department, noise pollution has established general noise levels. The 24-hour average noise level is not more than 70 decibels A and has a maximum value of not more than 115 decibels A. And the Ministry of Science, Technology, and the Environment in 1994 set standards for noise levels from traffic water vehicle. It is stipulated that the sound level measurement of a ship moored and in neutral gear measured at a distance of 0.5 meters must not exceed 100 decibels A [9]. The noise measurement was done using Sound Level Meters.

The standard air pollution emissions according to emission standards for vehicles in conjunction with fuel, which standards gasoline engine according to Euro 4 was released CO, HC, NOx and PM of 1.0, 0.1, 0.08 and no limit, respectively [10].

3. Results and Discussion

3.1. Result of the design modification electric power combined with the engine

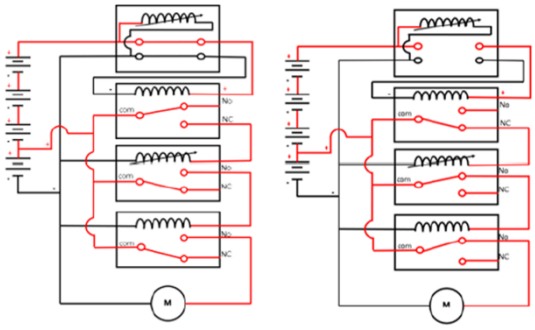
Design, modification, and installation of electric power in conjunction with the gasoline engine. It was found that it can be installed very well and can actually be used. An operational test for the gasoline engine was done for 3 km test drive. It was found that the speed that was achieved was not different from the normal gasoline engine, indicating that the clutch was selected. The centrifugal force used for the power cut has no loss of torque from the clutch assembly. The test run for the electric motor was carried out for 3 km, similar to the gasoline engine. It has the highest driving speed less than the speed of the gasoline engine, making the use of the electric motor speed slower than the gasoline engine. Because the gasoline engine has a reduction, it has enough torque to drive. Due to the reduction in torque to provide enough torque to drive according to design first [4].

A small hybrid boat was balanced while running normally. Because the mounting was designed to tilt in the opposite direction of the gasoline engine block and cylinder head, causing the weight to be counterbalanced by the transmission. As a result, the steering balance is no different from the original.

3.2. Switching tests of electric motors and engines for small boats

Switching from an electric motor to an gasoline engine when the battery is operating automatically by designing and constructing a switch mode that can be used to switch to an automatic engine when the battery runs out. In an experiment where the battery was charged to 100% (51.5V) and then driven down to 50% (48V) in shown in Fig 2, it was discovered that this switching mode may instantaneously stop and start the engine. As a result, power transmission will be halted temporarily. However, it has the ability to automatically keep running the same boat engine.

Mode changing by using a manual control switches the working mode from electric motor to gasoline engine. It can switch the operating mode manually, which has proven to be useful. There is the same problem with the automatic mode switch: a sudden breakdown of the system.



(a) Voltage more than 48V (Not operate) (b) Voltage less than 48V (Operate)

Fig. 2 Designing and constructing a switch mode.

3.3. Result of speed test

The speed test for the gasoline engine and electric motor It was found that the speed of gasoline engine and electric motors increased with time. The electric motor has a maximum average speed of 12.36 km/h, which is similar to previous research speed of 13.6 km/hr [11]. While the gasoline engine average speed has a maximum of 16.36 km/h. The speed tends to be steady and nearly constant at 6 s as shown in Fig 3 and Table 1.

The maximal acceleration of the gasoline engine and the change in speed behavior until the beginning speed achieves a steady state are found when the speeds that the gasoline engine and the electric motor can create are compared. The average speed from all 5 tests was 16.34 km/h of gasoline engine, which was height than the electric motor average speed was 12.36 km/h. The electric motor has maximum speed test result was 24.3% less than that of the boat with gasoline engine. However, the normally villagers use boats being driven in rivers or canals at low speeds. The size of the electric motor must be increased if the boat is used for commercial purposes that require higher speeds of more than 12 km/h, and the new ratio must be adjusted according to the desired application.

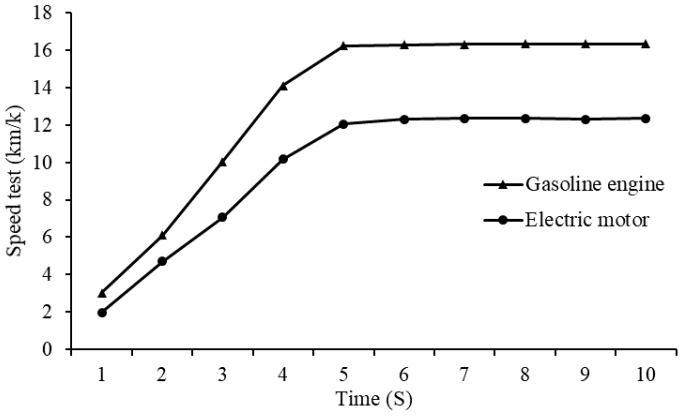


Fig. 3 speed test of gasoline engine and electric motor.

Table 1 Average speed test of gasoline engine and electric motor.

Time (s)	Average speed (km/hr)	
	Gasoline Engine	Electric Motor
1	3.02	1.98
2	6.12	4.7
3	10.06	7.06
4	14.2	10.18
5	16.26	12.06
6	16.3	12.3
7	16.32	12.36
8	16.34	12.36
9	16.34	12.32
10	16.36	12.36

3.4. Energy consumption

Test of fuel consumption for gasoline engines. The test takes run 1 kilometer at speeds of 3, 6, 9, and 12 km/h. As can be seen, fuel consumption increases as engine speed rises too. While the speed of the gasoline engine is decreased, the amount of fuel will also be decreased. The highest fuel consumption speed at 12 km/h is 17.65 MJ/km, resulting in an approximate average fuel cost of 13.19 baht/km.

The electric motor at 1 km was tested at speeds of 3, 6, 9, and 12 km/h. The battery was volt results decreased. And can determine the energy consumption by fully charging the battery, using a load to pull energy from the battery until it reaches an average volt drop at different speeds, and then charging. The battery is now fully installed. With a digital electric energy meter, the amount of recharged electricity will be measured while charging by taking the value from the electricity entering the charging cabinet to be used for input charging. It is obvious that battery consumption increases with the electric motor speed. But as the electric motor speed decreases, the battery capacity will also decrease. The highest fuel consumption speed at 12 km/h is 2.85 MJ/km, resulting in an approximate average fuel cost of 3.5 baht/km with less than fuel consumption of gasoline engines shown in Table 2.

The percentage difference between various energy usages was calculated. It was discovered that the gasoline engine used 81.35% more energy at 3 km/h than the electric motor did at 6 km/h. At a speed of 9 km/h, the gasoline engine used 80.12% more energy than the electric motor. At a speed of 12 km/h, the gasoline engine used 83.85% more energy than the electric motor, which compares the test results of the energy consumption of the gasoline engine and electric motor. It consumes 80.57% more energy than the electric motor.

Table 2 Energy consumption.

Parameter	Speed (km/hr)			
	3	6	9	12
Fuel				
Fuel volume (ml)	213.66	276.97	353.46	522.29
Fuel consumption (MJ/km)	7.2	9.36	11.95	17.65
Cost of fuel (Baht/km)	5.39	7	8.92	13.19

Parameter	Speed (km/hr)			
	3	6	9	12
Electricity				
Electricity using (kwh)	0.37	0.52	0.65	0.80
Electricity consumption (MJ/km)	1.34	1.86	2.32	2.85
Cost of electricity (Baht/km)	1.65	2.29	2.85	3.5

3.5. Noise pollution test

For measuring the noise level from the particular gasoline engine speed in decibels, noise level meters are used. It should not be louder than the legal limit and not be damaging to those using or hearing it. Table 3. shows the gasoline engine and electric motor noise levels at their rated speeds in the test. When compared to the electric motor and the gasoline engine at maximum speed, the gasoline engine has a noise level of 101.7 dB, which is higher than the allowable noise level of 85 dB. However, the noise level is regarded as being within acceptable limits. According to the Pollution Control Department, noise pollution set at a distance of 0.5 meters must not exceed 100 decibels.

Table 3 Noise pollution.

Speed (rpm)	Electric motor (db)	Gasoline engine (db)
500	55.7	86.7
1,000	61.8	87.1
1,500	65.8	89.7
2,000	73.7	92.6
2,500	76.7	96.5
3,000	77.3	101.2
3,500	81.0	101.7

Table 4 Air pollution emission of the engine engine.

Speed (rpm)	CO (%)	Standard of CO (%)	HC (ppm)	Standard of HC (ppm)
500	5.33	2.5	225	1,000
1,000	5.47	2.5	180	1,000
1,500	5.89	2.5	141	1,000
2,000	5.36	2.5	135	1,000
2,500	5.36	2.5	134	1,000
3,000	2.65	2.5	84	1,000
3,500	2.87	2.5	82	1,000

3.6. Air pollution test

According to Department of Transportation emissions measurement standards, pollution testing will be carried out on existing outboard engines. According to the pollution test findings from the original boat engine, there was a significant amount of carbon monoxide gas. At 1,500 rpm, the highest occurrence 5.89%, was above average. According to the experimental findings, the hydrocarbon gas

nevertheless complied with the standard's value. The original boat engines will pollute the environment with carbon monoxide, especially in areas where there is a lot of boat activity. While using electricity won't cause environmental pollution. But if there is no method to dispose of it is disposed of improperly, it will lead to future issues with electronic trash (e-trash).

4. Conclusion

The design, modification, and installation of electric power together with the original split engine for transmission by using the same propulsion shaft to propel small cruise ships that are less than 5 meters in length can propel the ship efficiently. Although the maximum thrust when using electric power is less than that of the gasoline engine, it is enough to propel the boat as needed. Design and construction of an automatic switching mode when electric power is switched to marine engine power mode It was found that the aforementioned toggle mode design works perfectly. It can instantly switch to the gasoline engine when the power runs out. Comparison of the speed at which the gasoline engine can operate more quickly than an electric motor. The electric motor average speed was 12.36 km/h, compared to the gasoline engine average speed of 16.34 km/h. At a speed of 12 km/h, it was discovered that the engine uses 83.85% more energy than the electric motor. It was discovered that using an electric motor does not produce noise at high rpm, in contrast to using a noisy exhaust engine that complies with the required regulations. Gasoline engines can exacerbate the negative environmental effects of carbon monoxide emissions to communities, while using electricity will not result in environmental pollution.

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