INVESTIGATION OF GASOHOL PFI PERFORMANCE AND EMISSION FOR LONG-TAILED BOAT APPLICATIONS

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ABSTRACT

Long-tailed boats are widely used in Thailand. The engines installed for such boats are old diesel, gasoline, or general purpose engines. Generally, these engines are not designed for boat. Thus using these engines might cause many problems such as air/noise pollution, low performance, and high fuel consumption. Furthermore, since the world is now focusing on environment protection. Thus, in order to continue using these engines, a modification is required. For this reason we can add the electronic control unit to control the engine to work more efficiently e.g. increasing the efficiency of the fuel consumption and also decreasing the emission from an engine.

Using low emission fuel is another propose in attempt to reduce emission. Ethanol is one of interesting choice. It can help reducing the global warming by the carbon neutral especially for the crops that use carbon dioxide in photosynthesis which can make up for the release emission. Ethanol is an oxygenated fuel that can improve the complete combustion and also reduce the emission (CO HC PM) from incomplete combustion. In this research, Gasoline, 1ZZ-FE, 1.794 litres, is used as boat engine. The experiment setup, this engine will be fuelled with E0 to E85 and will be operated at 30 to 50% load condition for performance analysis. Moreover, the emission from the engine will be measured by using gas analyser for emission analysis purpose.

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CHAPTER 1
INTRODUCTION

1.1 Background

Long-tailed boats are widely used in Thailand. The engines installed for such boats are old diesel, gasoline, or general purpose engines. Generally, these engines are not designed for boat. Thus using these engines might cause many problems such as air/noise pollution, low performance, and high fuel consumption.

Furthermore, since the world is now focusing on environment protection. Thus, in order to continue using these engines, a modification is required. For this reason we can add the electronic control unit to control the engine to work more efficiently e.g. increasing the efficiency of the fuel consumption and also decreasing the emission from an engine.

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In this research, gasoline port-fuel injection spark ignition engine (PFI Engine) fuelled with gasoline, gasohol and hydrous ethanol is use as the boat engine.

In an experimental study, the effects of using ethanol–gasoline fuel blends (E10, E20 and E85), hydrous ethanol (Eh95) and pure gasoline on spark ignition engine performance and exhaust emission that use in long-tailed boat application were investigated. The tests were performed on an engine dynamometer at different load of long-tailed boat's condition.

The results from using an electronics control is improve brake power, brake thermal efficiency and fuel consumption. And reduce regulated pollutant and particle emissions produced by internal combustion engines, as well as to reduce the greenhouse effect impact of transportation.

1.2 Objective

To investigate effect of ethanol–gasoline fuel blends and hydrous ethanol in port-fuel injection spark ignition boat engine.

To improve fuel efficiency (brake specific fuel consumption and brake specific energy consumption), break thermal efficiency and exhaust emission of gasohol port-fuel injection spark ignition boat engine.

1.3 Scope of Work

1.3.1 Power and torque calculation for choosing a proper engine

First, this study is the calculation of required power and torque for any boat condition to choose the proper engine for the prototype boat.

1.3.2 Investigated the effect of using ethanol-gasoline blended fuel on an engine

This study focused on investigated the effect of the different fuel using on an engine.

1.3.3 Improve the engine control system to use ethanol-gasoline blended fuel

This study focused on improving an engine control system by adding sensors (Wind band oxygen sensor and flex fuel sensor) for making an engine work more precisely.

CHAPTER 2

LITERATURE REVIEWS

2.1 Introduction

The rapid depletion of the world's crude oil reserves and environmental considerations has focused on the clean, renewable and sustainable energy systems. The energy crisis and environmental pollution created an incentive to study and evaluate alcohols as a fuel in spark ignition engines. The increasing of air pollution is one of the most important problems of developed countries today. Exhaust emissions from motor vehicles was the main problem on this pollution. It is not sufficient to change the design of motor to cope with the legal regulations, so it is necessary to continue to work on alternative fuel technologies. [1]

The sources of greenhouse gas emissions in the European Union (EU-27) in 2010. Around 80% came from energy-related sources, with about 63% from direct combustion of fuels, including about 20% from fuel combustion for transportation as shown in figure 2.1

The main alternative fuels utilized so far are oxygenates (alcohol, ether etc.), vegetable oils and their esters, gaseous fuel (hydrogen, liquefied petroleum gas etc.), gas to liquids (GTL) and coal derivatives. Ethanol has attracted attention worldwide because of its potential use as an alternative automotive fuel. [2] A primary alcohol "Ethanol" that produced from plants is one way to reduce pollution from incomplete combustion and global warming from fossil fuels. It is a carbon neutral fuel because the plants that used for produced it used carbon-dioxide for the photosynthesis, so it compensate with carbon dioxide that occur from the engine. It is also reduce carbon monoxide, hydrocarbon and particulate matter from the exhaust gas due to the oxygen atom in itself.

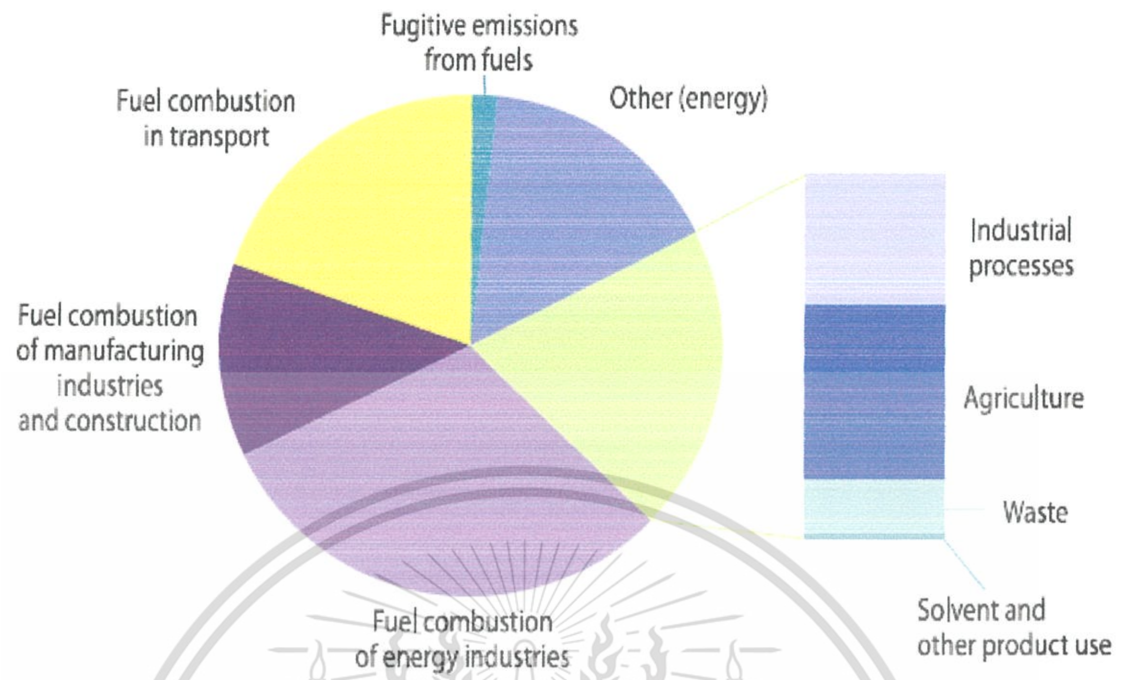


Figure 2.1 Sources of greenhouse gases in the European Union, 2010

In this chapter, the reviewed papers will be presented the fundamental of boat resistance calculation, effect of injection timing and effect of using alternative fuel. Finally, In order to improve Engine performance and exhaust emission, influenced parameters were considered.

2.2 Spark ignition engine emissions

The emission levels of a spark-ignition engine are particularly sensitive to air–fuel ratio. This can be seen in Figure 2.2, taken from Heywood (1988), which shows schematically the level of emissions from a spark-ignition or Otto cycle engine as a function of relative air–fuel ratio. At rich air–fuel ratios, with ϕ greater than 1.0, unburned HC levels are high since there is not enough air to completely burn all the fuel. Similarly, CO levels are high, because there is not enough oxygen present to oxidize the CO to CO_2. CO almost completely disappears, while HC emissions reach a minimum near ϕ=0.9. For ϕ less than about 0.9, some increased misfiring occurs because of proximity to the lean misfire limit, and HC emissions begin to rise again. The main factor in production of NO is combustion temperature: the higher the temperature, the greater the tendency to oxidize nitrogen compounds into NO. Since the combustion temperature is at a maximum near stoichiometric conditions where ϕ=1.0, and falls off for both rich and lean mixtures, the NO curve takes the bell shape shown in Figure 2.1 [4].

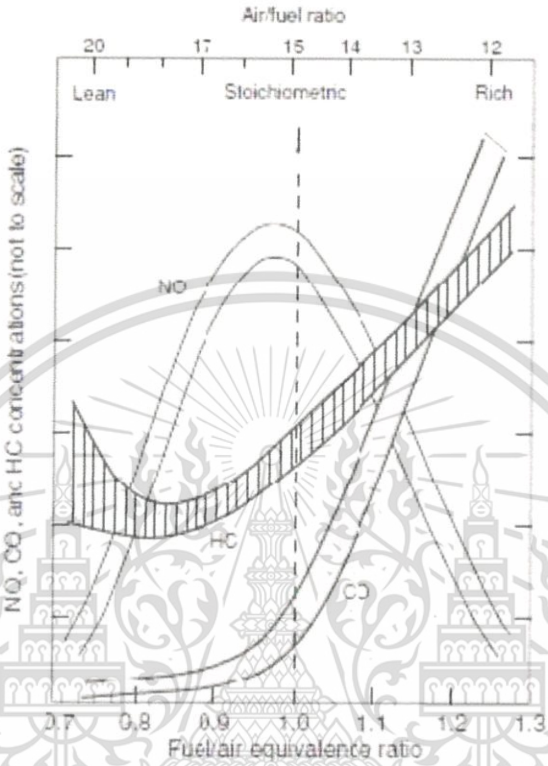


Figure 2.2 Emissions as a function of fuel–air equivalence ratio ϕ [4]

2.3 Alternative fuel: Ethanol

The majority of the energy used today is obtained from the fossil fuels. Due to the continuing increases in the cost of fossil fuels, demands for clean energy have also been increasing. Therefore, alternative fuels sources are sought. Some of the most important fuels are biogas, natural gas, vegetable oil and its esters alcohols and hydrogen. Ethyl alcohol, which is one of the renewable energy sources and is of ethyl alcohol with comparison to gasoline are given in Table 2.1 [2].

Ethanol (C_2H_5OH) is an ecological fuel, as it is obtained from renewable energy sources. It is a color less, transparent, neutral, volatile, flammable, oxygenated liquid hydrocarbon, which has a pungent odor and a sharp burning taste [1]. At present, however, blends of bioethanol and gasoline are more common in vehicles with fuel injection engines [3].

Since the oxygen contain has positive effect on environment. In spite of its positive effect when used in gasoline engine as alternative fuel, it is necessary to make some modification on the engine. The fuel system requires more fuel. The vehicle takes less distance with alcohol fuel than gasoline. Because of the first cold starting problem of the pure ethanol, the blend called E85 has a widespread usage as alternative fuel. This fuel consists of 15 vol% unleaded gasoline and 85 vol% ethanol. However, the other blend consisting of 90% gasoline and 10% ethanol called as gasohol. In addition, the flame of the alcohol is colorless in the natural burning processes and this is another advantage of alcohols [4,5].

Presently, ethanol is prospective material for use in automobiles as an alternative to petroleum based fuels. The main reason for advocating ethanol is that it can be manufactured from natural products or waste materials, compared with gasoline, which is produced from non-renewable natural resources. In addition, ethanol shows good anti-knock characteristics. However, economic reasons still limit its usage on a large scale. At the present time and instead of pure ethanol, a blend of ethanol and gasoline is a more attractive fuel with good anti-knock characteristics [6].

Alcohol fuels and particularly ethanol can be produced from renewable sources, such as sugar cane, cassava, many types of waste biomass materials, corn and barley. Ethanol has some advantages over gasoline, such as the reduction of CO, volatile organic compounds (VOC) and unburned hydrocarbon (UHC) emissions and better anti-knock characteristics, which allow for the use of higher compression ratio of engines. Since ethanol is a liquid fuel, the storage and dispensing of ethanol is similar to that of gasoline [7].

Table 2.1 Properties of ethyl alcohol with comparison to gasoline [1]

Property	Unit	Gasoline	Ethanol
Chemical formula	-	C_5-C_{12}	C_2H_5OH
Molecular weight	kg $kmol^{-1}$	114.15	46.07
C-fraction	mass %	87.4	52.2
O-fraction	mass %	0	34.7
H-fraction	mass %	12.6	13.0
H/C	atom ratio	1.795	3
O/C	atom ratio	0	0.5
Specific gravity	-	0.7-0.78	0.794
Density (at 15 C)	kg m^{-3}	750-765	785-809.9
Stoichiometric air-fuel ratio	w/w	14.2-15.1	8.97
Kinematic viscosity	mm^2/s	0.5-0.6	1.2-1.5
Reid vapor pressure at 37.8 C	kPa	53-60	17
Research octane number	-	91-100	108.61-110
Motor octane number	-	82-92	92
Cetane number	-	8	5-20
Enthalpy of formation			
(a)Liquid	kJmol^{-1}	−259.28	−224.1
(b)Gas	kJmol^{-1}	−277	−234.6
Higher Heating Value	MJ kg^{-1}	47.3	29.7
Lower Heating Value	MJ kg^{-1}	44.0	26.9
LHV at stoichiometric mixture	MJ kg^{-1}	2.77	2.70
Latent of vaporization	kJ kg^{-1}	380-400	900-920
Specific heat			
(a)Liquid	kJ/kgK	2.4	1.7
(b)Vapor	kJ/kgK	2.5	1.93
Freezing Point	C	−40	−114
Boiling Point	C	27-225	78
Flash point	C	−45 to −13	12-20
Auto ignition temperature	C	257	425
Vapor Flammability Limits	vol%	0.6-8	3.5-15
Laminar flame speed at 100 kPa, 325 K	cm/s	~33	~39
Distillation			
(a)Initial boiling point	%	45	78
(b)10	%	54	78
(c)50	%	96	78
(d)90	%	168	79
(e)End boiling point	%	207	79
Water solubility	%	0	100
Aromatics volume	%	27.6	0
Vapor toxicity	-	Moderate irritant	Toxic in large doses
Smoke character	-	Black	Slight to none
Conductivity	-	None	Yes
Color	-	Colorless to light amber glass	Colorless

Ethanol can be manufactured from many source such as fermentation of sugar derived from grain starches (wheat and corn), sugar beets, or sugar crops using microorganisms, fermentation of the non-sugar lignocellulose fractions of crops (grasses and trees), Synthetically, through direct hydration of ethylene (derived from petroleum) and high temperature catalytic conversion of synthesis gas to liquid fuels by the Fischer–Tropsch process to produce a mixture of alcohols. Fermentation is the primary method for production of beverage alcohol and much of the alcohol used in industry. Fermentation uses a variety of sources including grains such as corn, potato mashes, fruit juices, beet and cane sugar, molasses, and non-sugar lingo-cellulose fractions of crops and grasses.

Enzymes such as microscopic yeasts in the absence of oxygen convert carbohydrates to ethanol. There are two main ways to produce ethanol: one is alcoholic formation and another is the reaction of ethane with steam, as shown in Equation (2.1)–(2.3) [1].

Alcoholic fermentation:

$C_{12}H_{22}O_{11} + H_2O \rightarrow xC_2H_{12}O_6 + (2\text{-}x)C_6H_{12}O_6$ (2.1)
(Glucose) (Glucose) (Fructose)

$C_2H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ (2.2)
(Fructose) (Ethanol)

Reaction of ethane with steam:

$C_2H_4 + H_2O \rightarrow C_2H_5OH$ (2.3)
(Ethane) (Steam) (Ethanol)

World ethanol production as a fuel increased steadily through-out last decade (Figure 2.3). In 2012, the total production of ethanol fuel reached 85.985 billion L. The United States is the largest ethanol producer in the world with 88.4 % of the total production level. Fuel ethanol production has increased remark ably, because many countries are now looking for reducing oil imports, boosting rural economies and improving air quality.

In Thailand, Ethanol can be produced from many sources of national agriculture products as renewable fuel, the raw materials for ethanol production, cassava and sugarcane, are also the main economic crops in Thailand. Furthermore, ethanol was strongly promoted by government due to its many merits for use in transportation field and can be improved national economic by reduced imported oil dependency [2].

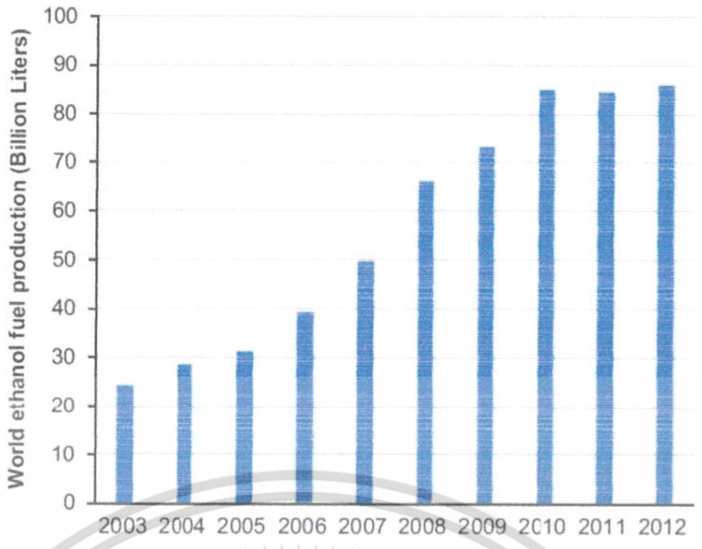


Figure 2.3 World ethanol fuel productions [1]

2.3.1 Effects of ethanol –gasoline blends on exhaust emissions

Sustaining a clean environment has become an important issue in an industrialized society. The air pollution caused by automobiles and motorcycles is one of the important environmental problems to be tackled. Since using ethanol–gasoline blended fuels can ease off the air pollution and the depletion of petroleum fuels simultaneously, many have been devoted to studying the effect of these alternative fuels on the performance and pollutant emission of an engine [8]. In exhaust emission aspects, NOx emission might be reduced by lower combustion temperature due to high latent heat property of the ethanol [Table 2.1].

Ioannis etal. [10] investigated NOx emission with different blends at 2000 rpm in wide open throttle (WOT) condition. From Figure 2.4, it is seen that, NOx emission decreased with increasing ethanol concentration. Because of the higher heat of vaporization of ethanol compared to gasoline, the combustion temperature of the blend decreases.

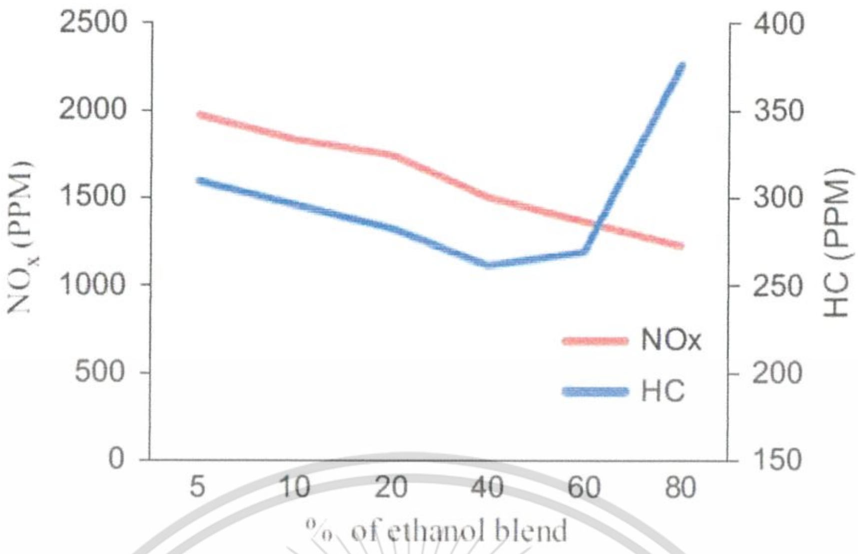


Figure 2.4 Correlation of NOx and HC emission with ethanol percentage at 2000 rpm [9]

In case of HC emission, up to certain concentration of ethanol, HC emission is reduced as the oxygen content of ethanol causes the reaction to move towards complete combustion. However, a greater concentration of ethanol in the gasoline reduces the flame temperature, which increases HC emission. It is seen that E40 is a good option for reduced HC emission and E80 is suitable for lower NOx emission. When compare with the gasoline, CO and HC emission of the ethanol are lower. Since, ethanol contained with the oxygen and lower in carbon atom. However, although ethanol has many merits in SI combustion, cold statibilty and aldehyde including formaldehyde emission remain the problem and challenge for utilization of ethanol in SI engine.

For hydrous ethanol, Table 2.2 presents the physical–chemical characteristics of hydrous ethanol and the gasoline-ethanol blend [10]. For the same air quantity, a higher amount of hydrous ethanol is required to produce a stoichiometric mixture in comparison to the fuel blend. The use of hydrous ethanol results in higher fuel consumption. Despite its lower heating value, hydrous ethanol has a higher octane number than the fuel blend. This allows for use of higher compression ratios, thus improving engine performance [11]. The higher oxygen content in the hydrous ethanol molecules favors conversion of the CO produced during combustion into CO_2. Figure 2.5 has shown that the use of hydrous ethanol is beneficial with respect to emissions control, as CO is a regulated pollutant. On the other hand, the global warming effects of CO_2 must be considered when choosing hydrous ethanol as fuel. And hydrous ethanol also appears to be a good choice for HC emissions reduction. The chemical structure of the gasoline-ethanol blend, with higher presence of carbon and hydrogen (Table 2.2), is more favorable for unburned HC formation than hydrous ethanol [12].

Table 2.2 Physical-chemical properties of gasoline-ethanol blend and hydrous ethanol

Parameter	78% Gasoline 22% ethanol	Hydrous ethanol
Density (kg/l)	0.74	0.81
Lower heating value (kcal/kg)	9400	5970
Stoichiometric air/fuel ratio	13.1	8.70
Chemical structure	$C_{6.39}\ H_{13.60}\ O_{0.61}$	$C_2\ H_{6.16}\ O_{1.08}$
Carbon mass (%)	76.7	50.59
Hydrogen mass (%)	13.6	12.98
Oxygen mass (%)	9.7	36.42
Sulphur mass (%)	0.09	0
Self-ignition temperature (°C)	400	420
Temperature of vaporization (°C)	40–220	78
Heat of vaporization (kcal/kg)	105	237
Research octane number (RON)	-	106
Motor octane number (MON)	80	87
Vapour pressure (bar)	27.5	29
Laminar flame speed (m/s)	0.30	0.42

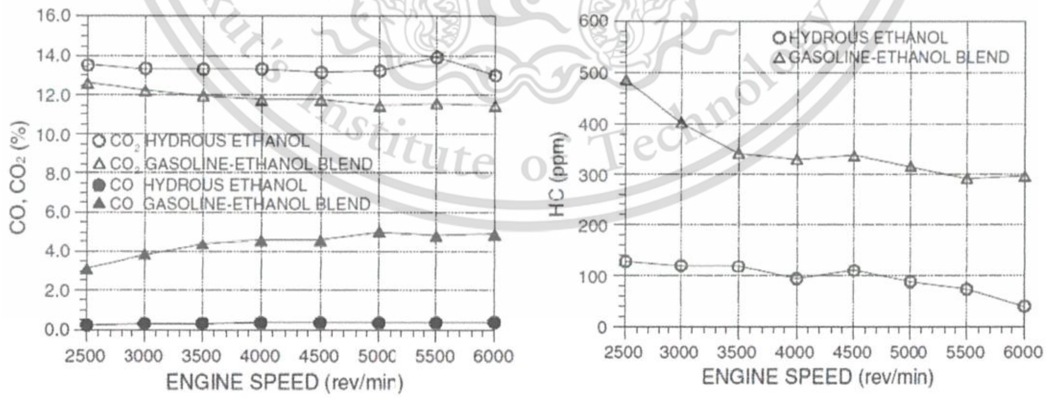


Figure 2.5 Fuel influence on carbon monoxide, carbon dioxide and total hydrocarbon emissions

2.3.2 Effects of ethanol –gasoline blended on engine performance

The usage of ethanol in spark ignition engine can be either in the form of neat fuels, blending with base fuels (gasoline or diesel) or even as an additive (such as ETBE). Utilizing ethanol in SI engines have long been researched and developed. The main features of the ethanol that impress to the SI combustion research were the ethanol is the oxygenated fuel and have the high heat of vaporization. That means, ethanol can improve volumetric efficiency of the combustion by cooling effect. Furthermore, octane rating of ethanol was higher than conventional gasoline. Thus, the engine can either run with the higher compression ratio or more degree of spark advance. The later reasons were directly promoted to the thermal efficiency of the engine which fuelled with the ethanol.

Ethanol combustion is faster and flame temperature is lower in comparison to gasoline. As a result, lower heat loss to the combustion chamber walls and higher thermal efficiency is attained. Ethanol combustion generates a higher product volume and, thus, higher pressures are reached in the cylinder.

Owen and Coley [11] described an improvement of 16% on the performance of a single-cylinder, ethanol-fuelled engine when the compression ratio was increased from 8.0 to 18.0. Although the output power can be improved, fuel consumption is always higher when methanol or ethanol is used as fuel in place of gasoline.

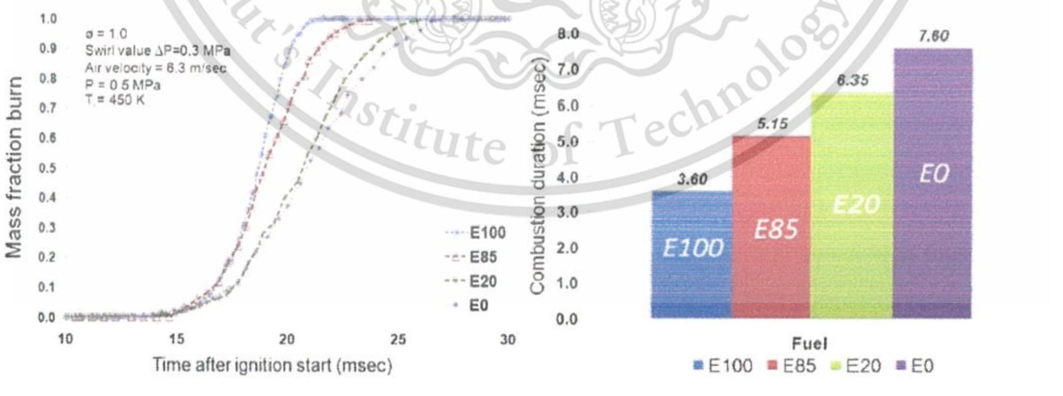


Figure 2.6 Mass fraction burn of various ethanol/gasoline blends and combustion duration at ϕ =1.0[2]

Figure 2.6 show the results of mass fraction burn rate and combustion durations of various ethanol-gasoline blended fuels at medium swirl condition (ΔP= 0.3 MPa) in stoichiometric mode (ϕ =1.0). The combustion periods were to be shortened and accelerated by high concentration of ethanol in blend fuel.

The combustion duration were 3.6 ms, 5.2 ms, 6.4 ms, and 7.6 ms in case of E100 (pure ethanol), E85, E20 and E0, respectively. From these results, it demonstrates that high ethanol content may accelerate the beginning of combustion period and reduce time of heat loss in early stage of the combustion [2].

Octane number (ON) parameters such as RON and MON are critical properties of fuel that reflect their propensity to resist "knock" in spark-ignited engines, which can cause engine damage when severe. Knock results from premature auto ignition of the mixture of fuel, air, and combustion end-gas located outside of the advancing flame front in the cylinder. Autoignition is caused by the increased temperature and pressure in the cylinder that results from normal combustion of fuel within the flame front Alcohols and other oxygenates are believed to retard the progress of the initial, low-temperature autoignition reactions through consumption of radical species and production of unsaturated hydrocarbons that retard oxidation reactions. As a result of their greater resistance to knock, fuels with higher Octane number can provide modest improvements in fuel economy in standard compression-ratio gasoline engines with knock-limited spark advance technology and enable the use of engines with higher compression ratios having greater thermal efficiency and potential for further engine downsizing to improve vehicle fuel economy. [13].

The physical properties of ethanol provide important benefits when added to gasoline. Ethanol has both a higher octane rating and a higher heat of vaporization than typical gasoline (Table 2.1). The octane rating of a fuel is a measure of the fuel's ability to resist auto-ignition and knock in a spark-ignited engine. Ethanol improves octane ratings when added to gasoline. When ethanol is added to the blendstock, the RON and MON increase of the resulting ethanol–gasoline blend is nonlinear with respect to volumetric ethanol content but has recently been shown to be essentially linear when evaluated using molar ethanol content [14].

Estimates of RON of ethanol–gasoline blends were calculated using the methodology introduced by Anderson et al. [14] in which the RON of an ethanol–gasoline blend (RON_{blend}) is a linear function of the molar ethanol concentration (x_{alc}), the RON of the gasoline blendstock ($RON_{gasoline}$), and a blending RON value ($bRON_{mol,alc}$) for ethanol in the blendstock, as shown in the following equation:

$$RON_{blend} = (1 - x_{alc})RON_{gasoline} + (x_{alc})(bRON_{mol,alc}) \quad (2.4)$$

Molar ethanol concentrations were calculated using equation (2.5) and (2.6),

Where C_{alc} = volumetric concentration (%) of ethanol, and r_{mv} = ratio of liquid molar volumes of ethanol and gasoline blendstock (v_{alc} and $v_{gasoline}$, cm^3/mol).

$$x_{alc} = C_{alc}/[C_{alc} + (1 - C_{alc})\, r_{mv}] \quad (2.5)$$

The liquid molar volume ratio, r_{mv}, was estimated using molecular weights (M_{alc} and $M_{gasoline}$, g/mol) and densities (ρ_{alc} and $\rho_{gasoline}$, kg/m^3) of the alcohol and blendstock.

$$r_{mv} = V_{alc} / V_{gasoline} = (M_{alc} / \rho_{alc}) / (M_{gasoline} / \rho_{gasoline}) \quad (2.6)$$

All calculations assume a blendstock with a representative molecular weight of 110 g/mol and density of 0.75 kg/L at 25 °C. Ethanol has a molecular weight of 46 g/mol and density of 0.785 kg/L. For this combination of properties, $r_{mv} = 0.40$. Eqs. (1)–(3) are summarized in figure 2.7 showing estimated RON values of ethanol–gasoline blends following contour lines of constant blendstock RON.

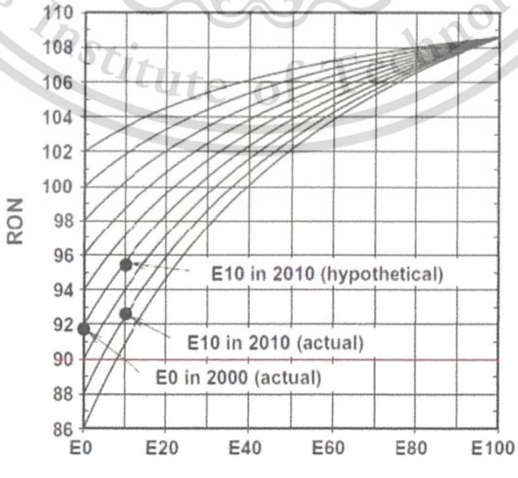


Figure 2.7 Estimated RON values for ethanol–gasoline blends with contour lines of constant blendstock RON

2.4 Ship resistance and propulsion

Ship Resistance and Propulsion is dedicated to providing a comprehensive and modern scientific approach to evaluating ship resistance and propulsion. The study of propulsive power enables the size and mass of the propulsion engines to be established and estimates made of the fuel consumption [18]. One of the most important considerations for a ship is the powering requirement. Once the hull form has been decided upon, it is necessary to determine the amount of engine power that will enable the ship to meet its operational requirements. Knowing the power required to propel a ship enables to select a propulsion plant, determine the amount of fuel storage required. Ship propulsion performance (referred to as the performance) is a measure of the energy consumption at a certain state, i.e. speed, loading condition, weather condition and other factors. During the life time of the ship the performance will decrease. The fuel consumption will increase at the certain state or the speed will decrease at a certain power setting. This is mainly due to fouling of the hull and propeller. Ship is subjected to external factors such as wind, waves, shallow water, change in sea water temperature, ect. As illustrated in Figure 2.8 [19].

2.4.1 Brake Horsepower (BHP)

Brake horsepower (BHP) is the power produced by the ship's prime mover. The prime mover is portion of the drive train that converts heat energy into rotational energy. For most ships, the prime mover is a steam turbine, gas turbine, or diesel engine. For some ships, the prime mover can be a large electric motor (electric drive). The output speed of the prime mover is usually quite high (several thousand rpm for a gas turbine at full power) and must be reduced to a usable rotational speed [21].

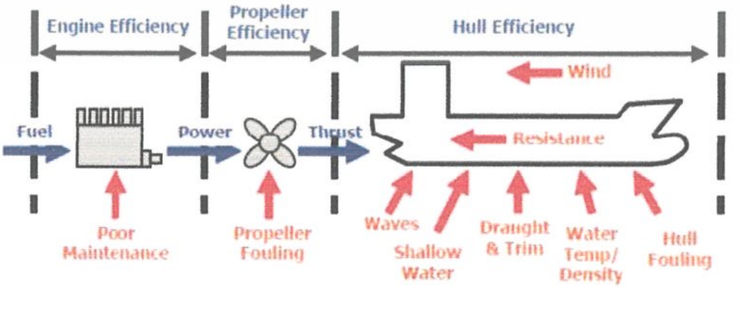


Figure 2.8 Performance variables [20]

2.4.2 Shaft Horsepower (SHP)

Shaft horsepower (SHP) is the power output the reduction gears (if installed). Reduction gears are necessary to reduce the high revolutions per minute (rpm) of the prime mover to a much slower shaft rotation speed required for efficient screw propeller operation.. In order to accomplish the speed reduction between the prime mover and propeller shaft, and to produce the torque necessary to spin the propeller, a reduction gear is usually quite large and heavy. Reduction gears are very efficient at power transmission, with only a one or two percent loss of power between input (BHP) and output (SHP). The relationship between BHP and SHP is called the gear efficiency (ηgear), and is written as follows:

$$\eta gear = \frac{SHP}{BHP} \qquad (2.7)$$

The shaft efficiency is normally around 0.99, but can vary between 0.96 and 0.995.

2.4.3 Delivered horsepower (DHP)

Delivered Horsepower (DHP) is the power delivered by the shaft to the propeller. The amount of power delivered to the propeller will be less than shaft horsepower (SHP) because of transmission losses in the shaft. Losses are usually quite small: 2-3%. These losses occur in the bearings, stern tube and its seal, and strut bearings. The thrust bearing takes the axial propeller thrust produced by the rotation of the propeller shaft and transmits the linear force of the thrust to the ship, which in turn produces translational motion of the ship. Line shaft bearings are used to support the weight of the propeller shaft between the reduction gear and stern tube. The stern tube and seal are necessary to keep the ocean out of the ship. Transmission losses are primarily due to friction and can be felt as heat in the bearings. The difference between delivered horsepower and shaft horsepower is referred to as shaft transmission efficiency (η_{shaft}), and is defined as:

$$\eta_{gear} = \frac{DHP}{SHP} \qquad (2.8)$$

2.4.4 Thrust Horsepower (THP)

Thrust Horsepower (THP) is the power produced by the propeller's thrust. THP is smaller than DHP due to inefficiencies inherent in converting the rotational motion of the propeller into linear thrust. The propeller is the least efficient component of the ship's drive train. Delivered and thrust horsepower are related through a quantity called the propeller efficiency.

Propeller efficiency η_O is related to working in open water, i.e. the propeller works in a homogeneous wake field with no hull in front of it. The propeller efficiency depends, especially, on the speed of advance V_A, thrust force T, rate of revolution n, diameter d and, moreover, i.a. on the design of the propeller, i.e. the number of blades, disk area ratio, and pitch/diameter ratio.

The propeller efficiency η_o can vary between approx. 0.35 and 0.75, with the high value being valid for propellers with a high speed of advance V_A.

Typically, a well-designed propeller will have an efficiency of 70-75% at the ship's design speed [21]. Figure 2.9 shows the obtainable propeller efficiency η_O shown as a function of the speed of advance V_A,

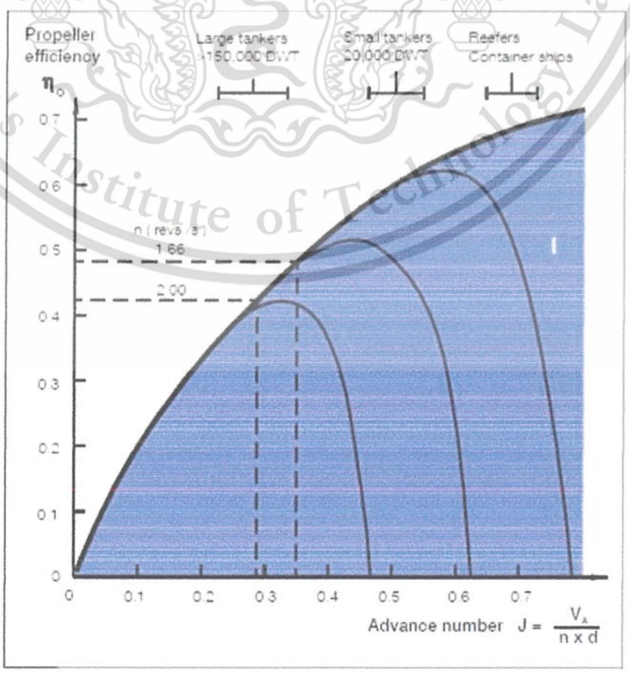


Figure 2.9 Obtainable propeller efficiency [21]

2.4.5 Effective Horsepower (EHP)

Up to this point, each of the powers (BHP, SHP, and DHP) can be physically measured someplace in the ship. However, these powers are of no use in the initial design stages of a ship's hull. Shaft horsepower and brake horsepower are quantities that are purchased from the engine manufacturer.

Likewise, the amount of thrust a propeller can produce is a product of analysis and calculation. However, the naval architect must still determine the amount of power (BHP or SHP) actually required to propel the ship through the water. The amount of power is determined through the concept of Effective Horsepower (EHP).

2.4.6 Propulsive Efficiency

Having established that the link between the power required to tow a ship through the water (EHP) and the power produced by the propeller (THP) is the hull efficiency, it is now possible to determine the shaft or brake horsepower the ship will need. Figure 2.10 shows a block diagram of the various components of a ship's drive train and the powers associated with each component that can aid in the determination of the required SHP or BHP [21].

Figure 2.10 Block diagram of a ship's drive train [21]

Instead of having to deduce the effect of all the separate efficiencies of each component in the drive train, the separate efficiencies are often combined into a single efficiency called the propulsive efficiency (η_P) or propulsive coefficient (PC).

$$\eta_{gear} = PC = \frac{EHP}{SHP} \quad (2.8)$$

The propulsive efficiency is the ratio of effective horsepower to shaft horsepower, therefore allowing the designer to make a direct determination of the shaft horsepower required to be installed in the ship. Common values of propulsive efficiency typically range from 55% to 75%.

2.4.7 Ship resistance

A ship's resistance is particularly influenced by its speed, displacement, and hull form. The total resistance R_T, consists of many source resistances R. Basic Principles of Ship Propulsion which can be divided into three main groups viz: frictional resistance, residual resistance and air resistance. The influence of frictional and residual resistances depends on how much of the hull is below the waterline, while the influence of air resistance depends on how much of the ship is above the waterline. In view of this, air resistance will have a certain effect on container ships which carry a large number of containers on the deck [22].

2.4.7.1 Air resistance

In principle air resistance is proportional to the square of the ship's speed, and proportional to the cross-sectional area of the ship above the waterline. Air resistance normally represents about 2% of the total resistance [25]. Air resistance can be calculated by using equation [3,6]. For container ships in head wind, the air resistance can be as much as 10%. The air resistance can, similar to the foregoing resistances but is sometimes based on 90% of the dynamic pressure of air with a speed [23,25].

$$R_a = 0.9 \times \frac{1}{2} \rho C_d A V^2 \qquad (2.9)$$

ρ is the density of the air equal to 1.1644 kg/m^3, A is the cross-sectional area of the vessel above the water equal to 2 m^2, and V is design speed of boat in m/s.

2.4.7.2 Frictional resistance

The frictional resistance is an important parameter in the powering performance prediction method, and to obtain an accurate estimate is of great importance for the final results. As there are not conducted any separate resistance test, all necessary frictional parameters must be extracted from the load varying propulsion test. The frictional resistance RF of the hull depends on the size of the hull's wetted area, and on the specific frictional resistance coefficient. The friction increases with fouling of the hull, i.e. by the growth of, algae, sea grass and barnacles.

When the ship is propelled through the water, the frictional resistance increase at a rate that is virtually equal to the square of the vessel's speed. The frictional resistance is found as follows:

$$R_f = C_f \left(\frac{\rho}{2}\right) S V^2 \qquad (2.10)$$

C_f is the coefficient of frictional resistance, has a value determined by the Reynolds number, ρ is 995.6502 kg/m^3, S is wetted Area of Boat equal to 30 m^2, V is the design speed of boat.

$$C_f = 0.02058\left(\frac{V \times L}{v}\right)^{-\frac{1}{8}} \qquad (2.11)$$

L is the length of the surface of water in this calculation is 10 m, and v is kinematic viscosity of water equal to 0.801 x 10^{-6} m^2/s

2.4.7.3 Residual resistance

Residual resistance RR comprises wave resistance and eddy resistance. Wave resistance refers to the energy loss caused by waves created by the vessel during its propulsion through the water, while eddy resistance refers to the loss caused by flow separation which creates eddies, particularly at the aft end of the ship. Wave resistance at low speeds is proportional to the square of the speed, but increases much faster at higher speeds. The residual resistance normally represents 8-25% of the total resistance for low-speed ships, and up to 40-60% for high-speed ships [23,24]. Residual resistance of boat can be calculation from the ratio of the residual resistance and the total resistance from Analysis of the total resistance of the destroyer Yudachi into its components of frictional and residual resistance at various speeds that illustrated in Figure 2.11 [25, 26]. The frictional resistance that use for calculate residual resistance is from equation (2.8).

The results of the towing tests on the Japanese destroyer Yudachi were broken down into frictional and residual resistance by Izubuchi. The frictional resistance was computed from the results of towing tests made with a plank 77.3 feet long and 0.525 feet thick as described by Hiraga [27]. This was scaled up to apply to the 232-foot destroyer with the aid of equation (2.8) above. The result of the analysis is shown in Figure 2.11 from which it may be seen that at all speeds the residual resistance forms a relatively small portion of the total. In the Inset of the figure the frictional resistance is expressed as a percentage-of the total resistance at different speeds. At the comparatively low speed of 14 knots the frictional resistance amounts to as much as 87 per cent of the total. As speed increases, the relative importance of frictional resistance diminishes, but at the maximum speed of 27 knots it still amounts to as much as 50 per cent of the total [28].

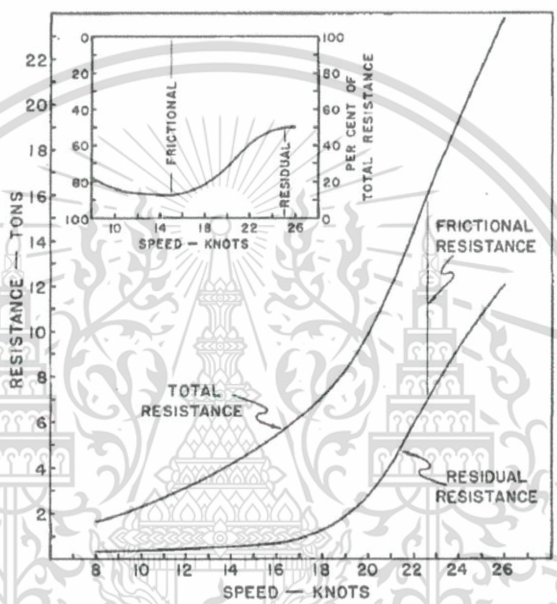


Figure 2.11 Analysis of the total resistance of the destroyer Yudachi into its components of frictional and residual resistance at various speeds [26]

2.4.7.4 Total ship resistance

When dividing the residual resistance into wave and eddy resistance, as earlier described, the distribution of the total ship towing resistance RT could also, as a guideline, be stated as shown in Figure 2.12. The right column is valid for low-speed ships like bulk carriers and tankers, and the left column is valid for very high speed ships like cruise liners and ferries. Container ships may be placed in between the two columns. The main reason for the difference between the two columns is, as earlier mentioned, the wave resistance. Thus, in general all the resistances are proportional to the square of the speed, but for higher speeds the wave resistance increases much faster, involving a higher part of the total resistance [22]. Total resistance is the summation of Frictional resistance, Residual resistance and Air resistance.

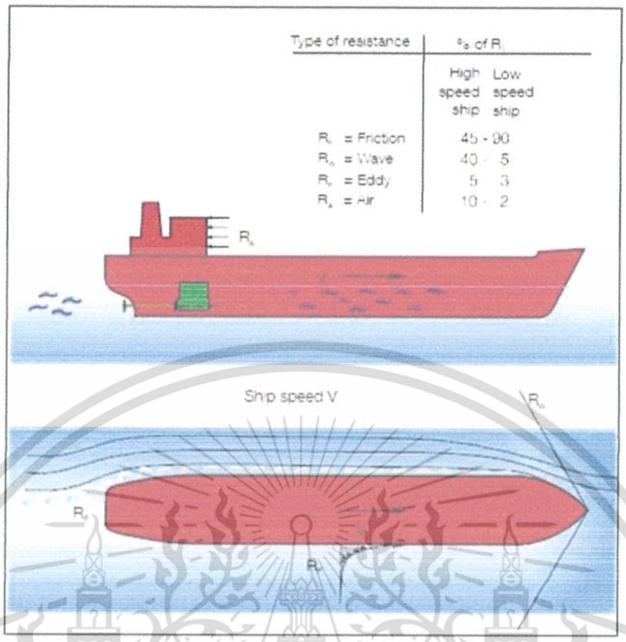


Figure 2.12 Total ship resistance [22]

CHAPTER 3

EXPERIMENTAL APPARATUS AND PROCEDURE

3.1 Experimental apparatus

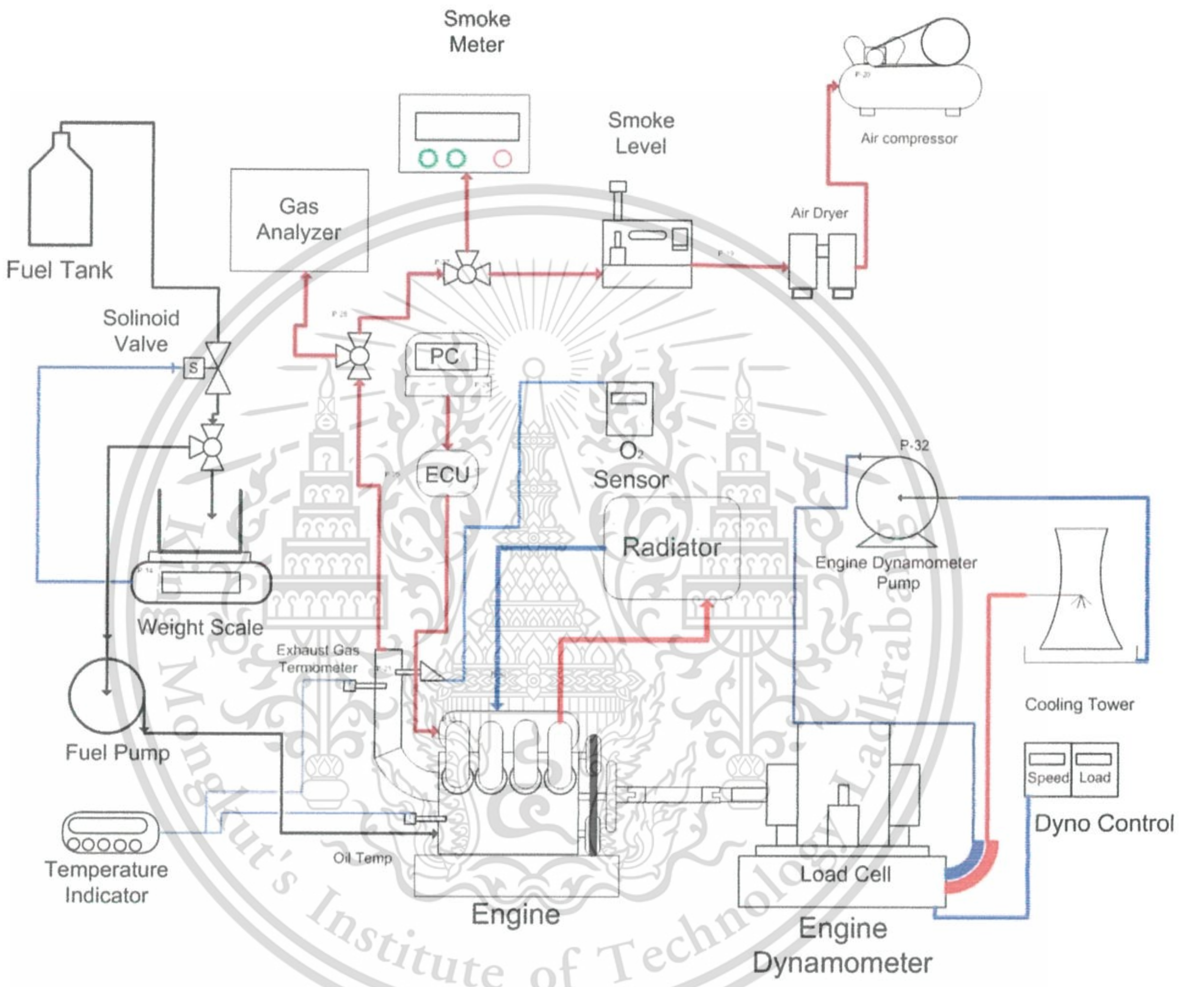


Figure 3.1 Schematic diagram of experimental setup

Figure 3.1 shows the schematic diagram of an experimental apparatus which used in this research. It had six main sections the test engine, electronic control unit, fuel weight measurement, temperature measurement, exhaust gas measurement and engine dynamometer.

3.1.1 Engine

Port-fuel injection spark ignition engine (PFI), Toyota 1ZZ-FE, was selected for this experiment. The engine was operating on the eddy current engine dynamometer for both of performance and emission investigation. And the test was performed at long-tailed condition. The specifications of the engine are shown in table 3.1 and the performance curve of the engine is seen in figure 3.2.

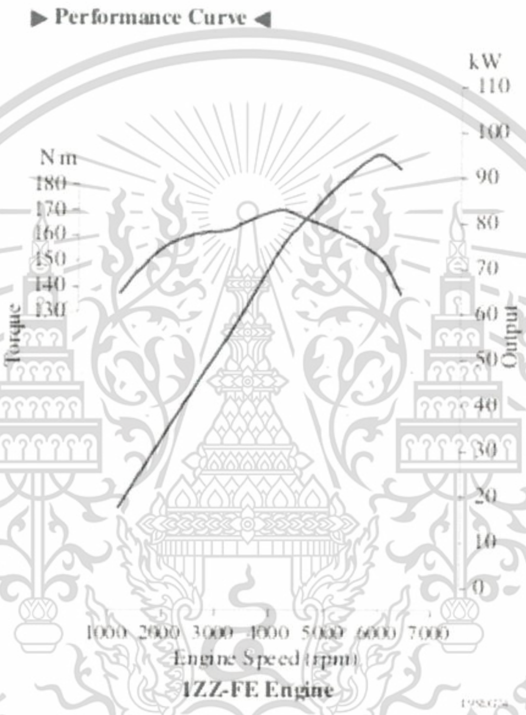


Figure 3.2 1ZZ-FE engine performance curve

The Toyota 1ZZ-FE engine is a 1.8 L. straight-4 piston engine series. Bore is 79 mm and stroke is 91.5 mm. Compression ratio is 10.1:1. Output is 143 hp (105 kW) at 6400 rpm with 125.8 ft·lb (171 N·m) of torque at 4200 rpm and It uses multi-point fuel injection, has VVT-i and features die-cast aluminum engine block with thin press fit cast iron cylinder liners, and aluminum DOHC 4-valve cylinder heads, fracture-split forged powder metal connecting rods, one-piece cast camshafts. The camshafts are chain-driven. The former was optimized for economy and torque.

Table 3.1 Engine specification

Description	**Specification**
Model	Toyota, 1ZZ-FE
Type	In-line, OHV
Displaced volume	1,794 cc
Fuel injection	Multi-point
Stroke	91.5 mm
Bore	79 mm
Compression ratio	10.1:1
Maximum Power	105 kW(143hp)@6400 rpm
Maximum torque	171 Nm @4200 rpm

3.1.2 Engine dynamometer

The test engine is connecting with the Tokyo Plant model ED-150 Horizontal. The type of dynamometer is eddy current engine dynamometer. In the experiment an engine dynamometer is used for apply load and also measured power and torque that the test engine can produced against the load. Eddy current engine dynamometer interface with in-house program be able to adjust the load rapidly. This engine dynamometer consists of an electrically conductive core moving across a magnetic field to produce resistance to movement. The heat energy of current through the stator and also rotational movement by braking are absorb and cooling by cooling water.

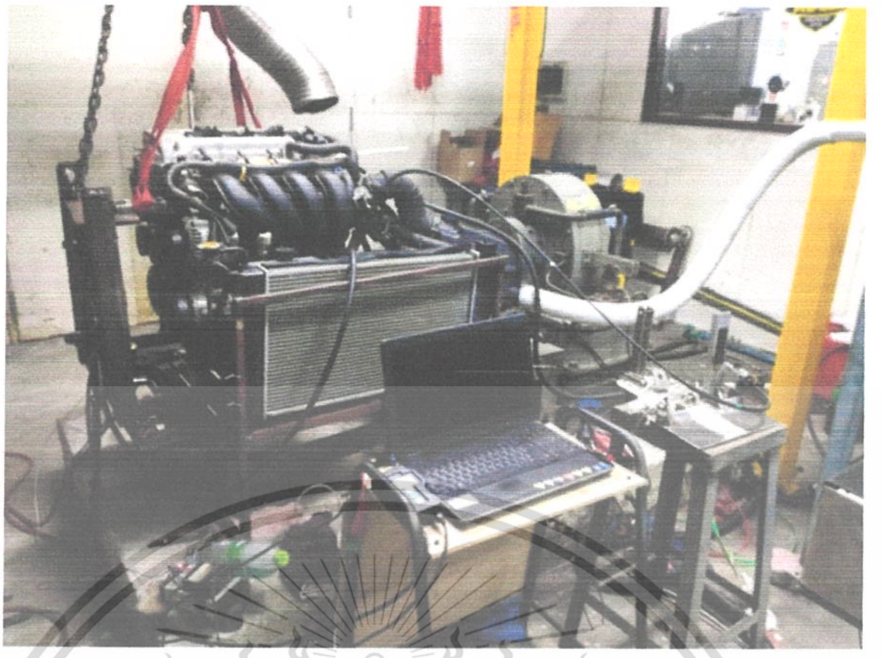


Figure 3.3 Engine Dynamometer

3.1.3 Fuel system

In this system, tested fuels from the fuel tank were feed by automotive fuel pump. The fuel regulator is adjusted at 301 to 347 kPa (3.1-3.5 kgf/m^2, 44-50 psi) from the standard specification. The flow rate of fuel pump was 120 litre per hour, and the excess fuel will be regulated and drained back to fuel tank. The fuel supply system was controlled by the engine dynamometer interface with the in-house program. The program can controlled solenoid valves for open and close. This system had 2 solenoid valves, the first valves was use to controlled fuel flow from the fuel tank and the second valve was use to filled the fuel into the beaker as shown in Figure 3.6. The fuel system can to set as automatic filling by measured fuel weight using digital weight scale which connected to an engine dynamometer program.

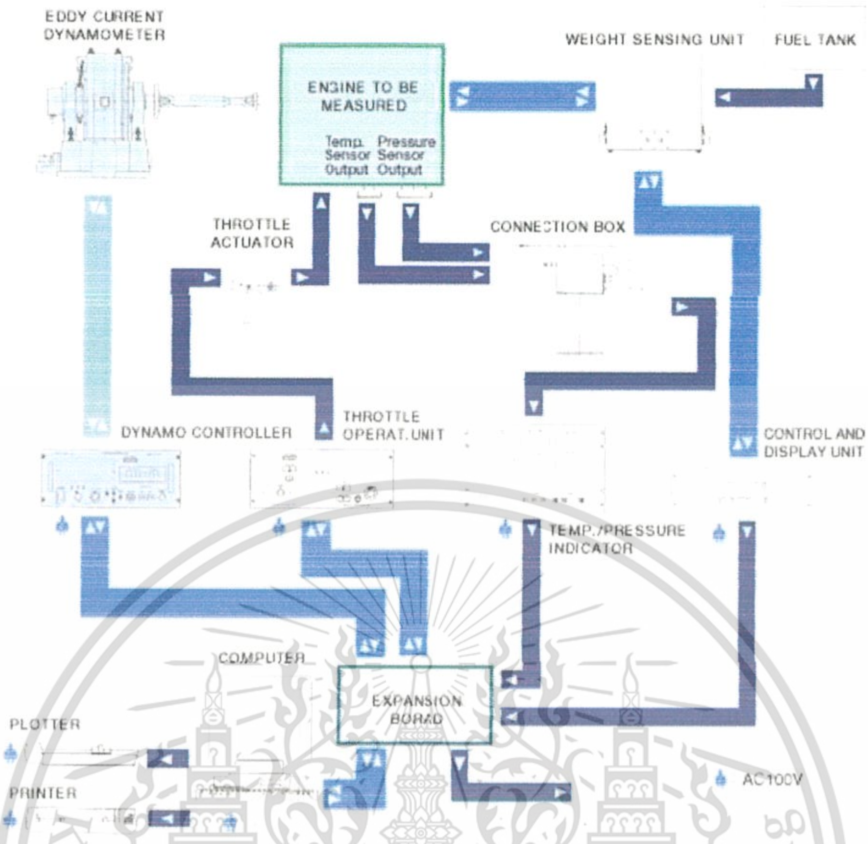


Figure 3.4 Schematic diagram

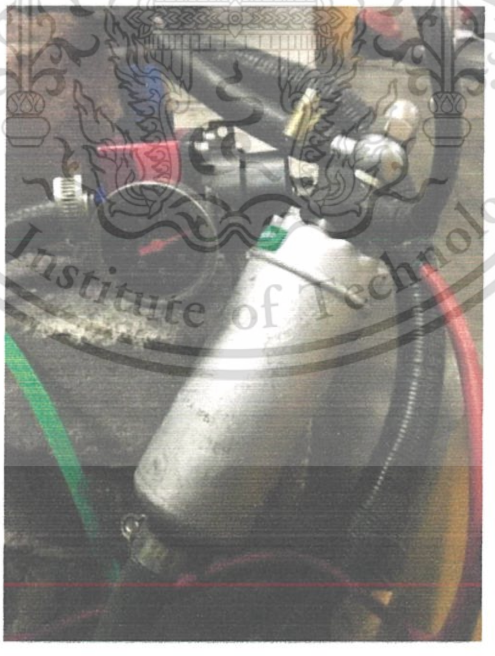


Figure 3.5 Fuel pump and regulator

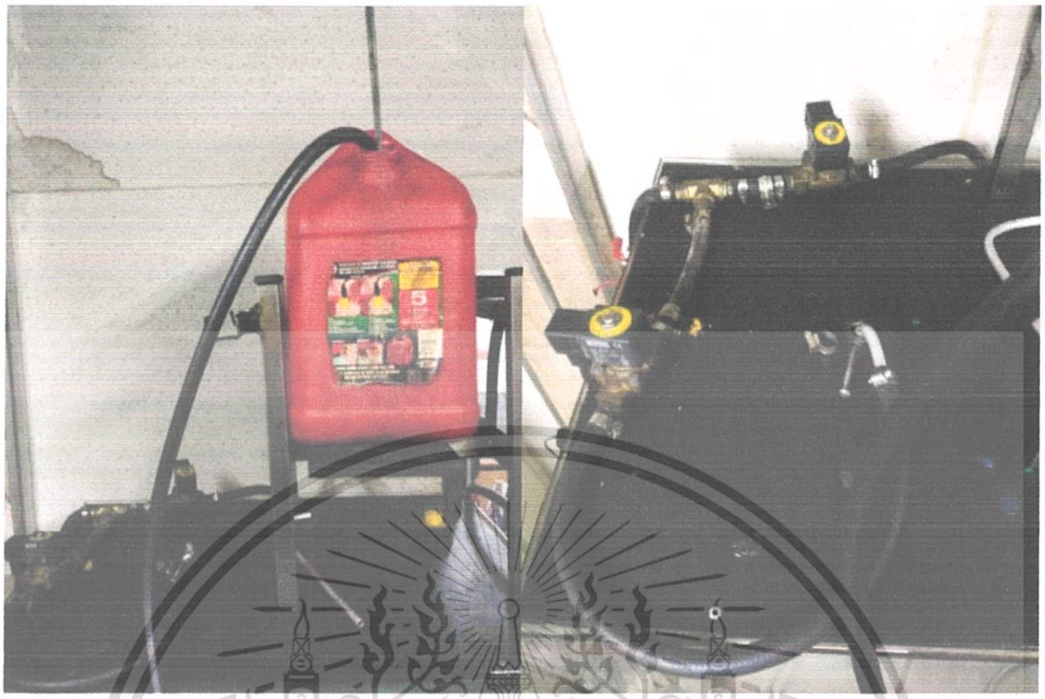


Figure 3.6 Fuel supply system

Figure 3.7 digital weight scale

Table 3.2 Fuel properties

Fuel properties	Gasoline	E10	E20	E85	E100	Eh95
Formula	C_4 to C_{12}	$CH_{2.043}O_{0.065}$	$CH_{1.63}O_{0.065}$	$CH_{2.822}O_{0.425}$	C_2H_5OH	$CH_{3.08}O_{0.54}$
Carbon (mass%)	85 to 88	86.7	79.85	55.36	52.2	51.2
Hydrogen (mass%)	12 to 15	13.2	12.88	12.89	13.13	13.09
Oxygen (mass%)	0	1.94	7.54	31.75	34.73	35.77
Heat of vaporasation (kJ/kg)	305	-	-	610 to 762.5	923	992.1
Vapour pressure	48 to 103	59.6	58.3	35 to 70	15.9	15.4
Lower heating value (MJ/kg)	44	40.97	40.6	29.5	28.67	26.79
Research octane number	92.4	98.1	98.3	101.6	108.6	106
Motor octane number	81.2	82.3	84.6	91.1	92	87
Stoichiometric air/fuel ratio	14.7	14.05	13.51	9.87	9.03	8.41

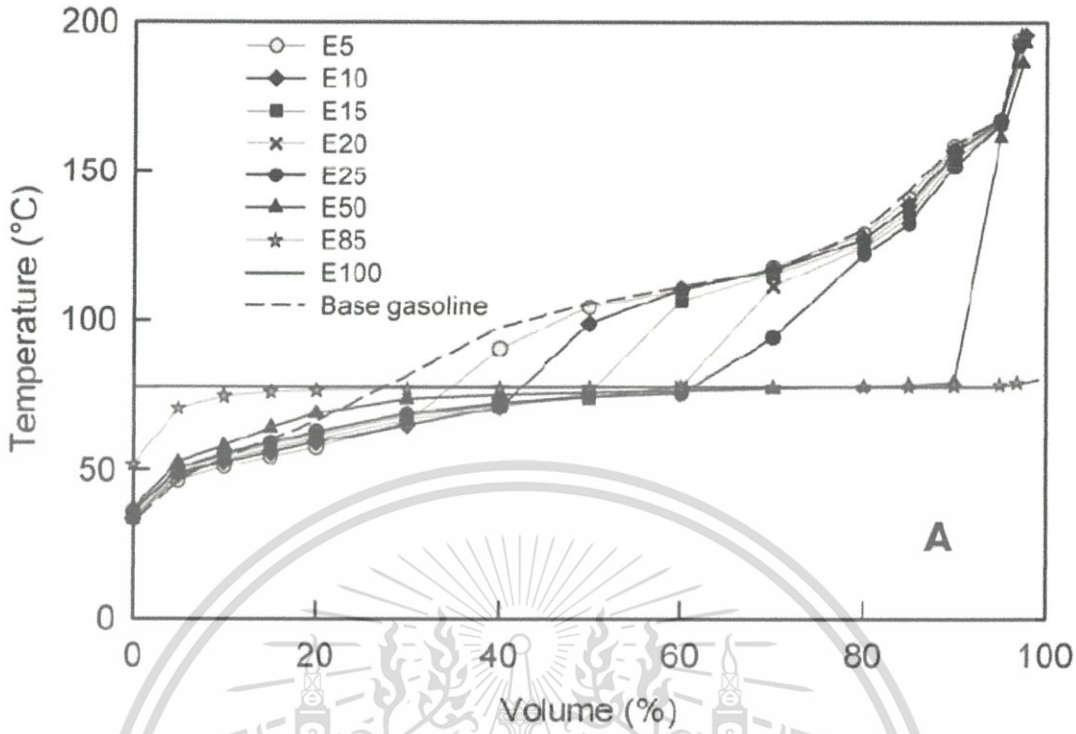


Figure 3.8 Distillation curve for Ethanol-Gasoline Blends

3.1.4 Fuel distillation

Distillation is an excellent method for purifying a liquid. A liquid contains closely packed but mobile atoms or molecules of varying energy. When a molecule of the liquid approaches the vapor-liquid phase boundary, it may, if it possesses sufficient energy, pass from the liquid phase into the gas phase. Only molecules energetic enough to overcome the forces which hold them in the liquid phase can escape into the vapor phase. Distillation curves for ethanol blends are shown in Figure 3.7 and are provided in tabular form in the Supporting Information. These curves provide information as to the efficiency of the separation of components of a mixture. Another advantage of fractional distillation is that the flat portions (plateaus) of the graph of boiling point vs distillate volume can be more easily distinguished than in a simple distillation. Therefore, the boiling points are more accurate and can be used to help identify the boiling fractions. A mixture of 95.5% ethanol and 4.5% water boils below the boiling point of pure ethanol, and thus 100% ethanol cannot be prepared by distillation. A mixture of liquids of a certain definite composition that distills at a constant temperature without change in composition is called an azeotrope (constant boiling mixture). A positive azeotrope is 95.63% ethanol and 4.37% water (by weight). Ethanol boils at 78.4 °C, water boils at 100 °C, but the azeotrope boils at 78.2 °C, which is lower than either of its constituents. Indeed, 78.2 °C is the minimum temperature at which any ethanol/water solution can boil at atmospheric pressure. While the addition of 5-25% ethanol blended with gasoline leads to little discernible change in IBP, there is a substantial decrease in distillation temperature over the middle portion of the distillation curve. As the fraction of ethanol increases from E10 to E25, each distillation curve moves progressively closer to that of gasoline over the first approximately 30% of the volume distilled. The IBPs for E50 and E85 blends are substantially greater than those of the base gasoline and trend toward that for pure ethanol at 78 degree Celsius. Its distillation can enhance performance in mixture vaporization process. Thus, when the ethanol was subject into base gasoline, evaporation rate was also accelerated. As describe in distillation curve, E100 is completely vaporized at the certain temperature while E0, which is comprise of many H-C chain, the evaporative rate may be less than E100 at a given temperature. Thus, some of fuel remained in liquid phase. These may be lead to the small number of molecules ready to react with oxygen. In the other hand, E100, that is completely vaporized, has more quantity of molecules and also more possibility to react with oxygen.

3.1.5 Temperature indicator

Temperature indicator use in this research was thermocouple type K. The indicator was use to monitor the temperature of an engine coolant temperature, engine dynamometer coolant water, engine oil temperature, exhaust gas temperature, and ambient temperature. And the temperature indicator was shown in fig 3.9.

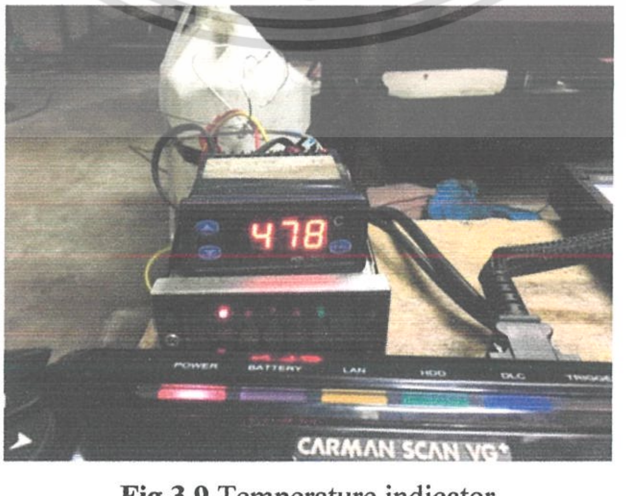


Fig 3.9 Temperature indicator

- Engine coolant water temperature

An engine coolant water temperature sensor was located at water outlet pipe of engine for measured the coolant temperature of the engine to ensure that the coolant temperature was under controlled.

- Engine dynamometer coolant water temperature

An engine dynamometer coolant temperature was use to cool the dynamometer from the heat damage. The temperature was located at water inlet and outlet pipe of the coolant water. The limit of engine coolant water is 60 degree Celsius.

- Engine oil temperature

An engine oil temperature sensor was located at engine oil tank to monitor the lubricant oil temperature to ensure that the engine is operated at the normal condition.

- Exhaust gas temperature sensor

An exhaust gas temperature sensor was located at the exhaust gas manifold to monitor the exhaust gas temperature. Exhaust gas temperature can indicated the combustion characteristic of engine under the different condition and fuel.

- Ambient temperature

An ambient temperature sensor was used for monitor the temperature inside the test room. The temperature must be under the controlled to ensure that the inlet air was at the same in every test condition in order to get the same output. The sensor was located inside the test room.

3.1.6 Data acquisition system

A data acquisition system was connected to an engine dynamometer by the external wire. A desktop computer was used for commanded an engine dynamometer, which operated by National Instrument LabVIEW system. This program can command, measured, calculated and stored data from an engine dynamometer. The program can operate in 2 main conditions, constant load mode and constant speed mode, as shown in figure 3.10.

3.1.7 Engine control unit

An engine control unit (ECU) is a type of electronic control unit that controls a series of actuators on an internal combustion engine to ensure optimal engine performance. In this experiment, stock ECU (OEM ECU) and standalone ECU were used to control an engine. The standalone ECU used in this project is Link G4+ Xtreme which has a several useful function that can use to control an engine to operate more precisely such as tuning an injection timing, ignition timing, ethanol content compensation, wide-band oxygen sensor support, auto tune, cold start setting, closed loop lambda control, and more auxiliary input/output.

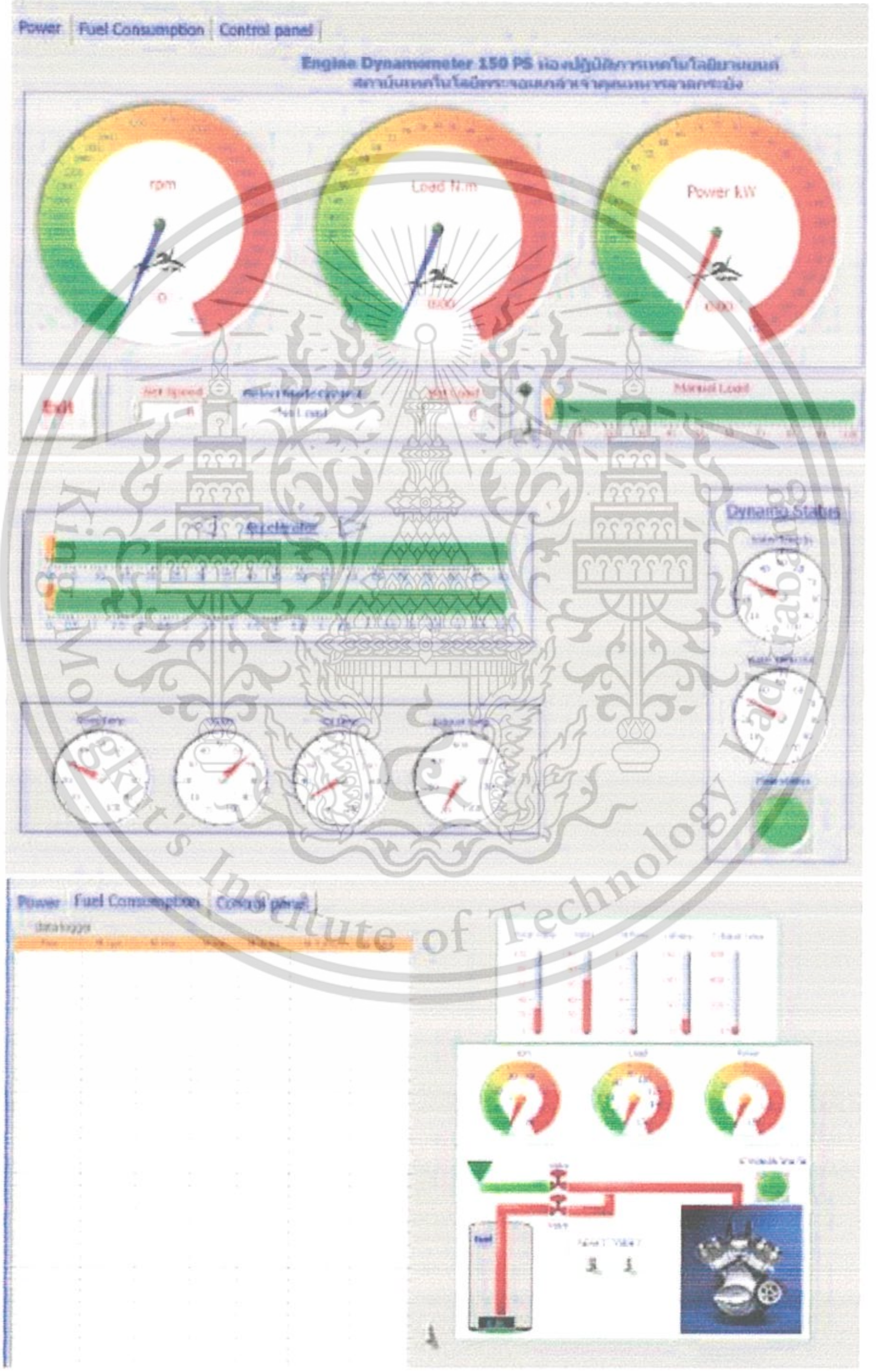


Figure 3.10 Engine dynamometer program interface

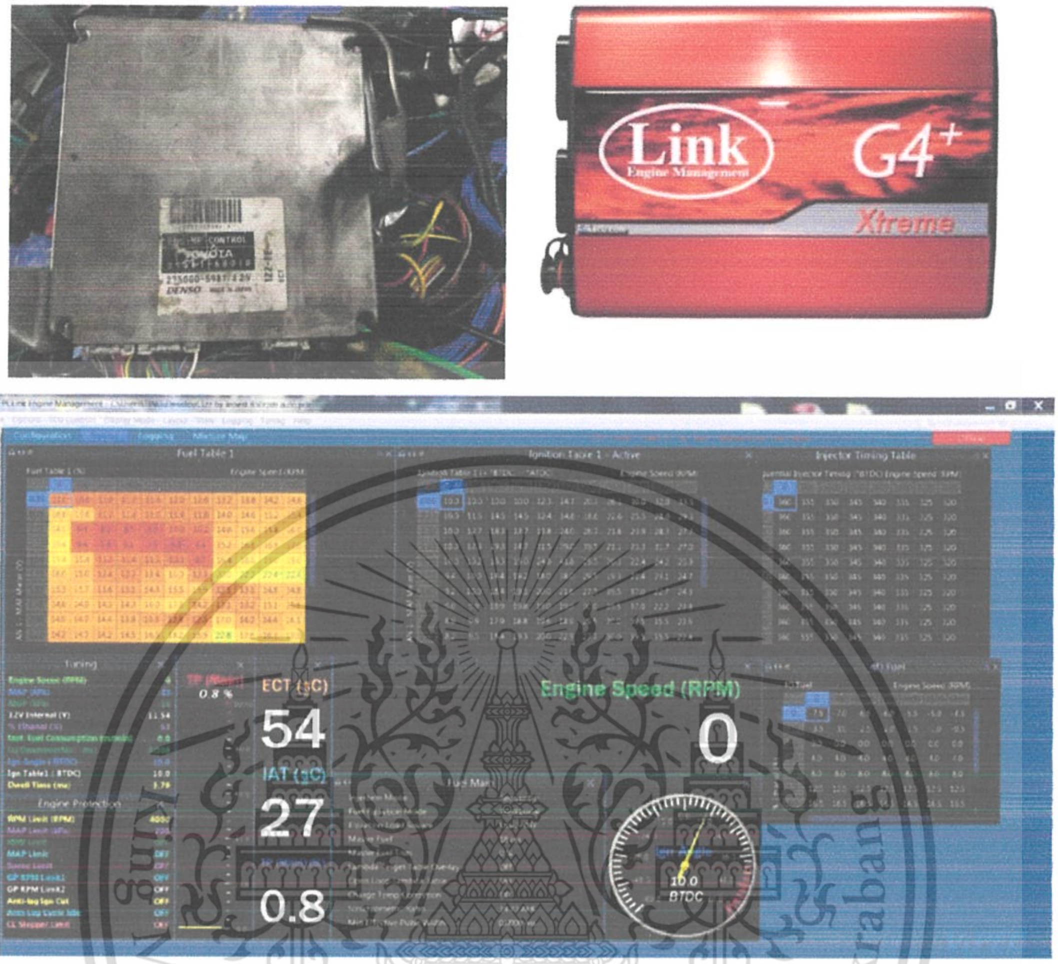


Figure 3.12 Engine control unit and Link ECU program interface

3.1.8 Flex fuel ethanol sensor

In this experiment ethanol sensor was used to measured percentage of ethanol in ethanol-gasoline blended fuel as shown in fig 3.13. Ethanol sensor can used by connected with the function in Link ECU.

Figure 3.13 Flex fuel ethanol sensor

3.1.9 Gas analyzer

In this experiment an automotive gas analyzer model KEG-500 was used to measure exhaust gas from the test engine. This analyzer is configured to perform a measurement by applying Non Dispersive infra-Red (NDIR) method for analying CO, CO2 and HC, and electrochemical method for analyzing O2 and NOx. In the NDIR analyzing method, a flashing lamp which flashes the infrared rays is attached the one end of the simple cell and at the other end a detecting sensor is attached so that it can detect the component of a gas and then calculate the gas density. The electrochemical method measures the gas density by using the quantity of electron which produced in the time of oxidation and reducing reaction of the gas.

Figure 3.14 Automotive gas analyzer model KEG-500

3.1.10 Data logger

In this experiment, The VBOX sport data logger was used to collect the performance data of the vehicle. The VBOX can analyze a speed, time, distance, acceleration and location from GPS satellite as shown in figure 3.15

Figure 3.15 VBOX sport data logger

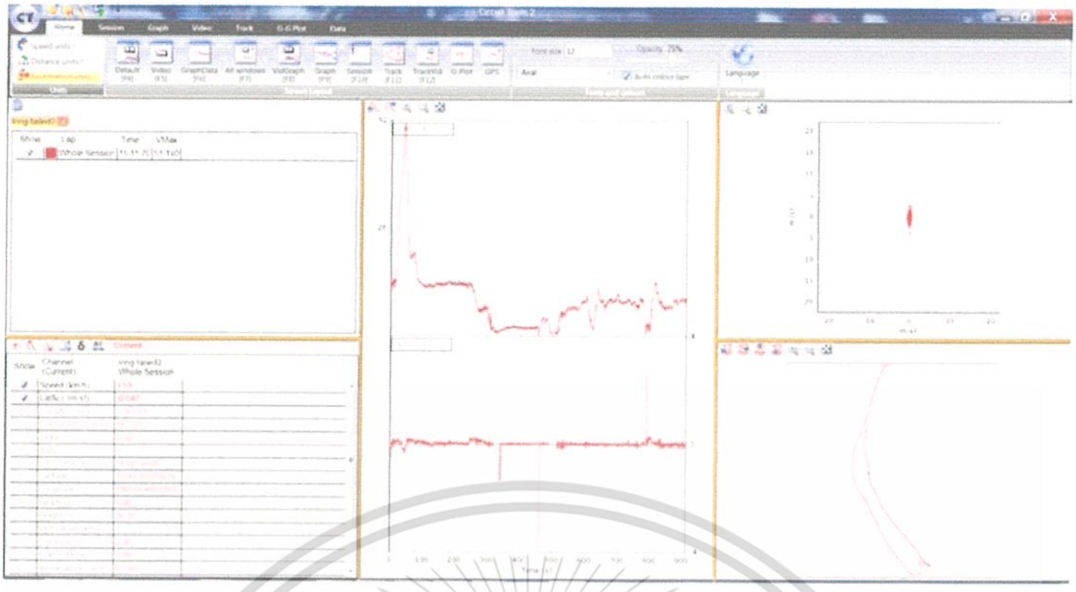


Figure 3.16 VBOX sport data logger program interface

3.1.11 Vehicle diagnostics and OBD II scan

Carman Scan VG+ is an advanced vehicle diagnostics and OBD II scan. Carman Scan VG+ was use in this experiment in order to observe the signal from engine sensors as shown in figure 3.17.

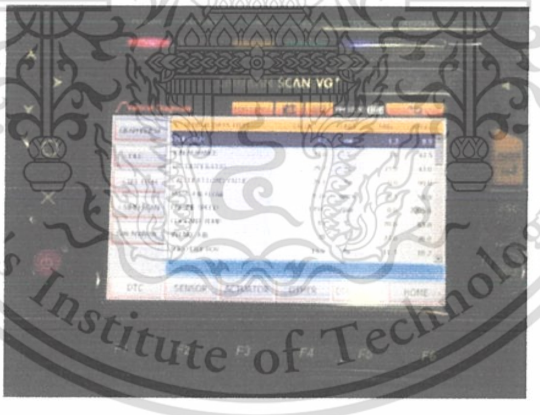


Figure 3.17 Vehicle diagnostics and OBD II scan device

3.1.12 Oxygen Sensor

The innovate motorsport model LM-2 digital air/fuel ratio meter connected with wide-band oxygen sensor was used in the experiment for measured the proportion of oxygen (concentration) in the exhaust gas to determine the air-fuel ratio of combustion in real time to ensure that how the engine burns the fuel. The signal from the oxygen sensor was converted from voltage signal to air-fuel ratio number by an air-fuel ratio meter. By using the signal from LM-2, ECU can use this information to controlled operating condition of an engine.

Figure 3.18 LM-2 digital air/fuel ratio meter

3.2 Methodology

3.2.1 Survey data

This research focused on transportation by the boat in Thailand. Table 3.3 as showed a survey data of transportation in Klong saen seab and Chao Phraya River. Klong saen seab and Chao Phraya River were chosen for surveyed because these places had the most trip of boat in Bangkok.

Table 3.3 Survey data of transportation in Bangkok

Boat type	engine	Passengers	Maxspeed (kph)	Operating speed(kph)
Khlong Saen Saep Boat	Isuzu 6HF1 7.8L 220hp@2400rpm 735Nm@1400rpm	80	35	30
Chao Phraya Express Boat	-	90	28	25
Chao Phraya Tourist Boat	-	90	20	20
Long-Tailed Boat	Isuzu 4BD1 3.9L 96hp@3200rpm 255Nm@1900rpm	10	50	10-15
Prototype Boat	-	16	-	10-30

3.2.2 Boat resistance calculation

To analyze the performance and emission from the test engine, the engine will operate at long-tailed boat condition. This research is concerning on long-tailed boat speed 10 to 30 kilometers per hour. From the survey data we have to find a proper engine to match with prototype boat. To use a prototype boat as a transport boat in Chao Phraya River the engine of the boat should have enough power and torque to run as the same speed with carrying passengers. The prototype of long-tailed boat and detail of the long-tailed boat and assumption for calculation are show in table 3.4.

Table 3.4 Detail of the prototype boat and assumption for calculation

Frontal Area	2 m^2
Boat length	11 meter
Passengers	11 person
Wetted surface area	31.9117 m^2
Air density	1.1839 kg/ m^3
Water density	995.6502 kg/ m^3
Water viscosity	0.801x10-6 m^2/s
Wind Speed	Equal to boat speed
Calculation at 30 degree Celsius	

A boat's resistance is particularly influenced by its speed, displacement, and hull form. To calculate the resistance of boat the total resistance consists of many source-resistances which can be divided in to three main groups. The first one is frictional resistance, the second one is residual resistance, and the third one is air resistance. The external factors of boat are illustrated in Figure 3.19

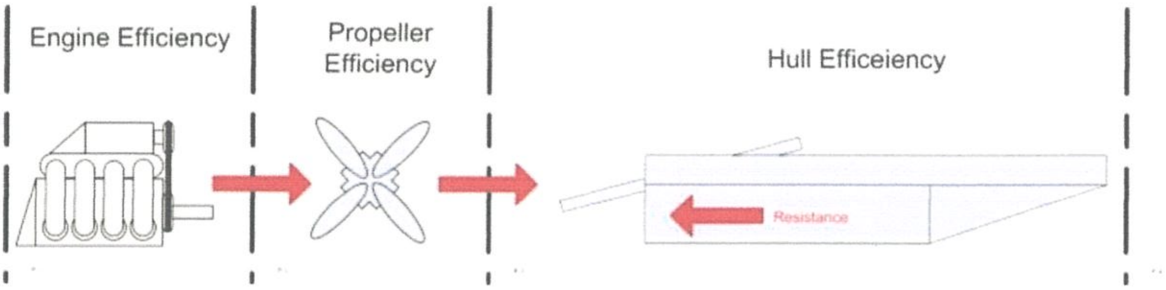


Figure 3.19 The external factors of boat

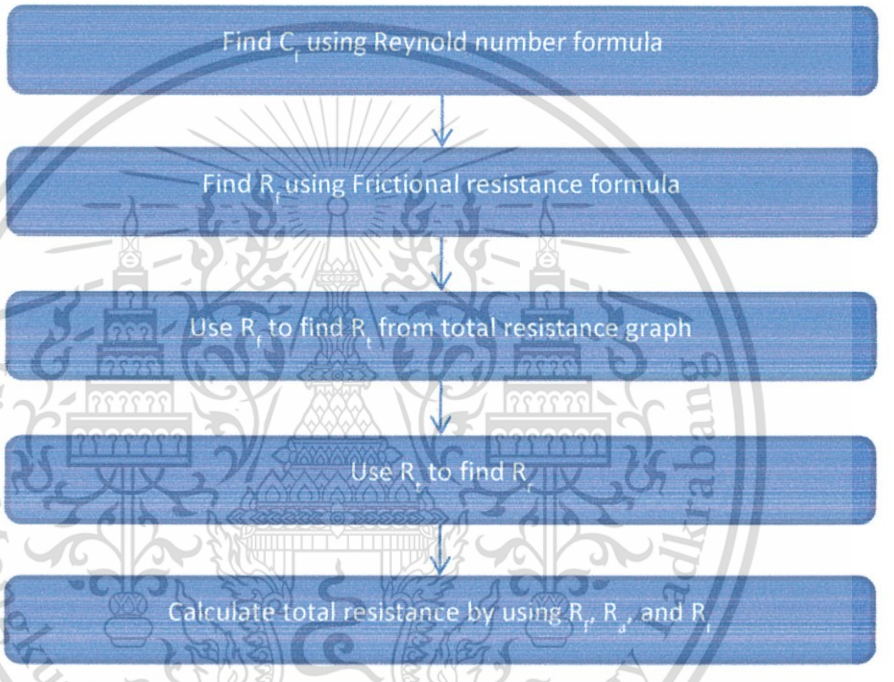


Figure 3.20 Boat resistance calculation experimental procedures

3.2.2.1 Air resistance

In principle air resistance is proportional to the square of the ship's speed, and proportional to the cross-sectional area of the ship above the waterline. Air resistance can be calculated by using equation

$$R_a = 0.9 \times \frac{1}{2}\rho C_d A V^2 \quad (3.1)$$

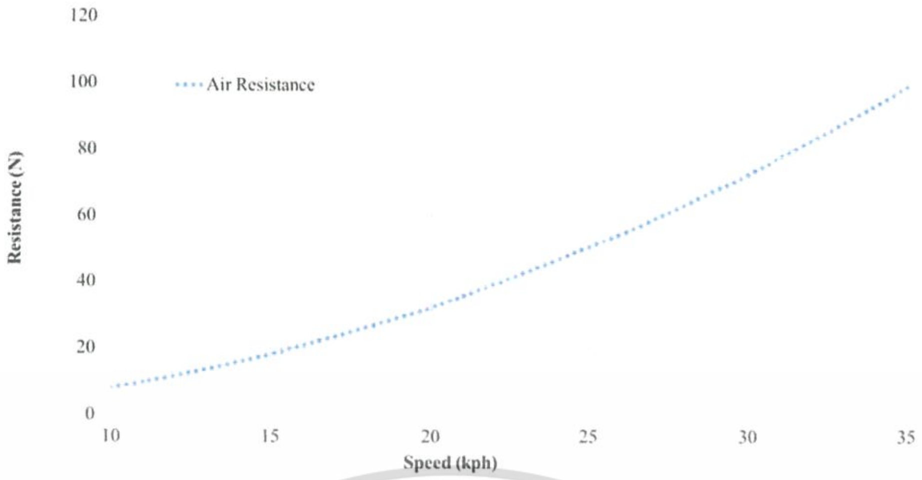


Figure 3.21 Air resistance of long-tailed boat at various speeds

3.2.2.2 Frictional resistance

Frictional resistance of the boat can be calculated by using equation 3.2 and 3.3.

$$R_f = C_f\left(\frac{\rho}{2}\right)SV^2 \tag{3.2}$$

$$C_f = 0.02058\left(\frac{V\times L}{v}\right)^{-\frac{1}{8}} \tag{3.3}$$

3.2.2.3Residual resistance

Residual resistance of boat can be calculation from the ratio of the residual resistance and the total resistance from Analysis of the total resistance of the destroyer Yudachi into its components of frictional and residual resistance at various speeds.

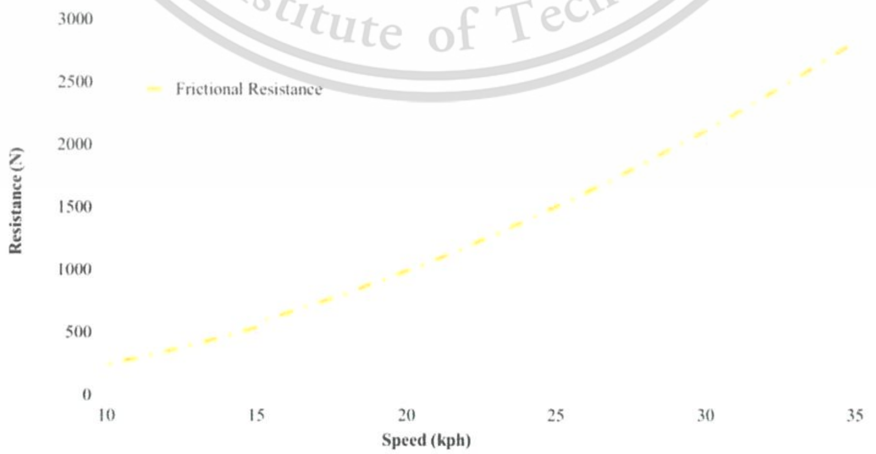


Figure 3.22 Frictional resistance of long-tailed boat at various speeds

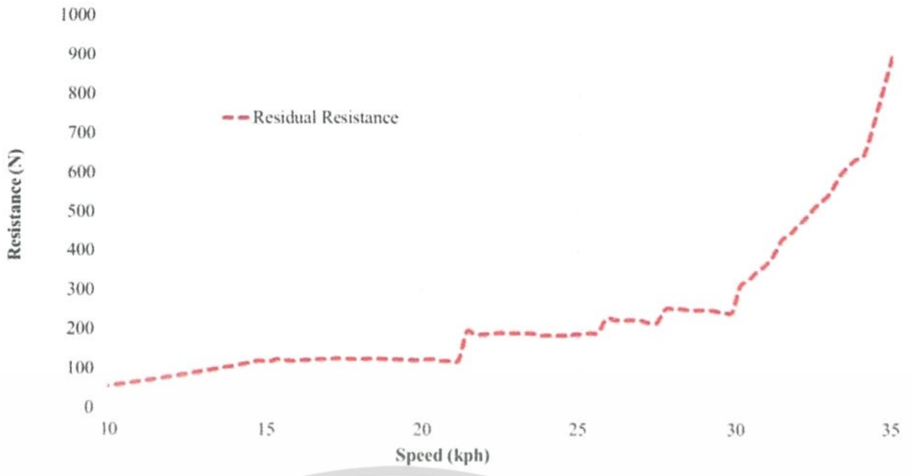


Figure 3.23 Residual resistance of long-tailed boat at various speeds

3.2.2.4 Total resistance

Total resistance is the summation of Frictional resistance, Residual resistance and Air resistance of the prototype boat that illustrated in figure 3.24.

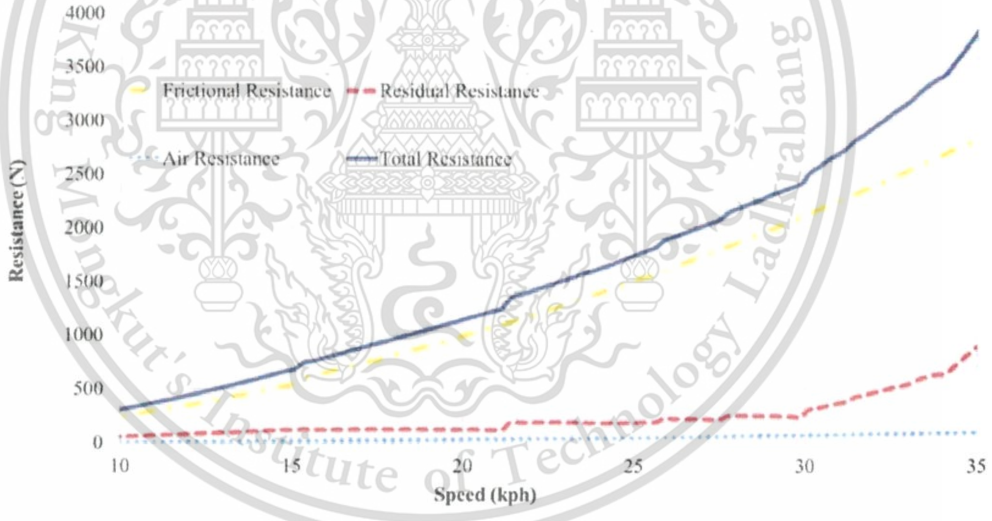


Figure 3.24 Total resistance of prototype boat

3.2.3 Require power and torque calculation

3.2.3.1 Required power calculation

The required power of prototype boat can be calculate by using formula

$$P = Fv \quad (4)$$

F is total resistance from the calculation and v is the speed of boat from 10 to 30 kilometer per hour. The calculation of required power of prototype is illustrated in Figure 3.25.

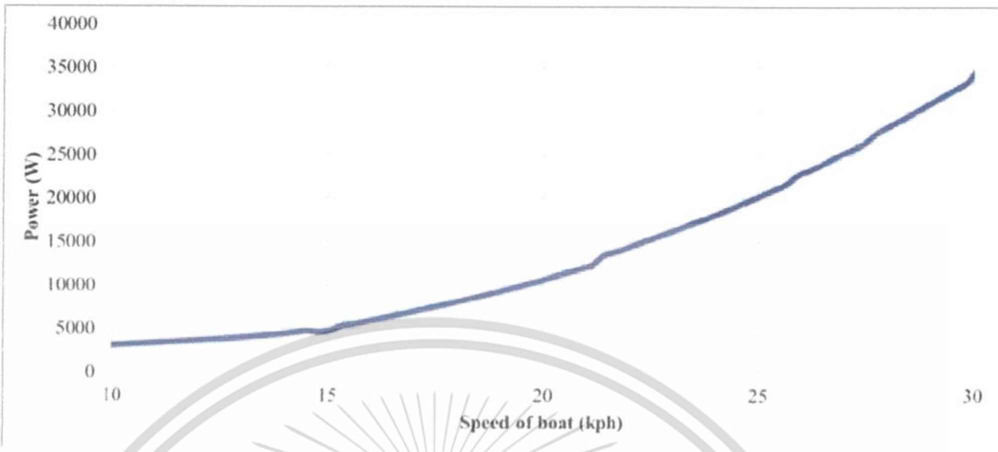


Figure 3.25 Required power for prototype boat

3.2.3.2 Require torque calculation

The required torque of the boat is calculated from using formula

$$P = 2\pi N\tau \quad (5)$$

Where P is the power in Watt, N is the number of design engine speed revolutions per unit time and τ is the torque. In this research require engine speed is 1500 – 3500 rpm and τ is required torque of the boat engine. And the propeller efficiency that use in this calculation is 60%. A required torque of the boat as shown in figure 3.26.

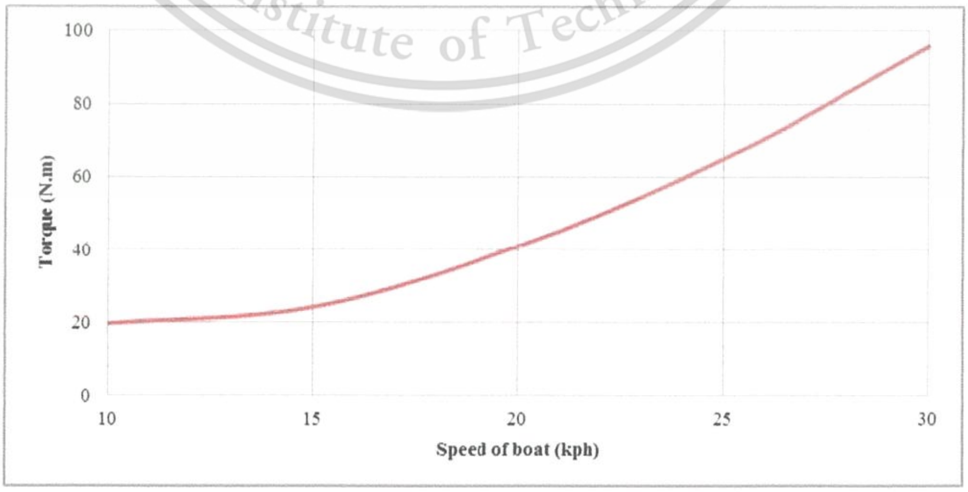


Figure 3.26 Required torque of the boat

3.2.4 Experimental conditions

A port-fuel injection spark ignition engine was measured performance and emissions at long-tailed boat condition with no gear box, using gasoline, ethanol-gasoline blended and hydrous ethanol fuel, respectively. The 10 to 25 kilometer per hour boat's speed condition was selected to study. All the conditions investigated were carried out at $\lambda=1$. The test conditions are shown in Table 3., 3. and 3.. Exhaust emissions include of CO, CO_2 and HC were sampled from an exhaust pipe directly in order to be measured by a gas analyzer. In addition, performances: brake specific fuel consumption (BSFC), brake specific energy consumption (BSEC) and break thermal efficiency were measured at long-tailed boat condition to find the optimum point.

Table 3.5 Test Condition (No Gear Box)

Boat speed (kph)	engine speed (rpm)	Power (W)	Torque (Nm)
10	1500	3083	19.64
15	2000	5059	24.71
20	2500	10733	41.02
25	3000	20407	64.99

Table 3.6 Test Condition (Gear ratio 1.25:1)

Boat speed (kph)	engine speed (rpm)	Power (W)	Torque (Nm)
10	1800	3083	24.55
15	2400	5059	30.21
20	3000	10733	51.27
25	3600	20407	81.24

Table 3.7 Test Condition (Gear ratio 0.83:1)

Boat speed (kph)	engine speed (rpm)	Power (W)	Torque (Nm)
10	1800	3083	16.36
15	2400	5059	20.13
20	3000	10733	34.17
25	3600	20407	54.14

Table 3.8 Test Condition

Fuel	E0, E10, E20, E85 and Eh95
Conditions	10 to 25 kph boat speed with different gear ratio
Lambda	1

3.3 Experimental procedures

In this research, the experimental procedures were divided in two main parts of performances and exhaust gas emissions. At first the engine was operate with original equipment manufacturer ECU and compered with Link G4+ ECU. After that two different conditions with Link G4+ ECU and original equipment ECU were compered in term of performances and exhaust gas emissions. The procedure of each study is explained by using the flow chart which consists of apparatuses, parameters, conditions and results.

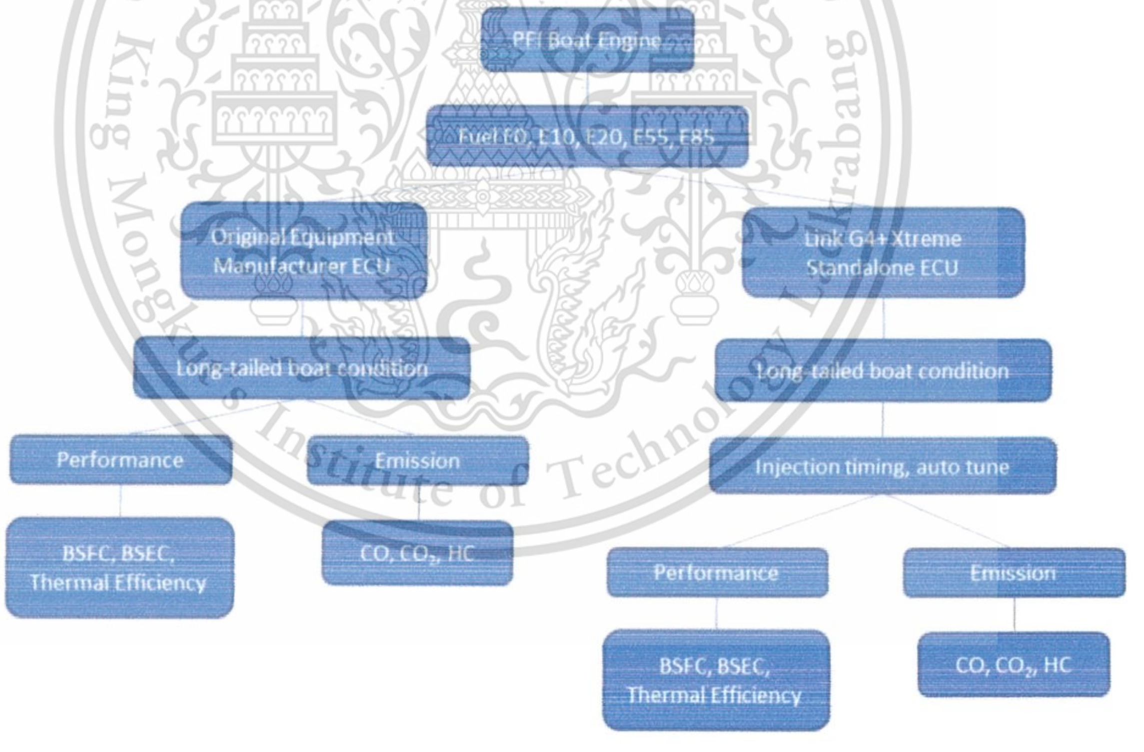


Figure 3.27 Experimental procedures

3.3.1 Performances

To investigate PFI engine performances, Eddy current engine dynamometer was used to control the engine operating at long-tail boat condition and the engine was fuelled with gasoline, ethanol-gasoline blended and hydrous ethanol fuel. In the experiment two different ECUs were used in this study, OEM ECU and Link G4+ extreme ECU. The test engine running with Original equipment manufacturer (OEM) ECU cannot optimize the performance of the engine it was tuned by the manufacturer. A Link G4+ standalone ECU able to optimize the performance of test engine by adjust injection duration. A lambda was control to be 1 in all test conditions but an engine operating with OEM ECU cannot control the air/fuel to stoichiometric for each fuel.

3.3.2 Exhaust gas emission

To investigate an exhaust gas emission of the test engine, the engine has to operate in long-tailed boat condition by using an engine dynamometer.

Exhaust gas emission from the engine were sampled directly from the exhaust pipe. Gas analyzer was used to measure gas emissions include of CO, CO_2 and HC concentration, respectively. The results showed the comparison of gas emissions concentration from using pure gasoline, ethanol-gasoline blended and hydrous ethanol as a fuel.

CHAPTER 4
RESULTS AND DISCUSSIONS

4.1 Efficiency

In thermodynamics, the thermal efficiency is a dimensionless performance measure of a device that uses thermal energy, such as an internal combustion engine. For a power cycle, thermal efficiency indicates the extent to which the energy added by heat is converted to average output.

4.1.1 Engine without transmission

4.1.1.1Engine with original equipment manufacturing ECU

Brake specific fuel consumption (BSFC), is calculated from the result of an engine dynamometer, use for understand the variations of fuel consumption of using different alcohol-gasoline blended fuels. BSFC (g/kJ) is the ratio of the rate of fuel consumption (g/sec) and the brake power (kW), and BSFC should be increased when the increasing of ethanol content in fuel.

To determine brake specific fuel consumption, at steady working conditions (constant speed, constant torque) consumption period of certain amount of fuel were measured and brake specific fuel consumption (BSFC) was calculated. Figure 4.1 shows the variation in BSFC of engine using E0, E10, E20 and E85 fuel with respect to long-tailed boat condition.

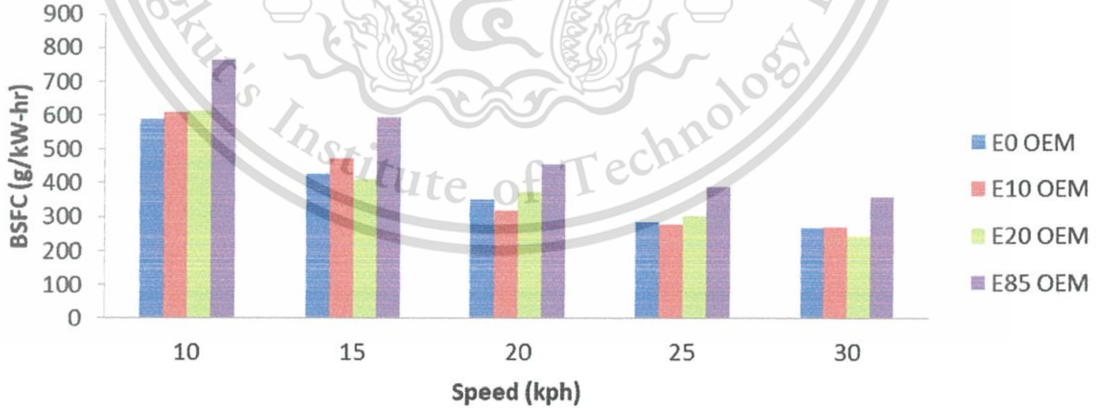


Figure 4.1 Brake specific fuel consumption on various conditions with OEM ECU

The bar chart in Figure 4.1 show the result of BSFC, Gasohol E85 has the highest BSFC following with gasohol E20, E10 and gasoline E0. Due to the LHV of fuel blended with ethanol is lower than that of gasoline.

Heating value of fuel is an important factor which affects brake specific fuel consumption (BSFC) of engine. This increasing relies on the percentage of ethanol in fuel where ethanol has heating value less than gasoline around 30%.
More ethanol blended in the fuel to produce same heat energy at similar condition resulted to the increment of BSFC.

Brake specific energy consumption is the ratio of energy obtained by burning fuel for an hour to the actual energy. And brake specific energy consumption is defined as product of BSFC and calorific value of fuel. Brake specific energy consumption (BSEC) is described as the quantity of energy consumed per unit power developed in a unit of time that described as how efficiently of energy obtained from its fuel.

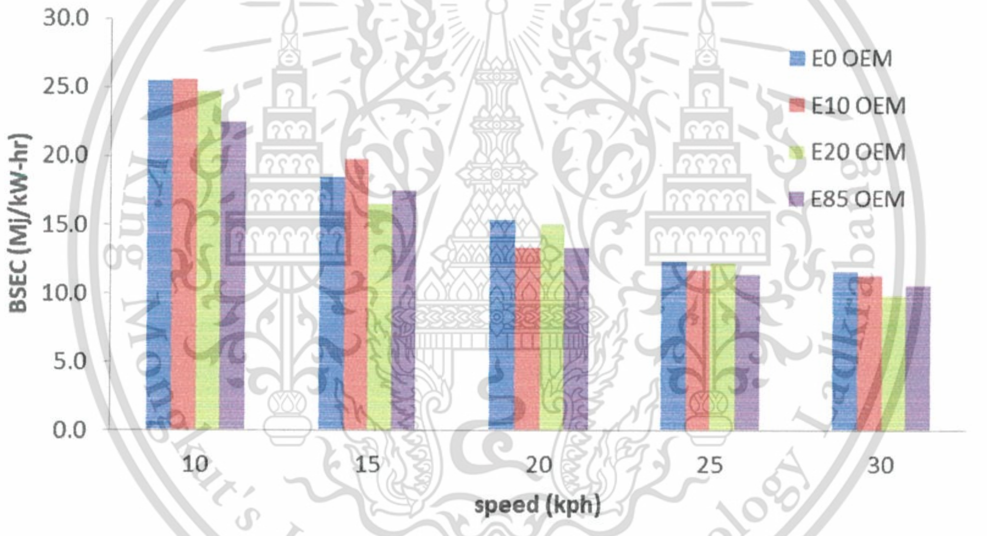


Figure 4.2 Brake specific energy consumption on various conditions with OEM ECU

Figure 4.2 signify that BSEC of gasoline is highest at 10 and 15 kph boat speed. That means fuel blends with ethanol use heat energy to operate for same output lower than gasoline Even though, the amount of fuel blends with ethanol is larger. The total energy input is lower than gasoline due to low heating value. Hence, BSEC is decrease when blended more of ethanol. But for 20 and 25 kph boat speed, original equipment manufacturing ECU cannot control lambda equal to 1 that affect to decrease the performance of engine and BSEC of E85 were rising.

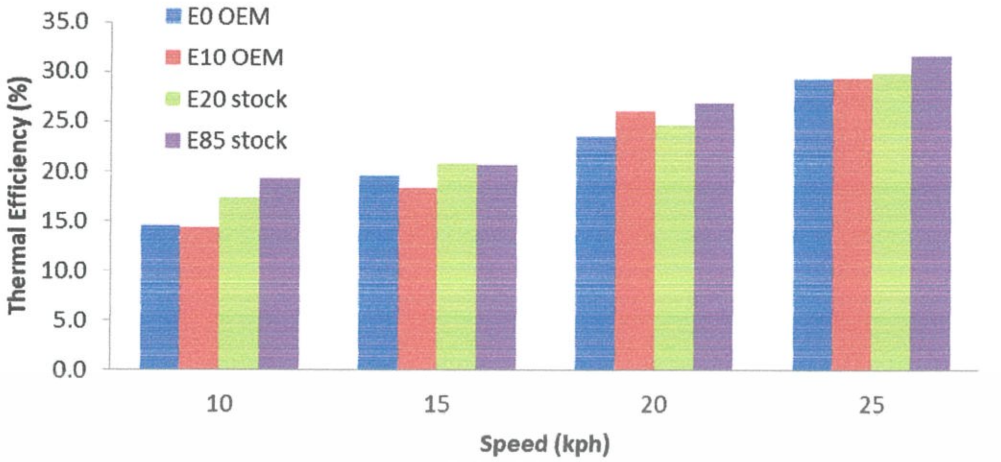


Figure 4.3 Thermal efficiency on various conditions with OEM ECU

Figure 4.3 show the result of thermal efficiency for E0, E10, E20 and E85 at speed 10 to 25 kph. Thermal efficiency is work-out divided by input energy.
The results show that at speed 10, 15, and 20 kph gasohol E20 represent the highest thermal efficiency following with E0, E10 and E85. However, at speed 25 kph E10 represent the highest thermal efficiency following with E20, E85 and E0. And thermal efficiency of E10 and E85 at speed 15 and 20 are lowest affect from higher BSFC and BSEC. It's conclude that if the engine is have not any modification , using gasohol E20 the engine can produce the highest efficiency in 10, 15, and 20 kph boat condition. On the other hand for high speed boat conditions (25 kph) the ethanol content should be reduced.

4.1.1.2 Engine with standalone ECU

The performance of spark ignition engines is a function of many factors. The amount of injected fuel, is one of the most important factors that use to determine the air-fuel ratio in the engine.

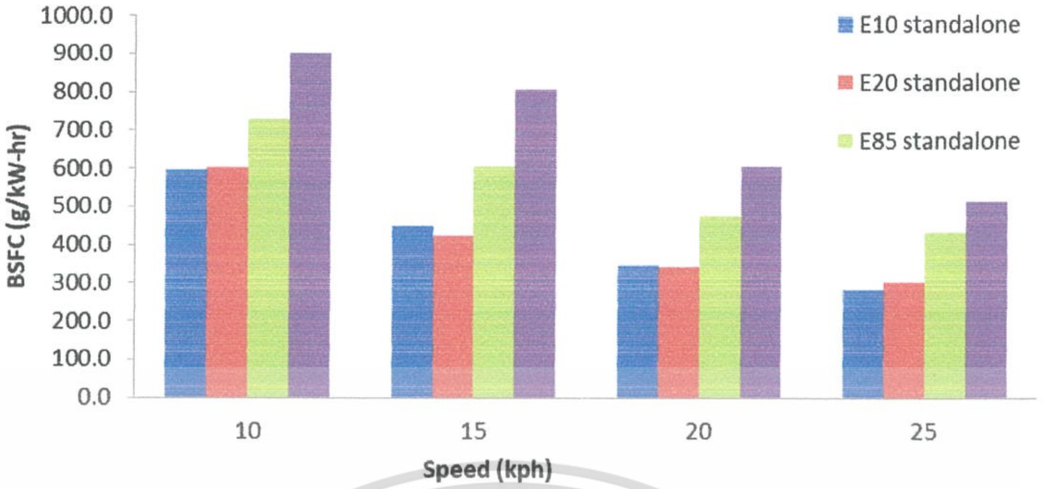


Figure 4.4 Brake specific fuel consumption with standalone ECU

The bar chart in Figure 4.1 show the result of BSFC, Gasohol E85 has the highest BSFC following with gasohol E55, E20 and gasoline E10. Due to the LHV of fuel blended with ethanol is lower than that of gasoline.

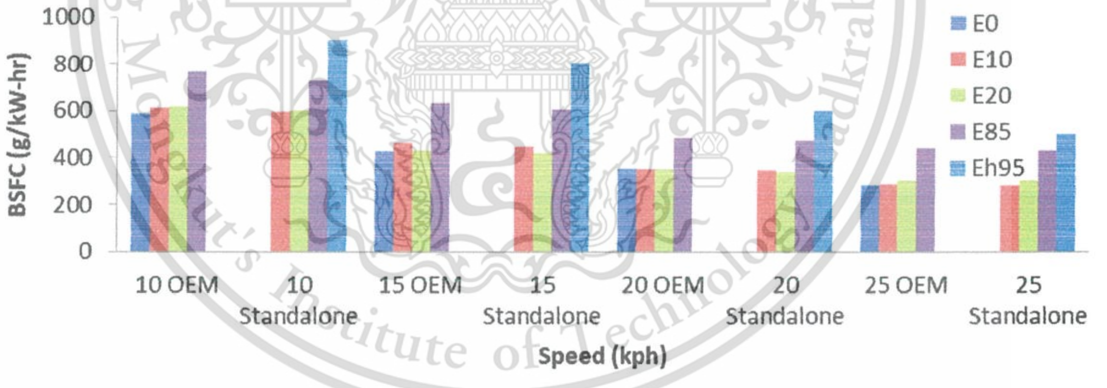


Figure 4.5 Break specific fuel consumption between OEM and standalone

Figure 4.5 shown the results of BSFC between original equipment ECU and standalone ECU. The results shown that the stand alone ECU can reduce the BSFC in every condition 2-15% in same fuel for all boat condition.

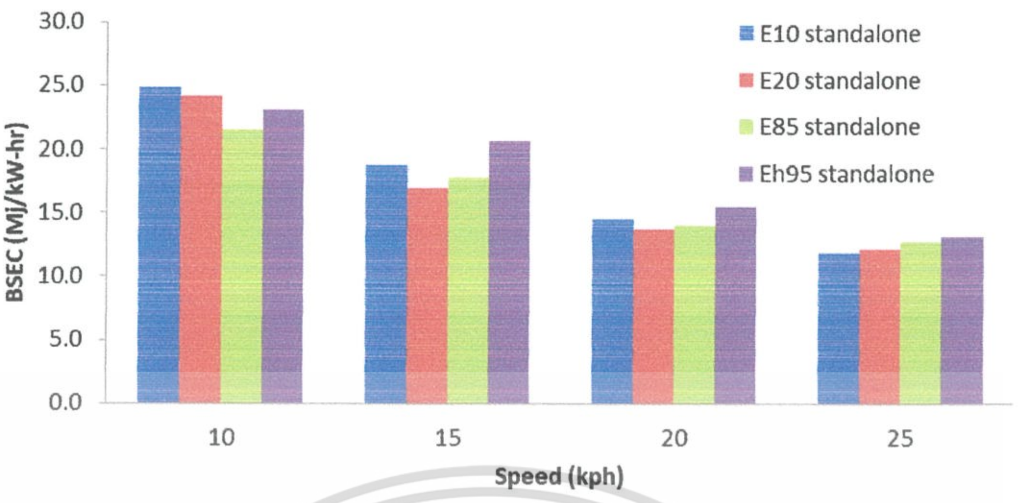


Figure 4.6 Brake specific energy consumption with standalone

The bar chart is Figure 4.6 and 4.7 are showing the comparisons of BSEC in each fuel on 4 different speed of boat with OEM and Standalone ECU. The results show that changing the OEM ECU to standalone can reduce BSEC in any fuel. In results of standalone ECU,

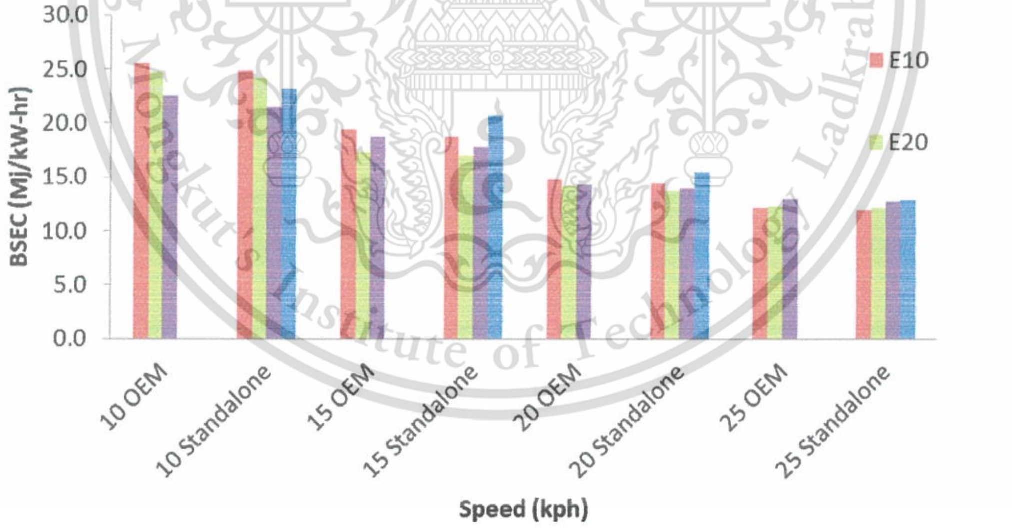


Figure 4.7 Break specific energy consumption between OEM and standalone

For the result of thermal efficiency, Figure 4.8 showed the relation between thermal efficiency and speed of boat. For speed 10-15 kph, E20 has the highest thermal efficiency.

The results indicate that E85 have the highest thermal efficiency following with E20, E10 and Eh95 for any boat speed. From the result engine running with E10 and E20 was using standalone ECU significant increased thermal efficiency up to 2% in same fuel from OEM ECU on any boat speed. And for E85, thermal efficiency increased 1% at 10 to 15 kph boat speed and up to 6% at 20 to 30 kph. The efficiency of Eh95 still low due to heat loss in combustion chamber.

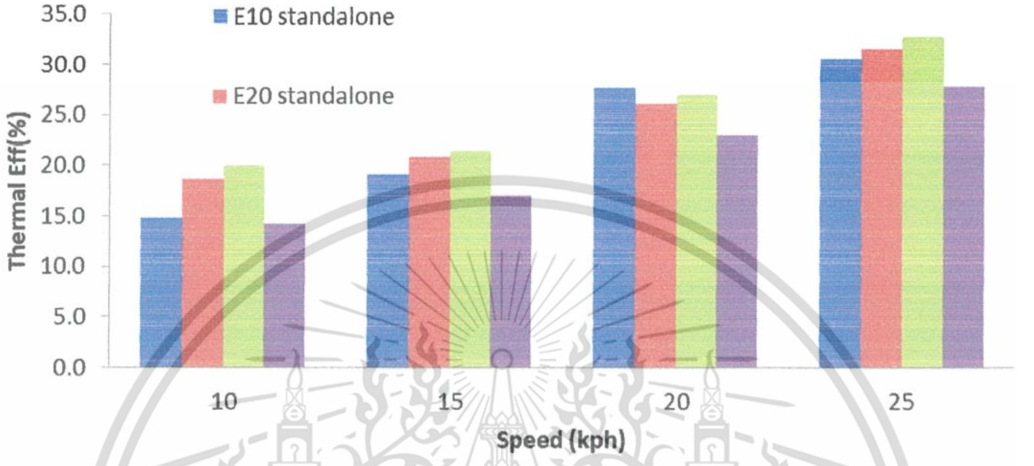


Figure 4.8 Thermal efficiency with standalone ECU

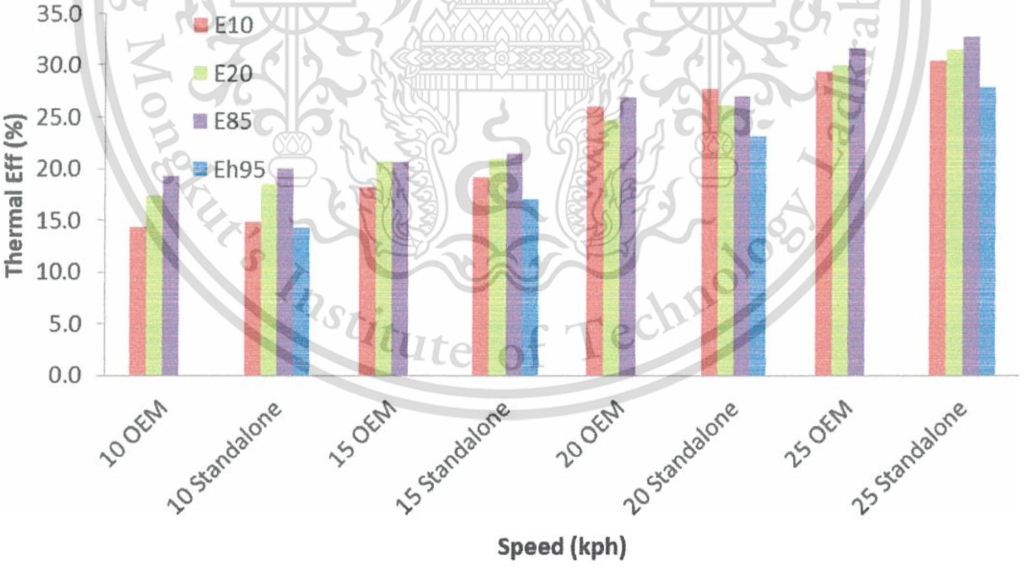


Figure 4.9 Thermal efficiency between OEM and standalone

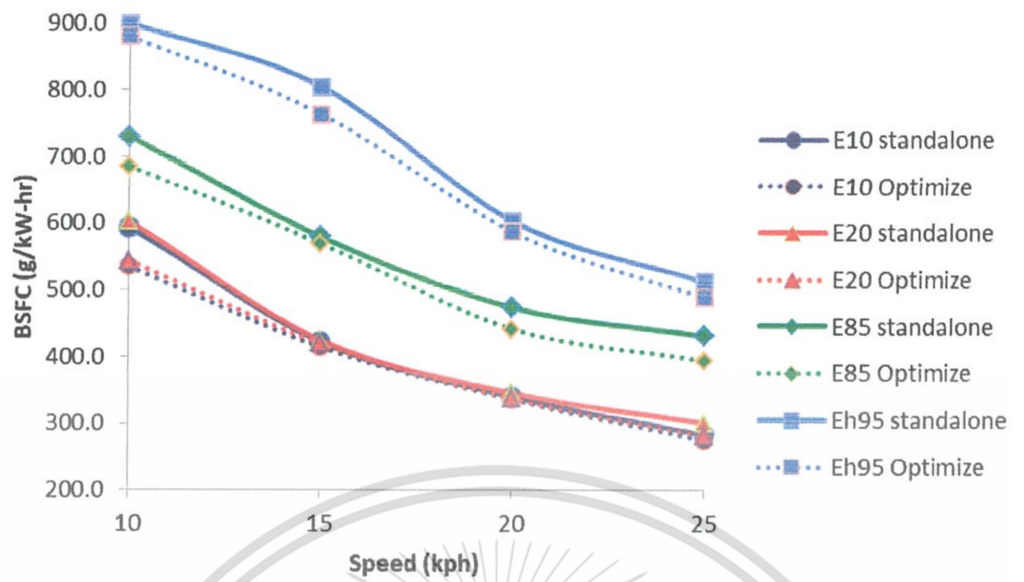


Figure 4.10 BSFC between different ECU

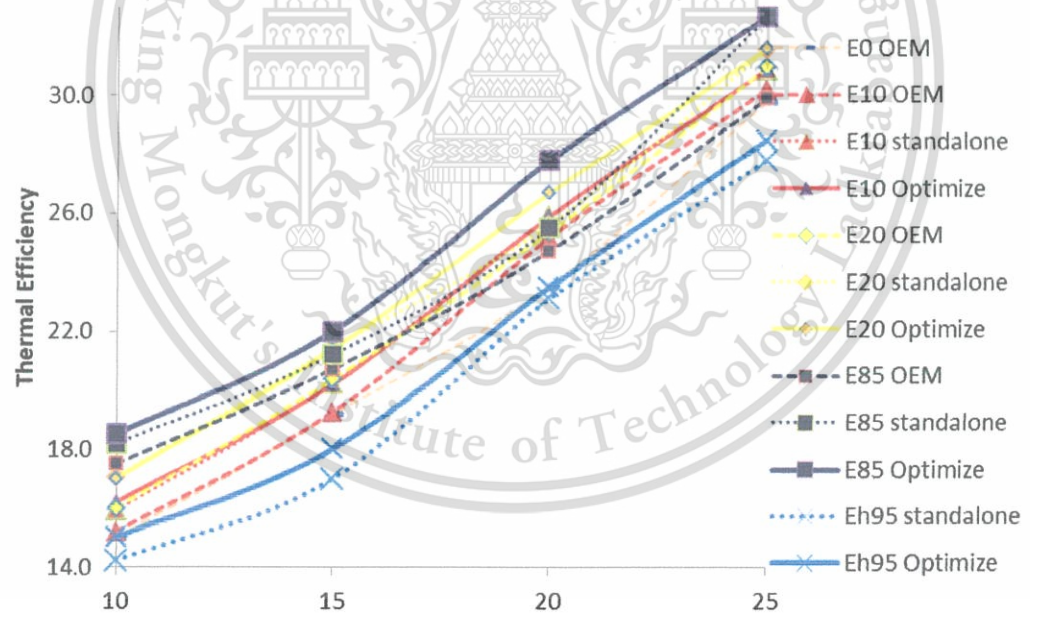


Figure 4.11 Thermal Efficiency between different ECU

Figure 4.10 shown break specific fuel consumption compare between standalone ECU and the optimize data from ignition timing. The result of BSFC in 10, 15, 20, 25 and 30 kph boat operating conditions were the same trend, Eh95 have the highest BSFC following with E85,E20 and E10 Due to the LHV of fuel.

Figure 4.11 presents the effect of using ethanol–unleaded gasoline blends on brake thermal efficiency. As shown in the figure, thermal efficiency increases as the ethanol content increases. The maximum thermal efficiency(32.8%) is recorded with 85% ethanol in the fuel blend for all boat speeds. To discuss the nature of the previous result, it is necessary to discuss the nature of the compression and combustion processes. The vaporization of fuel continues during the compression stroke. This tends to decrease the temperature of the working and increase the quantity of vapor in the working charge. When the latent heat of the fuel used is low, as in the case of unleaded gasoline, the effect of cooling is not sufficient to overcome the effect of additional vapor. Increasing the latent heat of the fuel blend used by increasing the ethanol percentage increases the effect of cooling.

4.1.2 Engine with transmission

A transmission is a machine in a power transmission system, which provides controlled application of the power. Often the term transmission refers simply to the gearbox that uses gears and gear trains to provide speed and torque conversions from a rotating power source to another device.

4.1.2.1 Engine operating with 1.25 : 1 gear ratio

Figure 4.12 – 4.13 are showing the effect of injection timing on BSFC with 1.25 by1 gear ratio. The result indicate that at 10, 15, 20 and 25 kph boat speed with 2 different gear ratio BSFC are showing in the same trend, Eh95 have the highest BSFC following with E85,E20 and E10 Due to the LHV of fuel. Eh95 and E85 can advance an ignition timing farthest following with E20 and E10 due to the anti-knock performance. And consider effect of gear ratio, 1.25 by 1 gear ratio produce a lowest BSFC than no gear box in any fuel.

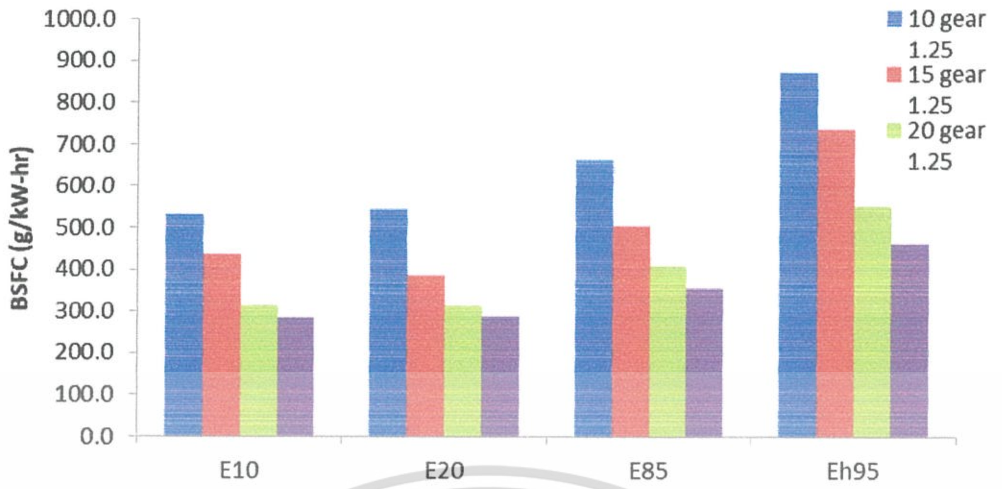


Figure 4.12 Break specific fuel consumption of gear ratio 1.25

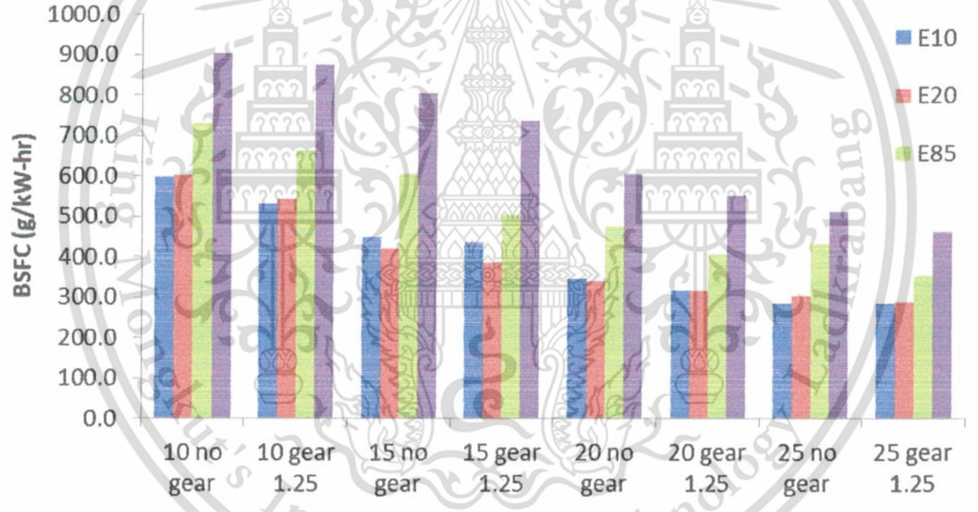


Figure 4.13 Break specific fuel consumption of different gear ratio

Figure 4.13, The bar chart shown the comparisons of BSFC in each fuel on 4 different speed of boat with 3 condition, no gear box and 1.25 by1 gear ratio. The lowest BSFC are bringing to show in each speed of boat and each condition. The result showed that BSFC of E95 fuel still highest followed with E85,E20 and E10 due to the LHV.

The bar chart indicates that using 1.25 gear ratio BSFC in each speed also lowest than no gear box. And engine running with 1.25 by 1 gear ratio can reduce BSFC average 8.1%, 8.5%, 10.1% and 7.1% for 10, 15, 20 and 25 kph boat speed of each fuel.

Figure 4.15 shown the comparisons of BSEC in each fuel on 4 different speed of boat with 2 conditions, no gear box and 1.25 :1 ratio. The result showed that BSEC of E95 fuel still highest followed with E10, E20 and E85. The bar chart indicates that using 1.25 gear ratio. Energy consumption in each speed also lowest than no gear box.

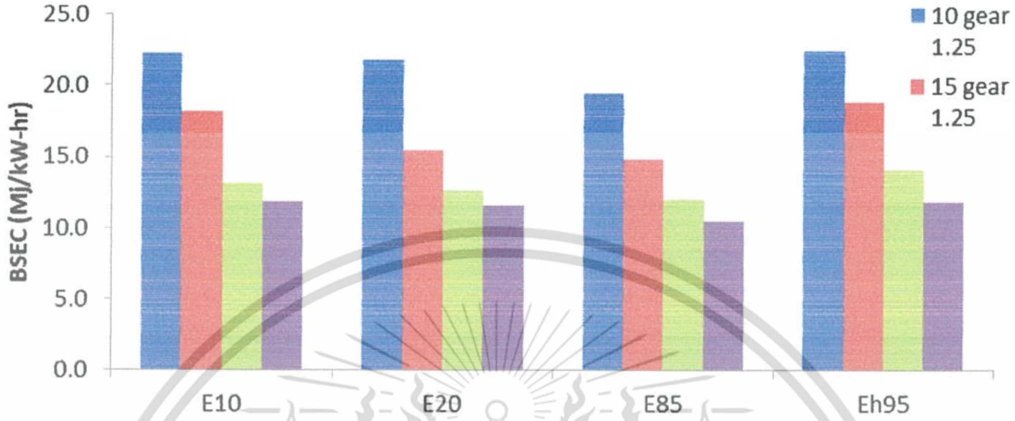


Figure 4.14 Break specific energy consumption of gear ratio 1.25

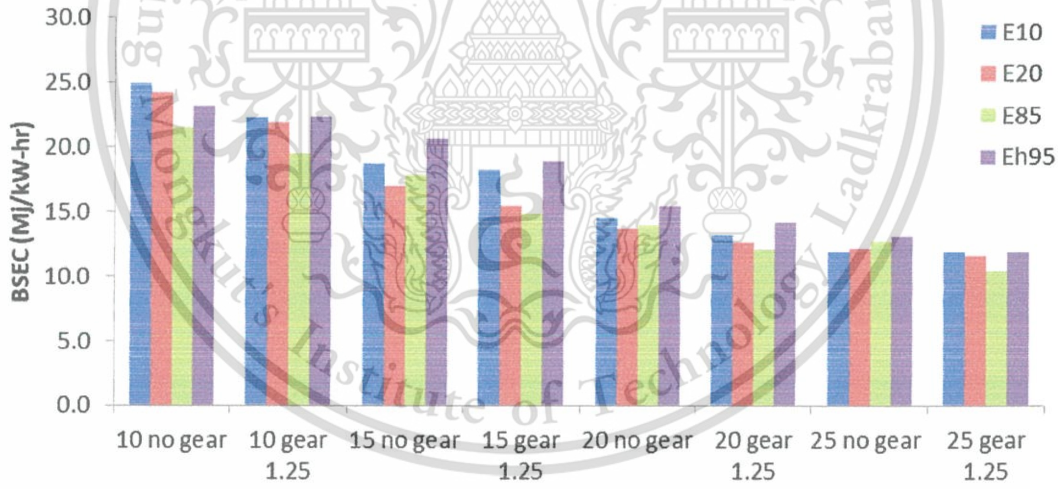


Figure 4.15 Break specific energy consumption of different gear ratio condition

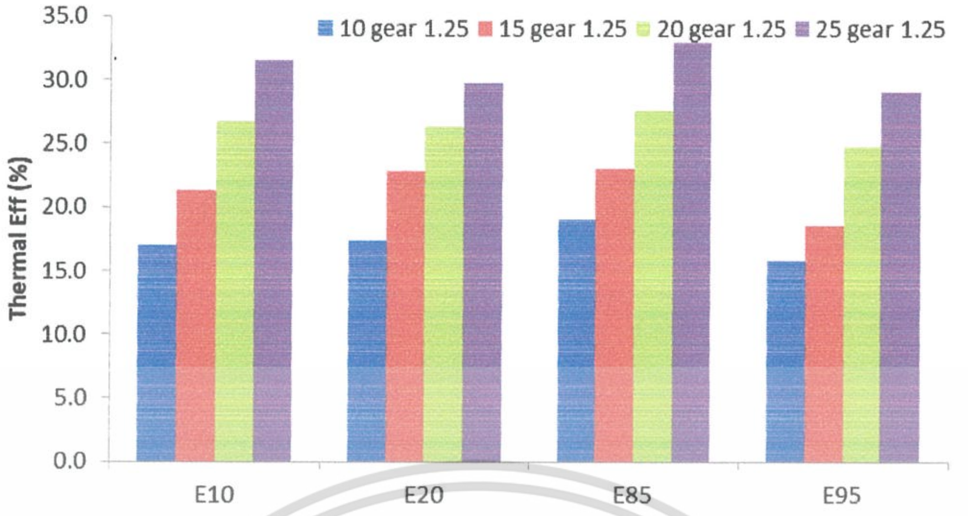


Figure 4.16 Thermal Efficiency of gear ratio 1.25

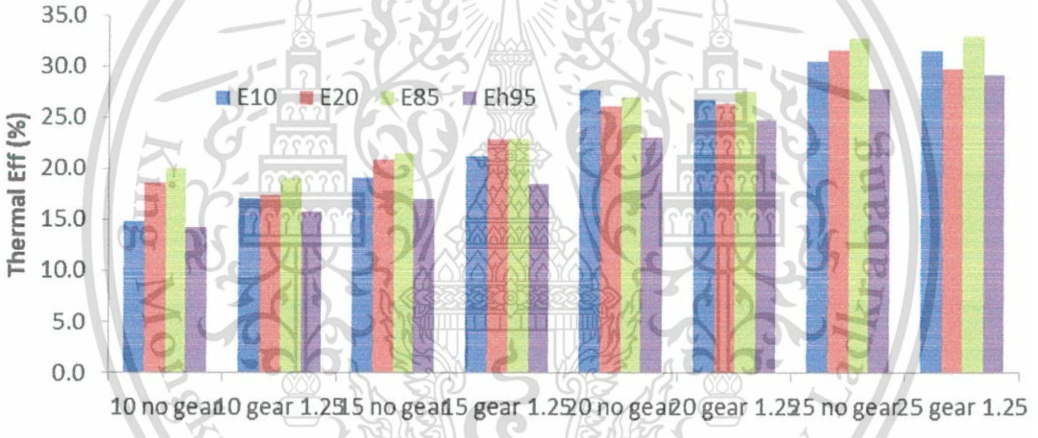


Figure 4.17 Thermal efficiency of different gear ratio condition

From the overall of result and discussion in part of 1.25 by 1 gear ratio efficiency, it suggests that using E85 fuel operation appear to be a good choice for engine efficiency. And in the term of transmission , using 1.25 by 1 gear ratio the engine produces the better efficiency approximately 1 to 3.5% than and no transmission.

4.1.2.2 Engine operating with 0.83 : 1 gear ratio

Figure 4.18-4.19 shown the BSFC of 0.83 by 1 gear ratio. The result indicate that at 10 to 25 kph boat speed with 2 different gear ratio BSFC are showing in the same trend, Eh95 have the highest BSFC following with E85,E20 and E10 Due to the

LHV of fuel and BSFC decrease with risen ignition advanced to a point ,and then increase slightly when the knock is occur. And consider in different gear ratio, using and 0.83 by 1 gear ratio produce the lowest BSFC in any fuel.

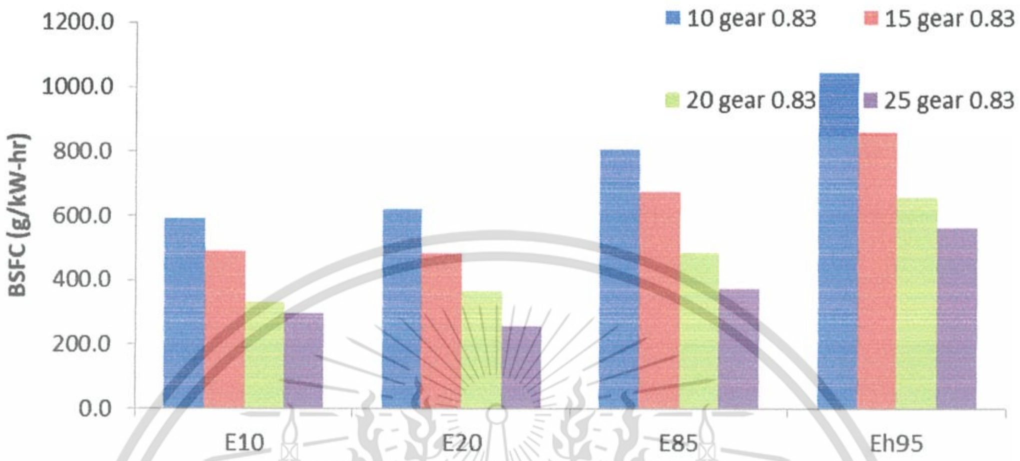


Figure 4.18 Break specific fuel consumption of gear ratio 0.83

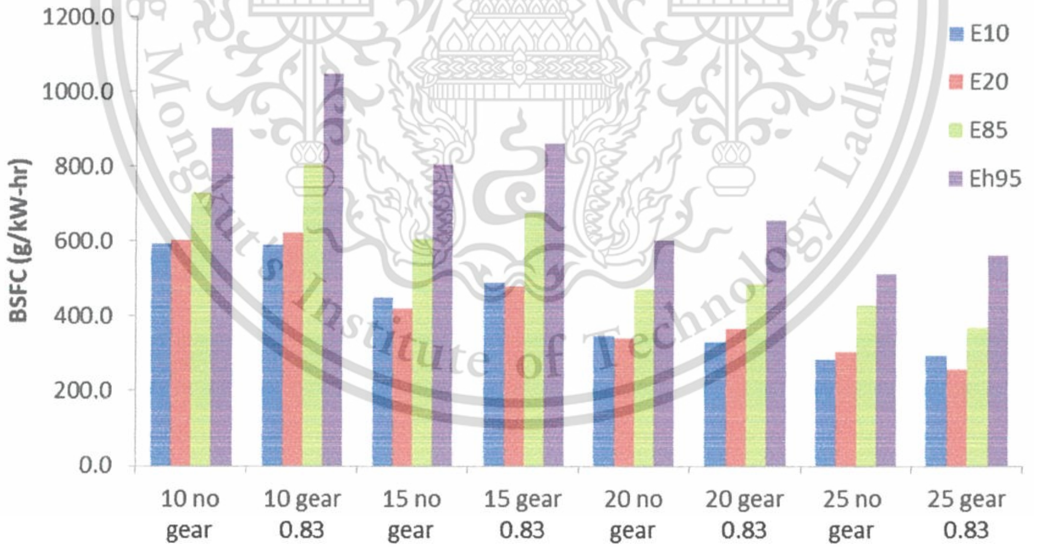


Figure 4.19 Break specific fuel consumption of different gear ratio

Figure 4.20-4.21 the effect of ignition timing on BSEC at 10 to 25 kph boat speed with 0.83 by 1 gear ratio and no gear box. The result shown that BSEC of gear ratio 0.83 is higher than no gear box condition. And Eh95 have the highest BSEC following with E10,E20 and E85 for any boat speed with 2 gear ratio.

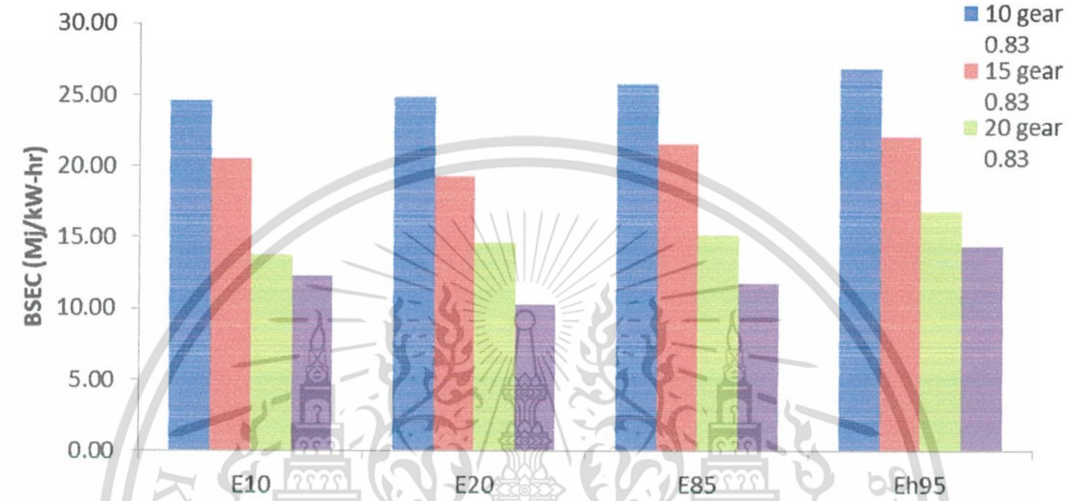


Figure 4.20 Break specific energy consumption of gear ratio 0.83

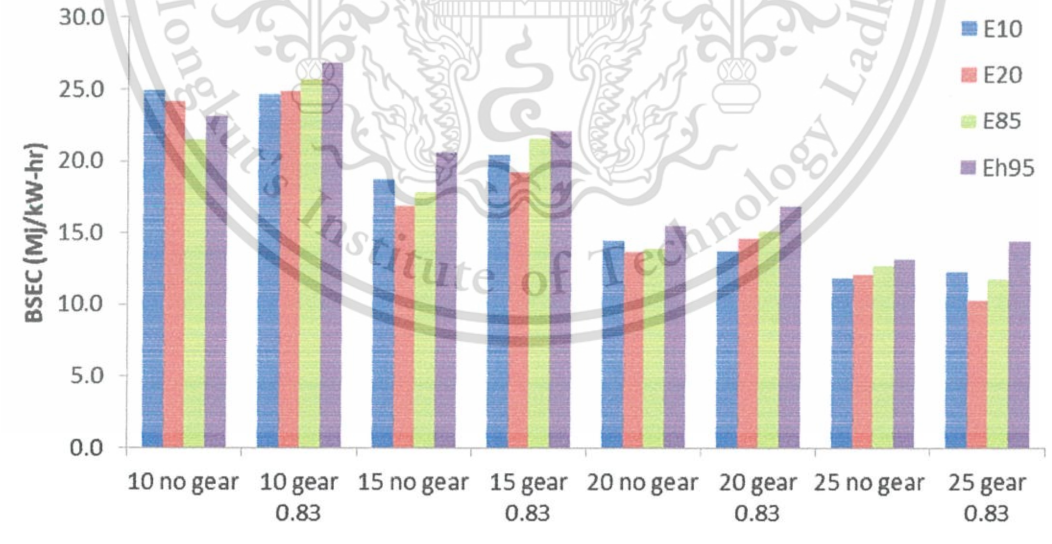


Figure 4.21 Break specific energy consumption of different gear ratio

Figure 4.23 shown the comparisons of thermal efficiency in each fuel on 4 different speeds of boat with 2 conditions, no gear box and 0.83 by 1 gear ratio. The result showed that thermal efficiency of E85 fuel still highest followed with E20, E10 and Eh95.

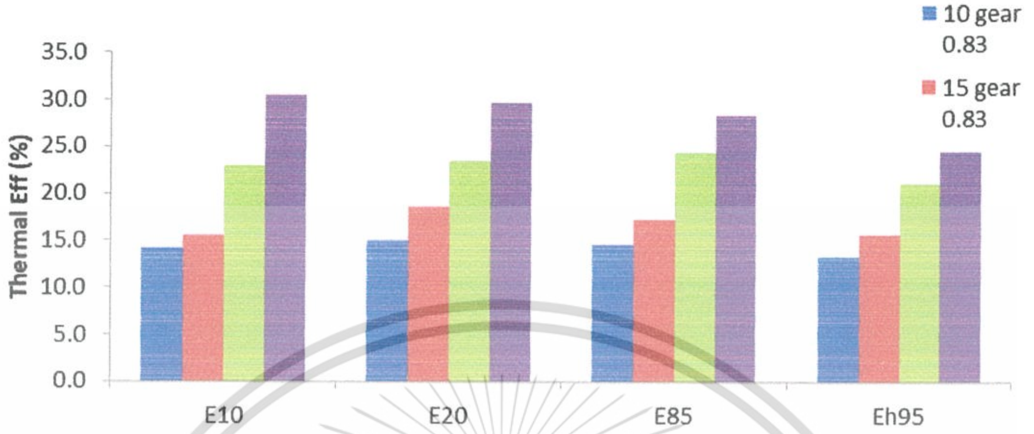


Figure 4.22 Thermal Efficiency of gear ratio 0.83

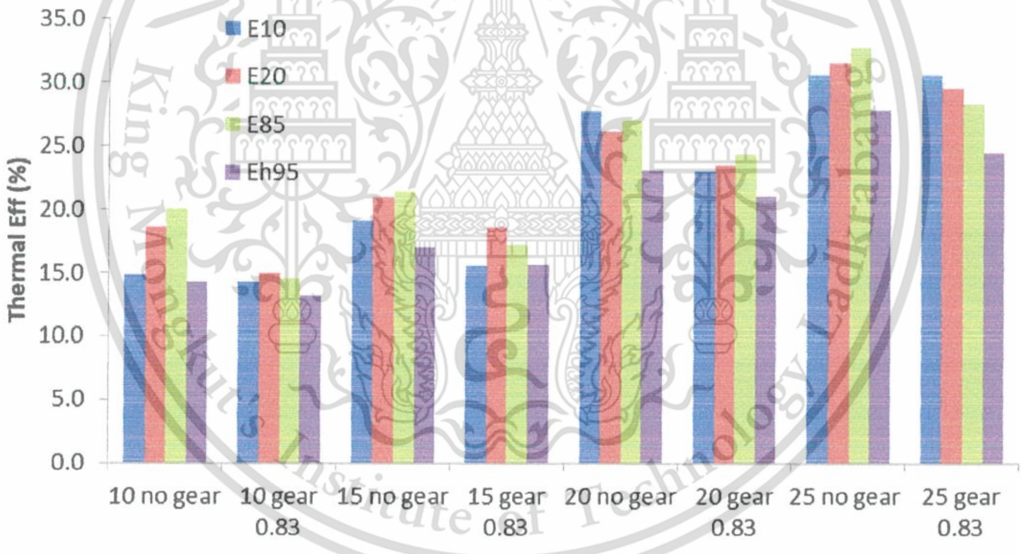


Figure 4.23 Thermal efficiency of different gear ratio condition

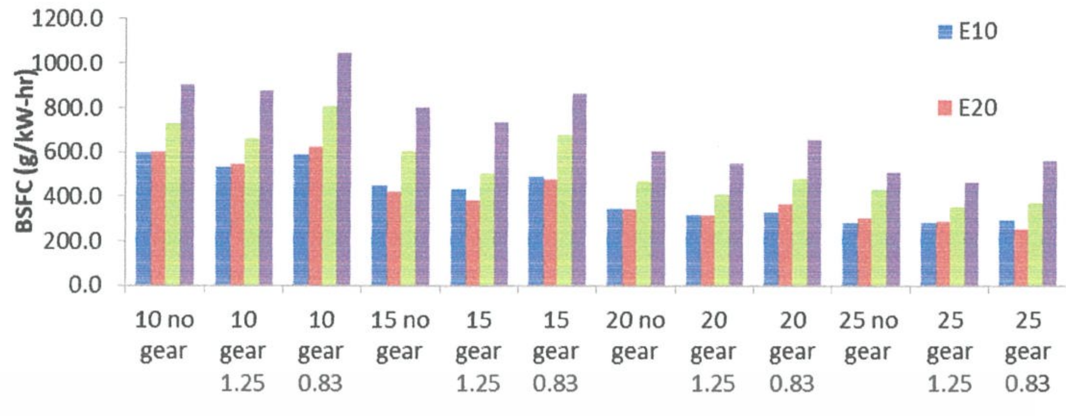


Figure 4.24 Comparison of overall break specific fuel consumption at speed 10-25

Figure 4.59 showed the comparisons of BSFC in each fuel on 4 different speed of boat with 3 condition, no gear box, 1.25 by1 gear ratio and 0.83 by 1 gear ratio. The lowest BSFC are bringing to show in each speed of boat and each condition. The result showed that BSFC of E95 fuel still highest followed with E85, E20 and E10 due to the LHV.

The bar chart indicates that using 1.25 gear ratio, BSFC in each speed also lowest than no gear box. And engine running with 1.25 by 1 gear ratio can reduce BSFC average 8.1%, 8.5%, 10.1% and 7.1% for 10, 15, 20 and 25 kph boat speed of each fuel.

Figure 4.26, The bar chart are showing the comparisons of BSEC in each fuel on 4 different speed of boat with 3 condition, no gear box, 1.25 by1 gear ratio and 0.83 by 1 gear ratio. The lowest BSEC are bringing to show in each speed of boat and each condition. The result showed that BSEC of E95 fuel still highest followed with E10, E20 and E85 due to the LHV. The bar charts indicate that using 1.25 gear ratio BSEC in each speed also lowest than no gear box. It's suggest that 1.25 by 1 gear ratio produce a better energy consumption than 0.83 by 1 gear ratio and no gear ratio.

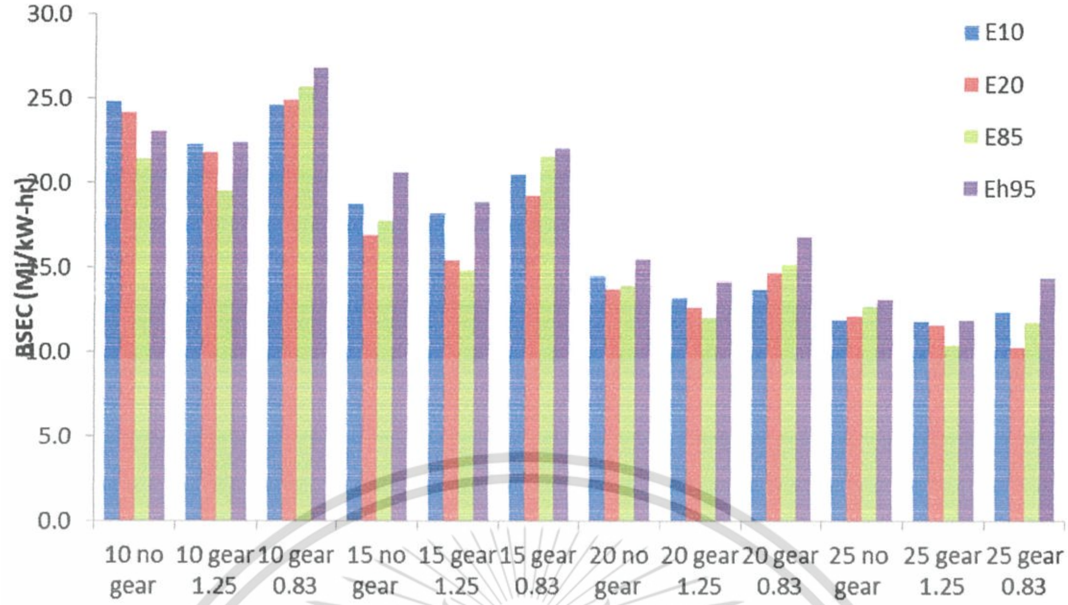


Figure 4.25 Comparison of overall break specific energy consumption at speed 10-25 kph

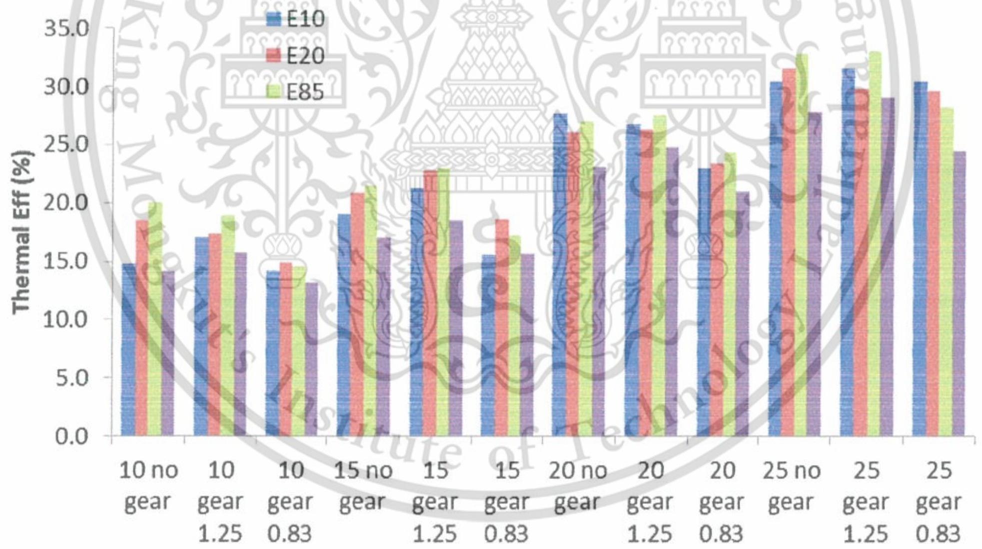


Figure 4.26 Comparison of overall thermal efficiency at speed 10-25 kph

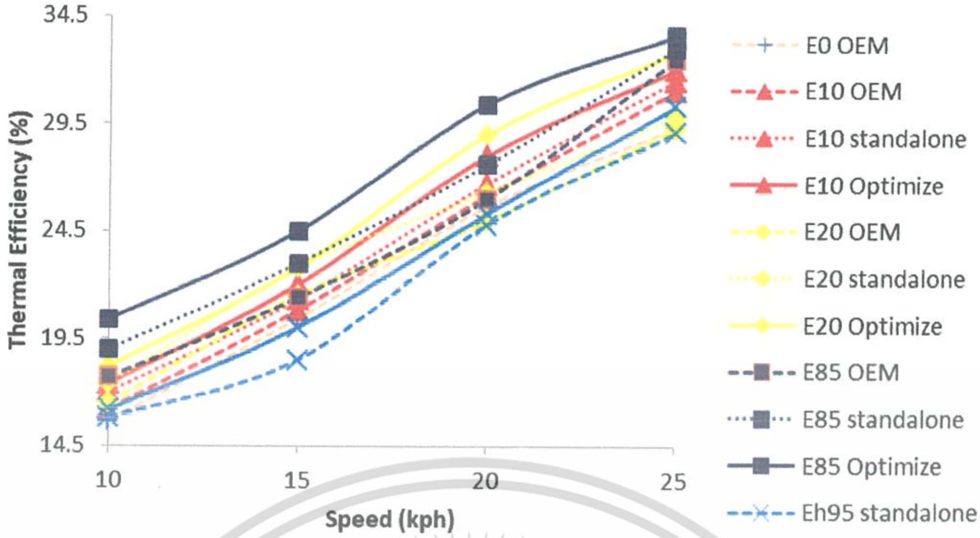


Figure 4.27 Comparison of thermal efficiency between different ECU and speed at gear ratio 1.25:1

Figure 4.26 shown the comparisons of thermal efficiency in each fuel on 4 different speed of boat with 3 condition, no gear box, 1.25 by1 gear ratio and 0.83 by 1 gear ratio. The highest thermal efficiency was brought to show in each speed of boat and each condition. The result showed that thermal efficiency of E85 fuel still highest followed with E20, E10 and Eh95.

From the results were describing with the high ethanol content may accelerate the beginning of combustion period and reduce time of heat loss in early stage of the combustion lower heat loss to the combustion chamber walls and higher thermal efficiency is attained. Ethanol increases volumetric efficiency as it has a higher latent heat of vaporization, resulting in a cooler air-fuel mixture compared to gasoline. And Ethanol has a higher octane rating to resist auto-ignition and knock. It's mean that more of ethanol content can provide more of ignition advanced BTDC more of fuel can combust and give more power. But for Eh95 water in fuel take a significant amount of energy when it convert from liquid to vapor state which causes the thermal cooling of charge inside the cylinder that why the thermal efficiency of Eh95 are lowest.

And consider in different gear ratio , 1.25 by 1 gear ratio produce the highest thermal efficiency and 0.83 by 1 gear ratio produce the lowest thermal in any fuel.

Figure 4.27 shown the comparison between the thermal efficiency in each ECU, the results shown that using E85 with the optimization provided the best thermal efficiency (33.6%, improve up to 3.8% when compared with OEM ECU).

4.2 Emission

To consider the impact of timing, advance in ignition timing is important strategy when using ethanol due to higher of octane number and latent heat of vaporization compare to gasoline which cause prolong of ignition delay from heat absorption. Then, reduction of those emissions from the short duration between the terminate of fuel injection and ignition timing contributes to improvement of flame propagation from increasing of turbulence intensity and high mixture stratification which defined as the mixture near the spark plug which is locally rich and retains a constant overall lean air-fuel ratio

4.2.1 Engine with original equipment manufacturing ECU

Carbon monoxide (CO) and hydrocarbon (HC) are influenced by oxygen which available during combustion. So, there are anticipated to reduce as the mixture becomes leaner. In general, the unburned hydrocarbon in exhaust is mainly caused by three mechanisms misfiring or incomplete combustion, which occurs in highly rich or lean situation, or when the air–fuel mixture contains large amount of burned exhaust or nitrogen to make flame propagate incompletely in combustion chamber, flame quenching effect, which takes place near combustion chamber surface area or clearance and deposits or oil membrane, which absorbs fuel. Figure 4.29 shows the variation of HC emission for different ethanol–gasoline-blended fuels under different long-tailed boat working condition. It can be found that the minimum HC emission occurs in gasohol E85 fuel operation.

Figure 4.28-4.30 are showing The bar chart of exhaust emission concentration at 10 to 30 kph boat speed with OEM ECU. Starting with CO, and HC at 10 and 15 kph boat speed, the result indicate that increasing the ethanol content, the concentration of CO and HC decrease in comparison to base gasoline E0. The lowest CO and HC emission was obtained with E85 fuel operation while the CO and HC emission with E0 due to it can be completely vaporized easier and have more oxygenated properties which make the stoichiometric in the wider area than gasoline. Thus, flame speeds were also increased at let more complete of combustion. and for the 20 to 30 boat speed, operating lambda of e85 are increase than 1 from the limit of ECU but E85 still showing the lowest CO and HC due to the oxygen enrichment coming from ethanol and oxygen enhancement.

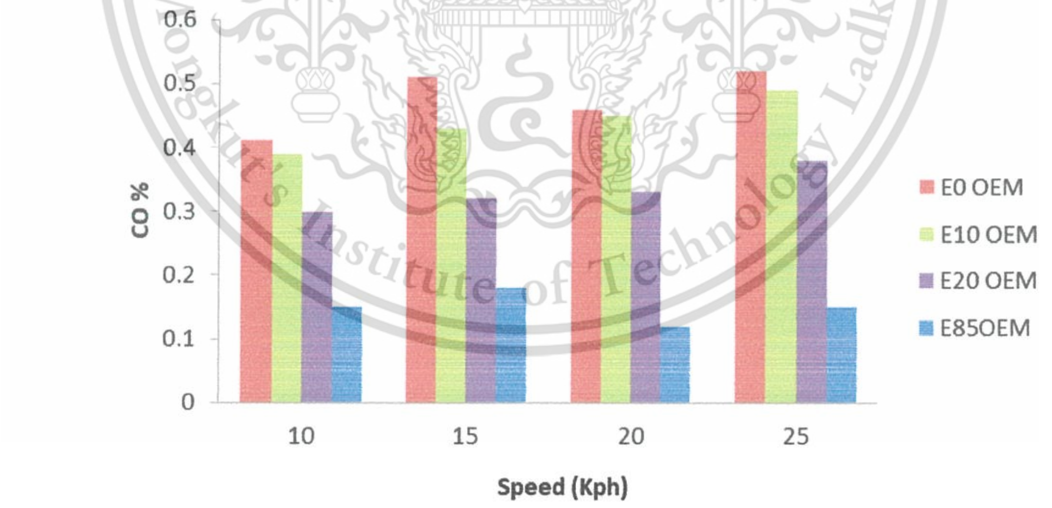


Figure 4.28 Carbon monoxide emission of OEM ECU

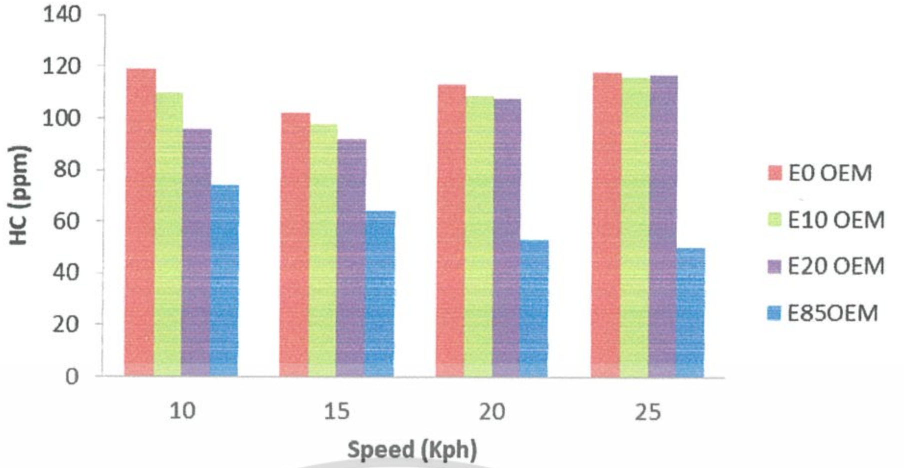


Figure 4.29 Hydrocarbon emission of OEM ECU

Even though, the fuel quantities of ethanol blended is more than gasoline, but the oxygen content in ethanol lets excess air to combust residue emissions and enhance complete combustion which leads higher of CO_2. Figure 4.12 the result signify that CO_2 increase as the ethanol content in the blended fuel increase due to the improve combustion. However, at 20 to 30 kph boat speed CO_2 of E85 are lower than E20 fuel operation due to the leaning air/fuel ratio.

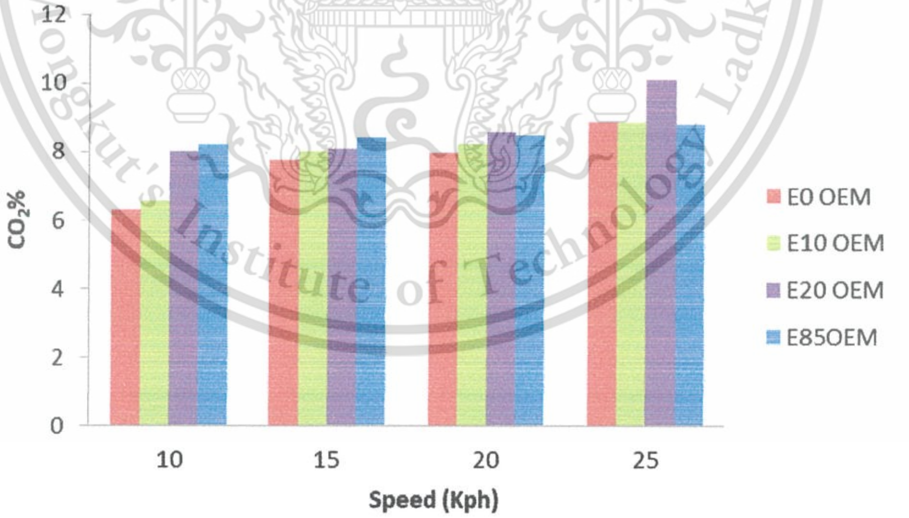


Figure 4.30 Carbon dioxide emission of OEM ECU

4.2.2 Engine with standalone ECU

The bar chart showing the exhaust emission concentration in E10, E20, E85 and eh95 when the engine operate with Standalone ECU. The result indicate that increasing of ethanol content in blended fuel CO and HC decrease in comparison to base gasohol E10. And CO emission in case of Eh95 are 76%, 70%, 69%, 69% , and 66% lower than those in case of gasohol E10 for 10,15,20,25and 30 boat speed condition.

Figure 4.32, the concentration of HC emission is showing in the same trend of CO emission. The lower CO and HC than those of gasoline due to oxygen content of ethanol in blended fuel mount up the ratio of oxygen to fuel in over-rich zone. The actual of air-fuel ratio becomes stoichiometric whereas increasing of ethanol content in fuel contributes to more complete combustion which leads to decrease soot formation.

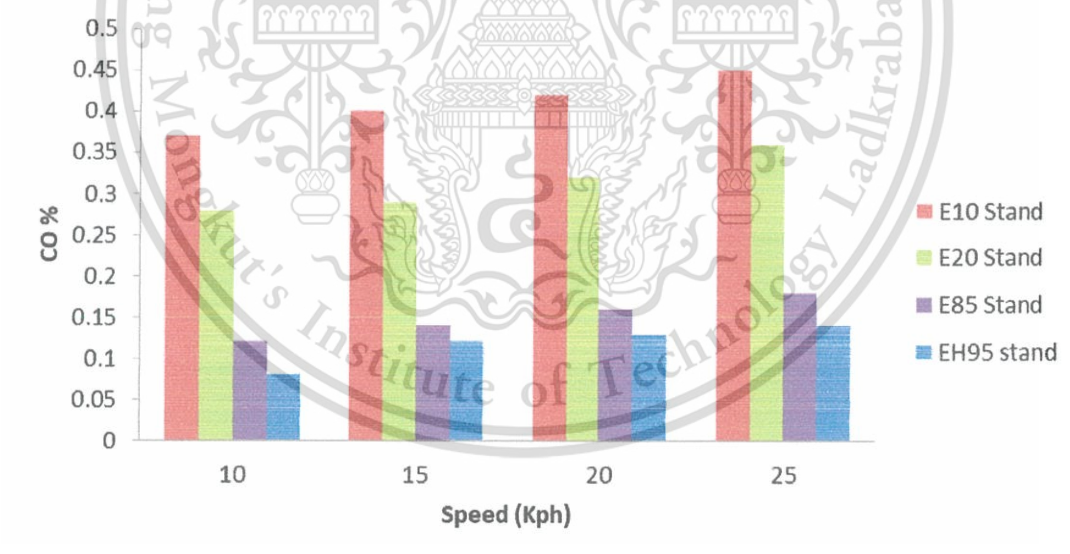


Figure 4.31 Carbon monoxide emission of standalone ECU

For CO_2 emission, Figure 4.33 indicate that Eh95 produce the highest CO_2 concentration following with E85, E20 and E10 due to the improve combustion of ethanol content.

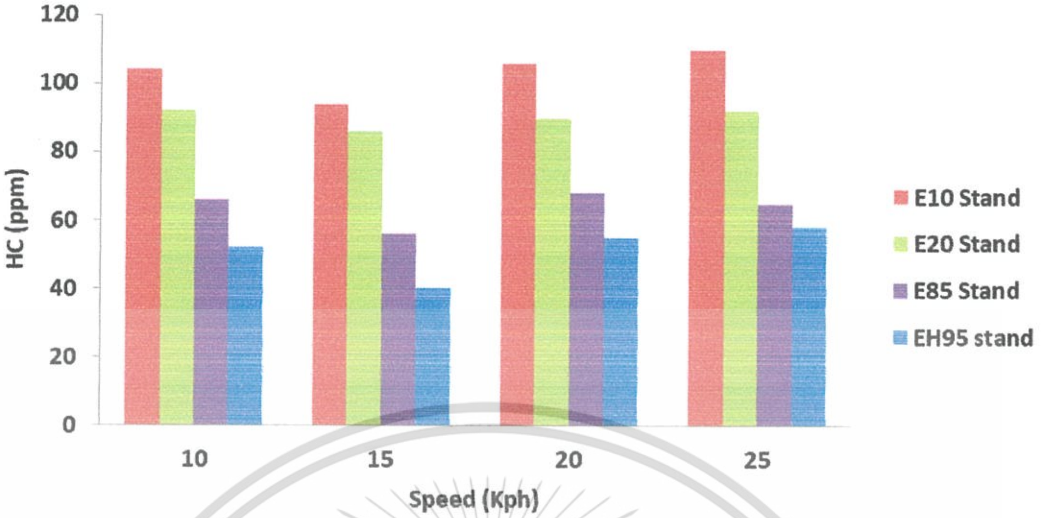


Figure 4.32 Hydrocarbon emission of standalone ECU

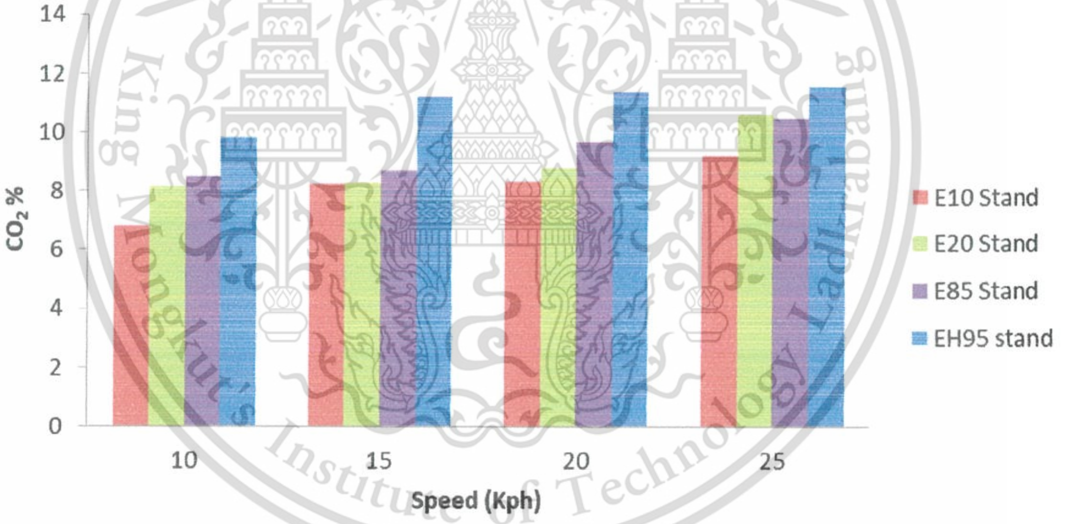


Figure 4.33 Carbon dioxide emission of standalone ECU

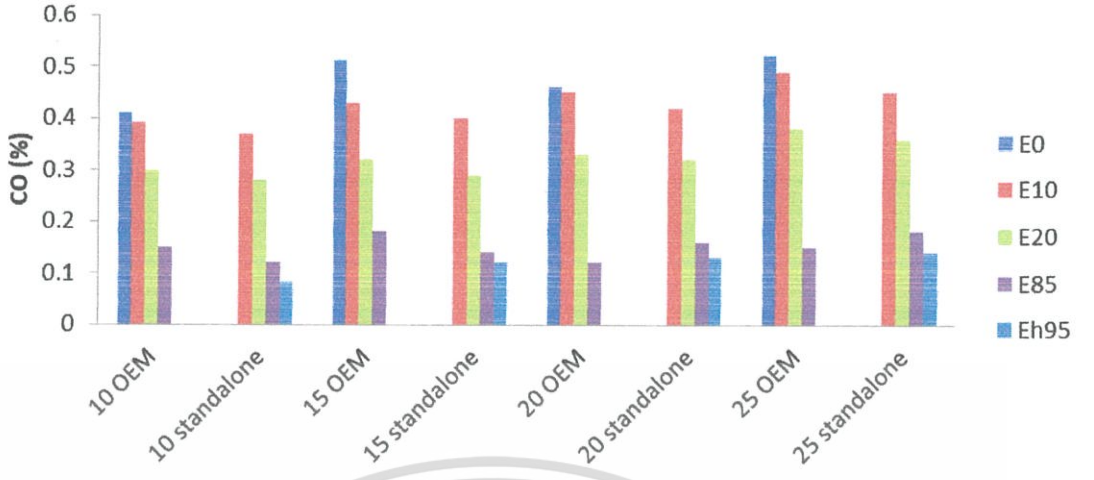


Figure 4.34 Comparisons of carbon monoxide emission in different ECU

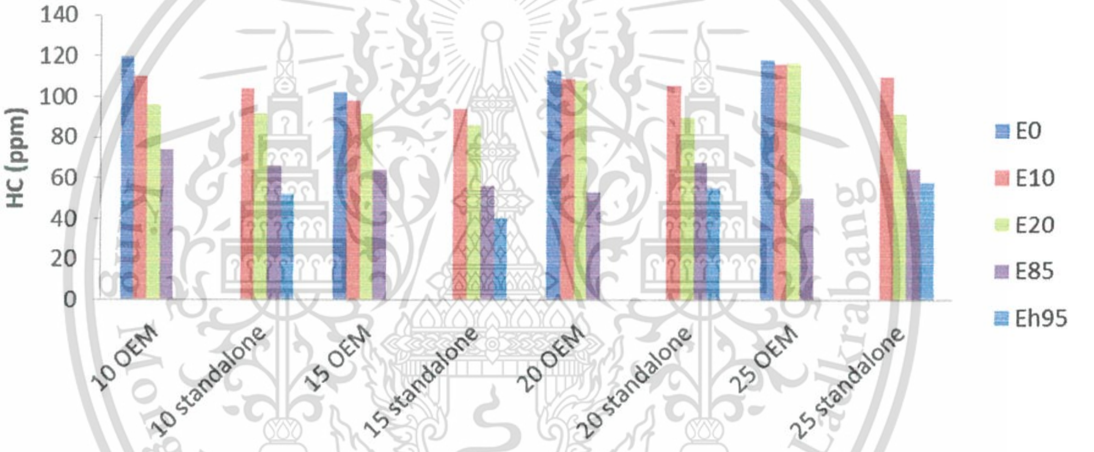


Figure 4.35 Comparisons of hydrocarbon emission in different ECU

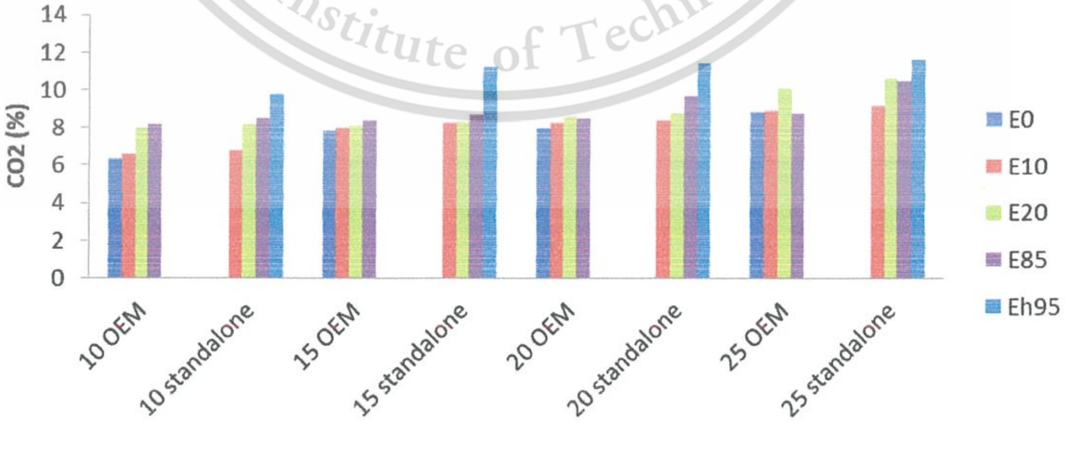


Figure 4.36 Comparisons of carbon dioxide emission in different ECU

4.2.2 Engine with transmission

4.2.2.1 Engine operating with 1.25 : 1 gear ratio

Figure 4.37-4.42 showing the exhaust emission concentration in E10, E20, E85 and Eh95 when the engine operates with 1.25 gear ratio. The results of exhaust emission concentration are showing in the same trend that I discussed in previous slide. For CO, and HC emission E10 also still have the highest concentration following with E20, E85 and Eh95

CO and HC emissions are reduced when increasing the ethanol concentration due to the leaning effect cause by the ethanol addition. Thus, flame speeds were also increased at let more complete of combustion. Using Eh95 a decrement of 83%, 82%, 74% and 71% in co emission is observe from the gasohol E10 value for 10, 15, 20 and 25 kph boat speed condition respectively. And HC emission in case of Eh95 are63%, 55%, 57%, 53% lower than those in case of gasohol E10 for 10, 15, 20 and 25kph boat speed condition.

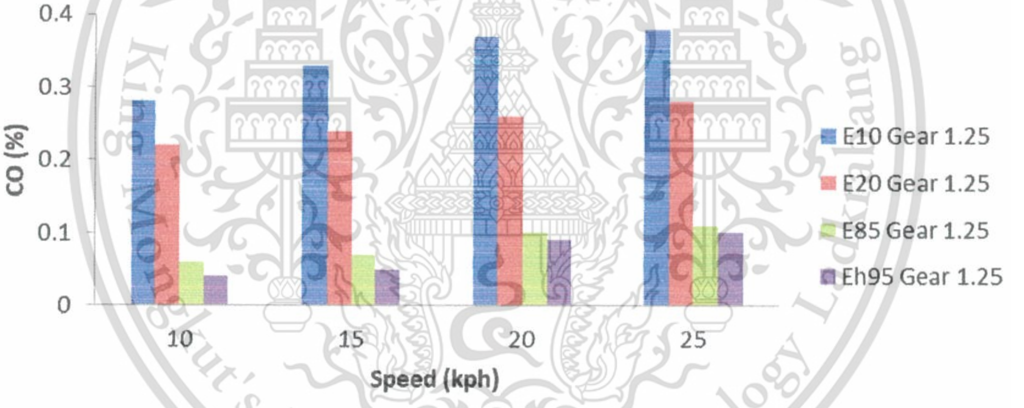


Figure 4.37 Carbon monoxide emissions of 1.25 gear ratio condition

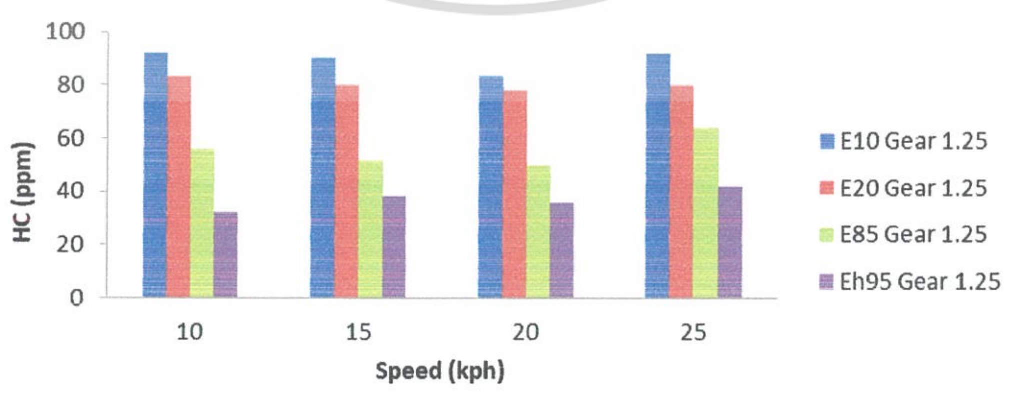


Figure 4.38 Hydrocarbon emissions of 1.25 gear ratio condition

From the describing of CO and HC concentration, more complete of combustion lead to increase CO_2 concentration. Figure 4.39 has shown Eh95 have the highest of CO_2 concentration following with E85, E20 and E10. The average of increasing in CO_2 from E10 to Eh95 is 37%.

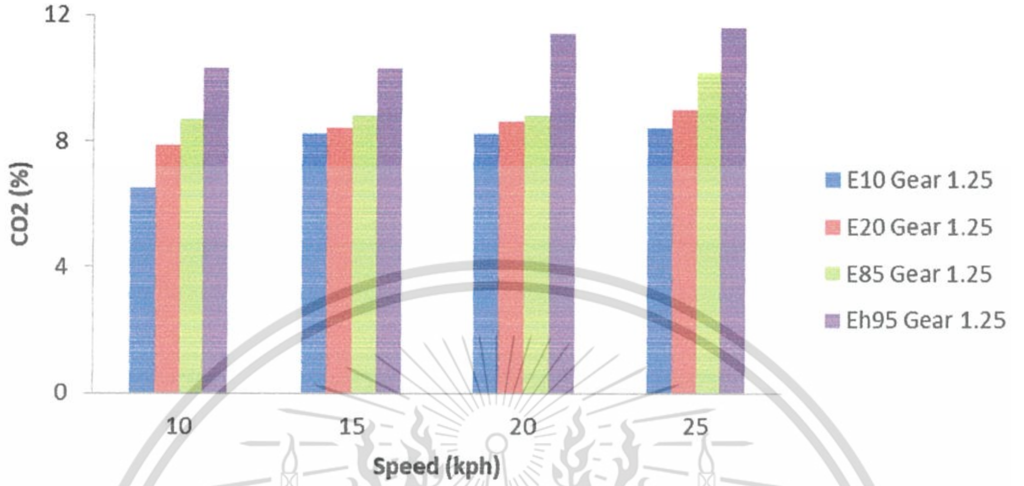


Figure 4.39 Carbon dioxide emissions in 1.25 gear ratio condition

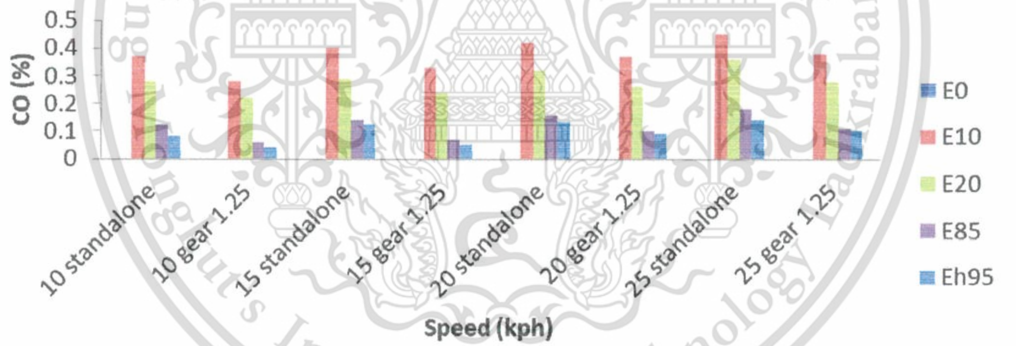


Figure 4.40 Comparisons of carbon dioxide emissions in 1.25 gear ratio and No-gear box condition

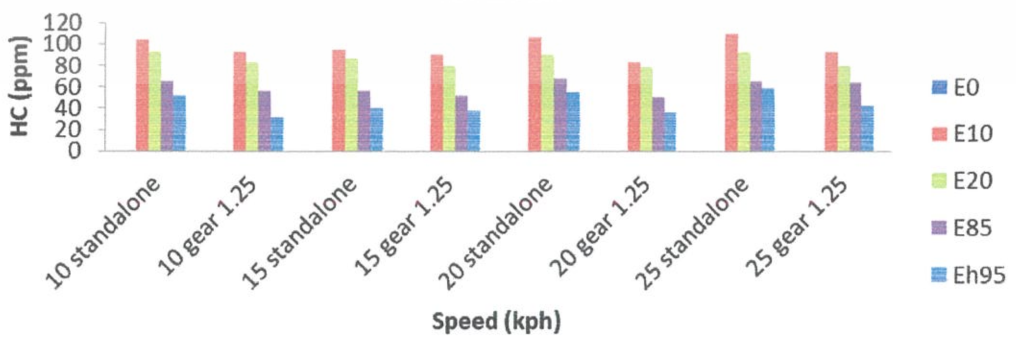


Figure 4.41 Comparisons of hydrocarbon emission in 1.25 gear ratio and no gear box condition

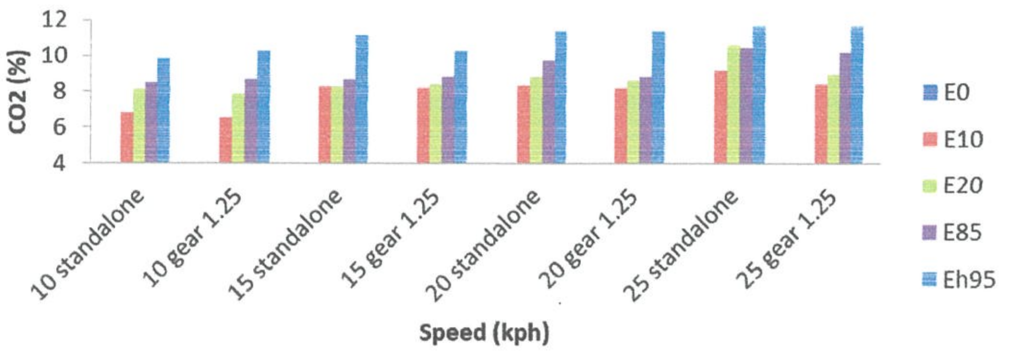


Figure 4.42 Comparisons of carbon dioxide emission emission in 1.25 gear ratio and no gear box condition

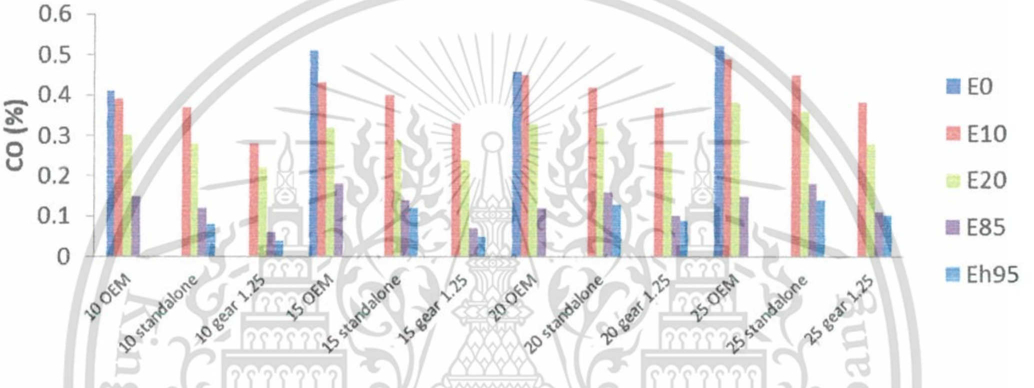


Figure 4.43 Comparisons of carbon monoxide emission in all condition

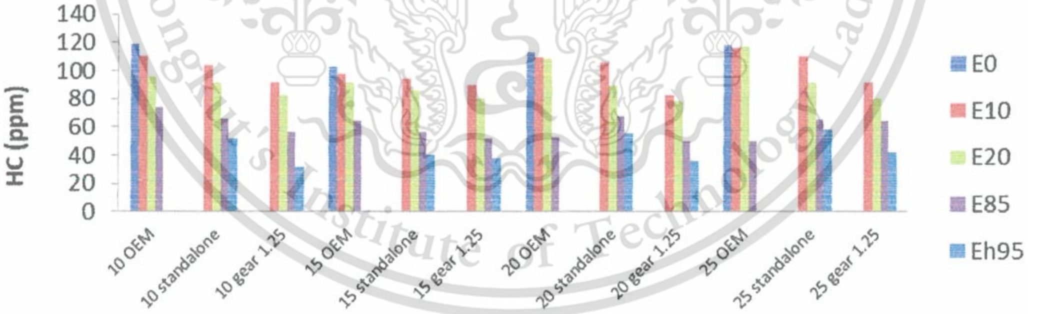


Figure 4.44 Comparisons of hydrocarbon emission in all condition

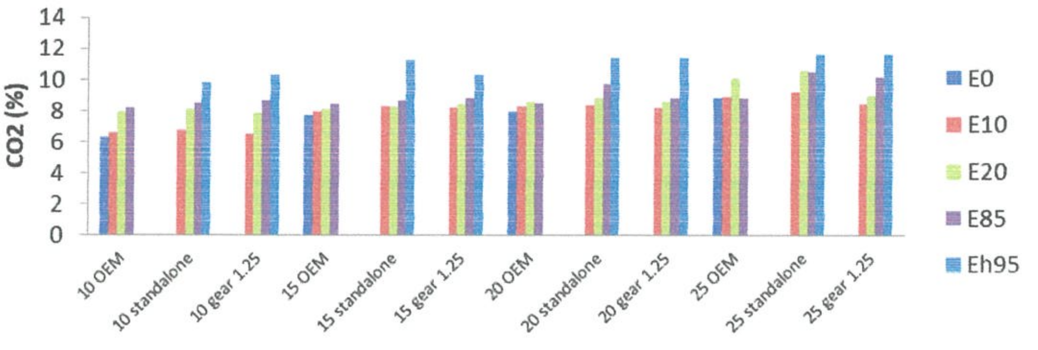


Figure 4.45 Comparisons of carbon dioxide emission in all conditions

Figure 4.43-4.44 the bar chart are showing a comparison overall result of CO and HC emission in 5 different speed with 3 different gear ratio. For the result indicate that using Eh 95 fuel to operate in Long-tailed boat is beneficial with respect of the emission control, as CO and HC are regulated pollutant. And consider in the transmissions ratio, 1.25 by 1 ratio al so appear to be a good choice for CO and HC emission for operate with boat engine. For HC emission, even though using ethanol can help reduce the HC emission, but the HC emission from formaldehyde group in ethanol must be considered.

Figure 4.25, the result signify that increasing of ethanol content in fuel the concentration of CO_2 increased due to the improve combustion. The results indicate that Using Eh95 in long-tailed boat engine, the global warming effects of CO_2 emission must be consider.

CHAPTER 5
CONCLUSIONS

1. For the long-tailed boat working condition, the optimal ethanol–gasoline blend rate can be concluded in 2 cases. In case of using OEM ECU without any modification of the engine, at low speed boat conditions (10 to 15 kph),an increment of ethanol content up to 85 % in gasoline provides better engine efficiency(1-2% better), for high speed boat conditions (20-25 kph) the ethanol content should be reduced (E20 is slightly better than E10). In case of using a modified engine control, the boat provides the highest efficiency (32.7% at speed 25 kph) than other fuel with ethanol-gasoline blended fuel up to 85% and able to operate with hydrous ethanol (eh95) in all long-tailed boat conditions.

2. The Increasing of ethanol percentage in gasoline affect to the increasing of thermal efficiency(up to 2.8%). This could be explained by less heat loss through cylinder walls because of higher laminar flame speed in case of ethanol. (E20 is 16.5% faster than E0, E85 is 32% faster than E0)

3. In some case that when the ethanol percentage is increasing but the thermal efficiency is not increasing because the higher ethanol percentage the higher octane number of fuel and more ignition delay can be.

4. The experimental results indicated that the engine running with gasohol E85 fuel provide the maximum brake thermal efficiency(32.7%) and the lowest break specific energy consumption in all long-tailed boat conditions.

5. The results show that the engine using 1.25:1 transmission effect to improve a thermal efficiency 0.5-2.8% and reduce exhaust emission in same fuel at long-tailed boat condition. (as for the optimized condition can improve up to 5%)

6. Ethanol-gasoline blended fuels show the significant reduction in CO and HC emission when compared with gasoline. Using gasohol E85 a decrement up to 70% in CO emission and 46% in HC emission are observed from the gasoline value for long-tailed boat condition respectively.

7. The average of HC and CO emission of hydrous ethanol are 52% and 74% lower than gasoline in all boat condition due to the oxygen atom and carbon content in ethanol molecule promotes complete combustion . In addition, lower heating value of ethanol leads to higher fuel consumption, compared to gasoline.

RECOMMENDATION

From the result and conclusion, the engine fuelled with Gasohol E85provided the highest efficiency than pure gasoline, gasohol E10, gasohol E20, gasohol E85 and hydrous ethanol Eh95. However, the use of hydrous ethanol Eh95 as fuel carbon monoxide and hydrocarbon emission from the boat engine are lowest than pure gasoline, gasohol E10, gasohol E20 and gasohol E85 for any boat conditions.

To use gasohol E85 and hydrous ethanol Eh95 as fuel with the highest efficiency at first, the engine must be change the original equipment manufacturing ECU to the new ECU that can adjust injection duration and ignition timing. Second, change the oxygen sensor to wide band oxygen sensor and add an ethanol content sensor.

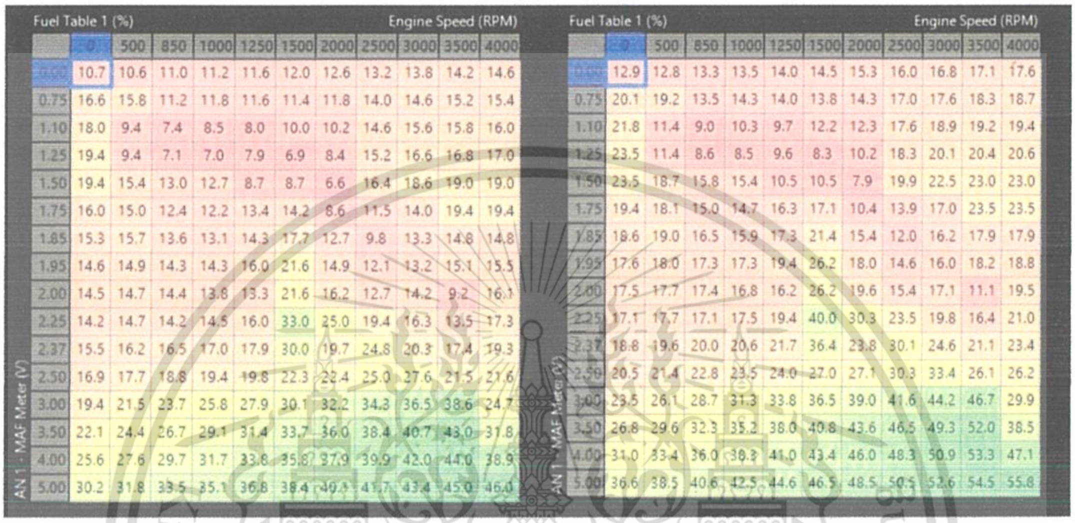
Table 5.1 Apparatus price lists

Apparatus	Diesel engine	Gasoline PFI Engine
Engine	130,000	30,000
New ECU + Tuning		20,000
Semi-Wide band O2 sensor		5,000
Ethanol sensor		5,000
Gear box		10,000
	130000 Baht	70000 Baht

Table 5.1 showed a comparison price of diesel engine with gasoline engine if users want to swap the old diesel engine to use gasoline engine working on gasoline E85 and hydrous ethanol Eh95. A price of gasoline PFI engine is lower than diesel engine but it needs more sensors and gear box to increase engine efficiency closed to diesel engine.

To select a new ECU it must have ability to working with semi-wide band oxygen sensor and ethanol concentration sensor. Semi-wide band oxygen sensor was chooses to work with the new engine because the price are lower than wide band oxygen sensor and many band of ECU are design to work with this sensor. Ethanol sensor used to monitor a concentration of ethanol in fuel that work with ECU to compensate a fuel that injected to the engine and feedback a lambda value to ECU with oxygen sensor.

The price of diesel engine and gasoline PFI engine with new sensors and gearbox in table 5.1 indicated that using gasoline PFI engine the user can reduce the cost up to 46% compared with diesel engine.



Fuel Table 1 (%) — Engine Speed (RPM) — AN 1 - MAF Meter (V) (Left)

	0	500	850	1000	1250	1500	2000	2500	3000	3500	4000
0.00	10.7	10.6	11.0	11.2	11.6	12.0	12.6	13.2	13.8	14.2	14.6
0.75	16.6	15.8	11.2	11.8	11.6	11.4	11.8	14.0	14.6	15.2	15.4
1.10	18.0	9.4	7.4	8.5	8.0	10.0	10.2	14.6	15.6	15.8	16.0
1.25	19.4	9.4	7.1	7.0	7.9	6.9	8.4	15.2	16.6	16.8	17.0
1.50	19.4	15.4	13.0	12.7	8.7	8.7	6.6	16.4	18.6	19.0	19.0
1.75	16.0	15.0	12.4	12.2	13.4	14.2	8.6	11.5	14.0	19.4	19.4
1.85	15.3	15.7	13.6	13.1	14.3	17.7	12.7	9.8	13.3	14.8	14.8
1.95	14.6	14.9	14.3	14.3	16.0	21.6	14.9	12.1	13.2	15.1	15.5
2.00	14.5	14.7	14.4	13.8	13.3	21.6	16.2	12.7	14.2	9.2	16.1
2.25	14.2	14.7	14.2	14.5	16.0	33.0	25.0	19.4	16.3	13.5	17.3
2.37	15.5	16.2	16.5	17.0	17.9	30.0	19.7	24.8	20.3	17.4	19.3
2.50	16.9	17.7	18.8	19.4	19.8	22.3	22.4	25.0	27.6	21.5	21.6
3.00	19.4	21.5	23.7	25.8	27.9	30.1	32.2	34.3	36.5	38.6	24.7
3.50	22.1	24.4	26.7	29.1	31.4	33.7	36.0	38.4	40.7	43.0	31.8
4.00	25.6	27.6	29.7	31.7	33.8	35.8	37.9	39.9	42.0	44.0	38.9
5.00	30.2	31.8	33.5	35.1	36.8	38.4	40.1	41.7	43.4	45.0	46.0

Fuel Table 1 (%) — Engine Speed (RPM) — AN 1 - MAF Meter (V) (Right)

	0	500	850	1000	1250	1500	2000	2500	3000	3500	4000
0.00	12.9	12.8	13.3	13.5	14.0	14.5	15.3	16.0	16.8	17.1	17.6
0.75	20.1	19.2	13.5	14.3	14.0	13.8	14.3	17.0	17.6	18.3	18.7
1.10	21.8	11.4	9.0	10.3	9.7	12.2	12.3	17.6	18.9	19.2	19.4
1.25	23.5	11.4	8.6	8.5	9.6	8.3	10.2	18.3	20.1	20.4	20.6
1.50	23.5	18.7	15.8	15.4	10.5	10.5	7.9	19.9	22.5	23.0	23.0
1.75	19.4	18.1	15.0	14.7	16.3	17.1	10.4	13.9	17.0	23.5	23.5
1.85	18.6	19.0	16.5	15.9	17.3	21.4	15.4	12.0	16.2	17.9	17.9
1.95	17.6	18.0	17.3	17.3	19.4	26.2	18.0	14.6	16.0	18.2	18.8
2.00	17.5	17.7	17.4	16.8	16.2	26.2	19.6	15.4	17.1	11.1	19.5
2.25	17.1	17.7	17.1	17.5	19.4	40.0	30.3	23.5	19.8	16.4	21.0
2.37	18.8	19.6	20.0	20.6	21.7	36.4	23.8	30.1	24.6	21.1	23.4
2.50	20.5	21.4	22.8	23.5	24.0	27.0	27.1	30.3	33.4	26.1	26.2
3.00	23.5	26.1	28.7	31.3	33.8	36.5	39.0	41.6	44.2	46.7	29.9
3.50	26.8	29.6	32.3	35.2	38.0	40.8	43.6	46.5	49.3	52.0	38.5
4.00	31.0	33.4	36.0	38.3	41.0	43.4	46.0	48.3	50.9	53.3	47.1
5.00	36.6	38.5	40.6	42.5	44.6	46.5	48.5	50.5	52.6	54.5	55.8

Figure 5.1 Comparison between fuel injection graph; Left:OEM fuel injection, Right:E85 fuel injection for long-tailed boat condition

Table 5.2The ignition timing comparison timing between OEM ECU and Optimized timing for E85 at gear ratio 1.25:1 for long-tailed boat condition

Speed (kph)	OEM ignition timing	Optimized ignition timing
10	17.5 BTDC	33 BTDC
15	22 BTDC	35 BTDC
20	25 BTDC	37.5 BTDC
25	25 BTDC	37.5 BTDC

Figure 5.1 shown the injection table from OEM ECU from car (E0) and the optimization injection timing for long-tailed boat (E85). The different between car and boat is that boat only need to accelerate one time and run at constant speed due to the driving cycle from the survey data. So the injection in the acceleration part is considered.

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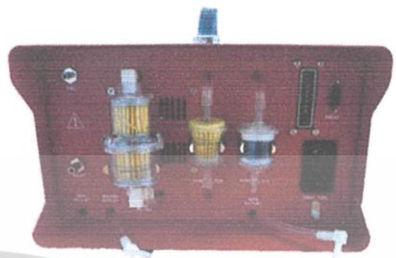
APPENDICES

APPENDIX A: Material specification

A-1 : Gas analyzer model KEG-500 specification.



Model	KEG-500		
Measuring gas	CO, HC, CO2, O2, Lamda(Air surplus rate), AFR, NOX, (5gas)		
Sensor Theory	CO, HC, CO2, Non-Dispersive Infared Analysis(NDIR) O2,NOX: Electrochemical Cell		
Measuring range	CO%	HC(ppm)	CO2(%)
	0.00~10	0~9999	0.0~20
Resolution	0.01(%)	1 ppm	0.1 (%)
Measuring range	O2(%)	λ	NOX(ppm)
	0.00~25.00 %	0~2	0~5000
Resolution	0.01(%)	0.001	1 ppm
Display	4 digit 7segment LED		
Repetition Rate	Less than 2% FS		
Response time	Within 10 seconds		
Preheat time	Approx. 2~8 minutes		
Flow rate	4 ~ 6 L/min		
Power	110V-220V±10%, 50/60Hz		
Standard Accessories	Probe, Probe hose, Fuse, Leak test cap, Spare filter, Power cord, RS232, Built-in Printer, Printer paper, Communication cable		

APPENDIX B: Fuel Distillation

PTT PUBLIC COMPANY LIMITED
QUALITY ANALYSIS DEPARTMENT SUPPLY AND TERMINAL OPERATIONS OIL BUSINESS
555 ARDNARONG RD. KLONGTOEY BANGKOK 10260 THAILAND
TEL +66(0)2239-7148 FAX +66(0)2239-7149 WWW.PTTPLC.COM

Certificate of Analysis

Product : Gasoline E 0

Certificate No. : T-12/29294
Sample Lab No. : OP-GSH-1230331
Customer/Supplier : International College, King Mongkut's Institute of Technology
International College, King Mongkut's Institute of Technology Ladkrabang,
Chalongkrung Rd. Ladkrabang BKK 10520
Sample Location : LKB
Batch No. : -
Product Source : -

Received Date : 18 Dec 2012
Date of Test : 18 Dec 2012
Date of Sampling : 18 Dec 2012
Sample Condition : Normal

Test Item	Test Method	Limit	Result
1. Distillation :Initial Boiling Point,°C	ASTM D 86-11b	-	35.0
2. Distillation : 10% vol. Evaporated,°C	ASTM D 86-11b	-	51.5
3. Distillation : 50% vol. Evaporated,°C	ASTM D 86-11b	-	78.2
4. Distillation : 90% vol. Evaporated,°C	ASTM D 86-11b	-	154.0
5. Distillation End Point,°C	ASTM D 86-11b	-	197.3
6. Distillation Recovery,% vol.	ASTM D 86-11b	-	97.9
7. Distillation Residue,% vol.	ASTM D 86-11b	-	1.1

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Position Title : Vice President in Quality Analysis Department
Date of Issue : 25 Dec 2012

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Certificate of Analysis

Product : E 10

Certificate No. : T-12/29295
Sample Lab No. : OP-GSH-1230332
Customer/Supplier : International College, King Mongkut's Institute of Technology
International College, King Mongkut's Institute of Technology
Ladkrabang,
Chalongkrung Rd. Ladkrabang BKK 10520
Sample Location : LKB
Batch No. : -
Product Source : -

Received Date : 18 Dec 2012
Date of Test : 18 Dec 2012
Date of Sampling : 18 Dec 2012
Sample Condition : Normal

Test Item	Test Method	Limit	Result
1. Distillation :Initial Boiling Point,°C	ASTM D 86-11b	-	36.5
2. Distillation : 10% vol. Evaporated,°C	ASTM D 86-11b	-	51.6
3. Distillation : 50% vol. Evaporated,°C	ASTM D 86-11b	-	70.2
4. Distillation : 90% vol. Evaporated,°C	ASTM D 86-11b	-	160.2
5. Distillation End Point,°C	ASTM D 86-11b	-	187.2
6. Distillation Recovery,% vol.	ASTM D 86-11b	-	97.9
7. Distillation Residue,% vol.	ASTM D 86-11b	-	1.0

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(Phunta Pothisuk)
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Certificate of Analysis

Product : E 20

Certificate No. : T-12/29296
Sample Lab No. : OP-GSH-1230333
Customer/Supplier : International College, King Mongkut's Institute of Technology
International College, King Mongkut's Institute of Technology
Ladkrabang,
Chalongkrung Rd. Ladkrabang BKK 10520
Sample Location : LKB
Batch No. : -
Product Source : -

Received Date : 18 Dec 2012
Date of Test : 18 Dec 2012
Date of Sampling : 18 Dec 2012
Sample Condition : Normal

Test Item	Test Method	Limit	Result
1. Distillation :Initial Boiling Point,°C	ASTM D 86-11b	-	37.8
2. Distillation : 10% vol. Evaporated,°C	ASTM D 86-11b	-	53.5
3. Distillation : 50% vol. Evaporated,°C	ASTM D 86-11b	-	70.8
4. Distillation : 90% vol. Evaporated,°C	ASTM D 86-11b	-	155.0
5. Distillation End Point,°C	ASTM D 86-11b	-	184.6
6. Distillation Recovery,% vol.	ASTM D 86-11b	-	98.1
7. Distillation Residue,% vol.	ASTM D 86-11b	-	1.1

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Certificate of Analysis

Product : E 85

Certificate No. : T-12/29298
Sample Lab No. : OP-GSH-1230334
Customer/Supplier : International College, King Mongkut's Institute of Technology
International College, King Mongkut's Institute of Technology
Ladkrabang,
Chalongkrung Rd. Ladkrabang BKK 10520
Sample Location : LKB
Batch No. : -
Product Source : -

Received Date : 18 Dec 2012
Date of Test : 18 Dec 2012
Date of Sampling : 18 Dec 2012
Sample Condition : Normal

Test Item	Test Method	Limit	Result
1. Distillation :Initial Boiling Point,°C	ASTM D 86-11b	-	41.3
2. Distillation : 10% vol. Evaporated,°C	ASTM D 86-11b	-	66.6
3. Distillation : 50% vol. Evaporated,°C	ASTM D 86-11b	-	77.5
4. Distillation : 90% vol. Evaporated,°C	ASTM D 86-11b	-	77.8
5. Distillation End Point,°C	ASTM D 86-11b	-	80.5
6. Distillation Recovery,% vol.	ASTM D 86-11b	-	98.7
7. Distillation Residue,% vol.	ASTM D 86-11b	-	0.9

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Certificate of Analysis

Product : E 100

Certificate No. : T-12/29299
Sample Lab No. : OP-GSH-1230335
Customer/Supplier : International College, King Mongkut's Institute of Technology
International College, King Mongkut's Institute of Technology
Ladkrabang,
Chalongkrung Rd. Ladkrabang BKK 10520
Sample Location : LKB
Batch No. : -
Product Source : -

Received Date : 18 Dec 2012
Date of Test : 18 Dec 2012
Date of Sampling : 18 Dec 2012
Sample Condition : Normal

Test Item	Test Method	Limit	Result
1. Distillation : Initial Boiling Point,°C	ASTM D 86-11b	-	77.6
2. Distillation : 10% vol. Evaporated,°C	ASTM D 86-11b	-	77.8
3. Distillation : 50% vol. Evaporated,°C	ASTM D 86-11b	-	77.9
4. Distillation : 90% vol. Evaporated,°C	ASTM D 86-11b	-	78.0
5. Distillation End Point,°C	ASTM D 86-11b	-	80.0
6. Distillation Recovery,% vol.	ASTM D 86-11b	-	99.3
7. Distillation Residue,% vol.	ASTM D 86-11b	-	0.7

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APPENDIX C: Publications

Investigation of Flex-Fuel PFI Engine Control System for Boat Application

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ABSTRACT: ECU is use to control engine to run at a proper condition. In modern cars, they are equipped with numerous electronic control units to make the car being controlled more precisely. We have to calculate the required torque for choosing an engine to use in our boat application. In this research, Gasoline, 1ZZ-FE, 1.794 litre, is use as boat engine. For the method of experiment, this engine will be fuelled with E0 to E85. And we will run the test for an engine emission for each fuel to see which fuel is good for use in boat application.

KEY WORDS: **heat engine, spark ignition engine,** Flame, Electric Fields (A1)

1. INTRODUCTION

The long-tail boat, or as known as Ruea Hang Yao in the Thai language, is a type of watercraft native to Southeast Asia, which is widely use long-tail boat for many applications such as transportation, tourist, and fishery. Normally, the engine that use for boat motor is old diesel, gasoline, or General Purpose Engines. These engines are not design for use as the boat engine, so using these engines will cause the problem such as air noise pollution, cannot use the engine at the maximum efficiency, and high fuel consumption. And as for now that the world are focus on environment protection, so if we can have the electronic control unit to control the engine to work more precisely. We can develop the efficiency of the fuel consumption and also decreased the emission from an engine [1].

Port-Fuel injection spark ignition engine (PFI engine) is one of the good choices to use this as the boat engine because the new technology that included in this engine. Also, this engine can use the ethanol blended as fuel. And for using this engine as the boat engine, we have to change some parts and tune up the ECU (electronic control unit) for matching the condition that use in boat application. We have to consider the fuel injection timing, the angle of ignition for more precisely in control. And also, we have to modify some part to match for the boat application [2].

Ethanol is also the one way for energy conservation because ethanol is an alternative fuel that can produce by the agriculture in country that can reduce the import of fossil fuel. Ethanol can also help to reduce the increasing of global warming by the carbon neutral especially for the crop that use carbon dioxide in photosynthesis that can make up for the release emission. Ethanol is an oxygenated fuel that can improve the complete combustion and also reduce the emission (CO HC PM) that from incomplete combustion [3-5].

2. DESIGN AND EXPERIMENT APPARATUSES

2.1. Boat Resistance Calculation

There are 3 main parts of resistance for using to calculate boat resistance. The first one is air resistance, the second one is frictional resistance or water resistance, and the third one is residual resistance or wave resistance [6].

The boat size that use for calculate in this research is longtail boat with the length 11.6 m and 1.6 m width.

The picture of longtail boat and engine mounting location can be seen in Fig 1. a). and Fig 1. b).

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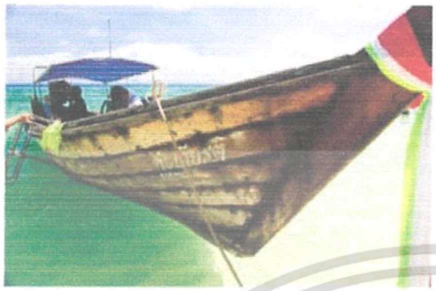

a)

b)

Fig 1 Picture of a) Longtail boat in Thailand and b) Engine mounting position

2.1.1. Air Resistance

Air resistance can be calculated by using equation [6]

$$R_a = \frac{1}{2}\rho C_a A V^2 \quad (1)$$

In this calculation ρ is 1.1644 kg/m³, assume C_a is 0.9, A is 2 m², and V is design speed of boat in m/s. In this research, the design speed of boat is 8 to 20 knots (4.112 to 10.28 m/s).

2.1.2. Frictional Resistance

Frictional resistance of the boat can be calculate by using equation[6,8]

$$R_f = C_f \left(\frac{\rho}{2}\right) S V^2 \quad (2)$$

In this calculation ρ is 995.6502 kg/m³, S is wetted Area of Boat equal to 30 m², V is design speed of boat, and C_f is the coefficient of frictional resistance, has a value determined by the Reynolds number

$$C_f = 0.02058\left(\frac{V \times l}{\nu}\right)^{-\frac{1}{6}} \quad (3)$$

V is the design speed of boat, L is the length of the surface of water in this calculation is 10 m, and ν is kinematic viscosity of water equal to 0.801×10^{-6} m²/s.

2.1.3. Residual Resistance

Normally, residual resistance of boat can be found by using the towing test, but in this research will use the calculation from the ratio of the residual resistance and the total resistance from graph in Fig.3 [6].

The frictional resistance that use for calculate residual resistance is from equation (2).

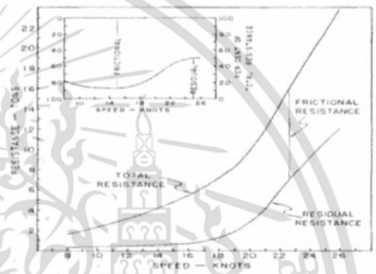

Fig 3 Analysis of the total resistance of the destroyer Yudachi into its components of frictional and residual resistance at various speeds.

2.1.4. Total Resistance

Total resistance is the summation of Air resistance, Frictional resistance, and Residual resistance.

2.2. Required Power and Torque Calculation

After gets the total resistance of the boat. Next is to choose an engine for use in the boat.

Normally, the boat will run at the speed around 2000-3000 rpm, so the engine that will be use need to have more power than the required power and torque at 2000-3000 rpm due to the calculation.

2.2.1. Required Power Calculation

The required power calculation can be calculate by using formula P = FV [7]. F is total resistance from the calculation, and V is the speed of boat from 8 to 20 knots (4.112 to 10.28 m/s).

2.2.2. Required Torque Calculation

The required torque of an engine for using in the boat is calculated from using formula $P = 2\pi NT$ [7], P is power in Watt, N is design engine speed, in this research is 2500 – 4000 rpm, and T is required torque of the boat engine. And the losses from engine to propeller that use in this calculation is 40% [8].

2.3. Fuel

The use of ethanol in this research was considered due to the reduction of particle emissions and fossil fuel consumption in automotive and the domestic production can reduce amount of fossil fuels import. Ethanol has higher octane number than gasoline which can perform a better anti-knocking from increased the compression ratio. Ethanol also has higher heat of vaporization, the higher densities in the intake can increase the volumetric efficiency. And ethanol is also an oxygenated-fuel, a fuel which contains oxygen in its molecule which can help to complete combustion. However, ethanol has lower heating value than the gasoline which increased the amount of fuel injection to achieve the same amount of energy compared to gasoline.[9] Fuels properties can be seen in Table I.

Table 1. Fuels properties [10]

Fuel properties	Ethanol	Gasoline
Formula	C_2H_5OH	C_4 to C_{12}
Molecular weight [g/mol]	46.70	100-105
Carbon [mass%]	52.20	85-88
Hydrogen [mass%]	13.10	12-15
Oxygen [mass%]	34.70	2.70
Density, kg/l, 15/15°C	0.79	0.72-0.77
Boling point, °C	78	27-225
Vapor pres., kPa at 38°C	15.90	48-103
Specific heat, kJkg-1K-1	2.40	2
Viscosity, mPa s at 20	1.19	0.37-0.44
Low, heating val., 103 kJ/l	21.10	30-33
Auto ignition temp.,	423	257
Research octane number	108.60	98
Motor octane number	92	87
(R+M)/2	100	92.50
Flammability lim., Vol%	4.30/19	1.40/7.60
Water Tolerance, Vol%	Compl miscible	Negligible
Stoichiometric air/fuel ratio	9	14.70
Carbonyl [ppm] as C-O	567	-
Carbonyl [ppm] as acetone	1117	-
Carbonyl [ppm] as acetaldehyde	893	-
Sulphur [mg/kg]	0.80	10
Copper [mg/kg]	0.10	-

2.4. Research Methodology and Procedures

In order to know the effect of ethanol to the frame propagation, the flame propagation in the lamp was investigated. Capture the image of flame propagation from the oil lamp by using digital camera. In this research will focus on E0, E10, E20, and E85. Use image processing in order to measure the length of the flame from each fuel by convert the pixel length to the real length in mm.

To find the emission from the engine, the engine will operate at no load condition and run at engine speed 1000, 1500, 2000, and 2500 rpm. All condition of each speed will be run at the same A/F ratio. The emission will be measure by using gas analyzer.

3. RESULTS AND DISCUSSION

Total resistance of the boat can be calculated from the summation of Air resistance, Frictional resistance, and Residual resistance.

Air resistance depends on the drag coefficient (C_d), the surface area of the boat, and the speed of the boat.

Frictional resistance depends on the Frictional resistance coefficient which depends on the kinematic viscosity of the water, the length of the water line of the boat, wetted area of the boat, the density of water, and the speed of the boat.

Residual resistance in this research is calculated from the total resistance graph in Fig. 3[6].

In Fig.4 will show air resistance, residual resistance, frictional resistance, and total resistance from the calculation.

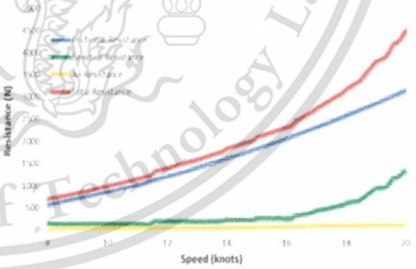

Fig 4. Resistance from the calculation of the boat versus speed

3.1. Required Power and Torque

The required power is calculated from multiply Total resistance and boat speed. And for the mechanic loss of the engine to the propeller, in this research is equal to 40%[8], means that the engine need 40% more power to run the boat at the design speed. And use this power to calculate the required torque as can see in Fig.5 and the required torque at different engine speed can be seen in Fig 6.

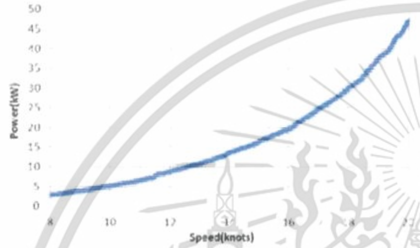

Fig 5. Required power versus speed from the calculation

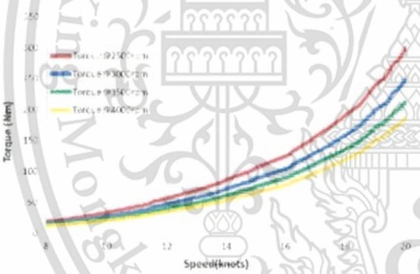

Fig 6. Required torque from the calculation versus speed

3.2. Required Engine

The normal speed of the long-tail boat in Thailand is around 30 km/h or around 8.33 m/s, and the required torque for engine to make the boat run at this speed is around 140 Nm for running engine at 2500 rpm, 115 Nm for running engine at 3000 rpm, 100 Nm for running engine at 3500 rpm, and 90 Nm for running engine at 4000 rpm.

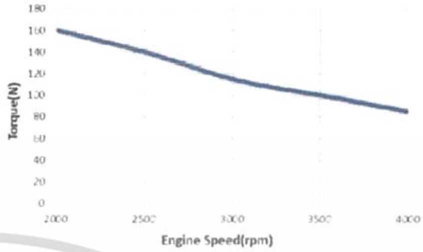

Fig 7. Required torque for running boat at different engine speed for running boat at 30 km/h

Fig.7 is shown that the required torque for running the boat at 30 km/h at different engine speed.

The engine that use in this research is 1ZZ-FE, 1794cc, maximum power is 105 kW (140 hp) at 6400 rpm and maximum torque 171 Nm at 4200 rpm, which have enough power for running the boat at speed 30 km/h. The detail of an engine specification can be seen in Table 2.

Table 2 Engine specification

Model	1ZZ-FE
Type	In-line, OHV
Number of cylinders	4
Displacement	1.794 Litre
Fuel injection	Multi-point
Bore	79 mm
Stroke	91.5 mm
Maximum Power	105 kW(140hp) @ 6400 rpm
Maximum Torque	171 Nm @ 4200 rpm

Fig 8. Flame length from the lamp from left to right E0, E10, E20, E85

3.3. Flame Length

From the measurement, the length of E0 is 190 pixel, the length E10 is 137 pixel, the length E20 is 126 pixel, and the length of E85 is 52 pixel. The picture of the flame can be seen in Fig 8. And after convert the length from pixel to mm, flame length of E0 is 20.108 mm, E10 is 14.499 mm, E20 is 13.335 mm, and E85 is 5.503 mm. And the percentage of flame from E10, E20, and E85 compare with flame length from E0 is 72.1%, 66.3%, and 27.4%.

The length of flame in E85 which has higher concentration of ethanol was shorter than the length of E0, E10, and E20 due to ethanol has less amount of carbon in molecule than gasoline, and ethanol has oxygen in its atoms that promote more complete combustion which can be seen by the reducing of the black smoke from the flame.

3.4. Effect of Ethanol on Emission

From Fig 9-11 is shown the effect of ethanol percentage to the HC, CO, and CO_2 emission. Fig. 9 shown that as the percentage of ethanol increase, the amount of HC emission is decrease for every engine speed. This is clearly can be shown that the oxygen in ethanol help to improve the complete combustion. Fig. 10 is shown that the CO emission from E20 is lower than E10 at every engine speed, but the emission from E0 is lower than the emission from E10 at engine speed 1000, 2000, and 2500 rpm. This might not clear as the Fig 9, but when we compare just E10 and E20, this can be seen as the increasing in ethanol help to improve complete combustion. Hence, the more the complete combustion the higher emission from CO2 can be seen as in the Fig 11.

And for E85, in this experiment, the engine can not run at the same A/F ratio as the other fuel. This may be from the limit of the injector, or the control unit. The further research will be use the standalone ECU to control this engine for running with E85.

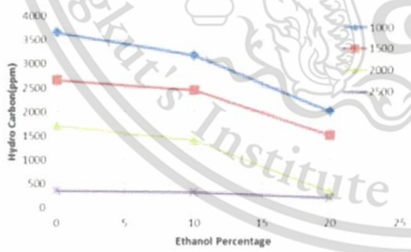

Fig 9. The effect of ethanol percentage to HC emission

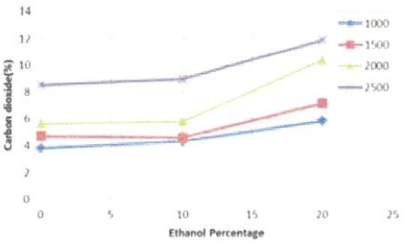

Fig 10. The effect of ethanol percentage to CO emission

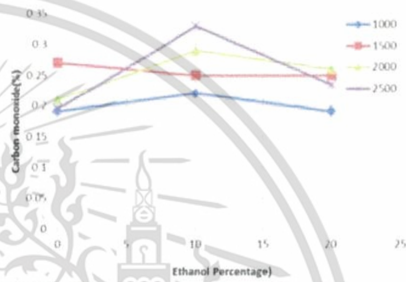

Fig 11. The effect of ethanol percentage to CO_2 emission

4. CONCLUSION

This resistance calculation for choosing boat engine is use to choose the engine.

The total resistance will grow stronger when the boat that running at higher speed.

And for the required torque, if the engine running at the low engine speed, it's need more torque to make the boat run at the same speed than the engine run at higher speed.

The diffusion flame of the lamp with have higher ethanol content has the shorter length than the lamp with lower ethanol content due to ethanol has lower carbon content in its atom.

The emission from HC and CO is decreasing, but CO_2 is increasing at every engine speed when the amount of ethanol content is increasing due to ethanol is oxygenated fuel which help in complete combustion.

In this experiment, the engine can not run with E85 at the same A/F ratio as the other fuel without tuning up the engine.

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Publications:

1) Kraiwut K., Kittichart T., Chinda C., Chaiwat N., Teera P. and Masaki Y.," Investigation of Flex-Fuel PFI Engine Control System for Boat Application", the 2015 JSAE Annual Congress (Spring). Yokohama, Japan, May 20-22, 2015.