PERFORMANCE STUDYING OF GASOHOL PFI ENGINE IN LONG-TAILED BOAT APPLICATIONS

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ABSTRACT

Nowadays, human realize to the environment pollution cause from old engine and use the engine misapply. These engines will cause the problem such as air pollution and cannot use the engine to work at the high efficiency. Using new development technologies and renewable oxygenated fuels are considered the most suitable solution for sustainable future. Optimization of electronic control unit (ECU) makes an engine to work in high efficiency and decrease the environment pollution. In this research, gasoline port-fuel injection spark ignition engine is use as the boat engine. To use car engine as boat engine, the control system has to be modify and tune up for proper condition. The goal is to modify the control system and optimization for use in boat application to reduce the emission of greenhouse gas and environment pollution. For the method, the parameters that used to control and optimization are the boat's running condition to tune up injection duration, ignition timing, and also the engine special function. Performances of the engine were invested in the point of brake specific fuel consumption, brake specific energy consumption and break thermal efficiency. And the exhaust gas pollution were invested in the point of carbon dioxide, carbon monoxide and hydro carbon concentration.

The advantage of this study can serve as the reduction of exhaust gas emissions and improving performances from gasoline port-fuel injection spark ignition engine by using ethanol.

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CHAPTER 1
INTRODUCTION

1.1 Background

Nowadays, human realize to the environment pollution cause from old engine and use the engine misapply. These engines will cause the problem such as air pollution, noise pollution and cannot use the engine to work at the high efficiency and fuel consumption. The air pollution from these engines can be the cause of greenhouse effect. The new technology of electronic control unit able to control the engine to work more precisely.

In Thailand many peoples extensively use Long-tailed boat in transportation, for example, the transportation in "Khlong Saen Saep" and "Chao Phraya River". Most of long-tailed boats use an old diesel engine or gasoline engine from car and truck. It's not design to use for boat. Many factors are different from road to the river. The misuse of an engine leads to many problem such as "Low performance, low efficiency and high emission.

The environment pollution cause from old engine and use the engine misapply can be reduce from using alternative energy, for example, ethanol–gasoline fuel blends (gasohol). It's developed to alternative energy, resembles performance and characteristic as gasoline. Moreover, gasoline can relive troubles as pollution from vehicle that emphasized in global by outstanding specification; high antiknock quality than gasoline. And ethanol that produced from plants is one way to reduce pollution from incomplete combustion and also reduce the emission of greenhouse gas from the incomplete combustion and global warming from fossil fuels because it is a carbon neutral fuel. The plants that used for produced an ethanol 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. Gasohol can improve the complete combustion.

The dynamic, comfort and emission performances of vehicle directly dependent on the control of engine. Engine electronic control unit (ECU) receives the signals from the sensors, and gets the current engine status. Then depending on the signals, the ECU calculates fuel injection rate, injection timing and quantity. 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. Installations a car engine as boat engine the parameters that have to control are the injection timing, injection duration, ignition timing, and also the engine speed.

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 optimization of electronic control unit of boat's engine fuelled with ethanol produce as a result to 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

The first study would be aimed in calculation of require power and torque for any boat condition to choose a proper engine for the prototype long-tailed boat.

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

This study focused on improving the engine control system by adds more sensors (Flex fuel sensor and wide band oxygen sensor) to make the engine work more precisely.

1.3.3 Optimization of gasohol PFI Engine best operating boat condition.

This study focused on the optimize ignition timing , injection duration and gear ratio of the engine and then the result would be analyzed in the view point of engine performance (power, torque, bsfc, bsec and break thermal efficiency) and exhaust emission (CO, CO2 and HC concentration).

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

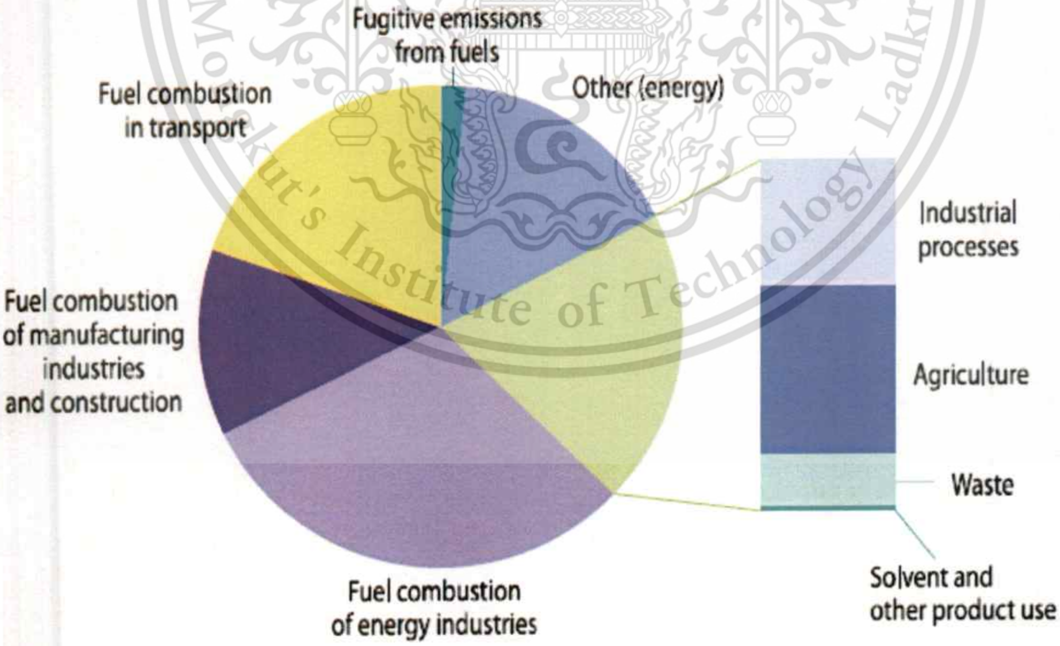

Figure 2.1 Sources of greenhouse gases in the European Union, 2010

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.

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

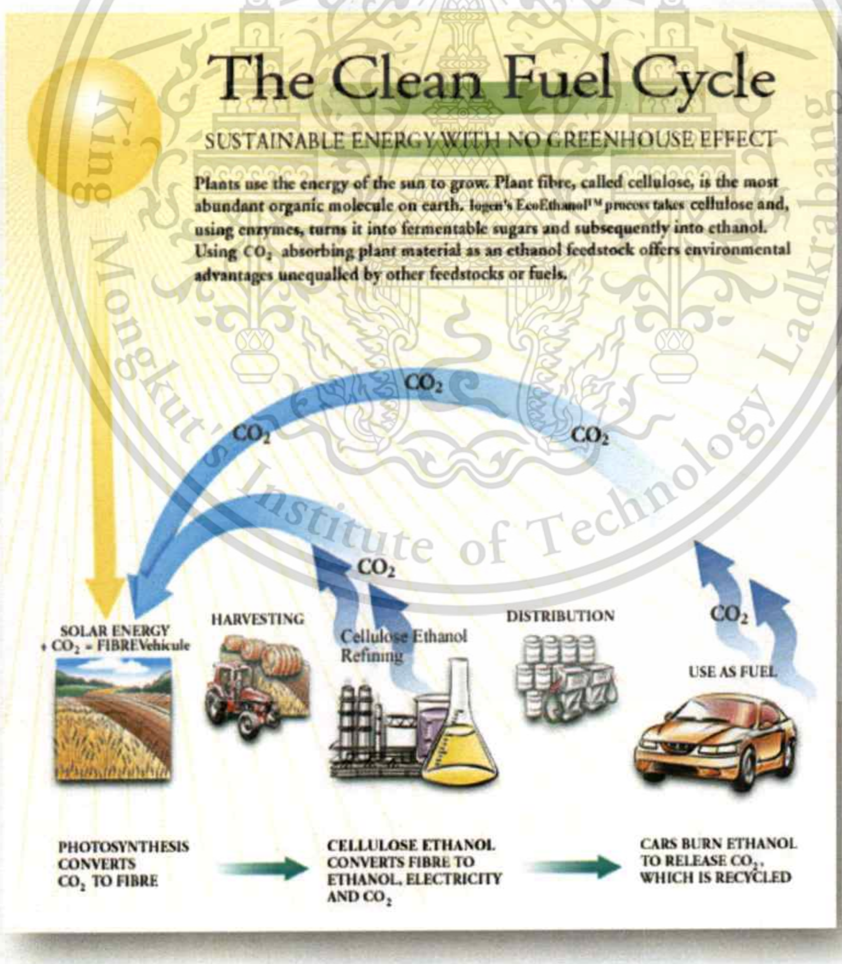

Figure 2.2 The clean fuel cycle [3]

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 2.3, 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 CO2. 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].

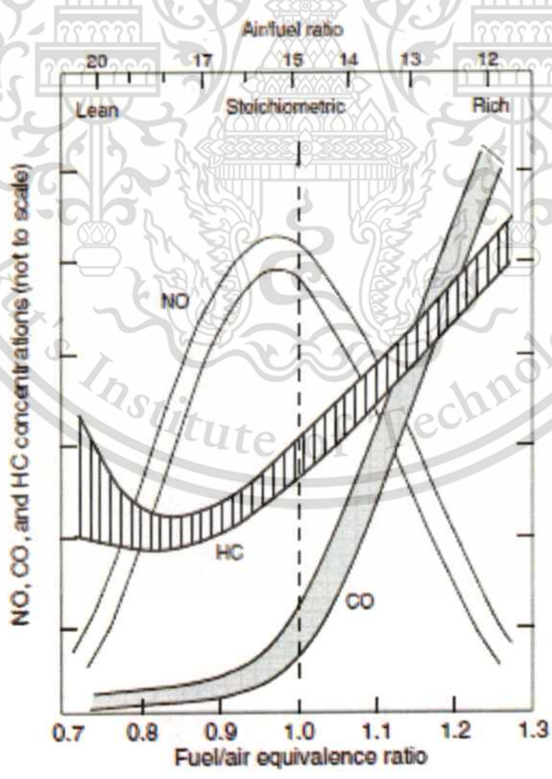

Figure 2.3 Emissions as a function of fuel–air equivalence ratio ϕ [4]

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 obtained from biomass, has been tested intensively in the internal combustion engines. Some properties of ethyl alcohol with comparison to gasoline are given in Table 2.1 [2].

Ethanol (C2H5OH) 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].

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

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].

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:

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

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

Reaction of ethane with steam:

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

World ethanol production as a fuel increased steadily through-out last decade (Figure 2.4). In2012, 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].

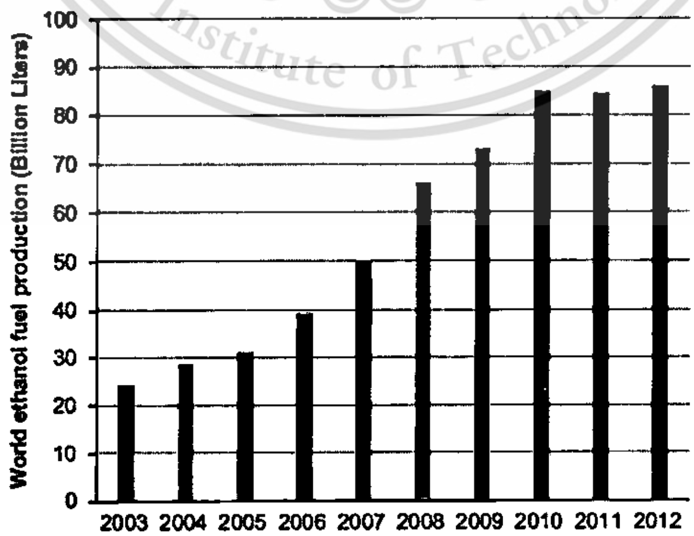

Figure 2.4 World ethanol fuel productions [1]

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 2.5, 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.

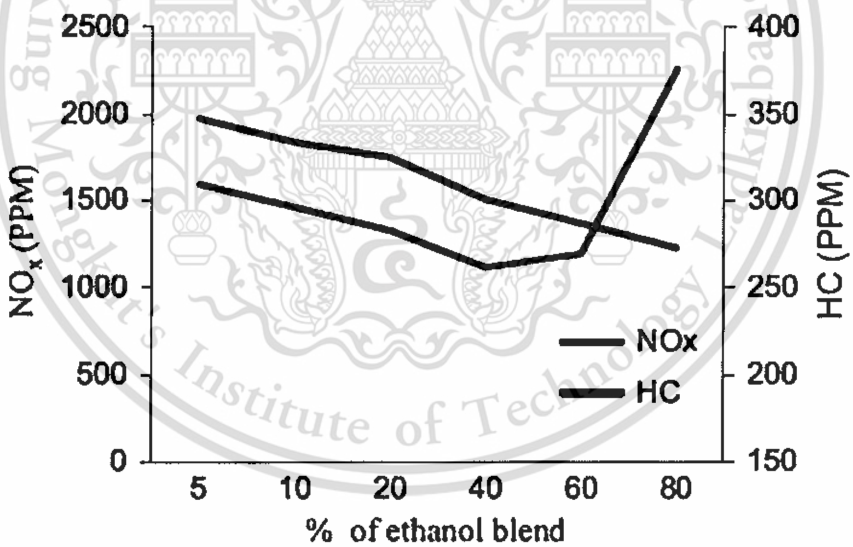

Figure 2.5 Correlation of NOx and HC emission with ethanol percentage at 2000 rpm [9]

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 have many merits in SI combustion, cold startibilty 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 CO2. Figure 2.6 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 CO2 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	$C_{6.39}H_{13.60}O_{0.61}$	$C_2H_{6.16}O_{1.08}$
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

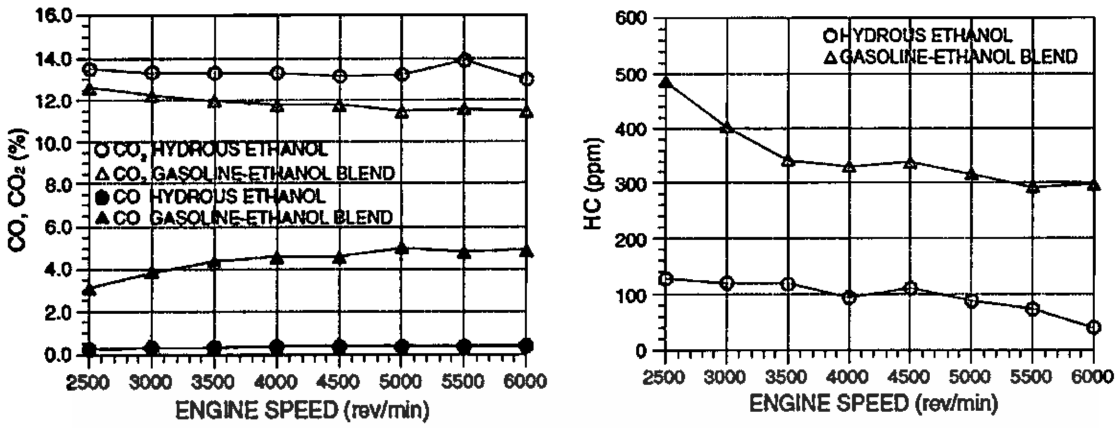

Figure 2.6 Fuel influence on carbon monoxide, carbon dioxide and total hydrocarbon emissions

2.3.2 Effects of ethanol –gasoline blends 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.

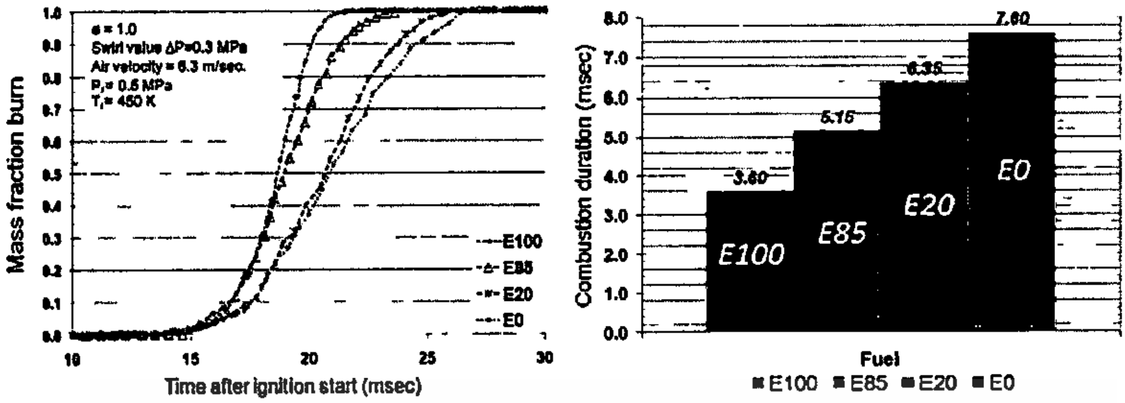

Figure 2.7 Mass fraction burn of various ethanol/gasoline blends and combustion duration at ϕ =1.0[2]

Figure 2.7 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 msec., 5.2 msec., 6.4 msec., and 7.6 msec. 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 $v_{gasoline}$, cm3/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/m3) 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, rmv = 0.40. Eqs. (1)–(3) are summarized in figure 2.8 showing estimated RON values of ethanol–gasoline blends following contour lines of constant blendstock RON.

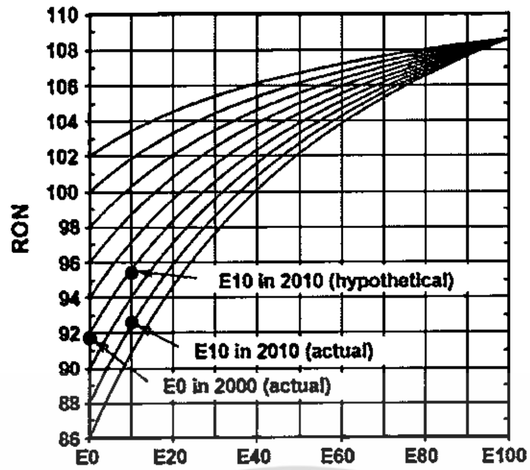

Figure 2.8 Estimated RON values for ethanol–gasoline blends with contour lines of constant blendstock RON

2.4 Effect of ignition on the performance

The performance of spark ignition engines is a function of many factors. Ignition timing also the one of the most important parameters for optimizing efficiency and emissions, permitting combustion engines to conform to future emission targets and standards. Ignition timing, in a spark ignition engine, is the process of setting the time that an ignition will occur in the combustion chamber (during the compression stroke) relative to piston position and crankshaft angular velocity. Setting the correct ignition timing is crucial in the performance and exhaust emissions of an engine [15].

Best performance will be achieved when the greatest portion of the combustion takes place near top dead center. If the ignition timing is not advanced enough, the piston will already be moving down when much of the combustion takes place. In this case we lose the ability to expand this portion of the gas through the full range, decreasing performance. If the ignition timing is too advanced, too much of the gas will burn while the piston is still rising. Spark timing affects peak cylinder pressure and therefore peak unburned and burned gas temperatures. Retarding spark timing from the optimum reduces these variables. As mentioned above when the spark timing is very much retarded to near the TDC, the combustion would take place very much down the expansion stroke, with the forces acting on the piston due to combustion, not unleashed early enough. On the other hand, when the spark timing is far advanced, combustion would commence very much before the completion of the compression stroke and the piston has to do more work on the burning gases, which would lead to loss of power [16].

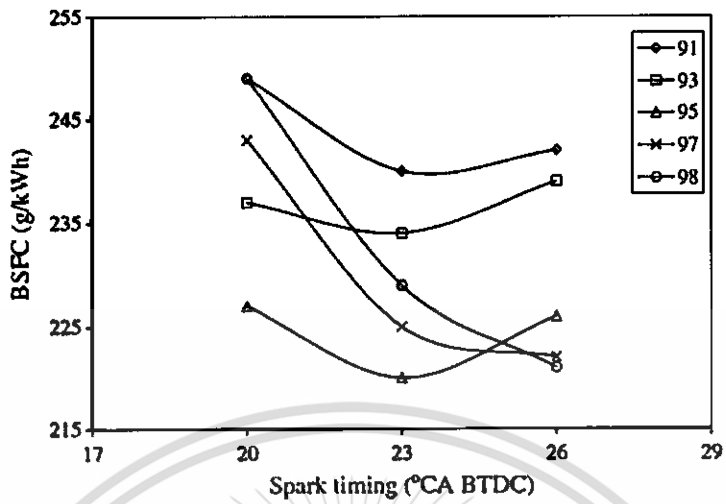

Figure 2.9 BSFC results at different spark timing [17]

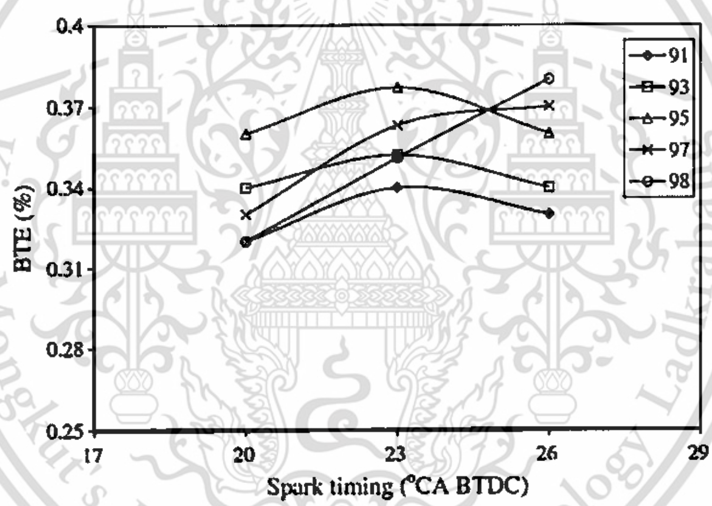

Figure 2.10 BTE results at different spark timing [17]

BSFC and BTE result are shown in figure 2.9 and 2.10, higher RON gasoline (such as 97 and 98 RON) improved with the increased spark timing. When the spark timing was increased, knock occurrence was observed with 91, 93 and 95 RON gasoline. On the other hand, knock occurrence was not observed with higher RON gasoline Increased spark timing augmented ignition delay and improved knock tolerance for 97 and 98 RON gasoline. So, these effects increased maximum cylinder gas pressure and reduced fuel consumption [17].

The concept of the MBT spark timing would help understand this variation. If combustion starts too early in the cycle, the work transfer from the piston to the gases in the cylinder at the end of the compression stroke is too large; if the combustion starts too late, the peak cylinder pressure is reduced and the expansion stroke work transfer from the gas to the piston decreases. There exists a particular spark timing, which gives maximum engine torque at fixed speed and mixture composition and flow rate. It is referred to as MBT (maximum brake torque timing). This timing also gives maximum brake power, which signifies maximum brake thermal efficiency and minimum brake specific fuel consumption [16].

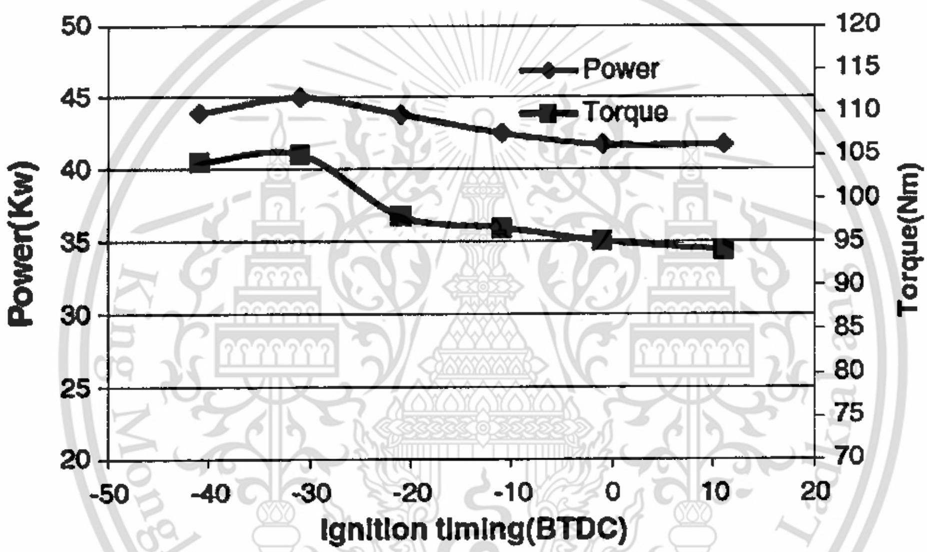

Figure 2.11 The relationship between power and torque versus ignition timing [15]

Figure 2.11 show that power tends to increase with spark advance between 17 and 35°CA BTDC. It is expected that power should increase with spark advance to a point, and then drop off. Best performance will be achieved when the greatest portion of the combustion takes place near top dead center. If the spark is not advanced enough, the piston will already be moving down when much of the combustion takes place. Also it shows that the torque increases with increasing ignition advance. This is due to increasing pressure in the compression stroke and consequently more net work is produced [15].

2.5 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 2.12 [19].

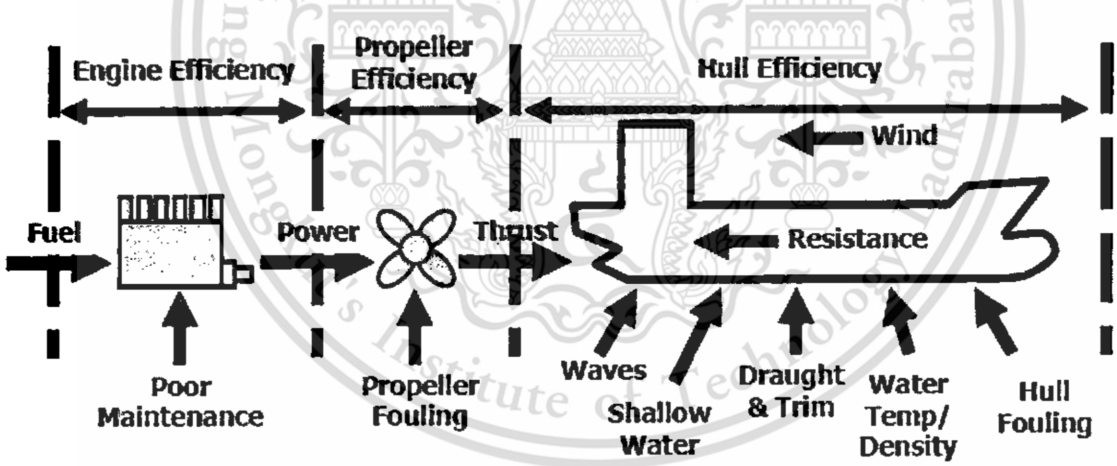

Figure 2.12 Performance variables [20]

2.5.1 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].

2.5.2 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 (η_{gear}), and is written as follows:

$$\eta_{gear} = \frac{SHP}{BHP} \tag{2.7}$$

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

2.5.3 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:

$$\eta_{shaft} = \frac{DHP}{SHP} \tag{2.8}$$

2.5.4 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 2.13 shows the obtainable propeller efficiency η_O shown as a function of the speed of advance V_A,

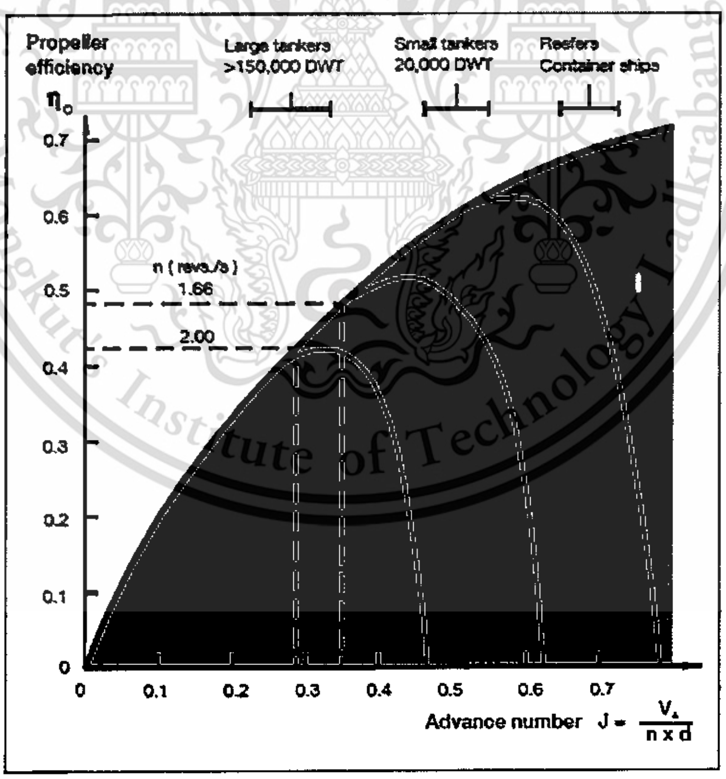

Figure 2.13 Obtainable propeller efficiency [21]

2.5.5 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).

2.5.6 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 2.14 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 2.14 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).

$$\eta_P = PC = \frac{EHP}{SHP} \tag{2.8}$$

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%.

2.5.7 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].

2.5.7.1 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 R_F 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, i.a. algae, sea grass and barnacles. When the ship is propelled through the water, the frictional resistance increases at a rate that is virtually equal to the square of the vessel's speed. The frictional resistance is found as follows:

$$R_f = C_f \left(\frac{\rho}{2}\right) SV^2 \tag{2.9}$$

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.

$$C_f = 0.02058 \left(\frac{V \times L}{v}\right)^{\frac{-1}{8}} \tag{2.10}$$

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

2.5.7.2 Residual resistance

Residual resistance R_R 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 2.15 [25,26]. The frictional resistance that use for calculate residual resistance is from equation (2.8).

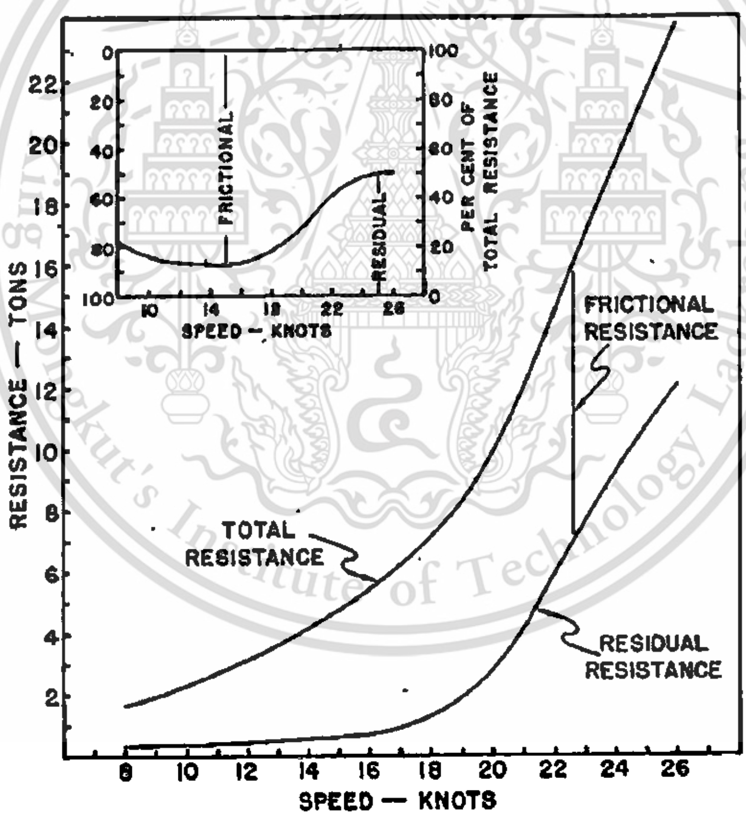

Figure 2.15 Analysis of the total resistance of the destroyer Yudachi into its components of frictional and residual resistance at various speeds [26]

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 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].

2.5.7.3 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].

$$R_a = 0.9\left(\frac{1}{2}\rho A V^2\right) \tag{2.11}$$

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.

2.5.7.4 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 2.16. 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.

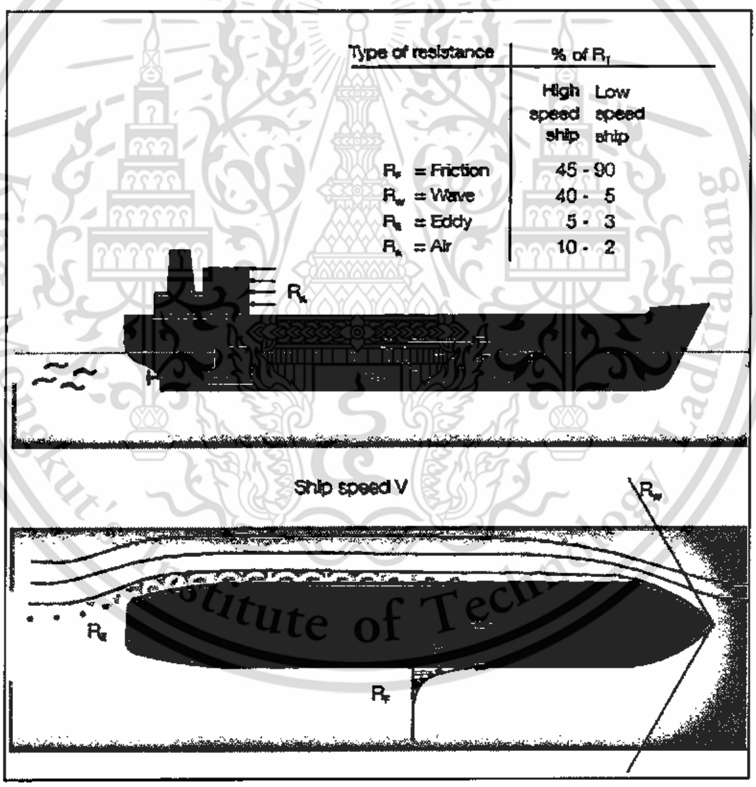

Figure 2.16 Total ship resistance [22]

CHAPTER 3
EXPERIMENTAL APPARATUS AND PROCEDURE

3.1 Experimental apparatus

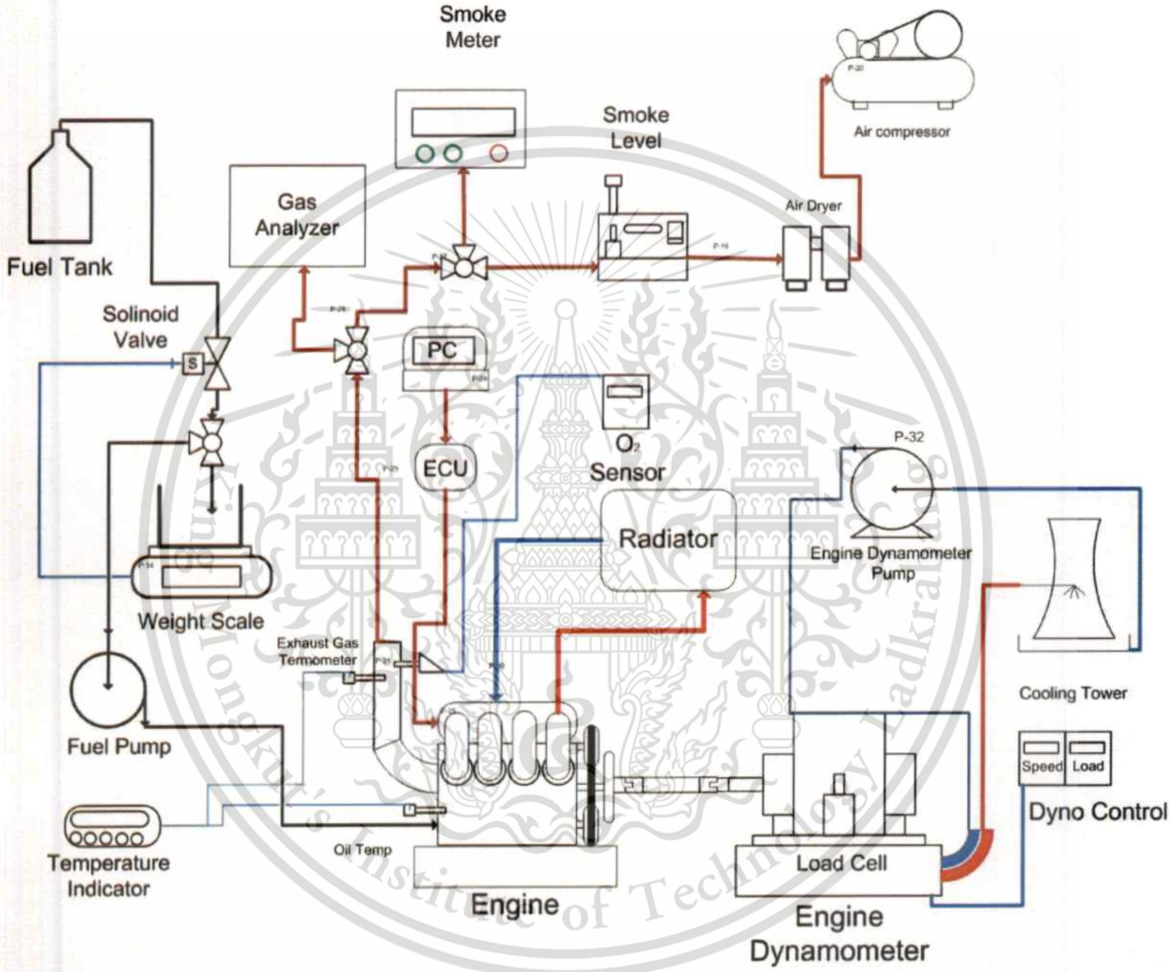

Figure 3.1 Schematic diagram of experimental setup

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

3.1.1 Engine

The port-fuel injection spark ignition engine, Toyota 1ZZ-FE, is selected for this experiment. The engine was operating on the eddy current engine dynamometer for both of performance and emission. 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.

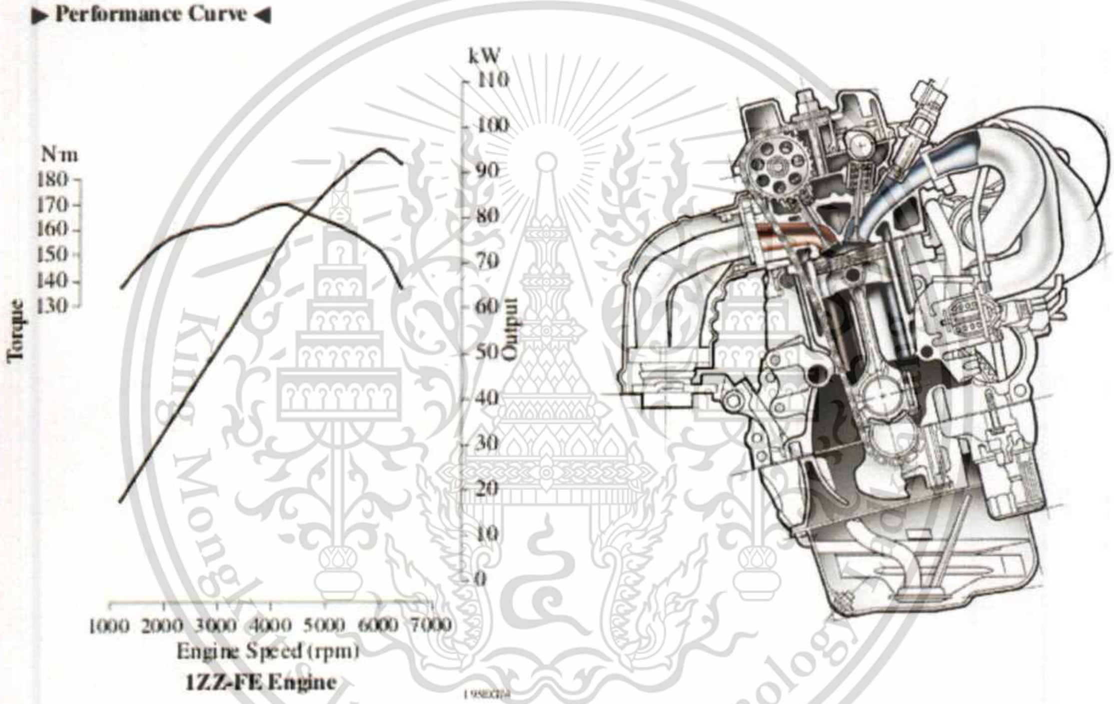

Figure 3.2 1ZZ-FE engine performance curve

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 engine dynamometer is using for apply a load and also measuring power and torque that the test engine can produce 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

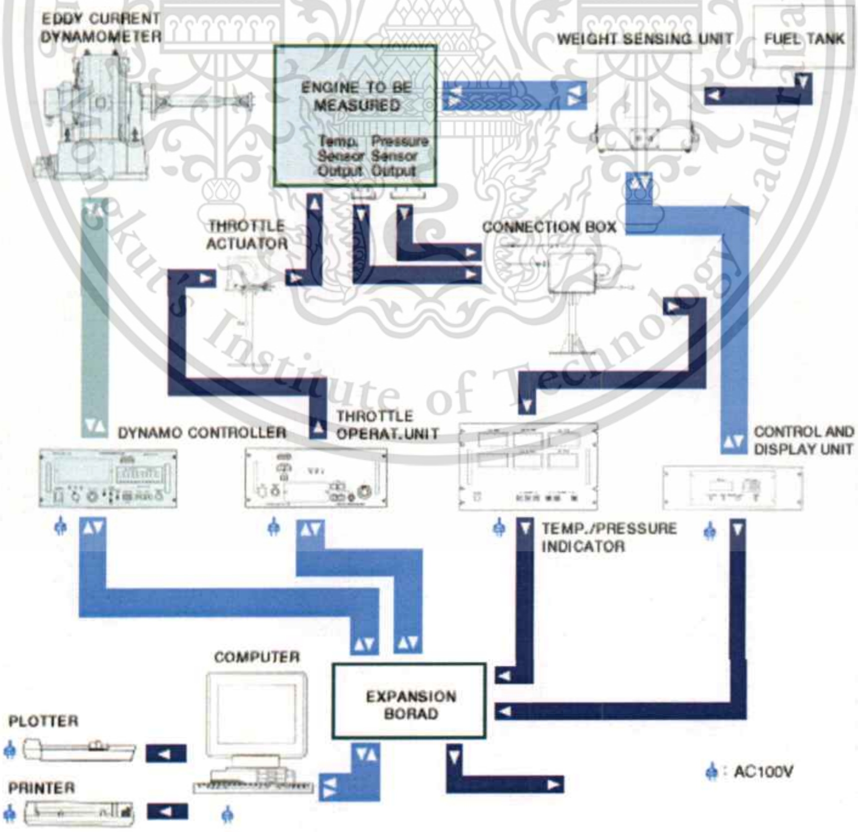

Figure 3.4 Schematic diagram

3.1.3 Fuel system

In this system the petrol is supplied with pressure by automotive fuel pump and adjust the fuel pressure regulator around 301 - 347 kPa (3.1 - 3.5 kgf/sq.cm, 44 - 50 psi) from the standard specification. And flow rate of the fuel pump was 120 liter per hour. After that, excess fuel will be regulated and drain back to the fuel tank. The fuel supply system was control by the engine dynamometer interface with in-house program. In-house program can control solenoid valves for open and close. This system has 2 solenoid valve, the first valve was used to control the fuel flow out from the fuel tank and the second valve was used to filling a fuel to the beaker as shown in Figure 3.5. The fuel supply system can be set to auto filling mode by measuring the fuel weight. The fuel weight was measure by a digital weight scale connected to engine dynamometer program.

Figure 3.5 Fuel supply system

Figure 3.6 digital weight scale

Table 3.2 Fuel properties

Fuels properties	Gasoline	E10	E20	E85	E100	Eh95
Formula	C_4 to C_{12}	$CH_{2.043}O_{0.015}$	$CH_{1.63}O_{0.065}$	$CH_{2.822}O_{0.425}$	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 vaporization [kJ/kg]	305	-	-	610 to 762.5	923	992.1
Vapor pressure [kPa]	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

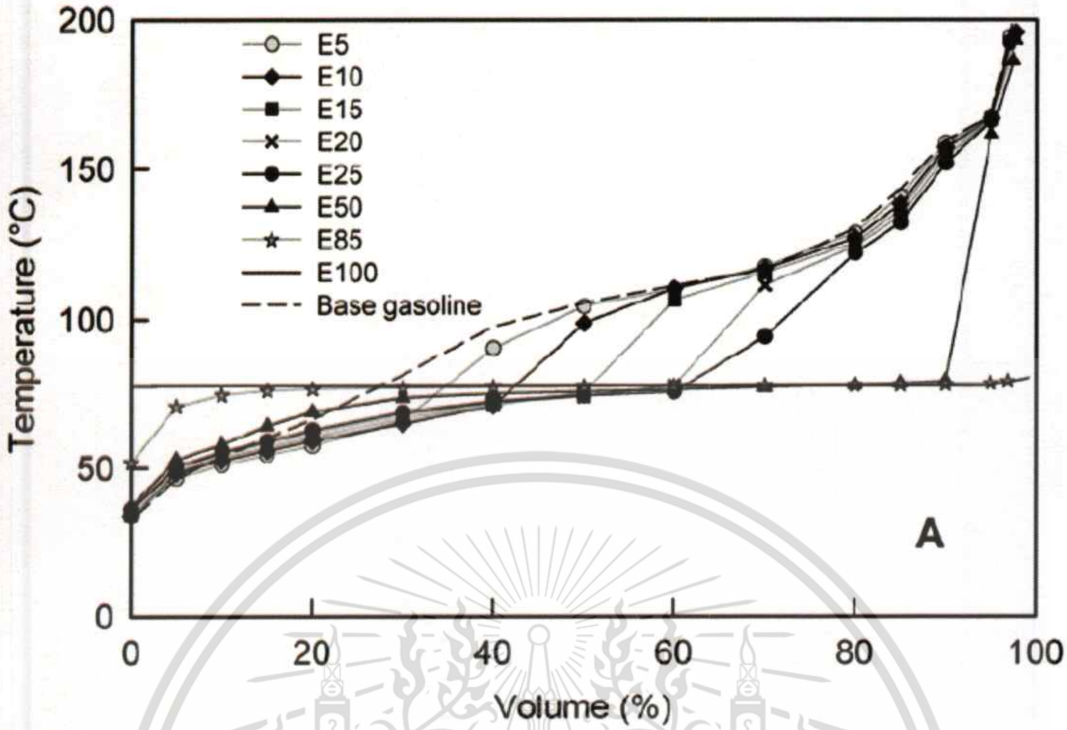

Figure 3.7 Distillation curve for Ethanol-Gasoline Blends

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

In this experiment, Thermocouple was connected to the temperature indicator to monitoring the temperature of engine cooling water, engine dynamometer cooling water, engine oil temperature, exhaust temperature and ambient temperature. The temperature indicator was show in figure 3.8.

Figure 3.8 Temperature indicator and thermocouple

- Engine cooling water temperature

An engine cooling water sensor was located at the water outlet pipe of engine. It used to measure the coolant temperature of the engine that can control the cooling temperature for the test condition that show in figure 3.9.

Figure 3.9 Engine cooling water sensors

- Engine dynamometer cooling water temperature

Dynamometer absorbs horse power by changing this heat energy by cooling water. An engine dynamometer cooling water sensor was located at the water inlet and outlet pipe of the engine dynamometer to monitoring the cooling water temperature. To protect the engine dynamometer from heat damage the upper limit of dynamometer cooling water temperature is 60 degree Celsius, cooling water inlet temperature is 35 degree Celsius.

- Engine oil temperature

An engine oil temperature sensor was located at the engine oil tank to monitoring the temperature of lubrication system which can be used to ensure the operation of the engine.

- Exhaust gas temperature

An exhaust gas temperature sensor was located at the exhaust manifolds that show in figure 3.10 in order to monitoring the temperature of the exhaust gas. The exhaust gas temperature can indicate the combustion characteristic of the engine that working in each condition and each fuel.

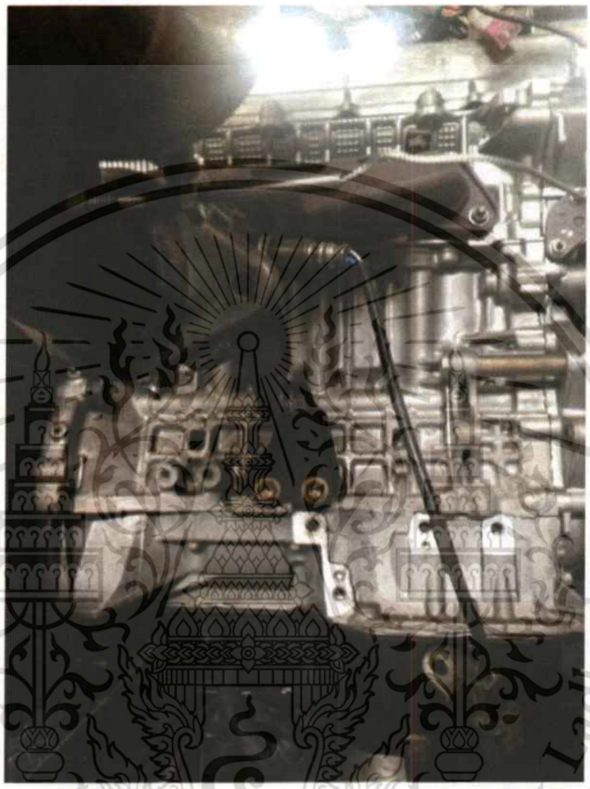

Figure 3.10 exhaust gas temperature sensor

- Ambient temperature

An ambient temperature sensor was located in the engine test room in order to monitoring and control the temperature for the testing condition. An ambient temperature of the engine test must be control in the range because an ambient air is the temperature of the intake air. The intake air temperature must be controlled to be same temperature in every operation condition of the engine in order to have the same output engine power.

3.1.6 Data acquisition system

A data acquisition system was connected to the engine dynamometer by an external wire. A desktop computer was used to command the engine dynamometer, which operated by National Instrument LabVIEW system. This program can command, measure, calculate and store the data from engine dynamometer. The engine dynamometer program can operate in 2 main condition which of constant load mode and constant speed mode, as shown in figure 3.11.

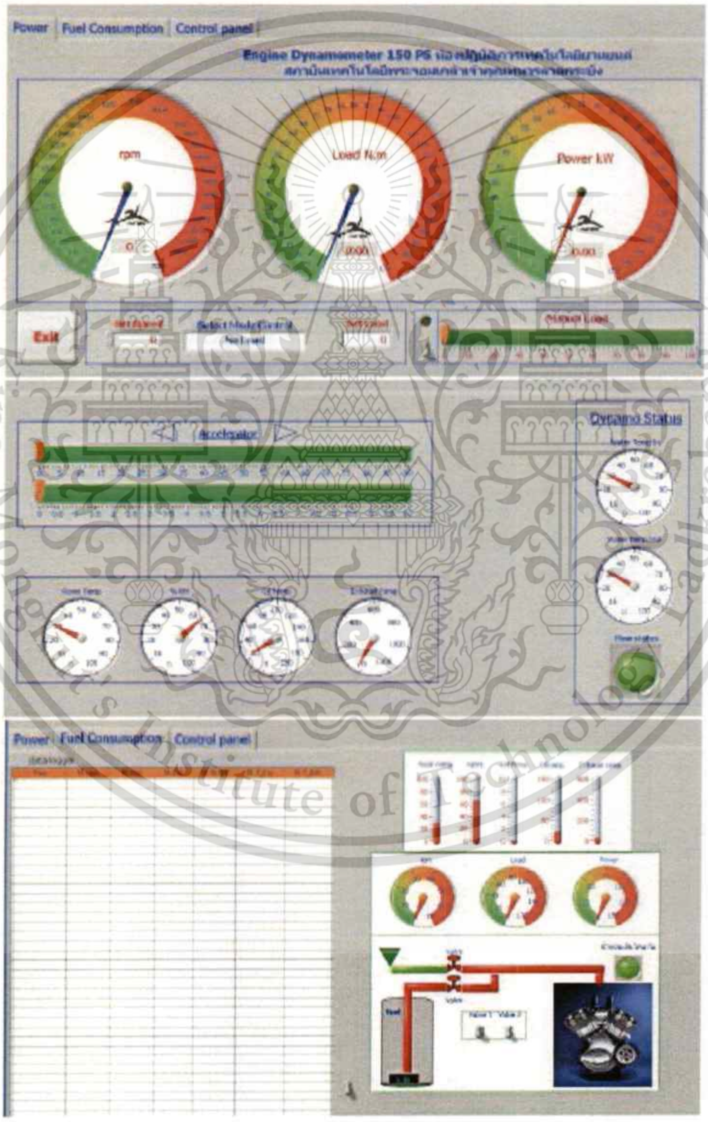

Figure 3.11 Engine dynamometer program interface

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 2 type of ECU was compared. An original equipment manufacturer ECU and ECU model link G4+ extreme was used as an engine control unit to control the amount of fuel that injected into each cylinder and ignition timing that the spark plug should fire in each cylinder. The Link G4+ extreme ECU have many special function that make the engine work more preciously such as auto tuning for working with different ethanol concentration in fuel, wide-band oxygen sensor support, auto adjusts cold start settings based on current fuel blend, close loop lambda compensation and many auxiliary output.

Figure 3.12 Engine control unit

Figure 3.13 Link G4+ extreme ECU program interface

3.1.8 Flex fuel ethanol sensor

In the experiment flex fuel ethanol sensor was used as detector of ethanol concentration in ethanol-gasoline fuel mixture as show in figure 3.14. Flex fuel ethanol sensor working with supportted ECU able to control the injection duration from ethanol percentage.

Figure 3.14 Flex fuel ethanol sensor

3.1.9 Gas analyzer

In the 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, CO_2 and HC, and electrochemical method for analyzing O_2 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.

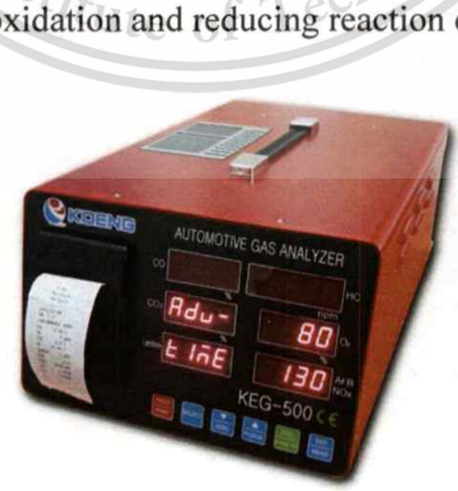

Figure 3.15 Automotive gas analyzer model KEG-500

3.1.10 Data logger

In the 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 3.16

Figure 3.16 VBOX sport data logger

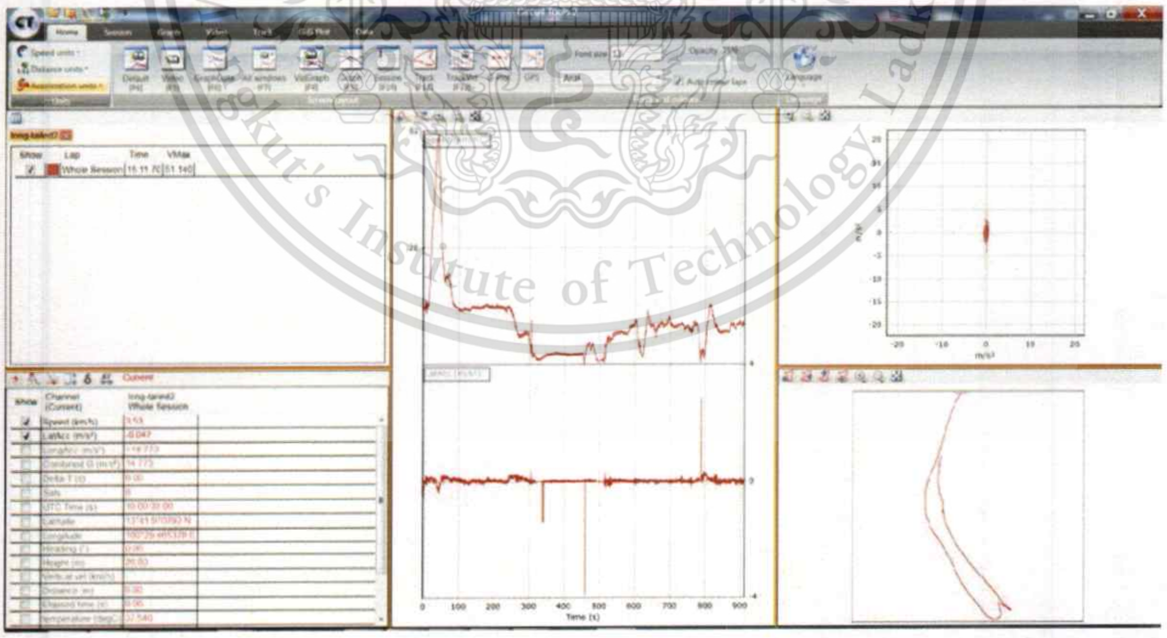

Figure 3.17 VBOX sport data logger program interface

3.1.11 Vehicle diagnostics and OBD II scan

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

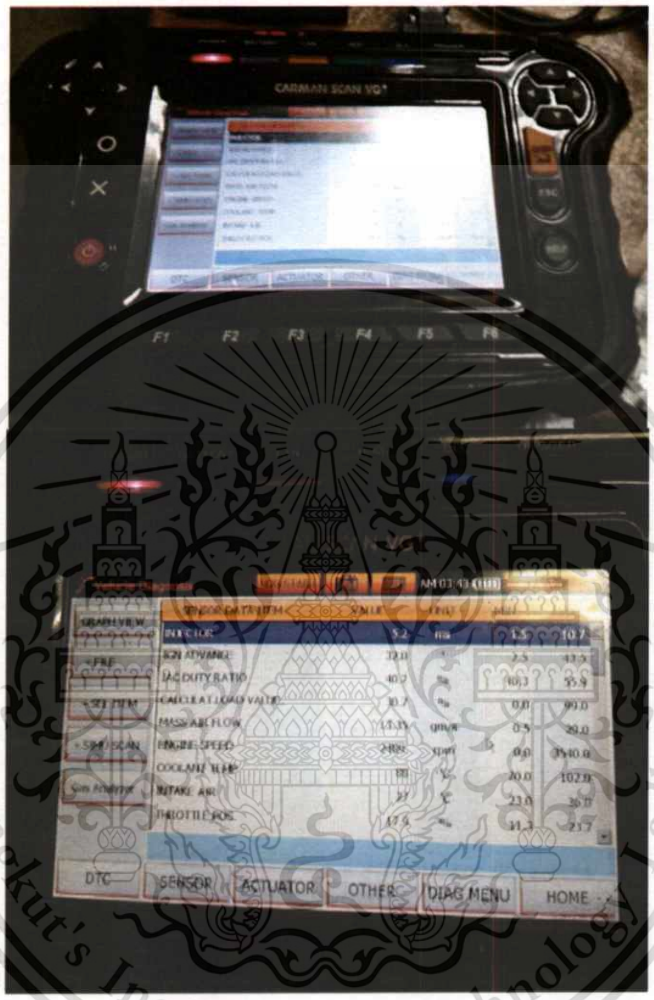

Figure 3.18 Vehicle diagnostics and OBD II scan device

3.1.12 Oxygen Sensor

The innovate motorsport model LM-2 digital air/fuel ratio meter connecting with wide band oxygen sensor was used in the experiment for measuring 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 convert from voltage signal to air-fuel ratio number by an air-fuel ratio meter.

Figure 3.19 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 canel and Chao Phraya River . Klong saen seab canel and Chao Phraya River were shoosed for surveying because these place had the most trip of boat in Bangkok.

Table 3.3 Survey data of transportation in Bangkok

Boat type	Engine	Passengers	Max speed (kph)	Operatin g 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

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 as shown in figure 3.20 and detail of the long-tailed boat and assumption for calculation are show in table 3.4.

Figure 3.20 Prototype boat

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	0.801×10^{-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 3.21

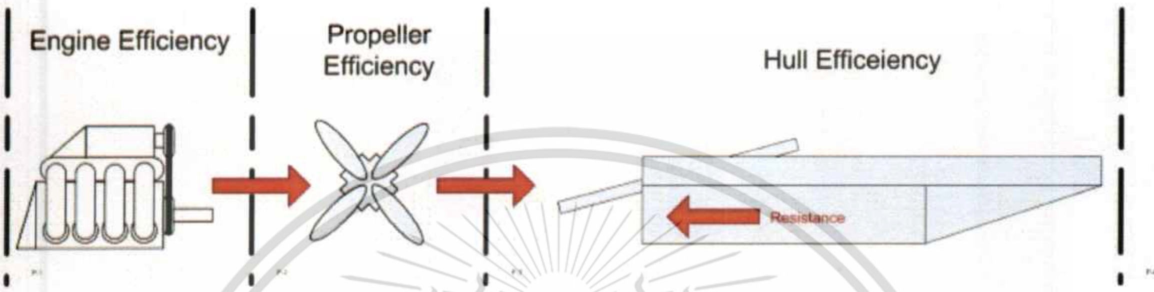

Figure 3.21 The external factors of boat

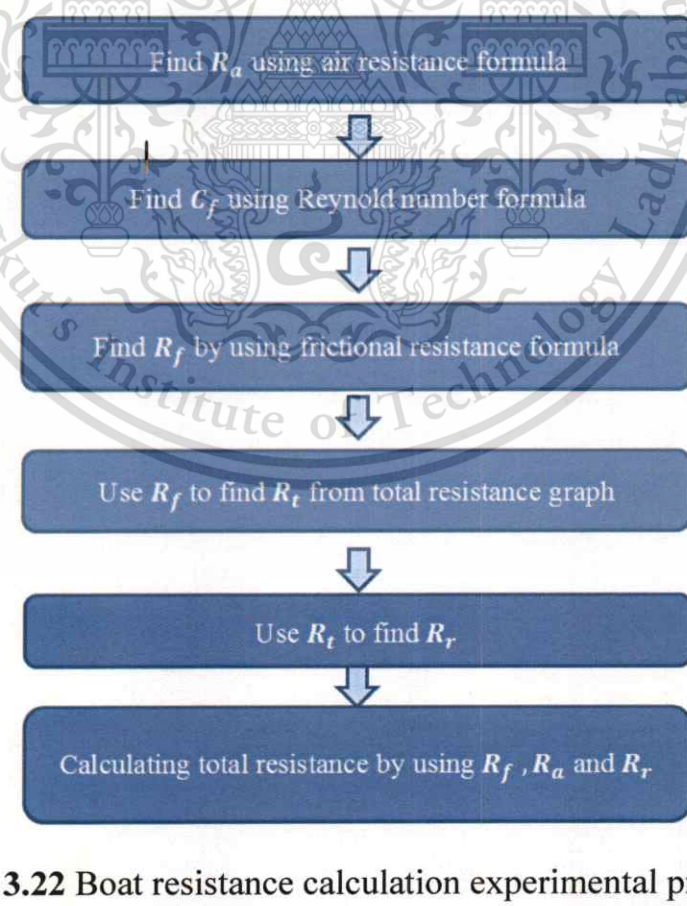

Figure 3.22 Boat resistance calculation experimental procedures

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

$$R_a = 0.9\left(\frac{1}{2}\rho A V^2\right) \tag{3.1}$$

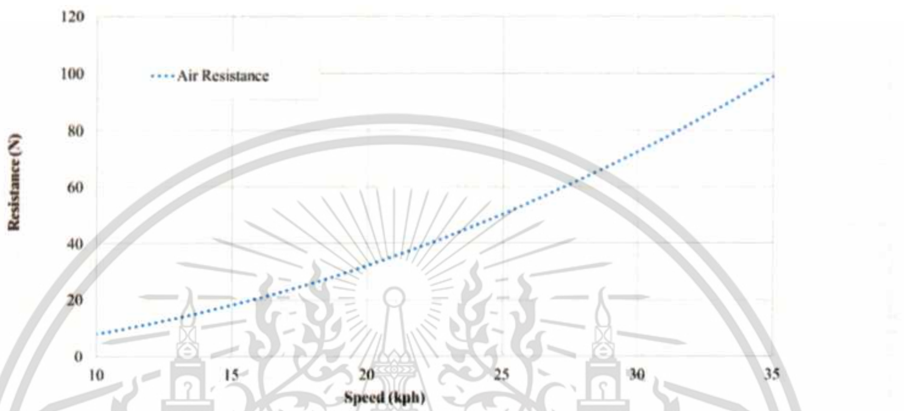

Figure 3.23 Air resistance of long-tailed boat at various speeds

3.2.2.2 Frictional resistance

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

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

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

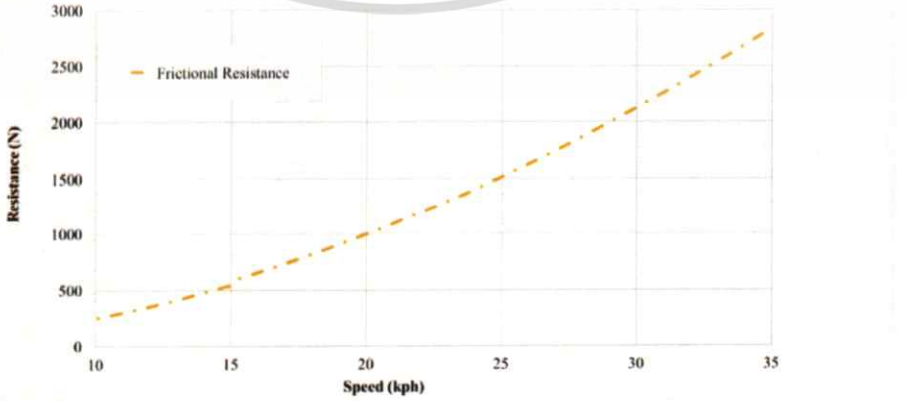

Figure 3.24 Frictional resistance of long-tailed boat at various speeds

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.

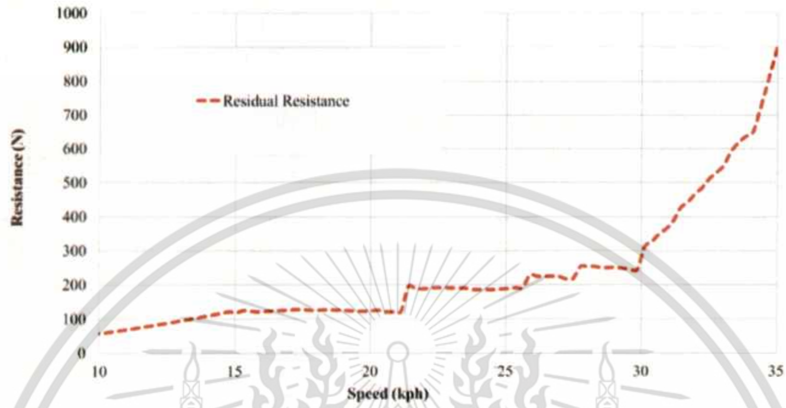

Figure 3.25 Residuall resistance of long-tailed boat at various speeds

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 3.26.

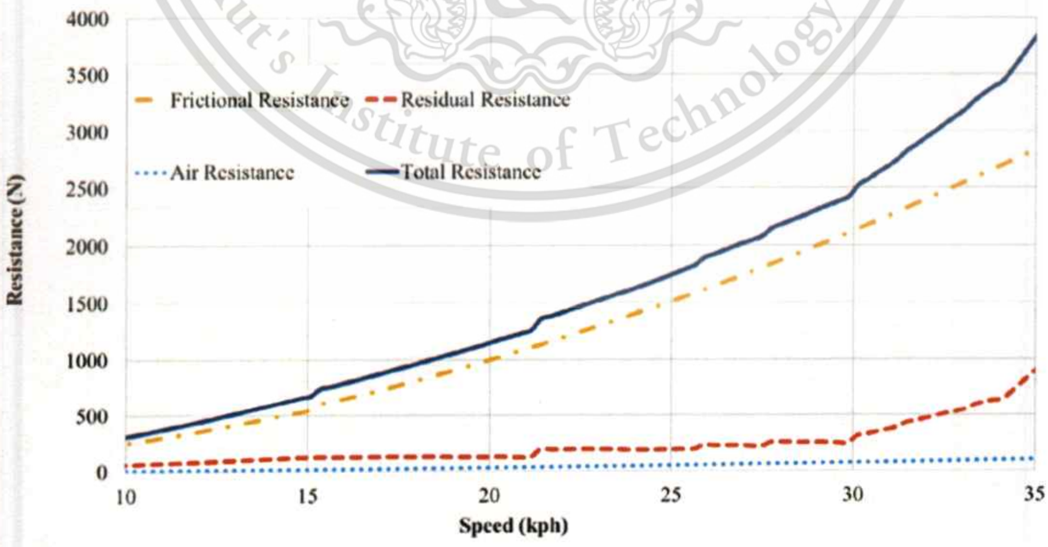

Figure 3.26 Total resistance of prototype boat

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

$$P = Fv \tag{4}$$

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 3.27.

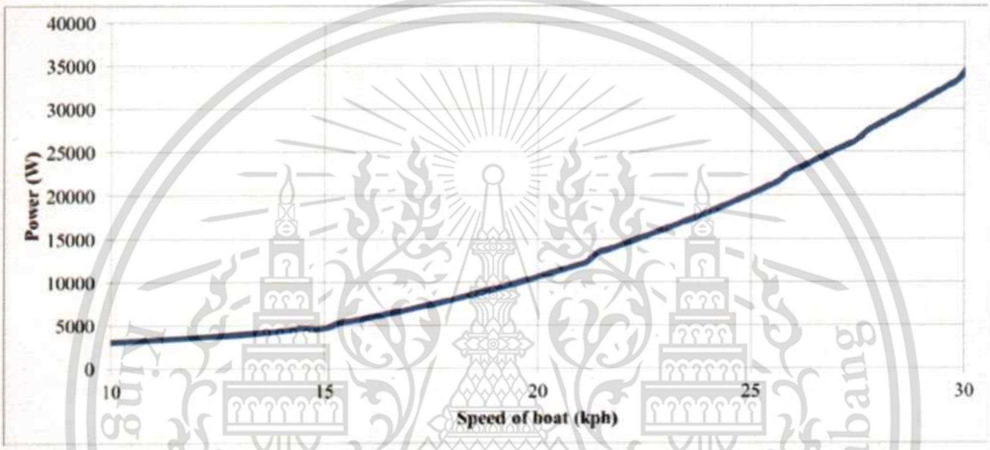

Figure 3.27 Required power for prototype boat

3.2.3.2 Require torque calculation

The required torque of the boat is calculated from using formula

$$P = 2\pi N\tau \tag{5}$$

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 3.28.

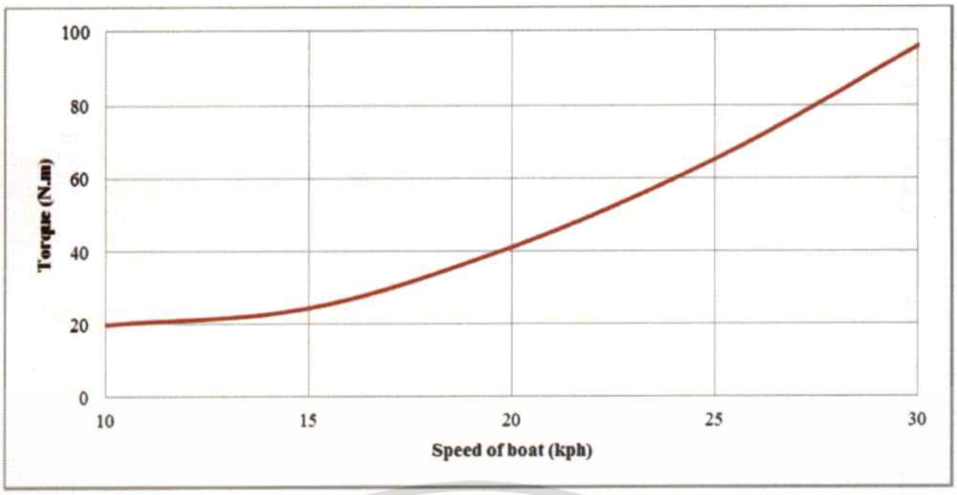

Figure 3.28 Required torque of the boat

3.2.4 Optimization of gear ratio

From a surveying data, most of long-tailed boats are running without gear box or running with 2 gear 1:1 forward and back ward gear ratio. A gear ratio can increase the output torque or output speed of a mechanism. Optimization of gear ratio aim to increase efficiency of long-tailed boat engine. In the experimental two different gear ratio were optimized. Required torque for each gear ratio as shown is figure 3.29 and 3.30.

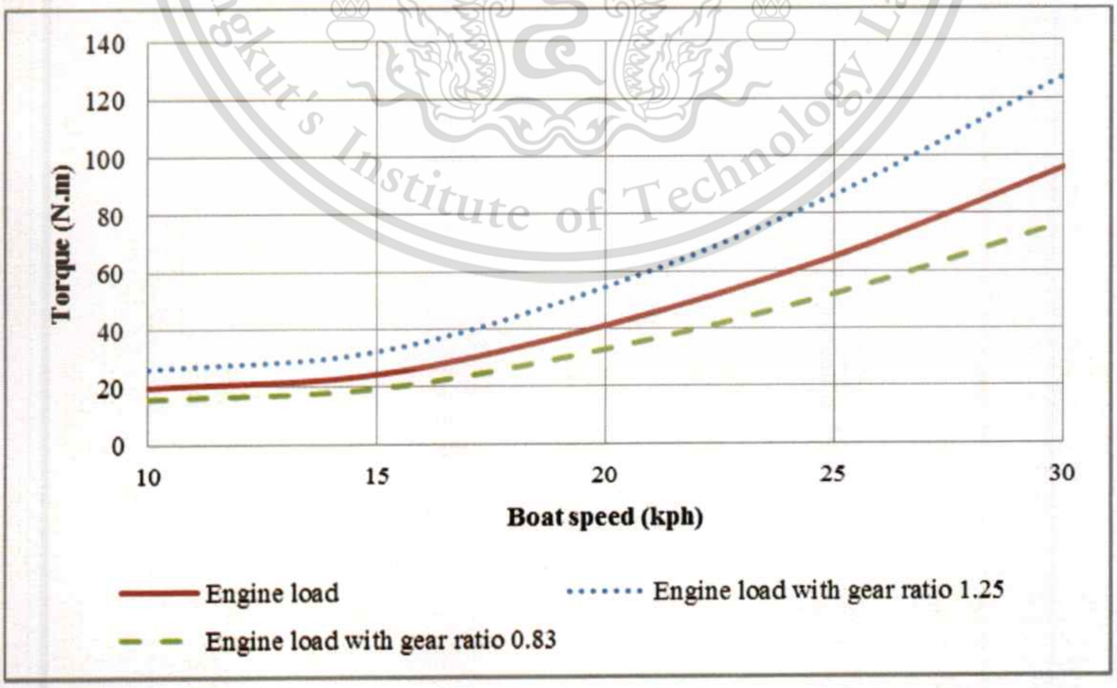

Figure 3.29 A require torque for each gear ratio

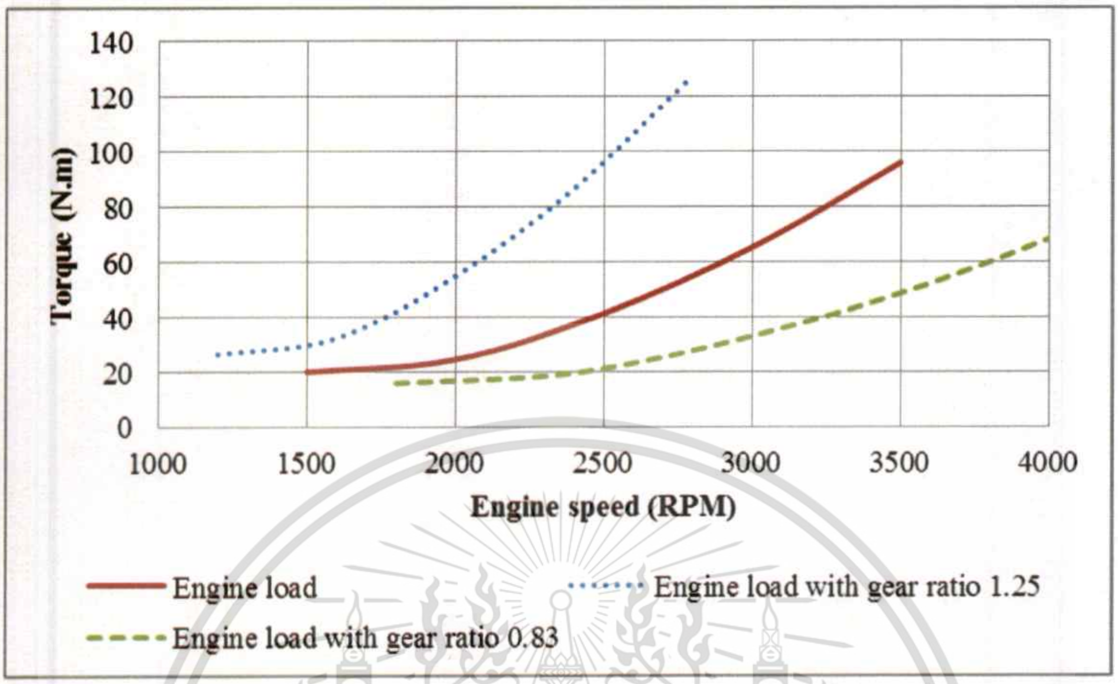

Figure 3.30 A required torque and engine speed of different gear ratio

3.2.5 Experimental conditions

A port-fuel injection spark ignition engine was measured performance and emissions at long-tailed boat condition with no gear box and two different gear ratio, using gasoline, ethanol-gasoline blended and hydrous ethanol fuel, respectively. The 10 to 30 kilometer per hour boat's speed condition was selected to study. All the conditions investigated were carried out at λ=1. The test conditions are shown in Table 3.5, 3.6 and 3.7. 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 conditions (No gear box engine)

Boat speed (kph)	Engine speed	Power (W)	Torque (N.m)
10	1500	3083	19.64
15	2000	5059	24.17
20	2500	10733	41.02
25	3000	20407	64.99
30	3500	35115	95.86

Table 3.6 Test conditions (1.25:1gear ratio)

Boat speed (kph)	Engine speed	Power (W)	Torque (N.m)
10	1200	3083	24.55
15	1600	5059	30.21
20	2000	10733	51.27
25	2400	20407	81.24

Table 3.7 Test conditions (0.83:1gear ratio)

Boat speed (kph)	Engine speed	Power (W)	Torque (N.m)
10	1800	3083	16.36
15	2400	5059	20.13
20	3000	10733	34.17
25	3600	20407	54.14

Table 3.8 Test conditions

Fuel type	E0, E10, E20, E85 and Eh95
Conditions	10 to 30 kph boat's speed with different gear ratio
Lambda (λ)	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 with no gear box and compered with Link G4+ ECU. After that two different ratio of gear box and no gear box with Link G4+ 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.

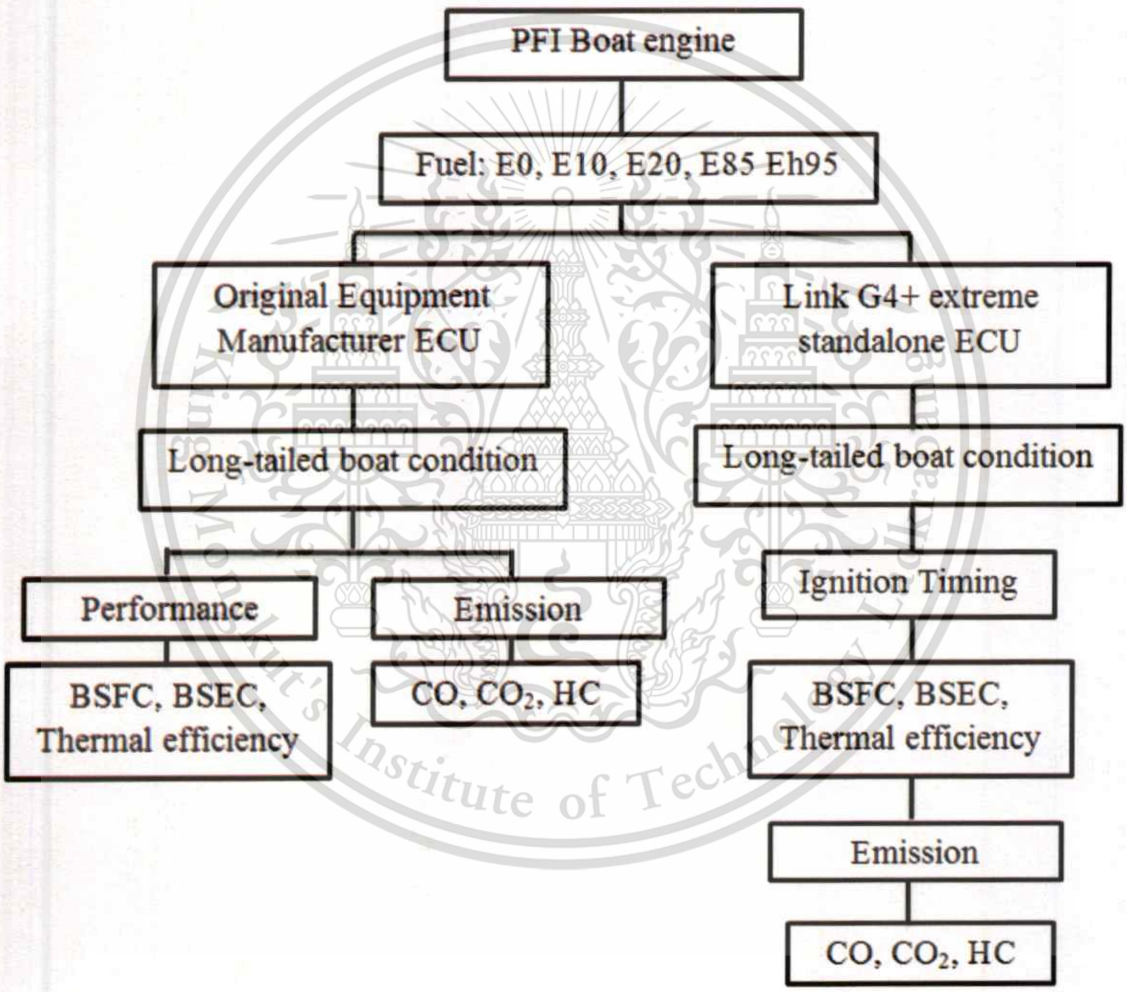

Figure 3.31 Experimental procedures

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 ECU was 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 and ignition timing. 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. In addition, the maximum brake thermal efficiency was considered by the ignition timing modulation. The ignition timing was modulated in the advanced direction: increment of before top death center degree.

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

4.1.1.1 Engine with original equipment manufacturing ECU

Brake specific fuel consumption (BSFC) is calculated from result of engine dynamometer to understand the variations of fuel consumption in the test engine using different alcohol-gasoline blended fuels. BSFC (g/kJ) is defined as the ratio of the rate of fuel consumption (g/sec) and the brake power (kW). And BSFC should be increased with the increase of ethanol content.

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.

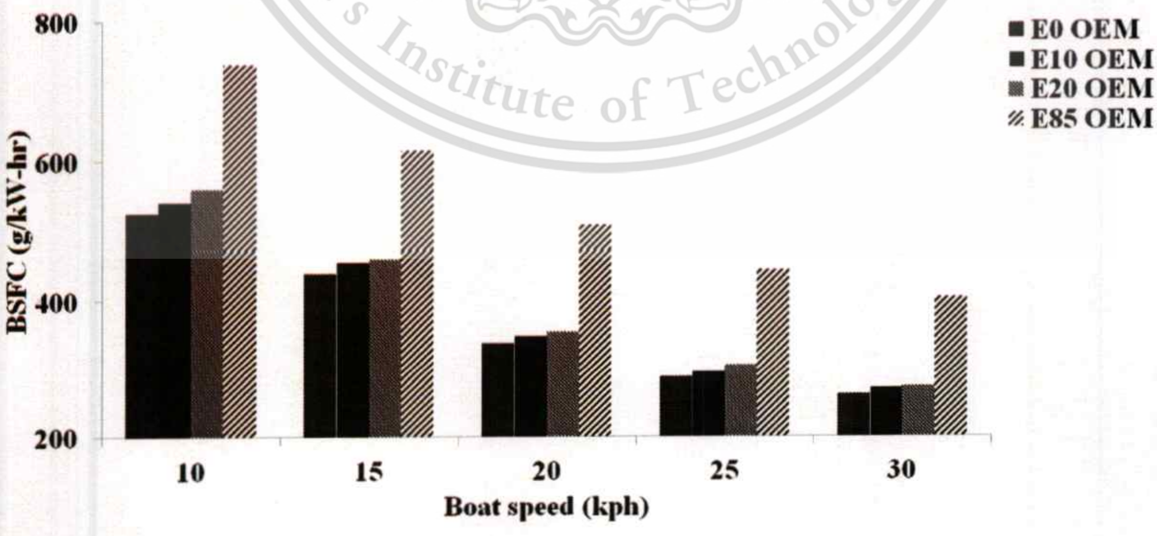

Figure 4.1 Brake specific fuel consumption on various condition with OEM

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

The 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.

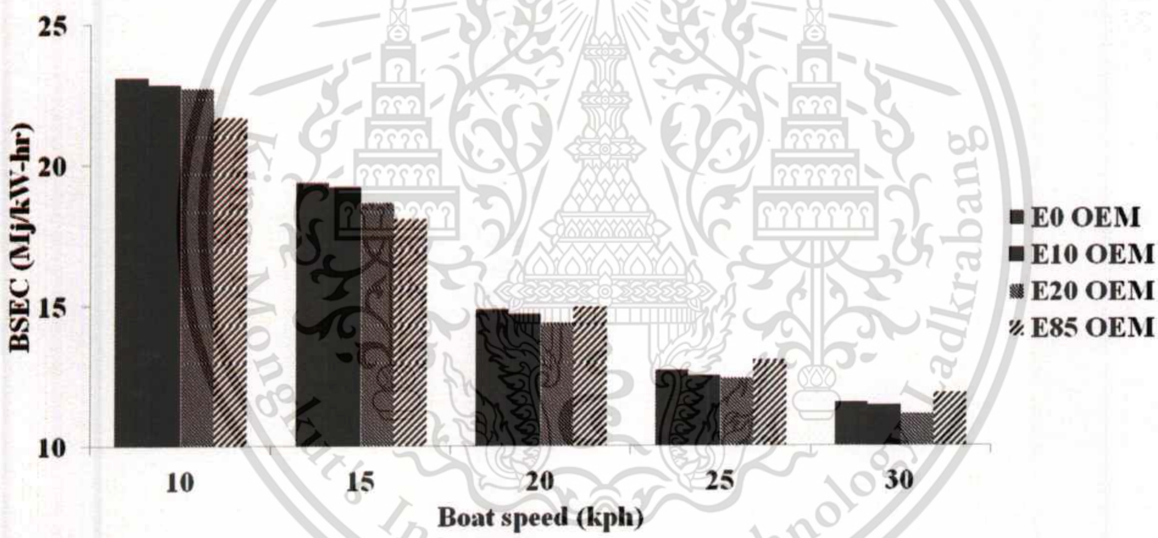

Figure 4.2 Brake specific energy consumption on various condition with OEM

Figure 4.2 signify that BSEC of gasoline is highest at 10 and 15 kph boat speed. That's 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, 25 and 30 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.

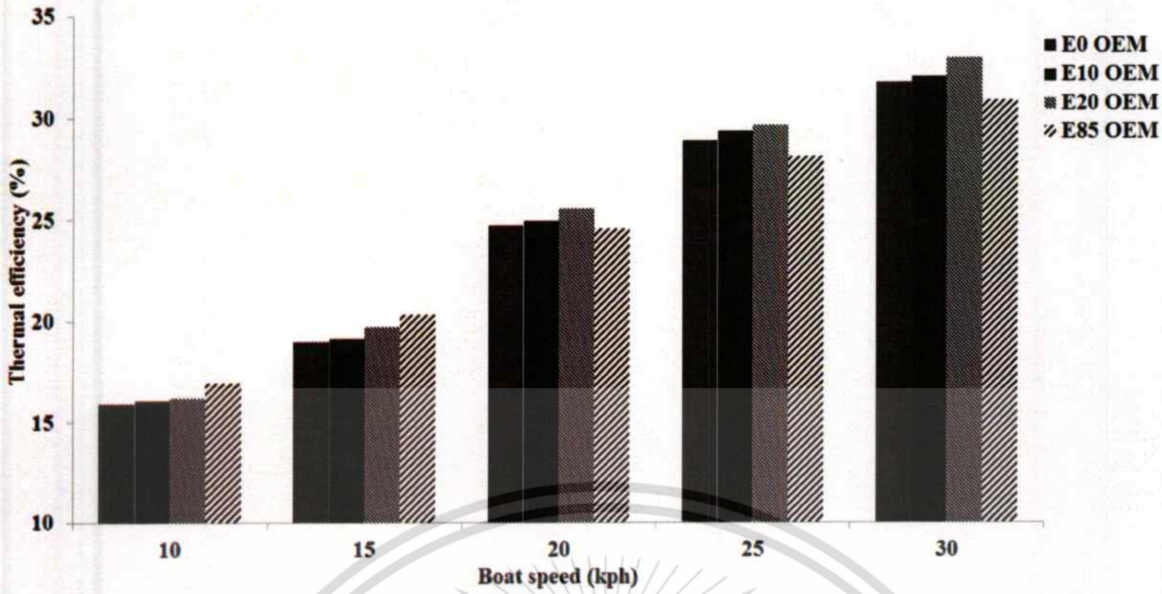

Figure 4.3 Thermal efficiency on various condition with OEM

Figure 4.3 show the result of thermal efficiency for E0, E10, E20 and E85 in 10 to 30 kph boat speed. Thermal efficiency is work-out divided by energy-in. The result show that in 10 and 15 kph boat speed gasohol E85 represent the highest thermal efficiency following with E20, E10 and E0. However, For 20,25 and 30 kph boat speed E20 represent the highest thermal efficiency following with E10 and E0,And thermal efficiency of E85 at 20 to 30 kph boat speed are lowest affect from higher BSFC and BSEC. It's conclude that if the engine is have not any modification , using gasohol E85 the engine can produce the highest efficiency in 10 and 15 kph boat condition. On the other hand for high speed boat conditions (20-30 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. One of the most important ones is ignition timing. Also it is the one of the most important parameters for optimizing efficiency and emissions, permitting combustion engine to conform to the future emission targets and standard. The 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.

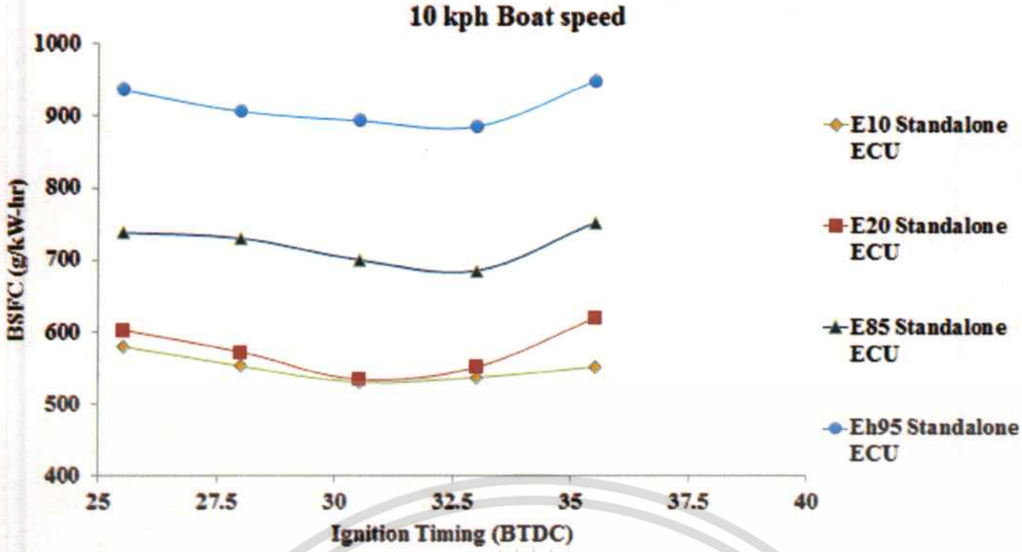

Figure 4.4 Brake specific fuel consumption at 10 kph

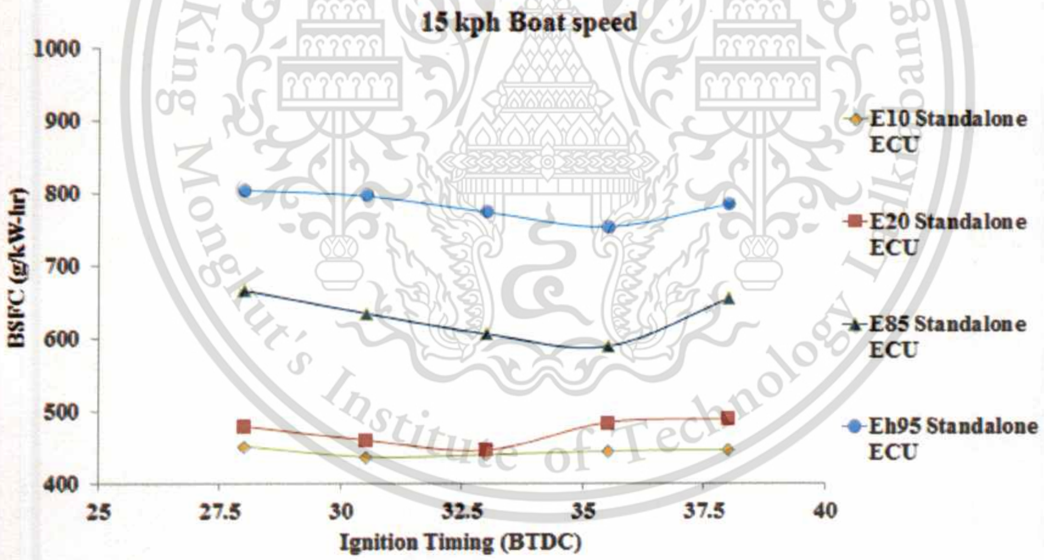

Figure 4.5 Brake specific fuel consumption at 15 kph

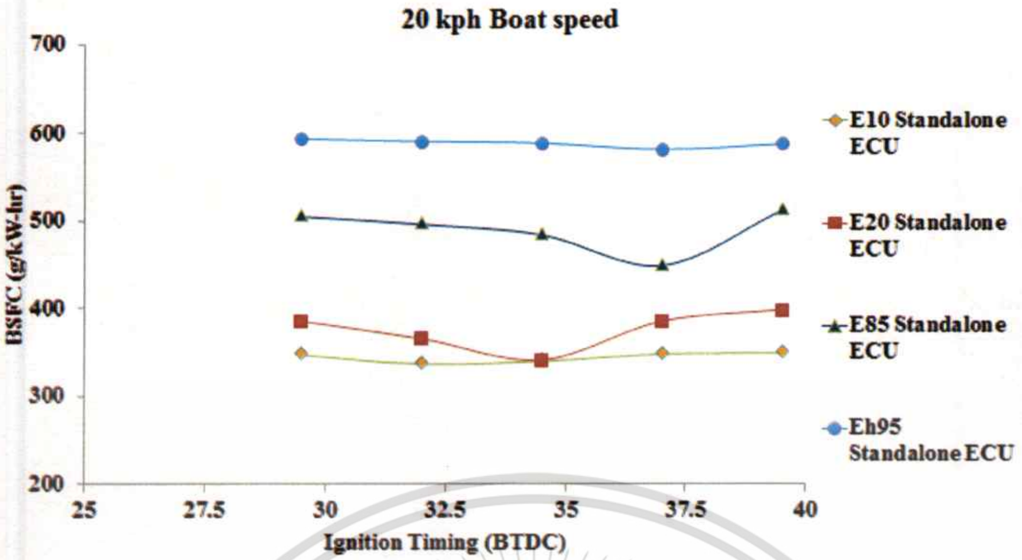

Figure 4.6 Brake specific fuel consumption at 20 kph

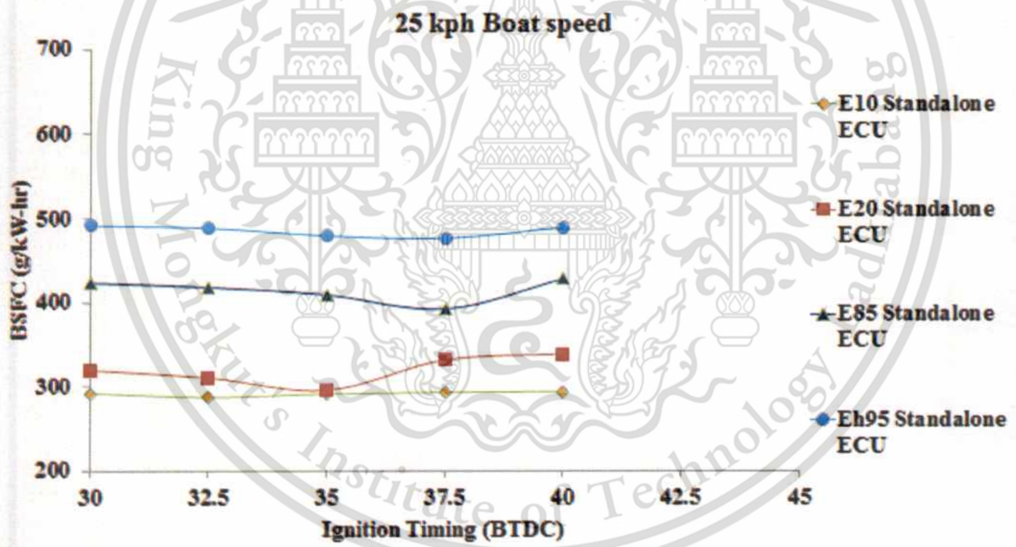

Figure 4.7 Brake specific fuel consumption at 25 kph

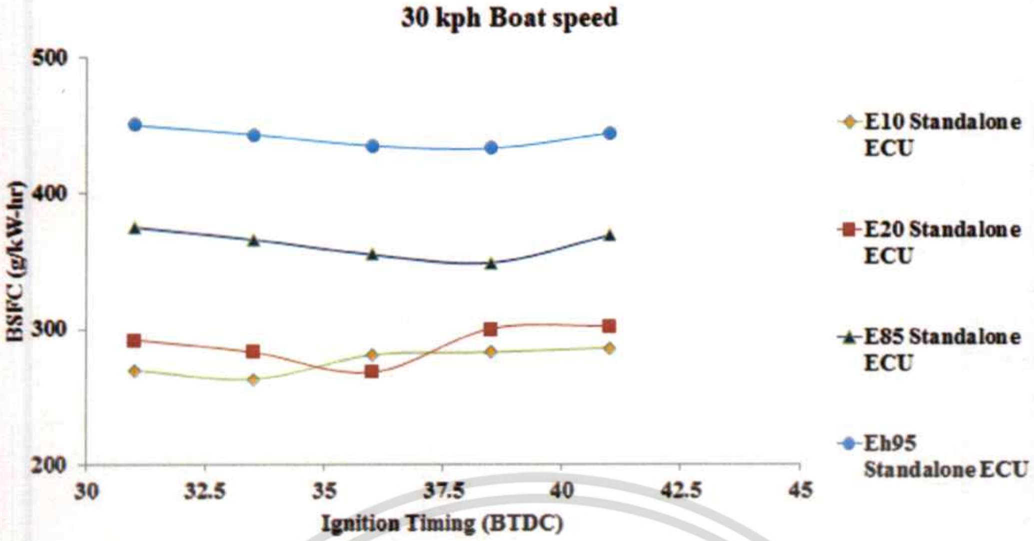

Figure 4.8 Brake specific fuel consumption at 30 kph

Figure 4.4 – 4.8 are showing the effect of ignition timing on break specific fuel consumption. The starting point of ignition timing all of figure are from the original equipment manufacturing ECU. The result of BSFC in 10, 15, 20, 25 and 30 kph boat operating condition are showing in the same trend, Eh95 have the highest BSFC following with E85,E20 and E10 Due to the LHV of fuel.

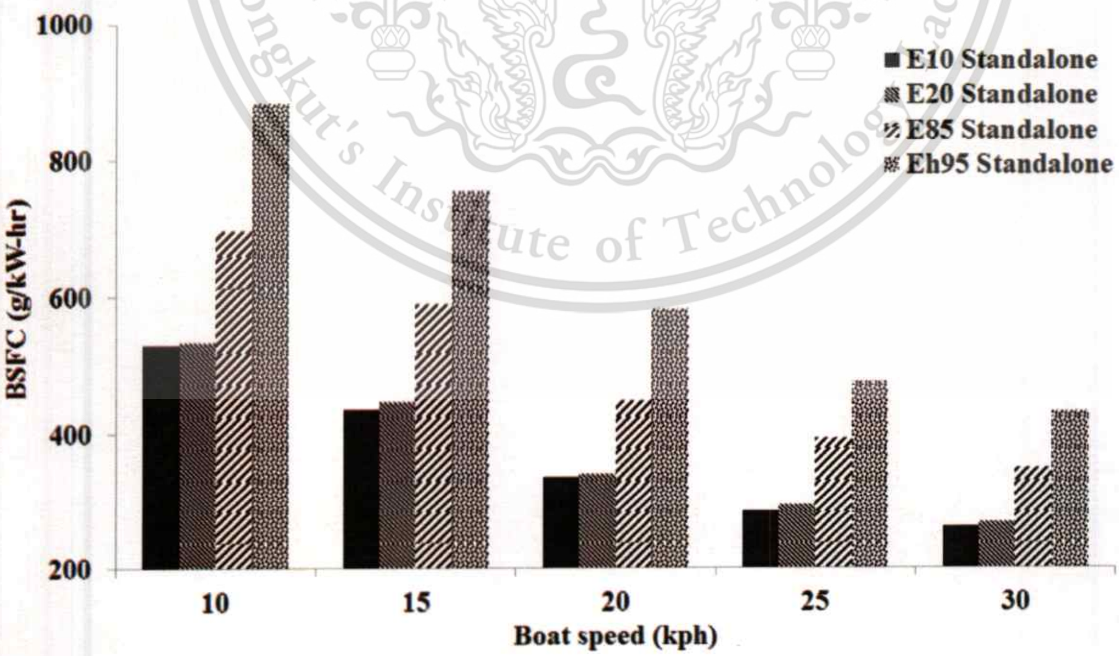

Figure 4.9 Brake specific fuel consumption with standalone

The bar chart in Figure 4.9 is showing the lowest value of BSFC for each fuel after optimization ignition timing. Eh95 have the highest BSFC following with E85, E20 and E10 for any boat speed Due to the LHV of fuel. And Figure 4.10 is showing the comparisons of BSFC in 10 to 30 kph boat speed with OEM and standalone ECU with E0, E10, E20, E85 and Eh95 fuel operating, the result indicate that optimization of ignition timing lead to decrease BSFC 2-7% in same fuel for all boat condition.

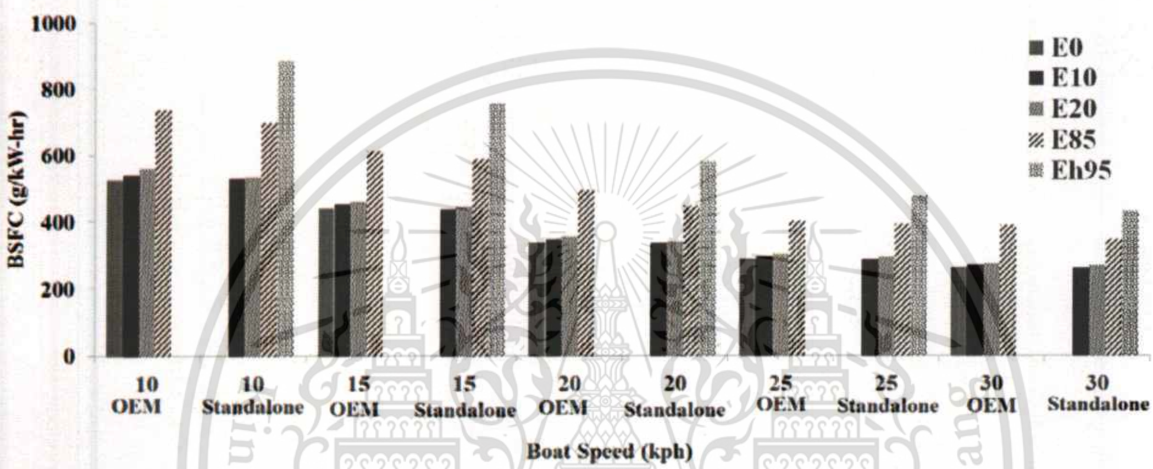

Figure 4.10 Break specific fuel consumption between OEM and standalone

Figure 4.11-4.15 are show The effect of ignition timing on BSEC. The lowest of BSEC are appearing in the highest of thermal efficiency. At 10 to 30 kph boat speed , result of BSEC are showing in the same trend, gasohol E85 fuel had given the highest efficiency following with E20,E10 and Eh95. It can be seen that the BSEC decrease with risen ignition advanced to a point, and then increase slightly when the knock is occur.

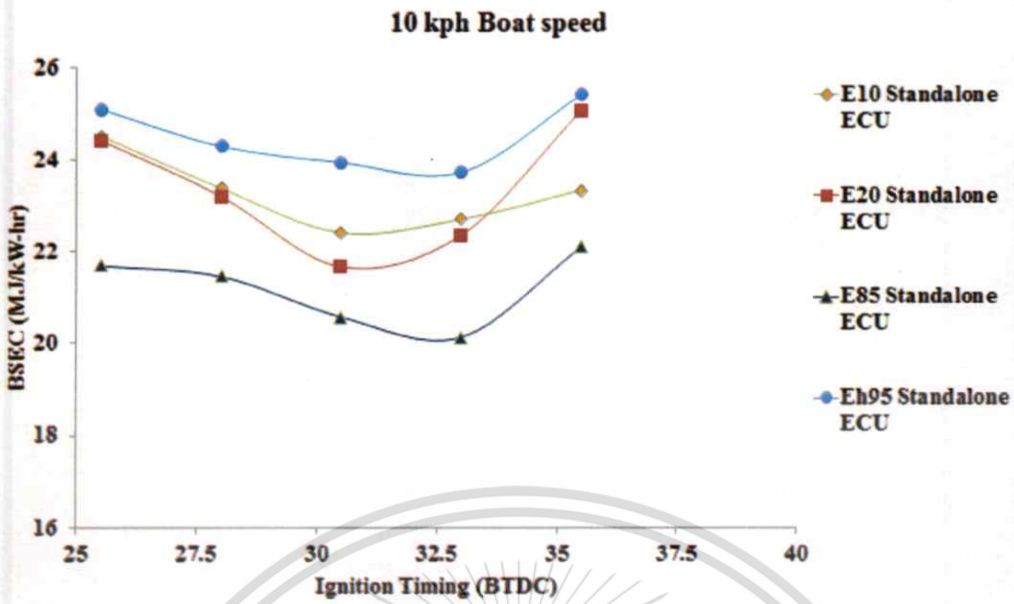

Figure 4.11 Brake specific energy consumption at 10 kph

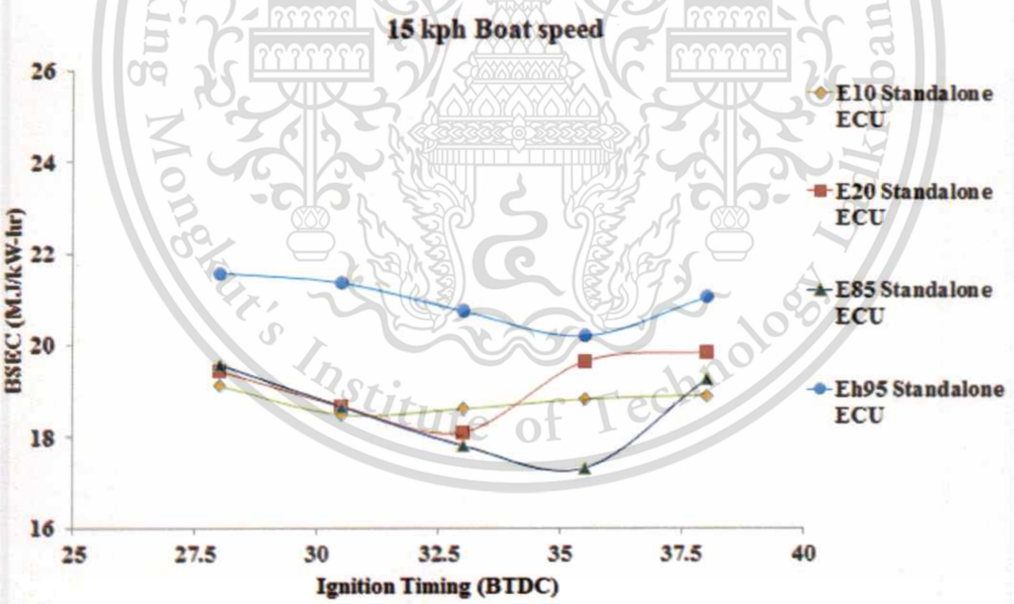

Figure 4.12 Brake specific energy consumption at 15 kph

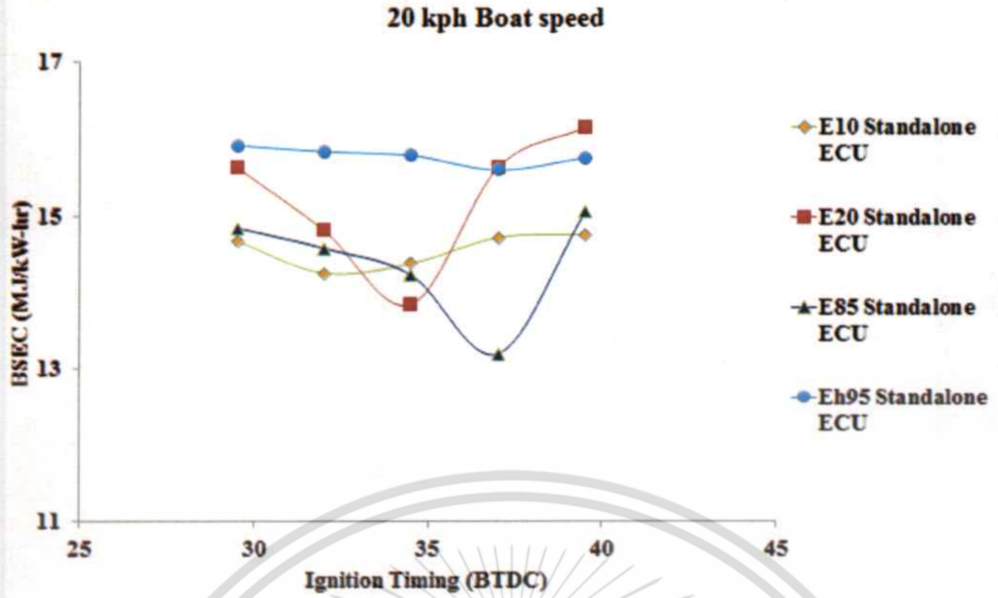

Figure 4.13 Brake specific energy consumption at 20 kph

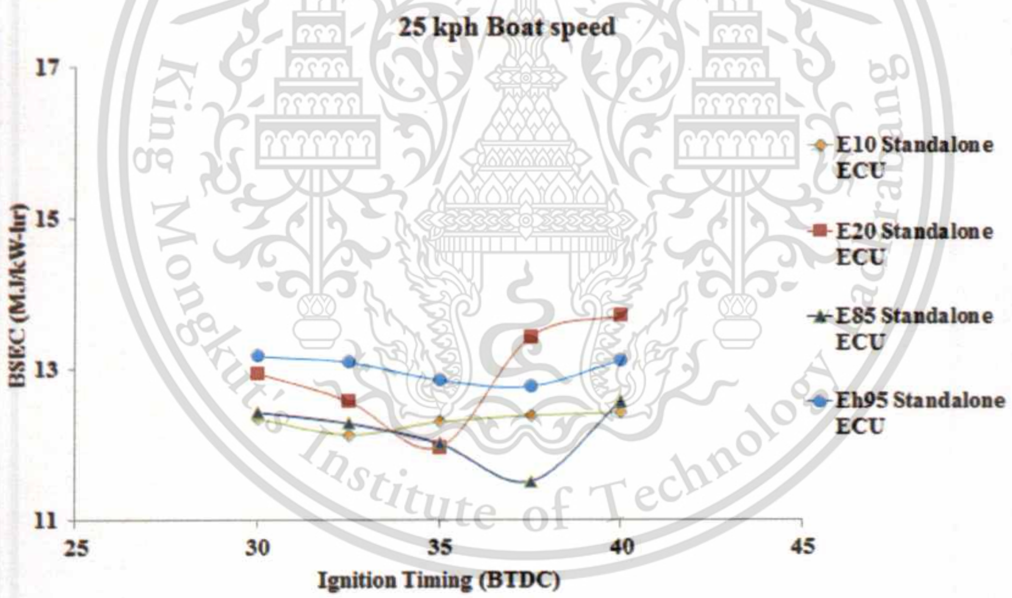

Figure 4.14 Brake specific energy consumption at 25 kph

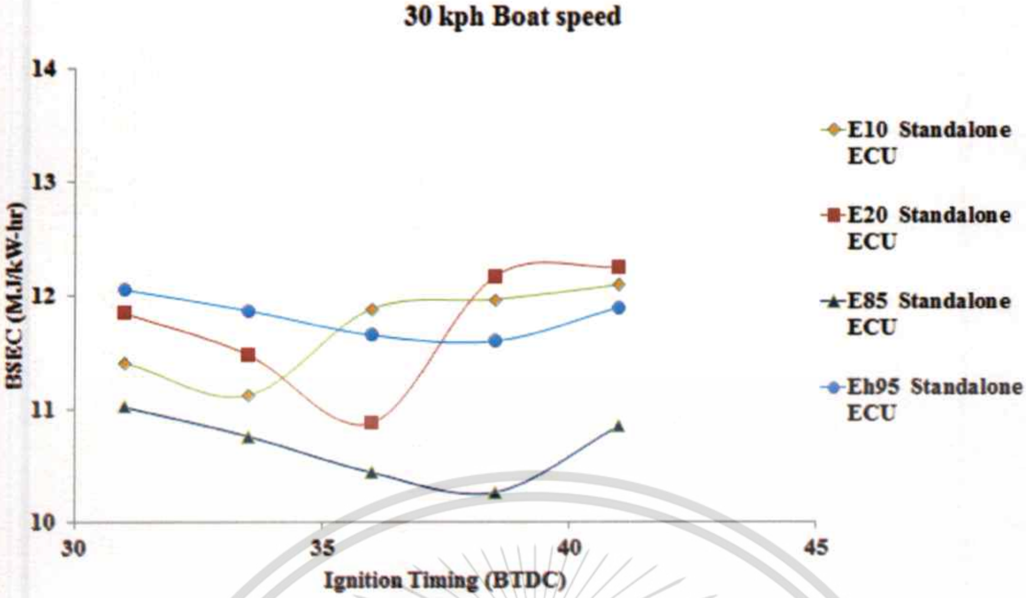

Figure 4.15 Brake specific energy consumption at 30 kph

The bar chart is Figure 4.16 and 4.17 are showing the comparisons of BSEC in each fuel on 5 different speed of boat with OEM and Standalone ECU. The lowest of BSEC in each fuel are bring to plot in these chart. The results show that changing the OEM ECU to standalone with optimized ignition timing lead to decrease BSEC in any fuel. In result of standalone ECU, E85 showing the lowest BSEC following by E20, E10 and Eh95 in all boat speed. Eh95 signify the highest BSEC due to the heat loss to vaporize the water. And at 10,15,20,25 and 30 kph boat speed running with E10 E20 and E85 BSEC are decrease approximately about 4.0%, 3.7%, 6.3%, 6.2% and 6.4% with standalone compared with OEM ECU in the same fuel.

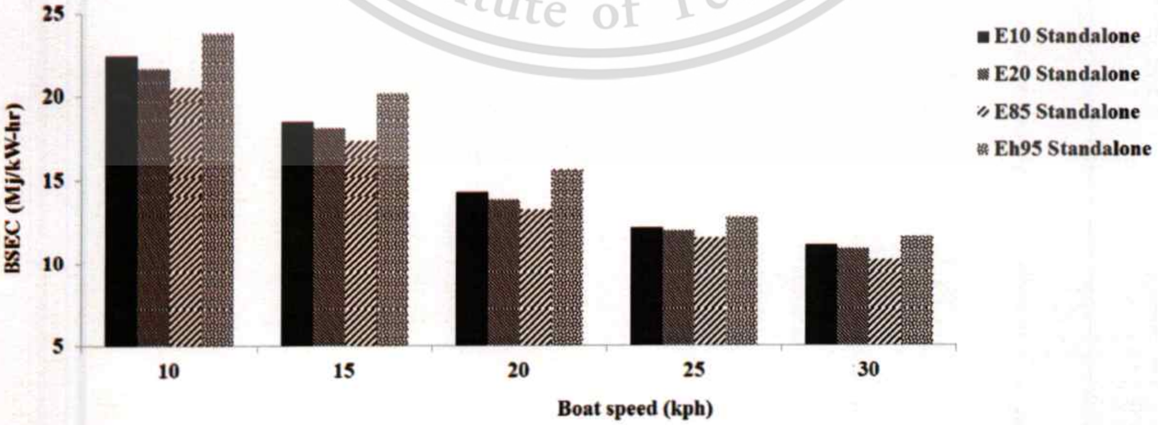

Figure 4.16 Brake specific energy consumption with standalone

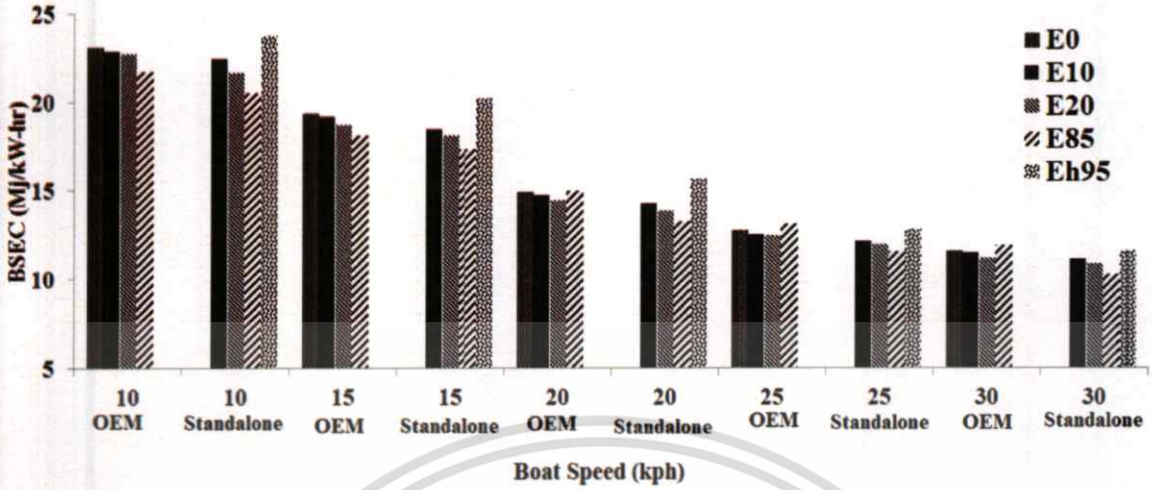

Figure 4.17 Break specific energy consumption between OEM and standalone

Figure 4.18-4.22 are show the effect of ignition timing on Thermal efficiency. Thermal efficiency value is inverse with BSEC value. The lowest of BSEC are appearing in the highest of thermal efficiency. At 10 and 15 kph boat speed , result of thermal efficiency are showing in the same trend, Eh85 fuel had given the highest efficiency following with E20,E10 and Eh95. It can be seen that the thermal efficiency increase with risen ignition advanced to a point, and then reduces slightly when the knock is occur.

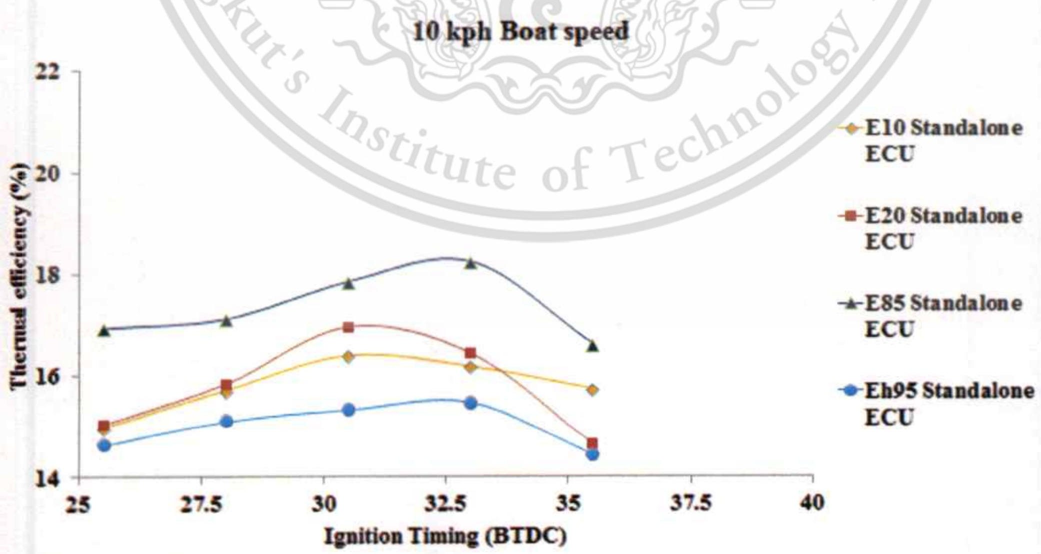

Figure 4.18 Thermal efficiency at 10 kph

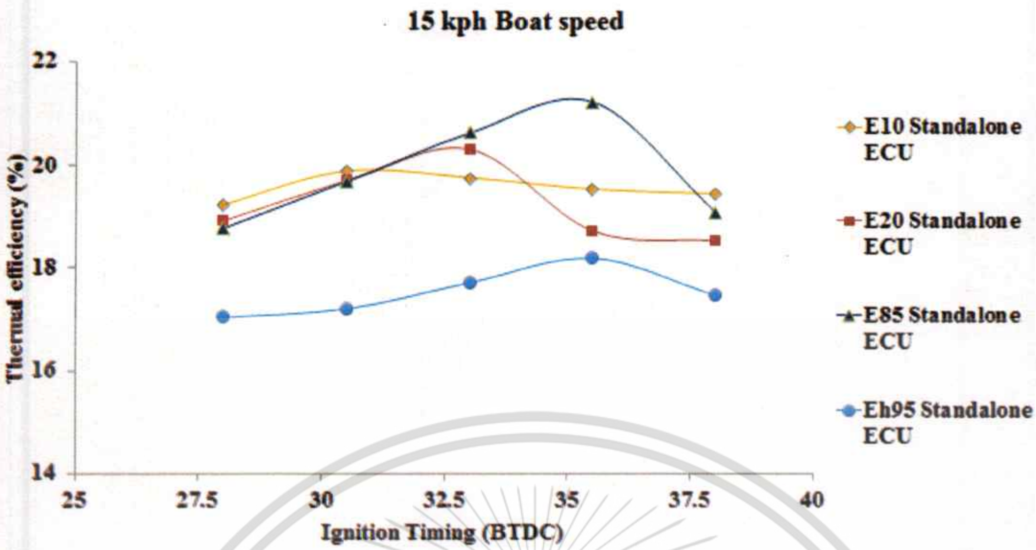

Figure 4.19 Thermal efficiency at 15 kph

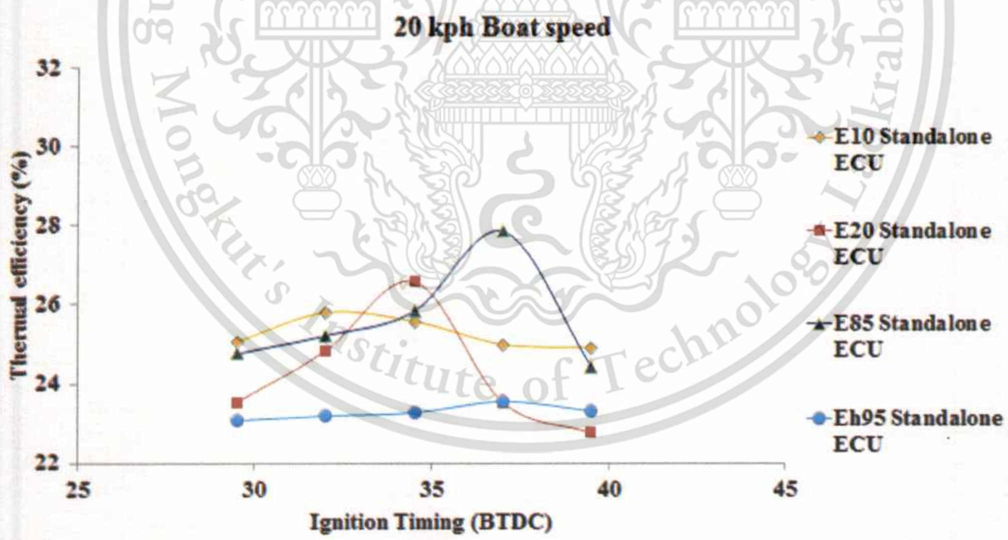

Figure 4.20 Thermal efficiency at 20 kph

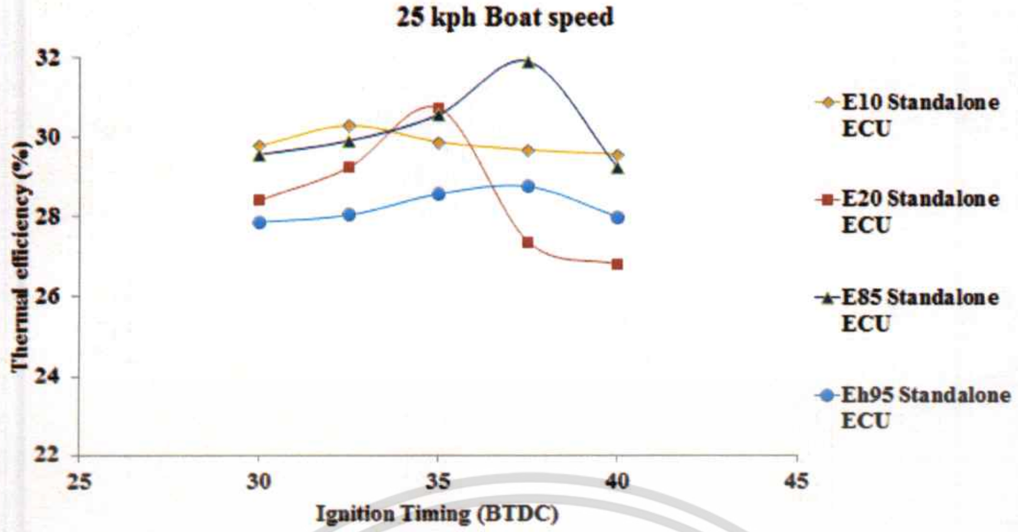

Figure 4.21 Thermal efficiency at 25 kph

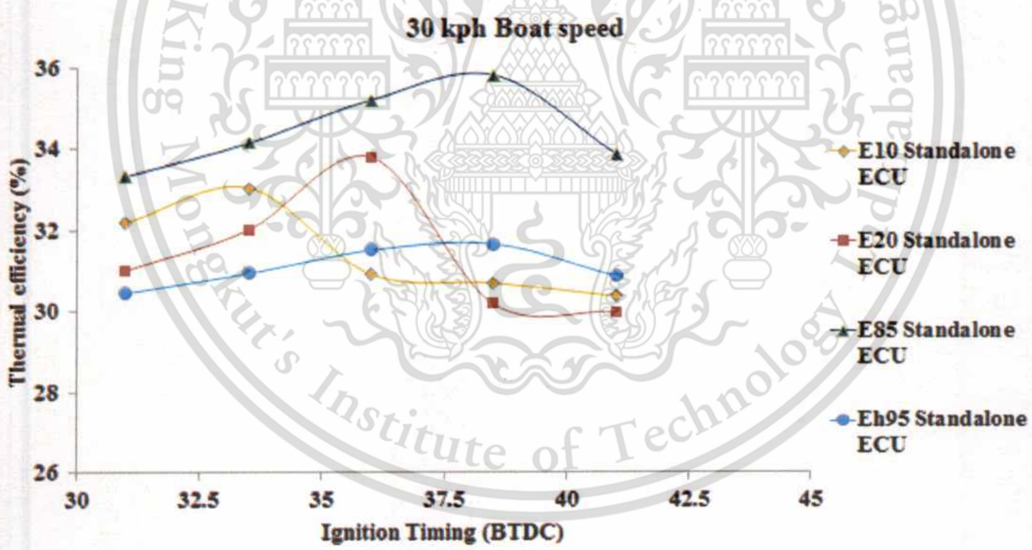

Figure 4.22 Thermal efficiency at 30 kph

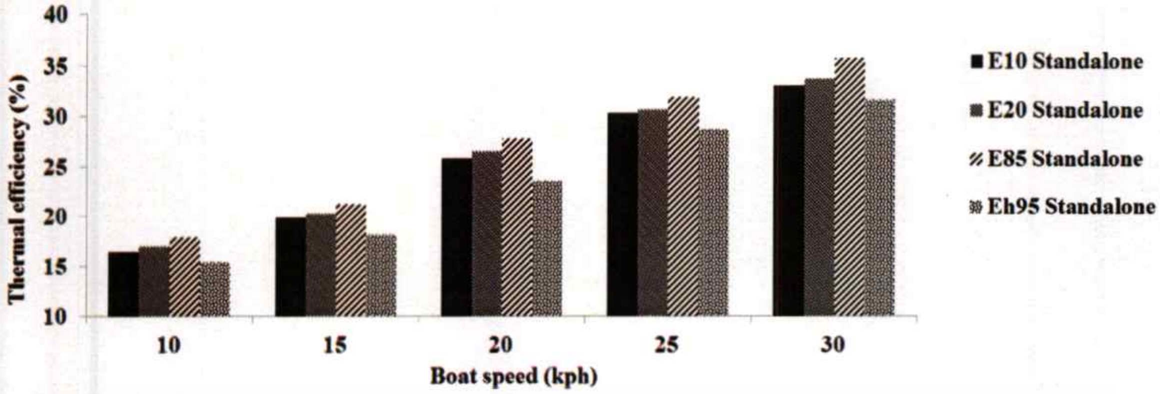

Figure 4.23 Thermal efficiency with standalone

For the result of thermal efficiency, Figure 4.23 showed the relation between thermal efficiency and speed of boat. The highest of thermal efficiency in each fuel and each speed of boat are bringing to plot in this chart. 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.

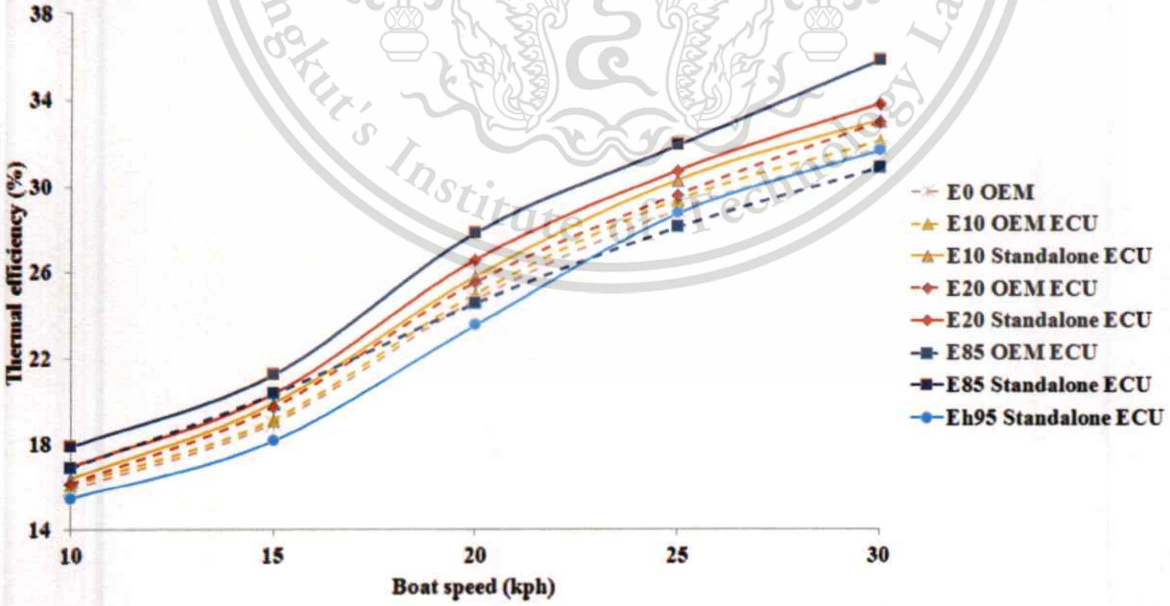

Figure 4.24 Thermal efficiency between OEM and standalone

Figure 4.24 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 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 4.25 – 4.28 are showing the effect of ignition 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. BSFC decrease with risen ignition advanced to a point, and then increase slightly when the knock is occurring. 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.

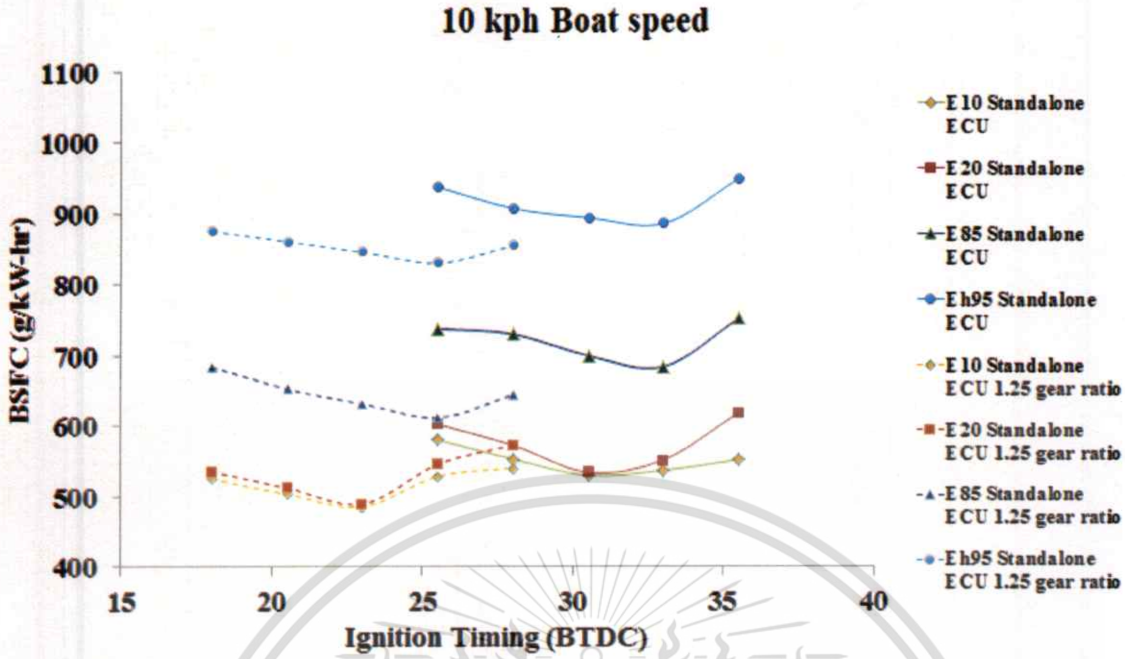

Figure 4.25 Break specific fuel consumption at 10 kph with 1.25:1 gear ratio

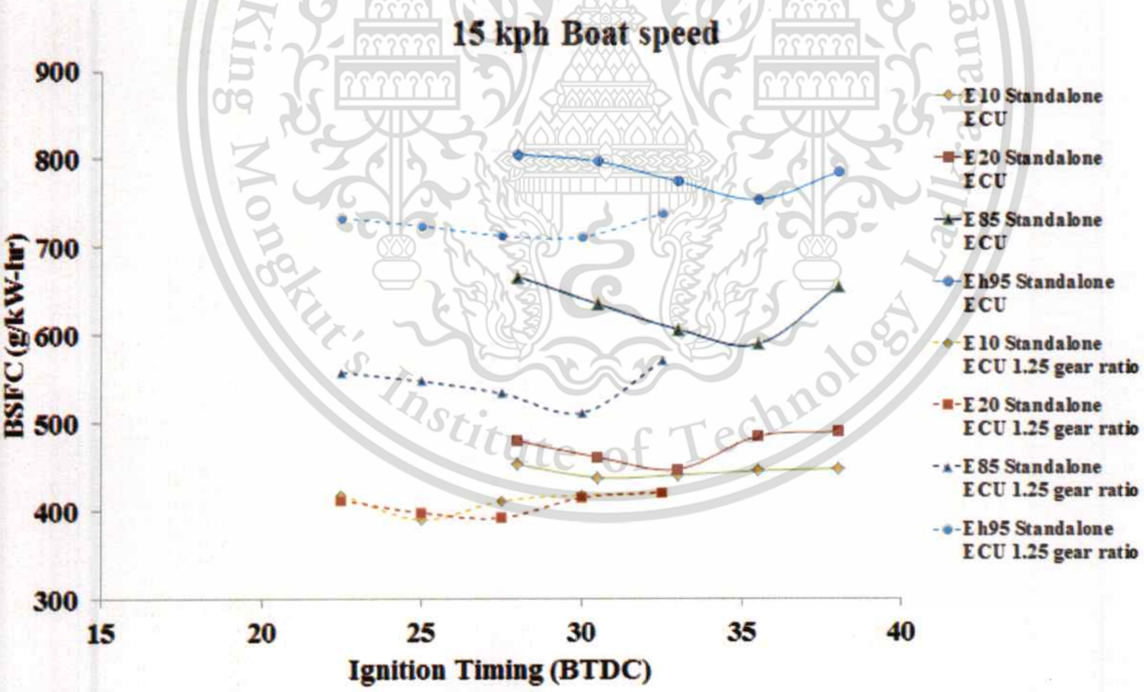

Figure 4.26 Break specific fuel consumption at 15 kph with 1.25:1 gear ratio

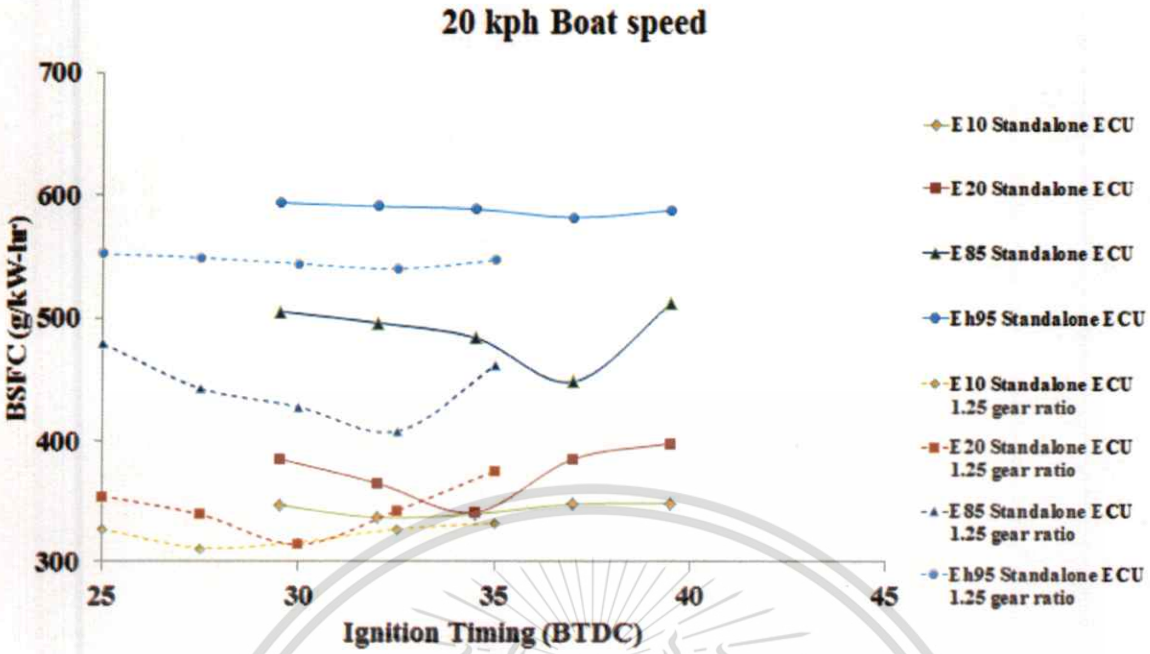

Figure 4.27 Break specific fuel consumption at 20 kph with 1.25:1 gear ratio

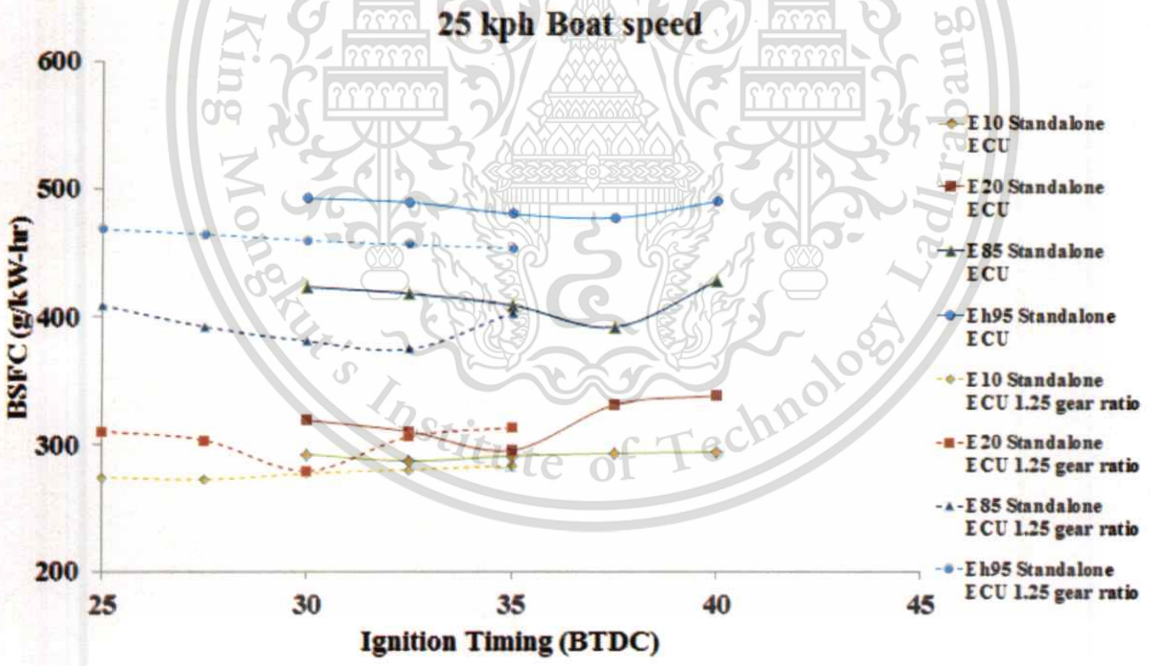

Figure 4.28 Break specific fuel consumption at 25 kph with 1.25:1 gear ratio

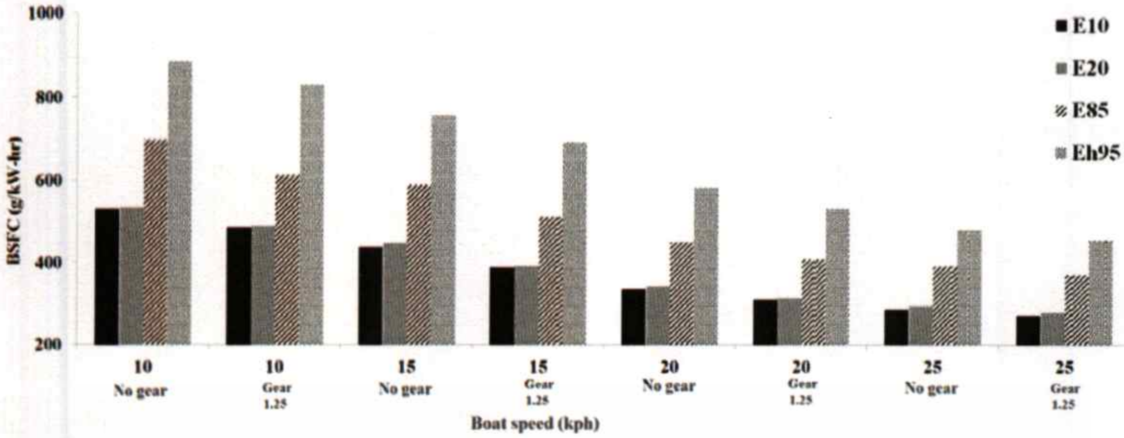

Figure 4.29 Break specific fuel consumption in different gear ratio

Figure 4.29, The bar chart are showing 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.

About the effect of ignition timing on BSEC at 10 to 30 kph boat speeds with 1.25 by 1 gear ratio. Figure 4.30-4.33 shows the result that decreased in BSEC is appear when the ignition was advanced. On the other hand it was raised when the ignition timing was advanced too much. And Eh95 have the highest BSEC following with E10, E20 and E85 for any boat speed. When consider in gear ratio condition, 1.25 by 1 gear ratio produce better energy consumption than no gear box.

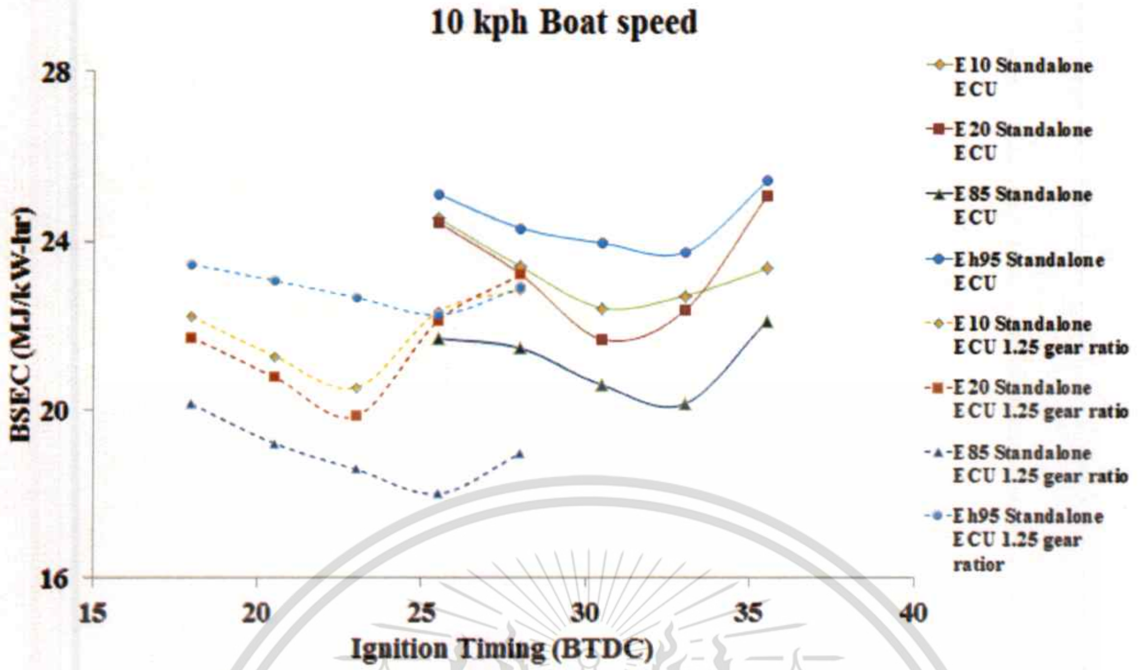

Figure 4.30 Break specific energy consumption at 10 kph with 1.25:1 gear ratio

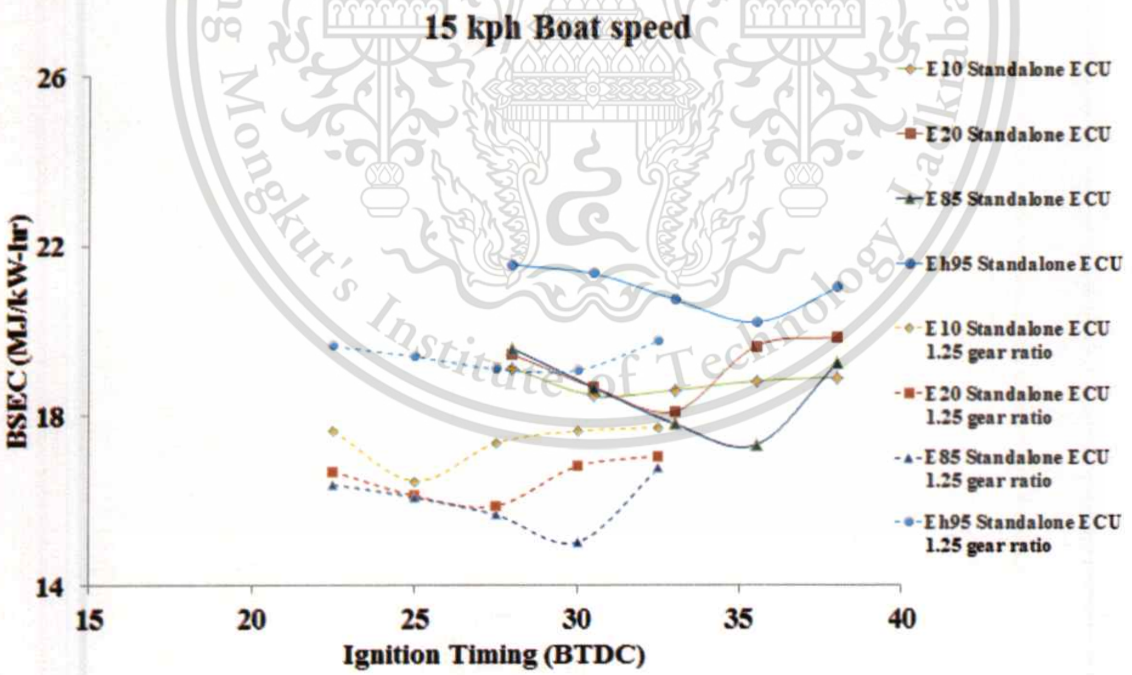

Figure 4.31 Break specific energy consumption at 15 kph with 1.25:1 gear ratio

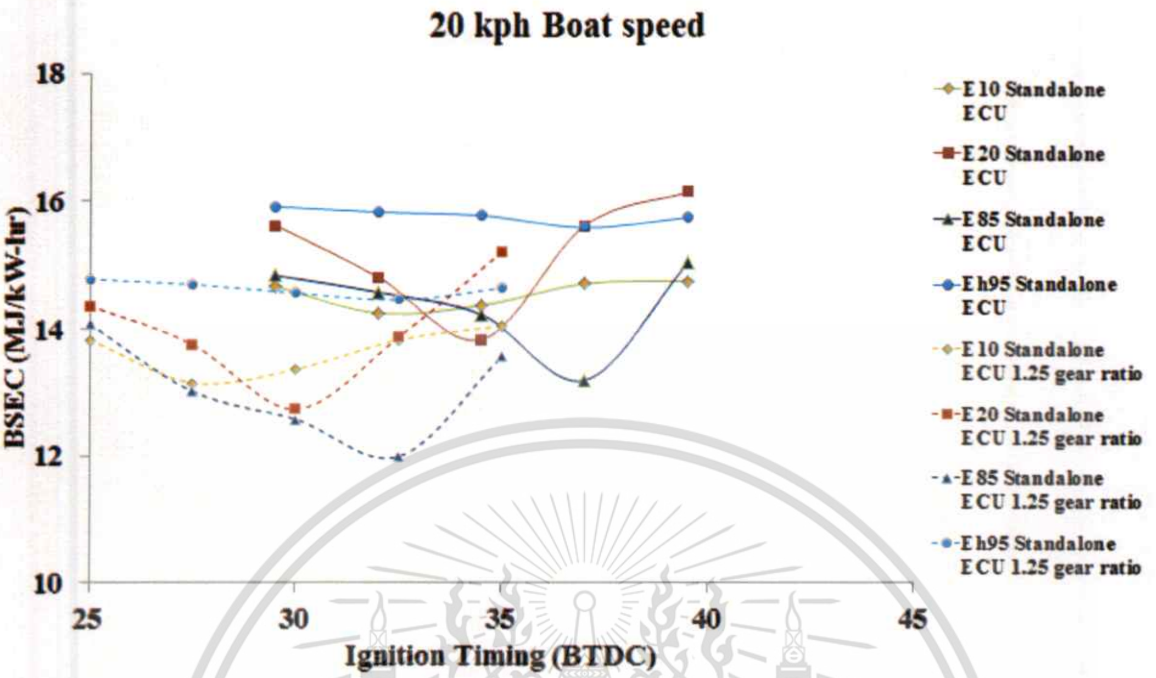

Figure 4.32 Break specific energy consumption at 20 kph with 1.25:1 gear ratio

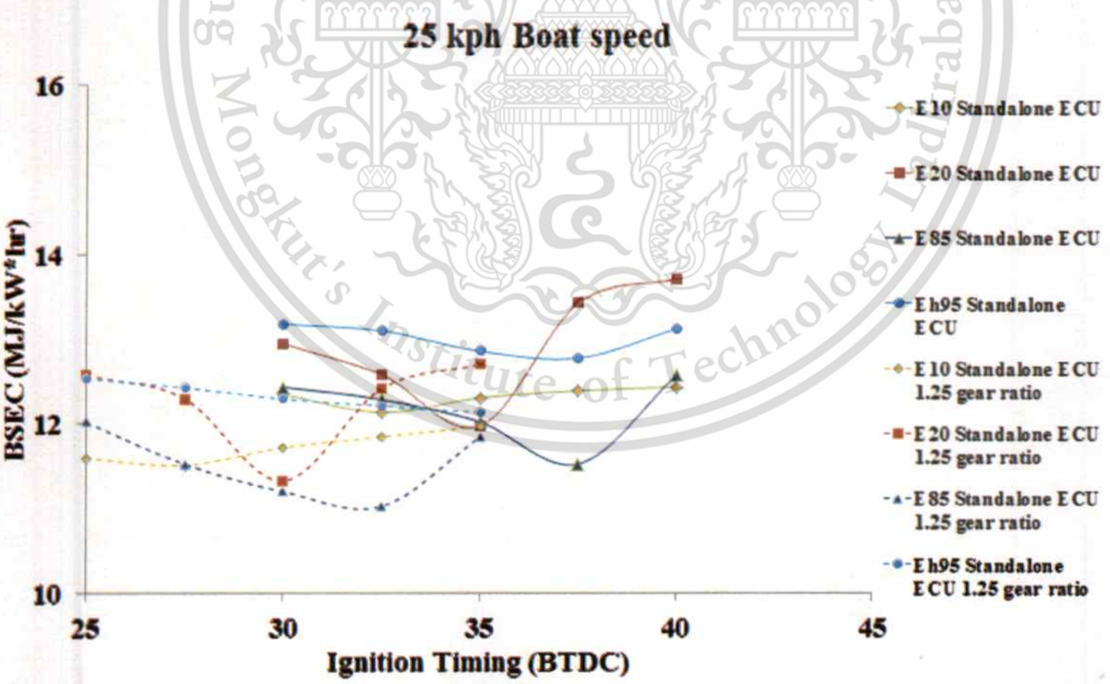

Figure 4.33 Break specific energy consumption at 25 kph with 1.25:1 gear ratio

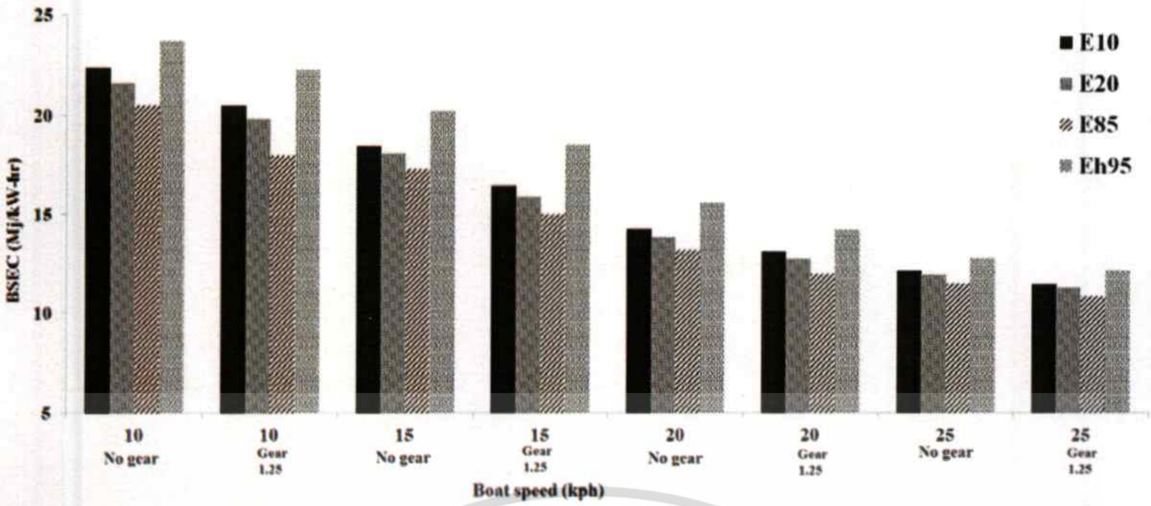

Figure 4.34 Break specific energy consumption in different gear ratio condition

Figure 4.34 are showing the comparisons of BSEC in each fuel on 4 different speed of boat with 2 conditions, no gear box and 1.25 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. The bar chart indicates that using 1.25 gear ratio, Energy consumption in each speed also lowest than no gear box.

Figure 4.35-4.38 are showing the effect of ignition timing on break thermal efficiency at 10, 15, 20 and 25 kph boat speed. These results indicate that gasohol E85 can produce the highest thermal efficiency following with E20, E10, and Eh95.Eh95 still lowest in every condition due to the effect of high heat of vaporization. This result expected that Thermal efficiency increase with risen ignition advanced to a point, and then reduces slightly when the knock is occurring. Eh95 and E85 can advance an ignition timing farthest following with E20 and E10 due to the anti-knock performance.

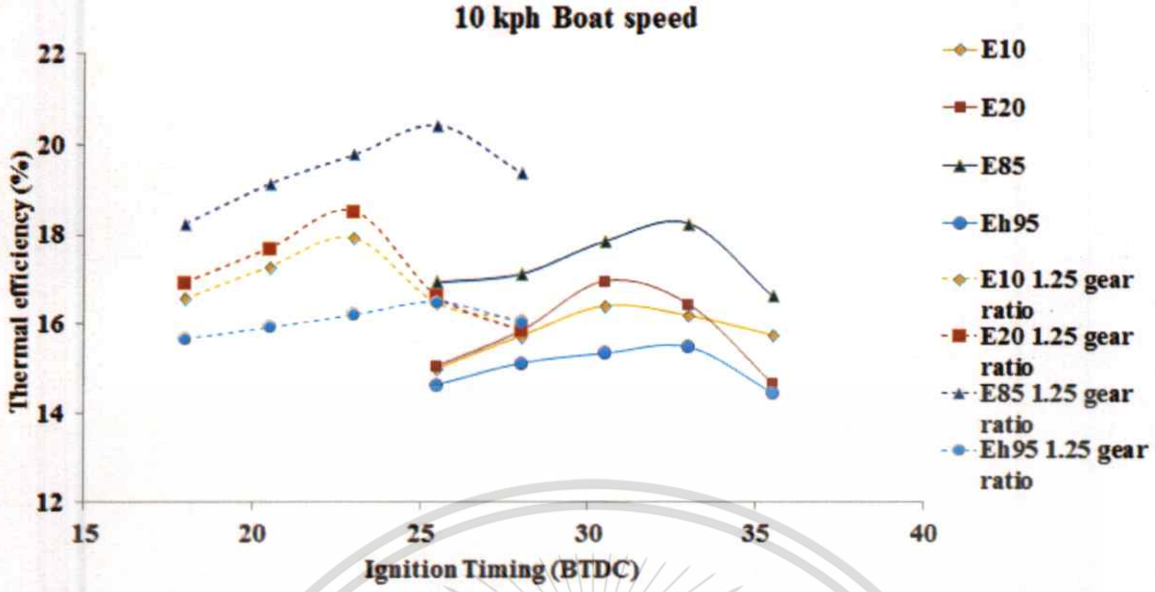

Figure 4.35 Thermal efficiency at 10 kph with 1.25:1 gear ratio

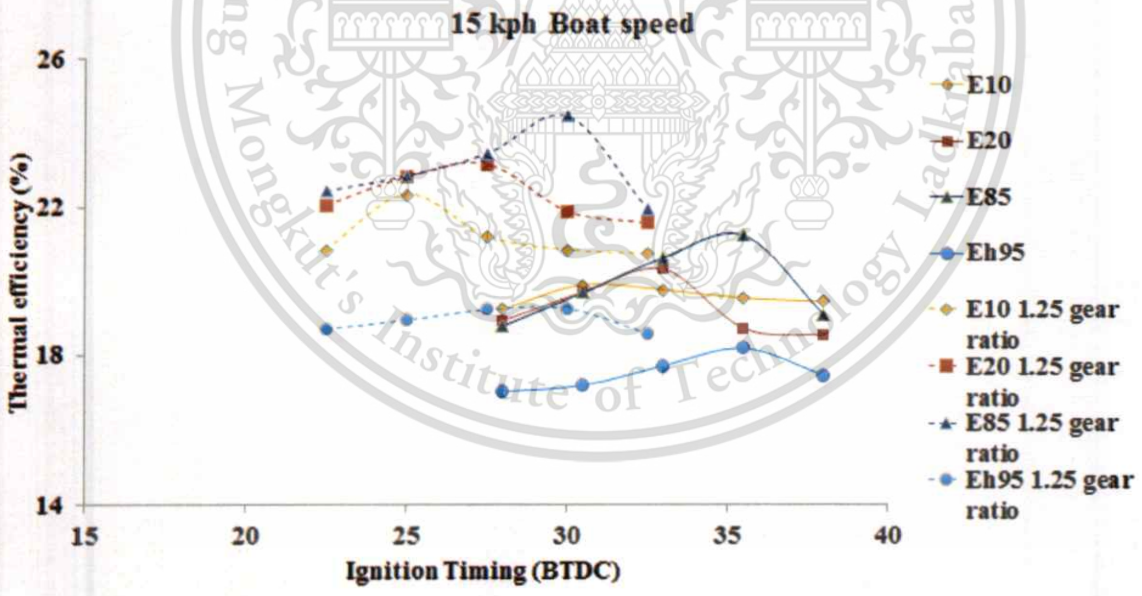

Figure 4.36 Thermal efficiency at 15 kph with 1.25:1 gear ratio

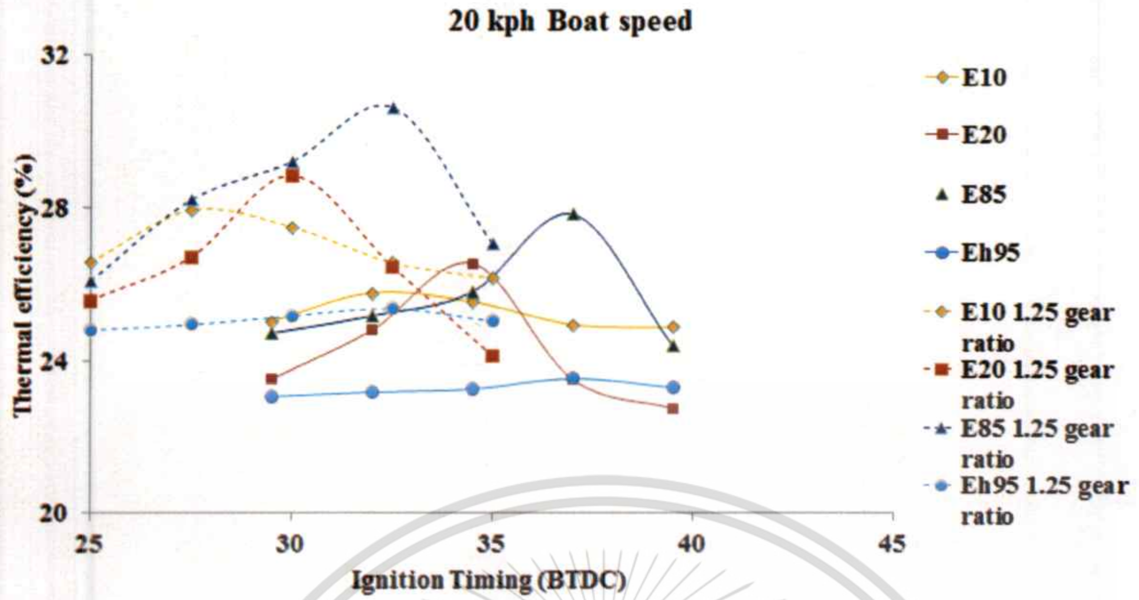

Figure 4.37 Thermal efficiency at 20 kph with 1.25:1 gear ratio

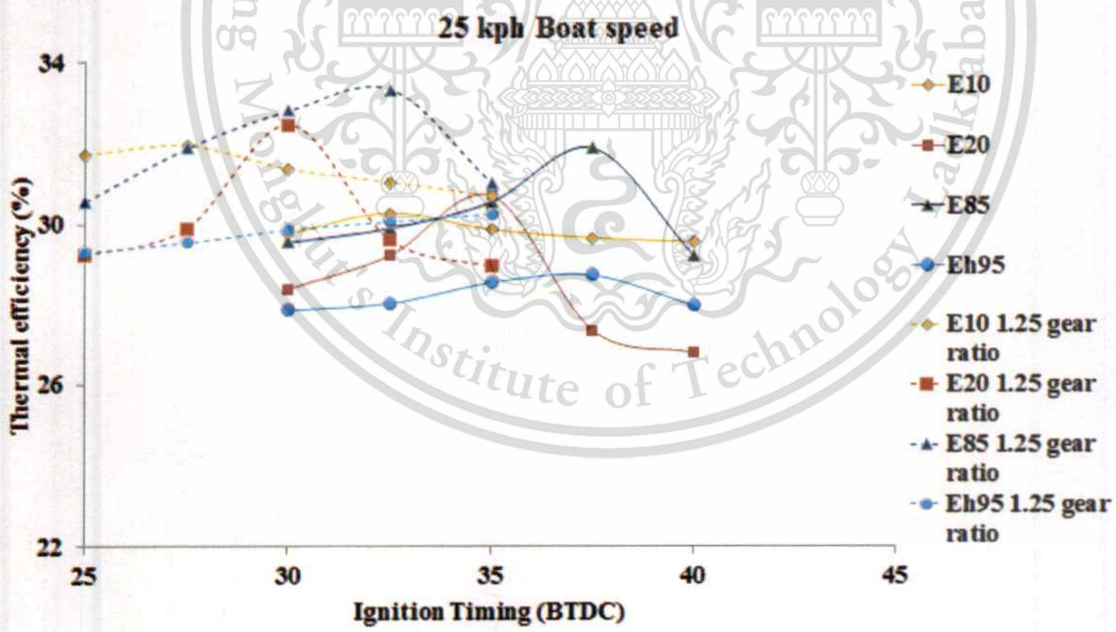

Figure 4.38 Thermal efficiency at 25 kph with 1.25:1 gear ratio

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 2 to 6% than and no transmission.

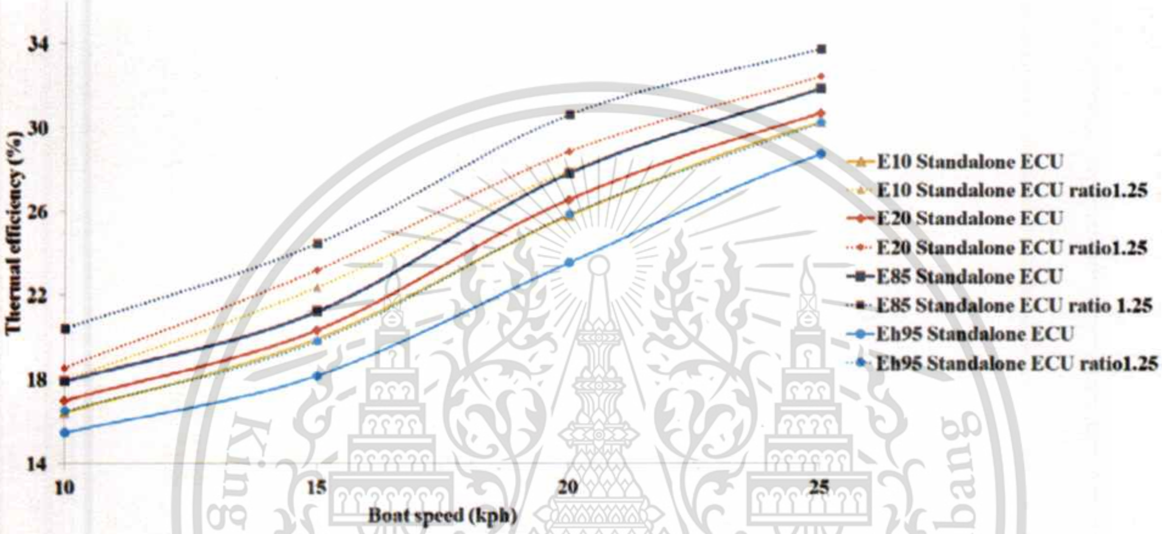

Figure 4.39 Comparisons of break thermal efficiency between 1.25:1 gear ratio and no gear box condition

4.1.2.2 Engine operating with 0.83 : 1 gear ratio

Figure 4.40-4.43 are showing the BSFC of 0.83 by 1 gear ratio. The result indicate that at 10 to 30 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. Eh95 and E85 can advance an ignition timing farthest following with E20 and E10 due to the anti-knock performance. And consider in different gear ratio, using and 0.83 by 1 gear ratio produce the lowest BSFC in any fuel.

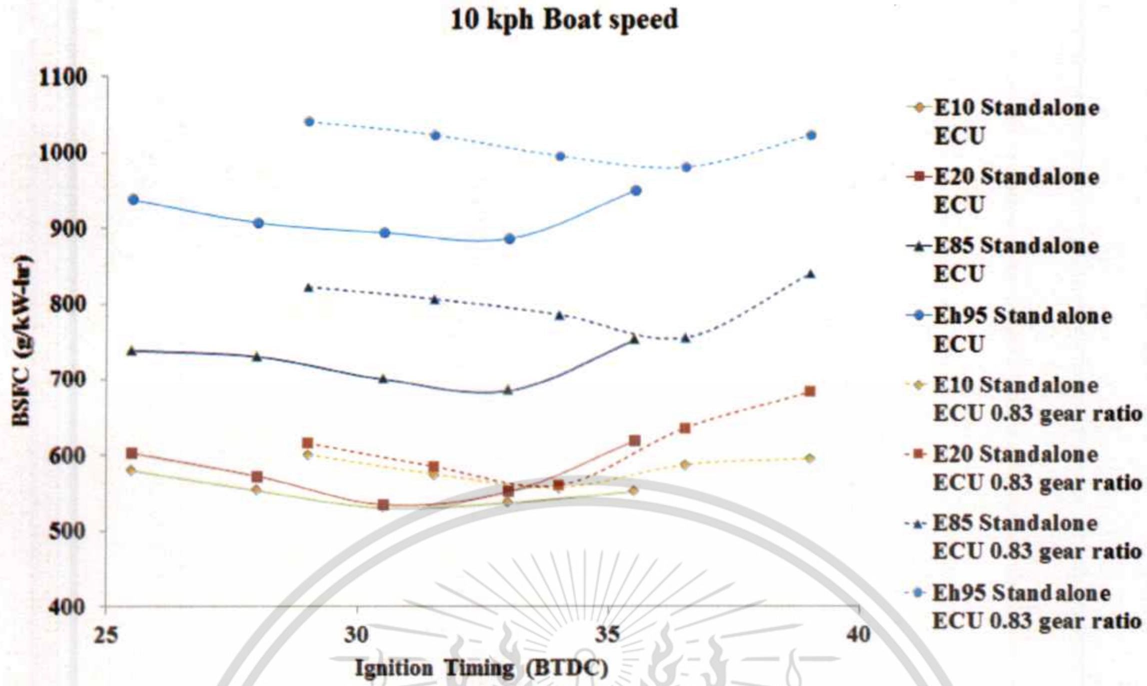

Figure 4.40 Break specific fuel consumption at 10 kph boat with 0.83 gear ratio

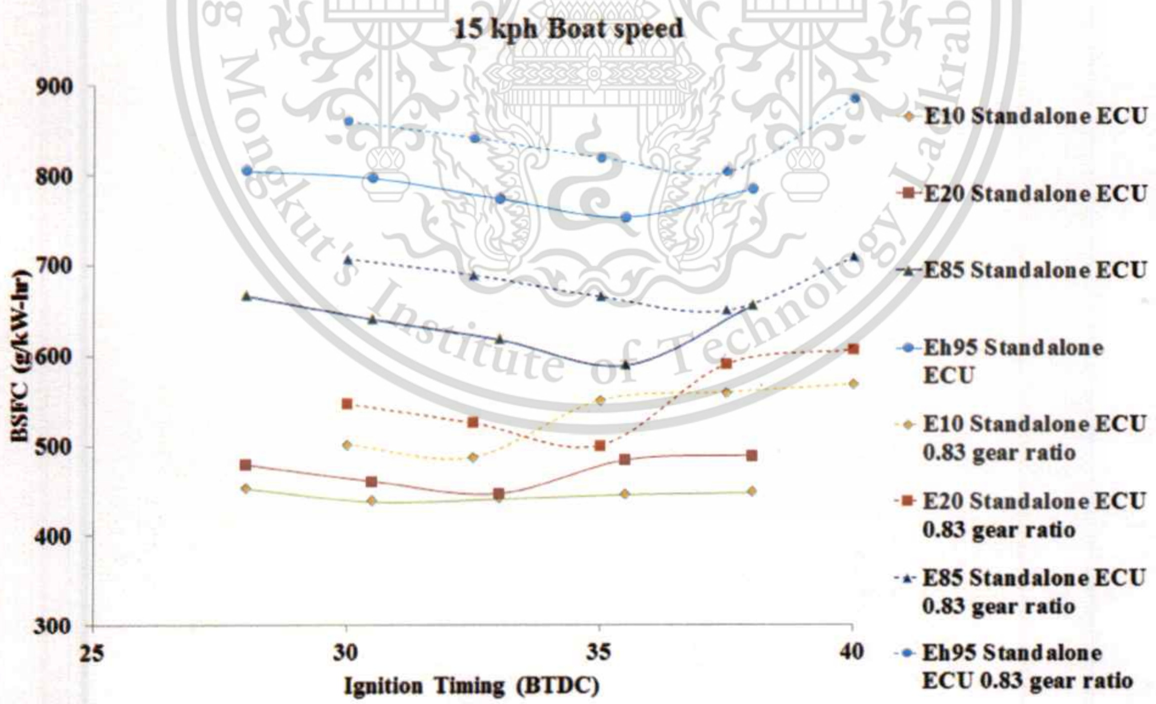

Figure 4.41 Break specific fuel consumption at 15 kph with 0.83 gear ratio

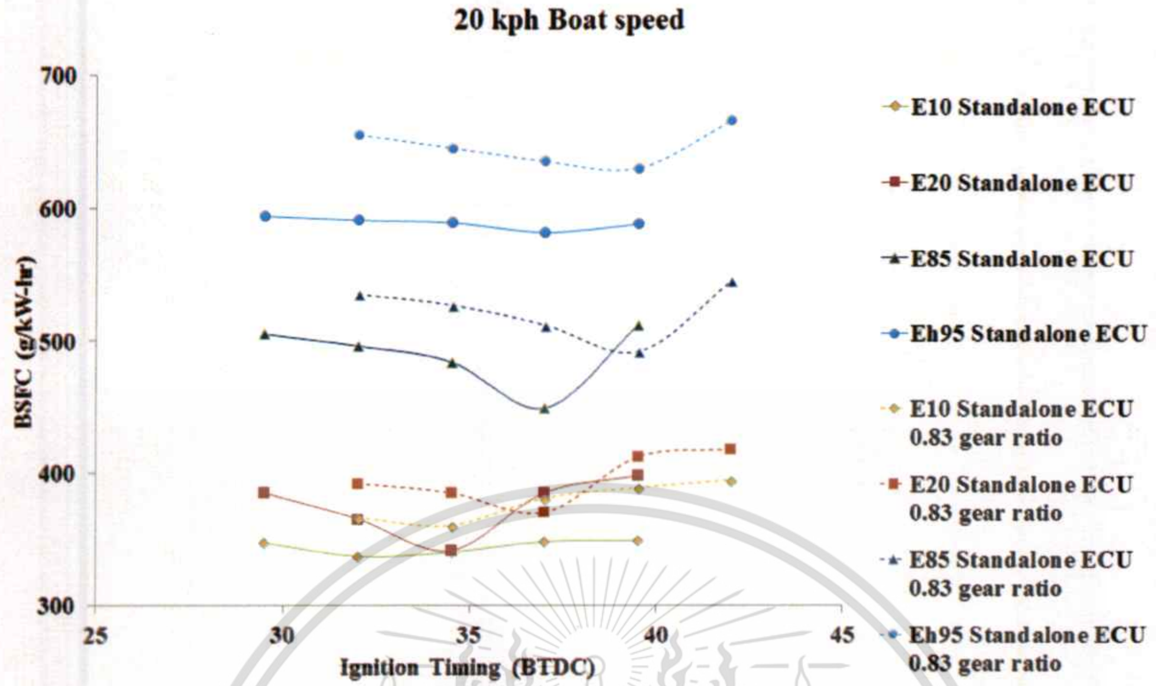

Figure 4.42 Break specific fuel consumption at 20 kph with 0.83 gear ratio

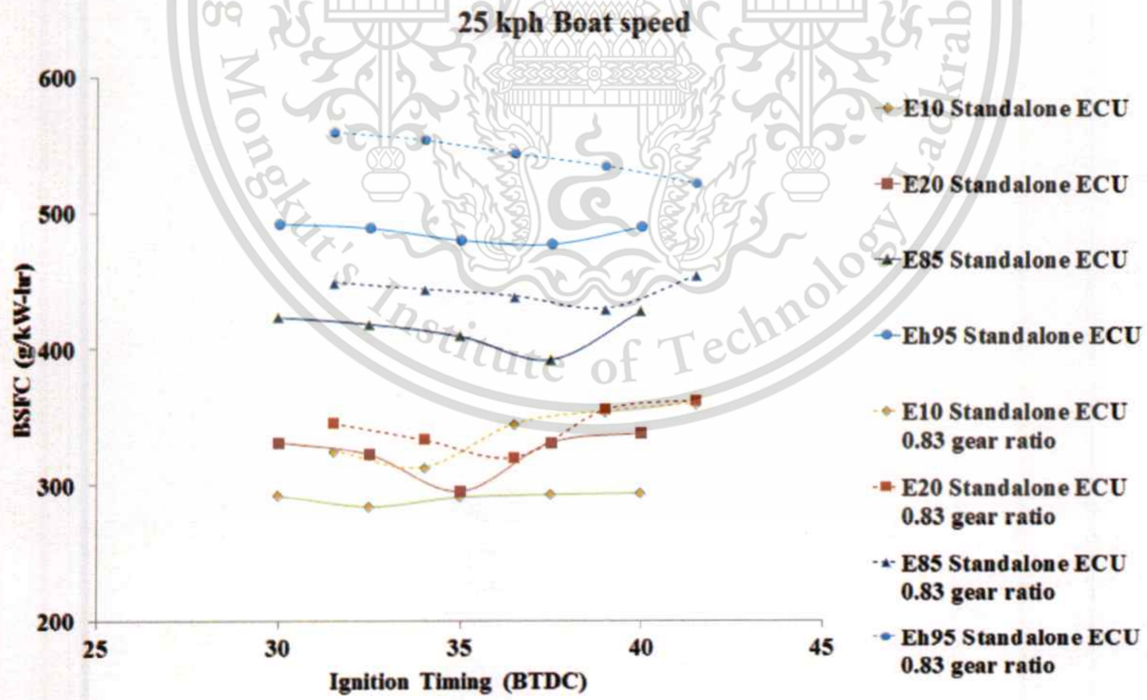

Figure 4.43 Break specific fuel consumption at 25 kph with 0.83 gear ratio

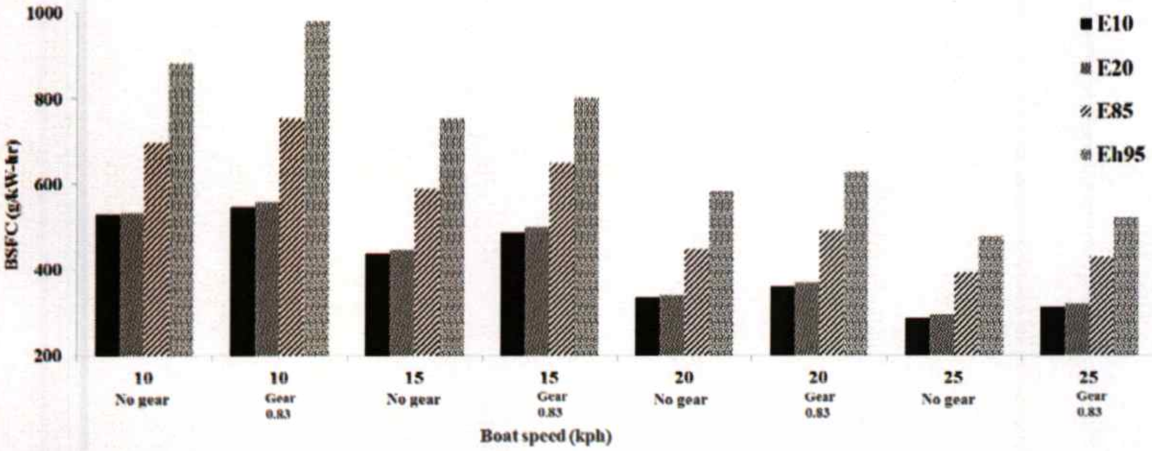

Figure 4.44 Comparisons of break specific fuel consumption with 0.83 gear ratio and no gear

Figure 4.45-4.48 the effect of ignition timing on BSEC at 10 and 15 kph boat speed with 1.25 and 0.83 by 1 gear ratio. The result show that decreased in BSEC is appearing when the ignition was advanced. On the other hand it was raised when the ignition timing was advanced too much. And Eh95 have the highest BSEC following with E10,E20 and E85 for any boat speed with 2 gear ratio.

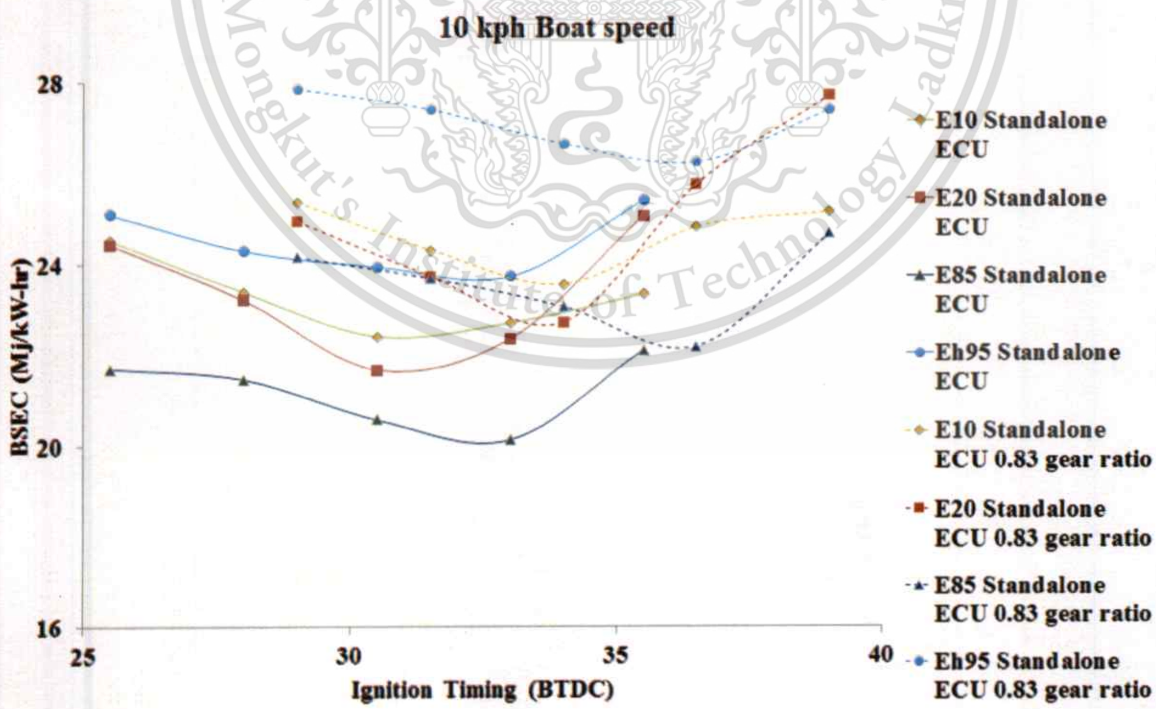

Figure 4.45 Break specific energy consumption at 10 kph with 0.83 gear ratio

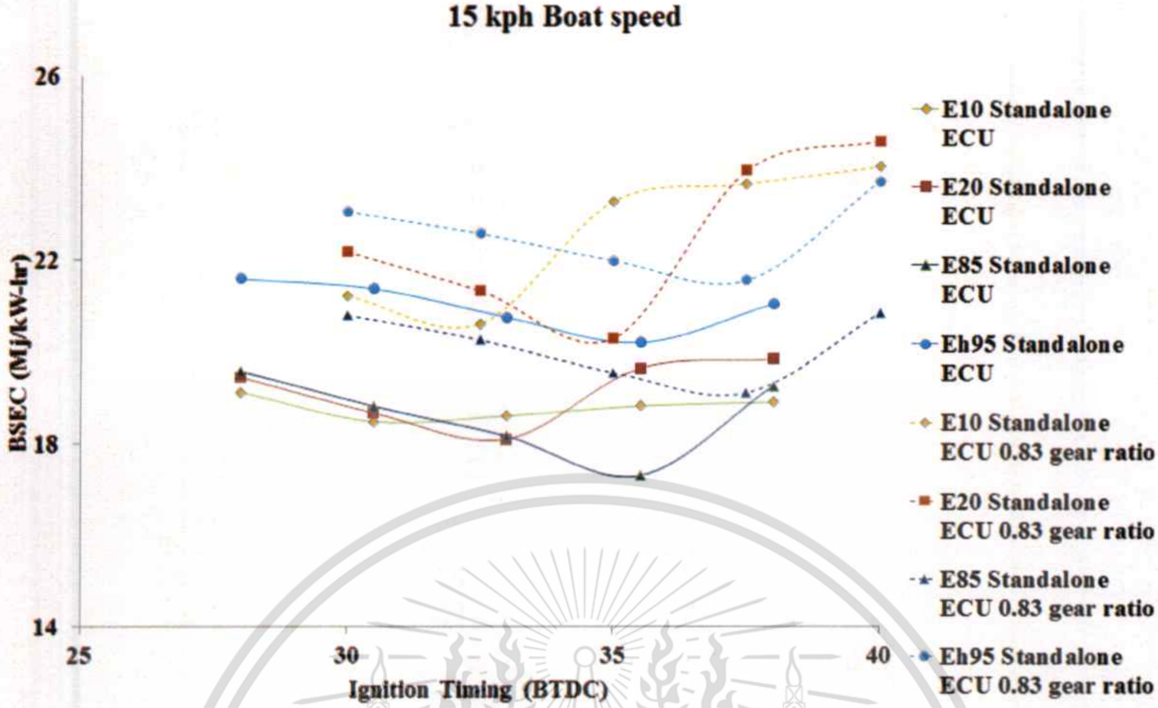

Figure 4.46 Break specific energy consumption at 15 kph with 0.83 gear ratio

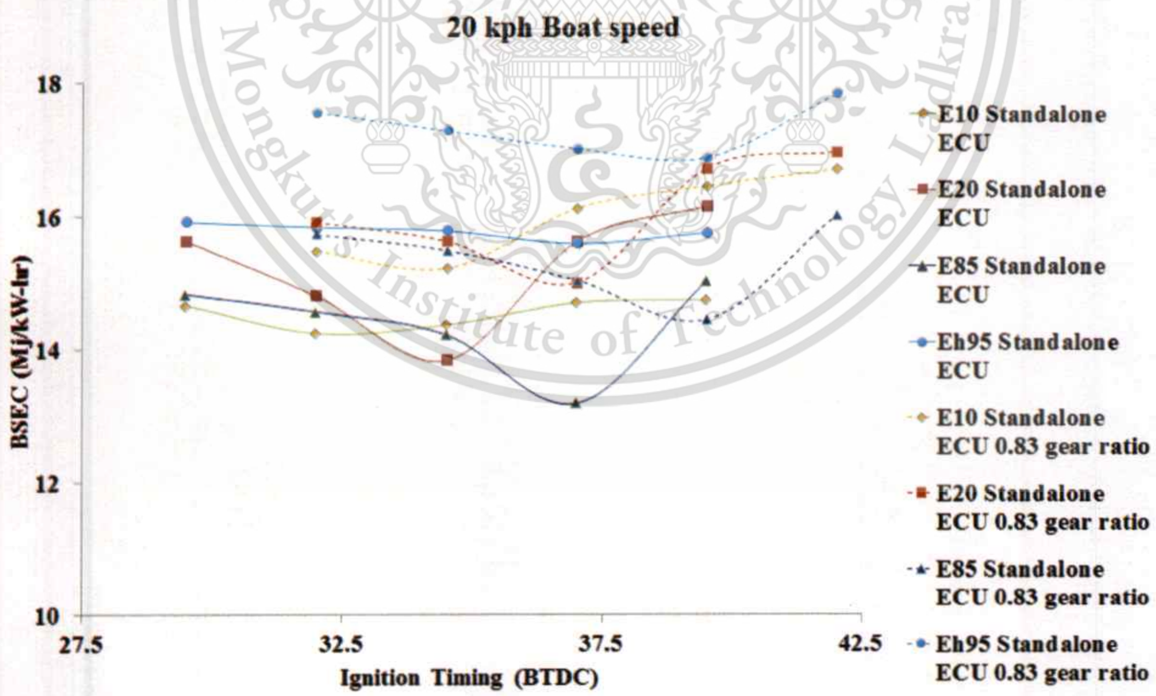

Figure 4.47 Break specific energy consumption at 20 kph with 0.83 gear ratio

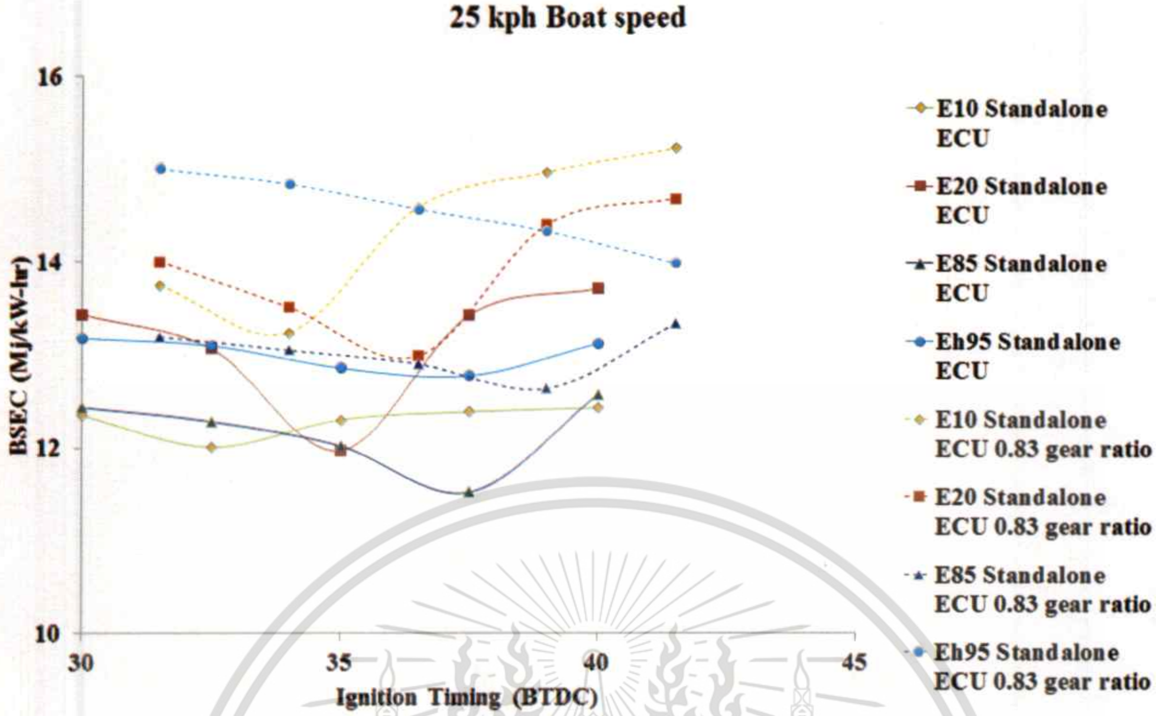

Figure 4.48 Break specific energy consumption at 25 kph with 0.83 gear ratio

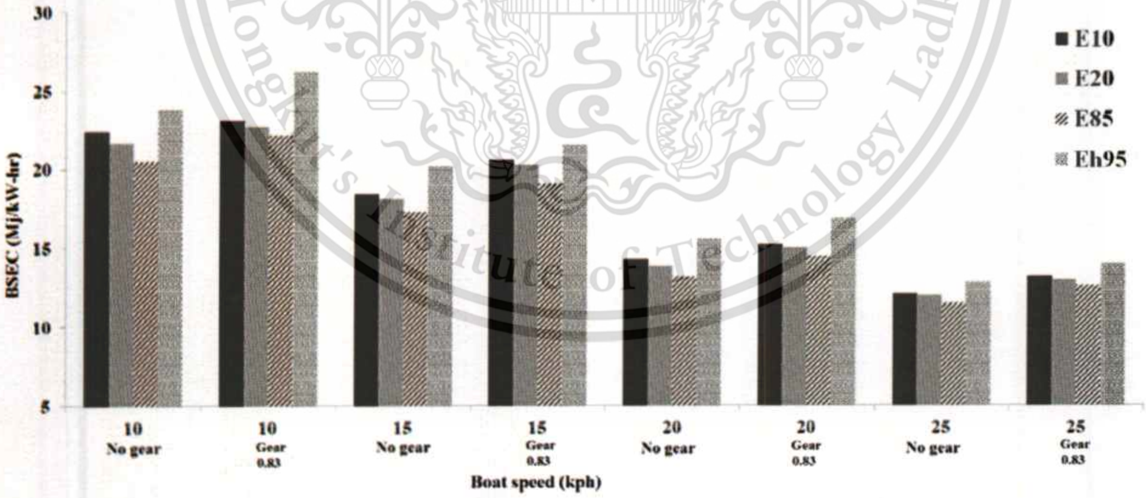

Figure 4.49 Comparisons of break specific energy consumption in 0.83 gear ratio and no gear

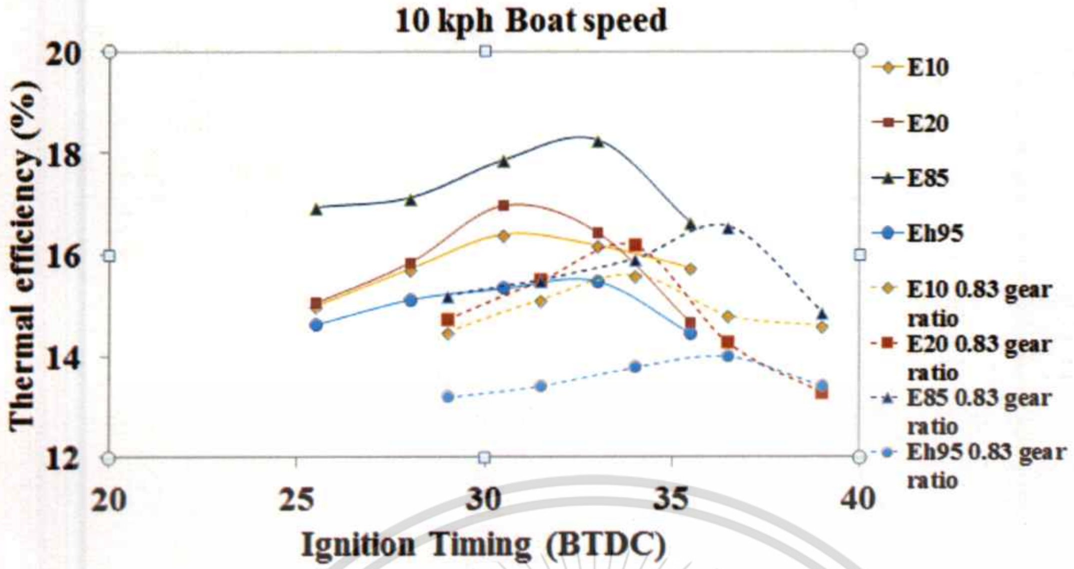

Figure 4.50 Break thermal efficiency at 10 kph with 0.83 gear ratio

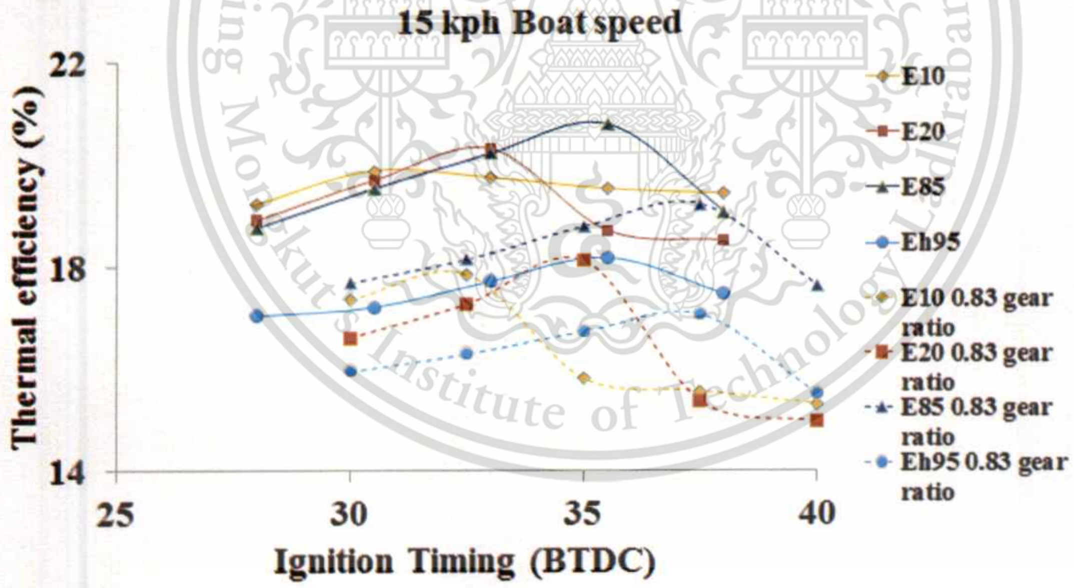

Figure 4.51 Break thermal efficiency at 15 kph boat condition with 0.83 gear ratio

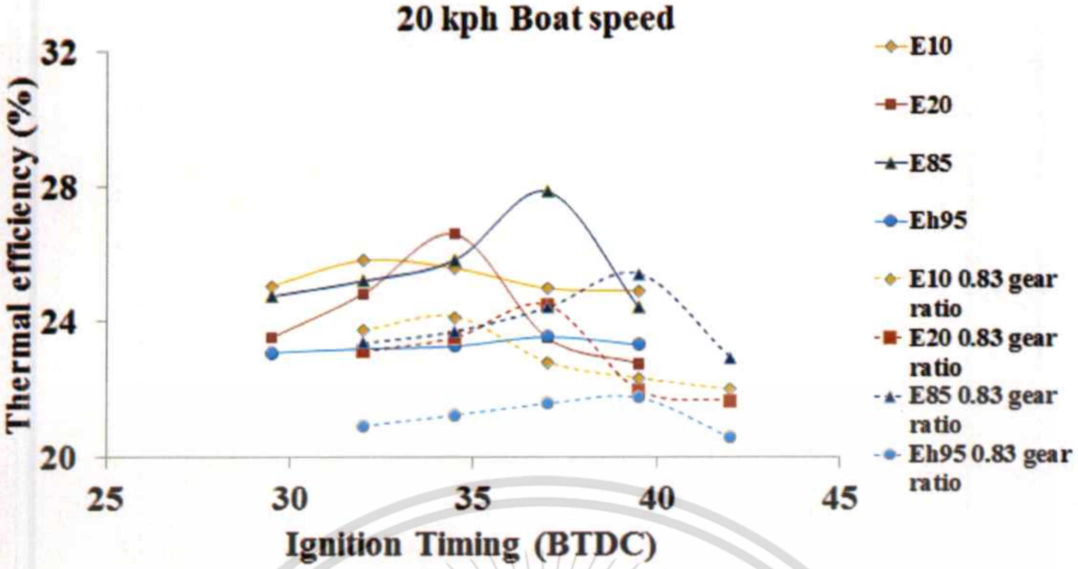

Figure 4.52 Break thermal efficiency at 20 kph with 0.83 gear ratio

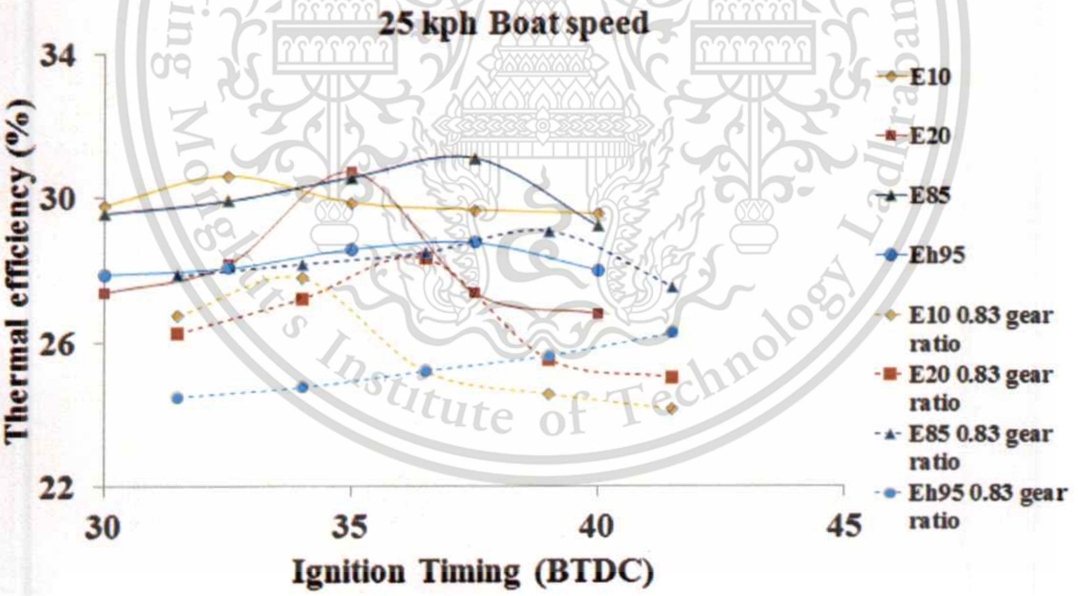

Figure 4.53 Break thermal efficiency at 25 kph with 0.83 gear ratio

Figure 4.54 showing the comparisons of thermal efficiency in each fuel on 4 different speeds of boat with 2 condition, no gear box and 0.83 by 1 gear ratio. The highest thermal efficiency are bring 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.

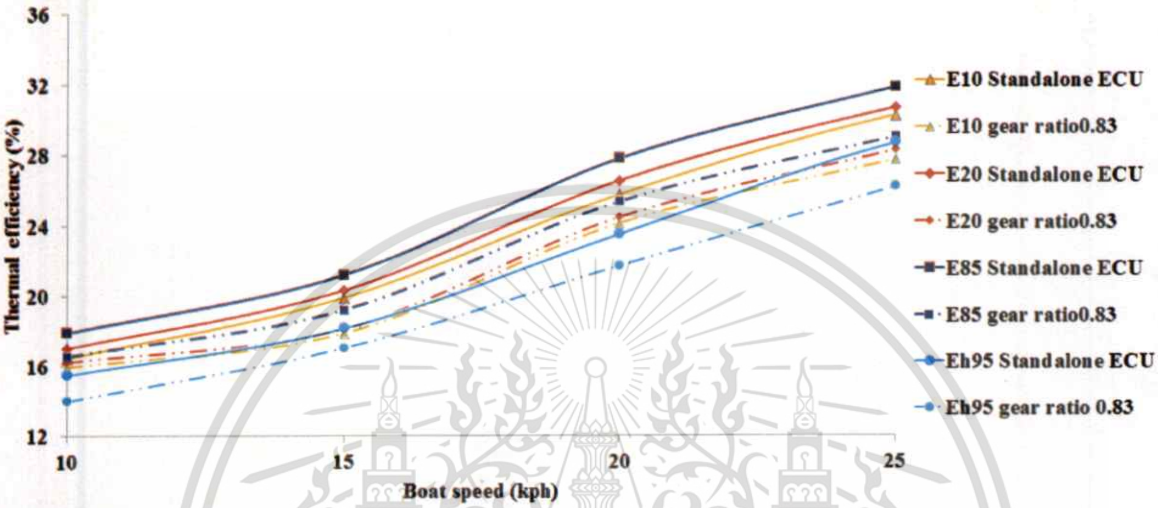

Figure 4.54 Comparisons of break thermal efficiency in 0.83 gear ratio and no gear

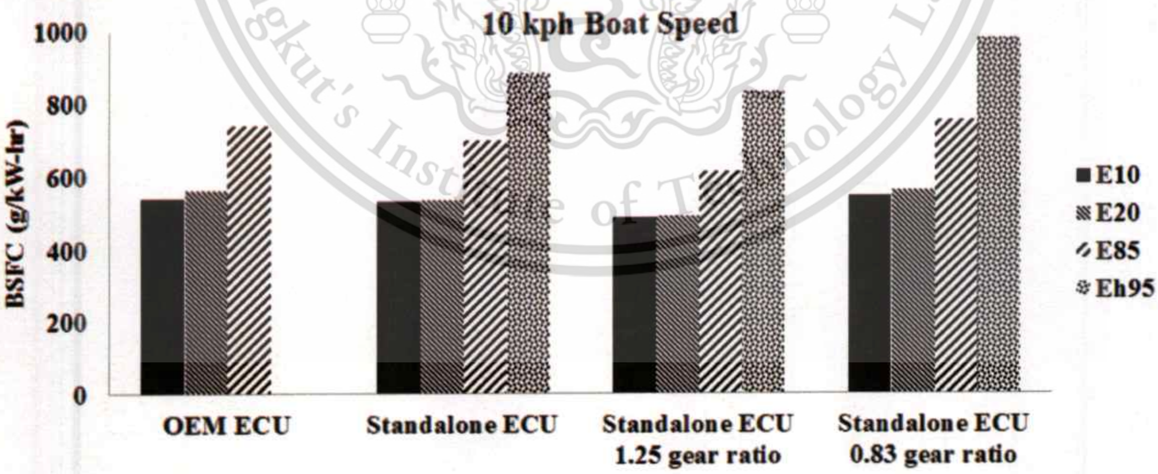

Figure 4.55 Comparisons overall of break specific fuel consumption at 10 kph boat condition

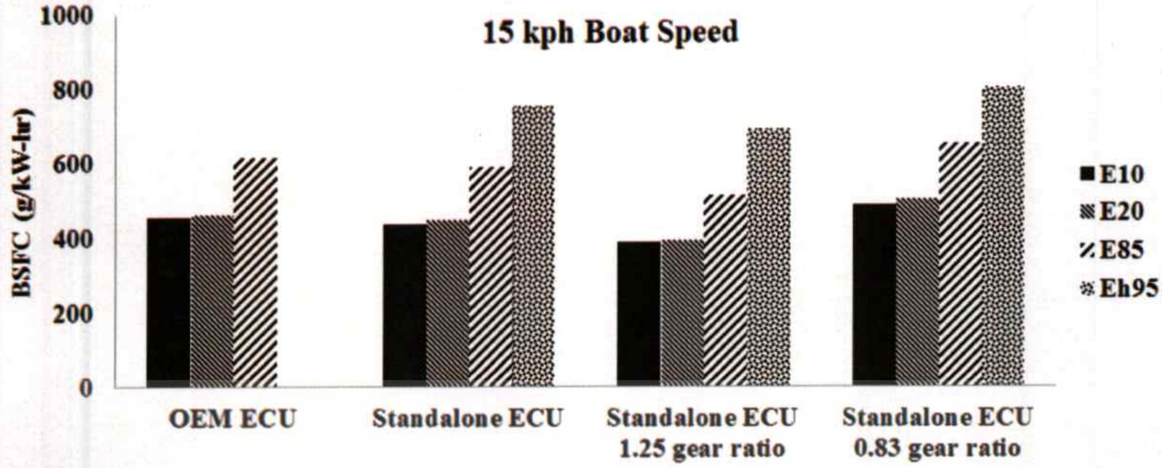

Figure 4.56 Comparisons overall of break specific fuel consumption at 15 kph boat condition

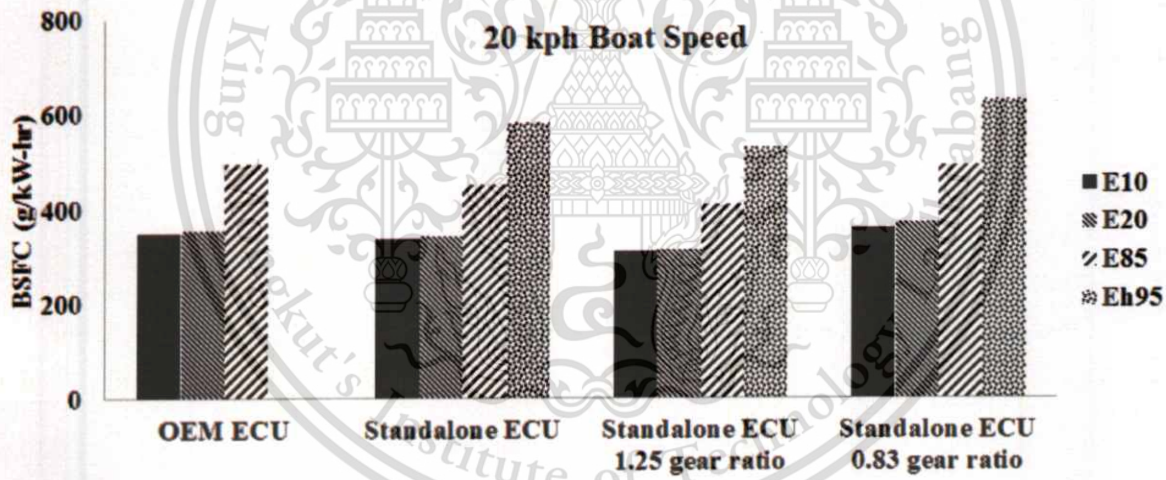

Figure 4.57 Comparisons overall of break specific fuel consumption at 20 kph boat condition

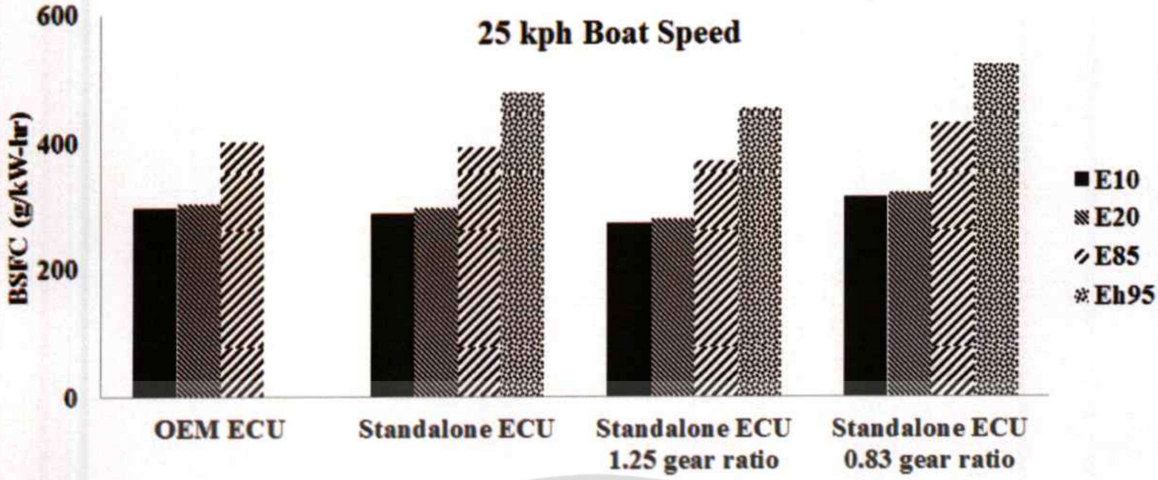

Figure 4.58 Comparisons overall of break specific fuel consumption at 25 kph boat condition

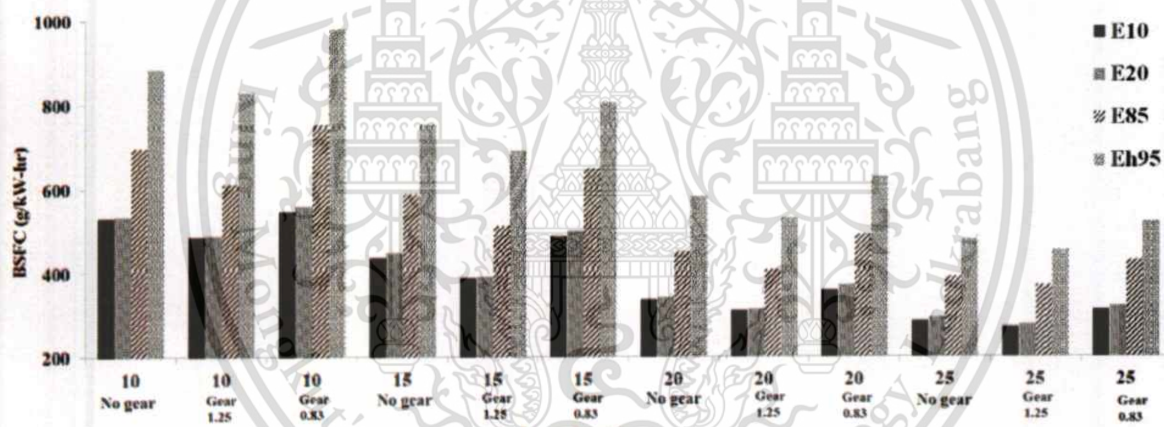

Figure 4.59 Comparisons overall of break specific fuel consumption at 10-25 boat condition

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.

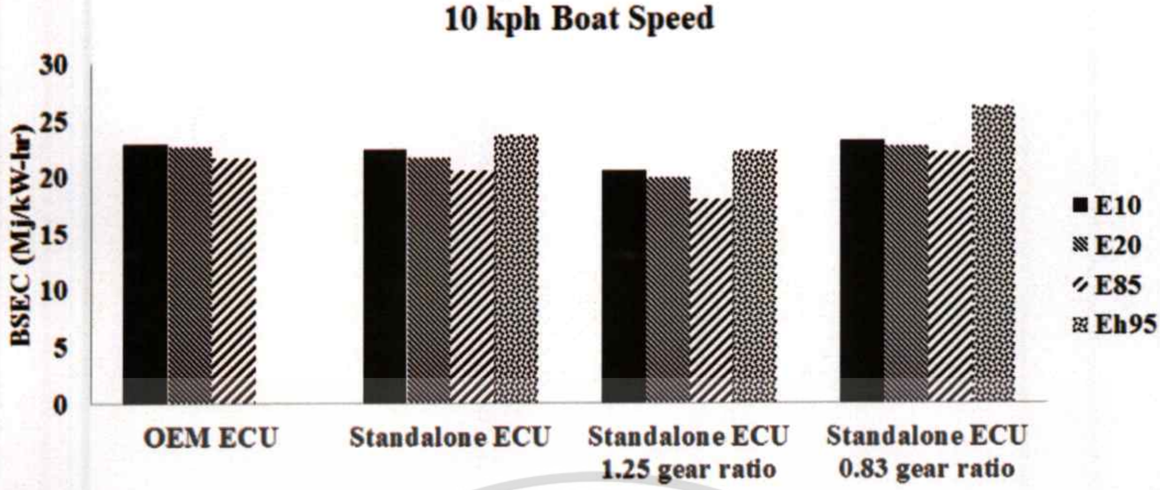

Figure 4.60 Comparisons overall of break specific energy consumption at 10 kph

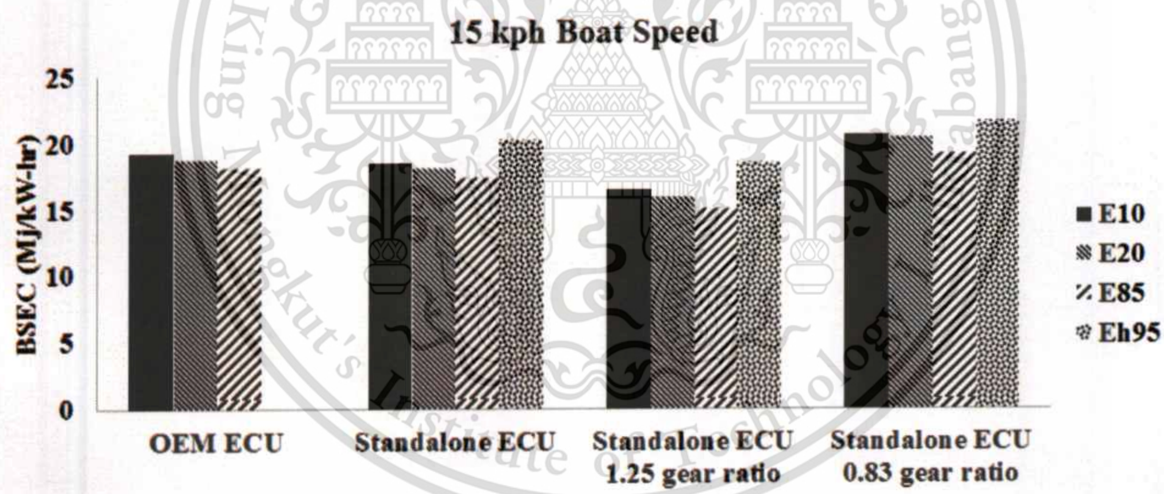

Figure 4.61 Comparisons overall of break specific energy consumption at 15 kph

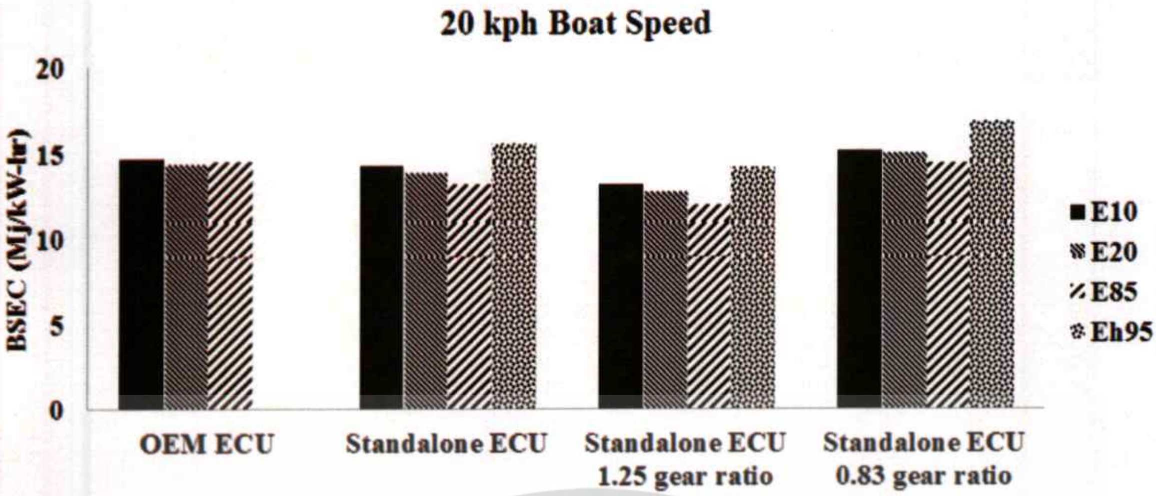

Figure 4.62 Comparisons overall of break specific energy consumption at 20 kph

Figure 4.63 Comparisons overall of break specific energy consumption at 25 kph

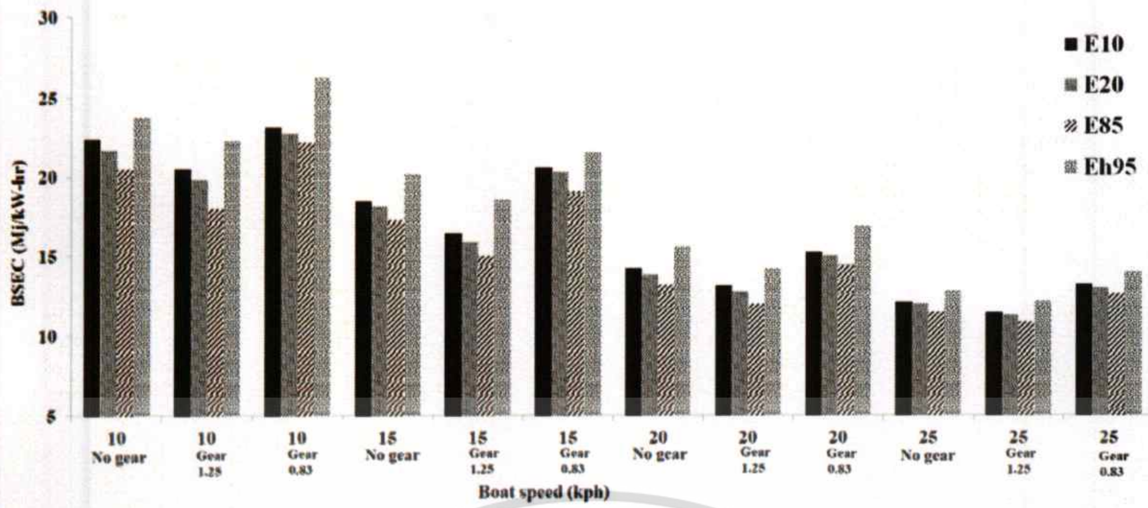

Figure 4.64 Comparisons of break specific energy consumption at 10 to 30 kph

Figure 4.64, 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.

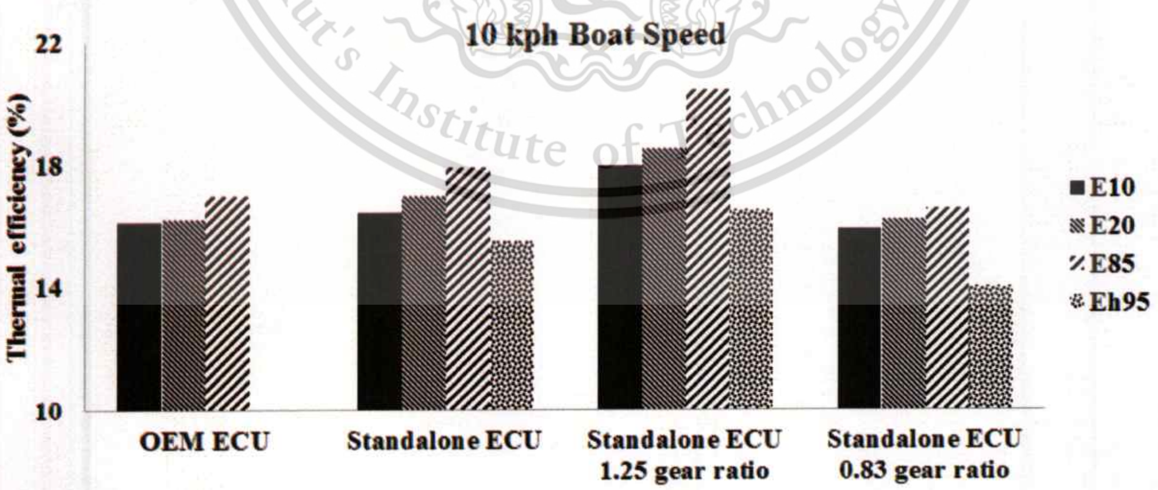

Figure 4.65 Comparisons overall of break thermal efficiency at 10 kph

Figure 4.65-4.70 are showing 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 are bring 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 result are 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. 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.

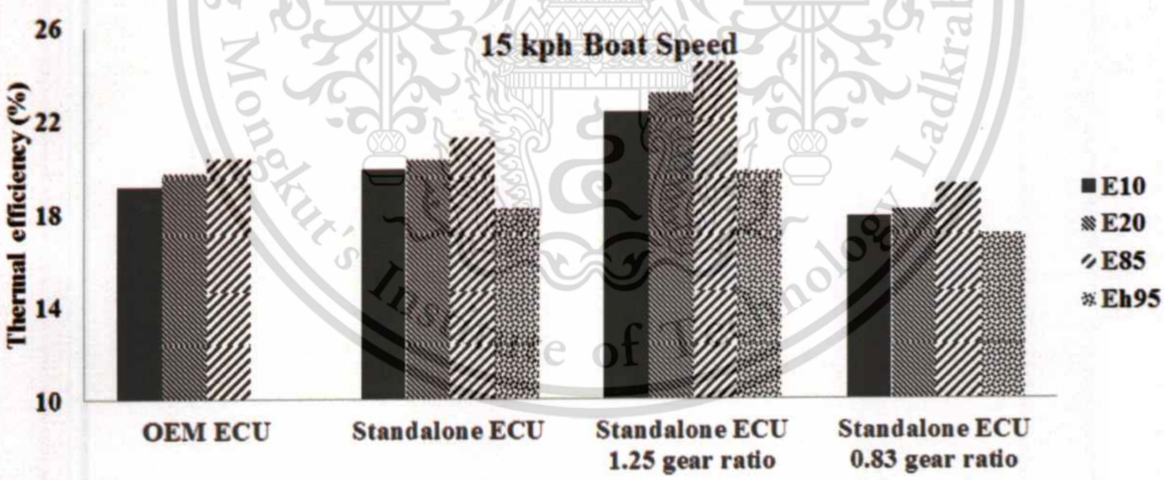

Figure 4.66 Comparisons overall of break thermal efficiency at 15 kph

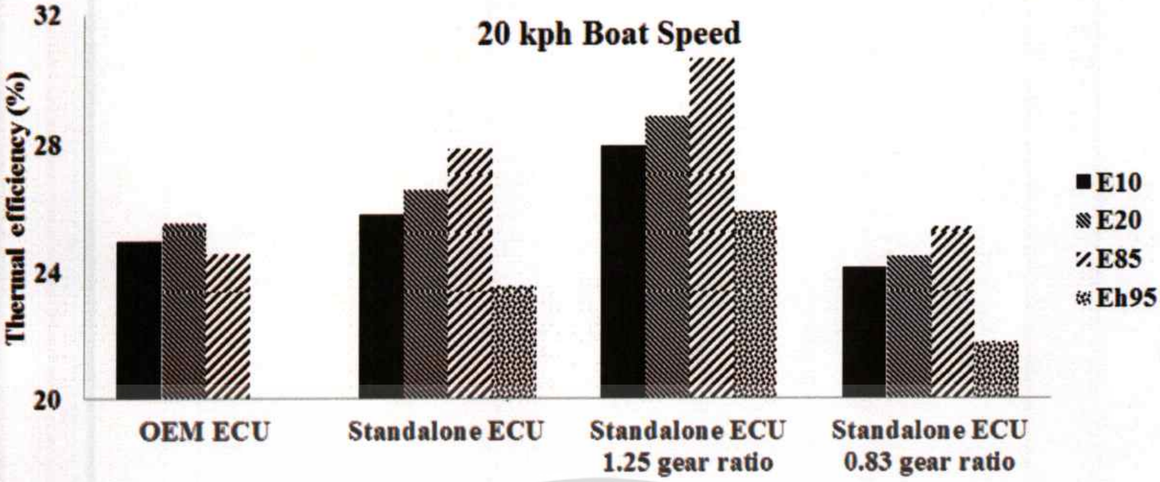

Figure 4.67 Comparisons overall of break thermal efficiency at 20 kph boat condition

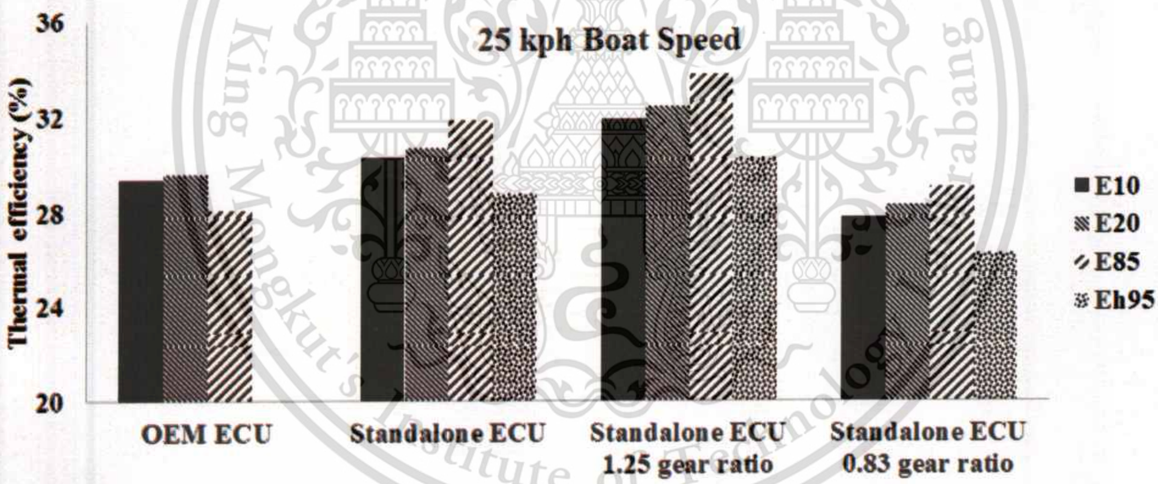

Figure 4.68 Comparisons overall of break thermal efficiency at 25 kph boat condition

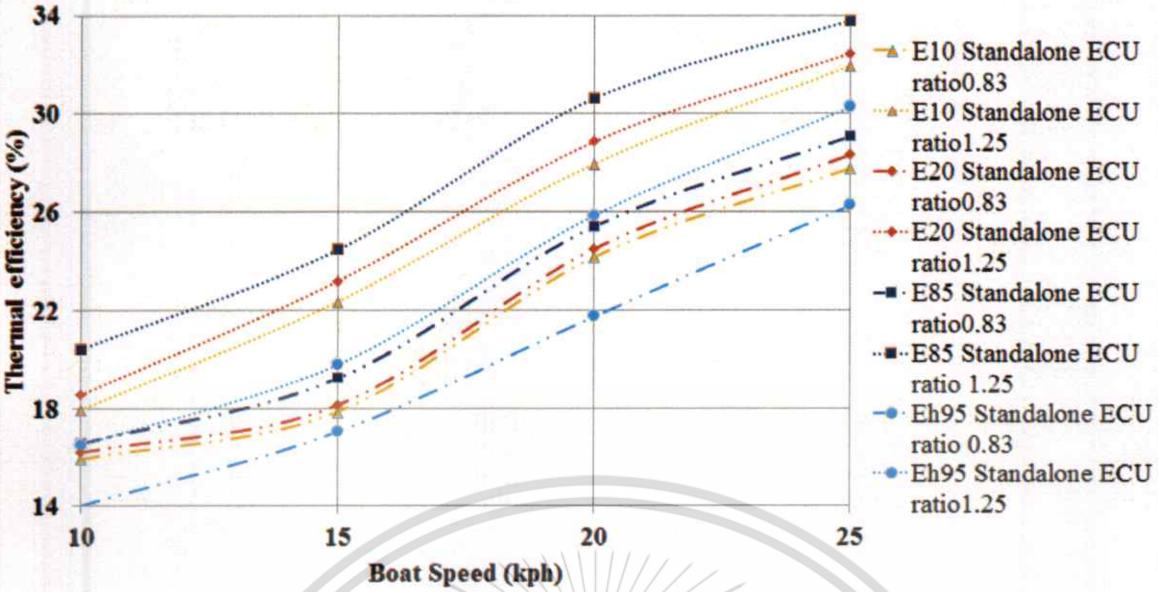

Figure 4.69 Comparisons of thermal efficiency with 1.25 and 0.83 gear ratio

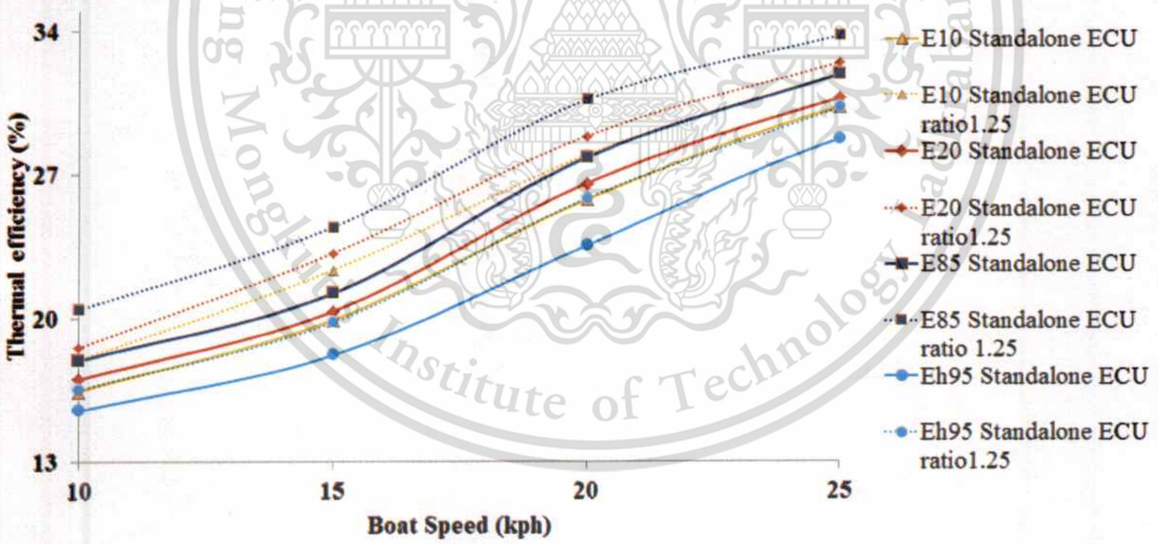

Figure 4.70 Comparisons of thermal efficiency with 1.25 gear ratio and no gear box

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 without transmission

4.2.1.1 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 4.73 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 4.71-4.73 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.

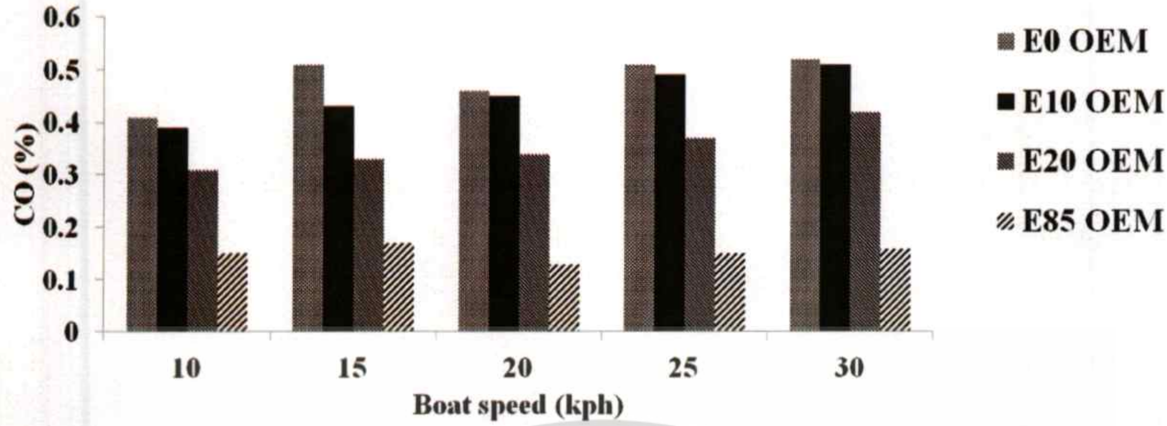

Figure 4.71 Carbon monoxide emission of OEM ECU

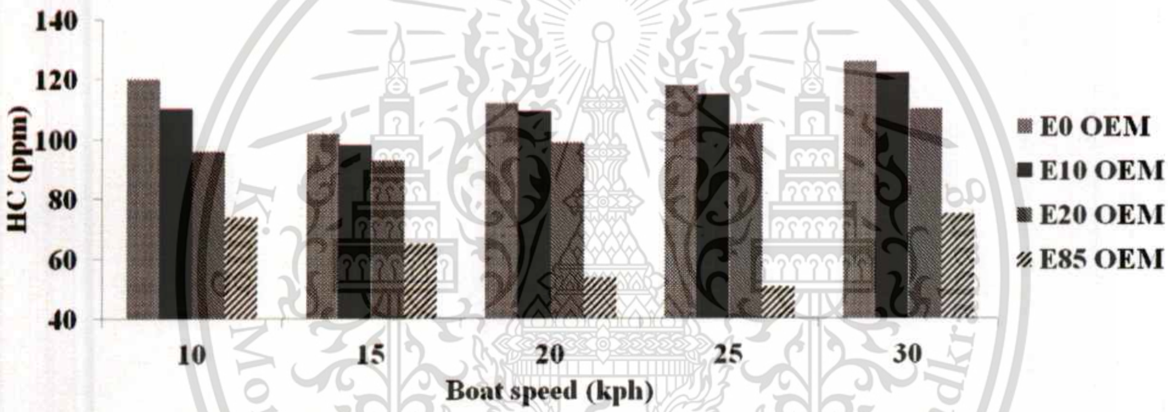

Figure 4.72 Hydrocarbon emission of OEM ECU

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 4.73 the result signify that CO2 increase as the ethanol content in the blended fuel increase due to the improve combustion. However, at 20 to 30 kph boat speed CO2 of E85 are lower than E20 fuel operation due to the leaning air/fuel ratio.

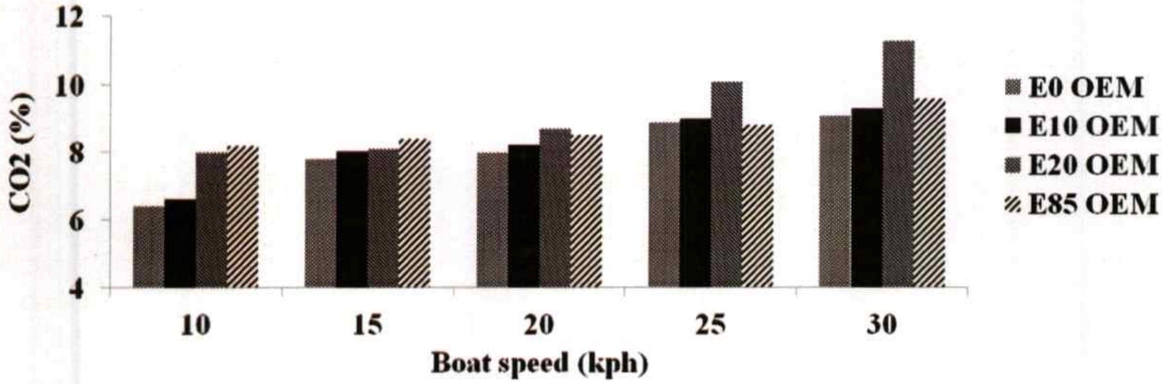

Figure 4.73 Carbon dioxide emission of OEM ECU

4.2.1.2 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% ,66% lower than those in case of gasohol E10 for 10,15,20,25and 30 boat speed condition.

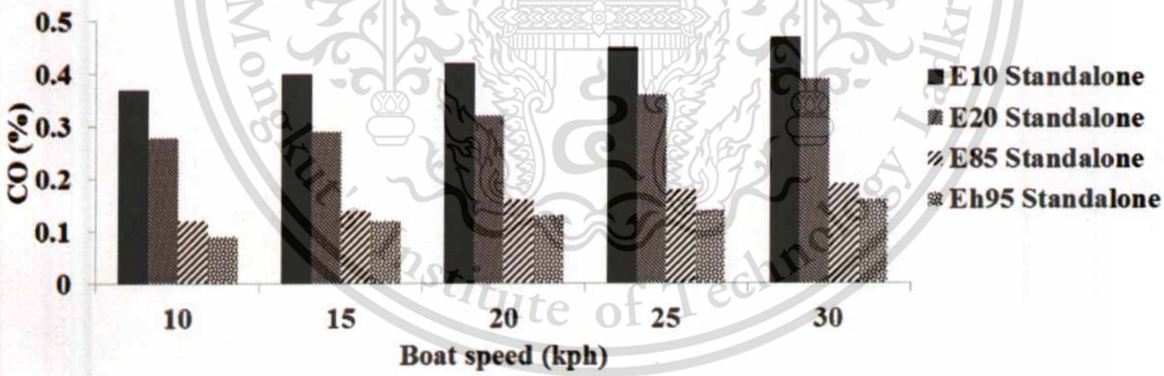

Figure 4.74 Carbon monoxide emission of standalone ECU

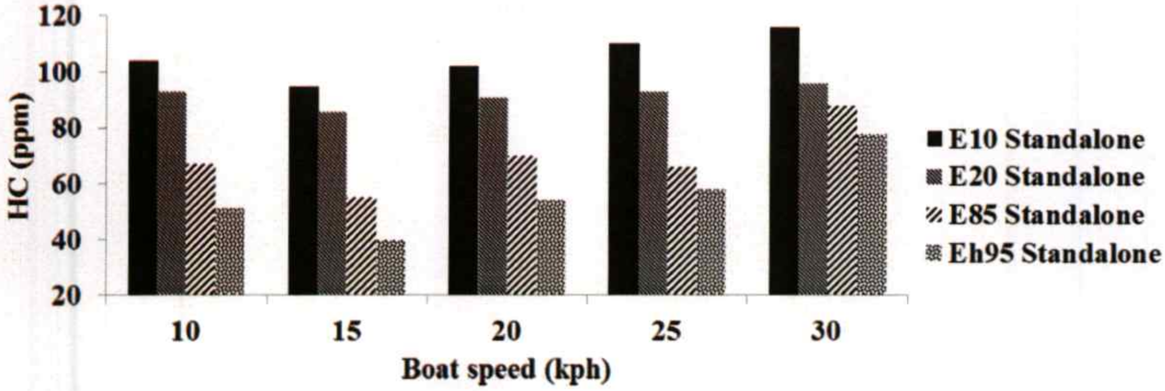

Figure 4.75 Hydrocarbon emission of standalone ECU

Figure 4.75, 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.

For CO2 emission, Figure 4.76 indicate that Eh95 produce the highest CO2 concentration following with E85, E20 and E10 due to the improve combustion of ethanol content.

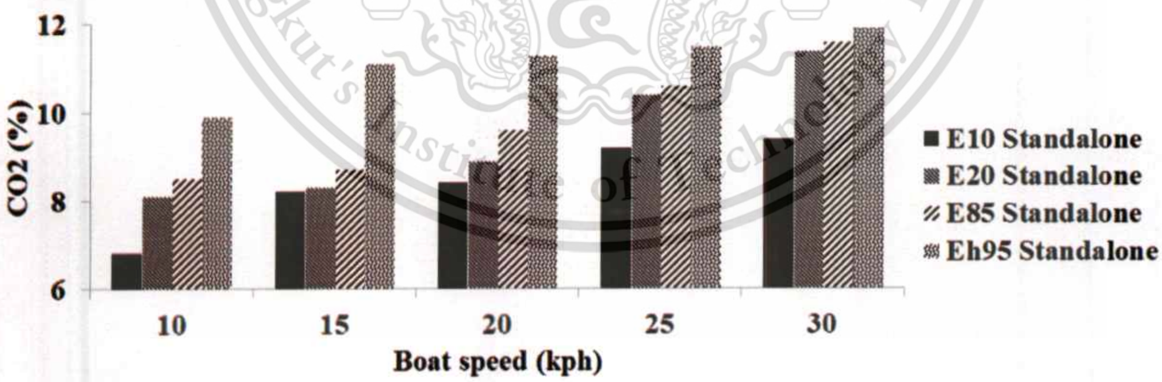

Figure 4.76 Carbon dioxide emission of standalone ECU

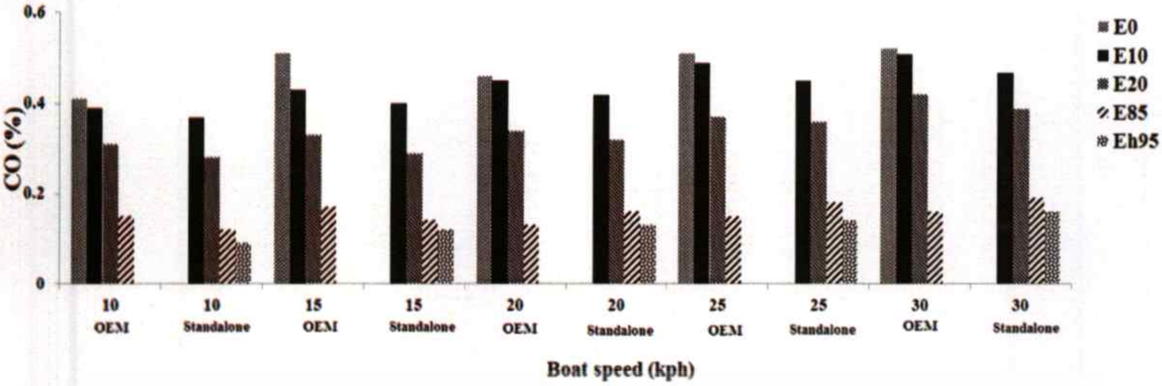

Figure 4.77 Comparisons of carbon monoxide emission in different ECU

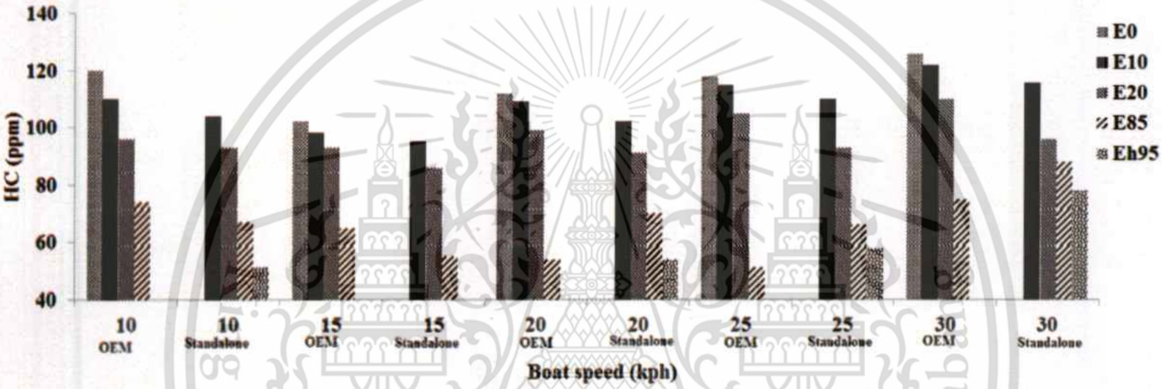

Figure 4.78 Comparisons of hydrocarbon emission in different ECU

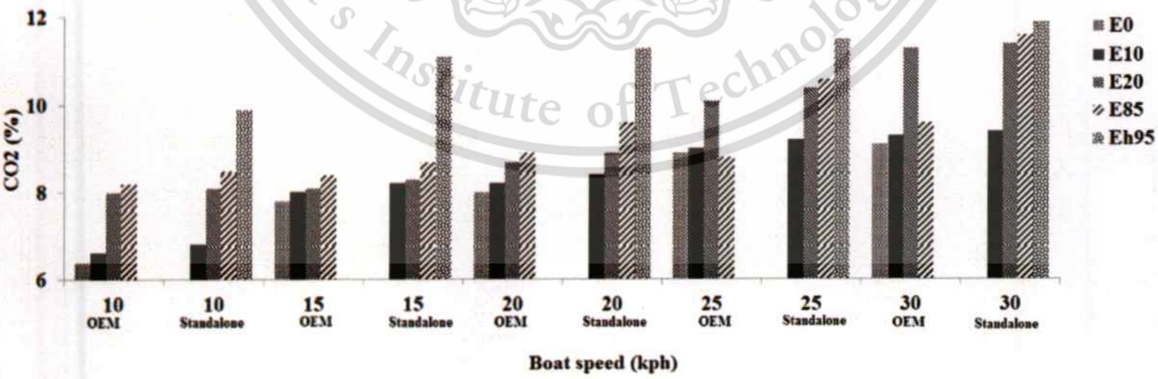

Figure 4.79 Comparisons of carbon dioxide emission in different ECU

4.2.2 Engine with transmission

4.2.2.1 Engine operating with 1.25 : 1 gear ratio

Figure 4.81-4.86 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.

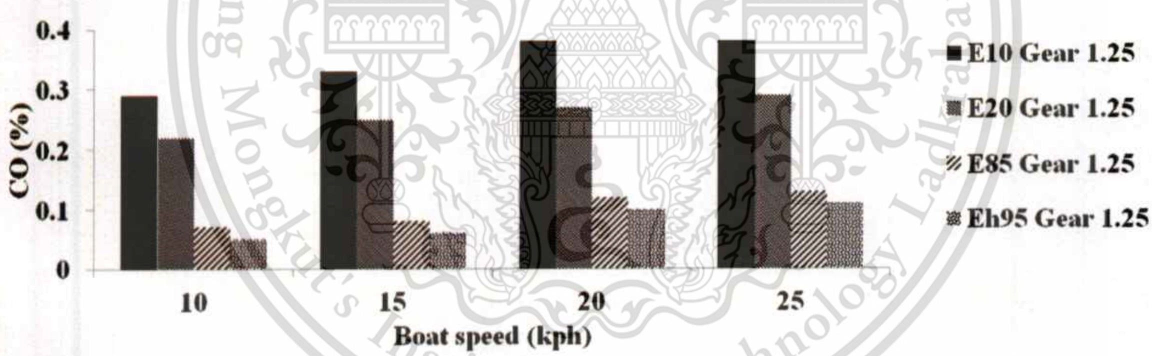

Figure 4.80 Carbon monoxide emission in 1.25 gear ratio condition

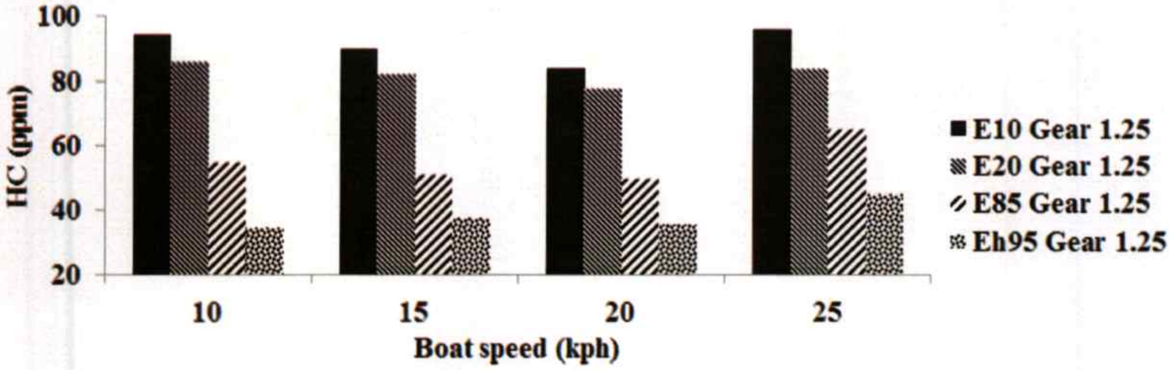

Figure 4.81 Hydrocarbon emission in 1.25 gear ratio condition

From the describing of CO and HC concentration, more complete of combustion lead to increase CO2 concentration. Figure 4.83 has shown Eh95 have the highest of co2 concentration following with E85, E20 and E10. The average of increasing in CO2 from E10 to Eh95 is 37%.

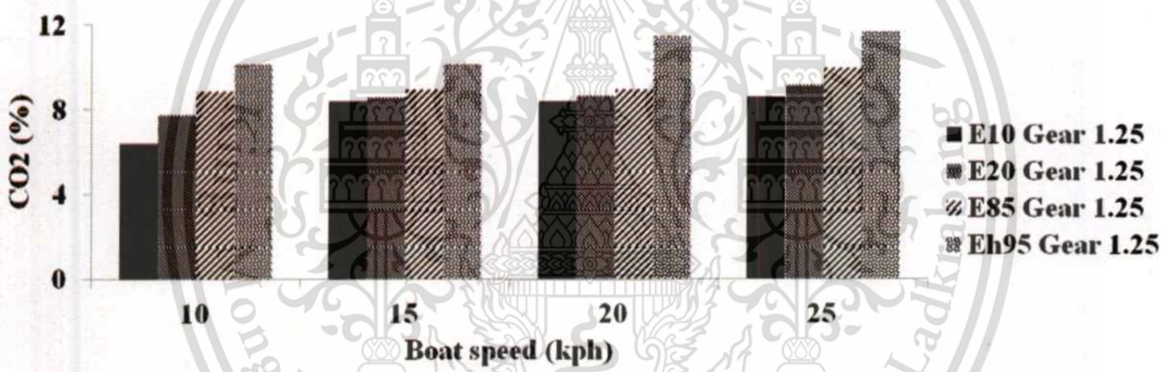

Figure 4.82 Carbon dioxide emissions in 1.25 gear ratio condition

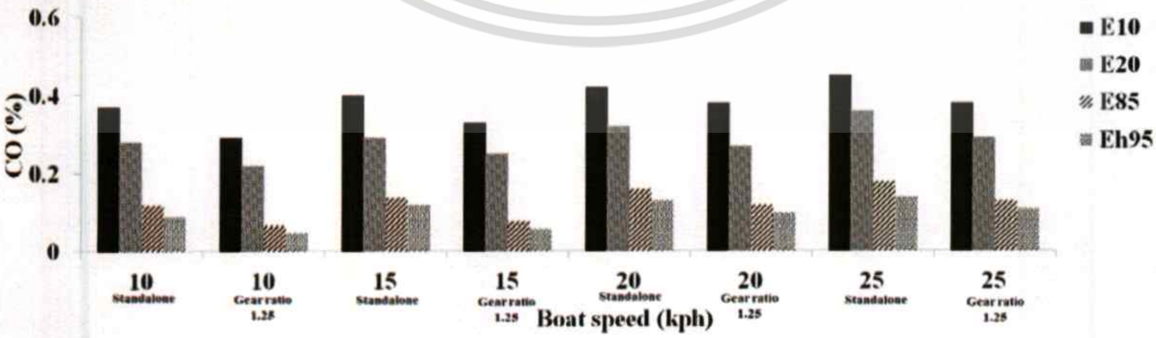

Figure 4.83 Comparisons of carbon dioxide emission in 1.25 gear ratio and no gear box condition

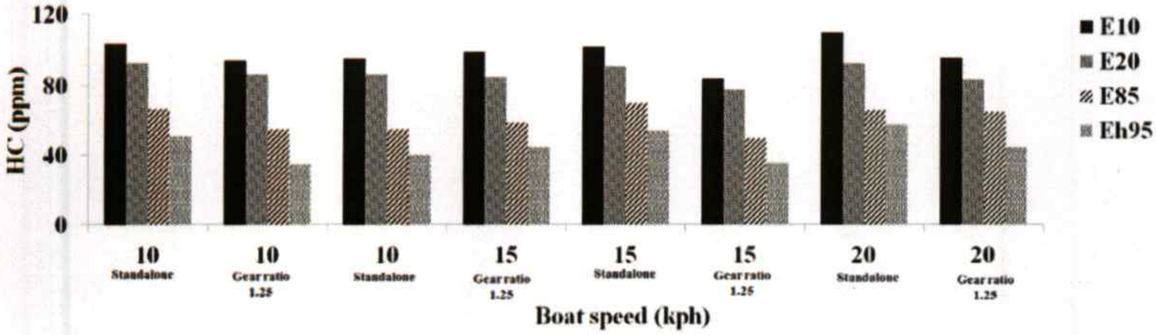

Figure 4.84 Comparisons of hydrocarbon emission in 1.25 gear ratio and no gear box condition

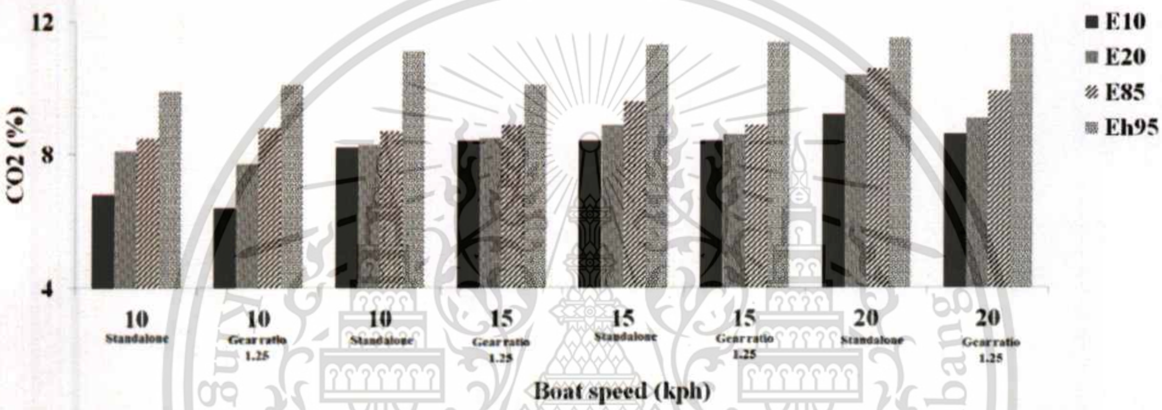

Figure 4.85 Comparisons of carbon dioxide emission emission in 1.25 gear ratio and no gear box condition

Figure 4.86-4.87 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.

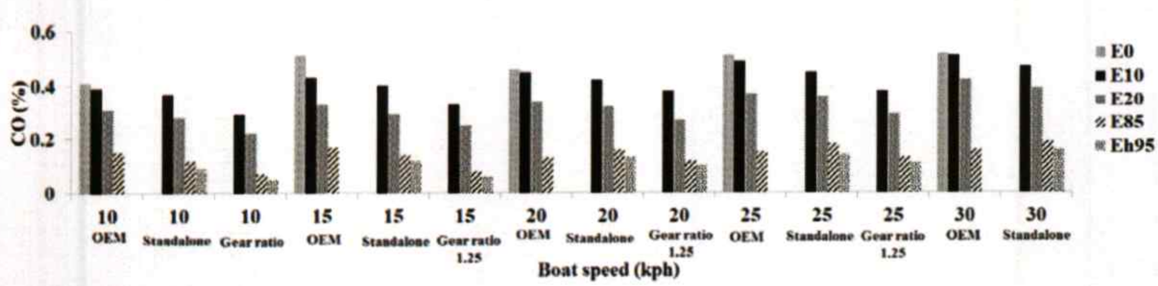

Figure 4.86 Comparisons of carbon monoxide emission in all condition

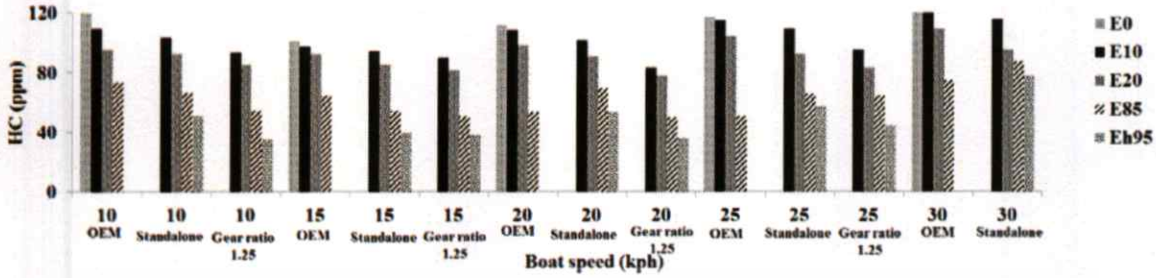

Figure 4.87 Comparisons of hydrocarbon emission in all condition

Figure 4.88, the result signify that increasing of ethanol content in fuel the concentration of CO2 increased due to the improve combustion. The results indicate that Using Eh95 in long-tailed boat engine, the global warming effects of CO2 emission must be consider.

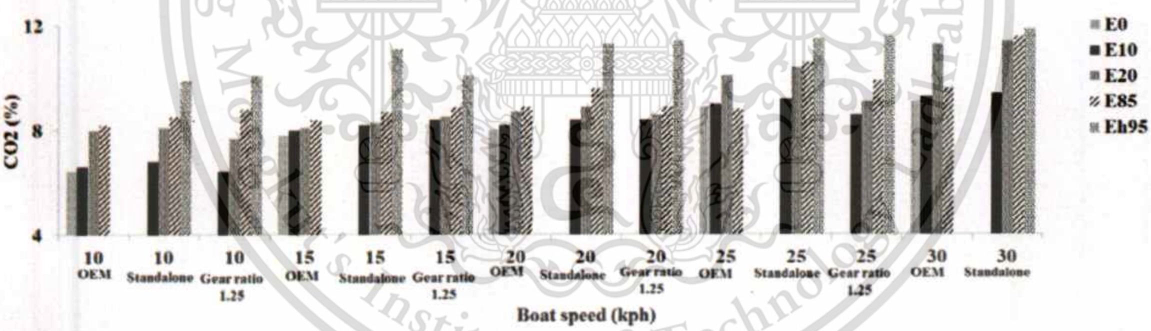

Figure 4.88 Comparisons of carbon dioxide emission in all condition

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 original equipment manufacturer 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, for high speed boat conditions (20-30 kph) the ethanol content should be reduced. In case of using a modified engine control, the boat provides the highest efficiency 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. This could be explained by less heat loss through cylinder walls because of higher laminar flame speed in case of ethanol. And another reason is the engine can advance more of ignition timing from higher octane number and ignition delay. More of energy can produce higher power and torque.

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

4. When Using Hydrous ethanol (Eh95) the engine efficiency is decreased due to the water contents. It is expected that during the combustion process water takes the significant amount of energy, when it converts from liquid to vapor state which causes the thermal cooling of charge inside the cylinder.

5. The results show that the engine using 1.25:1 transmission effect to improve a thermal efficiency 2-6% and reduce exhaust emission in same fuel at long-tailed boat condition.

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. An average of HC and CO emission of hydrous ethanol (Eh95) 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 E85 provided 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 oxygen sensor		5,000
Ethanol sensor		5,000
Gear box		10,000
	130,000 Bath	70,000 Bath

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.

References

[1] Mustafa K., Yakup S., Tolga T., Huseyin S., The effects of ethanol–unleaded gasoline blends on engine performance and exhaust emissions in a spark-ignition engine,Renewable Energy, vol34, 2009, pp.2101–2106

[2] Masumn B.M., Masjuki H.H., Kalam M.A., Rizwanul Fattah I.M., Palash S.M. and Abedin M.J. (2013). Effect of ethanol–gasoline blend on NOx emission in SI engine, Renewable and Sustainable Energy Reviews, vol.24, August 2013, pp 209–222.

[3] Ganguly A., Chatterjee P.K. and Dey A. (2012), Studies on ethanol production from water hyacinth, Renewable and Sustainable Energy Reviews, vol.16(1), January 2012, pp.966–972.

[4] Hsieh W.D., Chen R.H. , Wu T.L. and Lin T.H. (2002) . Engine performance and pollutant emission of an SI engine using ethanol–gasoline blended fuels, Atmospheric Environment, vol.36(3), December 2002, pp. 403–410.

[5] Yücesu HS, Topgül T, ÇinarC, Okur M. Effect of ethanol–gasoline blends on engine performance and exhaust emissions indifferent compression ratios. Applied Thermal Engineering2006;26(17–18):2272–8.

[6] M. Al-Hasan,Effect of ethanol–unleaded gasoline blends on engine performance and exhaust emission, Energy Conversion and Management, vol 44, 2003, pp.1547–1561

[7] Piyaboot Ornman, Experimental investigation in combustion characteristics of ethanol-gasoline blends for stratified charge engine via constant volume combustion chamber,2011

[8] F. Scha¨fer, R.v. Basshuysen, Reduced Emissions and Fuel Consumption in Automobile Engines, Springer-Verlag Wien and Society of Automotive Engineers, Inc., Altenburg, 1995.

[9] Park C., Choi Y., Kim C., Oh S., Lim G., Moriyoshi Y. (2010). Performance and exhaust emission characteristics of a spark ignition engine using ethanol and ethanol-reformed gas,Fuel,vol.89(8) , February 2010, pp.2118–25.

[10] Amaral RA., Influence of engine geometric and operating parameters on aldehyde emissions from an ethanol fuelled vehicle, M.Sc. dissertation. Brazil Pontifical Catholic University of Minas Gerais, 2000.

[11] Owen K, Coley T. Automotive fuels reference book. 2nd ed. USA: Society of Automotive Engineers, Inc.; 1995.

[12] Costa R.C., Sodré J.R. (2010). Hydrous ethanol vs. gasoline–ethanol blend: engine performance and emissions, Fuel, vol.89(2), February 2010, pp287–293.
[13] L.M. Das, Y.V.R. Reddy, Evaluation of alternative fuels for internal combustion engine, in: First Trabzon International Energy and Environment Symposium, July 29–31, 1996, pp. 951–958.
[14] Anderson J., DiCicco D., Ginder , J.M. a, Kramer U., Leone T., Raney-Pablo H., Wallington T., High octane number ethanol–gasoline blends, Quantifying the potential benefits in the United States, Fuel vol.97, 2012, pp. 585–594.
[15] Cenk S., The impact of varying spark timing at different octane numbers on the performance and emission characteristics in a gasoline engine, Fuel, vol. 97, 2012, pp.856–86.
[16] Zareei & A. H., Study and the effects of ignition timing on gasoline engine performance and emissions, EUROPEAN Transport Research Review, vol.5, 2013, pp.109–116 DOI 10.1007/s12544-013-0099-8
[17] Syed Y., Mohammad M., Effect of ignition timing and compression ratio on the performance of a hydrogen–ethanol fuelled engine, International journal of hydrogen energy, vol. 34, 2009, pp.6945 – 6950.
[18] http://iogen.ca/markets/index.html
[19] Benjamin P.P. and Jan L.(2009). Modeling of Ship Propulsion Performance, Technical University of Denmark.
[20] Anthony F., Stephen R. and Dominic A., Ship Resistance and Propulsion: Practical Estimation of Ship Propulsive Power, Cambridge University Press, 978-0-521-76052-2.
[21] Anderson J., Kramer U., Mueller S. and Wallington T., Octane Numbers of Ethanol- and Methanol-Gasoline Blends Estimated from Molar Concentrations , Energy Fuels, vol.24, 2010, pp.6576–6585, DOI:10.1021/ef101125c
[22] Izubuchi T. (1934). Increase in Hull Resistance Through Ship bottom Fouling, Journal of Zosen Kiokai, December 1934, no.55.
[23] Enhagen S.V. (1758). Basic Principles of Ship Propulsion, Enginee Future - since 1758, MAN Diesel & Turbo, Denmark.
[24] Charles W., Ethanol as Fuel for Recreational Boats, The Thayer School of Engineering at Dartmouth College, March 2004.
[25] CHAPTER 2 Ship Resistance, MARINE FOULING AND ITS PREVENTION,WOODS HOLE OCEANOGRAPHIC INSTITUTION WOODS HOLE, MASSACHUSETTS.

[26] WILLIAM F.,Principal of the School of Marine Construction, THE RESISTANCE AND PROPULSION OF SHIPS, Cornell University
[27] Technical discussion with Keld K.N., Burmeister and Wain S., Copenhagen.
[28] Paul H. Miller, Chap 7 Resistance and Powering of Ship presentation‖, U.S. Naval Academy, Annapolis, MD 21402.

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 Infrared 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

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QUALITY ANALYSIS DEPARTMENT, SUPPLY AND TERMINAL OPERATIONS, OIL BUSINESS
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Page 1 of 1

Certificate of Analysis

Product : Gasoline E 0

Certificate No. : T-12/29294
Sample Lab No. : OP-03H-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

Approved by : [signature]
(Phurita Pothisuk)
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
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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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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
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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	**Received Date**	: 18 Dec 2012
Customer/Supplier	: International College, King Mongkut's Institute of Technology International College, King Mongkut's Institute of Technology Ladkrabang, Chalongkrung Rd. Ladkrabang BKK 10520	**Date of Test**	: 18 Dec 2012
		Date of Sampling	: 18 Dec 2012
Sample Location	: LKB	**Sample Condition**	: Normal
Batch No.	: -		
Product Source	: -		

Test Item	Test Method	Limit	Result
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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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Position Title : Vice President in Quality Analysis Department
Date of Issue : 25 Dec 2012

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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
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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

JSAE 20159819 / SAE 2015-32-0819

Impact of Alcohol–Gasoline Fuel Blends in Long-Tailed Boat Application

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ABSTRACT

Nowadays, human realize to the environment pollution cause from old engine and use the engine misapply. These engines will cause the problem such as air pollution and cannot use the engine to work at the maximum efficiency and fuel consumption. The new of control technologies can solve problems from misuse engine by an electronic control unit work with many sensors. Optimization of electronic control unit (ECU) makes an engine to work in maximum efficiency and decrease the environment pollution. In this research, Port-fuel injection spark ignition engine (PFI Engine) fuelled with gasoline is use as the boat engine. To use car engine as boat engine, the control system has to be modify and tune up for proper condition. For the method, the parameters that used to control and optimization are the boat's running condition to tune up injection timing, injection duration, ignition timing, and also the engine special function. And this paper aim to investigate and improve performance, efficiency and emission of misapply engine. After that we plan to do research on each part of the system that makes the engine run with alternative energy such as gasohol (E10 to E85) to reduce the emission of greenhouse gas and environment pollution.

Keywords: PFI Engine, Optimization, Alternative energy, Gasohol

INTRODUCTION

Thailand peoples extensively use Long-tailed boat in transportation, for example, the transportation in "Khlong Saen Saep" and "Chao Phraya River". Most of long-tailed boats use a diesel engine or gasoline engine from car and truck. It's not design to use for boat. Many factors are different from road to the river. The misuse of an engine leads to many problem such as "Low performance, low efficiency and high emission.

The environment pollution cause from old engine and use the engine misapply can be reducing because we can use alternative energy, for example, alcohol–gasoline fuel blends (gasohol). It's developed to alternative energy, resembles performance and characteristic as gasoline. Moreover, gasoline can relive troubles as pollution from vehicle that emphasized in global by outstanding specification; high antiknock quality than gasoline. Gasohol can improve the complete combustion and also reduce the emission of greenhouse gas from the incomplete combustion.

In this research, Impact of alcohol–gasoline fuel blends (E10, E20 and E85) and pure gasoline in long-tailed boat application were investigated. In the experiments, port-fuel injection spark ignition engine (PFI Engine) fuelled with gasoline is use as the boat engine. The tests were performed on an engine dynamometer at different load of long-tailed boat's condition. And this paper aim to investigate effect of alcohol–gasoline fuel blends on emission of greenhouse gas and environment pollution.

DESIGN AND EXPERIMENT APPARATUSES

Experimental apparatus includes three major parts, boat resistance calculation, required power and torque calculation and exhaust measurement system. The engine system used in this experiment is a spark-ignition engine 1ZZ-FE, 1794cc, maximum power is 105 kW (140 hp) at 6400 rpm and maximum torque 171 Nm at 4200 rpm. The general specification of the test engine is given in Table 1. In the experiment, the concentrations of CO, CO2, O2, NOx and HC in the exhaust gas are measured on-line by the automotive gas analyzer KEG-500. The specification and accuracies of the gas analyzer measurement are given in Table 2. And Tokyo Plant 150 PS engine dynamometer is working at a part of long-tailed boat condition control. The schematic view of the engine test bed is illustrated in Figure 1.

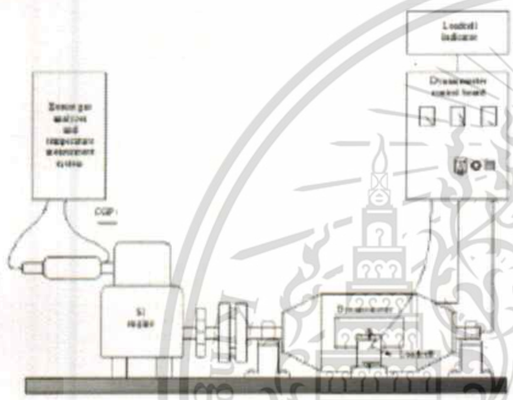

Figure 1. The schematic view of the engine test bed.

Table 1
Specification of the test engine.

Model	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(140hp)@6400 rpm
Maximum Torque	171 Nm @4200 rpm

Table 2
The specification and accuracies of the gas analyzer measurement

Model	KEG-500		
Measuring gas	CO, HC, CO2, O2,Lamda(Air surplus rate), AFR, NOX (5gas)		
Sensor Theory	CO, HC, CO2, Non-Dispersive Infrared 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		

BOAT RESISTANCE CALCULATION

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 [3]. The external factors of ship are illustrated in Figure 2. The long-tailed boat size that use for calculate in this research is 11 m length and 1.6 m width. The long-tailed boat in Thailand and engine mounting location are illustrated in Figure 3 and Figure 4.

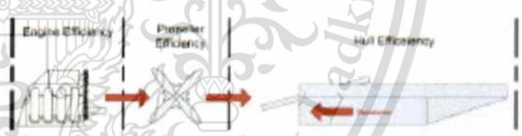

Figure 2. Performance variables [4].

Figure 3. Long-tailed boat in Thailand.

Figure 4. Long-tailed boat engine mounting area

<u>Frictional Resistance</u>

The frictional resistance of the hull depends on the size of the hull's wetted area and on the specific frictional resistance coefficient [3]. Frictional resistance of the boat can be calculated by using equation [6, 8].

$$R_f = C_f\left(\frac{\rho}{2}\right)SV^2 \quad (1)$$

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.

$$C_f = 0.02058\left(\frac{V\times L}{\nu}\right)^{\frac{-1}{8}} \quad (2)$$

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

<u>Residual resistance</u>

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 [1,2]. 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 5 [2,6]. The frictional resistance that use for calculate residual resistance is from equation (1).

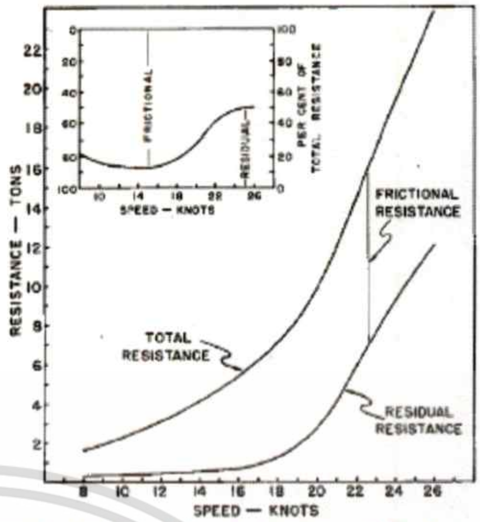

Figure 5. Analysis of the total resistance of the destroyer Yudachi into its components of frictional and residual resistance at various speeds. Inset. Percentage of total resistance due to frictional and residual resistance at different speeds.

<u>Air Resistance</u>

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 [1]. 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 [1,3].

$$R_a = 0.9\left(\frac{1}{2}\rho AV^2\right) \quad (3)$$

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. In this research, the design speed of boat is 8 to 20 knots (4.112 to 10.28 m/s).

<u>Total Resistance</u>

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

<u>Require Power and Torque Calculation</u>

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

Require power Calculation

The required power calculation 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 8 to 20 knots (4.112 to 10.28 m/s).

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 2500 – 4000 rpm and τ is required torque of the boat engine [5]. And the propeller efficiency that use in this calculation is 60% [6].

Ethanol fuel as a gasoline substitute

Ethanol (C_2H_5OH) is an ecological fuel, as it is obtained from renewable energy sources. It is a colorless, transparent, neutral, volatile, flammable, oxygenated liquid hydrocarbon, which has a pungent odor and a sharp burning taste [7]. Generally, ethanol or bioethanol is more reactive than hydro- carbon fuels, such as gasoline [8]. Recently, ethanol has been used extensively as a fuel additive or an alternative fuel in spark ignition (SI) engines as well as in diesel engines as it is a high octane, clean- burning fuel [11-13]. Burning of ethanol in SI engines also reduces emissions of carbon monoxide (CO), hydrocarbon (HC), and so on, but there are some inconsistencies in NOx emissions as shown by many researchers [11].

Research Methodology and Procedures

To analyze the performance and emission from the test engine, the engine will operate at long-tailed boat condition and run at engine speed 2000, 2500, 3000, 3500 and 4000 rpm. And this research concerning on long-tailed boat speed at 20 km/h and 30 km/h running on pure gasoline 95, gasohol E10, gasohol E20 and gasohol E85. All condition of each speed will be run at lambda equal to 1. But for some of high load condition ECU cannot control lambda equal to 1. The emission will be measure by the automotive gas analyzer KEG-500. Tokyo Plant 150 PS engine dynamometer is used to measure engine performance and control a long-tailed boat condition.

RESULTS AND DISCUSSION

Power and Torque Calculation

From the calculation of boat resistance total resistance of long-tailed boat is illustrated in Figure 6. And the required power and torque for all speed are is illustrated in Figure 7 and Figure 8. The required power and torque are calculated from total of boat resistance and efficiency of propeller.

Total Resistance of long-tailed boat.

Table 3
Assumption for friction resistance calculation.

Frontal Area	2 m^2
Boat length	11 meter
Wetted surface area	31.9117 m^2
Air density	1.1839 kg/m^3
Water density	995.6502 kg/m^3
Water viscosity	0.801×10^{-6} m^2/s
Wind Speed	Equal to boat speed
Calculation at 30 Degree Celsius	

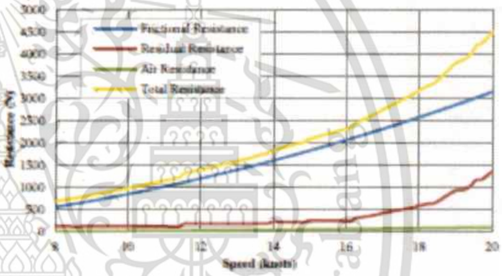

Figure 6. Total Resistance of long-tailed boat.

Require power of long-tailed boat.

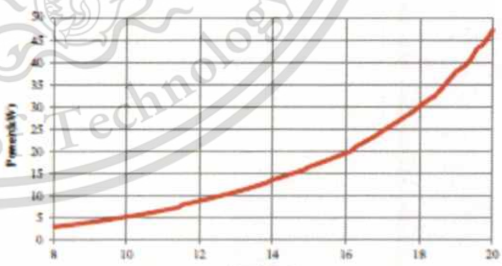

Figure 7. The required power of long-tailed boat.

Require Torque of long-tailed boat.

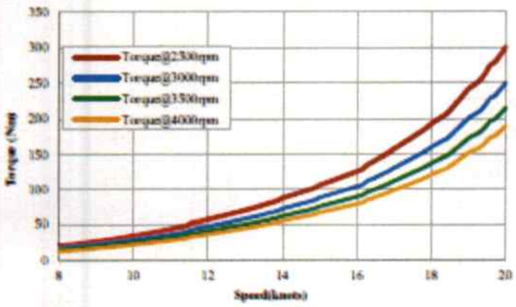

Figure 8. The required torque of long-tailed boat for each engine speed.

Load of engine for long-tailed boat's condition

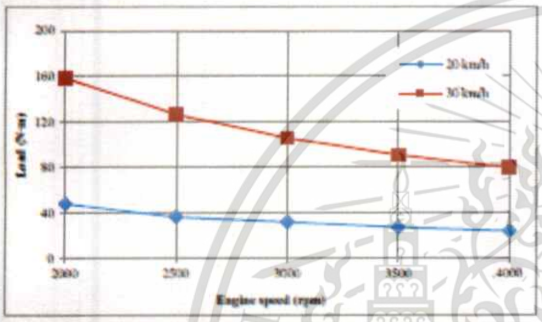

Figure 9. Load of engine for each long-tailed boat speed.

Pollutant emissions

Recently, we consider in the reduction of exhaust emission in each fuel at long-tailed boat condition. The fuel that use for test in this condition have three type of gasohol (E10, E20 and E85) and pure gasoline. The effects of alcohol-gasoline blended on exhaust emission are illustrated in Figure 10-13.

Exhaust emission

The pollutant emissions of exhaust gas are concentrations of CO, CO2 and HC emissions.

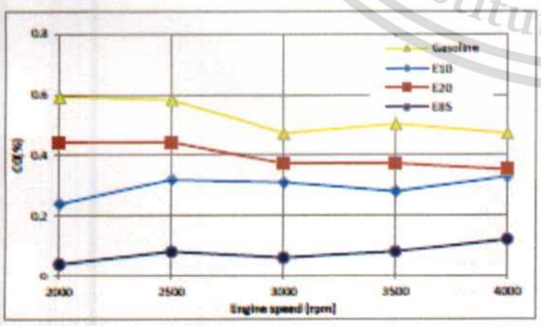

Figure 10. The effect of alcohol-gasoline blended on CO emission at 20km/h long-tailed boat speed.

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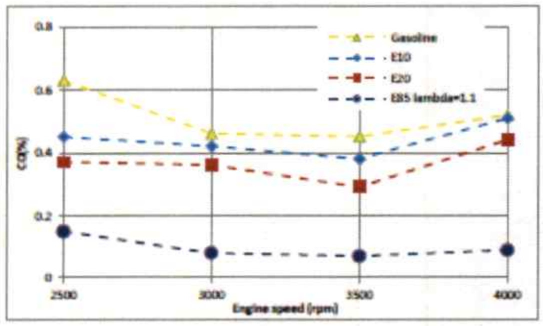

Figure 11. The effect of alcohol-gasoline blended on CO emission at 30km/h long-tailed boat speed.

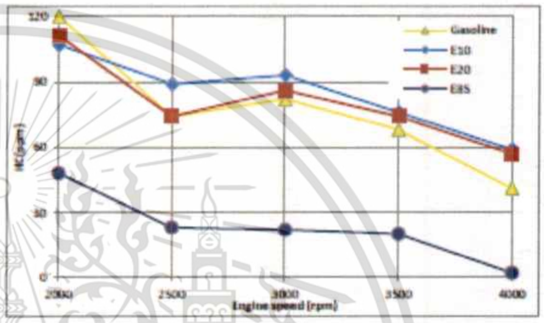

Figure 12. The effect of alcohol-gasoline blended on HC emission at 20km/h long-tailed boat speed.

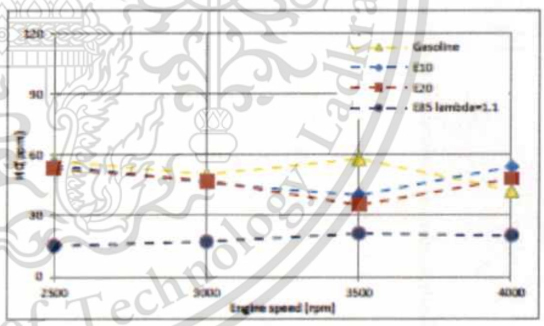

Figure 13. The effect of alcohol-gasoline blended on HC emission at 30km/h long-tailed boat speed.

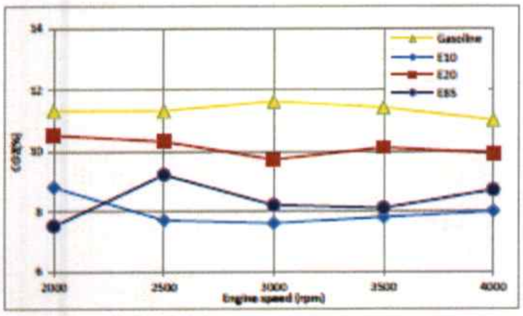

Figure 14. The effect of alcohol-gasoline blended on CO_2 emission at 20km/h long-tailed boat speed.

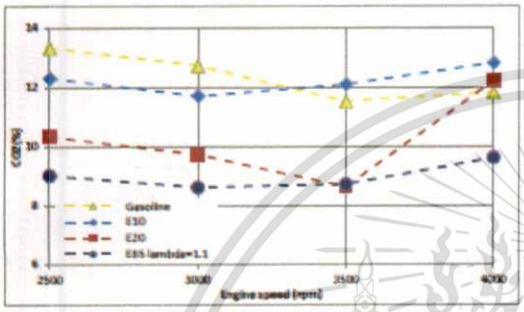

Figure 15. The effect of alcohol-gasoline blended on CO_2 emission at 30km/h long-tailed boat speed.

Fuel efficiency

Brake specific fuel consumption (bsfc) is calculated from result of engine dynamometer to understand the variations of fuel consumption in the test engine using different alcohol-gasoline blended fuels. bsfc (g/kJ) is defined as the ratio of the rate of fuel consumption (g/sec) and the brake power (kW). And bsfc should be increased with the increase of ethanol content [18]. Brake specific energy consumption (bsec) 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[30] of fuel. It means how efficiently fuel energy obtained from given fuel.

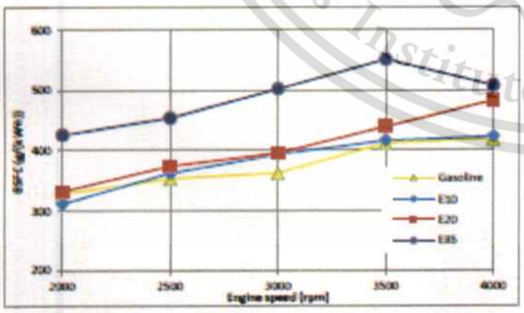

Figure 16. The variations of bsfc for different alcohol-gasoline blended fuels under various engine speeds at 20km/h long-tailed boat speed.

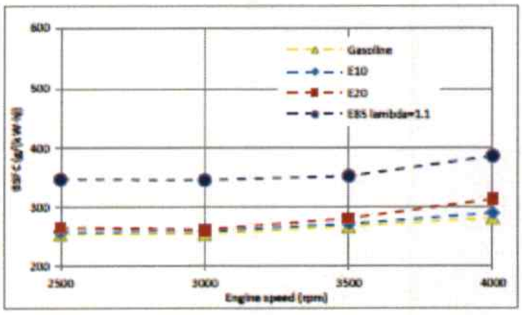

Figure 17. The variations of bsfc for different alcohol-gasoline blended fuels under various engine speeds at 30km/h long-tailed boat speed.

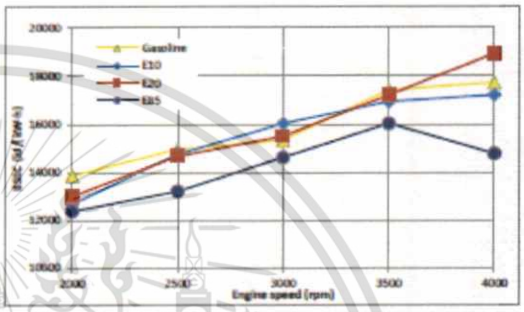

Figure 18. The variations of bsec for different alcohol-gasoline blended fuels under various engine speeds at 20km/h long-tailed boat speed.

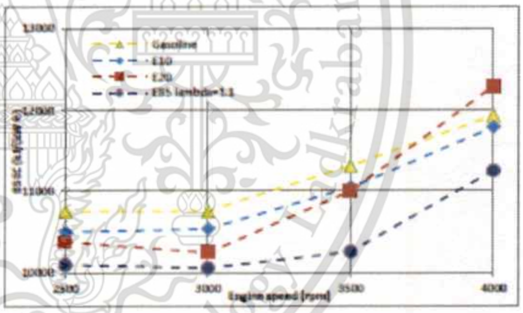

Figure 19. The variations of bsec for different alcohol-gasoline blended fuels under various engine speeds at 30km/h long-tailed boat speed.

SUMMARY/CONCLUSIONS

The pollutant emission and fuel efficiency of test engine have been investigated by using alcohol–gasoline blended fuels (E10, E20 and E85) and pure gasoline operating on long-tailed boat condition. Experimental results indicated that using alcohol–gasoline blended fuels leads to a significant reduction in exhaust emissions. CO and HC emissions are decrease dramatically. And CO_2 are also decrease because of fuel energy obtained that illustrated in figure18 and figure19 in bsec content. And brake specific fuel consumption value is increased respectively depend on ethanol percentage. Finally, we intended to present a complete optimization of the alcohol–gasoline blended fuels in long-tailed boat engine. The experiment also in processing and will be reported in the near future.

REFERENCES

1. Technical discussion with Keld K.N., Burmeister and Wain S., Copenhagen.
2. Izubuchi T. (1934). Increase in Hull Resistance Through Ship bottom Fouling, Journal of Zosen Kiokai, December 1934, no.55.
3. Enhagen S.V. (1758). Basic Principles of Ship Propulsion, Enginee Future - since 1758, MAN Diesel & Turbo, Denmark.
4. Benjamin P.P. and Jan L.(2009). Modeling of Ship Propulsion Performance, Technical University of Denmark.
5. Paul H. Miller, Resistance and Powering of Ship presentation, U.S. Naval Academy, Annapolis.
6. Ganguly A., Chatterjee P.K. and Dey A. (2012). Studies on ethanol production from water hyacinth, Renewable and Sustainable Energy Reviews, vol.16(1), January 2012, pp.966–972.
7. Costa R.C., Sodré J.R. (2010). Hydrous ethanol vs. gasoline–ethanol blend: engine performance and emissions, Fuel, vol.89(2), February 2010, pp287–293.
8. Masumn B.M., Masjuki H.H., Kalam M.A., Rizwanul Fattah I.M., Palash S.M. and Abedin M.J. (2013). Effect of ethanol–gasoline blend on NOx emission in SI engine, Renewable and Sustainable Energy Reviews, vol.24, August 2013, pp 209–222.
9. Park C., Choi Y., Kim C., Oh S., Lim G., Moriyoshi Y. (2010). Performance and exhaust emission characteristics of a spark ignition engine using ethanol and ethanol-reformed gas,Fuel,vol.89(8) , February 2010, pp.2118–25.
10. Pang X., Mu Y., Yuan J. and He H. (2008). Carbonyls emission from ethanol-blended gasoline and biodiesel-ethanol-diesel used in engines, Atmospheric Environment, vol.42(6), November 2008,pp.1349–1358.
11. Hsieh W.D., Chen R.H., Wu T.L. and Lin T.H. (2002). Engine performance and pollutant emission of an SI engine using ethanol–gasoline blended fuels, Atmospheric Environment, vol.36(3), December 2002, pp. 403–410.
12. Thummarat T. (2007). Gasohol Specification Issue:Effect on Vehicle Emissions and Driveability,5'th Asian Petroleum Technology Symposium, January 2007,Jakarta, Indonesia.

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