Modification of Design and Testing of Power Recovery on Single Cylinder SI Engine Carbureted with Sole Ethanol

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Abstract: **This paper is concerned with the design modification for power recovery on single cylinder spark ignition engine using with the ethanol as the alternative fuel in Myanmar. 95 percent of ethanol product is available in local market. The main purpose of the experiment is to recover the power downgrade using the locally produced ethanol in Myanmar and to test the engine performance compared with the gasoline and ethanol usage in rural areas. This is intended how to upgrade the engine performance when using the gasoline engine with ethanol. The engine is firstly modified the engine's carburetor to put more fuel because the ethanol has less calorific heating value compared with that of gasoline. After that, the engine power is still downgrading. As the second step, cylinder head is grinded to increase the compression ratio from 8 to 9 because of its higher octane number. There is the important factor to optimize the spark ignition timing. The normal spark advance ignition timing for the gasoline at 3000rpm is 30ºBTDC. The optimum spark timing for ethanol is 35ºBTDC. According to the test, the result of using locally produced pure ethanol after modification of the engine parts is that the brake power for the ethanol is the same as the usage of gasoline at 2450 rpm in running condition. At the speed of 3000rpm, the brake power can be upgraded up to approximately 4% when using ethanol. As a disadvantage, the fuel consumption of ethanol is still approximately 35% higher than that of gasoline. The exhaust emission of ethanol is good enough to clean the environment as a benefit.**

Indexed Terms — **95percent Ethanol, Increasing Compression Ratio, Modified Engine's Carburetor, Optimum Spark Timing, Recover Power Downgrade.**

I. INTRODUCTION

All over the world, people have been using the fossil fuels as the major fuels not only in the internal combustion engines and gas turbines but also stationary factory machines. However, the emission of CO2 in the use of fossil fuels affected the global warming and air pollution. Therefore, the scientists and engineers are finding out the solution of how to prevent the environmental impact due to the use of fossil fuels. The alternative fuels from the biomass are much more popular to replace the use of fossil fuels as the technology has been developing. The ethanol and methanol are the example of alternative fuels instead of using fossil fuels. In Myanmar, as the developing country, the usage of alternating fuels is much more expansive compared with the fossil fuels nowadays. In future, the using of alternative fuels might be much more popular for the internal combustion engine. Ethanol which is a renewable energy source that can be easily obtained from agricultural biomass products like corn and sugarcane can be used in spark ignition engines on its own or blended with gasoline.

The ethanol is mostly used in alcohol production in Myanmar. The maize, cassava, potato, sweet potato, yam, broken rice, and sweet sorghum are utilized in the production of ethanol. Among them, the main raw material of production ethanol in urban areas is broken rice meanwhile the use of sugarcane in production of ethanol transcends in rural areas. The production price is important role for changing ethanol as the alternative fuel instead of fossil fuel such as gasoline in Myanmar because Myanmar people are sensitive in price of goods and the price of alternative fuels are very few expensive compared with that of gasoline in the capitals of Myanmar except of rural areas. [2] Moreover, the major transportation of higher city in Myanmar is their own vehicles and the bus. Therefore, the price of fuel is much more vital for transportation. The overflow of sugar output is necessary to transform into bioethanol to utilize as an alternative fuel in vehicles which are used in rural areas. On the other hand, dehydrating of ethanol in dissolving water is not economically viable in Myanmar Market so that 95 percent of ethanol product is available in local market. The price of ethanol product (7500MMK/gallon) is quite cheaper than that of gasoline price in rural areas (9000MMK/gallon). [2] However, ethanol price transcended more in urban areas because the main raw materials of ethanol production is broken rice in Myanmar.

The main problem of using ethanol in petrol engine is that the engine caused the sudden stall and starting difficulty. The ethanol which is available in Myanmar is distilled with 5% water. It causes the fuel line corrosion and power downgrade because of its calorific value.

II. EXPERIMENTAL METHOD

In this experiment, there are two aspects of engine design modification between using a sole ethanol and pure gasoline to improve the engine performance. As the first step, the engine was theoretically analyzed with the air-standard cycle and fuel-air cycle. On the other hand, the engine performance is also analyzed and modified to recover the power when using the sole ethanol. The engine used in this paper is CL3900 engine testing with measuring devices. The engine size is 208 cubic centimeter attached with the measuring devices to figure out the engine performance parameters. There are three modification steps to improve the engine power for the sole ethanol usage that is available in Myanmar. The main problem statement is that the sole ethanol, which is available in Myanmar, compounded with 95% of alcohol and 5% of water. The water combination in ethanol can cause not only engine parts damaging but also downgrading the engine power. Moreover, the engine running condition was not stable when the engine started to run.

To solve this problem statement, Firstly, the amplified main jet in the carburetor is needed to get more the fuel consumption in engine. The mass of fuel (petrol) is 1.4286x10-5kg meanwhile the mass of fuel (ethanol) is much more needed to put the engine due to the calorific value of ethanol. Therefore, the mass of fuel (ethanol) is 2.402x10-5kg after theoretical approach.

In the same amount of fuel in carburetor, the work done per cycle using gasoline is 328.2 J/cycle meanwhile the work done per cycle using ethanol is 277.7 J/cycle. Therefore, the power is still downgraded to 15.38%. The combination of heating value and stoichiometry also affects the airflow requirements at a given power output. This will impact the throttle setting which has a strong influence on the overall efficiency of the engine. The different calorific value effected the mass flow rate of fuels. The main jet is needed to modify in carburetor of the fuel injection system by the use of ethanol.

The manufacturer of the portable generator SI engine available in Myanmar produced 0.8mm diameter of the main jet of the carburetor. When using the ethanol, the diameter of main jet is essential to be the range of 1mm to 1.5mm due to the calorific value and air fuel ratio. The compression ratio 8 is the standard for the corolla CL 3900 portable generator. Therefore, the engine was essential to amplify up to 1mm for using ethanol not to occur the engine sudden stall and engine starting difficulty.

Fig 1. Carburetor with the Main Jet

The major modification to change the compression ratio is to grind the cylinder head. According to the measuring results, there is enough space in cylinder head to change the compression ratio 9. The gasket thickness is too thin to change clearance volume. The gasket thickness is 0.4mm. It is observed that the cylinder head thickness can be grinded up to 4mm until the inlet valve and outlet valve are not fixed tightly so that their movements let the air-fuel mixture inhale and exhale in the combustion chamber. To transform the compression ratio 9, the cylinder head has to grind up to 2mm thickness to reduce the clearance volume. However, the spare cylinder head is essential to replace the original cylinder head because the grinded head cannot be changed to compression ratio 8. There are 2 types of cylinder head to assemble to obtain the various results of different compression ratios. For using the ethanol, the modification's carburetor is installed before starting the engine because the engine cannot run on the original carburetor due to the less mass flow rate of ethanol in carburetor.

Fig 2. Modification of Engine's Cylinder Head

The CL 3900 Engine is designated for the use of gasoline with the electrical dynamometer. Therefore, there is a factor to find the optimum spark advance timing for the use of ethanol in this engine. Generally, the engine started with the use of gasoline at 30 BTDC spark advance timing at the engine speed of 3000 rpm. The mechanism, which can change the advance spark timing with the cam profile, is installed at the end of the crankshaft of the engine. This is the battery type ignition coil system. There are the ignition coil, cam profile point contact, battery and casing in this ignition system.

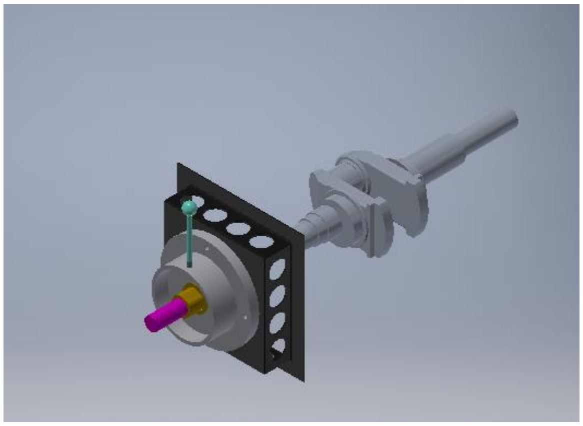

Fig 3. Cam Profile Ignition Coil Assembly Design Drawing

Before installing the ignition coil at the end of the crankshaft, it is considered that the ventilation air flow rate of the engine cooling system. The engine crankshaft is connected with the electric dynamometer and on the other side, the engine cooling fan covered with the shell. Therefore, the casing to install the spark ignition coil system is required to find the air flow rate of the cooling for this engine. The proper calculated holes are eliminated to get more air for the engine cooling system. The following figure 4.9 to 4.11 are demonstrated to measure the air ventilation and design to install ignition system.

Fig 4. Spark Ignition Timing with Cam Profile Ignition Coil

III. ENGINE SET-UP WITH MEASURING EQUIPMENT

the engine is assembled with the fuel tank which is separated for gasoline and ethanol. Before mixing the fuel and air in the carburetor, the fuel gauge meter to measure the fuel volume flow rate is connected with two lines which has the valves to open or close the fuel passing from the fuel tanks. At the entrance of the intake air system before the carburetor, the air box is connected to passage of the inlet manifold. The exhaust gas temperature sensor (thermocouple K type) which linked with the display unit box is located at the muffler. The clamp meter or multi-meter to measure ampere and volt meter to measure voltage are installed obtaining the power consumption from switching on or off electric bulbs. Another necessary instrument such as ambient temperature sensor and pressure sensor is installed in display unit box.

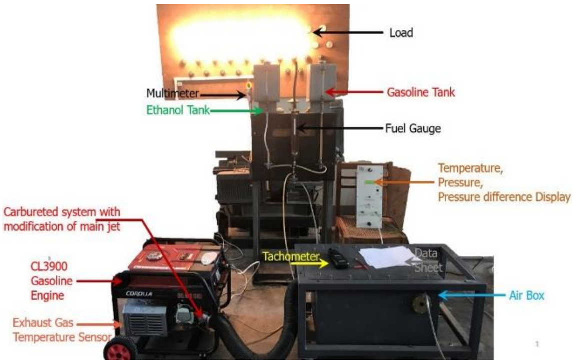

Fig 5. Single Cylinder SI Engine Portable Generator Installed with Measuring Instruments

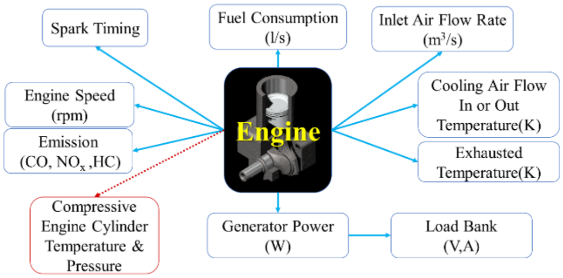

Fig 6. Measuring Flow Diagram

In this equipment, the speed is tested with the tachometer at the end of the crank shaft of the engine. At the edge of the crank shaft is installed dynamometer to measure the brake power. To measure the crank angle of the spark timing, which is varied with the speed, the reflection tape was glued at the end of crank shaft with the use of ignition timing light or flash gun.

IV. RESULTS AND DISCUSSION

There are the engine performance graphs of testing single cylinder SI Engine with ethanol and gasoline.

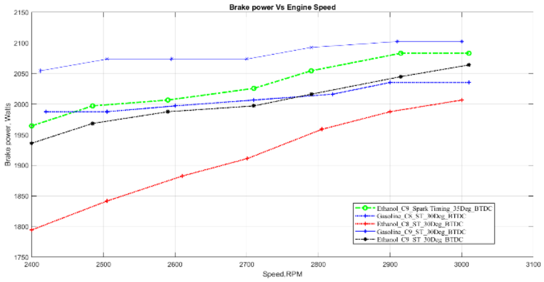

Fig 7. Comparison of Brake Powers with Varied Speed between Compression Ratio 9 and 8

In Fig 7, the dominant trend represented indicates that brake power increases slightly with the increase in speed, except for ethanol with compression ratio 8, which increases dramatically. For gasoline, the brake power for compression ratios 9 and 8 stands at approximately 2055 watts and 1960 watts, respectively. At 3000rpm, they both gradually rise to 2100Watts and 2025Watts, respectively.

For ethanol, the brake power for compression ratio 9 is nearly 1950 watts while that of compression ratio 8 is about 7% lower, which is only 1790 watts at 2400 rpm. The value of break power for compression ratio 9 does not change much, only about 2025 watts at 3000rpm. However, the pattern for compression ratio 8 changes modestly, which reaches about 2000Watts at 3000rpm. The break power for ethanol at compression ratio 9 (spark timing 35 degrees) starts at around 1925 Watts at 2400 rpm and it rises steadily, reaching about 2060 Watts at 3000 rpm.

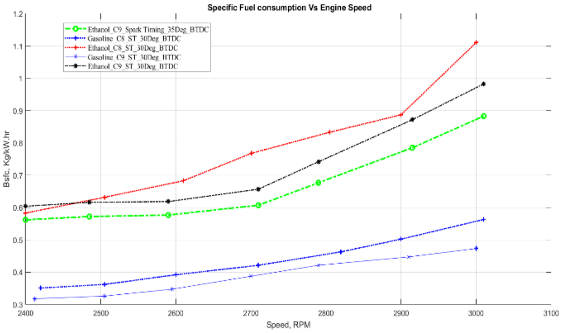

Fig 8. Comparison of Brake Specific Fuel Consumptions with Varied Speed between Compression Ratio 9 and 8

In Fig 8, the specific fuel consumption for ethanol is higher than that of gasoline. At 2400rpm, the specific fuel consumption value for ethanol for both compression ratios is about the same, at around 0.6kh/kW.hr. They both rise steadily, but the specific fuel consumption for ethanol with compression ratio 8 is higher than that of compression ratio 9, starting from about 2480rpm. At 3000 rpm, the value for compression ratio 8 is 1.1kh/kW.hr, and for compression ratio 9, the value is about 0.98kh/kW.hr. For gasoline, at 2400rpm, the specific fuel consumption for compression ratios 8 and 9 is about 0.34 kh/kW.hr. The values then go up to about 0.55kh/kW.hr and 0.46kh/kW.hr, respectively.

The specific fuel consumption for ethanol at compression ratio 9 (spark timing 35 degrees) is almost stable between 2400 and 2600rpm, which is about 0.56kh/kW.hr. It surges gradually and reaches about 0.88kh/kW.hr at 3000rpm.

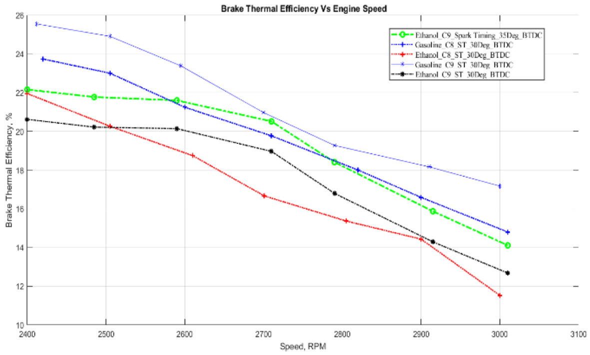

Fig 9. Comparison of Brake Thermal Efficiencies with Varied Speed between Compression Ratio 9 and 8

In Fig 9, it can be clearly seen from the graph that the higher the brake thermal efficiency, the lower the speed of an engine becomes. Brake thermal efficiency for gasoline for compression ratio 9 at about 2400 RPM is higher than that of compression ratio 8. When the speed increases, the break thermal efficiency for both compression ratios 8 and 9 declines steadily and reaches approximately 17% for compression ratio 9 and 14.5% for compression ratio 8. However, break thermal efficiency for ethanol at compression ratio 9 is almost steady between 2400 and 2500 rpm. Then, it dropped significantly and reached about 12.5% at 3000 rpm. The break thermal efficiency for ethanol at compression ratio 8 went down gradually from 22% at 2400 rpm to about 11.8% at 3000 rpm. The efficiency for ethanol at compression ratio 9 (spark timing 35 degrees) falls roughly 5% between 2400 and 2700 rpm, then it declines significantly to 14% at 3000 rpm.

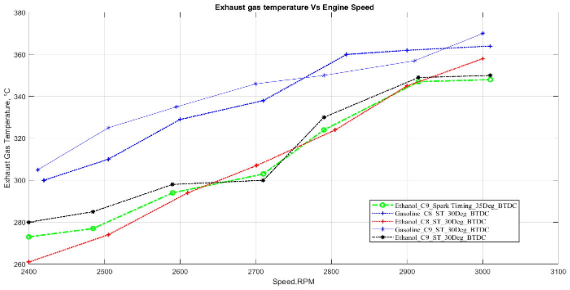

Fig 10. Comparison of Exhaust Gas Temperatures with Varied Speed between Compression Ratio 9 and 8

In Fig 10, the main pattern indicates that the exhaust gas temperature increases with a rise in engine speed. The exhaust gas temperature for gasoline is higher than that of ethanol.

For ethanol, the exhaust gas temperature for compression ratio 8 grows gradually starting from 260 degrees at 2400 rpm to about 356 degrees at 3000 rpm. However, for compression ratio 9, the gas temperature increases moderately between 2400 and 2700 rpm, then goes up to around 350 degrees at 3000 rpm, which is about 7degree lower than that of compression ratio 8.

For gasoline, the temperature for both compression ratios 8 and 9 does not have much difference, commencing with about 300 degrees at 2400 rpm and climbing to about 370 degrees at 3000 rpm.

The temperature for ethanol at compression ratio 9 (spark timing 35 degrees) rises considerably from approximately 275 degrees to 350 degrees, which is about the same as that of ethanol for compression ratio 8.

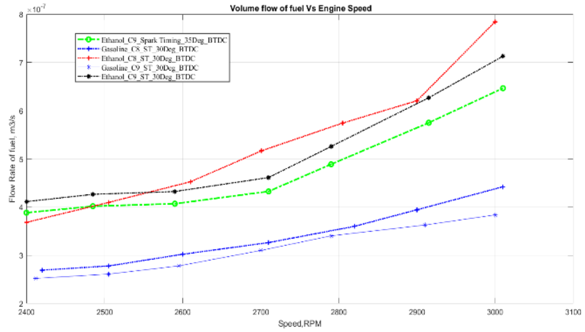

Fig 11. Comparison of Flow Rate of Fuel with Varied Speed between Compression Ratio 9 and 8

In Fig 11, the graph shows that when the speed of an engine increases, the volume of fuel flow increases. There is not much difference in the volume flow of fuel for gasoline at compression ratios of 8 and 9 at 2400 rpm, which is about both of them go up steadily. However, there is a significant difference at 3000 rpm, with 4.4 for compression ratio 8 and 3.8 for compression ratio 9. At 2400 rpm, the volume flow of fuel for ethanol at compression ratio 8 is about 3.7, which is lower than that of compression ratio 9 (4.1). The fuel volume flow for both compression ratios climbs moderately. But, the value for compression ratio 8 starts higher than that of compression ratio 9, beginning at around 2550 rpm. They both then surge and reach about 8 for compression ratio 9 and 4.4 for compression ratio 9.

The volume flow of fuel for ethanol at compression ratio 9 (spark timing of 35 degrees) follows the same pattern as that of compression ratio 9 (30 degree), starting from 3.9 at 2400 rpm to 6.5 at 3000 rpm.

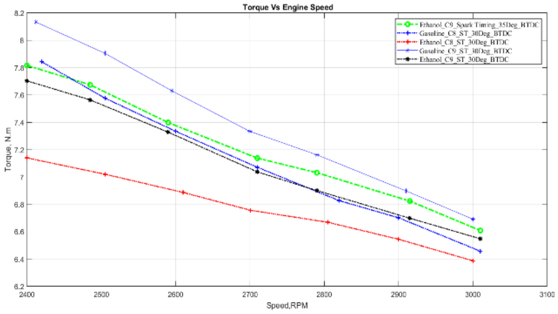

Fig 12. Comparison of Torques with Varied Speed between Compression Ratio 9 and 8

In Fig 12, the line graph indicates that the torque sharply declines with the increase in engine speed. For ethanol at 2400 rpm, the torque for compression ratio 8 is nearly 7.2 N.m, which is approximately 6.8% lower than that of compression ratio 9. The value of torque then slumped significantly with the increase in speed. At 3000 rpm, the torque for compression ratio 9 is about 6.55 N.m, which is slightly higher than that of compression ratio 8, which reaches exactly 6.4N.m. For gasoline at 2400rpm, the torque for compression ratio 9 is approximately 8.15 N.m and for compression ratio 8, the value is around 7.88 N.m. The numbers then fall gradually and reach about 6.7 N.m and 6.45 N.m, respectively, at 3000 rpm. The torque value of fuel for ethanol at compression ratio 9 (spark timing of 35 degrees) declines significantly from 7.8 N.m at 2400rpm to 6.6 N.m at 3000rpm, which is slightly lower than the value of torque for gasoline with compression ratio 9.

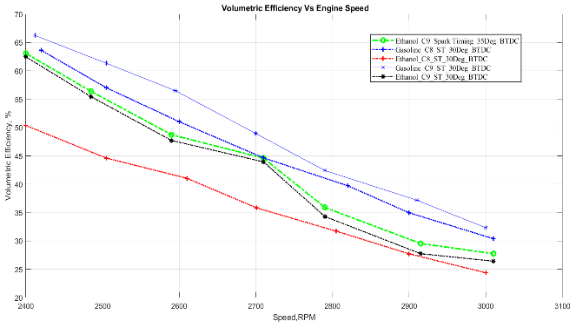

Fig 13. Comparison of Volumetric Efficiencies with Varied Speed between Compression Ratio 9 and 8

The main trend in Fig 13 indicates that volumetric efficiency decreases with the engine speed. The volumetric efficiency for gasoline with compression ratio 9 is the highest, standing at about 67% and that of gasoline with compression ratio 8 is slightly lower at 63%. They both then decline gradually and ending with about 32.5% for compression ratio 9 and 30% for compression ratio 8 respectively at 3000 rpm. For gasoline, there is a huge difference in volumetric efficiency at 2400 rpm, with around 62.5% for compression ratio 9 and 50% for compression ratio 8. While the volumetric efficiency for compression ratio 9 slumped enormously by about 35% at 3000rpm, the value for compression ratio 8 dropped moderately and reached to 25% at 3000rpm. The volumetric efficiency for ethanol at compression ratio 9 (spark timing of 35 degrees) follows a similar pattern with ethanol at compression ratio 9 (30 degree), and reaches to 26% at 3000 rpm.

CONCLUSION

In Myanmar, portable generator is widely used for the deficient electricity not only in urban areas but also in rural areas. One of the most used fuel in portable generators are gasoline. The alternating fuel usage is not much popular in Myanmar, developing countries. However, the price of ethanol in rural areas is cheaper than in urban areas in Myanmar. The ethanol cannot be used directly in gasoline engine. It occurred the sudden engine stall and engine start difficulty. As the side effect, the ethanol has the lower heating value and the more mass flow rate is applied to get the same power output as usage of gasoline. As the advantage, the ethanol can reduce the emission gases such as Nox and carbon monoxide, CO compared with gasoline ("RON92") which is currently available in Myanmar. There is a reason why longer delay period of ethanol can avoid from the detonation problem in combustion. The CL3900 engine is designated for the higher octane number fuel. The high octane number fuels such as E10, E20 and ethanol can reduce engine noise and more stable than the gasoline used in engine. For using only ethanol, the power downgrade is more than 15% than gasoline. To solve this problem, the engine requires to put more fuel (ethanol) in the carburetor. Therefore, the main jet in the carburetor is needed to amplify from 0.8mm (origin) to 1.3mm. Though the mass flow rate is more required, the power can recover to the same amount. After the modification of carburetor, the engine is more stable and it can reduce the engine-starting problem. The brake power of ethanol is 1795 watts at 2400 rpm and that of gasoline is 1985 watts at the same speed. The power is still downgrade up to 10% at that time. The fuel consumption is also more than gasoline because of calorific value of ethanol. The brake specific fuel consumption of ethanol is 0.58kg/kWhr meanwhile that of gasoline is 0.35kg/kWhr at the speed of 2400 rpm. The brake thermal efficiency is 22% and 24% respectively at the speed of 2400 rpm. The volumetric efficiency of ethanol is 50% and the gasoline is approximately 65%. Though the brake power increased at the higher engine speed, 3000 rpm, the gap between the ethanol and gasoline is narrow in the engine performance. It is obvious that there is a limitation to measure the engine performance at the lower engine speed or ideal engine speed because the engine governor controlled to drive the electrical dynamometer. It required the higher engine speed to maintain the engine stability. The modified carburetor is needed to change the fully ethanol in engine. If not, the engine cannot start for the running condition.

The change of compression ratio affects to good advantages. As ethanol has the higher octane number up to 110, the fuel consumption can save up to 16% at the speed of 2700 rpm. The problem is to change the cylinder head manually to get the higher compression ratio. Therefore, two cylinder heads are required to change the compression ratio. After modification of engine compression ratio, the brake power upgraded up to approximately 7% at the speed of 2400 rpm. The same amount of brake power between ethanol and gasoline is 2015 watts at the speed of 2790rpm. After that, the brake power of ethanol is exceeded than that of gasoline at the higher engine speed. The fuel consumption of ethanol is still required more compared with the gasoline. The brake specific fuel consumption of ethanol with modification of compression ratio (55kg/kWhr) differed less from the original compression ratio at the speed of 2400rpm. At the higher speed, the fuel consumption can reduce with higher compression ratio.

CL3900 engine is still needed to modify the advance timing to reach the optimum timing. The more the engine speed, the more the advance timing is required. There is the important factor to find the optimum advance spark timing for the ethanol because the octane number of ethanol is higher than the gasoline. The gasoline octane number is 92 meanwhile the ethanol octane number is in the range of 105 to 110. Therefore, it is stated that the spark timing can be increased for the ethanol to avoid the engine detonation. The optimum spark advance timing is 35º BTDC for the use of ethanol because of the higher octane number of ethanol. After modification of engine spark timing, the brake power of ethanol is 1965watts at the 2400 rpm. The brake powers of ethanol and gasoline are the same at the speed of 2460 rpm. After that, the brake power of ethanol is increased gradually than that of gasoline. The maximum brake power of ethanol is 2080watts at the speed of 3000 rpm, which is surplus up to 3% compared with the gasoline. As the disadvantage, the fuel consumption cannot be recovered compared with gasoline because of the lower calorific value of ethanol. As the benefit, the brake power is saved up to 3% at the higher engine speed.

In conclusion, ethanol's price is lower than that of gasoline in rural areas. It is self-sufficient and provides to environmental sustainability. After modification of advance timing and change of compression ratio, the power can upgrade nearly up to 5% compared with the any modification design using ethanol. However, it will cost the additional charges for this modification.

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