CHAPTER 3

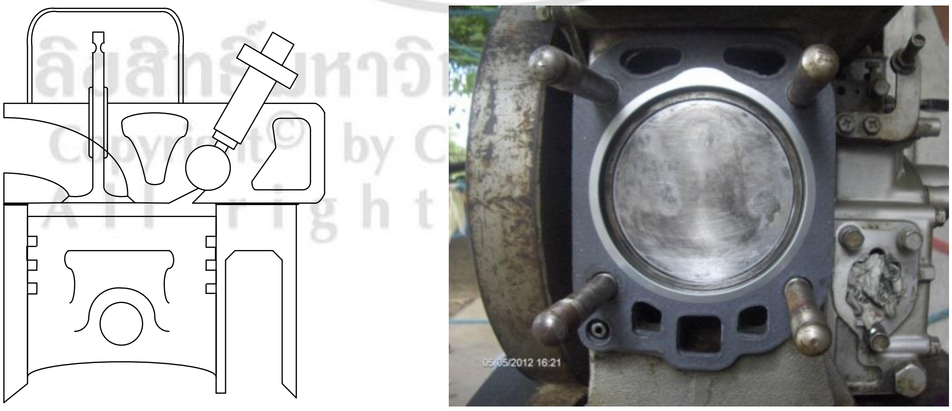
Modification of Small Producer Gas Engine

The objective of this chapter is to explain the need for modifications to be made for the benefit of producer gas. This chapter is divided into three main topics. The first provides original engine configuration. That topic explains characteristics and principles of small diesel engines before modified into spark ignition engine. The second explains the necessary modifications of engine for it to work well with producer gas. The topics are explained by materials and by methods for converting the engine in technical terms. The last topic provides the specifications of modified small producer gas engine. The detail contents of this chapter are as follows.

3.1 Original Engine Configuration

The original engine used here in this work was a small agricultural diesel engine, which is sold in the Thailand market, shown in Figure 3.1. The reasons for choosing this engine are that, the engine is widely used in agricultural, industry and transportation in Thailand. In agriculture, the engine is used mostly for tilling, pumping or as an energy resource for processing crops and is increasing every year from 2011-2013 (DEDE, 2013). The industrial use is as a power source for machinery in factories. The transportation industry uses the engine to power farm and light trucks which are used in north, central and east north of Thailand. Secondly, the engine can be simply, disassembled and modified due to its single cylinder, smaller and uncomplicated components. Importantly, the modification of compression ratio is simple. Furthermore, the diesel engines are stronger and more durable than gasoline engines (Dung, 2012). Figure 3.2 (a) and (b) shows cut-away view of swirl combustion chamber and inner cylinder. The conventional engine is a four-stroke, single cylinder and 21:1 of compression ratio. The displacement is 0.598 liter, rated at 8.2 kW of power output diesel. The cylinder head is flat and two valves, shown in Figure 3.3 (a) and (b). The injection timing is between of 19-21 degree before top dead center. The injector nozzle is pintle type and in a range of 120-125bar at pressure nozzle. In experiment the engine was installed and coupled to a 5 kW of alternator. The detail specification of the conventional engine is given in Table 3.1.

Figure 3.1 Small agricultural diesel engine



(a) (b)

Figure 3.2 Swirl combustion chamber and cylinder head

(a) (b)

Figure 3.3 Cylinder head of diesel engine

Table 3.1 Specification of small agricultural diesel engine (Kubota, 1999)

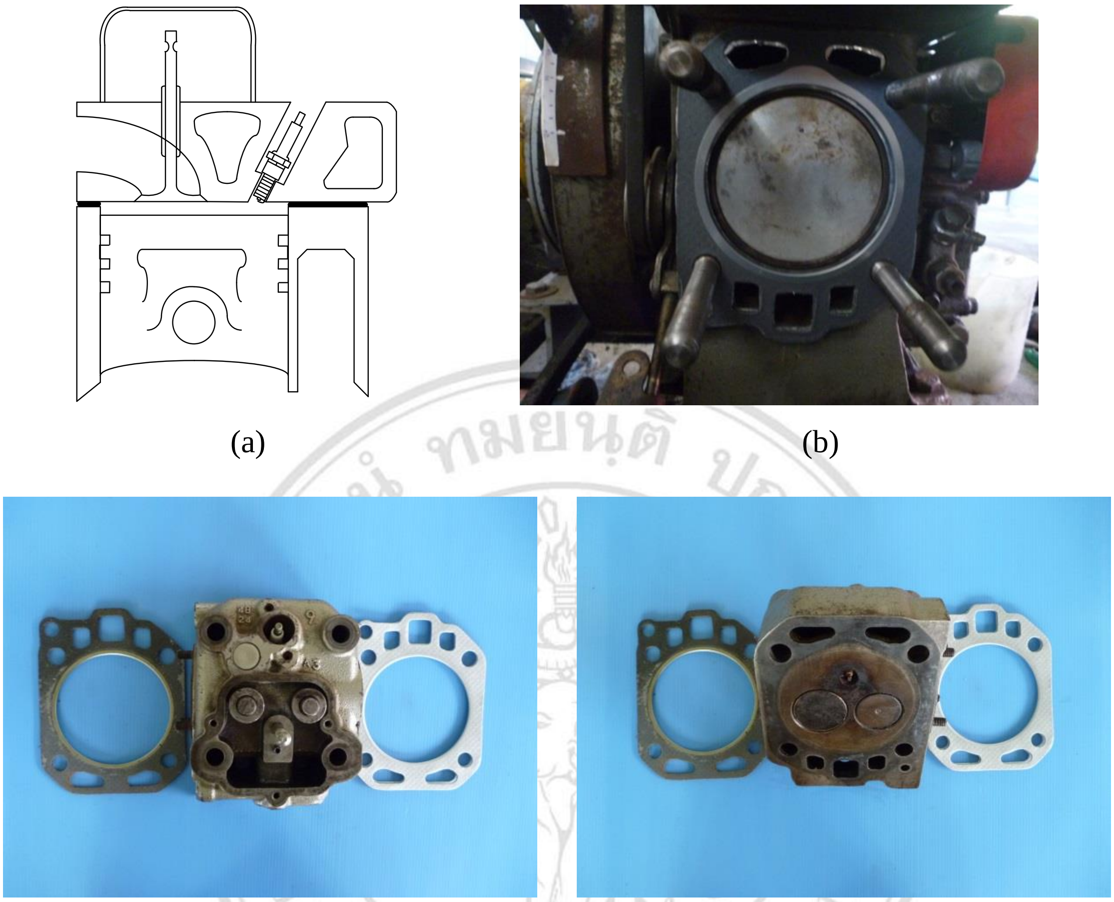
Parameter	Specification
Make and Model	Kubota, ET11, Coupled to a 5 kW alternator
Engine Type	Four stroke, Horizontal, Naturally aspirated
Rated Output (in diesel)	8.2 kW @ 2400 rpm
Net Output (in diesel)	7.0 kW @ 1800 rpm
Type of Cooling	Water, Thermo Siphon System and radiator
Bore x Stroke	92 x 90 mm
Number of cylinder	Single cylinder
Swept Volume	598 cm^3
Compression Ratio	21:1
Combustion Chamber	Swirl and Flat Cylinder Head
Ignition System	Compression
Intake Port	Directed Type
Valve Timing	19-21 degree
Fuel	Diesel
Injector nozzle	Pintle type
Pressure nozzle	120-125 bar
SFC, g/kWh -	2.17 liters/hour
Alternator Efficiency	85%

3.2 Modification of Engine

The SI producer gas engine was modified from a small diesel engine. The detail of modification engine can be divided into four steps. The first is the modification of the combustion chamber and compression ratio, secondly the ignition system, thirdly, the air-gas mixer to replace the diesel fuel injector system and replacement of push rods and stud bolts. The details of modification small CI engine into SI producer gas engine are as follows.

3.2.1 Combustion chamber

Modification of the combustion chamber geometry was carried out on two configurations which include bath tub combustion chamber and cavity combustion chamber. Figure 3.4 (a) shows cut-away view of the bath tub combustion chamber. The combustion chamber is basic in SI engine and the features are simple design. Figure 3.4 (b) shows the piston crown of engine before installing the cylinder head. The piston crown is flat and smooth. The piston and piston ring are similar to the original engine. The clearance of piston ring from measurement is less than standard specification. Figure 3.4 (c) shows the cylinder head that is installed with a spark plug and has two valves. The intake and exhaust valve used are the same as the diesel engine while the auxiliary combustion chamber will be removed and that area will be replaced with flat plate, shown in Figure 3.4 (d). Both ports of cylinder head are similar to original engine. The variable of compression ratio engine was to be in the range of 9.7-17:1. Variable compression ratios were achieved using thicker head gaskets between 4.7-8.2 mm which is commonly used with the gas engine (Siripornakarachai et al, 2007), (Hassan et al, 2009). Figure 3.5 shows the gasket used in the work, including a gasket kit and special gasket. The gasket kit can be bought in parts stores and the thickness of 1.35 mm per sheet. The special gaskets are made from steel and between of 1mm-5mm of gasket thickness.



(a) (b)

(c) (d)

Figure 3.4 Bath tub combustion chamber and cylinder head

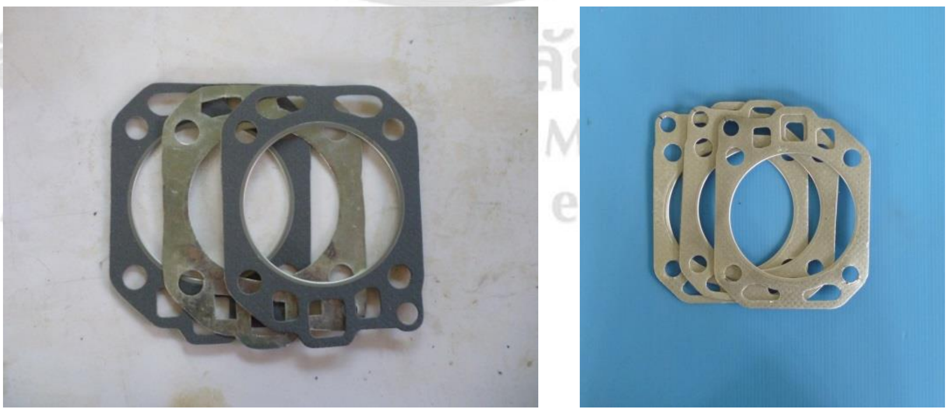
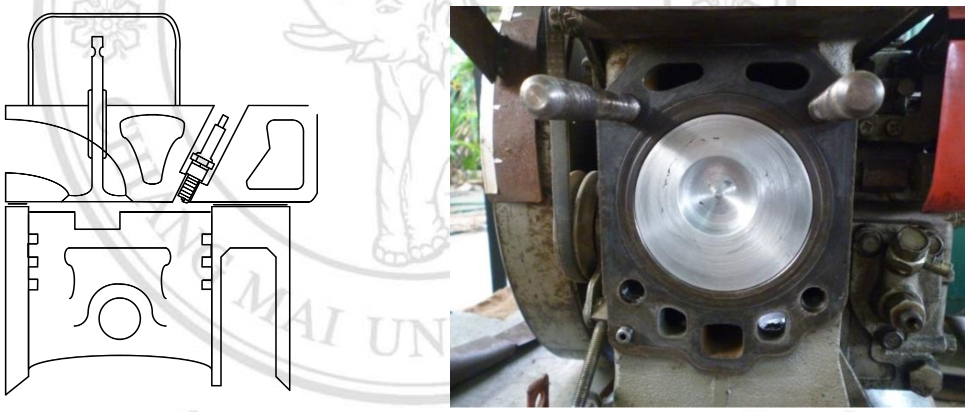


Figure 3.5 Gasket kit and special gasket of cylinder head in modified engine

Figure 3.6 (a) shows cut-away view of the cavity combustion chamber, the piston of this combustion chamber adapted from Kubota engine, model RT110 DI. It is open combustion chamber of small diesel engine. Modification combustion chamber use changing piston crown geometry with thicker head gaskets (Shinde, 2012). The hole of original piston crown is octagonal, and afterwards converted into a circle. Figure 3.6 (b) shows the piston crown of engine which is flat. The cylinder head and other components are the same as previous combustion chamber shown in Figure 3.7 (a) and (b). At 9.7:1, 14:1 and 17:1 of compression ratio, 55mm, 44mm, 40mm of a hollow in piston bowl diameter were used, respectively. The gaskets used in the work were from an original gasket kit. The detail of the thicker head gaskets of both combustion chambers is given in Table 3.2.



(a) (b)

Figure 3.6 Cavity combustion chamber and piston crown

(c)

(d)

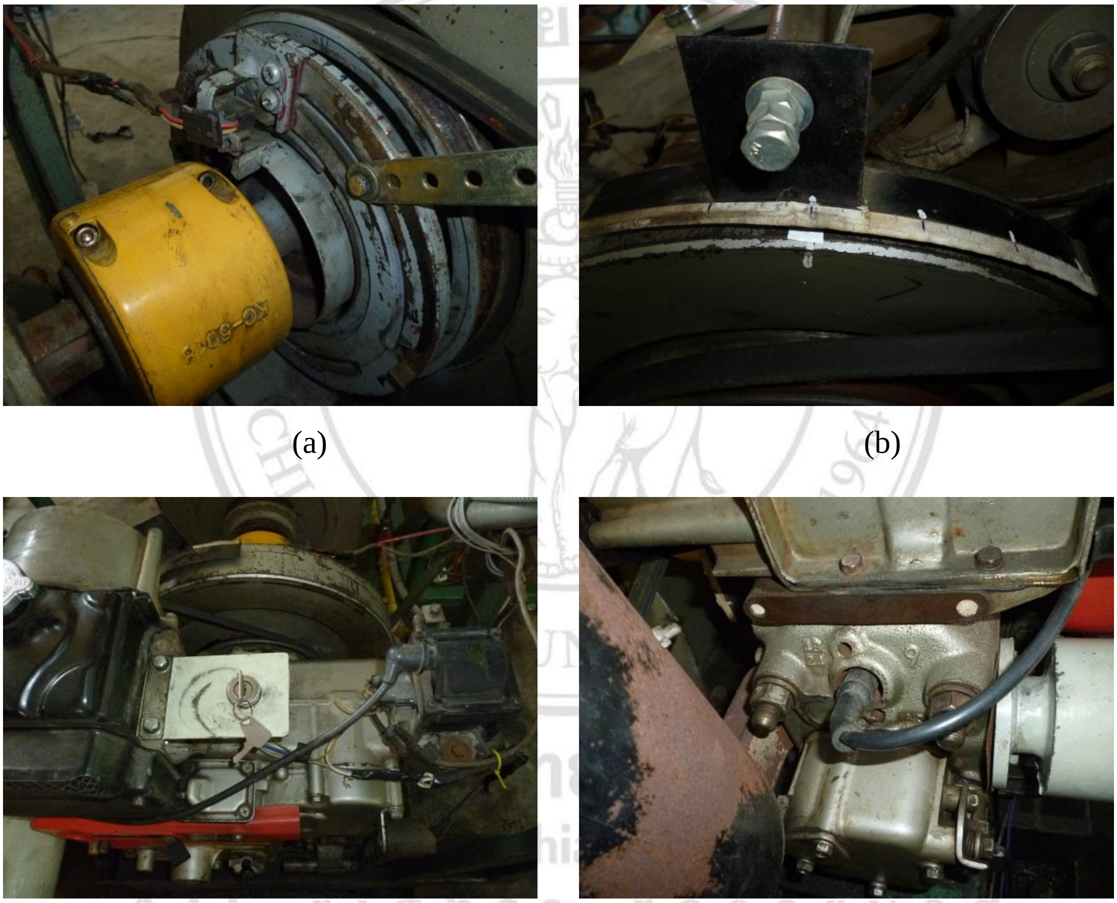
Figure 3.7 Cylinder head of cavity combustion chamber

Table 3.2 Number of gasket of SI producer gas engine

Compression ratio	Combustion chamber	
	Bath tub	Cavity
9.7:1	2 sheet gasket kit (1.7 mm) 1 sheet special gasket (4 mm)	3 sheet gasket kit (1.7 mm) piston bowl diameter (50 mm)
14:1	3 sheet gasket kit (1.7 mm)	2 sheet gasket kit (1.7 mm) piston bowl diameter (40 mm)
17:1	2 sheet gasket kit (1.7 mm) 1 sheet special gasket (0.51 mm)	1 sheet gasket kit (1.7 mm) piston bowl diameter (43.4 mm)

3.2.2 Ignition system

When switched to producer gas, the ignition system is to be changed to a spark ignition system. The overviews of modified ignition system are shown in Figure 3.6. Figure 3.8 (a) shows the installation of the magnetic pick up to produce an electric signal to the ignition system. This magnetic pick up is used as distributor from a Mitsubishi 4G15 engine with three wire connection; 12 volts, ground and signal. The magnetic pick up was installed on a smooth plate, between 3 mm of gap and gear. Figure 3.8 (b) shows the position of top dead center and scale panel for adjusted spark timing of engine. The variability of spark timing can be adjusted in a range of 0° to 60° and operate together with the timing light. Figure 3.8 (c) shows installation of ignition coil and ignition switch on the engine. This original ignition coil installed in electronic ignition system of vehicle and generated voltage in a range of 10-45 kV. Figure 3.8 (d) shows installation of spark plug in the cylinder head. After removal of the auxiliary combustion chamber and surface of the cylinder head made smooth, drilling and tap internal threading of cylinder head was performance (Ponsri et al, 2011).



(a) (b)

(c) (d)

Figure 3.8 Modification ignition system of SI producer gas engine

3.2.3 Air-gas mixer

There are a few air-gas mixers for SI producer gas engines currently available, but most are designed for larger engines. The concept and design can be briefly summarized as follows. Janisch, (1991) designed and patented air-fuel mixing of SI producer gas engine that use gasoline start up before operated on full producer gas. The working principle of the mixing device is that the air flows through an adjustable air venturi and is then mixed with producer gas before flowing to the cylinder, this is a three way model. The increasing of engine speed is controlled with the throttle valve and installed inlet port. Shidhar, (2003) conducted design and manufacture air-gas mixer for the larger engine, that mixer can be used with another gases due to wide stoichiometry. The gas mixers are three ways that use flap areas, separate and adjust the producer gas and air. Producer gas inlet is controlled with zero pressure regulators which use a diaphragm controlled open and close valve seat. The pressure of diaphragm controlled from pressure of air intake. Dasappa et al, (2013) designed and patented air-fuel mixing for producer gas and biogas, that device is modified and improved from air-gas mixer of Shidhar, (2003). The working principle of mixing device is similar. Improvement importance of this air-fuel mixing was adding a by-pass system for start the engine which installed a straddling zero pressure regulators.

From studying the air-gas mixer of SI engine operated on producer gas, the most successful air gas mixer used for the larger engine with a device adjusting air fuel ratio is either a flap or throttle valve. The resolution is lower. However, the adjusting air fuel ratio is needed for small engine with effect on engine speed, acceleration and power output. Therefore, in this work, new air gas mixer that adjusted suitable air fuel ratio for the small SI engine is built. Figure 3.9 shows cut-away view of air-gas mixer for small producer gas engine. The air mixer is three way and mixed with venturi. The air flow through main tube while producer gas mixed from the side and flow through the hole in area of throat venturi before flowing into the cylinder, That was good mixing and acceptable pressure loss (Danardono et al, 2011). Tuning of air fuel ratio was done by adjusting screws whose distance is equally dependent on adjusted gas pressure in the pipes. The photo of air gas mixer components is shown in Figure 3.10. Figure 3.11 shows installed air-gas mixer with small producer gas engine. The metering adjusting screw and throat venturi are made of aluminum.

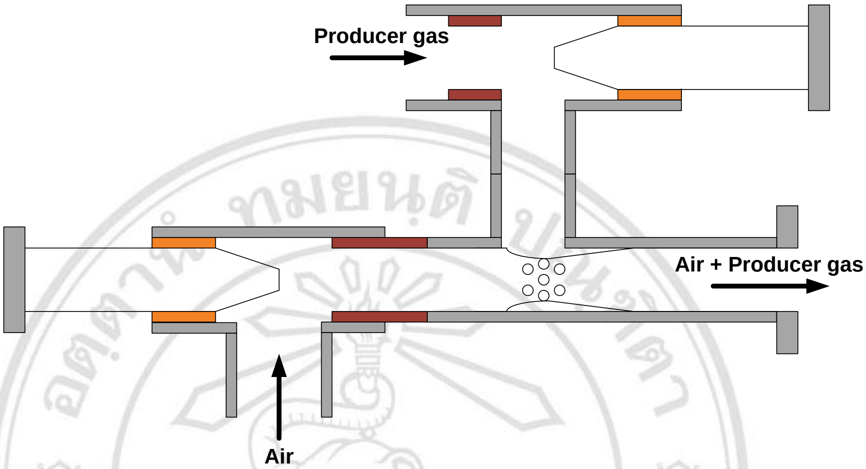


Figure 3.9 Cut-away view of air-gas mixer for small SI producer gas engine

Figure 3.10 Components of SI producer gas engine air-gas mixer

Figure 3.11 Air-gas mixer installed with small SI producer gas engine

3.2.4 Push rod length and stud bolt

Adjusting compression ratio in the combustion chamber led to incorrect clearance of valve contact and rocker arm. Reducing compression ratio needs to increase thickness of gasket cylinder. On the other hand, increasing compression ratio needs to have decreased thickness of gasket cylinder. For various compression ratios, the clearance of valve contact and rocker arm is either decreased or increased. Therefore, in this work, it was needed to modified push rod to comply with the changes. While, stud bolt of cylinder head needed to increase the length to tighten the nuts properly (Siripornakarachai et al, 2008). Figure 3.12 shows the push rod of original and modify engine. The push rod of original engine is shorter than producer gas engine by 5 cm of length. Variable clearance of valve can be adjusted with an additional screw of rocker arm. The clearances of intake and exhaust valve in original engine were 0.025 mm and 0.030 mm, respectively. Figure 3.13 shows comparison of stud bolt cylinder head of original and the modified engine. The stud bolt of modified engine is longer than the original engine by 5 cm and nut off original cylinder head is used.

Figure 3.12 Push rod of original and modified engine

Figure 3.13 Stud bolt of original and modified engine

3.2.5 Overhauled engine

The engine used in this experiment needed to be overhauled as the engine was in used before. The engine overhaul was achieved, following the service manual of KUBOTA. In this work, the procedures of engine performance evaluation began with introduction to overhaul the existing small diesel engine. Then, the diesel engine and diesel-producer gas performance was carried out. Next, the modification to the small diesel engine into SI engine was completed. The first combustion chamber is bath tub and then cavity combustion chamber, respectively. The overhaul existing small diesel engine is shown in Figure 3.14 (a)-(d). The engine parts to be replaced include piston pin, piston pin bearing, connecting rod bearing, piston ring, piston, liner, intake valve, exhaust valve and valve guild. The fuel system, the high pressure pump and injector were repaired and replaced by new components. The modification of the bath tub combustion chamber into cavity combustion chamber was carried out. The piston, piston ring, and geometry of combustion chamber were changed. The characteristics of piston crown of bath tub and cavity combustion chamber in variable compression ratio are shown in Figures 3.15 and 3.16.

(a)

(b)

(c)

(d)

Figure 3.14 Component parts to be removed and replaced from the engine.

Figure 3.15 Piston crown of bath tub and cavity combustion chamber (9.7:1)

Figure 3.16 Piston crown of cavity combustion chamber at 14:1 and 17:1 of CR

3.3 Specification of the Modified Engine

Modification of the compression ignition engine into a spark ignition engine can be summarized. The four procedures include modification of combustion chamber and compression ratio, modification ignition system, design and manufacturing air-gas mixer and modification of push rod lengths and stud bolts. The detail of modifications can be illustrated in new specification of SI producer gas engine. The main differences to the original engine consist of fuel, rated output, compression ratio, combustion chamber, ignition system, ignition timing, fuel distributor and rated speed. The detail of differences between both engine types is shown in Table 3.3.

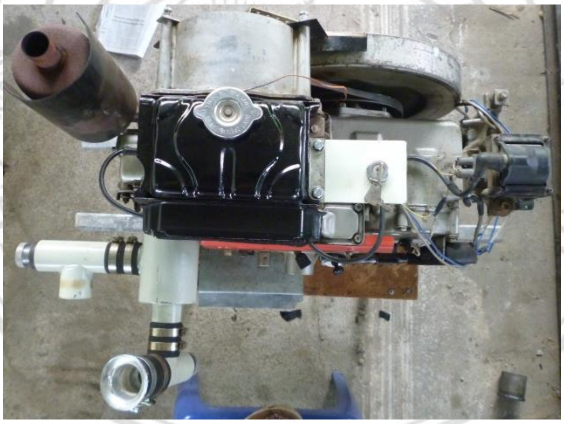
Table 3.3 Specification of original and modified engine

Parameter	Original engine	SI producer gas engine	
	Swirl	Bath tub	Cavity
Make and Model	Kubota, ET11, Coupled to a 5 kW alternator		
Engine Type	Four stroke, Horizon, Naturally aspirated		
Fuel	Diesel	Producer gas	Producer gas
Rated Output	8.2 kW/1800 rpm	3.2 kW/1700 rpm	3.2 kW/1700 rpm
Bore x Stroke	92×90 mm	92×90 mm	92×90 mm
Swept Volume	598 cm^3	598 cm^3	598 cm^3
Number of cylinder	Single	Single	Single
Compression Ratio	21:1	9.7:1-17:1	9.7:1-17:1
Combustion Chamber	Swirl	Bath tub	piston cavity
Cylinder head	Flat	Flat	Flat
Ignition System	Compression ignited	Spark ignited	Spark ignited
Ignition timing	19-21 degree	25-55 degree	25-55 degree
Fuel Distributor	Injector	Air-gas mixer	Air-gas mixer
Rated speed	2400 rpm	1900 rpm	1900 rpm
Type of cooling	Water	Water	Water

Figure 3.17 shows each side of the engine of the modified engine. Effect of modification led to increased width to engine. Figure 3.17 (a) shows side view of the engine. The original engine will be installed in the intake manifold, control adjusting, diesel filter. When the engine is modified, all devices will be removed and installed to replace the air gas mixer. Figure 3.17 (b) shows the opposite side, device of this side has rarely changed, except for installation scale panel for adjusted spark timing. Figure 3.17 (c) and (d) show front and rear view. The size of front view is increased due to installing air gas mixer while the rear view has no added device. Figure 3.17 (e) shows top view of engine. The removal of the fuel tank from the engine and the replacement of the ignition switch with ignition coil can be seem.

(a) (b)

(c) (d)



(e)

Figure 3.17 Side view, front view and top view of modified engine