The Influence of the Piston Head Shape on the Performance of a Single Cylinder Diesel Engine: An Experimental Study

To cite this article: D Khusna *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **462** 012039

IOP Conf. Series: Materials Science and Engineering 462 (2019) 012039 doi:10.1088/1757-899X/462/1/012039

The Influence of the Piston Head Shape on the Performance of a Single Cylinder Diesel Engine: An Experimental Study

D Khusna[1], A Susilo[2], Sudarto[2], A Suharyanto[2]

[1] Department of Mechanical Engineering, Faculty of Industrial Engineering, Institut Teknologi Adhi Tama, 60111 Surabaya, Indonesia
[2] Brawijaya University, 65145 Surabaya, Indonesia

d.khusna2017@gmail.com

Abstract. Air pollution due to motor vehicles encouraged this research to develop proper combustion in the combustion chamber. The combustion in motor vehicles produces not only environmentally friendly combustion but also better engine performance. In a diesel engine, diesel fuel is put into the combustion chamber using injection through a nozzle. This fuel spray is subjected to break up and atomization before getting mixed with air and experiencing combustion in the combustion chamber. Diesel engine combustion chamber with different piston head will affect the combustion process and eventually affect the diesel engine performance. This research used the experimental method with the piston head shapes being tested were a low standard, semi-spherical, and multispherical. While the engine performance sought as a result of changes in the piston head shape are power (N), the use of specific fuel (Sfc), and thermal efficiency (ηth).

1. Introduction

A diesel engine is one type of engine or internal combustion engine with diesel fuel. In the beginning, this engine was discovered by Rudolf Diesel who designed a diesel engine using coal as fuel. However, in the future, the use of liquid oil results in more efficient engine performance. In the history of its application, the Packard diesel engine was used as an aircraft propulsion engine in early 1927, and Charles Lindbergh flew the Stinson SM1B with Packard diesel engine in 1928. The journey of cars with a diesel engine was completed on 6 January 1930. That journey was started from Indianapolis to New York City - as far as 1,300 km. Today, the diesel engine has been widely used in the field of transportation.

The diesel engine is called as Compression Ignition Engine or CI Engine because the combustion process occurs due to compression at high pressure and temperature. The fuel is put into the combustion chamber using injection through a nozzle. The fuel spray from this nozzle is subjected to fogging and atomization [1]. This fogging process is the first step before getting mixed with air and undergoing combustion due to high pressure and temperature.

The excellent mixing process of air and fuel will result in proper combustion. The mixed air and fuel to the combustion chamber happen when the piston goes to the top dead point. As a result, there is a combined flow in the swirl, the flow in the radial direction from the top of the piston crown (squish), and tumble. The flow of this air and fuel mixture is closely related to the shape of the piston head. Therefore, the shape of the piston head affects the combustion occurred [1,2]. On this basis, this research was prepared to determine the extent of the influence of the piston head shape on diesel engine performance.

IOP Conf. Series: Materials Science and Engineering 462 (2019) 012039 doi:10.1088/1757-899X/462/1/012039

2. Theory

2.1 Diesel Engine Performance
The most discussed performances of the diesel engine are power, torque, average effective pressure (BMEP), specific fuel consumption (SFC), and thermal efficiency. Power on a diesel engine is a measure of diesel engine ability to do a work per unit of time. The tool used to measure power is dynamometer. This research used electric dynamometer in which the engine power was measured by the electrical power produced by the generator to ignite the lamp load on the electric circuit. Specific fuel consumption is a measure of the fuel amount needed per unit of power per hour. While the thermal efficiency is defined as the efficiency of using heat from fuel converted into mechanical fuel (shaft). This research did not discuss the average effective pressure and torque because the value can be obtained from the known power.

2.2 Mathematical Model
A mathematical model for calculating generator power, engine power, specific fuel consumption, and thermal efficiency used equations (1), (2), (3) and (4) as follows:

$$N_g = V.I.Cos(\varphi) \quad (1)$$

$$N_e = \frac{N_g}{\eta_g} \quad (2)$$

$$SFC = \frac{3{,}6\dot{m}_f}{N_e} \quad (3)$$

$$\eta_{th} = \frac{10^6 N_e}{\dot{m}_f.LHV} \quad (4)$$

where: V = electrical voltage (Volt); I = electric current (Ampere); cos(φ) = electrical power coefficient; N_g = generator power (watt); N_e = engine power (watt); η_g = generator efficiency; SFC = specific fuel consumption (kg/(watt.jam)); $\dot{m}_f$= fuel (consumption) rate (g/s); η_{th} = engine thermal efficiency; LHV = lower heat fuel value (kJ/kg)

3. Method

3.1 Test Material
Materials tested here were three (3) types of the piston with different piston head shapes, namely flow standard, semi-spherical, and multi-spherical as shown in figure 1.

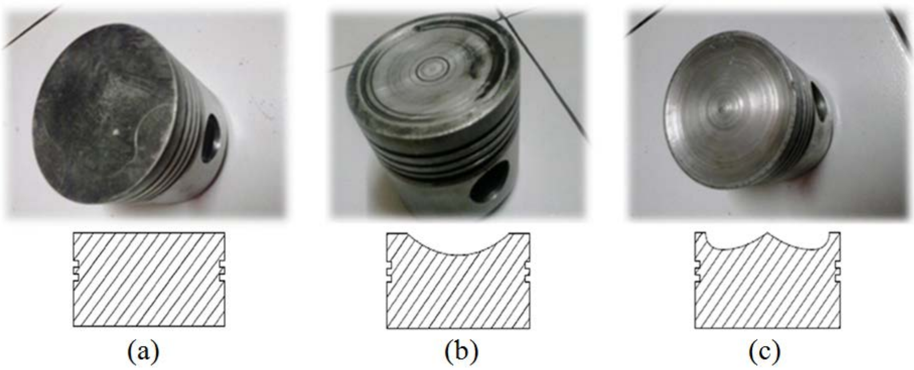

Figure 1. Piston types (a) flat standard, (b) semi-spherical, (c) multi-spherical

3.2 Test Material
The equipment used for this research are listed as follows:

Table 1. Data of Equipment used

No	Equipment	Description/Specification
1	Diesel Engine	7 HP number type of MD175A, one horizontal cylinder block, four steps, 75 mm bore, 80 mm stroke, the compression ratio of 21±1, the standard power of 4.41 kW at 2200 rpm, an injection pressure of 14±0.5 Mpa, water fluid cooling, fuel advanced angle of 21 ± 1^{0}CA
2	Generator	1 phase, 3 kW power, Cos θ = 1, max rpm of 1800 rpm, 50/60 Hz, 0.8 efficiency, 230/115 V voltage, 13/26 A current at 1500/1800 rpm, 70 kg weigh
3	Electric Load Circuit	(for generator loading when measuring engine power)
4	Measuring tube	(for measuring fuel consumption)
5	Amperemeter	(for measuring the electric current when loading)
6	Voltmeter	(for measuring the voltage when loading)
7	Tachometer	Fuji Kogya brand, min/max 10/10.000 rpm, 1 rpm accuracy
8	Stopwatch	Chrono brand (made in Jepang), 0,1 s accuracy
9	Toolkit	(for unloading the engine when changing the piston)

The equipment circuit when testing is shown in figure 2.

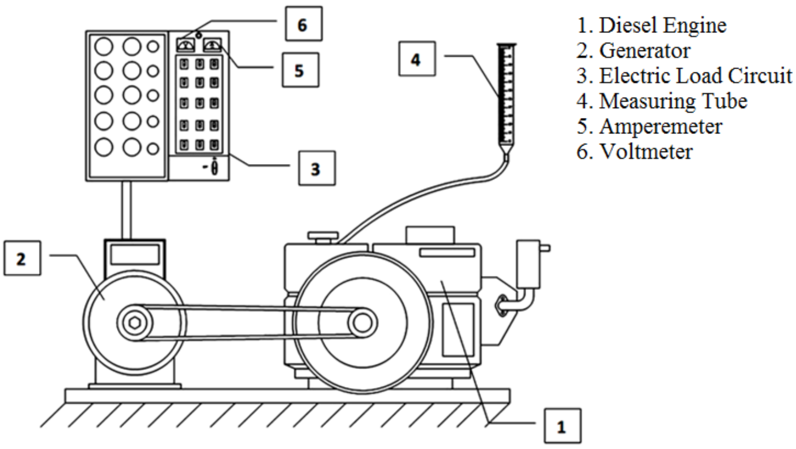

Figure 2. Test equipment circuit

4. Result and Discussion

4.1 Engine Power

Engine power is the power resulted from combustion process in the combustion chamber. The greater the engine speed, the more combustion cycles occurred so that the engine power will increase as well. The increase in engine power with the increase in engine speed can also be predicted theoretically from the mathematical equation of the relationship between power and engine speed.

In the electrical load circuit, the addition of electric load will burden the generator driven by the engine so that the engine rotation will tend to decrease. Therefore, it takes additional fuel to maintain constant engine rotation. Thus, the increase in electricity load will be accompanied by an increase in fuel consumption and vice versa.

In this research, it was found that the use of piston type 2 (semi-spherical) and type 3 (multi-spherical) provided greater power than type 1 (flat standard). The combustion process occurred in diesel engine began with a fogged fuel spray. In this fogging process, there was fuel breakup and atomization, as well as getting mixed with air (oxygen) causing combustion due to high pressure and temperature. In semispherical and multi-spherical piston type, the after chamber in the combustion chamber allowed the air-fuel mixture to swirl, squish, and tumble causing the mixture to be more homogeneous and resulted in better combustion. Better combustion generated better power.

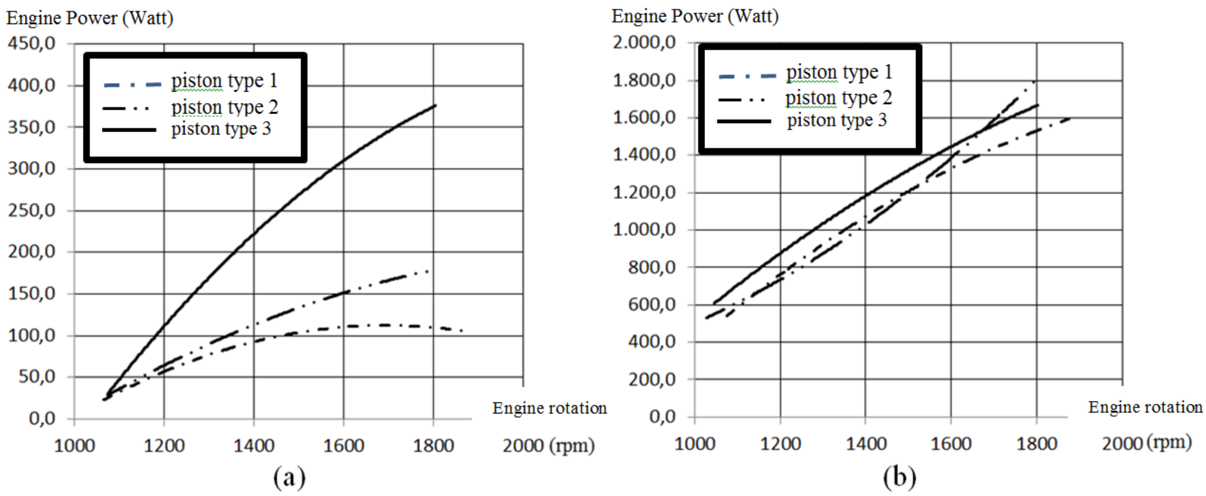

Figure 3. Engine power at (a) 200 W electric load, and (b) 1000 W electrical load

In this research, it was found that at small electrical load (200 W), the percentage of increased power due to the use of piston type 2 and 3 was greater than in greater electric load (1000 W). As previously described, small electric load consumed small amount of fuel. This small fuel consumption caused fuel spray easy to be subjected to fogging which led to good combustion and fast increase of engine power.

4.2 Specific fuel consumption (SFC)

Specific fuel consumption is fuel consumption per unit of power per hour. By using piston type 2 and 3, the increase in power might reduce the specific fuel consumption. The use of piston type 2 and 3 in this research gave a greater percentage of SFC reduction at small electric load (200 W) compared to in greater electric load (1000 W) in the same rotation, as shown in Figure 4. This can be explained since small electric load (200 W) had a higher percentage of power increase. It could also mean that at the same rotation and load, the use of semi-spherical and multi-spherical piston resulted in greater fuel consumption savings compared to the flat standard piston.

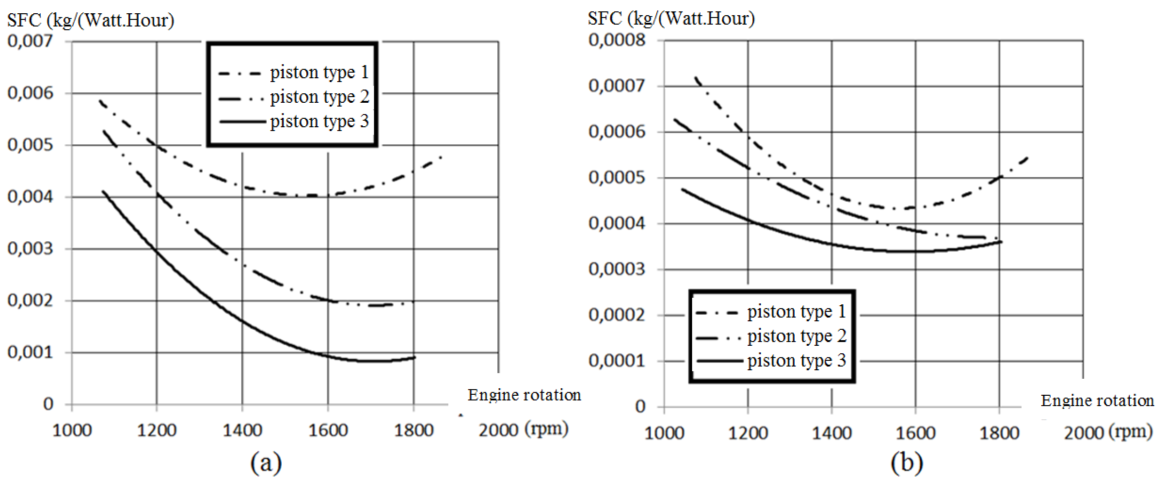

Figure 4. SFC graph at (a) 200 W electric load, and (b) 1000 W electric load

4.3 Thermal Efficiency

As in other internal combustion engines, in this research, thermal efficiency showed a low value on small engine rotation then getting higher with the increase in engine rotation. The low value of thermal efficiency at small electric load (200 W) as in Figure 5 (a) was due to the low output power to rotate the generator. Therefore, with fixed fuel consumption, the effect on efficiency value became low, as if the heat energy from fuel was only used to rotate the engine and generator without any energy (electricity) being used.

The use of semispherical and multi-spherical piston type gave greater efficiency effect since the engine output power was greater. This explanation was similar to the explanation of engine power that in these piston types, fuel spray had a greater chance for breakup in the after chamber of the combustion chamber so that the atomization became more complete and resulted in better combustion.

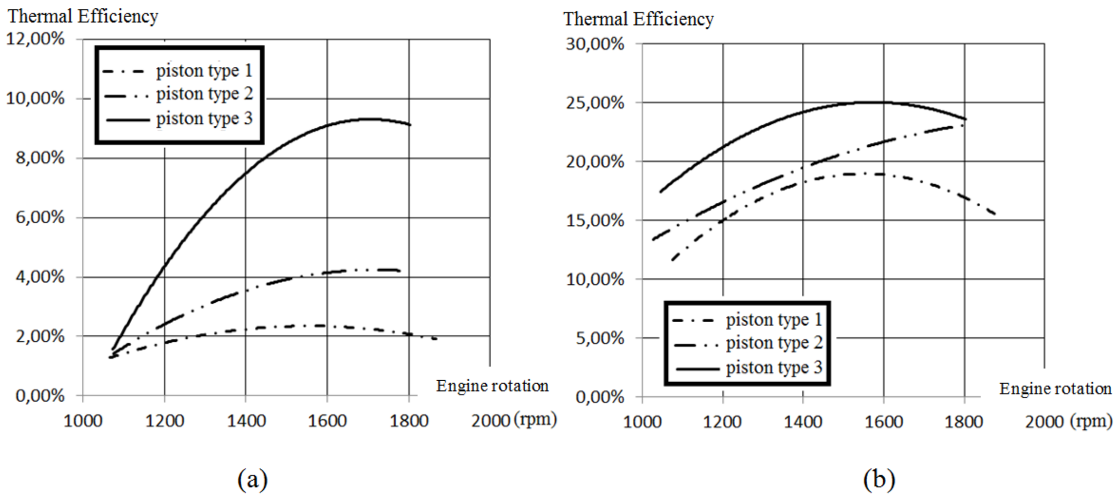

Figure 5. Efficiency graph at (a) 200 W electric load, and (b) 1000 W electric load

5. Conclusion

From this research, it can be concluded that, the use of semi-spherical and multi-spherical piston provided increased power and efficiency as well as reducing specific fuel consumption. The effect of increased power and efficiency, as well as reduced specific fuel consumption, was greater at low electricity load.

6. References

[1] Morris C J and Dent J C 2016 *Proc. Instn. Mech. Engrs.* (Pennsylvania: Pennsylvania State University) Vol 190 41/76
[2] Prasad S L V et al 2011 *Int. J. of Engr. Sci. and Technol. (IJEST)* **3:2** 1571-75
[3] Congbo Y, Zhendong Z, Yuedong S, Tao S and Renjie Z 2016 *J. Engr. Appli. of Comp. Fluid Mech.* **10:1** 311-29
[4] Olumide AT and Ademola AD 2018 *Europ. J. of Engr and Technol.* **6:1** 13-25
[5] Peeraiah M et al 2015 *Inter. J. of Emerg. Trends in Engr. Research (IJETER)* **Vol. 3 No.6** 499-510
[6] Chandrashekharapua R R et al 2012 *J. Transact. of the Canad. Soc. for Mech. Engr.* **Vol. 36 No. 4** 429-438
[7] A. Necati Ö 2017 *Int. J. of App. Sci. and Technol.* **vol**. 1, NO:1, 22-8
[8] Heywood J B 1988 *Internal Combustion Engine Fundamentals* McGraw-Hill, New York p 491.
[9] Hiroyasu H, Kadota T and Arai M 1989 *Development and Use of a Spray Combustion Model to Predict Diesel Engine Efficiency and Pollutant Emission* Bulletin of the JSME vol. 26, no. 24, Paper 214-12, pp. 569-575.

[10] Khusna D 2009 *Karakteristik Semprotan Menumbuk Dinding Piston Type Mexican-Hat Dengan Bahan Bakar Biodiesel Dalam Ruang Bakar Bertekanan* Digital Library ITS Master Theses Rekayasa Konversi Energi Surabaya p 73-9
[11] Wjayanti F and Dadan I 2014 *Analisis Pengaruh Bentuk Permukaan Piston Terhadap Kinerja Motor Bensin* Jurnal Ilmiah Mesin Universitas Islam 45 Bekasi, Vol.02 No.01, 2014
[12] Khusna D and Dhofir M 2016 *Pengaruh Penggunaan Bahan Bakar Biodiesel Hasil Pengolahan Minyak Jelantah dan Solar B0, B20 dan B40 Terhadap Performa dan Emisi Gas Buang Pada Mesin Diesel 2 tak untuk Kapal* Jurusan Teknik Mesin ITATS Surabaya

Acknowledgement

The authors would like to thank the Department of Mechanical Engineering ITATS that has facilitated this research.