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Experimental study of the effect of displacement volume on torque and engine power of the Mandalika Desantara vehicle

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ABSTRACT: As the number of vehicles increases, so does fuel consumption. With the dwindling stock of fuel oil, it has become imperative for humans to find alternative ways to save fuel without compromising vehicle performance. One promising solution is the development of energy-efficient vehicles with improved fuel efficiency, as demonstrated by the MandalikaDesantara Team. Their approach includes modifications such as reducing engine displacement volume by decreasing cylinder volume and increasing the compression ratio. This study aims to investigate the effects of varying displacement volumes (59.13 cc, 85.88 cc, and 97.19 cc) and engine speeds on performance parameters such as torque and effective power. The engine performance tests were conducted using a rope brake dynamometer and gasoline fuel, which has an octane rating of 90. The results indicate that a 59.13 cc displacement volume yields more efficient fuel consumption compared to the other displacement variations (85.88 cc and 97.19 cc). Additionally, the test results revealed the highest torque value of 6.06 Nm at an engine speed of 6000 rpm and the highest power output of 6.377 PS at an engine speed of 7000 rpm for a cylinder volume of 97.19 cc.

KEYWORDS: Piston diameter, Displacement volume, Engine performance, Compression ratio**.**

I. INTRODUCTION

As the number of vehicles increases, fuel consumption also increases. As fuel stocks decrease, various efforts need to be made in an effort to save fuel by finding new alternatives that do not reduce vehicle performance. Now, the automotive industry is focusing on increasing energy efficiency. The goal is to reduce energy consumption but increase vehicle efficiency[1],[20]. One solution is to make energy-efficient vehicles with better fuel efficiency. Energy-efficient vehicles are not only about replacing the energy sources used[3], or no longer using fossil fuels but also about how to use the vehicle's fuel to be more efficient and of course more environmentally friendly[2]. One way to overcome the energy crisis in the automotive sector, especially in vehicles, is to hold the Shell Eco-marathon competition. Shell Eco-marathon is an event to develop innovative mobility solutions in designing, manufacturing, testing and driving future vehicles that meet safety elements and can travel the furthest distance using minimal energy sources. Shell Eco-marathon is an activity open to all international students[6]. This event challenges young people around the world to work together in teams and explore transportation solutions and energy challenges today and for the future. The categories of vehicles competed are prototypes and urban concepts[16].

MandalikaDesantara is a team competing in the Shell Eco-marathon Asia Pacific & Middle East competition from the University of Mataram, West Nusa Tenggara. One of the modifications made to the vehicle engine is reducing the vehicle's cc in order to save fuel consumption. The solution used to reduce the vehicle's cc is by reducing the cylinder volume by reducing the piston diameter from 50 mm to 39 mm and increasing the engine compression ratio in order to reduce fuel consumption. Many methods are used to save vehicles, one of which is by changing the cylinder volume and increasing the compression ratio of the vehicle's engine. Where the cylinder volume is influenced by the piston diameter and piston stroke[14],[15]the piston is an important part of the main engine in compression which produces a compressive force that causes the motor to work. When the piston moves from TDC to BDC, the

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suction valve opens, and air enters the cylinder. Then, when the piston moves from BDC to TDC, the intake valve and exhaust valve close, and the air in the cylinder is utilized, increasing the air pressure and temperature [13].

The piston stroke volume (displacementvolume) is the amount of cylinder volume when the piston is at the top dead centre (TMA) until the piston is at the bottom dead centre (BDC)[8]. The amount of cylinder volume will affect the amount of power produced by the engine[8], [9]. The larger the cylinder volume, the more fuel and air mixture can be sucked into the cylinder so that this will affect the engine performance of the vehicle[17]. Where the cylinder volume also affects the compression ratio[4]. The compression ratio is the value indicated by the comparison between the engine cylinder volume and the combustion chamber volume. The compression ratio is the result of dividing the total volume by the remaining volume of the combustion chamber (clearance volume)[19].

Based on research by Mara, et al., (2018)[10] regarding the analysis of exhaust emissions and motorcycle power at reduced cylinder volume, it was found that reducing the piston diameter can reduce: fuel consumption, motorcycle power and exhaust emissions produced by the vehicle. Many studies have been conducted to understand the relationship between volume displacement and fuel efficiency in various types of vehicles[5], [7], including motorcycles. This research is important considering that fuel efficiency not only has an impact on the user's operating costs, but also on the greenhouse gas emissions produced.

From the description above, this study wants to study and find out how the effect of cylinder volume variation on the engine performance of energy-efficient vehicles of the MandalikaDesantara team in the prototype internal combustion engine (ICE) category, especially on fuel consumption by varying the cylinder volume with the cylinder volume (97.19 cc, 85.88 cc and 59.13 cc) and determining the compression ratio. This study aims to analyse the effect of displacement volume on engine performance and engine fuel consumption.

II. EXPERIMENTAL SET UP

This study uses an experimental study method, using two research variables, namely dependent variables and independent variables. The dependent variables in this study are engine performance parameters (torque, effective power, fuel consumption, and specific fuel consumption effective) while the independent variables consist of variations in cylinder volume (59.13 cc, 85.88 cc, and 97.19 cc) and engine speed (4000 rpm, 5000 rpm, 6000 rpm, and 7000 rpm). The schematic diagram is as shown in Figure 1

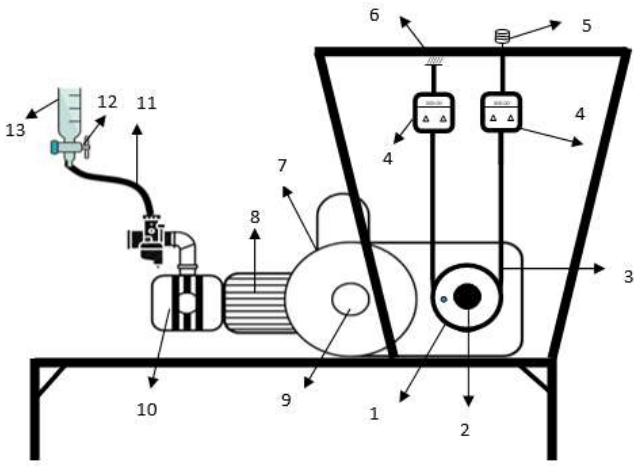

Figure 1. Layout of rope brake dynamometer test equipment layout of test equipment: (1) pulley, (2) Output shaft, (3) Rope, (4) Digital balance, (5) Load adjusting bolt, (6) Lock, (7) Engine Prototype, (8) Cylinder block, (9) Magneto, (10) Cylinder head, (11) fuel line, (12) Fuel tank valve, (13) Burette.

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The tools and materials used in this study are as follows:
1. Rope brake dynamometer
2. Tachometer, Burette, stopwatch, tools set, gloves, digital scales, and rope
3. Cylinder head gasket, cylinder block gasket, glue, fuel, cylinder head, and cylinder block
4. Prototype vehicle engine

The stages carried out in this study are the process of changing the cylinder block, the process of installing the piston, installing the cylinder block, the process of installing the cylinder head, assembling the rope brake dynamometer test tool, and calibrating the measuring instrument.

III. RESULT AND DISCUSSION

3.1 Determination of Displacement Volume and Compression Ratio

Tabel 1. Ratio compression

Piston diameter (mm)	Displacement Volume (cc)	Clearance Volume (cc)	Ratio compression
39	59,13	7,5	8,88:1
47	85,88	11	8,81:1
50	97,19	12,5	8,78:1

From table 1 above, the combustion chamber volume of each cylinder volume variation is different, this is due to the adjustment of the piston and cylinder diameters which are reduced and adjusted to the size of the piston diameter used. So that the smaller the piston diameter, the cylinder volume (Vd), the combustion chamber volume (Vc) is also smaller and the resulting compression ratio is attempted to remain the same or close to the same. So in this study, an attempt was made to determine the compression ratio by reducing the thickness of the cylinder head in the volume clearance section to adjust the combustion chamber volume to the cylinder volume.

3.2 Engine torque

The following table 2 displays the torque data in Newton meters produced by the engine at 4000–6000 rpm using a displacement volume of 59.19 cc, 85.88 cc and 97.13 cc

Table 2. Engine Torque (Nm)

Engine revolution	Displacement volume		
	59.19 cc	85.88 cc	97.13 cc
4000 rpm	2.71	3.92	4.79
	3.09	3.37	4.67
	2.81	3.81	4.59
Average	**2.87**	**3.70**	**4.68**
5000 rpm	3.53	4.76	4.92
	3.42	4.39	4.90
	3.35	4.33	4.89
Average	**3.43**	**4.49**	**4.90**
6000 rpm	4.07	4.90	6.00
	3.81	4.86	6.14
	4.07	4.82	6.03
Average	**3.98**	**4.86**	**6.06**

In general, the data shows that with increasing rpm (revolutions per minute) and displacement, the resulting value also increases. This can be interpreted that engines with larger displacement tend to produce higher performance at higher rpm speeds. In other words, the larger the displacement of the engine, the higher the value achieved at each rpm level. The lowest torque is obtained at an engine speed of 4000 rpm with a displacement volume of 59.19 cc, which is 2.87 Nm and the highest torque is produced at an engine speed of 6000 rpm with a displacement volume of 97.13 cc, which is 6.06 Nm.

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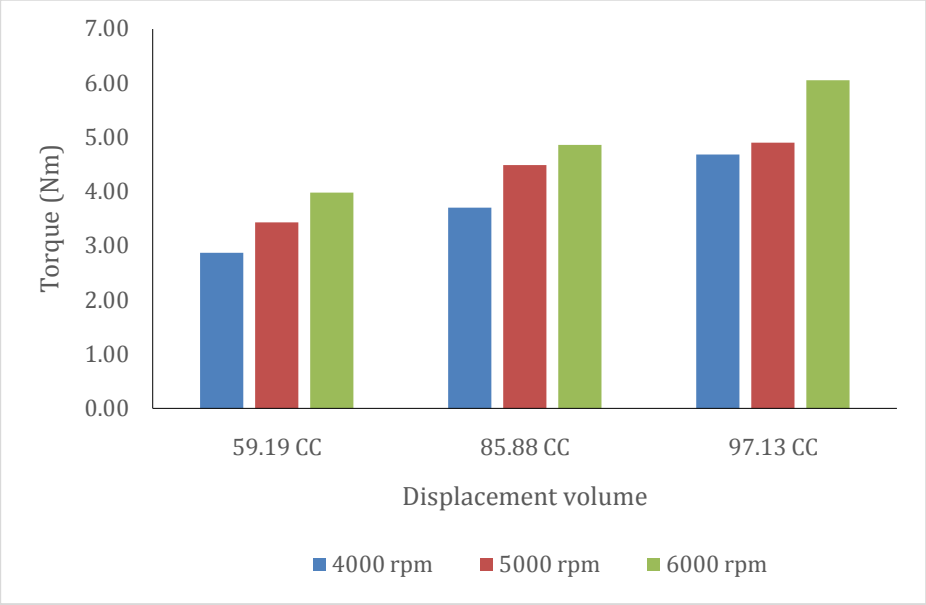

Figure 2. Relationship between torque and engine speed

Based on Figure 2, it can be seen that the torque generated increases directly proportional to the increase in engine speed. The torque generated through fuel combustion increases because the amount of fuel entering the combustion chamber increases as the engine speed increases. However, the torque will decrease when the torque reaches its maximum torque limit. At higher engine speeds, more air-fuel mixture can enter the cylinder. This increases the volume of combustible gas and produces more power[18]. With a higher air-fuel mixture, combustion in the cylinder produces higher pressure. This pressure pushes the piston with greater force, producing higher torque. This means that the force generated by the combustion pressure is applied to the crankshaft arm more quickly and more frequently, increasing the amount of torque generated. This is similar to research[10],[11], [12].

At a cylinder volume of 59.19 cc produces the lowest average torque value compared to cylinder volumes of 85.88 cc and 97.19 cc at an engine speed of 4000 rpm. The torque produced at an engine speed of 4000 rpm from a cylinder volume of 59.19 cc is 2.87 Nm, a cylinder volume of 85.88 cc produces a torque value of 3.70 Nm and a cylinder volume of 97.13 cc is 4.79 N.m. Of the three average torque values, there is an increase in torque from a cylinder volume of 59.19 cc to 97.13 cc by 28.95%. At 5000 rpm engine speed, the cylinder volume of 59.19 cc obtained a torque value of 3.43 N., the cylinder volume of 85.88 cc produced a torque of 4.49 Nm and for the cylinder volume of 97.13 cc obtained a torque value of 4.90 N. the difference between the lowest torque value and the highest torque value at 5000 rpm engine speed of 25.60%. For 6000 rpm engine speed from the three variations of cylinder volume the torque value increased where the torque value at 59.19 cc cylinder volume was 3.98 Nm, at 85.88 cc cylinder volume the torque value was 4.86 Nm and for 97.13 cc cylinder volume was 6.06 Nm. Where at 6000 rpm engine speed the maximum torque is obtained, so that at 7000 rpm engine speed there is a decrease in torque in each variation of cylinder volume. At the cylinder volume of 59.19 cc there is a decrease of 11.36% from the engine speed of 6000 rpm to 7000 rpm, for the cylinder volume of 85.88 cc it decreases by 13.05% and the cylinder volume of 97.13 cc decreases by 13.18% from the engine speed of 6000 rpm to 7000 rpm. It can be seen that the variation of the cylinder volume affects the torque produced

3.3 Engine Power

Table 3 shows the engine power data in PS produced by the engine at 4000-6000 rpm using a displacement volume of 59.19 cc, 85.88 cc and 97.13 cc.

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Table 3. Engine power (PS)

Engine revolution	Displacement volume		
	59.19 CC	85.88 CC	97.13 CC
4000 rpm	1.47	2.12	2.59
	1.67	1.83	2.53
	1.52	2.06	2.48
Average	**1.55**	**2.00**	**2.53**
5000 rpm	2.41	3.25	3.36
	2.34	3.00	3.35
	2.29	2.96	3.34
Average	**2.35**	**3.07**	**3.35**
6000 rpm	3.36	4.05	4.95
	3.15	4.01	5.07
	3.36	3.98	4.98
Average	**3.29**	**4.01**	**5.00**

Table 3 shows the engine power values at various engine displacement volumes and engine speeds. The lowest engine power was obtained at a displacement volume of 59.19 cc and an engine speed of 4000 rpm of 1.55 PS, while the highest engine power was obtained at an engine speed of 6000 rpm and a displacement volume of 97.13 cc of 5.00 PS.

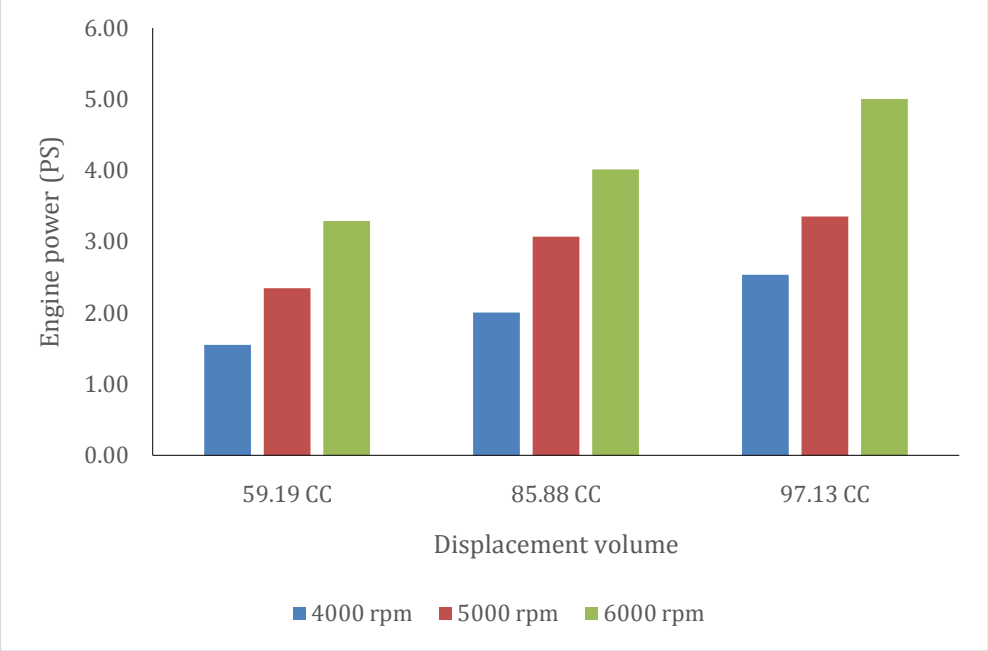

Figure 3. Relationship between effective power and engine speed

From Figure 3, it is known that the effective power generated is directly proportional to the engine speed, where the effective power increases as the engine speed increases. This is because the amount of fuel entering the combustion chamber increases as the engine speed increases, for high engine speeds the fuel requirement per unit time increases so that the energy generated through combustion per unit time will be greater. In addition to the engine speed affecting effective power, torque also affects power, which means that the greater the torque, the greater the effective power. Where in this study, the maximum effective power occurred at an engine speed of 7000 rpm

(±100 rpm) for each variation of the cylinder volume used. When viewed from the variation of the cylinder volume used, the greater the cylinder volume used, the greater the maximum effective power value produced and vice versa. This is in accordance with research [10],[11].

At 4000 rpm engine speed the highest average effective power value is found in the cylinder volume of 97.19 cc compared to the cylinder volume of 85.88 cc and 59.13 cc. The average effective power value at 4000 rpm for the cylinder volume of 97.19 cc is obtained at 3.182 PS, the cylinder volume of 85.88 cc is 2.673 PS and the cylinder volume of 59.13 cc is 2.261 PS. From the three variations of cylinder volume there is a decrease of 28.94% from the cylinder volume of 97.19 cc to the cylinder volume of 59.13 cc. At 5000 rpm engine speed there is an increase in the average value of effective power from each variation of cylinder volume used, while the percentage increase in effective power from 4000 rpm engine speed to 5000 rpm engine speed at 97.19 cc cylinder volume is 25.22%, at 85.88 cc cylinder volume is obtained by 30.68% and for 59.13 cc cylinder volume there is an increase in the average value of effective power by 28.58%. For 6000 rpm engine speed there is also an increase as in 5000 rpm engine speed, where at 97.19 cc cylinder volume there is an increase of 26.95% from 5000 rpm engine speed. Likewise at 85.88 cc cylinder volume there is an increase of 24.27% and for 59.13 cc cylinder volume there is an increase of 33.08%. At 7000 rpm engine speed there is an increase in the average effective power as occurs at 6000 rpm engine speed, but the increase in effective power at 7000 rpm engine speed is not too high, this is because there is a decrease in torque at 7000 rpm which affects the power produced by the engine. The increase in the percentage of effective power produced by the cylinder volume of 97.19 cc from 6000 rpm engine speed to 7000 rpm engine speed is 0.3%, at 85.88 cc cylinder volume is 0.43% and for 59.13 cc cylinder volume is 2.34%.

IV. CONCLUSION

Based on the results of the analysis and discussion of the research on the effect of cylinder volume variations on the engine performance of energy-efficient vehicles of the Mandalika Desantara team in the prototype internal combustion engine (ICE) category. The engine performance parameters analyzed include torque, effective power, fuel consumption and specific fuel consumption effective. The highest average torque value is produced at a cylinder volume of 97.19 cc of 7,700 N.m and the lowest torque is produced by a cylinder volume of 59.13 cc of 5,248 N.m at an engine speed of 6000 rpm. The highest average effective power value is produced at a cylinder volume of 97.29 cc of 6,377 PS and the lowest effective power is produced by a cylinder volume of 59.13 cc of 4,438 PS at an engine speed of 7000 rpm.

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