International Journal of Applied Engineering Research ISSN 0973-4562 Volume 13, Number 12 (2018) pp. 10598-10603
© Research India Publications. http://www.ripublication.com

Correlation between Camshaft Overlap Degree and Power, Torque and Fuel Consumption on 150 CC Four Stroke One Cylinder Otto Engine

Bhirowo Wihardanto[1], Wegie Ruslan[2], Djoko Setyanto[3]
[1,2,3]Mechanical Engineering Department, Faculty of Engineering,
Atma Jaya Catholic University of Indonesia,
Jalan Jenderal Sudirman No.51, Jakarta Indonesia 12930

Abstract

The performance of a one-cylinder four-stroke engine can be improved by changing camshaft overlap degree. In this paper will be presented the performance of one cylinder four stroke 150 cc otto engine with parameters to be considered are power, torque and fuel consumption on various degrees of camshaft overlap of 17 º, 23 º, 27 º (OEM Value) dan 30 º. The test is done on one-cylinder four-stroke 150 cc otto engine. At 27 º (OEM Value) condition, maximum power is 13.6 hp @ 9,500 RPM, maximum torque is 11.84 Nm @ 8,000 RPM, and fuel consumption is 30 km / L. Test results show that 30 º condition produces maximum power at 14.15 Hp @ 10,000 RPM and it is the largest among the variations of camshaft overlap degree tested. The 23 º condition produces maximum torque at 12.15 Nm @ 7.500 RPM and it is the largest among the variations of camshaft overlap degree tested. For fuel consumption, the condition of 17 º spent 1 Liter of fuel for 34 km distance.

Keywords: camshaft, power, torque

INTRODUCTION

There are many methods that can be used to improve the performances of motorcycles engine. Porting and polish, change exhaust gas channel design, increase compression, and change the camshaft overlap degree are some methods to improve the performances of the engine. The modification of camshaft overlap degree will affecting the degree of the opening state of intake valves and exhaust valves when both the intake valves and exhaust valves are opened at the same time, so that affecting the power and torque produced by motorcycles [1]. The time taken when the intake valves and exhaust valves in an open state simultaneously affecting the amount of gas production, as air and fuel mixture product, which is affecting power and torque.

Camshaft overlap degree in DOHC one cylinder four stroke otto engines is to be studied in this paper. Research of camshaft overlap degree in one cylinder four stroke otto engines performance is done to compare power, torque, specific fuel consumption and actual fuel consumption on each camshaft overlap degree studied. The objective of this research is to inform that power, torque, specific fuel consumption dan actual fuel consumption can be the increased or decreased by the modification of camshaft overlap degree.

BASIC THEORY

Camshaft is one of the most important components that can be analyzed to improve the performance of Otto Engine. The camshaft is designed to open the valve before the piston starts the step and closes it after the step, in order to streamlined the momentum or inertia of the fuel and air mixture movement during the four-step otto cycle. The camshaft placed in two locations, in the cylinder head (OHC) dan near crankshaft (OHV) [2].

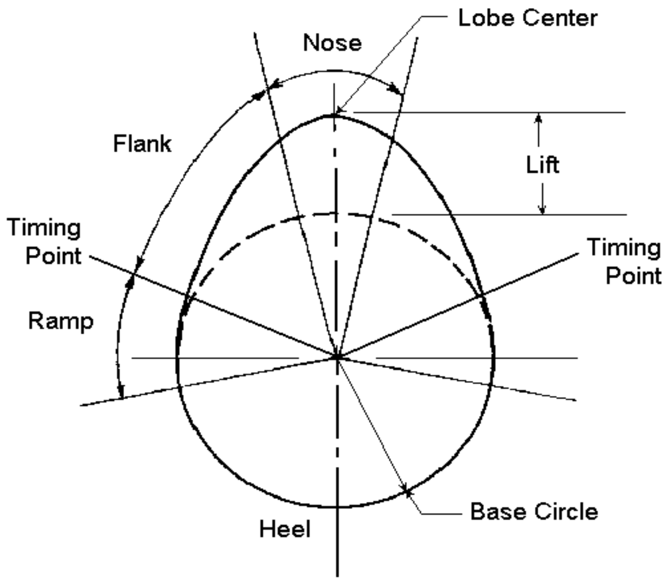

Figure 1. Camshaft [2]

In general, camshaft is made of aluminum and white metal mixture that can reduce heat due to friction with valve mechanism components. The camshaft has three points of loading, friction on the camshaft pad, bending on valve presses, and torque caused by the pull of the camshaft drive (chain / timing-belt) [3]. In Figure 2 is valve mechanism components. Camshaft starts pressing the valve lifter, the valve lifter pushes the valve so that the valve is opened.

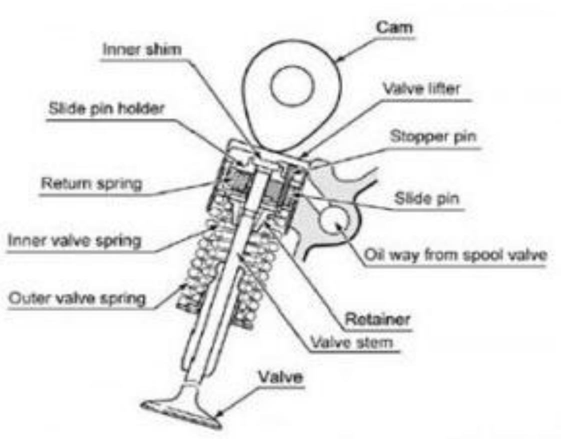

Figure 2. Valve mechanism components [4]

Overlap is the number of degree degrees when the exhaust valve closes and the inlet valve opens at the same time as shown in Figure 3. The number of overlap degrees affects both idle and low speed. At high rpm the time taken when the inlet valve opens is very short, the discharge of exhaust gas through the exhaust valve resulting vacuum condition in the combustion chamber, thus helping to suck the air and fuel mixture into the combustion chamber through the inlet valve. Increasing the overlap degree not only increase the upper limit of the rpm at the maximum power, but also will decrease the power at low rpm. It also reduces the burning quality at idle rpm because the exhaust gas can be pushed #out through the intake channel, thus blocking the entry of air and fuel [1].

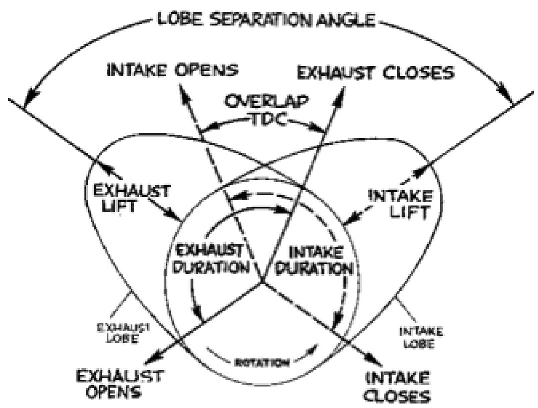

Figure 3. Camshaft Movement Diagram [5]

RESEARCH AND METHODOLOGY

The type of experiment conducted is pure experiment with the objection to analyze the causal relationship of the data obtained from the testing performed.

Testing parameters as follow:

A. Power and Torque Testing

Power and torque testing done using *dynamometer*. Testing procedure as shown below:

1. Prepare the motorcycle and turn on the engine on idle condition, about 1,500 rpm for a few minutes so that the engine reachs working conditions.
2. Place the motorcycle onto the dynamometer and fasten the knot so that the motorcycle remains in the center position.
3. Perform the testing using four different camshaft.

B. Specific Fuel Consumption Testing

Specific fuel consumption testing done using *dynamometer*. Testing procedure as shown below:

1. Prepare the motorcycle and set up the dynamometer to adjust the desired rpm. Turn on the engine for a few minutes so that the engine reachs working conditions on a stationary lap.
2. Measure 100 ml of fuel using measuring cup and put it in a bottle as fuel tank substitute.
3. Adjust the fuel hose position to bottle that had contained 100 ml of fuel.
4. Run the motorcycle at 5,000 rpm speed until the engine is off because run out of fuel. Use stopwatch to find out the running time.
5. Repeat steps with varied rpm, 7,000 rpm and 9,000 rpm.
6. Repeat step (1) – (5) with varied *camshaft*.

C. Actual Fuel Consumption Testing

Actual fuel consumption testing held in the street. Testing procedure as shown below:

1. Prepare the motorcycle and turn on the engine on idle condition. Pour 1 Liter of fuel into fuel tank.
2. Record the starting odometer as the starting point to determine the mileage.
3. Drive the motorcycle at 60 – 130 Km/hour speed until the fuel tank is out of fuel.
4. Record the odometer when the fuel tank is out of fuel and motorcycle is no longer able to run again.
5. Repeat the steps with varied camshaft.

Testing Equipment

Dynamometer

Equipment used is Dynojet 200i with the following specifications:

Max Speed (*Continuous*)	: 322 km/h
Max Tractive Effort	: 750 FT LBS
Max Power	: 750 HP
Drums	: 1
Drums Width	: 41.59 cm
Drums Diameter	: 45.72 cm
Operating Temperature Range	: 0 ºC to + 70 ºC

Camshaft

There are four types of camshaft overlap degree used in this study. The camshaft specification can be seen in Table 3.1.

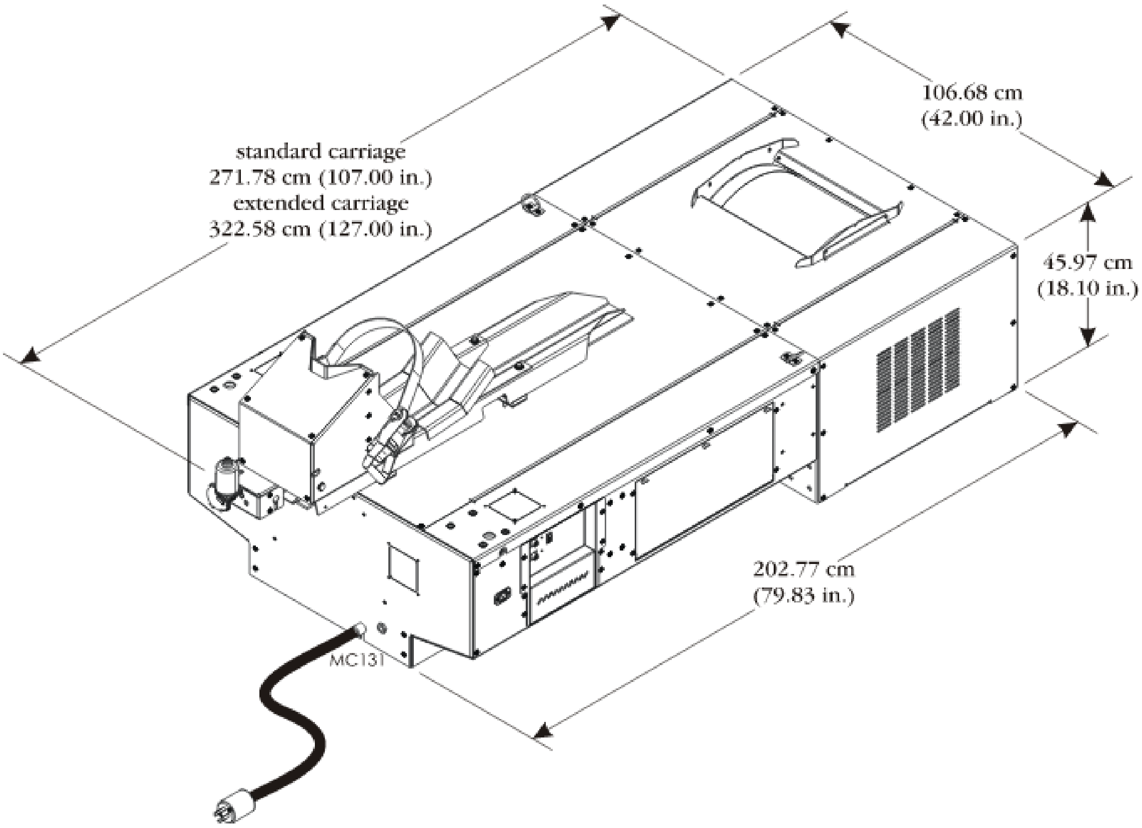

Figure 4. Figure of Dynojet 200i [6]

Table 1. Type of Camshaft Overlap Degree

No.	*Inlet Valve*			*Exhaust Valve*			*Camshaft Overlap Degree*
	Open	Close	Degree	Open	Close	Degree	{Open Inlet Valve + Close Exhaust Valve }
1	10^{O} BTDC	47^{O} ABDC	237^{O}	43^{O} BBDC	7^{O} ATDC	230^{O}	17^{O}
2	13^{O} BTDC	44^{O} ABDC	237^{O}	40^{O} BBDC	10^{O} ATDC	230^{O}	23^{O}
3	15^{O} BTDC	42^{O} ABDC	237^{O}	38^{O} BBDC	12^{O} ATDC	230^{O}	27^{O} (OEM Value)
4	17^{O} BTDC	40^{O} ABDC	237^{O}	37^{O} BBDC	13^{O} ATDC	230^{O}	30^{O}

Test Machine

Testing machine used is one-cylinder four-stroke 150 cc engine:

Table 2. Engine Specification [7]

Engine type	1 cylinder , 4 stroke
Dimension	1.960 mm x 675 mm x 980 mm
Weight	109 kg
Diameter	62 mm
Stroke	48,8 mm
Volume	150 cc
Compression ratio	10,5 : 1
Stationary	1.500 rpm
Cooling	Air and Oil Cooling
Ignition system	Capasitive Discharge

Figure 5. Engine Test Placement above Dynamometer

RESULTS AND DISCUSSION

A. Power Test Results

Result of power test using dynamometer shown in graph below. The graph indicates relation between power and engine rotation as shown in Figure 6.

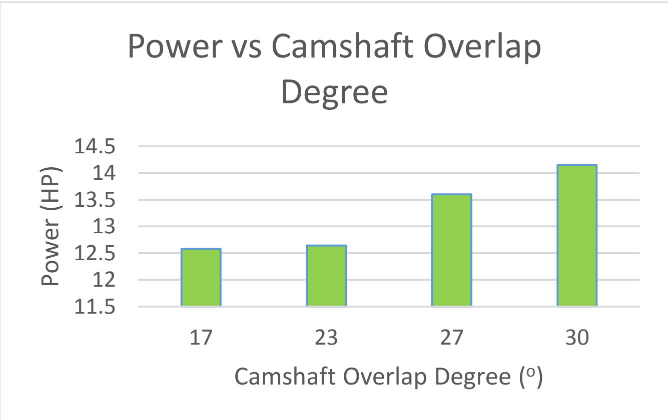

Figure 6. Relation between Power and Camshaft Overlap Degree

Figure 6 indicates the power of each camshaft. Maximum power at 23^{O} camshaft overlap degree is 12.64 HP at 9,350 rpm. After replacing camshaft overlap degree into 17^{O}, maximum power number decreased into 12.58 HP at 8,900 rpm. It can be seen that power number decrease 0.47%. Meanwhile, after replacing camshaft overlap degree into 27^{O} generates power at 13.6 HP at 9,250 rpm rotation. It can be seen that there was increasing of 7.5%. In the camshaft overlap degree 30^{O}, the result was increasing of 14.15 HP at 10,050 rpm. In the last combination, the power increase significantly 11.94% compared to OEM Value condition. In Figure 6 shows a linear relationship between camshaft overlap degree and power generated. The greater camshaft overlap degree, the greater power generated. This is because of fuel - air mixture volume entered is getting bigger so that can drive the combustion process during the usaha (work) - compression cycle. The fuel - air mixture used optimally during the combustion process.

B. Torque Test Results

Results of torque testing using dynamometer show in Figure 7. The graph indicates relationship between torque generated by engine rotation and camshaft overlap degree as shown in Figure 7. Maximum torque generated by the engine in camshaft overlap degree 27^{O}, that is 11.84 Nm at 8,100 rpm rotation. Installation 23^{O} camshaft overlap degree generates maximum torque 12.15 Nm at lower engine rotation, that is 7,550 rpm. It can be seen torque increased 2.61%. Meanwhile, after replacing the camshaft with 17^{O} camshaft overlap degrees, torque decreased to 11.75 Nm at 8,255 rpm rotation. It can be seen that torque decreasing occurred at number 0.76%. 30^{O} camshaft overlap degree generates torque at 11.35 Nm and 7,900 rpm. In this last combination, torque decreases significantly, that is 4.13%. Figure 7 shows that between camshaft overlap degree and torque generated are not linearly connected. This is because of the different characteristics between the fuel-air mixture and combustion product trapped in the combustion chamber. It will produced different force on pistons for each camshaft overlap degree.

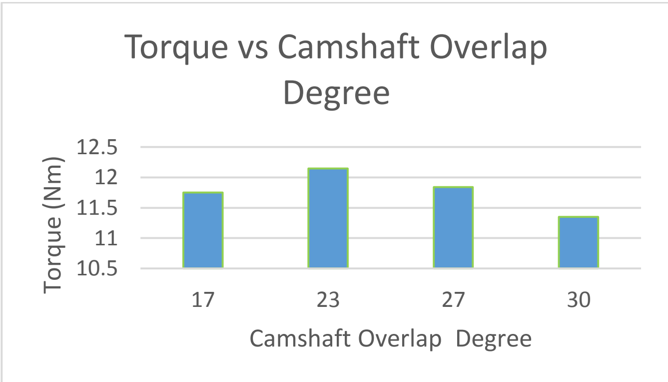

Figure 7. Relation between Torque Generated and Camshaft Overlap Degree

C. Correlation Between Camshaft Overlap Degree and RPM and Specific Fuel Consumption

This test is performed to determine changes in specific fuel consumption after camshaft changing.

According to Heywood, other factors affecting specific fuel consumption are the homogeneity of the fuel mixture, the availability of O_2 to react with fuel, time taken for combustion process (depending on engine rotation), compression ratio of combustion chamber, and design of the combustion chamber itself [3]

The graph of the specific fuel consumption can be seen in Figure 8.

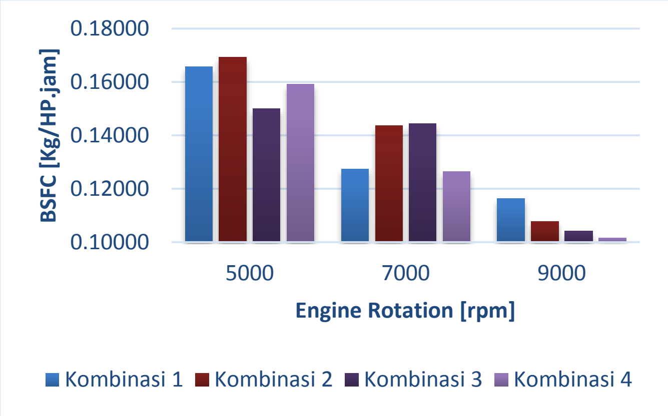

Figure 8. Specific Fuel Consumption Graph

In Figure 8, it can seen the results of specific fuel consumption testing at 5000 rpm, 7000 rpm, and 9000 rpm engine rotation. It is clear that on the same camshaft, BSFC number will decrease in higher engine rotation. This is because the fuel and gas mixture burned efficiently at higher speeds engine rotation.

➢ **5000 RPM**

In 17^{O} camshaft overlap degree, BSFC number is lower 2.09% compared to 23^{O} camshaft overlap degree. Lower BSFC number also occurs at 30^{O} overlap camshaft degree, that is lower 5.93% compared to OEM Value conditions. The lowest BSFC number in 5000 rpm condition occurs at 27^{O} camshaft overlap degree, that is 11.39%. At 5000 rpm condition, 27^{O} camshaft overlap degree is variant with the highest efficiency of fuel and gas mixture combustion compared to other combinations.

➢ **7000 RPM**

In 17^{O} camshaft overlap degree, BSFC number 11.26% lower than the OEM Value combination and decrease 24.13% compared to BSFC number at 5000 rpm. If compared to OEM Value conditions, the 30^{O} camshaft overlap degree has lower BSFC number at number 11.97%, and decrease at number 20.63% compared to 5000 rpm condition. For 27^{O} camshaft overlap degree, BSFC number 0.58% higher compared to OEM Value combination and decrease 3.73% compared to 5000 rpm condition. In 7000 rpm condition, 17^{O} camshaft overlap degree and 30^{O} camshaft overlap degree almost have same BSFC number. 17^{O} camshaft overlap degre and 30^{O} camshaft overlap degree have same combustion efficiency at 7000 rpm condition.

➢ **9000 RPM**

In 17^{O} camshaft overlap degree, BSFC number is higher 7.89% compared to 27^{O} camshaft overlap degree and decrease at number 29.78% compared to BSFC number at 5000 rpm condition. If it is compared to 27^{O} camshaft overlap degree, 30^{O} camshaft overlap degree has BSFC number 5.86% lower and decrease at number 36.24% compared to 5000 rpm condition. 23^{O} camshaft overlap degree has BSFC number 3.38% lower compared to OEM Value combination and decrease 30.52% compared to 5000 rpm conditions. In rpm 9000 condition, 30^{O} camshaft overlap degree has the highest efficiency of fuel and gas mixture combustion, compared to other combinations.

Figure 8 shows that between camshaft overlap degrees and specific fuel consumption number are not linearly connected. This is because in each engine rotation variable, each camshaft overlap degrees has different load, inertia and air-fuel mixture characteristics with combustion results trapped in the combustion chamber, so that resulting different forceon piston for each camshaft overlap degrees.

D. Result of Actual Fuel Consumption Testing

From the actual fuel consumption test result that has been done by running motorcycle on the road obtained graph of the relationship between the mileage that can be traveled and the camshaft overlap degree, as shown in Figure 9.

Figure 9 shows a linear relationship between camshaft overlap degree and mileage that can be traveled. The greater camshaft overlap degree, the closer mileage that can be traveled. This is because the greater camshaft overlap degree, the greater volume of air-fuel mixture inserted into the combustion chamber so that the distance reached will be closer than the smaller camshaft overlap degree.

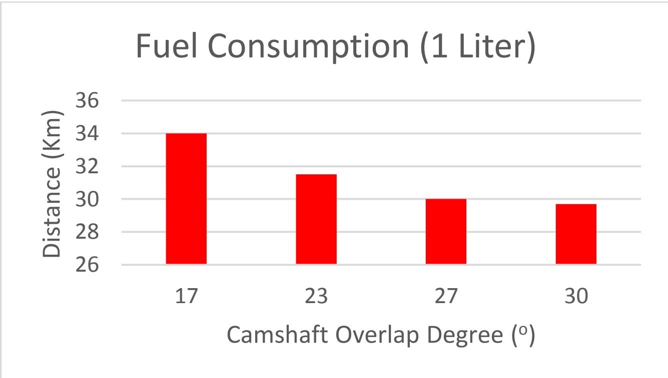

Figure 9. Relation between Actual Fuel Consumption and Camshaft Overlap Degrees.

CONCLUSION

From the testing results and analysis it can be concluded:

A. Camshaft overlap degree affect torque number generated. The higher camshaft overlap degree generates lower torque number compared to OEM Value condition. The lower camshaft overlap degree generates higher torque number compared to the OEM Value condition.

B. Camshaft overlap degree affect power generated. The higher camshaft overlap degree generates higher power compared to OEM Value condition. The lower camshaft overlap degree generates lower power compared to OEM Value conditions.

C. By changing camshaft overlap degree, specific fuel consumption is lower than OEM Value conditions in various engine rotation conditions.

D. Using 30^O camshaft overlap degree resulted the lowest actual fuel consumption. It is also 8.35% lower than the 27^O camshaft overlap degree condition (OEM Value condition).

E. Camshaft overlap degree and power are linearly correlated. The greater camshaft overlap degree, the greater the power.

F. Camshaft overlap degree and torque are not linearly correlated.

G. Camshaft overlap degree and specific fuel consumption are not linearly correlated.

H. Camshaft overlap degree and mileage traveled are linearly correlated. The greater camshaft overlap degree, the closer the mileage traveled.

SUGGESTION

After testing and analysis done, it is necessary to conduct further research and improvement such as:

A. Addition of the variation of camshaft overlap degree to get more data to be analyzed (power, torque, specific fuel consumption and actual fuel consumption)

B. Addition of LSA (*Lobe Separation Angle*) degree. Addition of variables at testing and analyzing stage for sharper and deeper analysis.

C. Same AFR (*Air Fuel Ratio*) at each camshaft overlap degree in actual fuel consumption testing, both on dynamometer and on the road.

D. Camshaft forming using CNC machine to get uniform form of camshaft.

E. Each camshaft formed using same material in any testing.

F. Dynamometer operator expected having professional certificate or competency OEM Value in *running* the dynamometer.

REFERENCES

[1] Des Hammil, How To Choose Camshafts & Time Them For Maximum Power, Veloce Publishing Ltd, 2002.

[2] A. Graham Bell, Four Stroke Performance Tuning, Haynes Publishing Ltd, 1998.

[3] J.G. Giles, Engine Design, Iliffe Books Ltd, 1968.

[4] Prasanna Sutrave, "www.engihub.com," 2017. [Online]. Available: https://www.engihub.com/valve-mechanism-of-i-c-engine/[Diakses 24 Februari 2018].

[5] Prasanna Sutrave, "www.corksport.com," 2016. [Online]. Available: https://corksport.com/blog/new-product-mazdaspeed-camshafts-for-disi-mzr-motor/ [Diakses 24 Februari 2018].