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# DETERMINATION OF OPTIMUM VALVE OPENING AND HEIGHT IN THE AUTOMOTIVE ENGINE

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**ABSTRACT**

The effects of the valve opening and opening height are very crucial in internal combustion engine. The optimum setup for the opening cam high and timing of camshafts in engines will improve fuel economy and exhaust gas emission. This improvement can be obtained from intake (inlet) valve timing and also from exhaust (outlet) valve timing. The challenging technique is to set up the engine to the optimum valve opening and closing for inlet and outlet in the combustion engine and to synchronize the timing of valves under range of speeds of the engine. The objective of this paper is to determine the optimum setup of engine cams to increase the efficiency. A small engine with one piston has been used to find the best valve opening and closing by replacing cams and then drawing graphs of loads for five different camshafts. The best points that give the highest load for the engine in a rage of speeds will be indicated after drawing the graphs. At the low engine speed, it was found the engine requires high breathing to give high efficiency and then required low breathing to get the best load among the designed camshafts and then earlier breathing. It was found also the improvement reached to 15% increase in load from the original setup after decreasing the inlet cam height by 3 mm at certain point of speed. The result highlights the importance of designing a flexible camshaft that can change its cam size and angle at the same time during engine operation to give more efficiency to engines.

**Keywords:** optimum valve timing, inlet valve open, engine manufacturing, combustion engine.

## INTRODUCTION

The optimization of intake and exhaust valve timing can provide significant reductions in pumping losses at part load operation [1-4] by changing the cam shape, height, and timing. And since one of biggest challenges among automotive industries is how to reduce automotive gases and increase engine power, this research uses one of new method to find the optimum valve timing. Different trials will be tested under variable timing of inlet and exhaust valves. Load graphs will be drawn for of each cam at different position and height then results will be compared.

Controlling the cams is one of the ways to achieve the best point of loads that increase the efficiency of the engine and reduce the harmful gases in the environment. The optimum shape and angle of the cam is changing according to engine speed and the challenge is how to change the cam angle and height at the same time. There are many researches done to solve that problem but mostly target angle, size or height of cams and that could be applied in some automotive industries but for discrete or for certain range of speeds.

There are two main types of internal combustion engine which are the spark ignition and compression ignition (CI). In the (SI) engines (petrol, gasoline, or gas engines), fuel ignition is caused by a spark. But in compression ignition (CI) engines (diesel engines), the pressure and temperature rise high enough to ignite the fuel. Valves are used in these engines to control the induction and exhaust processes.

Both types of engine are designed to operate in either two strokes of the piston or four strokes of the piston. The four-stroke operating cycle can be explained by reference to Figure-1. This figure describes the position of the piston and valves during each of the four strokes. As explained below:

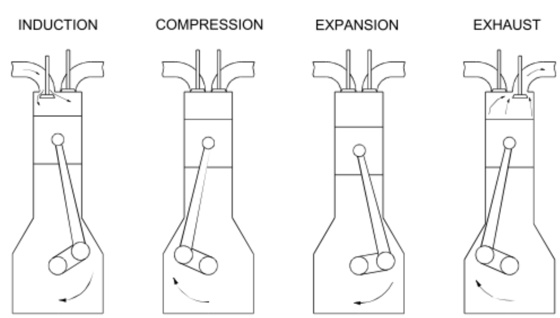


**Figure-1.** Four-stroke engine cycle.

1. During the induction stroke, the inlet valve is open. The piston moves down the cylinder and suck air or air with fuel mixture in some other types.

2. In the compression stroke, Inlet and exhaust valves are closed. The piston moves up the cylinder and

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cause compression to the volume and then after the piston approaches the top of the cylinder top dead center (TDC), the ignition occurs and burns the mixture of fuel. The former engines has mixture enters through the valve inlet but in modern engines direct injection (DI) is used and fuel is injected towards the end of the stroke.

3. In this step, the expansion stroke Combustion occurs causing a pressure and temperature to rise and lead to push the piston down. At the end of the stroke the exhaust valve opens.

4. The exhaust stroke, the piston moves up while exhaust valve is still open forcing exhaust gases out of the cylinder.[5]

The amount of air intake per unit engine displacement should govern the quantity of fuel that can burn and hence it influences the engine power and the fuel efficiency. When this amount changes to more or less then it will affect the power and load of the engine. [6]

## VARIABLE VALVE TIMING (VVT)

Figure-2 shows, results of engine performance simulated at various inlet valve opening (IVO) timing. It was found that by changing the (IVO) timing alone, it significantly affects the engine performance. By advancing the (IVO) timing (from standard, the break torque BT and volumetric efficiency VE get increased at high engine speeds. However at low engine speeds, they are reduced significantly. These behaviors are reversed when the timing is retarded. [7]

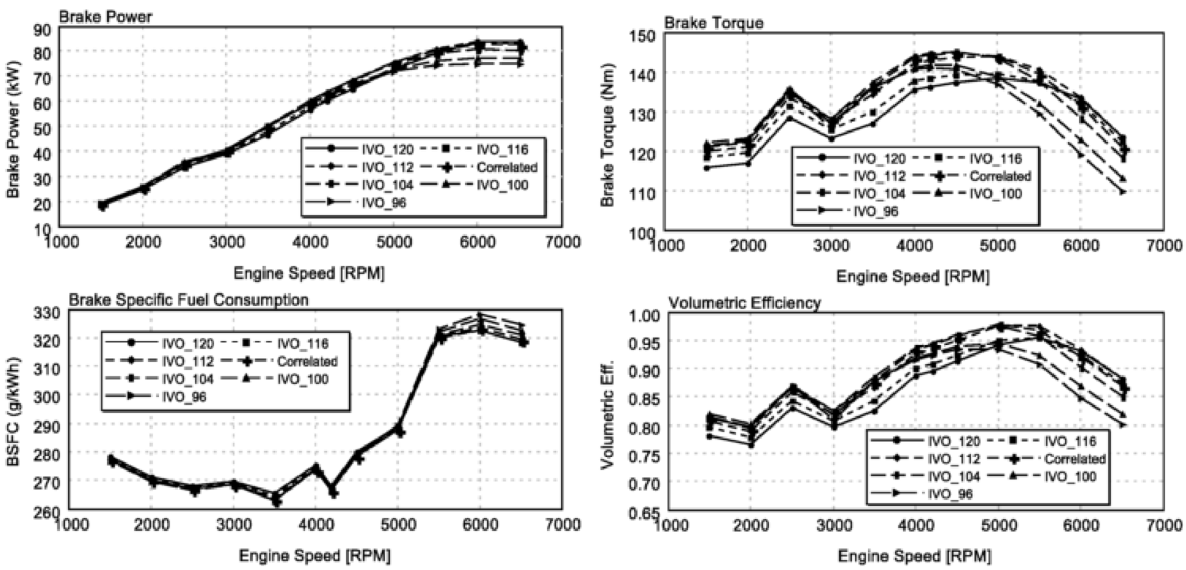


**Figure-2.** Effect of inlet valve open timing on engine performance.

A theoretical computational fluid dynamics (CFD) experimental investigations showed a significant improvement in engine power when using minimum intake valve lift, the fuel consumption decreased by 18.2%, [8]

The timing (or phase) of opening and closing of the intake (inlet) and exhaust (outlet) valves is determined by the valve lift profiles. In a conventional engine this timing is fixed at a value that represent the best compromise between conflicting requirements for idle speed quality, fuel-economy, low-speed torque, and power. Normally, the exhaust valve opening (EVO) occurs before the end of the power stroke to allow earlier release of the hot exhaust gas that is resulting in reduced pumping losses during the subsequent exhaust stroke. The exhaust valve closes just after the cylinder reaches the top dead center (TDC) at the end of the exhaust stroke [9] . (VVT) is used in spark ignition automotive engines to improve fuel economy, reduce NOx gas, and increase peak torque and power [10]

(VVT) is one important technique for improving the fuel economy of the gasoline engine [11].

To understand better the (VVT) systems, a close look over Figure-3 will reveal the parameters of gas exchange device.

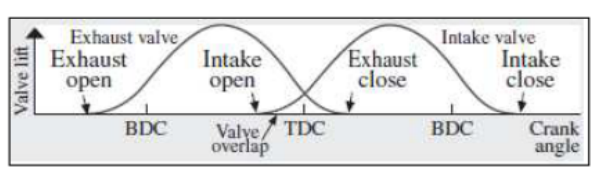


**Figure-3.** Opening, closing timing and lift of intake and exhaust valves.

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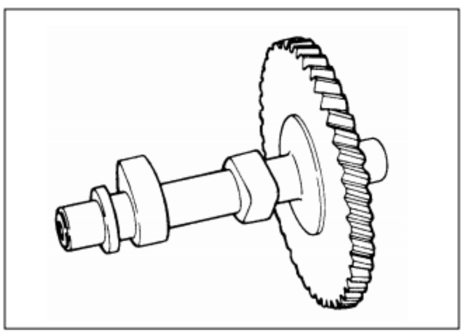
(VVT) system affect the performance of an internal combustion engine and the performance items of an internal combustion engine is define by torque output, fuel consumption and emissions. [12, 13]

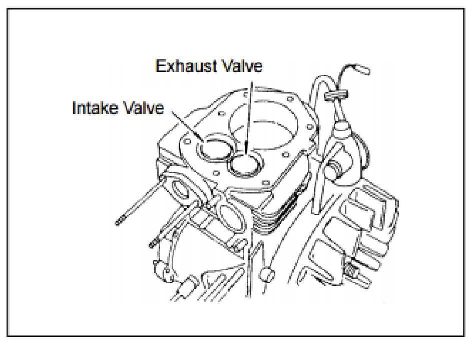
## EXPERIMENT CAM'S

This experiment focus on testing inlet valve opening in a gasoline engine and compare two different cam heights to the original cam as well as taking early open and late close of both inlet and exhaust valve at the same time then compare all figures to get the best load for the engine for rage of speeds star from 3000 and end to lowest possible engine running speed. In every test for each cam, the engine should be opened, drain the oil, and place the tested camshaft. The main part of the experiment is the engine and the testing machine. The engine which was selected is one of the popular engines in market that consists of one piston and 4 struck 5.0 EY 20-3. And the testing machine was Dynamometer Powerlink type used to measure the load and torque during the running of the engine. Figure-1.

**Figure-4.** Powerlink dynamometer.

The original camshaft is made of special cast iron, and camshaft and gear are cast together in one piece. Both sides of the shaft fit into the plain bearings on the crankcase and main bearing cover Figure-5. [14]





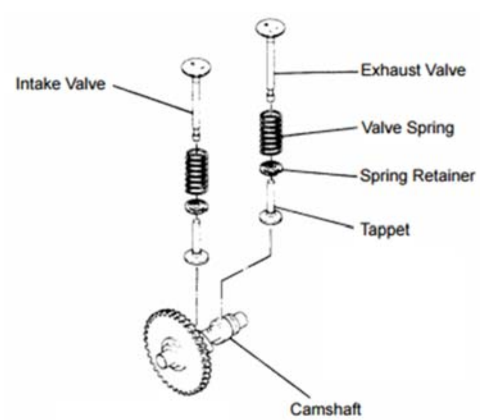




**Figure-5.** Cam shaft for engine, exhaust and intake valves.

Two camshafts have been utilized, one is the same of original and the other camshaft has been designed to be flexible for accommodating separate cams through machining the bar of the camshaft and remove original cams. Three cams have been designed and manufactured to have the same oval shape of the original cams and to fit into the camshaft bar that has been machined from the original camshaft. The designed cams contain holes from

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the side bottom of the cam to fix them in the bar of the machined camshaft. The original peak height of the original cam is (29 mm) measured from the center of the camshaft. The designed cams are three different sizes made of mild steel to represent inlet valve cam sized of (27.5mm and 26 mm) and one cam represent exhaust cam with size (29 mm). This combination will give two graphs to plot the engine speed as X-axis and load in Y-axis. In addition to that, another three figures were taken into consideration to represent the original camshaft, 15 degree advanced and 15 degree retarded from crank shaft angle. Those five position and designs of cams have been tested in the EY-20-3 engine and tested by dynamometer to get the loads for each one from the five combinations at different engine speeds and data was recorded. All experiments started from 3000 (RPM) with reduction of 50 (RPM) until the engine shutdown. After getting the data of each camshaft, curves are plotted in one graph for easy comparison and findings.

## RESULT

After experiments we get the summary of Table-1, which represent the five results for different compensation in height or angles of cams from the crank shaft. The change in cam angle was done using the original camshaft without change the overlap time between inlet valve and exhaust valve. It was found the designed cam height of exhaust valve has been reduced by 1 mm and become 28 mm in height from the center of the big circle of the cam oval shape. This reduction resulted by the friction during the rotation of the cam while running in the engine because it is made of mild steel with no heat treatment. The original cams are made of cast iron and hardened to resist erosion or wear.

**Table-1.** Experimental setup for angle and load.

| **Inlet cam** | | **Outlet cam** | | **Max load** (N) | **Engine speed** (RPM) |
|---|---|---|---|---|---|
| **Height** (mm) | **Angle** (deg) | **Height** (mm) | **Angle** (deg) | | |
| 27.5 | 0 | 28 | 0 | 6.32 | 1750 |
| 26 | 0 | 28 | 0 | 7.11 | 1900 |
| 29 | +15 | 29 | +15 | 6 | 2150 |
| 29 | -15 | 29 | -15 | 7.11 | 2150 |
| 29 | 0 | 29 | 0 | 7.19 | 2650 |

After getting the results, we notice from Table-1, that the maximum load significantly changes when using different angles or different cam heights. The camshaft which was used consists of two cams, one for the controlling the inlet valve (IV) and the other controls the exhaust valve (EV). Practically, the height of the cam gives more opening which transformed to breathing for (IV), and more height for (EV) gives more time for gas release.

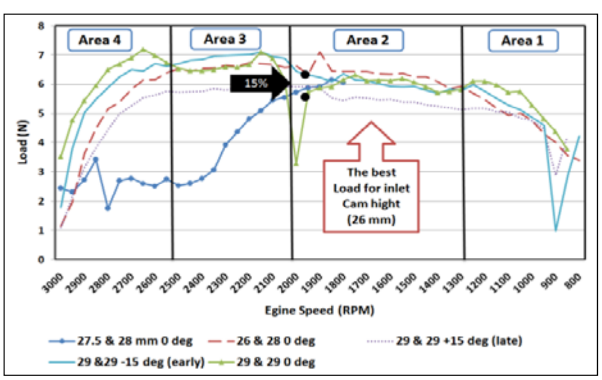


**Figure-6.** Load (N) Y-axis and engine speed (RPM) X-axis.

Detail analysis of the system as shown Figure-6, therefore, it conclude that;

1. The original cam height (line with triangle) gives the best load up to 1300 RPM (Area 1 Figure-6.).
2. The small inlet cam with height 26 mm (dash line) gives the best load up to 2000 RPM (Area 2 Figure-6.).
3. After that early breathing of the inlet valve (Cam angle -15 Degree from original angle represented by line in graph) gives the highest load up to 2500 RPM (Area 3 Figure-6.).
4. And finally again the original angle and original Cam height surpass the other load up to end. (Area 4 Figure-6.).

This phenomena can be interpreted as the beginning of starting engine, combustion chamber needs more air and fuel to run, then after running up to engine speed 1300 (RPM) it reduces its demand of air with fuel mixture then after 2000 RPM it requires more air and fuel mixture at earlier time up to 2500 RPM then again returns to later need of breathing with same quantity of air and fuel mixture.

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## CONCLUSIONS

The above results show a promising area for improving the load of the engines by changing the cam height and angles at different speed. It was shown in the graph (fig.6.) in the area 2 that the best load was obtained from the modified cam high to (26 mm) instead of original height which is (29 mm). The improvement in load reached up to (15%) which was in area 2 as in fig.6 (arrow shows two big dots). And the best load was obtained by using early opening of inlet valve and exhaust valve between engine speeds 2150 to 2600. After engine speed 2600, the best load was obtained by original camshaft at the same position. This method and findings can be used for optimizing variable valves timing to reach to best efficiency for the engines uses camshafts. It may also lead to flexible camshafts that are manufactured to give the optimum cam sizes and angles in at different engine speeds which will improve the engine efficiency and reduce harmful gases that leak to environment. To concur the finding, it is required further studies for different engines to find formula that correlate all results and design a flexible camshafts that give the combustion engine the amount required of oxygen and fuel for the best output in fuel consumption, reduction in gas emission, and in engine power.

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