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Evaluation of the Performance and Emission Characteristics of a Single Cylinder Four-Stroke SI Engine with Various Cam Profiles for Higher Performances

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Abstract: In a 4-stroke engine valve timing the intake and exhaust valves will not actually open and close at top dead center (TDC)and bottom dead center (BDC) for every 180 degrees when compared to the valve timing angles in theory. For high-performance designs, the intake and exhaust periods must be extended by opening valves early and closing them late. This extension results in both valves being open at the same time around TDC known as "valve overlap". The inlet and exhaust valves do not open and close instantly, because it requires time to move from one position to another.Usually the street purpose vehicles are optimized neutrally for better riding in traffic conditions instead of out-right performance. Depending upon the operating requirements of the engine valve timing was designed. The change in valve timing results in changing the volumetric efficiency of the engine, restricted valve openings restrict gas flow, so differing the valve timing by changing cam profile the performance of the engine varies to a greater levels.The main objective of this project is to evaluate the performance and emission characteristics of a 4-stroke SI engine running in different modified valve timings using different cam shafts with different cam profiles for higher power output. The present work has been carried out using a single cylinder 4-stroke air cooled gasoline engine by reducing and increasing the valve opening and closing duration. The performance and emission characteristics are studied and compared with the original valve timing.

Key words: The performance and emission characteristics are studied and compared with the original valve timing % Restricted valve openings restrict gas flow

INTRODUCTION

The intake and exhaust valves don't actually open and close at top dead center (TDC)and bottom dead center (BDC) (that is, every 180 degrees), even though, in theory, they do. In modern high-performance designs, engineers extend the intake and exhaust periods by opening valves early and closing them late. For example: the intake valve always opens before TDC at the end of the exhaust operation and the exhaust valve always closes after TDC at the beginning of the intake operation. This extension results in both valves being open at the same time around TDC known as "valve overlap," this seems counterproductive to efficient, powerful operation, but it isn't. There are two reasons for this extension of the intake and exhaust periods. First, poppet valves do not open and close instantly, like all mechanisms, they require time to move from one position to another.

In many 4-strokes, the crankshaft must rotate as much as 30 degrees before the valve is opened to 10 percent of its total lift. Restricted valve openings restrict gas flow. If the valves could open and close instantly, TDC and BDC still wouldn't be the best choices for their opening and closing; therefore, the second reason to extend the intake-open and exhaust-open periods involves the inertia of the gases involved. Inertia is often defined as, "A body at rest or in motion will continue in that state unless acted upon by an outside force." As the

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piston accelerates away from TDC at the beginning of the intake stroke, fresh air/fuel gases in the induction tract (the carburetor and intake manifold) are pushed into the cylinder by atmospheric pressure, but because of inertia, this isn't immediate. Moving slowly at first, the induction gases try to catch up with the rapidly accelerating piston; next, the piston decelerates rapidly as it nears BDC, but the mixture charge is now moving rapidly because of the inertia of its motion. If intake-valve closure is delayed until after BDC, the cylinder will continue to fill even as the piston begins its sweep toward TDC on the compression stroke. Extending the induction period maximizes cylinder packing and enhances cylinder pressure, crankshaft torque and engine power. The principles of inertia also apply to exhaust gases. The exhaust valve opens before the piston reaches BDC (toward the end of the power event) and this allows the still-pressurized cylinder gases to leave the engine. Dumping a bit of tail-end power-stroke pressure may seem counter-productive, but the tradeoff saves some of the rotational momentum that would otherwise be used to help scavenge exhaust gases. Because exhaust-gas acceleration and cylinder scavenging begin early, the slowing of the piston near TDC allows the formation of a negative pressure zone in the combustion chamber. The intake valve is opened before TDC and the partial vacuum promotes the delivery of a fresh mixture before the piston begins its intake stroke. Like the intake valve (which closes after BDC), the exhaust valve's closing after TDC enhances cylinder scavenging for the same reason: the inertia of the exhaust gases. The valves' opening and closing points affect the engine's ability to fill the cylinder with the fresh air/fuel mixture that is necessary for good torque and power production. The ideal valve timing will, however, depend on the type of engine under consideration by the designer: high-rpm, maximum-power-output engines require valves that open early and close late. Fuel-efficient, lower-power engines need valves that open and close closer to the dead centers with reduced valve overlap and less chance of the gases mixing and for reversion (exhaust escaping through the intake valve and into the intake tract).

Aim of the Project: The aim of the project is to experimentally determine the effect of changing the valve timing to the engine performance and volumetric efficiency.

The work also discuss about the increase in performance, emission, volumetric efficiency and fuel economy. The modification is done in cam by reducing the base circle diameter and thus increasing the opening duration and the valve lift. The engine testing was done with a rope dynamometer and the modified cam results are compared with the stock cam results.

Valve Timing and Performance Parameters

Blow down: In the power stroke, the combustion pushes the piston down in the cylinder. During this stroke, it is necessary to open the exhaust valve before the piston gets to the bottom of the cylinder. This will allow the excess pressure in the cylinder to "vent out" just before the piston reaches the bottom of the stroke. The term "Blow Down" is used to describe this event. Timing the exhaust valve in this manner assures no pressure is left in the cylinder to push against the piston on the exhaust stroke. Otherwise, there could be 20 PSI (or so) pushing against the piston as it starts up the cylinder. This would require some of your engine's power just to push the exhaust out of the cylinder! High RPM engines need to have the exhaust valve open sooner so the pressure has a better chance to exit the cylinder. However, at lower RPMs, opening the exhaust valve too soon means you didn't take full advantage of the power stroke

Overlap: As the engine cycles, there is a period when both the intake and exhaust valves are open at the same time. This valve timing is known as "overlap." The valves are timed so the intake valve opens slightly before the piston reaches top dead centre(TDC) on the exhaust stroke [1]. Likewise, the exhaust valve is timed to close just after the piston starts down on the intake stroke. The objective of overlap is for the exhaust gas which is already running down the exhaust pipe, to create an effect like a siphon and pull a fresh mixture into the combustion chamber. Otherwise, a small amount of burned gasses would remain in the combustion chamber and dilute the incoming mixture on the intake stroke. This valve timing is a product of the cam's duration and separation specs. The science involved with overlap is quite complex. Pressures, runner lengths, temperature and many other aspects influence how well the overlap effect works.

Ram Effect: When the piston reaches the bottom of the cylinder on the intake stroke, the intake valve doesn't immediately close at this point. The intake valve remains open even though the piston is starting up the cylinder on the compression stroke. The expression "ram effect" is used to describe this event.

Timing the intake valve in this manner allows an additional amount of fresh mixture to be rammed into the cylinder. What happens is that during the intake stroke the fresh mixture is running fast enough down the intake manifold and into the cylinder that it cannot instantly stop when the piston stops at the bottom of the intake stroke, the incoming mixture is rammed into the cylinder even though the piston may be starting up on the compression stroke. High RPM engines can have the intake valve remain open longer to take advantage of this ram effect. However, at low RPMs, the ram effect is not strong enough and the piston will start to push the fresh mixture back out of the cylinder. Of all different valve timing effects, this one can have the greatest impact on engine performance.

Cam Specifications and Effects

Duration: Duration refers to how long a valve is opened in relation to crankshaft rotation. This open valve time period is expressed in degrees of crankshaft rotation. For example, a cam specification of 220 degrees duration simply means the cam holds the valve open for 220 degrees of crankshaft rotation.

As strange as this may sounds, more duration can be helpful in high RPM engines but not low RPM engines. The extra degrees of open valve time in high RPM engines gives the air flow a little more time to get into (or out of) the cylinder in spite of the piston's stroke. At lower RPMs, more duration can cause less power because the valves will be open at the wrong time in relation to the piston's stroke up or down in the cylinder

Centreline: The cam's centreline specification is used to tie the valve timing to the crankshaft's rotation. This spec is expressed as the number of degrees the crankshaft must rotate from top dead centre until the cam has rotated to the peak (or centreline) of the lobe. The centre line spec and the duration spec can be used to calculate when the valves open and close in relation to the crankshaft's rotation. When the valves open (or close) relatively to the crankshaft rotation is known as valve events or valve timing. Some cam manufacturers will provide valve event information and others only provide duration and centreline information.

Understanding the effects of valve events or valve timing is the real secret to understanding engine performance. For the engine to run at its peak performance, the valves must open and close at the correct time in relation to the piston's position and the crankshaft's speed.

Separation: Separation refers to the spacing between the intake lobe and exhaust lobe on the cam shaft. This spacing (or separation) is expressed in degrees on the cam, not on the crankshaft. For example, a 108 lobe separation means the intake and exhaust lobes are 108 degrees apart from each other on the cam shaft.

This specification is a little more complicated though, because it is in cam shaft degrees and the crankshaft rotates two degrees for each one degree of cam rotation. Also, if the cam has been installed either advanced or retarded, the valve events will be different [2].

Lift: The final cam spec to understand is lift. While duration refers to how long the valve is opened, cam lift is used to determine how wide the valve is opened. If the valves are not opened wide enough, they will cause a restriction for the air trying to enter or exit the cylinder. However, opening the valve past a certain point will not increase the flow to (or from) the cylinder. It is necessary to understand a large amount of science to understand how the flow is related to how wide the valve is opened and how this affects the engine's power.

Methodology: The modification of valve timing is done by proper design of cam profile by taking the valve overlapping angle and valve opening and closing angle in account. The required valve timing modification is done from standard cam timing graph by modifying it to the required valve timing analytically.

The cam profile modification can be done by two methods

- By adding additional material over the cam.
- By reducing the base circle diameter of the cam.

Since the first method need a complex procedure involving metallurgical aspects of additional material and heat treatment methods the second method is taken for simplicity and affordable method of cam modification by grinding [3].

ENGINE SPECIFICATIONS

Engine	Suzuki Fiero
Type	4-Stroke, SOHC, single cylinder, air cooled, spark ignited, Vertically inclined.
Cubic capacity	147cc
Bore	57mm
Stroke	57.8mm
Compression ratio	9.2:1
Maximum power	12bhp @ 7500rpm
Maximum torque	1.07 kg-m @ 6500rpm
Fuel used	Gasoline
Fuel system	Mikuni side draught carburetor
Ignition system	CDI electronic
Lubrication type	Wet sump force feed lubrication
Lubricant used	SAE 20W 40

MODIFICATION DONE IN VALVE TIMING

Original valve timing:

Inlet valve opens	40 degrees BTDC (At the end of exhaust stroke)
Inlet valve closes	68 degrees ABDC (At the beginning of compression stroke)
Exhaust valve opens	28 degrees BBDC (At the end of expansion stroke)
Exhaust valve closes	10 degrees ATDC (At the beginning of suction stroke)

Modified valve timings:

Long duration camshaft

Inlet valve opens	57 degrees BTDC (At the end of exhaust stroke)
Inlet valve closes	83 degrees ABDC (At the beginning of compression stroke)
Exhaust valve opens	48 degrees BBDC (At the end of expansion stroke)
Exhaust valve closes	52 degrees ATDC (At the beginning of suction stroke)

Short duration camshaft

Inlet valve opens	28 degrees BTDC (At the end of exhaust stroke)
Inlet valve closes	50 degrees ABDC (At the beginning of compression stroke)
Exhaust valve opens	28 degrees BBDC (At the end of expansion stroke)
Exhaust valve closes	10 degrees ATDC (At the beginning of suction stroke)

RESULTS AND DISCUSSIONS

The long duration camshaft produces more power and torque at the higher engine speeds which is more suitable for high speed purposes like racing. The volumetric efficiency of the engine is increased at higher engine speeds compared to the original cam timing. The increase in valve overlap increases the midrange performance of the engine. But the emission was increased to a noticeable level which needs additional emission control systems. The fuel consumption also increased when compared to the original timing. Because of the long duration of valve opening the lower end performance of the engine reduces due to the pumping losses occurs at the lower engine speeds [4].

The short duration camshaft produces more power and torque at the lower end to the midrange of the engine speeds than the original camshaft. But the high speed performance of the engine is comparatively lower than the original in short duration camshaft. But the peak torque produced is more than the stock engine timing. And also emission levels are considerably less in the shorter duration valve timing than the stock timing.

The results also show that short valve overlap gives high performance for very lowandmid-engine speeds and long valve overlap for mid and high-engine speeds. It should be noted that, different valve opening and closing angles are obtained by reducing the base circle diameter of the cam i.e. with changes in the shape of lifting history and relative positions of inlet and exhaust valves.

Scope of Future Work: Neither the opening or closing angles for a specific cam, nor the relative position of exhaust and inlet valves for a specific camshaft, could be changed independently. Therefore, there is much to do with many more parameters so that better volumetric efficiencies could be obtained for a wider band of engine speeds as well as the above-discussed speeds.

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