"Kinematic Design and Simulation of a Flexible Valve Lift Mechanism for an IC Engine"

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Abstract

The automotive industry has been under continued pressure to improve the fuel efficiency owing to stringent pollution norms, global warming and rising petroleum prices. Various technologies have been developed in the recent years to mitigate these problems, common ones among them being, fuel cut off &/or cylinder deactivation during deceleration, enabling new combustion strategies, incorporating electronic valve lift/timing mechanism etc. Traditionally in IC-engines, the inlet and exhaust valve opening/lift is a fixed function of the crank shaft position. However in the light of new fuel induction systems that are currently available in recent and modern engines, significant improvements in fuel economy can be achieved if these values are actuated as a variable function of the crankshaft angular displacement through individual control of valve timing or by using electronically controlled valve timing mechanisms referred to as variable valve timing (VVT) mechanisms.

However in VVT cam mechanisms, the major problems is due to the noise and wear associated with high contact velocities during the opening and closing of valves. The other major problem is that, to date, the valve actuators for these types of applications primarily rely on resonant spring arrangements to achieve the required valve dynamics. This leads to a fixed amplitude of the valve trajectory and only allows for variable valve timing unless a fully flexible valve actuation system is conceived and designed.

An attempt is made in the proposal research work to design a new "TRI-LOBED-CAM" mechanism used in conjunction with a conventional cam operating mechanism that axially shifts the camshaft through a small displacement depending on the operating conditions of the engine viz., minimum valve displacement at lean loads/low engine speeds, medium valve displacement at intermediate loads and maximum valve displacement at high loads/high engine speeds. The proposed new design of the valve actuator mechanism is expected to overcome the inherent limitations of the fixed cam valve actuation mechanisms as well as the deficiencies of the VVT cam systems marginally.

Keywords: *Crank Shaft, Variable Valve timing, TRI-LOBED-CAM, Valve dynamics*

I. INTRODUCTION

With a forced, or pressurized, intake charge like that provided by a turbocharger, an engine can burn more fuel. Mainly Fuel consumption is based on Economy, Running costs, and Driving.

Fuel-economy also helps to protect the environment, Air pollution and global climate changes. So multi-valve technology became standard in engine design, Variable Valve Timing becomes the next step to enhance engine output, no matter power or torque.

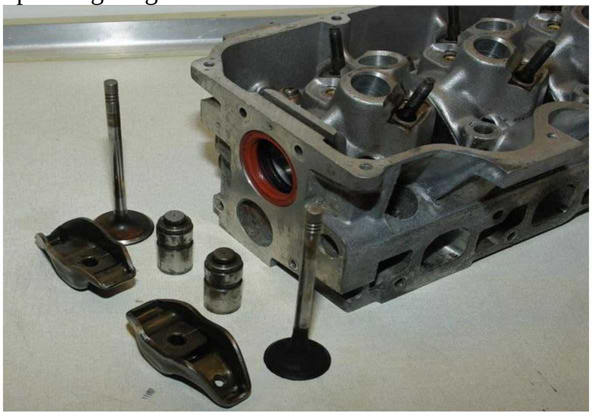
As you know, valves activate the breathing of engine. The timing of breathing, that is, the timing of air intake and exhaust, is controlled by the shape and phase angle of cams. To optimise the breathing, engine requires different valve timing at different speed. When the rev increases, the duration of intake and exhaust stroke decreases so that fresh air becomes not fast enough to enter the combustion chamber, while the exhaust becomes not fast enough to leave the combustion chamber.

Therefore, the best solution is to open the inlet valves earlier and close the exhaust valves later. In other words, the Overlapping between intake period and exhaust period should be increased as rev increases.

In conventional camshaft uses a fixed or variable cam profile to achieve a reasonable compromise between idle speed stability, fuel economy, and torque performance. Significant improvements in engine performance can be achieved through individual control of the valve timing.

So In internal combustion engines, Variable valve timing (VVT), also known as Variable valve actuation (VVA), is a generalized term used to describe any mechanism or method that can alter the shape or timing of a valve lift event within an internal combustion engine. VVT allows the lift, duration or timing (in various combinations) of the intake and/or exhaust valves to be changed while the engine is in operation. Two-stroke engines use a power valve system to get similar results to VVT. There are many ways in which this can be achieved, ranging from mechanical devices to electro-hydraulic and camless systems.

The valves within an internal combustion engine are used to control the flow of the intake and exhaust gases into and out of the combustion chamber. The timing, duration and lift of these valve events has a significant impact on engine performance. In a standard engine, the valve events are fixed, so performance at different loads and speeds is always a compromise between driveability (power and torque), fuel economy and emissions. An engine equipped with a variable valve actuation system is freed from this constraint, allowing performance to be improved over the engine operating range.



Piston engines normally use poppet valves for intake and exhaust. These are driven (directly or indirectly) by cams on a camshaft. The cams open the valves (*lift*) for a certain amount of time (*duration*) during each intake and exhaust cycle. The *timing* of the valve opening and closing is also important. The camshaft is driven by the crankshaft through timing belts, gears or chains.

Pressure to meet environmental goals and fuel efficiency standards is forcing car manufacturers to use VVT as a solution. Most simple VVT systems advance or retard the timing of the intake or exhaust valves.

The automotive industry has been under continued pressure to improve the fuel efficiency owing to stringent pollution norms, global warming and rising petroleum prices. Various technologies have been developed in the recent years to mitigate these problems, common ones among them being, fuel cut-off &/or cylinder deactivation during deceleration, enabling new combustion strategies, incorporating electronic valve lift/timing mechanism etc. Traditionally in IC-engines, the inlet and exhaust valve opening/lift is a fixed function of the crank shaft position. However in the light of new fuel induction systems that are currently available in recent and modern engines, significant improvements in fuel economy can be achieved if these values are actuated as a variable function of the crankshaft angular displacement through individual control of valve timing or by using electronically controlled valve timing mechanisms referred to as variable valve timing (VVT) mechanisms.

II. LITERATURE SURVEY

An IC engine valve's kinematics profiles (such as valve position versus time, valve speed versus time, and so on) are of fixed shape and are timed relative to the engine crankshaft position. From a control systems perspective, we say the engine valves are not controllable. If instead, we could independently control the duration, phase and lift of the valves, a marked improvement in emissions, efficiency, maximum power, and fuel economy would be seen. The engine's mechanical design, although simple, compromises the efficiency and maximum power of the engine [1&2]. However, any variable valve actuation system must be able to offer a variable valve profiles without compromising the essential characteristics of a conventional IC engine valve profile

In conventional IC engines, engine valve displacements are fixed relative to the crankshaft position. The valves are actuated with cams that are located on a belt-driven camshaft, and the shape of these cams is determined by considering a tradeoff between engine speed, power, and torque requirements, as well as vehicle fuel consumption. This optimization results in an engine that is highly efficient only at certain operating conditions [4], [5]. Instead, if the engine valves are actuated as a variable function of crankshaft angle, significant improvements in fuel economy - up to 20% - can be achieved [6]. In addition, improvements in torque, output power and emissions are achieved.

However in VVT cam mechanisms, the major problems are due to the noise and wear associated with high contact velocities during the opening and closing of valves. The valve seating velocity, which is the valve speed when the valve hits the cylinder head after the valve closing transition. In a typical IC engine, the seating velocity is less than 0.3m/s [3] at high speed and less than 0.05 m/s at idle. Higher valve seating velocities lead to excessive noise and potentially damage the engine. Thus, "soft landing" is an essential requirement for any valve actuation system. To overcome this fully flexible valve actuation system is conceived and designed.

In Solenoid-controlled systems are referred to as electro mechanical cam less valve trains (EMCVs) in this paper. In EMCVs [3], the valve is held in the middle position by a spring system. Two coils are energized alternately to attract an armature mounted on the valve into either the open or the closed position. A nonlinear relationship between force, position, and current occurs when the armature approaches either end. This makes it very difficult to regulate the seating velocity. However, great advances have been made in modelling and controlling [2], this device in recent years. Nevertheless, reliable control of the seating velocity in the presence of temperature changes and valve wear occurs.

Electro hydraulic systems often use piezo actuated valves to control the hydraulic fluid flow that is used to displace the valve [10]. Unfortunately, hydraulic systems suffer from viscosity changes across the required temperature range, since engine oil is typically used as the hydraulic liquid. Thus, the performance deteriorates at low temperatures. In addition, it is very difficult to achieve good energy efficiency with hydraulic systems, since there is no simple way to recover the kinetic energy of the valves when they are slowed down. Finally, hydraulic systems improve the air fuel mixtures are costly in terms of initial investment as well as maintenance. Despite of these problems, hydraulic systems are probably the most widely used FFVA system in engines laboratories.

To summarize, FFVA provides a simpler control strategy that can better accommodate for valve wear and temperature changes. In addition, the variable valve lift can be used to improve the air fuel mixture.

In internal combustion engines, Variable valve timing (VVT), also known as Variable valve actuation (VVA), is a generalized term used to describe any mechanism or method that can alter the shape or timing of a valve lift event within an internal combustion engine. VVT allows the lift, duration or timing (in various combinations) of the intake and/or exhaust valves to be changed while the engine is in operation. There are many ways in which this can be achieved, ranging from mechanical devices to electro-hydraulic and cam less systems.

The valves within an internal combustion engine are used to control the flow of the intake and exhaust gases into and out of the combustion chamber. The timing, duration and lift of these valve events has a significant impact on engine performance. In a standard engine, the valve events are fixed, so performance at different loads and speeds is always a compromise between driveability (power and torque), fuel economy and emissions. An engine equipped with a variable valve actuation system is freed from this constraint, allowing performance to be improved over the engine operating range.

The profile, or position and shape of the cam lobes on the shaft, is optimized for a certain engine revolutions per minute (RPM), and this tradeoff normally limits low-end torque, or high-end power. VVT allows the cam timing to change, which results in greater efficiency and power, over a wider range of engine RPMs.

So in FFVA designs, valve lift can also be varied according to engine speed. At high speed, higher lift quickens air intake and exhaust, thus further optimise the breathing. Of course, at lower speed such lift will generate counter effects like deteriorating the mixing process of fuel and air, thus decrease output or even leads to misfire. Therefore the lift should be variable according to engine speed

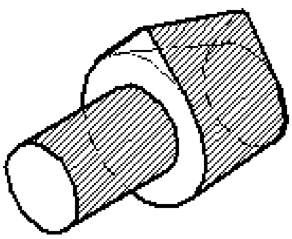
III. PROBLEM IDENTIFICATION

However in VVT cam mechanisms, the major problems are due to the noise and wear associated with high contact velocities during the opening and closing of valves. The other major problem is that, to date, the valve actuators for these types of applications primarily rely on resonant spring arrangements to achieve the required valve dynamics. This leads to a fixed amplitude of the valve trajectory and only allows for variable valve timing unless a fully flexible valve actuation system is conceived and designed.

IV. OBJECTIVE

An attempt is made in the proposal research work to design a new “TRI-LOBED-CAM” mechanism used in conjunction with a conventional cam operating mechanism that axially shifts the camshaft through a small displacement depending on the operating conditions of the engine viz., minimum value displacement at lean loads/low engine speeds, medium valve displacement at intermediate loads and maximum valve displacement at high loads/high engine speeds. The proposed new design of the valve actuator mechanism is expected to overcome the inherent limitations of the fixed cam valve actuation mechanisms as well as the deficiencies of the VVT cam systems marginally.

V. KINEMATIC ANALYSIS OF TRI-LOBED-CAM



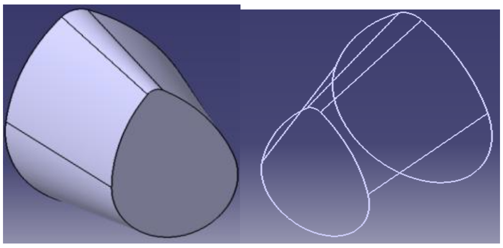


Fig 1: Tri Lobed CAM

Displacement, Velocity and Acceleration at 8^0 of taper turn in CAM

Displacement at the bigger side Cam

$$X= (R-r_1)(1-\cos\Theta)$$

$$X= (33.6-16)(1-COS42)$$

$$X=4.520mm$$

Displacement at the centre of Cam

$$X= (R-r_1)(1-\cos\Theta)$$

$$X= (34.62-16)(1-COS48)$$

$$X=6.160mm$$

Displacement at the Smaller side Cam

$$X= (R-r_1)(1-\cos\Theta)$$

$$X= (35.74-16)(1-COS52)$$

$$X=7.586mm$$

Velocity at the bigger side Cam

$$V = \omega (R-r_1) \sin\phi$$

$$V=\frac{2\Pi N}{60}(R-r_1) \sin\phi$$

$$V= \frac{2\Pi 340}{60}(33.6-16) \sin 42$$

$$V=419mm/s$$

Acceleration at the bigger side Cam

$$A_{max}= \omega^2 (R-r_1)$$

$$A_{max} = \left(\frac{2\Pi N}{60}\right)^2 (33.6-16)$$

$$A_{max}=22311.44mm/s^2$$

Displacement, Velocity and Acceleration at 9^0 of taper turn in CAM

Displacement at the bigger side Cam

$$X= (R-r_1)(1-\cos\Theta)$$

$$X= (33.45-16)(1-COS40)$$

$$X=4.520mm$$

Displacement at the centre of Cam

$$X= (R-r_1)(1-\cos\Theta)$$

$$X= (34.47-16)(1-COS46)$$

$$X=5.645mm$$

Displacement at the Smaller side Cam

$$X= (R-r_1)(1-\cos\Theta)$$

$$X= (35.74-16)(1-COS52)$$

$$X=7.586mm$$

Velocity at the bigger side Cam

$$V = \omega (R-r_1) \sin\phi$$

$$V=\frac{2\Pi N}{60}(R-r_1) \sin\phi$$

$$V= \frac{2\Pi 340}{60}(33.45-16) \sin 40$$

$$V=399.36mm/s$$

Acceleration at the bigger side Cam

$$A_{max}= \omega^2 (R-r_1)$$

$$A_{max} = \left(\frac{2\Pi N}{60}\right)^2 (33.6-16)$$

$$A_{max}=22121.3mm/s^2$$

Existing CAM SHAFT

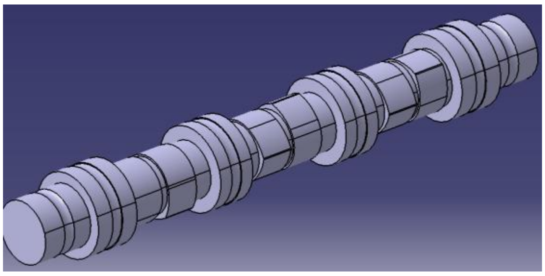


Fig 2: CAM SHAFT with Edges

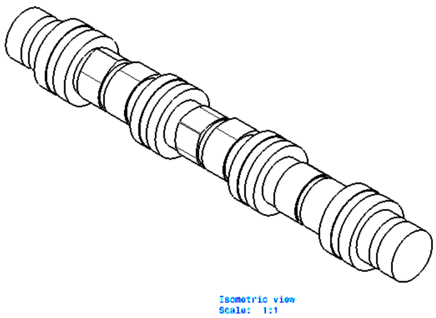


Fig 3: Iso-Metric View of CAM SHAFT

Camshaft is a shaft which carries one cam for each valve to be operated it also provides a drive for the ignition disrtibutor and mechanical fuel pump.The camshaft is driven by crankshaft by means of timing gears or chain drive at half the speed of crankshaft it is forged from alloy steel or hardeneble cast iron. It consists of cylindrical rod with a number of oblong lobes protruding from it, one for each valve. The cam lobes force the valve open by pressing of the valve.The profile of existing camshaft is not tapered.

Existing Rocker

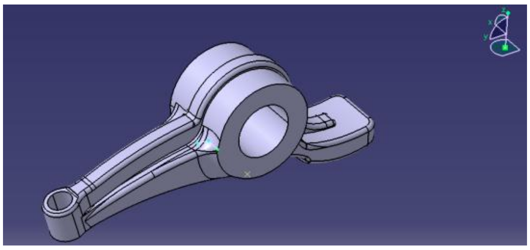


Fig 4: ROCKER with edges

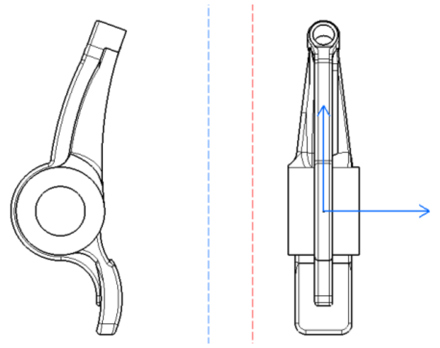


Fig 5: Rocker with Different Views

A rocker arm is an oscillating lever that conveys radial movement from the cam lobe into linear movement at the poppet valve to open it. One end is raised and lowered by a rotating of the camshaft while the other end acts on the valve stem. The existing rocker is having surface contact with the respective cam and it is made of forged steel or cast iron.

Co-ordinates for Modified CAM

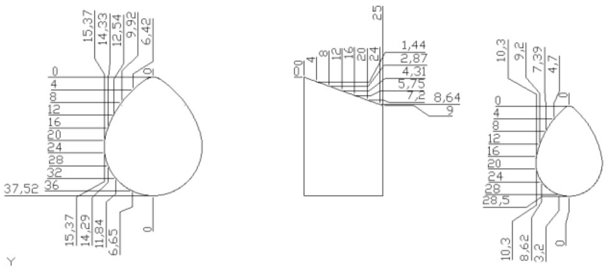


Fig 6: Cam with Maximum and Minimum Diameter

Modified Camshaft

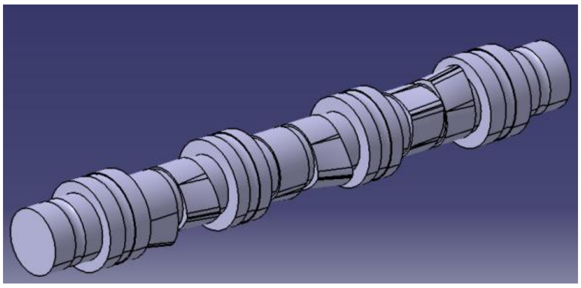


Fig 7: Modified Cam Shaft with Edges

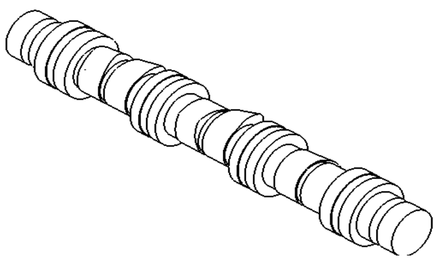


Fig 8: Modified Iso-Metric View of Cam Shaft

The modified camshaft is a shaft which carries one tapered cam for each valve to be operated. The camshaft is driven by the crankshaft by means of timing gears. It consists of cylindrical rod with a number of tapered lobes protruding from it, one for each valve. The profile of the modified camshaft is redesign with falt surface to tapered(slope) shape.

Modified Rocker

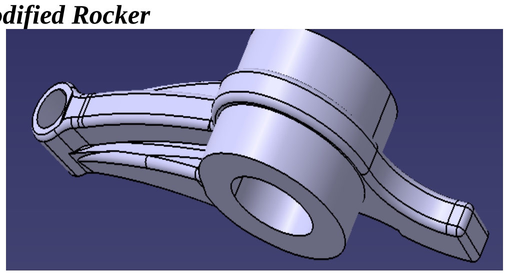


Fig 9: Modified Rocker with Edges

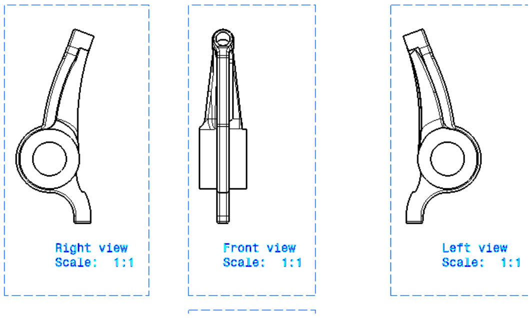


Fig 10: Different Views of Modified Rocker

A modified rocker arm is an oscillating lever that conveys radial movement from the cam lobe into linear movement at the poppet valve to open it. One end is raised and lowered by a rotating of the camshaft that is reduced their width while the other end acts on the valve stem. The modified rocker having point contact with the respective cam and it is made of forged steel or cast iron.

VI. EXPERIMENTATION OF VALVE DISPLACEMENT

Fig 11: Experimental Set up

- Position the dial indicator on the dial indicator comparator stand.
- Adjust the dial indicator in such a manner that when the contact point touches the valve so that the hand registers 0.000.
- Rotate the CAM SHAFT for minimum displacement of the CAM. So that there will be a valve displacement

- Then adjust the dial indicator in such a manner that the contact point touches the valve and note down the reading

Fig 12: Experimentation of Valve Displacement

VII. RESULTS AND DISCUSSION

Table 1: For 8^0 of taper turn in CAM

Sl No	Length of the cam (mm)	Degrees of taper turn in CAM	Diameter of the CAM (mm)	Valve Movement on CAM (mm)
1	17.44	8	33.6(Minimum)	4.396
2	17.44	8	34.62(Centre)	6.022
3	17.44	8	35.74(Maximu	7.319

At the 8^0 of taper turn in CAM the diameter of the CAM varies so that the valve movement also varies this is found at 3 different locations on the Cam shaft which is shown in the Table 1. As the diameter increases the valve movement will also increases.

Table 2: For 9^0 of Taper Turn in CAM

Sl	Length of the cam (mm)	Degrees of taper turn in CAM	Diameter of the CAM (mm)	Valve Movement on CAM (mm)
1	17.44	9	33.45(Minimum)	3.961
2	17.44	9	34.47(Centre)	5.925
3	17.44	9	35.74(Maximum	7.222

At the 9^0 of taper turn in CAM the diameter of the CAM varies so that the valve movement also varies this is found at 3 different locations on the Cam shaft which is shown in the Table 2. As the diameter increases the valve movement will also increases.

From the table 1 &2 the result is noted that the Valve movement on Cam is more in 8^0 of taper turn comparable to 9^0 of taper turn in CAM

Table 3: Experimental V/S Theoratical

Sl No	Valve Movement On CAM (mm) EXPERIMENTAL	Valve Movement On CAM (mm) THEORATICA	DEGREE OF CONTACT
1	4.396	4.520	42
2	6.022	6.160	48
3	7.319	7.586	52

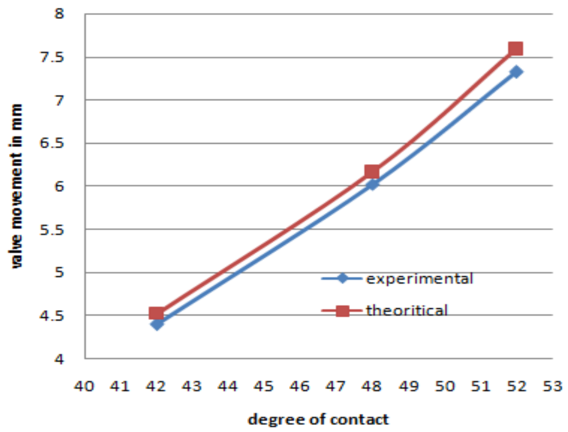


Fig 13: For 8^0 of Taper Turn in CAM

Sl No	Valve Movement On CAM (mm) EXPERIMENT	Valve Movement On CAM (mm) THEORATICAL	DEGREE OF CONTACT
1	3.961	4.082	40
2	5.925	5.645	46
3	7.222	7.586	52

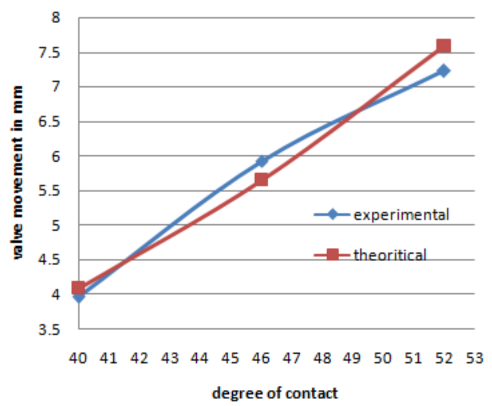


Fig 14: For 9^0 of Taper Turn in CAM

The Theoretical and the experimental values of the valve movement on CAM are nearer to each other at 3 different degree of contact in 8^0 & 9^0 of taper turn in CAM

VIII. CONCLUSION

A fully flexible valve actuation system of 8^0 and 9^0 taper turn in CAM is conceived and designed. So as to give variable valve displacement, flexibility and can be controlled.

In the present work a TRI LOBED CAM is developed that axially shifts the camshaft through a small displacement depending on the operating conditions of the engine viz., minimum value displacement at lean loads/low engine speeds, medium valve displacement at intermediate loads and maximum valve displacement at high loads/high engine speeds. So that the valve actuator mechanism is expected to overcome the inherent limitations of the fixed cam valve actuation mechanisms as well as the deficiencies of the VVT cam systems marginally.

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