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RESEARCH ARTICLE

DESIGN OF TRI LOBED CAM AND FINDING THE EFFECT ON EMISSION FOR A FLEXIBLE VALVE LIFT ACTUATION MECHANISM IN IC ENGINE

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ABSTRACT

In conventional engine design, the 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. The cams open the valves (lift) for a certain amount of time (duration) during each intake and exhaust cycle. 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. The major problem in variable valve timing (VVT) mechanism is that, 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. By placing the rocker at 3 different locations on the CAM Shaft the valve movement is varied 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 gives a fully flexible valve actuation motion of the engine. An emission characteristic is studied at 3 different profiles of cam where the emission is decreased.

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INTRODUCTION

Fuel-economy also helps to protect the environment, a pollution and global climate changes. So multi-valve technology was explored in engine design along with Variable Valve Timing to enhance engine output, power or torque. 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 optimize the breathing, engine requires different valve timing at different speed. When the rev increases, the duration of intake and exhaust stroke decreases with the result that fresh charge may not be admitted inside the cylinder fully while simultaneously the scavenging of exhaust gases from the previous cycle may not be take place completely.

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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. Without variable valve timing or variable valve lift, the valve timing must be the same for all engine speeds and conditions, therefore compromises are necessary. 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. The automotive industry has been under continued pressure to improve the fuel efficiency owing to stringent pollution norms, global warming and rising petroleum prices. The largest part of most combustion gas is nitrogen (N_2), water vapor (H_2O) and carbon dioxide (CO_2) these are not toxic. A relatively small part of combustion gas is undesirable noxious or toxic substances, such as carbon monoxide (CO) from incomplete combustion, hydrocarbons (properly indicated as C_xH_y, but typically shown simply as "HC" on emissions-test slips) from unburnt fuel, nitrogen oxides (NO_x) from excessive combustion temperatures, and particulate matter (mostly soot).

The basic task in the design and development of I.C Engines is to reduce the cost of production and improve the efficiency. In order to achieve the above task, the engineer has to compare the engine developed by him with other engines in terms of its efficiency. So 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.

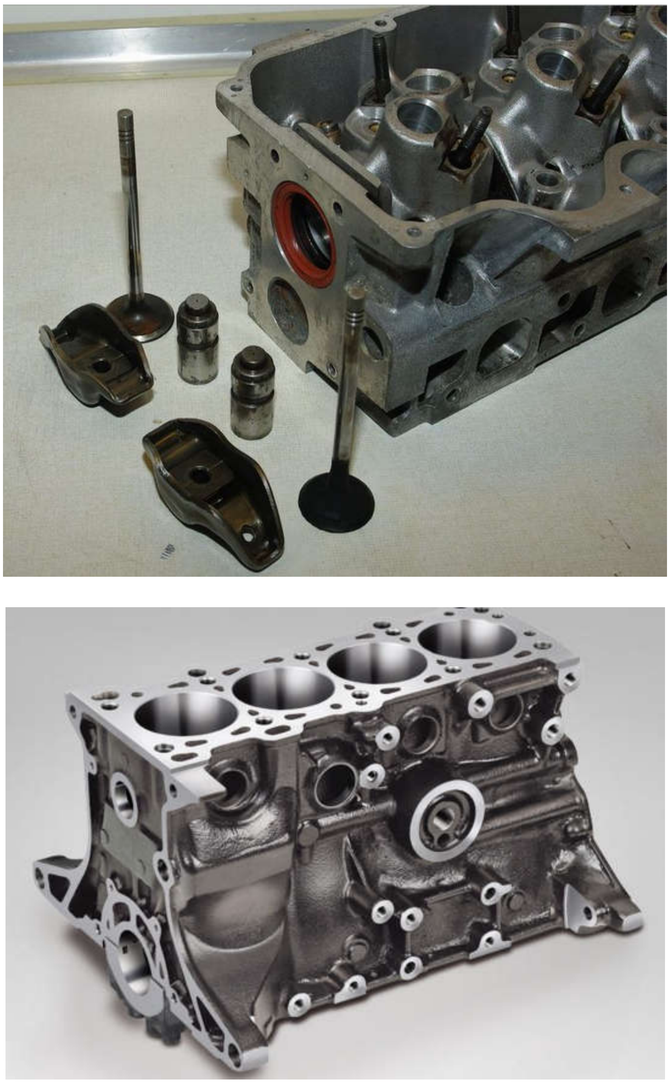

Fig. 1. Engine Head, Valve, Engine Block and CAM Shaft

Literature survey

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 (Chang, 2001; Levin and Schlecter, 1996). 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 (Miller *et al*., 1999). In addition, improvements in torque, output power and emissions are achieved. In Solenoid-controlled systems are referred to as electro mechanical cam less valve trains (EMCVs) in this paper. In EMCVs (Hoffmann *et al*., 2003), 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 modeling 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. Valve train control is one of the best strategies for optimizing efficiency and emissions of Internal Combustion (IC) engines. Applications of solenoid valve actuators in (IC) engines can facilitate operations such as variable valve timing and variable valve lifting for improved the engine performance, fuel economy and reduce emission, the electromechanical valve actuator (EMVA) uses solenoid to actuate valve movement independently for the application of (IC) engine. (Eid Mohamed, 2012)

As with traditional piston engines, VVT engines use cams on a camshaft to drive the flow of air into the intake and exhaust valves. The timing of this valve lifts directly affects how much air is taken in during each engine cycle. At times when the engine requires more air flow (for example high speeds or acceleration), a traditional piston engine often does not allow enough air to flow during each cycle, resulting in lower output performance. Conversely, a traditional piston engine that has been designed to feature longer exhaust and intake cycles will result in reduced fuel efficiency at slower speed (Osama *et al*., 2013). This paper also enhances the engine which uses variable valve timing allows the reduction of pumping loss, control of internal residual gas recirculation and emissions, along with improvement of performance over a wide range of revolutions per minute. All of these factors contribute to a considerable potential improvement in fuel economy. (Osama *et al*., 2013) The problem with fixed valve timing that the valve train is set by the automaker for peak efficiency running at a specific point in the engine's operating range. When the vehicle is moving slower or faster than this ideal operating point the engine's combustion cycle fails to properly burn the air/fuel mixture leading to considerably compromised engine performance and wastes fuel. Variable Valve Timing (*VVT*) is a solution developed to overcome this engine deficiency, dynamically altering the valve's opening and closing for optimal performance at any speed. The intension in this work is to contribute towards pursuing the development of variable valve timing (*VVT*) for improving the engine performance. This investigation covers the effect of exhaust valve opening (*EVO*), and closing (*EVC*) angle on engine performance and emissions. (new 13 2013) The results of the study howed that decreasing the valve lift at low engine speeds and increasing the lift at high speeds improve the engine performance. Moreover, it was concluded that the idle speed can be lowered by decreasing the valve lift at low engine speed (Fatih Uysal and Selami Sagiroglu, 2015)

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. 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. It also affects the emission characteristics in which emission will be reduced for variable valve lift.

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. Emission characteristics can be also controlled since the fuel efficiency is increased. So the emission characteristics is studied at 3 different locations of the CAM Shaft has the valve movement is varied and controlled by using the modified CAM Shaft.

Kinematic Analysis of TRI-LOBED-CAM

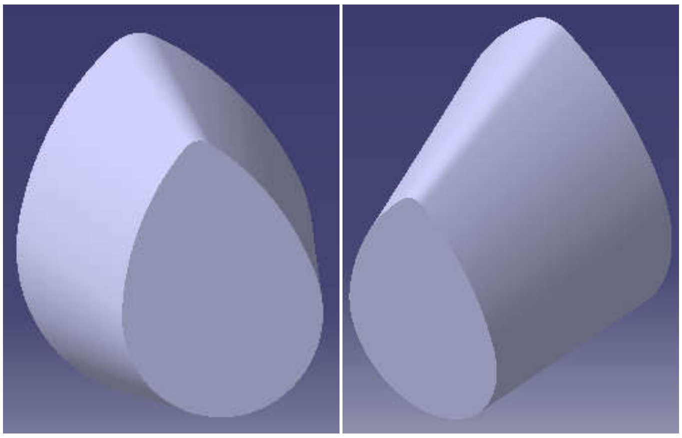

Fig. 2. Tri Lobed CAM

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

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

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

$V=\frac{2\Pi 340}{60}(33.6-16) Sin42$

$V=419mm/s$

Acceleration at the bigger side Cam

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

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

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

Existing CAM SHAFT

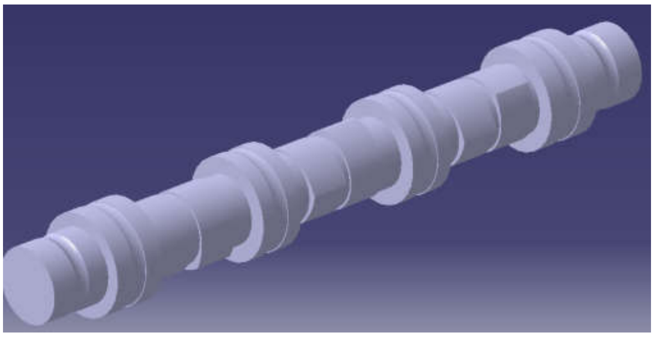

Fig. 3. Iso-metric view of CAM SHAFT

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

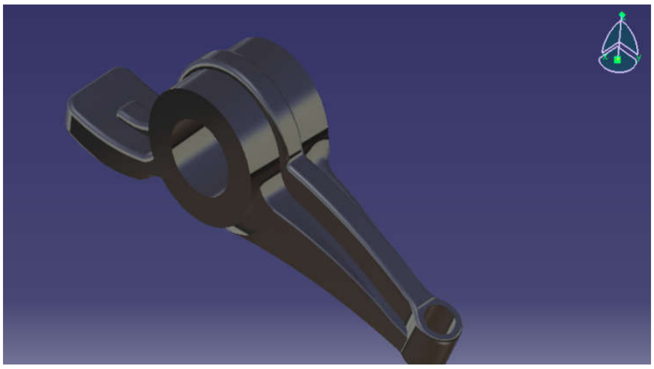

Fig. 4. ROCKER with edges

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.

Modified camshaft

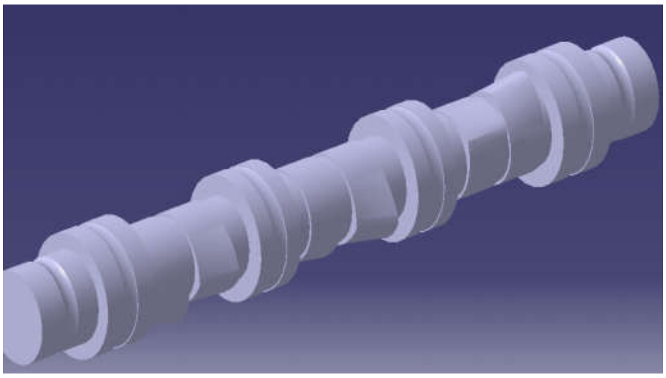

Fig. 5. MODIFIED Iso-metric view of CAM SHAFT

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

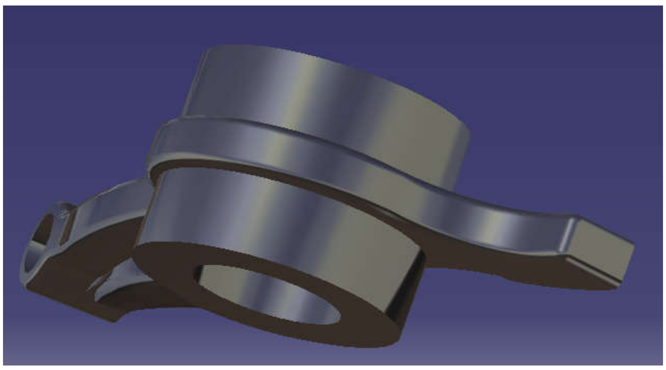

Fig. 6. MODIFIED ROCKER with Edges

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.

Experimentation of valve displacement

Fig. 7. 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.
- Record the zero reading on the dial indicator calibration form.
- 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
- Repeat the procedure for different probes of CAM

Fig. 8. Experimentation of Valve displacement

RESULTS AND DISCUSSION

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

S.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(Maximum)	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

S.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	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

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

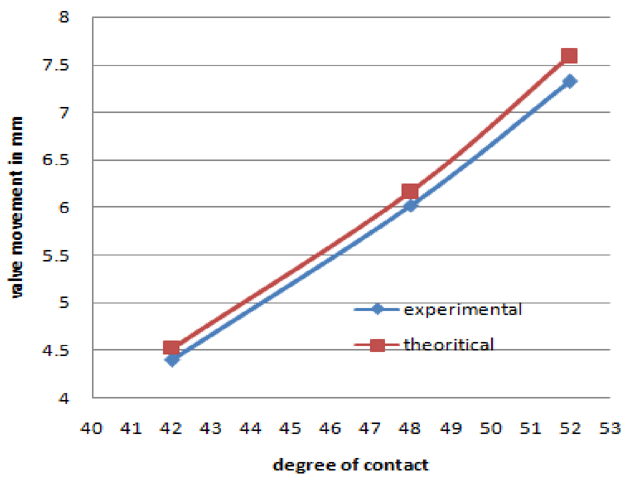

Fig. 9. For 8^0 of taper turn in CAM

S. No.	Valve Movement On CAM (mm) EXPERIMENTAL	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

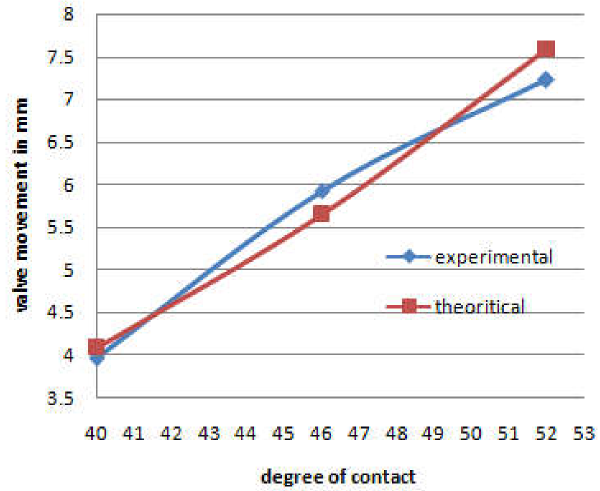

Fig. 10. For 10^0 of taper turn in CAM

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. By this we can conclude that the valve movent can be changed by altering the CAM Shaft.The Theoretical and the experimental values of the valve movement on CAM are nearer to each other at 3 different locations for 8^0 & 9^0 degree of taper turn in CAM.

Emission characteristics at 3 different locations for 8^0 & 9^0 degree of taper turn in CAM

Exhaust gas or flue gas is emitted as a result of the combustion of fuels such as natural gas, gasoline, petrol, biodiesel blends, fuel, fuel or coal. According to the type of engine, it is discharged into the atmosphere through an exhaust pipe, flue gas stack or propelling nozzle. Emissions of many air pollutants have been shown to have variety of negative effects on public health and the natural environment. Fuel (hydrogen, carbon, sulphur) + Air (nitrogen, oxygen) = Carbon dioxide + water vapour + oxygen + carbon monoxide + hydrocarbon + oxides of nitrogen + sulphur oxides.

Fig. 11. Emission Testing Machine

An instrument exhaust gas analyzer is used to find the emissions CO, HC and $C0_2$. The instrument which is used to find the emissions is shown below

For 8^0 of Taper turn in CAM

S. No.	Diameter of the CAM (mm)	Valve lift in mm	Exhaust Emission of CO	Exhaust Emission of HC	Exhaust Emission Of CO_2
1	35.74(Maximum)	7.319	3.640	501	11.24
2	34.62(Centre)	6.022	2.291	402	8.02
3	33.6(Minimum)	4.396	1.680	314	6.13

Exhaust emission at Maximum, Centre and Minimum for 8^0 of Taper turn in CAM in carburettor engine

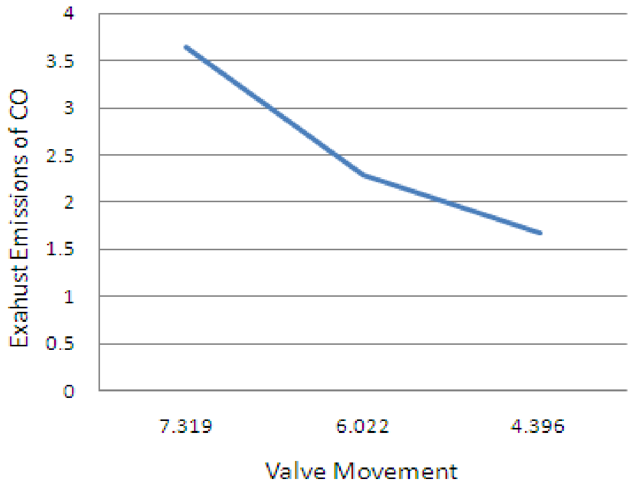

Fig. 12. Valve Movement V/S Exhaust emission of CO

When the rocker is placed on the maximum, centre and minimum diameter of the Cam Shaft then the valve movement is decreased so that the exhaust emission CO is reduced.

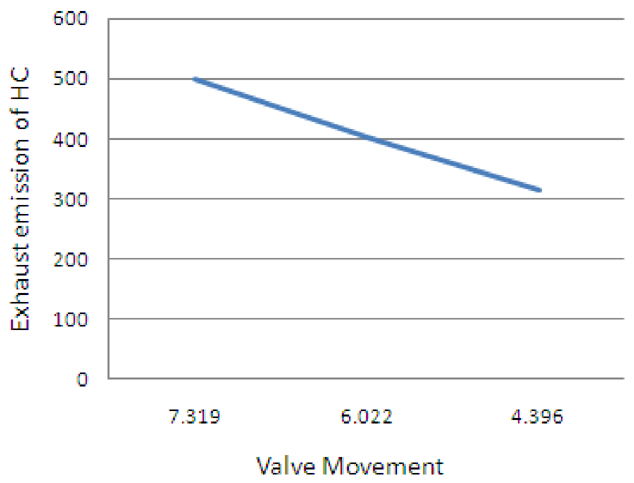

Fig. 13. Valve Movement V/S Exhaust emission of HC

When the rocker is placed on the maximum, centre and minimum diameter of the Cam Shaft then the valve movement is decreased so that the exhaust emission HC is reduced.

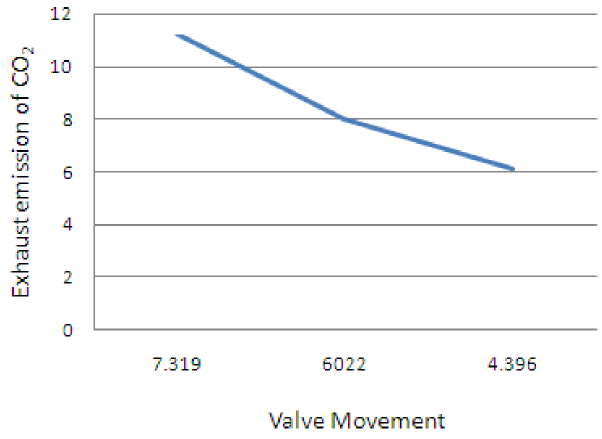

Fig. 14. Valve Movement V/S Exhaust emission of CO_2

Exhaust emission at Maximum, Centre and Minimum for 9^0 of Taper turn in CAM in carburettor engine

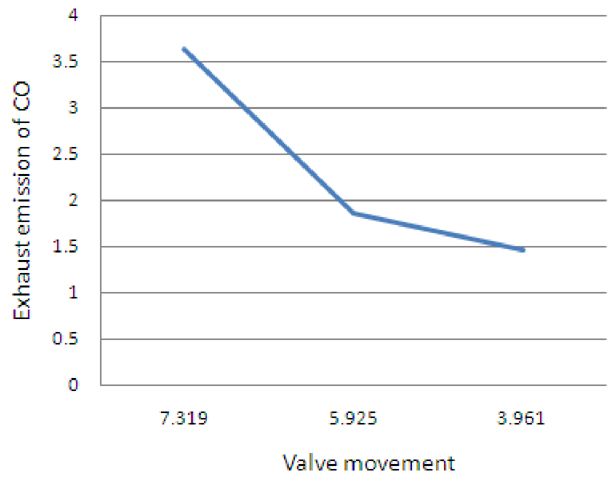

Fig. 15. Valve Movement V/S Exhaust emission of CO

When the rocker is placed on the maximum, centre and minimum diameter of the Cam Shaft then the valve movement is decreased so that the exhaust emission CO is reduced.

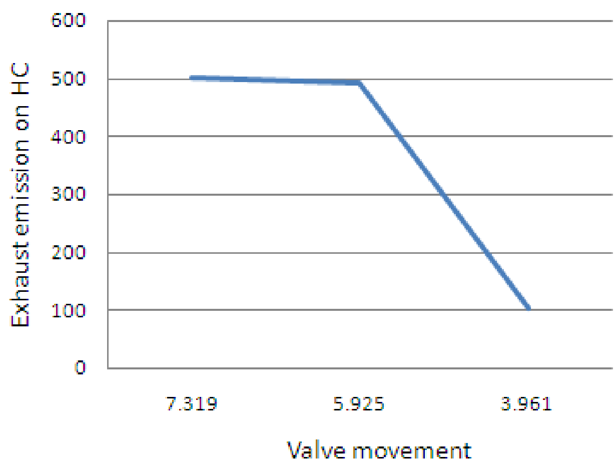

Fig. 16. Valve Movement V/S Exhaust emission of HC

When the rocker is placed on the maximum, centre and minimum diameter of the Cam Shaft then the valve movement is decreased so that the exhaust emission HC is reduced.

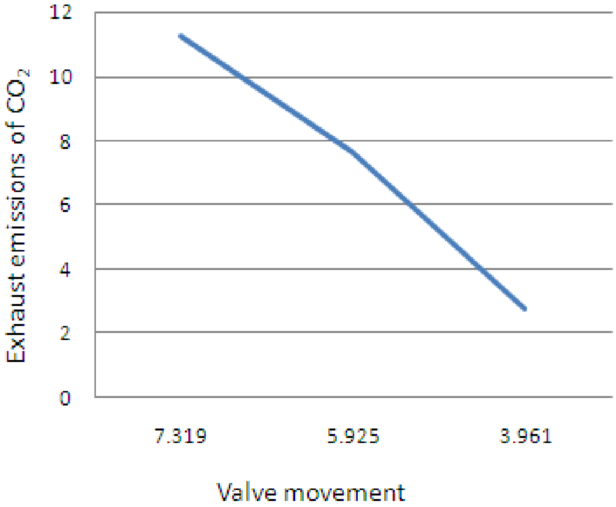

Fig. 17. Valve Movement V/S Exhaust emission of CO_2

When the rocker is placed on the maximum, centre and minimum diameter of the Cam Shaft then the valve movement is decreased so that the exhaust emission CO_2 is reduced.

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 and rocker is placed on different diameter of the CAM so that there will be variable valve 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. Emission characteristics can be also controlled since the fuel efficiency is increased. So the emission is reduced at 3 different locations of the CAM Shaft as the valve movement is varied and controlled by using the modified CAM Shaft.

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