SOME EXPERIMENTAL OBSERVATIONS ON A FULLY FLEXIBLE VALVE ACTUATION SYSTEM USING TRI LOBED CAM FOR AN MPFI ENGINE

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ABSTRACT

In Internal Combustion Engines, 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. 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 proposed 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 (MinVD) at lean loads/low engine speeds, medium valve displacement (MedVD) at intermediate loads and maximum valve displacement (MaxVD) at high loads/high engine speeds.

The proposed new design of the valve actuator mechanism has been tested on an 800cc Maruti MPFI engine by modifying its camshaft and rocker assembly. It has been observed that SFC for the FFVAS engine attains its lowest value of about 0.635-0.640 Kg/KWhr between 1/2 Load and 3/4 Load operation for MedVD position. At the other two extreme positions, the obtained SFC was higher between 1/2 Load and 3/4 Load operation. The volumetric efficiency also shows a marginal increase for MedVD configuration (58-73%) as compared to the MinVD configuration (54-61%).

The new design 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.

KEYWORDS: Tri Lobed Cam, Min VD, Med VD & Max VD

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INTRODUCTION

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. An engine equipped with a variable valve timing actuation system is freed from this constraint, allowing performance to be improved over the

engine operating range.

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.

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.

An attempt is made in the proposed 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.

METHODOLOGY

In the experimental test rig set up for the purpose, computer interfacing from the various transducers mounted on both the standard IC engine and the modified IC Engine acquires engine operating data like engine speed, fuel flow, air flow, crank displacement, pressure inside the combustion chamber (Cylinder Pressure) etc., and is directly fed to a digital computer through the high speed I/O ports provided on its motherboard.

Performance parameters like Specific Fuel Consumption, Volumetric efficiency, and Thermal efficiency is studied at 3 different positions of the CAM Shaft as the valve movement is varied and controlled by using the modified CAM Shaft.

- CAM Shaft is modified for 8^0 and 9^0 of Taper turns on CAM.
- By modifying the cam the valve movement is measured by using a dial gauge at 3 different locations viz maximum, center and minimum diameter position of the cam.
- CAM is modified and kinematically analyzed at 3 different locations.
- The valve movement which is measured experimentally will be compared with the theoretical value.
- Valve Movement is varied based on the lean loads/low engine speeds, intermediate loads and at high loads/high engine speeds.
- Performance characteristics are studied for the modified Cam.

- Performance parameters like Specific Fuel Consumption, Volumetric efficiency, and Thermal efficiency is studied.

Existing Cam Shaft

Figure 1: Existing Cam Shaft

Figure 1 shows the profile of the camshaft of the standard engine. Figure 2 shows the profile of the rocker of the standard engine. Figure 3 shows the modified camshaft of the MPFI engine having tapers of 8deg and 9deg.

Existing Rocker

Figure 2: Existing Rocker

Modified Cam Shaft

Figure 3: Modified Cam Shaft

The valve timing is controlled by the camshaft. It can be varied by modifying the camshaft, or it can be varied during engine operation by variable valve timing. It is also affected by the adjustment of the valve mechanism, and particularly by the tappet clearance.

The modified camshaft carries one tapered cam for each valve to be operated. The camshaft is driven by the crankshaft by means of timing gears. The profile of the modified camshaft is redesigned with tapered (sloping) surface.

Modified Rocker

Figure 4: Modified Rocker

Figure 4 shows the modified rocker that has been used in conjunction with the modified camshaft with a tapered surface that results in variable valve displacement as the modified camshaft slides axially along the splines provided on the shaft.

Kinematic Analysis of TRI-LOBED-CAM

Figure 5: Tri Lobed CAM

Figure 6: Rocker placing at Different Locations of Tri Lobed CAM

VALVE DISPLACEMENTS

Valve Movement at Different Positions for CAM Shaft Taper of 8° and 9°

Table 1: For CAM Shaft Taper of 8°

SI No	Cam Length (m)	Cam Taper	Cam Diameter (m)	Displacement of Valve (m)
1	0.0174	8°	0.0336	0.0043
2	0.0174	8°	0.03462	0.0060
3	0.0174	8°	0.03574	0.0073

At CAM Shaft taper of 8° the diameter of the CAM varies from one end to another end so that the valve movement changes when the rocker is placed on 3 different positions of Cam which is shown in Table 1.

Table 2: For CAM Shaft Taper of 9°

Sl No	Cam Length (m)	Cam Taper	Cam Diameter (m)	Displacement of Valve (m)
1	0.0174	9°	0.03345	0.00396
2	0.0174	9°	0.03447	0.00592
3	0.0174	9°	0.03574	0.00722

At CAM Shaft taper of 9° the diameter of the CAM varies from one end to another end so that the valve movement changes when the rocker is placed on 3 different positions of Cam which is shown in Table 2.

Calculation of Minimum Valve Displacement at the Smaller Side Cam for 8° Taper Turn

$$X = (R-r) (1-\cos\Phi)$$

$$X = (0.0336-0.016) (1-\cos 42)$$

$$X = 0.00452\text{m}$$

Exp Valve Displacement V/S Theoretical Valve Displacement

Table 3: Exp Valve Displacement V/S Theoretical Valve Displacement for CAM Shaft taper of 8°

Sl No	Valve Displacement (mm) Exp	Valve Displacement (mm) The	Degree of Contact
1	4.396	4.520	42
2	6.022	6.160	48
3	7.319	7.586	52

Figure 7: For CAM Shaft Taper of 9°

The valve displacement on CAM is noted exp for CAM Shaft taper of 8° and compared with the theoretical value.

The Experimental result is closer to the theoretical result as shown in the graph

By this, we can conclude that

- The valve movement can be changed by modifying the CAM Shaft.
- The valve movement varies as the degree of contact changes which depends on the diameter of the cam.

Table 4: Exp Valve Displacement V/S Theoretical Valve Displacement for CAM Shaft taper of 9°

Sl No	Valve Displacement (mm) Exp	Valve Displacement (mm) The	Degree of Contact
1	3.961	4.082	40
2	5.925	5.645	46
3	7.222	7.586	52

Figure 8: For CAM Shaft Taper of 9°

The valve displacement on CAM is noted exp for CAM Shaft taper of 9° and compared with the theoretical value. The Experimental result closely tallies with theoretical result as shown in a graph

The valve movement varies as the degree of contact changes which depends on the diameter of the cam. The Theoretical and the experimental values of the valve movement on CAM tally well with each other at 3 different locations for 8° & 9° degrees of taper turn on CAM.

MEASUREMENT OF PERFORMANCE PARAMETERS

Measurement of Cylinder Pressure

Piezoelectric sensor is embedded in one cylinder which acts as a pressure transducer which reads the pressure at each angle with the help of digital encoder engaged to the main shaft of the engine.

Figure 9: Piezo Electric Sensor for P-0

Measurement of Air-Consumption

Figure 10: Air Box with Orificemeter

Measurement of Fuel Consumption

A fuel tank is mounted at the top of the load cell and is connected to the fuel indicator which will read the total load i.e. total amount of fuel inside the tank. Tank consists of fuel pump which is connected to the ECU which is connected to the battery terminals. The difference in the mass of fuel for various running conditions to the initial fuel contained in the tank is calculated. The fuel rate is displayed in the indicator in terms of *Kg/hr*.

Description of Apparatus

Test rig consists of four stroke four cylinder MPFI petrol engine which is coupled to an eddy current dynamometer.

An airbox of cross section 400×400 is mounted on the engine frame which is connected to the air suction point of the engine.

An orifice of specific diameter is cut in the airbox to find the discharge which in turn is connected to air flow indicator.

The fuel tank is mounted on the frame which consists of a pump that drives the fuel to the engine. The load cell mounting with the fuel tank is connected to the fuel indicator which displays fuel consumption of the engine.

Engine control unit(ECU) is embedded with the multi-point fuel injection (MPFI) of the engine with the battery fixed on the frame

Cooling water is supplied to the engine from the external source which is connected to the water flow sensor.

Hand lever operates as a clutch to disengage the main shaft of the engine.

Figure 11: Digital Indicator of Air, Fuel and Speed

Figure 12: Overall Engine Test Rig

RESULTS & DISCUSSIONS

Specific fuel Consumption (Kg/KW-hr) v/s Load

SFC at Minimum Valve Displacement

Table 5

SFC V/S Load		
Load	SFC	SFC
0	0.786	0.82
0.25	0.768	0.79
0.5	0.647	0.73
0.75	0.659	0.737
1	0.8	0.83

Figure 13

Calculation SFC: $SFC = \text{Fuel Rate} / IP$

$$= 0.96 / 1.22$$

$$= 0.786 \text{ (Kg/Kw-hr)}$$

SFC at Medium Valve Displacement

Table 6

SFC V/S Load		
Load	SFC	SFC
0	0.71	0.716
0.25	0.73	0.75
0.5	0.64	0.68
0.75	0.635	0.69
1	0.69	0.7

Figure 14

SFC at Maximum Valve Displacement

Table 7

SFC V/S Load		
Load	SFC	SFC
0	0.81	0.81
0.25	0.85	0.85
0.5	0.84	0.84
0.75	0.7	0.7
1	0.8	0.8

Figure 15

Volumetric Efficiency

Volumetric efficiency at Minimum Valve Displacement

Table 8

VE V/S Load		
Load	VE	VE
0	56.21	43.23
0.25	57.81	41.01
0.5	53.84	49.04
0.75	61.36	55.93
1	70.95	70.73

Figure 16

Volumetric Efficiency at Medium Valve Displacement

Table 9

VE V/S Load		
Load	VE	VE
0	47.28	42.53
0.25	49.8	44.39
0.5	58.02	49.95
0.75	73.3	59.16
1	75.32	69.01

Figure 17

Volumetric Efficiency at Maximum Valve Displacement

Table 10

3.VE V/S Load		
Load	VE	VE
0	44.99	44.99
0.25	46.19	46.19
0.5	47.24	47.24
0.75	53.24	53.24
1	60.82	60.82

Figure 18

Thermal Efficiency

Thermal efficiency at Minimum Valve Displacement

Table 11

1. Thermal η V/S Load		
Load	Thermal η	Thermal η
0	10.8	10.4
0.25	11.18	10.8
0.5	13.25	11.68
0.75	13.01	11.64
1	9.6	10.23

Figure 19

Thermal Efficiency at Medium Valve Displacement

Table 12

1. Thermal η V/S Load		
Load	Thermal η	Thermal η
0	11.56	11.29
0.25	12	12
0.5	13.22	12.54
0.75	13.51	12.32
1	12.43	8.46

Figure 20

Thermal efficiency at Maximum Valve Displacement

Table 13

1.Thermal η V/S Load		
Load	Thermal η	Thermal η
0	9.76	9.76
0.25	10.07	10.07
0.5	10.2	10.2
0.75	12.26	12.26
1	10.7	10.7

Figure 21

CONCLUSIONS

- The theoretical and experimentally measured valve displacements tally with a good degree of precision.
- The SFC tends to be lowest at the MedVD position for the MPFI Engine for both 8deg taper and 9deg taper camshafts.
- The Volumetric efficiency also reflects this observation as it tends to take the highest values at the MedVD position of the valve at $\frac{3}{4}$ load engine loading conditions
- The above trend is also reflected in the graph of Thermal efficiency where it tends to peak at the MedVD position of the valve at $\frac{3}{4}$ load engine loading conditions
- The above observations point to the fact that MedVD valve position of the Tri-Lobed Camshaft engine and at engine operating conditions between $\frac{1}{2}$ and $\frac{3}{4}$ engine load may be the most optimum operating conditions to derive the highest fuel efficiency.

REFERENCES

1. Manjunath Gowda M.R, Harish Kumar R and N.S Venkatesh Guptha “Kinematic Design and Simulation of a Flexible Valve Lift Mechanism for an IC Engine” SSRG International Journal of Mechanical Engineering (SSRG-IJME), ISSN: 2348 – 8360 volume 2 Issue 8 – August 2015,
2. Manjunath Gowda M.R, Harish Kumar R and N.S Venkatesh Guptha “Design of Tri Lobed Cam for a Flexible Valve Lift Actuation Mechanism In IC Engine” International Journal Of Advances In Production And Mechanical Engineering (IJAPME) ISSN(Print):2394-6202,(Online):2394-6210,Volume-2,Issue-1,2016
3. Manjunath Gowda M.R, Harish Kumar R and N.S Venkatesh Guptha “Design of Tri Lobed Cam and Finding the Effect on Emission for a Flexible Valve Lift Actuation Mechanism In IC Engine” International Journal of Current Research Vol. 8, Issue, 02, pp.26777-26783, February, 2016
4. Shaikh M. C & Dange H. M, Performance Enhancement of Cooling System of a MPFI Multicylinder Petrol Engine by Using Nanofluids, International Journal of Mechanical and Production Engineering Research and Development (IJMPERD), Volume 3, Issue 4, September - October 2013, pp. 47-56
5. L. Mianzo and H. Peng, “Output feedback H preview control of an electromechanical valve actuator,” IEEE Trans.Control Syst. Technol., vol. 15, no. 3, pp. 428–437, Apr. 2007.
6. Eid Mohamed “Modeling and performance evaluation of an electromechanical valve actuator for a camless IC engine”, International Journal of Energy and environment, Volume 3, Issue 2, 2012 pp.275-294
7. Mr.Paresh K. Kasundra, Prof. Ashish V. Gohil, “Performance Test of CI Engine with Different Vegetable Oil as a Fuel” International Journal of Engineering Trends and Technology- Volume2Issue3- 2011
8. S. Naga Sarada, M.Shailaja, A.V. Sita Rama Raju, K. Kalyani Radha “Optimization of injection pressure for a compression ignition engine with cotton seed oil as an alternate fuel” International Journal of Engineering, Science and Technology Vol. 2, No. 6, 2010, pp. 142-149
9. Kern Y. Kang, Je H. Baek “Turbulence characteristics of tumble flow in a four-valve engine”. Experimental Thermal and Fluid Science 18 (1998) 231±243
10. G Lakshmi Narayana Rao, S Sampath, K Rajagopal “Experimental Studies on the Combustion and Emission Characteristics of a Diesel Engine Fuelled with Used Cooking Oil Methyl Ester and its Diesel Blends” World Academy of Science, Engineering and Technology 37 2008
11. J. Tsai, C. R. Koch, and M. Saif, “Cycle adaptive feedforward approach control of an electromagnetic valve actuator,” in Proc. 47th IEEE Conf. Decision Control, Cancun, Mexico, 2008, pp. 5698–5703
12. Kwanhee Choi, Hyungmin Lee, In Goo Hwang, Cha-Lee Myung and Simsoo Park, “ Effects of various intake valve timings and spark timings on combustion, cyclic THC and NOX emissions during cold start phase with idle operation in CVVT engine”, Journal of Mechanical Science and Technology 22 (2008) 2254~2262