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OPTIMISATION OF VARIABLE VALVE TIMINGS OF AN SI ENGINE USING CAE SOFTWARE

(JSS Academy of Technical Education Noida)

Aman Kumar,
aman31kmr@gmail.com, ,

Shubham Tyagi,
28shubhamtyagi@gmail.com,

Ankit Singh
ankit612singh@gmail.com

Gaurish Sharma
gourish.sharma91@gmail.com

ABSTRACT

The valve timing plays a crucial role in diagnosing the performance of an IC Engine mainly when examined in terms of produced Brake Power, Volumetric Efficiency and Emissions. In our project we aimed to improve the performance of an SI engine through simulation using Lotus Engine Software. The selected model was Royal Enfield Standard 350cc engine. This engine was selected as the performance of this engine had the scope of being significantly improved. We selected different valve timings for intake opening and closing of valves at different rpms, same procedure was repeated for Exhaust valve. The parameters considered for improvement were Brake Power, Braking Torque, Brake Specific Fuel Consumption (BSFC) and Volumetric Efficiency. Power and Torque were selected as they were absolute parameters of judging any engine. BSFC provided the fuel consumption while improving the performance and Volumetric Efficiency was important considering the charge required for combustion. On completion of our work we were able to determine different opening and closing angles at different rpms. These values provided an optimized performance of the engine considering fuel consumed and power produced, which were improved when compared with Royal Enfield Standard 350cc engine.

INTRODUCTION

In conventional IC engines, the intake and exhaust valve timings are designed to optimize operation at high engine speed, and wide-open throttle operating conditions. Variable valve timing relates both the opening and closing of the inlet and exhaust valves in relation to timings of actuation. It is represented in terms of the Crank angle at which the event occurs with

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respect to the Top Dead Centre and Bottom Dead Centre positions. The Engine performance, up to a great extent, is improved by these parameters varied in the Suction process. It was analysed that the Optimum Valve Timing, Lift and duration are different for low as well as high engine speeds. At high speed, the optimal setting would lead lesser Air and fuel mixture and hence resulting in power output loss. Similarly, any setting for high speeds would result in difficult idling and very rough engine performance at low speeds [11]. Hence, a setting of mid-Engine speed range is needed which is a compromise between low as well as high speed. Thus a need for a Variable type of valve timing setting was recognized which would thus not compromise on the Engine performance over the spectrum. Thus, VVT actuation process is the changing of timing and Lift of a valve lift event which further improves the fuel economy, torque characteristics, performance and emissions. Till now, various ways of achieving this system has been developed, ranging from simple mechanical systems to electro-mechanical, magnetic to camless systems. Various strict emissions norms and increasing overall air pollution have caused automotive industries to utilize VVT systems, although due to high cost, durability and reliability considerations it is limited to high-end cars. Therefore, with the latest technological developments consolidated with hydraulic valve control and electromagnetic and with the recent progress in microprocessors utilization, application of VVT in the near future is quite feasible.

II. LITERATURE SURVEY

Various attempts have been made by different companies since the early 20th century to vary the valve timing of commercial engines. The first attempt was made on some radial aeroplane engine in 1920s working with high compression ratio to improve its performance[1].Fiat was the first to develop Variable valve timing among automobile companies in late 1960.[2]Sensing its ability , Ford[3] and General Motors, Honda[4] soon began using it. Till date various methods have been presented to control inlet and exhaust valves. Pierik [5] studied and demonstrated that use of VVT mechanism showed BSFC improvements of 12% at idle load , 7-10% at medium load to high load and 3-4 % at low to high rpm and an average 3% increment in peak torque. Bohac [6] studied the effect of Exhaust valve opening and closing on hydrocarbon emissions and concluded that early Exhaust valve opening

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(EVO) is helpful in hydrocarbon reduction in steady state but not in start-up condition. Robert [7] used a simulation based approach to optimize independent control variables for a dual-independent engine. The variables were: intake cam phasing, exhaust phasing, spark timing and fuel air equivalence ratio. Improvement was observed in engine torque magnitude. Sellnau [8] developed a two-step VVA system using an early intake valve closing strategy, its application on production engine gave benefits of 4.5-4.8 percent on fuel economy. An enhanced Engine was developed based upon EIVC, valve lift profiles were also changed to maximize fuel economy potential. Leroy [9] studied air path control of a SI engine. VVT was used for recirculation of internal exhaust gas. Fontana [10] designed a small displacement engine to pursue both engine performance and fuel consumption at a part load condition and concluded that the VVA system was effective in reducing the pumping losses and fuel consumption, at partial loads. Regarding valve timing event in an IC engine H. Kakaee and M. Pishgooie in their research had suggested that at lower rpm, lower values of valves angles are desirable, i.e., lesser IVO (bTDC), lesser IVC (aBDC), lesser EVO (bBDC) and lesser EVC (aBDC).Similarly higher values of valve angles is desirable at higher rpms.[11]. The above researches and studies have showed the potential of VVA systems in engines. Modern day researches are now focusing on developing new systems to implement them more effectively. Cam switching was the first technique where an actuator is used to swap between two or more cam profiles. The other is the cam phasing where actuation is achieved by slightly rotating the cam with respect to crankshaft of the engine. This allows the continuous variation for a brief period. Such a system was proposed by Osama H.M Ghazal and Mohammed S.H Dado [12]. BMW, Nissan and Toyota have developed a new oscillating mechanism which uses a oscillating cam lobe which acts on a follower. The most new method in field of VVT are camless systems [13] which work independent from camshaft to operate the valves. These systems use electromagnetic, hydraulic, or pneumatic actuators to open the poppet valves. They generally face problems like high power consumption, accuracy at high speed, temperature sensitivity, weight and packaging issues, high noise, high cost, and unsafe operation in case of electrical problems, these were reported by Chihaya Sugimoto [14]. Dhruv Chawda [15] in 2014 developed a rack and pinion system which can provide continuous actuation and was able to achieve variation of valve timing and lift independently. **(Refer Fig.1)**

III. METHODOLOGY ADOPTED

Royal Enfield 350cc engine was selected by observing the scope of significant improvement in performance. The basic specifications of the selected model are given in table 1. For analysing the physical model, the characteristics of engine was modelled virtually in Lotus Engine simulation software. **(Refer Table 1)**.

LOTUS Engine Simulation software is a simulation tool that has been used extensively to develop wide range of Engines. The Lotus Engine Simulation software was used to calculate intake and exhaust optimum values to maximize performance parameters. Using the Lotus tool window sensors and actuators were added to the Basic engine model to incorporate VVT system. VVT Sensors and actuators were added by attaching a sensor to the cylinder to sense the engine speed and actuator was connected to inlet valves to alter inlet valve timing with varying engine speed. Crank speed was chosen as a sensing parameter and Maximum Opening Point (MOP in degrees) as actuator variable to perform iterations. Valve opening/closing angles and MOP were varied keeping all the parameters constant for different engine rpms. Different MOPs were considered and the significant improvement in Brake power, Brake torque, volumetric efficiency and BSFC were analysed graphically.
(Refer Fig.2)

IV. RESULTS

After performing various iterations, the result obtained were summarised in the graphical form. As shown in fig 3.1, an average 6.1% increment in Brake Power is observed when VVT actuated model is compared to the manual engine model. Similarly, fig 3.2 shows the reduction of BSFC in optimised model with VVT as compared to base model. The average reduction is near to 4.89%. In fig 3.3, torque increments are observed for various rpms and the average increment amount is about 6.47%. Volumetric efficiency vs engine speed characteristics as shown in fig 3.4, has the average increment of approx. 6%. Table II shows the improvement in Engine performance for various rpms. **(Refer Fig 3.1, 3.2, 3.3 or 3.4) & (Refer Table 2)**

V. CONCLUSION

The result obtained is in accordance with the theoretical and experimental trends. The above results are observed when valve lift is kept constant. VVT can show more improvement when valve lift is also varied with valve angle. VVT system implemented in the virtual model using Lotus software gave optimised results in the form of improved Brake power, torque, BSFC and Volumetric efficiency.

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Fig 1: Valve timing diagram showing timings along with MOP.

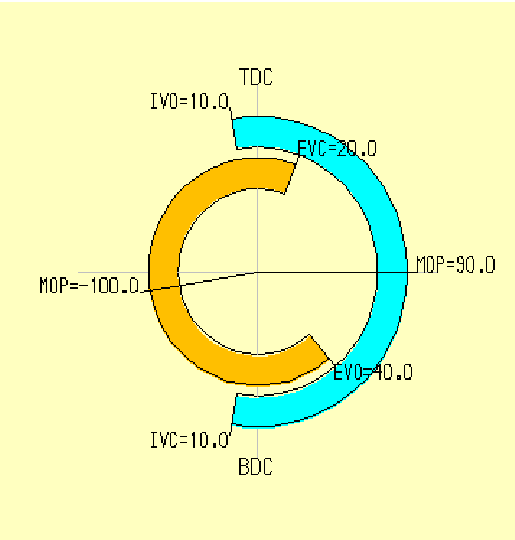

Fig 2: Lotus Simulation software workbench displaying VVT arrangement

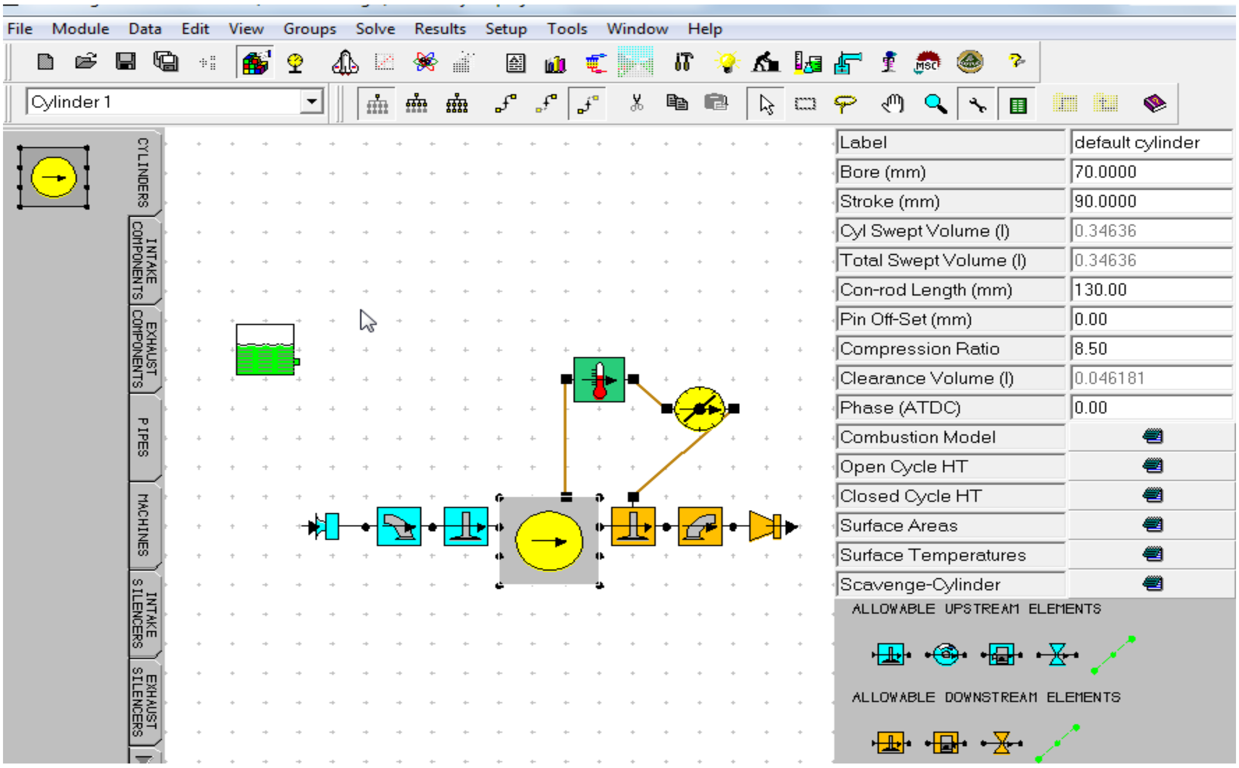

Fig 3.1: Brake Power Vs RPM

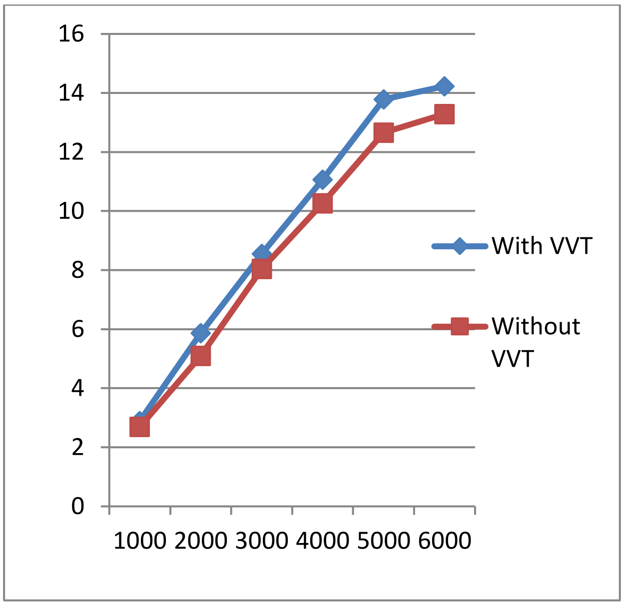

Fig 3.2: BSFC Vs RPM

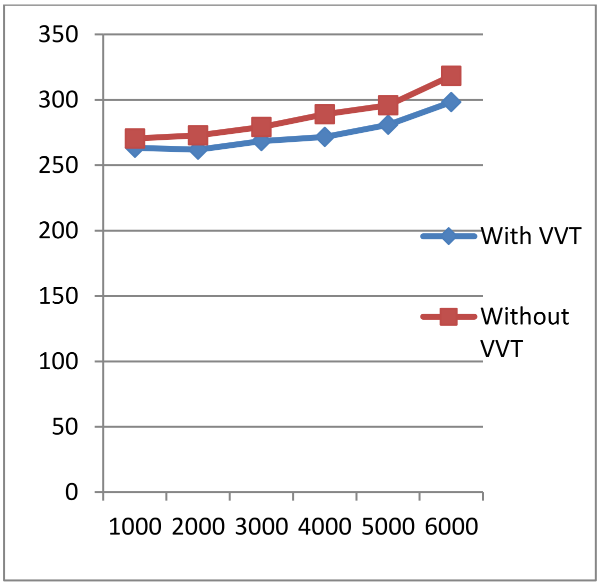

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Fig 3.3: Brake Torque Vs RPM

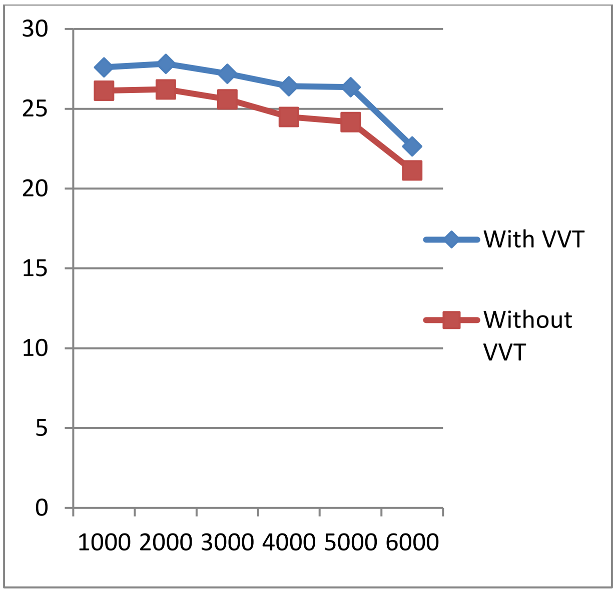

Fig 3.4: Volumetric Efficiency Vs RPM

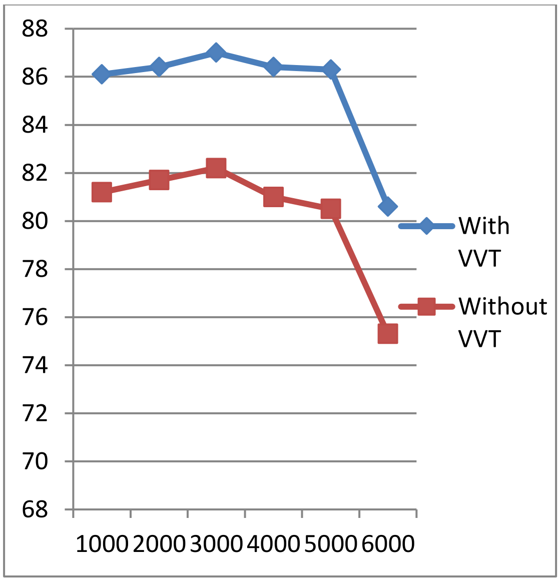

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Table 1: Basic Engine's specifications

Type of Engine	4-stroke
Bore	70
Stroke (mm)	90
Compression Ratio	8.5
Max Power	14.7KW@5250rpm
Max Torque	28N-m@4000rpm
Cylinders	1
Displacement (cc)	346
Valve Configuration	DOHC
Valves	2
Valves Per Cylinder	2

Table 2: Percentage improvement in Engine performance at different engine speeds

Engine Speed (rpm)	Brake Power Increment (%)	Brake Torque Increment (%)	Volumetric efficiency Increment (%)	BSFC Reduction (%)
1000	3.4	5.2	5.6	2.7
2000	5.3	5.7	5.4	4.18
3000	5.9	5.9	5.5	4.08
4000	7.3	7.3	6.2	6.4
5000	8.1	8.2	6.7	5.3
6000	6.6	6.5	6.5	6.7
Average Increment	**6.1**	**6.47**	**5.98**	**4.89**