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The Effects of Valve Mechanics on A Small SI Engine Performance

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ABSTRACT: Variable camshafts on car engines is a technology that is no longer called modern, but has been in use for a long time. Now even motorcycles and small-capacity engine vehicles have begun to apply this technology. The camshaft is optimally optimized for the fuel feeding speed as well as the discharge speed. As a result, fuel is burned more optimally, as well as when the combustion is finished, is discharged faster leading to increased engine power. Some effective technologies have been applied on internal combustion engine to increase engine power. Almost all of these technologies help engines to increase more free air into the cylinder of intake cycle and throw more exhaust gas in cylinder to outside air of exhaust cycle as a result engine effective have been efficiently improved. This paper presents solution via simulation to increase GV-300S engine power by re-designing cam profiles to improve efficiency of intake cycle and exhaust cycle. To achieve this goal, a simulation model of GV-300S engine has building via AVL-Boost software and an experimental system has installed with dynamo testing system. Effective technologies have been applied and the result of cam profile design shows an increase of 9.2% at 9000rpm and 4.97% for engine power and air mass flow respectively.

KEYWORDS: engine torque; valves lift; air mass flow; cam profile; re-designed cam profiles.

INTRODUCTION

In effort to improve engine performance characteristics as like as: To increase engine power, reduce fuel consumption or reduce NOx, CO, HC, PM in exhaust gas emission because these factor get big harmful on environment and human health or to increase engine power [1]. There are many researching projects were issued, all of those research presented the new solution for demand of improved engine performance characteristics [2]. Beside that modern gasoline engines have a maximum thermal efficiency of about 25% to 50% when used to power a car. In other words, even when the engine is operating at its point of maximum thermal efficiency, of the total heat energy released by the gasoline consumed, about 50-75% is rejected as heat without being turned into useful work, i.e. turning the crankshaft. Approximately half of this rejected heat is carried away by the exhaust gases, and half passes through the cylinder walls or cylinder head into the engine cooling system, and is passed to the atmosphere via the cooling system radiator [3]. Some of the work generated is also lost as friction, noise, air turbulence, and work used to turn engine equipment and appliances such as water and oil pumps and the electrical generator, leaving only about 25-50% of the energy released by the fuel consumed available to move the vehicle [4]. In automotive sensors, the camshaft position sensor functions to determine the position of the camshaft and provides information to the central processing unit to calculate the most appropriate timing of fuel injection. This sensor will work in tandem with the crankshaft position sensor to give the engine the optimum timing of fuel injection and ignition [5]. The camshaft position sensor is usually mounted at the top of the cylinder or at the cover of the camshaft housing [6]. When the camshaft position sensor is defective, some engine problems can occur as follows: Difficult to start the car, the engine suddenly dies, the engine leaves the engine or does not respond to acceleration, lights check engine [7].

Camshaft on each engine type of each car manufacturer with different production technology will be arranged in different installation positions. However, the mechanism to drive the shaft to the camshaft must be guaranteed. Each type of camshaft arrangement will correspond to each different drive type, the most common are the following three types: camshaft drive by gear transmission, camshaft drive by chain transmission and belt drive (transmission belt) [8]. Variable valve is to control opening and closing timing of intake and exhaust valve, VVT (Variable Valve Timing) intake and exhaust during the compression cycle of engine pistons [9]. In the combustion chamber, there will be a cycle where the fuel-air mixture gives and, and there will be a cycle where this mixture after machining is ejected. When the suction cycle, the intake valve will open, the exhaust valve will close. And in the discharge cycle, the intake valve will close, the exhaust valve will open [10]. This procedure is repeated regardless of operating conditions, regardless of high or low machine rpm, if normal camshaft is used. Pressure sensors are responsible for providing a vacuum pressure signal in the form of a voltage or frequency to the central processor to calculate the amount of fuel needed for the engine [11]. When the vehicle is in no-load or accelerated release mode, the vacuum pressure decreases. Conversely, when accelerating or heavy loading, the vacuum pressure increases. The intake air pressure sensor is usually mounted at the intake airflow at the suction neck. When this sensor is damaged, the vehicle will have signs such as: check engine lamp light and MAP sensor error, engine is not smooth, engine capacity is low, fuel consumption, smoky vehicle [12].

By those reason, researcher always try to improve engine efficiency by apply the new technical designed model or able to recover energy from heat loss of engine as like as: Xu et al [13] have performed an experimental study on the effects of variable valve timing and low lift cams on CAI (controlled auto-ignition) combustion. They have changed the valve lifts from 0.3 to 9.5 mm. They have seen the effects of low lift cams on SI (spark ignition) and CAI combustion, in-cylinder pressure and heat release rate. Pournazeri et. al [14] have performed Effects of valve lift on the combustion and emissions of a HCCI gasoline engine. Yoon [15] have performed how intake and exhaust influence on engine performance. Dimitrova [16] have performed flow coefficient measurements for an engine cylinder head under transient flow conditions with continuous valve lift change in order to determine the actual engine intake flow condition , the valve lift of the intake valve, whose rod is in contact with the camshaft, is varied continuously by rotating the cam-shaft directly [17].

In this paper, a solution to increase a small SI engine power was study. A more effective cam profiles were determined based on 28 mm basic circle diameter and 190 deg cam angle with valve lifts 6.5 mm for intake and 6.4 mm for exhaust by using classical spline method to add more air mass flow into cylinder while keep for air-mass ratio is constant that means fuel in to cylinder would be increased too.

METHODOLOGY

Experiment setup

The experiment were performed at engine speed testing band form 3000 rpm – 10000 rpm, compression ratio at 11.8:1, air/fuel ratio was 13,6 and air intake temperature was at (29,5-30 degC). Before the experiments all the test equipment were calibrated. The experiments were performed at steady state, at each engine speed the throttle angle was keep for 100% of opening.

Simulation model

AVL-Boost is an advanced and fully integrated “Virtual Engine Simulation Tool”. Boost simulates a wide variety of engines, 4 stroke or 2 stroke, spark or auto-ignited. Applications range from small capacity engines for motorcycles or industrial purpose up characteristics of pneumatic systems. Figure 2 shows GV-300S simulation engine model by AVL-Boost software, before building simulation model the structure of researching engine should be learned.

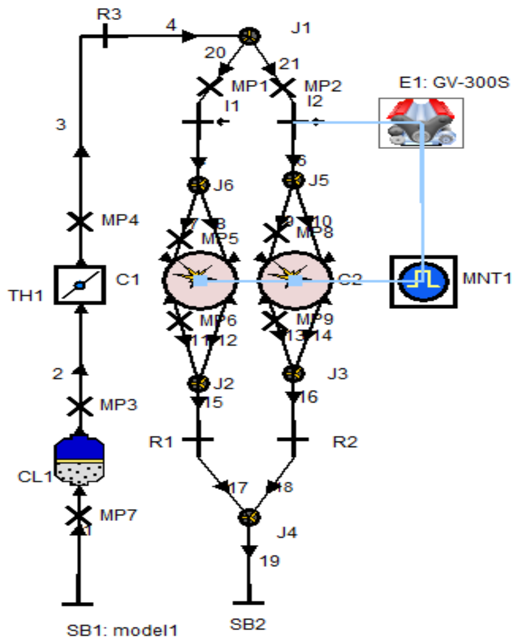

Figure 1. Simulation model.

Where: E1: Engine; MNT1: Monitor; SB1, SB2: System Boundary CL1: Air cleaner; TH1: Throttle; R1, R2, R3: Re-striction on the tube; J1, J2, J3, J5, J6: Junction on the tube; MP1, MP2: Measuring Point; I1, I2: Injector; C1, C2: Cylinder; 1, 2, 3...21: Intake tube and exhaust tube

Throttle angle would be open 100% thought simulation process. Restriction element R1, R2, R3 is used to consider a distinct pressure loss at a certain location in the piping system. By setting Measuring Point elements (MP1, MP2…) on the pipes to measure parameters of the flow in the pipes (parameters like: Temperature, pressure, velocity, mass flow…).

RESULTS AND DISCUSSION

This paper presents a method to increase air mass flow in to cylinder via re-designing cam profiles. With changed valve lift, it is lest cost and more effective method to increase air mass flow in to cylinder.

The equations (1) and (2) show how valve lifts influence on air mass flow in to cylinder [5].

$$C_f = \frac{Q}{A_{seat}.V_0}; \quad V_0 = \sqrt{\frac{2.\Delta P}{\rho}}; \quad A_{seat} = \frac{\pi}{4} D^2{}_{seat}; \tag{1}$$

Q: Measured volume flow rate (m^3/sec), V_0 : Velocity head (m^2/s), A_{seat}: Inner seat area (m^2)

D_{seat}: Intake valve seat diameter (m).

$$C_d = \frac{Q}{A_V.V_0}; \quad A_V = n.\pi.D^2.\frac{L}{D}.\cos\phi(1+\frac{L}{D}\sin\phi.\cos\phi) \tag{2}$$

A_V : Orifice area between valve head and seat (m^2); L : Valve lift (m); n: Number of intake valves per cylinder; Φ : Valve seat angle = 45^0.

Classical 5th-order spline approximation was used in the designing cam profiles for different valve lifts [18] by the equations (3)

$$S(\theta) = a(\frac{\theta-\chi}{t-\chi})^2 + b(\frac{\theta-\chi}{t-\chi})^2 + c(\frac{\theta-\chi}{t-\chi})^2 + d(\frac{\theta-\chi}{t-\chi})^2 + e(\frac{\theta-\chi}{t-\chi})^2 + f \quad (\chi \le \theta \le t)(1)(1) \tag{3}$$

Where "θ" is the cam angle, "χ" and "t" are the start and end timing of the function in terms of "θ" values.

Re-designed cam profile has 28 mm basic circle diameter and 190 deg cam angle with maximum valve lift is 6.5 mm. Basic circle diameter and cam angle are the standard values in the calculating of the cam profiles. Suitable valve lift, opening valve periods depend on cam designing method. Furthermore, smooth and efficient operation of valve mechanism can be ensured using proper cam profile design method. Hoang et. al [19] reported that the feature of single point contact of cam into follower has been lost with the increase of valve lift using 5th degree classical spline method. Re-designing of cam profiles with different valve lifts was calculated by using the following classical spline function with finite time difference [20]. In the Figure 3 the black curve is re-designed cam profile, the blue curve is the acceleration of the re-designing cam profile and the red curve is the velocity of the re-designing cam profile at 5000 rpm of engine speed. The velocity curve of the re-designed cam for different valve lifts were calculated by taking the first-order derivative of the displacement with respect to cam angle and the maximum value was 6.4 mm/deg. The acceleration profile of the re-designed cam for different valve lift was determined by using second-order derivative of the displacement with respect to cam angle and the maximum value was 0.0485 mm/deg^2.

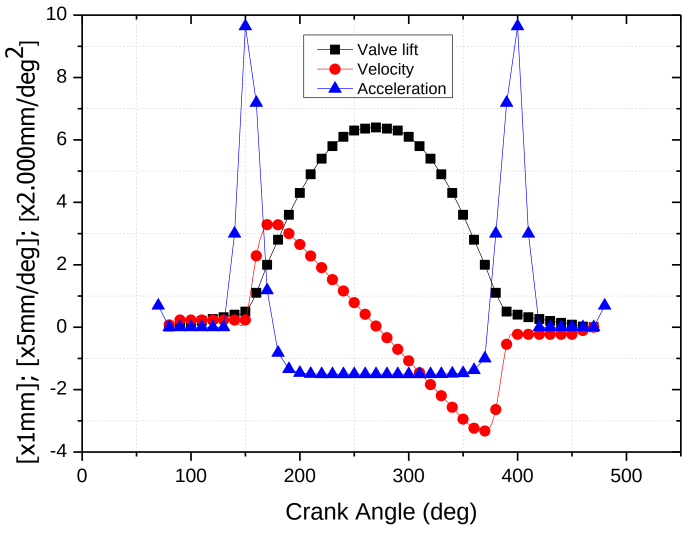

Figure 2. The displacement curve, velocity curve and acceleration curve of re-designed cam profile.

Figure 3, Figure 4, Figure 5 shows the comparison experiment results of two cases. The black curve is experiment results before re-designed cam profiles and the red curve is the experiment results after used re-designed cam profiles. When applied re-designed cam profiles air mass flow were increased when comparison with using original cam profiles. This is shows in Figure 3. The maximum difference of value is 4.97% at 1000 rpm of engine speed.

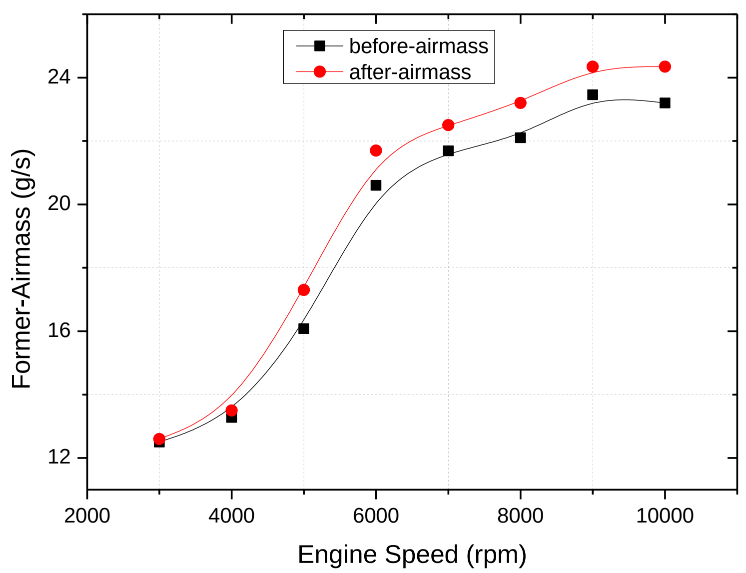

Figure 3. The comparison of profile between Intake original cam and re-designed cam.

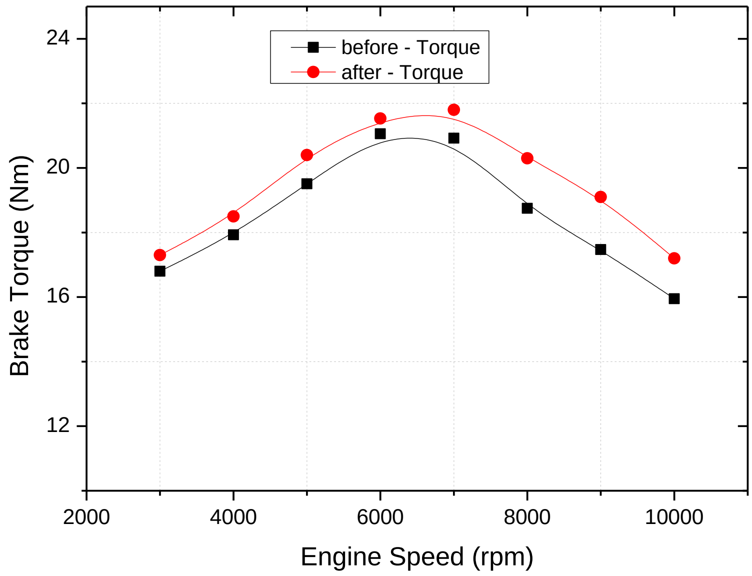

Figure 4. Comparison experiment torque before and after re-designing cam profile.

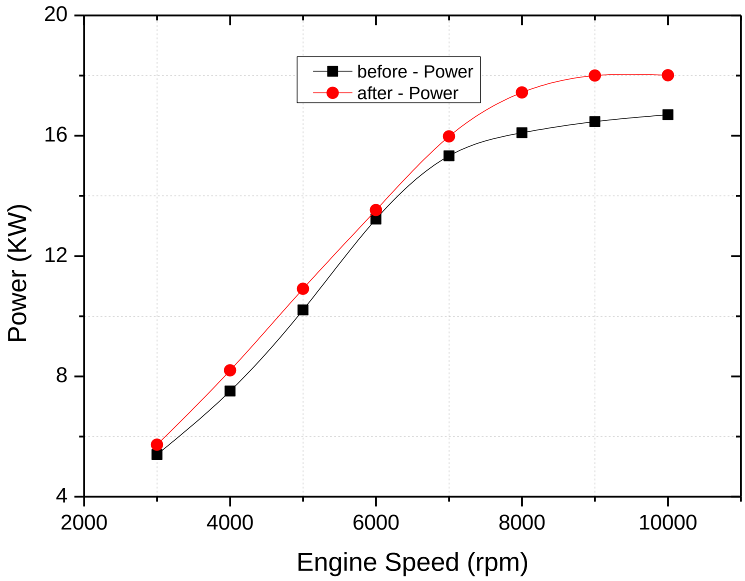

Figure 5. Engine power versus combustion ratio

The comparison of engine torque before and after applied re-designed cam profiles was shows in Figure 4. The engine torque which applied re-designed cam profiles is bigger than original engine torque at each engine speed. The maximum engine torque is 21.673 Nm increased 4.2% at 7000 rpm of engine speed. Beside that the maximum increased value of engine brake torque is 9.33% at 9000 rpm of engine speed. At 8000 rpm is 8.27% and 7.83% at 10000 rpm.

Figure 5 shows the comparison of engine power before and after applied re-designed cam profiles the value of engine power in case applied re-designed cam profiles is bigger than original engine torque at each engine speed. The maximum engine power is 18.11 KW increased 9.2% at 9000 rpm of engine speed. At 8000 rpm is 8 % and 7.8% at 10000 rpm.

CONCLUSIONS

A simulation study to improve the power of a small SI engine was presented using commercial AVL-Boost software. The effects of re-designing cam profiles on the engine torque and power were investigated. The timing of early opening and late closing of the valve according crankshaft angle greatly affects the technical features and emissions of the engine. The small load mode with the late opening and closing valve angle optimizes small changes compared to the original opening and closing angle to increase technical features and reduce engine emissions. The average load mode with the original angles is optimal because the engine is designed to work best in this load mode. The large load angle mode varies greatly from the original opening and closing angle to achieve the optimum angle of engine

The results show that: (1) From this research a new effective cam shaft has produced and applied an engine. (2) The small SI engine has achieved maximum engine brake torque is 19.1 Nm at 9000rpm of engine speed increasing 9.33% when comparison with formal engine brake torque. (3) Maximum power is 18.1 KW at 9000 rpm of engine speed increasing 9.2% when comparison with formal engine power. (4) The air mass flow also was increased 4.97% at 1000rpm of engine speed.

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