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Review on Working of Cam-less Engine

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Abstract- **This article presents an innovative application of an electromagnetic actuator for a future variable engine valve train. The engines powering today's vehicles whether they burn gasoline or diesel fuel rely on a system of valves to admit fuel and air into the cylinder and the exhaust gases to escape after combustion. Cam has been an integral part of internal combustion engine from its invention. Cam controls the breathing channels of the IC engines and hence maintains constant valve timing. The problem in using cam shafts is being major power wastage in accelerating and decelerating the components of the valve train.**

In response to the needs of improved engines some mechanical or hydraulic devices have been designed to achieve some variable valve timing and to reduce the disadvantages accompanied with the usage of cams. Most four-stroke piston engines today employ one or more camshafts operated poppet valves. A cam less (or, free valve engine) uses electromagnetic, hydraulic, or pneumatic actuators to open the poppet valves instead. Actuators can be used to both open and close the valves, or an actuator opens the valve while a spring closes it. Cam-Less internal combustion engines offer major improvements over traditional engines in terms of efficiency, maximum torque and power, and pollutant emissions. Electromechanical valve actuators are very promising in this context, but they present significant control problems

Keywords — IC Engine. Cam-Less Engine, Variable Valve timing, Electromagnetic Valve Actuator (EMV)

I. INTRODUCTION

In recent years Cam-Less engine has caught much attention in the automotive industry. Cam-Less valve train offers programmable valve motion control capability. Variable valve actuation (VVA) is an existing method that offers enhanced potential for improving the automotive internal combustion engine. Automobile manufacturers have recognized the compromises associated with engines that are governed by the rotation of a camshaft. This rotation, the speed of which is proportional to the engine's speed, determines the timing of the engine valves. For this reason, automotive engineers must make a decision early in the design process that dictates the performance of the automobile. The engine will either have powerful performance or increased fuel economy, but with the existing technology it is difficult to achieve both simultaneously. In response to the needs of improved engines, some manufacturers have designed mechanical devices to achieve some variable valve timing. These devices are essentially camshafts with multiple cam lobes or engines with multiple camshafts. This does represent an increased level of sophistication, but still limits the engine timing to a few discrete changes. The concept of variable valve timing has existed for some time. Unfortunately, the ability to achieve truly variable valve timing has eluded automotive manufacturers. Most variable timing mechanisms were created as tools for the automotive engineer. [1][2]

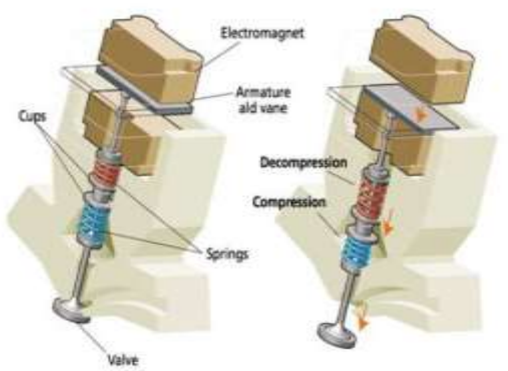


Fig 1. Components of Cam-Less Engine

Internal combustion engines traditionally use mechanically driven camshaft to actuate intake and exhaust valves. Their lift's profiles are a direct function of the engine crank angle and cannot be adjusted to optimize engine performance in different operating conditions. This results in a compromise design that impacts on achievable engine efficiency, maximum torque and power, and pollutant emission. Growing needs to improve fuel economy and reduce exhaust emissions lead to the development of alternative valve operating methods, which aim to alleviate or completely avoid the limitations imposed by a fixed valve timing. Electromechanical Cam-Less Valve train (EMCV) offers potential for making a high-performance engine. The overall results of a complete Cam-Less engine will provide the consumer with a vehicle that performs to expectations, but facilitates increased fuel economy. This combination is essential, since evidence shows consumers are not prepared to compromise on performance, while at the same time fuel prices continue to escalate. [3][4][5]

II. PRINCIPLE OF ELECTROMECHANICAL VALVE ACTUATOR

A typical construction of EMV consists of two magnets (closer and opener), two springs (an actuator and a valve spring) and a moving armature that is connected to an engine valve. Normally, most modern engines incorporate a hydraulic lash adjuster to ensure proper valve sealing under all thermal operating conditions. The current flowing in the coil creates a magnetic force on the armature to overcome compressive spring and friction forces. Both springs are adjusted such that they are always in compression for any armature position between the two electromagnets. Preloading these springs are ideal for achieving rapid flight time and minimizing electrical energy input. During normal operation, the spring forces are utilized to accelerate the moving masses while electromagnetic forces are utilized to attract and dwell the armature. [2]

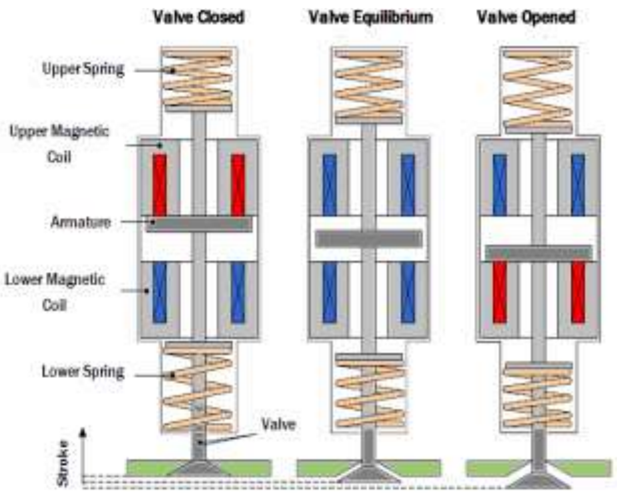
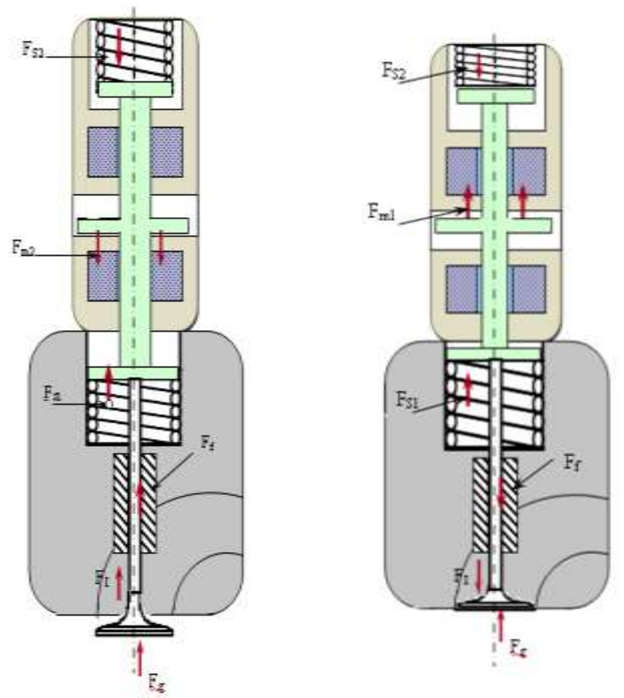


Figure 2. shows a schematic of an EMV actuator mounted on a cylinder head

Figure 2 illustrates a typical operational mode of the EMV actuator. To move the valve from neutral to closed position, a routine is initialized to impart sufficient armature momentum for the closer coil magnetic forces to attract the armature. Once contact is established and quasi-static conditions are reached, a holding current is applied to the upper coil so that sufficient magnetic force is generated to overcome spring forces while holding the armature and valve in the fully closed position. When the valve is commanded to open, the upper coil current is rapidly discharged, allowing magnetic force to decay and the actuator spring to push the armature down. The lower coil is then activated to capture the approaching armature. The electromagnetic force generated is proportional to the volume of the electromagnet. The design volume of the electromagnet is limited by the area in the cylinder head. Thus a compromise has to be made in the design and operation of an engine using EMV system. This compromise is usually in the form of a limited volumetric efficiency and maximum operating speed of the engine. [2]

III. EQUILIBRIUM OF FORCES ON EMV

The actuating forces on the valve armature are the magnetic, spring, inertia and frictional forces, in addition to the gas pressure force from the engine cylinder, the magnet force is applied to the valve directly through the armature. When no magnetic force exists, the armature is held by the upper and the lower spring in the middle position between the two magnets. This condition occurs when the engine is shut off. During engine operation, a current in the coil of the upper magnet is used to hold the armature against the upper magnet so that the valve is in the close position (equilibrium). To open the valve, the current is interrupted and the armature is moved by the spring-forces to the lower magnet. By providing a current to the coil of the lower magnet, the losses during the movement are compensated and the valve is held in the open position. To close the valve, the current is interrupted in the lower magnet and the current is re-applied to the coil of the upper magnet. [2]



(a) Valve opening (b) valve closed

Figure 3. Forces acting on valve train actuator during operation and EMV system modeling

$F_{m2} + F_{Su} - F_{SL} - F_f - F_{g1} = F_I$ For Valve Opening

$F_{m2} + F_{Su} – F_{SL} – F_f – F_{g1} = F_I$ For Valve Closing

where F_{m1}, F_{m2} are the lower and upper magnetic forces. Any reciprocating mass of the electromechanical valve train (armature and valve) produces cyclic inertia forces, which can be evaluated from:

$F_I = (m_v + m_{a)} * d_v/d_t$

Where m_v is the valve mass, m_a the armature mass and

d_v/d_t is armature valve acceleration.

The valve spring force F_s is obtained simply by spring stiffness and multiplying the spring rate by the deflection of the spring from its installation and adding any preload, where

$F_s = F_{in} + F_{con}$

$F_{in} = K* \delta_o$ and $F_{con} = K * x_v$ then, $F_s = K [\delta_o + X_v]$

The upper and lower spring forces:

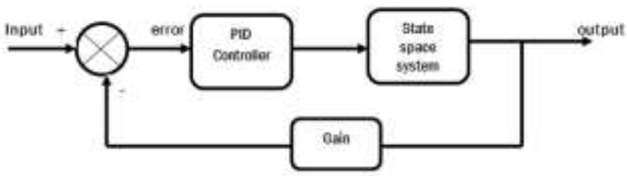
$Fs_L = K_L [\delta_{o1} + X_v]$

$Fs_u = K_u [\delta_{o2} + X_a]$

where F_{con} is the spring control force, F_{in} The spring initial support force, k_u, k_L are the upper and lower spring stiffness,δ_{o1},δ_{o2} the upper and lower spring initial deflections, X_v and the valve lift.

IV. CONTROL SYSTEM AND STABILITY

The system control of an electromagnetic valve (EMV) is described. This is using electromagnetic force to open and close the valve and a controller regulates the motion by control the variation of current duration with time. But, however the sensitivity of the transient motion to disturbances depends much on the system stability. The system has to be stabilized with a tuned PID controller before the system identification test could be executed. The PID controller works in a closed-loop system using the schematic in Figures 5 and 6. The variable *e* represents the tracking error, the sent to the PID controller and the controller computes both the derivative and the difference between the desired input value *R* and the actual output *Y*. This error signal *e* will the signal *u* just past the controller is now equal to the proportional gain KP times the magnitude of the error plus the integral gain KI times the integral of the error plus the derivative gain K_d times the derivative of the error.[2]



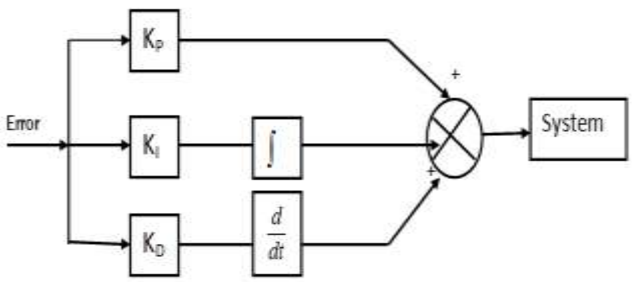


Figure 4. PID Controller without current applied

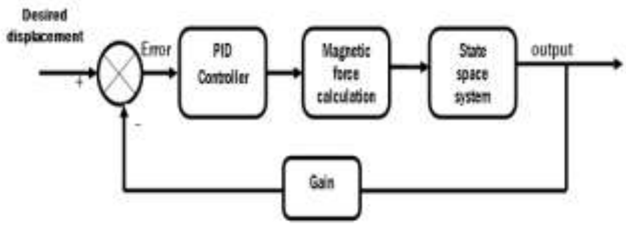


Figure 5. PID Controller with current applied

V. CONCLUSION

Internal combustion engines traditionally use mechanically driven camshaft to actuate intake and exhaust valves. Their lift's profiles are a direct function of the engine crank angle and cannot be adjusted to optimize engine performance in different operating conditions. This results in a compromise design that impacts on achievable engine efficiency, maximum torque and power, and pollutant emission. Growing needs to improve fuel economy and reduce exhaust emissions lead to the development of alternative valve operating methods, which aim to completely avoid the limitations imposed by a fixed valve timing and so Cam-Less engines are under study.

A Cam-Less engine that has valves operated by means of electromagnetic, hydraulic, or pneumatic actuators instead of conventional cams. Actuators can be used to both open and close valves, or to open valves closed by springs or other means. Review of the benefits expected from a cam less engine points to substantial improvements in performance, fuel economy, and emissions over and above what is achievable in engines with camshaft-based valve trains. The development of a cam fewer engines with an electro hydraulic valve train described in this report is only a first step towards a complete engine optimization.

Further Research and development are needed to take full advantage of this system.

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