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50. Internationales Wissenschaftliches Kolloquium
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R.G. Sousa/ H. A. Lepikson

Analysis and Development of an Actuator for a Camless Engine

ABSTRACT

THE MAJORITY OF AUTOMOTIVE ENGINES USE MECHANICAL VALVE TRAINS to activate the intake and exhaust valves. The valve motion is timed to the camshaft and crankshaft rotation, and has proven to be efficient and reliable over the years. However, the lack of flexibility of mechanical valve trains to vary timing and lift of intake valves is one of the major limits for significantly lowering fuel efficiency, which in the coming years will be of increasing importance. Increasing demands on the performance of automobile engines require the production of more mechanical energy for a given amount of chemical fuel with reduced emissions. Recognizing this compromise, automobile manufacturers have been attempting to provide vehicles capable of variable valve timing. Camless technology requires independent valve actuators that offer programmable valve motion control capability, which promises increased fuel economy, horsepower and reduced emissions and manufacturing costs. This paper investigates the advantages of camless technology and the main types of actuator used in camless engines as the first step to design an innovative actuator.

ADVANTAGES

ASIDE FROM LABORATORY USE, HISTORY SHOWS THAT THE IDEA OF A Camless internal combustion engine had its origins as early as 1899, when designs of variable valve timing surfaced. It was suggested that independent control of valve actuation could result in increased engine power [1]. More recently, however, the focus of increased power has broadened to include others benefits discussed below.

- **Reduced Emissions and Increased Fuel Economy -** control of intake valve opening, closing and lift provides optimal filling of the cylinder at all engine speeds, making it possible to reduce engine capacity and thus reduce consumption and increase fuel economy[2].

- **Increased power –** the variability of the electro-mechanical valve gives more power, as when acceleration is required, the valves open increasingly until they peak [3].
- **Lower manufacturer costs -** with camless technology we could remove or simplify many engine parts for example; camshaft, camshaft pulley, throttle body, rocker arms, pushrods, lifters and valve springs.
- **Decrease noise and vibration levels -** using a camless instead of mechanical valve train can reduce about 30% of moving parts and reduce noise and vibration levels.
- **Cylinder deactivation -** another benefit is the ability to cut the signal to the valves to make them inactive.
- **Variable compression ratio -** this can be accomplished by closing the intake valve earlier.
- **Starterless operation –** engine starting without a starter motor. Switching on the ignition, the computer recognizes all the valve positions and their relative piston positions, at this point the engine can then open all or most of the valves to relieve cylinder pressure. [3].

CAMLESS ACTUATORS

THERE ARE PRINCIPALLY TWO TYPES OF CAMLESS ACTUATORS, ELECTRO-Hydraulic valve (EHV) [4] and electro-mechanical valve (EMV) [5] actuators. However, there are some studies about piezoelectric applications.

3.1 Electro-hydraulic Valves

There are many examples of EHV actuators that have been proposed and patented to date. The functional principle is a hydraulic actuator controlled using solenoids valves. Through circuit control it is possible to vary timing and lift of intake valves.

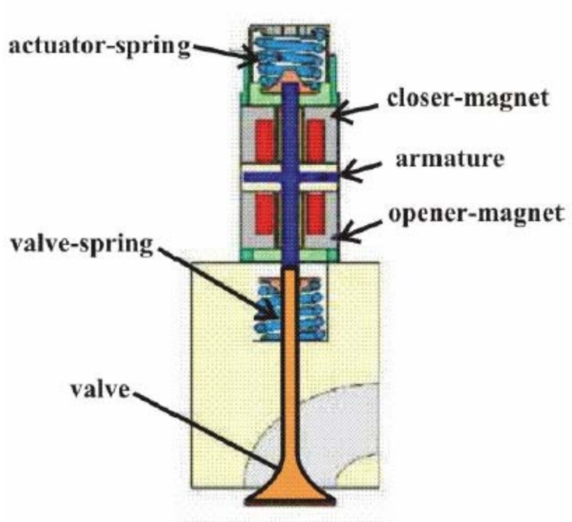

Figure 1 Schematic of the EMV system

3.2 Electro-mechanical Valves

The EMV [5], figure 1 [7], consists of two electric magnets, an armature, which moves between the two magnets, two springs, and an engine valve. When neither magnet is energized the armature is held equidistant from both magnets by the two springs located on either side of the armature. This system is then used to control the position of the engine valve. The engine valve is then in turn used to control the flow of air into and out of a combustion chamber.

DESIGN CONCEPT

BY USE OF INTEGRATED PRODUCT DEVELOPMENT TOOLS AND PRINCIPLES OF precision engineering, the concept design is being developed. Some results obtained from analysis of global function and functional structure of the prototype are shown below.

a) Global Function – the identification of input and output variables of the system, its interaction with the environment and humans can be visualised in fig. 2, where, *Mi, Mo* is the air/fuel mass, *n* is engine revolutions, *Wele* electrical potential, *Iki, Iko* human interaction, *Ai, Ao* engine interaction and *E* energy dissipated by the system.

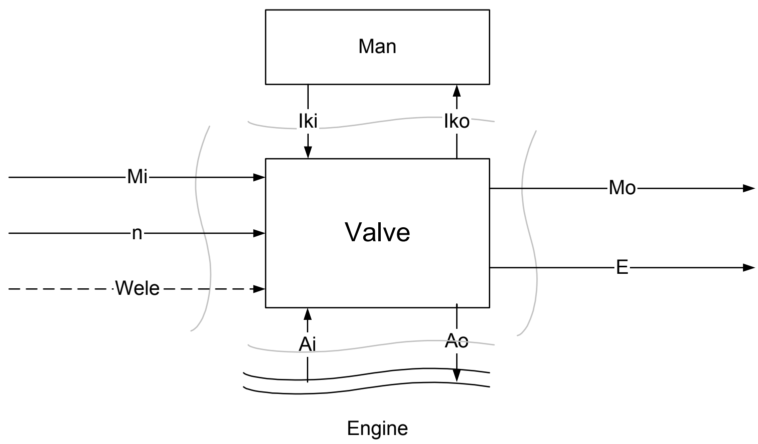

Fig. 2 – Global Function - Valve.

b) Functional Structure – in the functional structure, fig. 3, we can identify input and output variables for each function and its interaction with the control unit. The volume of air/fuel mixture (*mi*) enters in the first function identified as "COLLECTOR." The collector has the function of directing the volume of mixture to the next function, as there is no modification of the variable characteristics of input *mi* during this process, we can consider the output variable *mv* as being equal to input variable *mi* so (*mi=mv)*. The mixture *mo,* follows the next function, "DOSING". The doser has the function of controlling in a flexible way the flow of mixture to the combustion chamber *mo,* however the doser depends on the functions: "POSITIONING" and "CONTROLLING", so *mo=f(sy,mv).* The function "POSITIONING" has the objective of varying the position *sy* of the dosing element, with the object of controlling the mixture flow, but dependent on the controller signal *Iyi,* so, *sy=f(Iyi).* To increase the range of solutions for the positioner, this function was divided into other sub-functions. The function "CONTROLLING" is responsible for variable control of positioning *Iyi*, this function depends on other functions: "ANGLE MEASUREMENT," "ROTATION MEASUREMENT" and " POSITION MEASUREMENT," so, *Iyi=f(Iyo, Iq, In).*

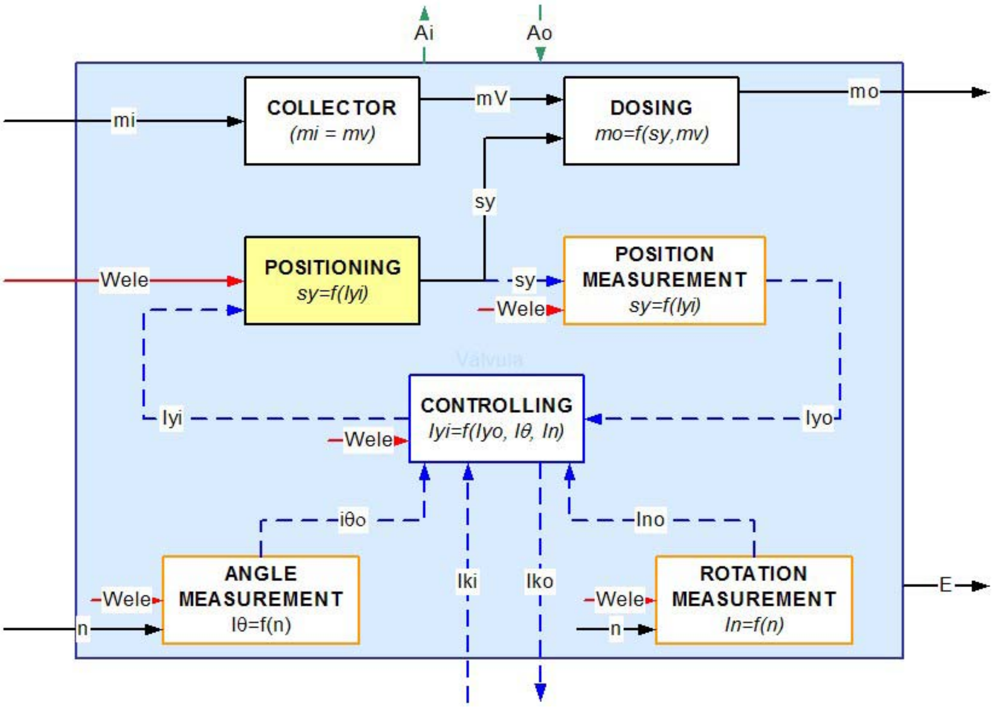

Fig. 3 – Functional Structure.

CONCLUSIONS

The objective of this project was to design and manufacture a device that proved the concept of a camless engine. More specifically, it is an electro-mechanical/piezoelectric device capable of producing engine valve displacement at typical automotive demands. The goals for maximum displacement and frequency are 14 mm and 250 Hz, respectively. In general, the unit must be capable of varying engine valve displacement and valve timing. The overall project was divided into four phases. First, conceptual development and a review of existing technology. Second, embodiment design. Third, manufacture and assembly of the camless engine. Finally, testing and analysis to proof of concept device.

To date, the conceptual design is finished. The list of requirements, global function, function structure, morphologic box and the evaluating of principles is completed. The system design utilized a customized piezoelectric stack combined with and electro-mechanical actuator. This device is capable of varying engine valve displacement and valve timing, controlling dynamically the piezoelectric and solenoid.

The first assembly will be realized in a 8HP mono-cylindrical engine, manufactured by Briggs Stratton, after that the prototype will be test in a 65 HP 1.0 L commercial engine. The first run of the camless engine is forecasted to February, 2006.

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