

RESEARCH OF THE ENGINE'S SPEED INFLUENCE ON THE INTAKE PROCESS OF A NATURALLY ASPIRATED ENGINE

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Abstract: *This paper presents the study of the influence of the valve train's dynamic behavior within the air intake process in the internal combustion engine. The software applications used in this study are Virtual Lab LMS and BOOST AVL. The first software was used for creating the valve train acting system, and the second software for the analysis of the engine intake process. Results show that the pumping work is influenced by the engine speed and the valve curve lift used in the analysis, cinematic or dynamic lift curve.*

Key words: *intake process, valve train, Virtual Lab, simulation.*

1. Introduction

The intake process has a major influence upon the internal combustion engine's energetic and ecological performances, especially its power, reason why it is necessary to determine the factors that have a negative influence.

This paper presents the study of the influence of the engine speed upon the lift curve, respectively upon the intake and exhaust process in a 4 stroke spark ignition engine. The results obtained in the analysis of the multy body model, intake and exhaust valve lift curves, are used as input data for the single cylinder engine virtual model.

The negative pump work diagrams for different engine speeds are compared in order to determine the influence of the dynamic behaviour upon intake and exhaust process.

2. Description of the Models

2.1. Virtual valve train model

The configuration of the valve train acting system is with 4 valves per cylinder.

The movement is transmitted from the cam to the valve through a finger follower, which is a third order lever. The finger follower is mounted at one end on to the hydraulic lash adjuster (HLA), and is supported by the valve stem at the other end [2].

The hydraulic lash adjuster has the role to maintain a zero valve clearance within the valve train mechanism.

The valve spring is mounted between the cylinder head and the retainer. It has the role to overcome the inertial forces of the valve and other parts of the mechanism and to maintain the valve on its seat, when the cam does not act upon the valve.

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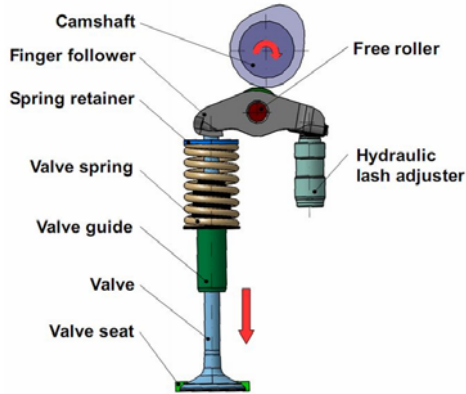


Fig. 1. Description of the multi body model used in the dynamic analysis

In order to simplify the virtual model, a single valve actuation system was chosen for analysis.

In the analysis there were used 2 cam profiles, one for the intake valve and the other for the exhaust valve.

The Figure 1 presents the configuration of the multi body used in the dynamic analysis of the valve train.

The virtual components of the model were created and assembled in CATIA and then using Virtual Lab software, from LMS, a virtual model of the mechanism was built.

The model consists of 11 rigid bodies, from which 4 are fixed to ground and 7 are free moving, as shown in Figure 2 [3].

The contact between the cam and finger follower and the one between the finger follower and valve are defined using an extrude to revolute contact element.

In this type of contact element the calculated force is based on the depth of penetration which is dependent on the thickness of the thick surface and the relative velocity normal to the contact surface, while friction forces are calculated based upon the relative velocities tangential

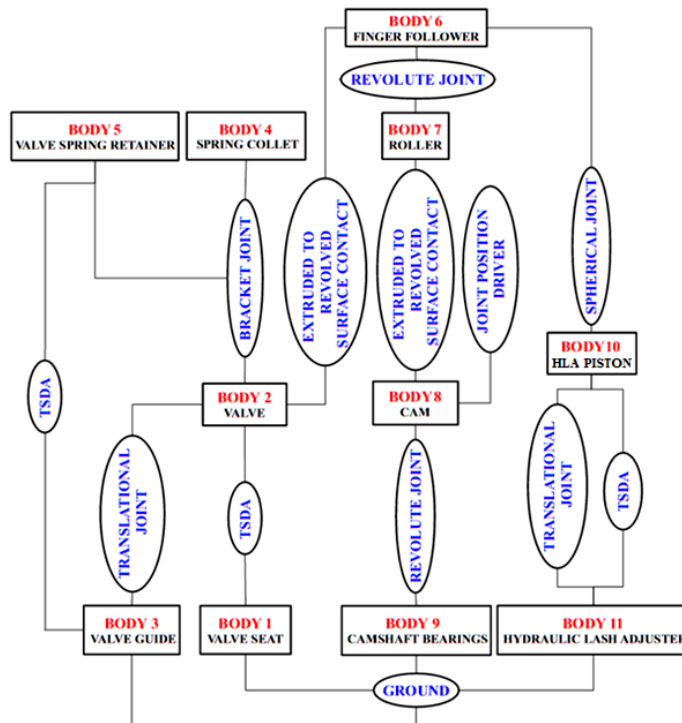


Fig. 2. The schematic of the dynamic model used in the analysis

to the surface. Spring and damping properties of the contact, may be defined through stiffness and damping constants, stiffness and damping curves, and through material properties (Young's modulus and coefficient of restitution) [5].

The displacements within the bearings along the three axes are not taken into consideration. Moreover the transmission which drives the camshaft was simplified by connecting the camshaft to the ground using a driven revolute joint [5].

The driver used for controlling the revolute joint, also called Joint Driver, uses the angular speed as input for the model.

2.2. Single cylinder engine virtual model

The virtual model of the single cylinder engine used in the analysis was created using the Boost software, provided by the AVL Company.

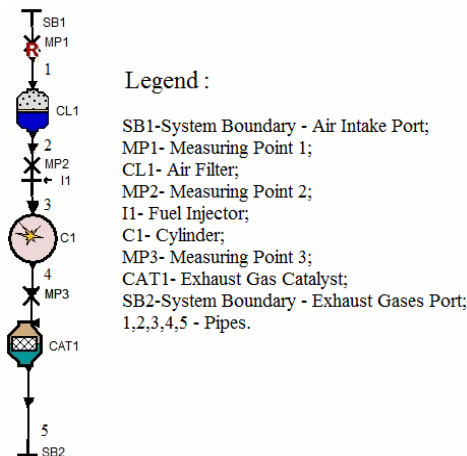


Fig. 3. *The schematic of the single cylinder engine virtual model*

AVL BOOST is an engine simulation tool applicable from the concept phase up to ECU calibration, addressing the needs of engine and powertrain simulation projects. The components of the engine are presented in Figure 3.

The characteristics of the gasoline indirect injection engine, used in the analysis, are presented in Table 1.

Table 1
The parameters of the single cylinder model

Number of cylinders	1
Bore [mm]	85
Stroke [mm]	90
Compression ratio	10
Valves per cylinder	4
Connecting rod [mm]	162

3. Single Cylinder Engine Input Data

3.1. Combustion model

For modeling the combustion process it is used the Vibe model. This model is defined by 4 parameters: start of combustion, combustion duration, shape parameter m and parameter a . They were chosen from AVL recommended values [4].

3.2. Heat transfer

The heat transfer model, used in the analysis, was the one developed by Woschni (1978). In the table below there are listed the values of the surface for the: piston, cylinder head and liner, all of them used in the analysis [4].

Table 2
Area values used in analysis

Piston area	5542 [mm ²]
Cylinder head area	7204 [mm ²]
Liner area	264 [mm ²]

3.3. Valves port

The number of valves is taken into account by specifying the flow coefficients and scaling factor in such way that the total

effective flow area of all considered values is obtained. Each ports will be modeled with one pipe each. In this case, the area is obtained by multiplying the actual area of the port with a factor of 1.71 [4].

4. Valve Train Data Input

The majority of the parameters values used in the analysis were experimentally determined, but some of them were adopted.

Input data table

Table 3

Contact	Parameter	Value	Units of Measurement
Cam-finger follower	Stiffness Coefficient	9e7	[N/m]
	Damping Coefficient	190	[kg/s]
	Transition Velocity	0.001	[m/s]
	Friction Coefficient	0.04	-
Finger follower-valve	Stiffness Coefficient	4e7	[N/m]
	Damping Coefficient	100	[kg/s]
	Transition Velocity	0.001	[m/s]
	Friction Coefficient	0.04	-
Valve spring	Stiffness Coefficient	35000	[N/m]

5. Results

The data obtained from the simulations are presented below.

Figure 4 presents the comparison between the valve's displacement curves, obtained from the dynamic, respectively kinematic analysis [1].

The lift curves of the intake and exhaust

valves were used as input data for the single cylinder engine. After the analysis, the graphs below were obtained.

After obtaining the negative pumping work diagrams (Figures 5 and 6), a calculus was made for determining the area of the diagrams, in order to find the value of the negative pumping work (Figure 7).

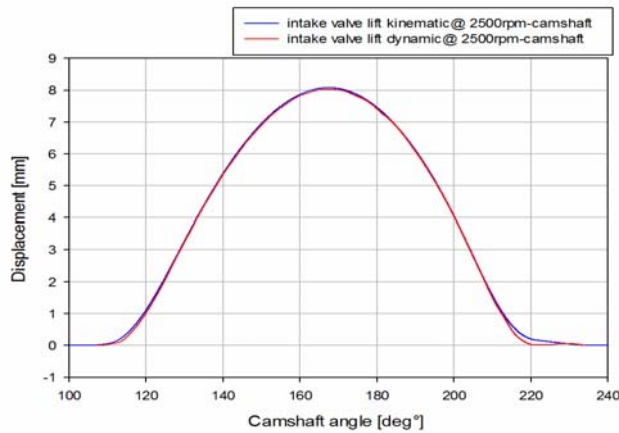


Fig. 4. Intake lift curves at 2500 rpm, obtained from the dynamic and kinematic analysis

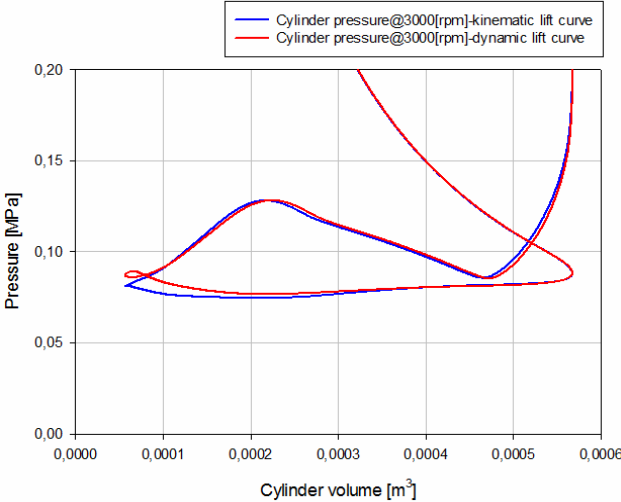


Fig. 5. Comparison between the pumping work obtained by using a kinematic lift curve and the one obtained by using a dynamic lift curve at 3000 rpm

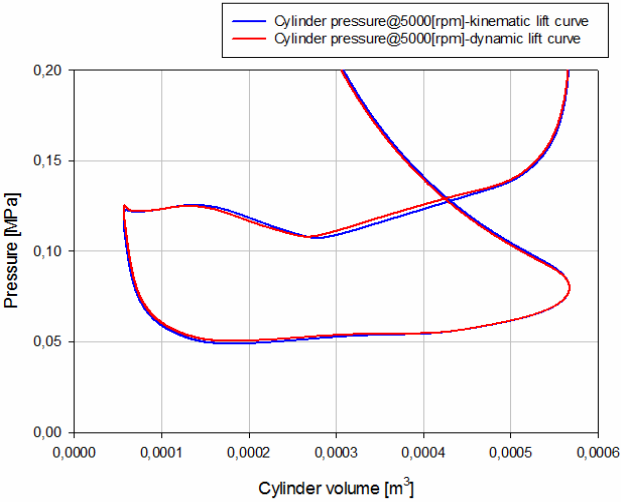


Fig. 6. Comparison between the pumping work obtained by using a kinematic lift curve and the one obtained by using a dynamic lift curve at 5000 rpm

6. Conclusions

As shown in the Figure 4, the lift curves of the intake valves are influenced by the dynamic behavior, respectively by the engine speed.

In the case of the dynamic analysis of the intake valve, this one opens later and closes

faster than in the case of the kinematic analysis, thus the intake air flow is reduced. Also the same phenomenon appears in the case of the exhaust valve.

The negative work consumed with the gas exchange is lower when using in analysis the dynamic valve lift curves.

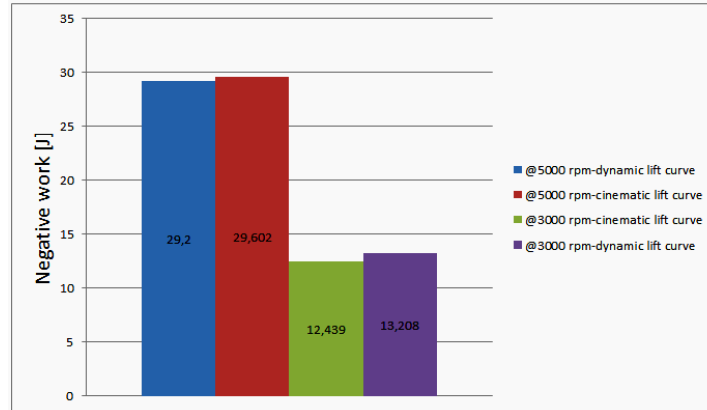


Fig. 7. Comparison between the negative works consumed with the gas exchange

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