MULTIBODY ANALYSIS OF THE FINGER FOLLOWER VALVETRAIN SYSTEM

Corneliu Cofaru, Gabriel Sandu*, Liviu Jelenschi, Serban Radu

Transilvania University of Brasov

KEYWORDS – valve train, hydraulic lash adjuster, multibody simulation, internal combustion engine, dynamic analysis.

ABSTRACT – This paper presents the study of a multibody virtual model, of a finger follower valve train system. The valve train mechanism has a very important role in the insurance of the economic and ecological performances, reason why it is important to assure its good functioning. The high speeds influence negatively the dynamic behavior of the valve train; this is why their thorough examination is required. The paper presents the analysis of a mechanism based on a single valve actuation system. The model used in this study, it is partly flexible. The spring model is designed using PDS (Powertrain Dynamic Simulator), a Virtual Lab tool. For this model the action of the valve is made indirectly, through the use of a finger follower, which is sustained at one end by a hydraulic lash adjuster. The first part of this paper, presents the conceptual model, which was designed using CATIA, Part Design module, and the cam's profile, which was used to generate the cam. The second part includes the description of the dynamic model used in analysis, and the comparison of the simulations results. Accelerations were considered as control parameters.

INTRODUCTION

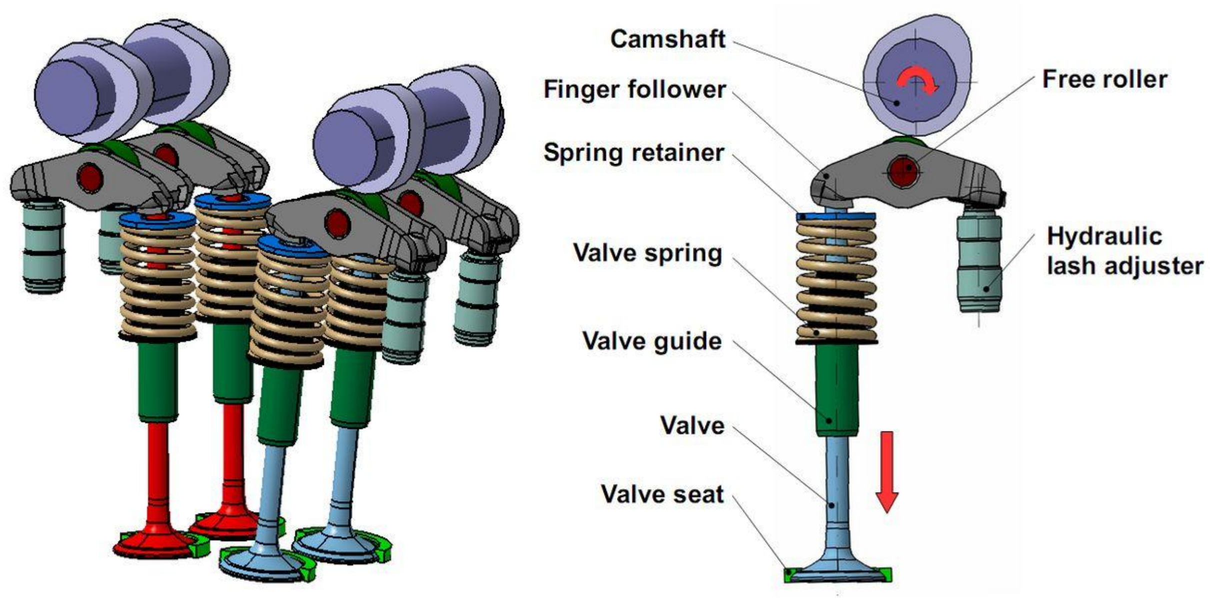
The valve train system is a common system used for internal combustion engines. This mechanism has a very important role in the insurance of the economic and ecological performances of the internal combustion engine. When the valve train system is functioning at high speeds, the dynamic behavior of the mechanism can be influenced negatively by the elastic links between the components, the mass distribution and the friction from the mechanism joints. Also, because of the high acceleration, may occur early fatigue of the components, and finally the destruction of the valve train mechanism.

This study is focused on the dynamic behavior of the finger follower valve train system, in particular on the influence of the camshaft speed. The purpose of this paper, is to present a virtual model which can be used in the dynamic analysis of a finger follower valve train mechanism, for determination of the accelerations, forces and torques, which can be used later for inquiry of the possible causes that can lead to the mechanism failure.

DESCRIPTION OF THE FINGER FOLLOWER VALVE TRAIN SYSTEM

This design variant of the studied mechanism has double overhead camshaft, and 4 valves per cylinder. In order to simplify the virtual model, a single valve actuation system was chosen for analysis. A general view of the studied mechanism is presented in figure 1a. In figure 1b it is shown the mechanism scheme, and its componentents.

The spring and the hydraulic lash adjuster have an important role in this mechanism. The hydraulic pivot element adjusts the thermal gap between the finger follower and the engine valve. The valve spring has the role, to return the valve on its seat.



a) **b)**

Figure 1 - a) Assembly view of the finger follower valve train system; b) The schematic of a single valve cam mechanism.

A roller (incorporated in the finger follower) reduces the friction forces between the cam's lobe and the finger follower. Also, this mechanism is wear resistant; due the fact the system tunes the thermal gap automatically. Another role of the finger follower is to multiply the displacement generated by the cam, acting as a 3th order lever.

GENERATION OF THE CAM PROFILE

The cam used in the analysis, has the following characteristics: the base circle radius, 14,7 mm and the maximum displacement, 4 mm. This cam has an asymmetric profile. The Cam's displacement law it is presented in figure 2. The cam construction consisted of the introduction of the all 360 points which define the cam profile, in CATIA, and the creation of a spline curve which passes through all points.

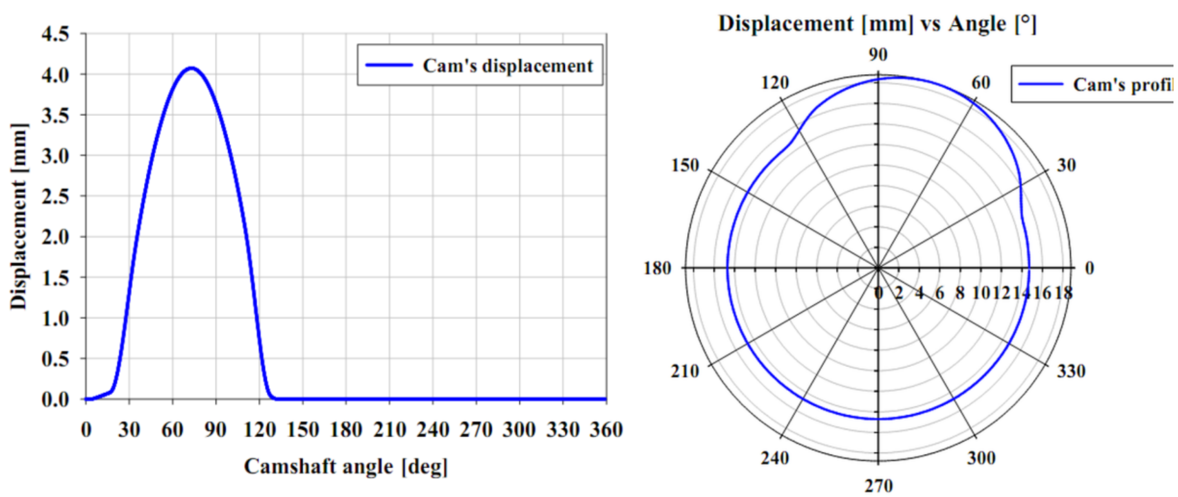


Figure 2 - Cam profile and displacement law

In the end the cam's profile was extruded at the design value. [1]

CREATION OF THE FLEXIBLE SPRING ELEMENT

The spring element is an important component of the valve train system. Therefore, the virtual model, of the spring element, must be very accurate, in order to obtain good results. For the creation of the flexible spring element it was used the Powertrain Dynamic Simulator program (also called PDS). This program was provided by LMS. Powertrain Dynamic Simulator is a software application that provides an intuitive and efficient environment, in which virtual prototypes of powertrain systems and subsystems can be constructed. These virtual prototypes can then be used to predict mechanical performance, helping to guide powertrain engineers through the exploration of a wide variety of design changes during the development process. The spring element was created using a specific tool from the PDS's library, which is called helical spring. [4]

Some of the input data for this program are: spring free length, cross section of the spring wire, number of bodies, the maximum acting force, and a text file which contains a series of points that define the helix curve (fig.3)

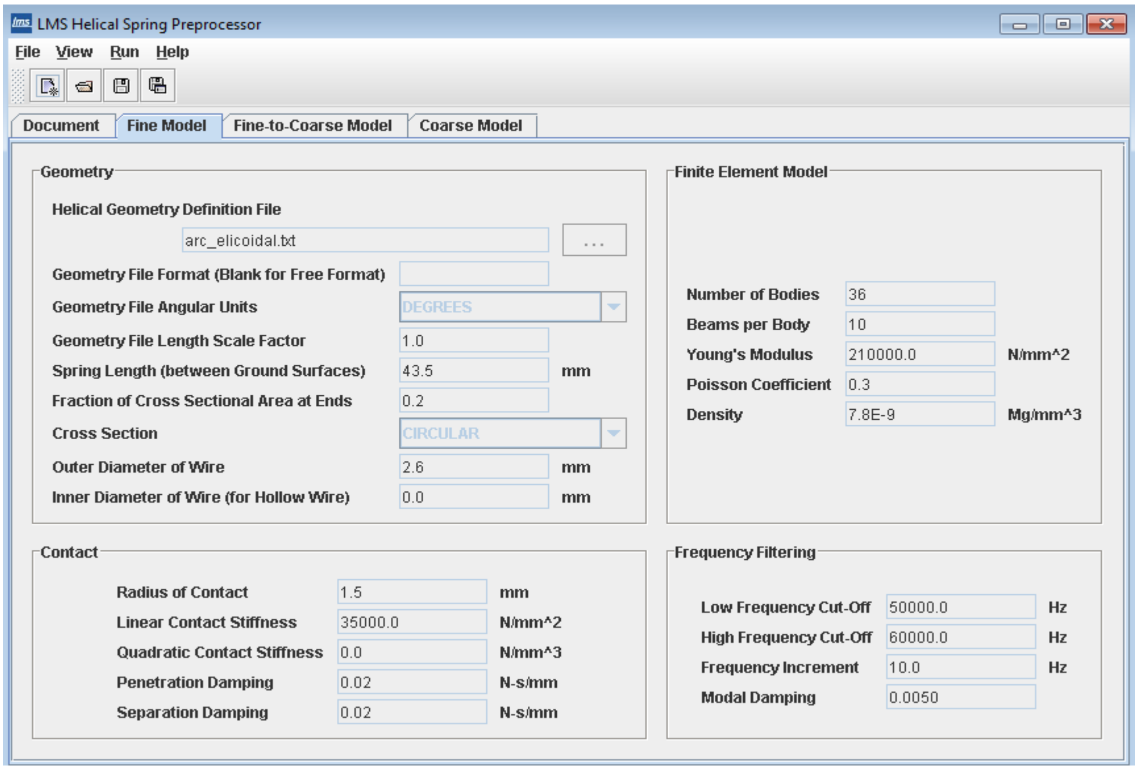


Figure 3 - The data input screen for the flexible spring model

The next step made in the creation of the helical spring, was the generation of the CATAnalysis document, which later on it was introduced in virtual model of the valve train system. [2]

In figure 4 are presented two simulation steps of the helical spring, in which the maximum displacement values can be seen.

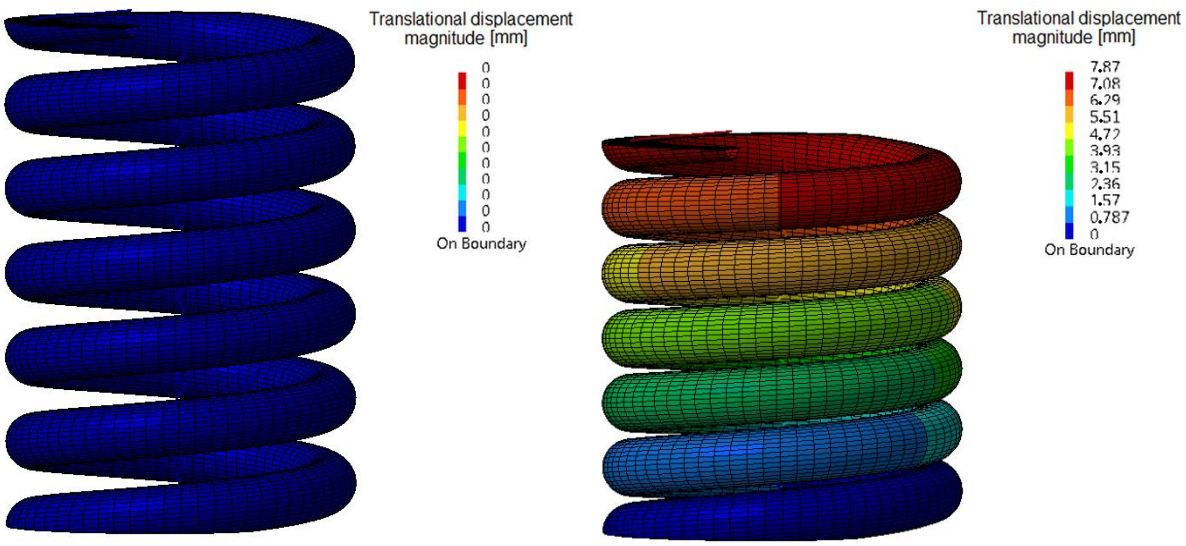


Figure 4 - Maximum displacement values for the helical spring used in analysis

DYNAMIC SIMULATION

DESCRIPTION OF THE DYNAMIC MODEL

This part of the paper describes the virtual model used in the dynamic analysis. The model consists of 10 rigid bodies, one flexible body and one massless part, as shown in figure 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. The driver used for controlling the revolute joint, also called Joint Driver, uses the angular speed as input for the model.

The next important link is represented by the contact between the cam and the finger follower roller. For this contact the Sphere-to-Extruded-Surface contact element was used.
This type of contact introduces contact forces which are based on the depth of penetration, which is dependent on the thickness of the surface and the relative velocity normal to the contact surface, while friction forces are calculated based upon the relative velocities tangential 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). Friction properties are defined by a friction coefficient and transition velocity.

The roller is bracketed to the finger follower.

For the next link, between the finger follower and the valve a Sphere-to-Revolved-Surface contact element was used. This type of contact was chosen because the curvature radius of the surfaces in contact does not vary in time.

The valve is connected to the ground by a translational joint and a spring-damper element. This spring-damper element is introduced in order to simulate the contact with the valve seat. Moreover the spring retainer is also attached to the valve. [3]

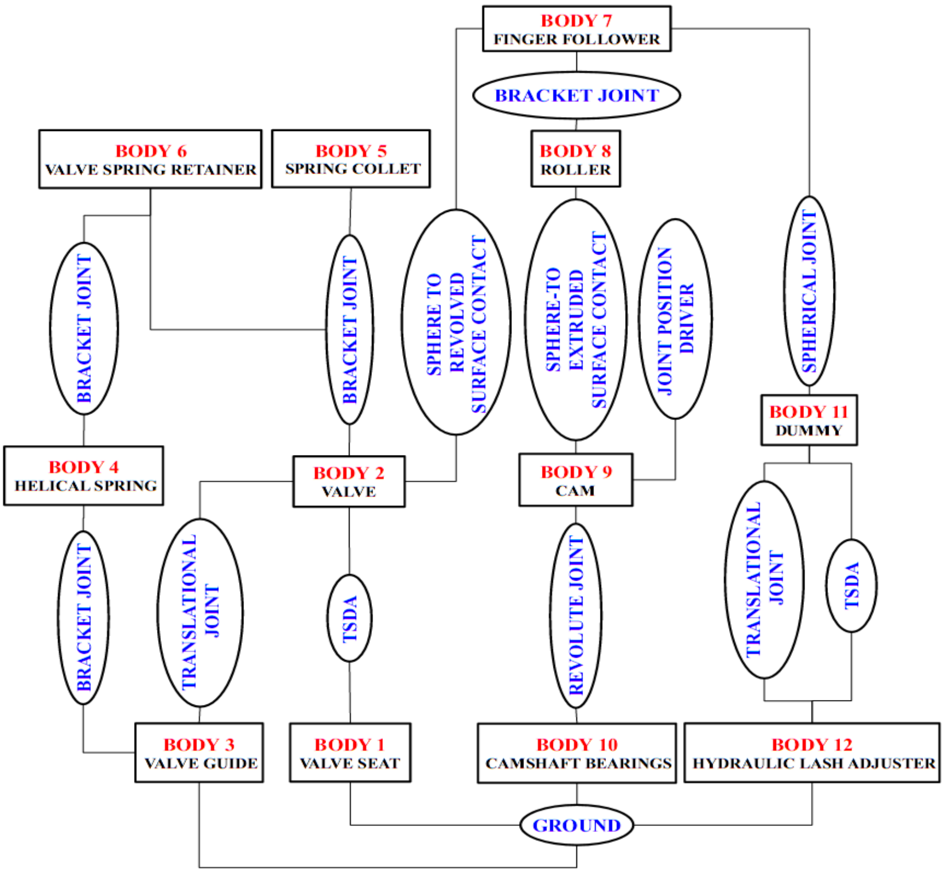


Figure 5 - The schematic of the dynamic model used in the analysis

Another important link is the helical spring which is placed between the spring retainer and the valve guide. This helical spring is bracketed at both ends, at one end with the retainer, respectively the valve guide. [1]

The hydraulic lash adjuster model used in the analysis consists of two bodies, a rigid body and a massless body, also called dummy. The rigid body is fixed to the ground. The massless body and the rigid body are connected by a translation joint and a spring damper, which has the role to limit the displacement along the z axis of the hydraulic lash adjuster element. The maximum value of the displacement is given by the HLA's stroke. The hydraulic lash adjuster assembly is connected to the finger follower by a spherical joint.

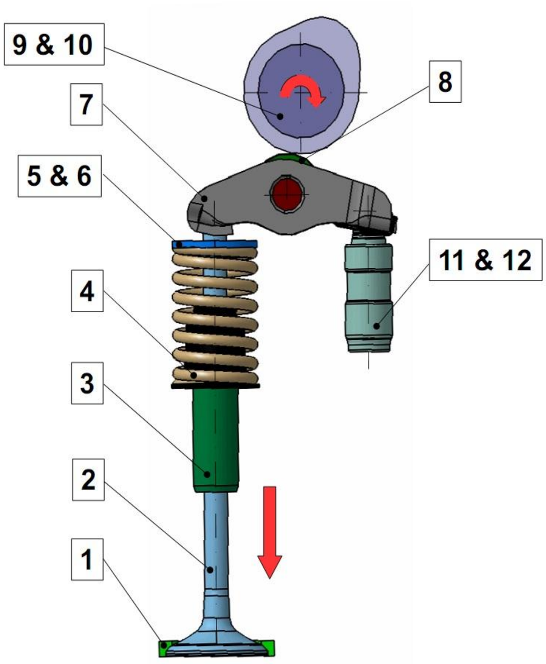


Figure 6 - The numbering of the model's bodies.

RESULTS

The data obtained from the simulations are presented below. Figure 7 presents the comparison between the valve's displacement curves, obtained from the dynamic, respectively kinematic analysis. Also in figure 7 is shown the valve's bounce phenomenon, which can appear due to the stiffness of the model.

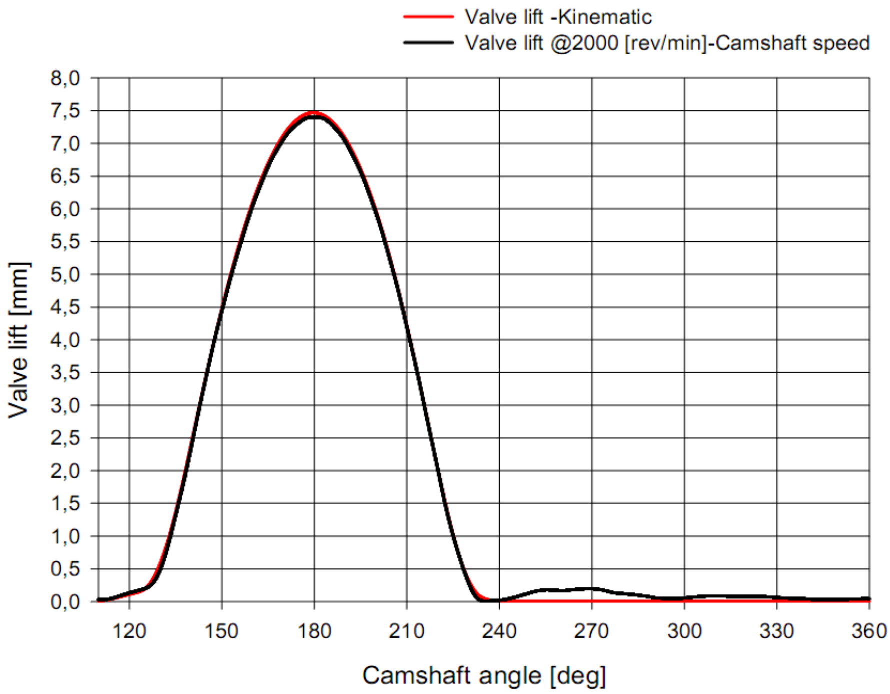


Figure 7 - Comparison between the kinematic and dynamic valve lift curve

The figures 8, 9 and 10 present the valve acceleration for different camshaft speeds.

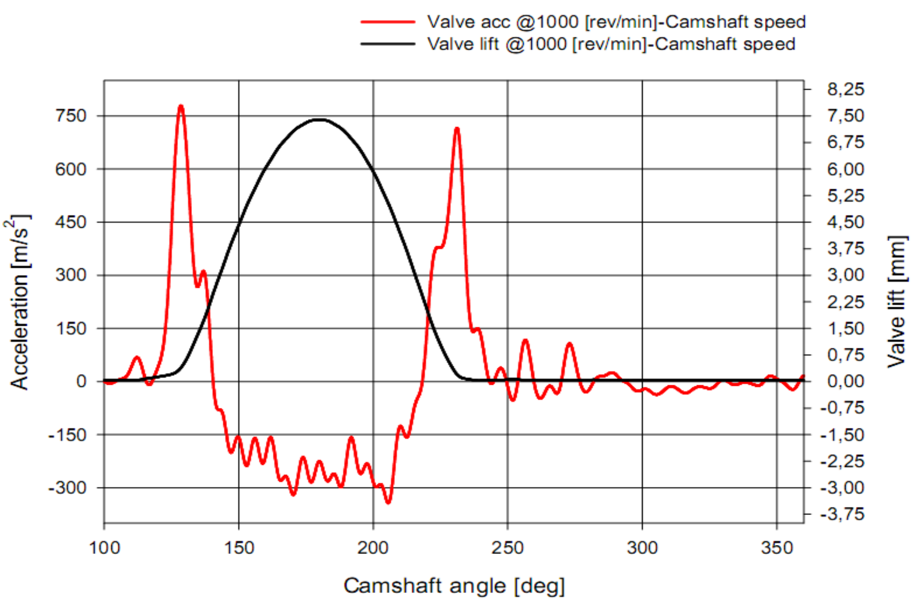


Figure 8 - Valve acceleration versus Valve lift at 1000 [rev/min] – Camshaft speed

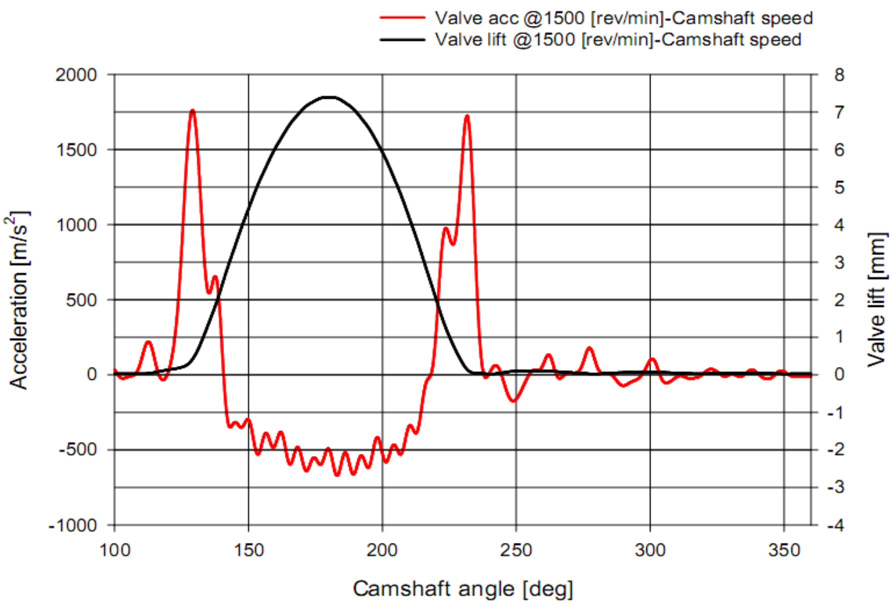


Figure 9 - Valve acceleration versus Valve lift at 1500 [rev/min] – Camshaft speed

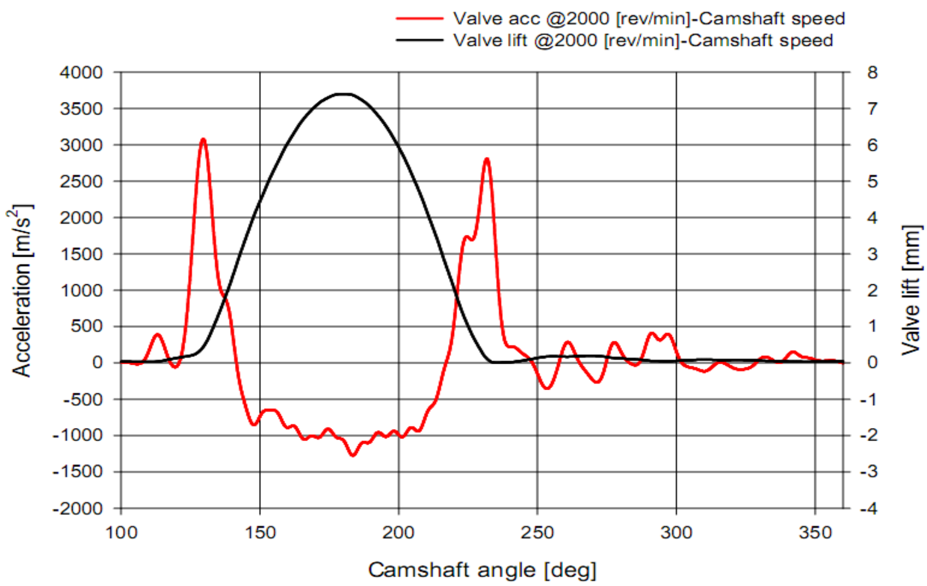


Figure 10 - Valve acceleration versus Valve lift at 2000 [rev/min] – Camshaft speed

In figure 7, it can be seen that the valve is closing sooner than in the kinematic analysis and that the maximum displacement of the valve decreases, which can lead to a lower gas flow in the engine cylinder. (fig.7)

The results as shown in figures 8, 9 and 10 are quite good for the positive accelerations. However the numerical response introduces several peaks on the negative accelerations' range. These peaks can appear due to the type of contact used in the model design and the fact that not all the parts of the model are flexible.

Figure 11 shows the valve's acceleration and lift obtained from the kinematic analysis.

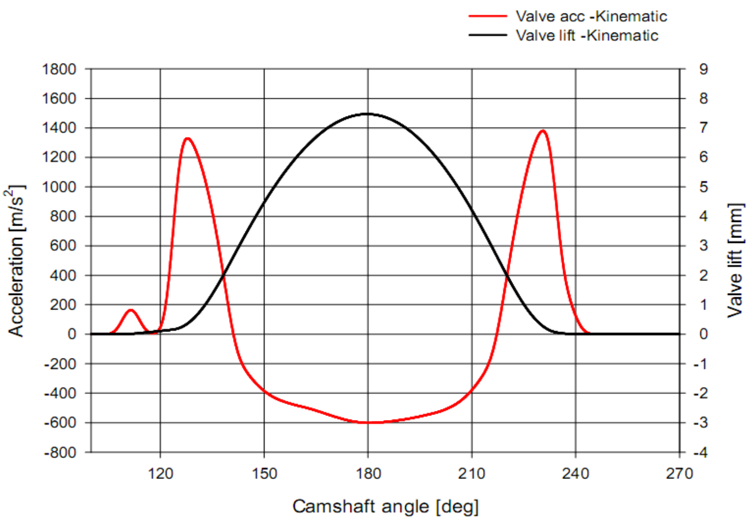


Figure 11 - Valve acceleration versus Valve lift – Kinematic analysis

CONCLUSIONS

This paper presents a preliminary model of a finger follower valve train system. The model consists of 10 rigid bodies, one flexible body and one massless part, which are linked by different kinds of joints. The contact between the cam and the finger follower, and the one between the finger follower and the valve are modeled using contact force elements.

Once the valve's bounce phenomenon appears, the dynamic behavior of the mechanism worsens. Also this thing can lead to a prematurely wear of the mechanism.

In future work, taking into account the flexibility of the studied mechanism, a flexible model will be created, which will lead to the increase of its effectiveness.

ACKNOWLEDGEMENT

This paper is supported by the Sectorial Operational Programme Human Resources Development (SOP HRD), financed from the European Social Fund and by the Romanian Government under the contract number POSDRU/88/1.5/S/59321.

REFERENCES

(1) Moreno D., Mucchi E., Dalpiaz G., Rivola A. MULTIBODY ANALYSIS OF THE DESMODROMIC VALVETRAIN OF THE DUCATI MOTOGP ENGINE. 2007
(2) Tichánek R., Fremut D., Čihák R. THE OVER-HEAD CAM (OHC) VALVE TRAIN COMPUTER MODEL. 2007
(3) Radu Gh. A., ANALIZA ÎN MEDIU VIRTUAL A PROCESULUI DE ADMISIE ÎN MOTORUL CU ARDERE INTERNĂ, Brasov: Transilvania University Publishing House. 2004
(4) LMS International. LMS Virtual.Lab 8A, 2010.

ABBREVIATIONS

HLA – Hydraulic Lash Adjuster
TSDA- Translational Spring-Damper-Actuator