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THE NECESSITY FOR ROTATIONAL MOVEMENT OF VALVE AND TAPPET IN INTERNAL COMBUSTION ENGINES

Liviu JELENSCHI*;Corneliu COFARU; Gabriel SANDU; Ioan-Serban RADU
Transilvania University of Brasov, Romania

Abstract:*The paper presents the research regarding the rotational movement of the engine valve and engine tappet for a direct acting valve train.The first part of the paper describes the necessity of the rotational movement of the engine valve and tappet, its advantages as well as its disadvantages. It also shows for which engine valve this motion is more necessary: intake valve or exhaust valve.The paper's main part presents the virtual model used in the analysis. The valve train model was created using LMS Virtual Lab. In the first stage of the CAE analysis, the bodies were considered as being rigid. Flexible bodies will be used in future stages in order to include the component deformation into the calculations. The analysis was performed considering: engine speed, eccentricity value of the cam in relative position to the tappet and the value of the friction coefficient. The simulations were done at the following engine speeds: 600RPM, 2500RPM, 3200RPM and 7200RPM (maximum engine speed). Three values for cam eccentricity were used: 1.5mm, 2mm and 3mm.The rotation direction and speed were considered as performance parameters for the analysis.The simulation results revealed that the eccentric position of the cam, the engine speed and the friction coefficient are the main factors that influence the rotational movement of valve and tappet. This study is an outcome of collaboration between the Transilvania University of Brasov, Romania and an automotive parts manufacturer. The results of the project will be used to improve the design of valve train components.*

Keywords: valve train, engine valve rotation, tappet rotation, virtual model, LMS Virtual Lab

INTRODUCTION

Due to diversification of the vehicles types and because of continuous increase in their number, vehicle manufacturers have developed powerful engines with low consumption without increasing cylinder capacity. The engine development entails the development of new types of valve train systems. Taylor (1) studied different types of valve train systems for highlights their advantages and disadvantages.
From these mechanisms, the direct acting valve train system is the most common type use in engine construction because of his simplicity, high speed that can be used, high stiffness and low variation during operation.
In addition to these benefits this type of valve train has several disadvantages: high friction between parts under relative motion, fact that causes a pronounced fatigue, and high dynamic masses which are causing high inertial forces.

* Corresponding author. Email: liviu.jelenschi@unitbv.ro

DESCRIPTION OF THE MECHANISM

The direct acting valve train system (see figure 1) consists of the camshaft, hydraulic tappet, cotter, spring retainer, conical spring, valve guide and valve seat.

The motion is transmitted from the camshaft to the valve through the hydraulic tappet. The hydraulic tappet is used to adjust the thermal gap between parts and to retrieve the lateral forces resulted from contact with the cam. It has also the role to reduce the valve's stem load.
The contacts between cam and tappet, tappet and valve are maintained by the valve spring. Its main role is to restore the original position of the valve after opening and to maintain the valve on valve's seat during the intake process. In order to meet those requirements, the valve spring is mounted with a preload.

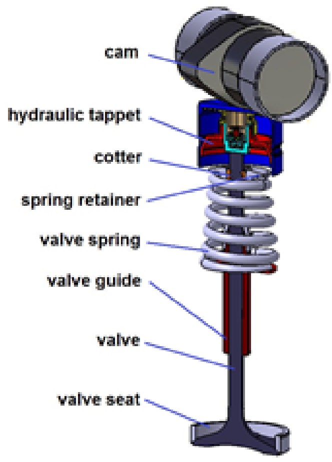

Figure 1. Components of the direct acting valve train system

The force acting on the valve and hydraulic tappet to maintain the contact with the cam is given by the difference between the inertia forces of the valve train parts and the valve spring force. The forces of inertia are rising when the engine's speed increases. This can lead to contact loss between parts. Because the inertia forces are larger than the helical spring force, a phenomenon known as the valve's bounce appears.

THE NECESSITY FOR ROTATIONAL MOVEMENT

The rotation of the valve is necessary for a uniform distribution of temperatures on the valve head and valve stem, to reduce the carbonate deposits on the valve head and valve seat, to improve the contact between the valve and the valve seat, to uniform the wear of the conical valve face and conical seat face and to uniform the lubrication between valve and valve guide.
A pronounced rotational movement of the valve leads to an increasing wear of the valve head and seat. This can lead to valve burning phenomenon and its removal from service.(3)(4)
Based on previous statements, we can conclude that the rotational movement is suitable for the exhaust engine valves.
The hydraulic tappet must rotate in order to reduce the wear by ensuring a uniform lubrication. If the tappet doesn't rotate, the wear is increasing and the life time decreases. The wear appears because of the contact between the cam and the tappet. The wear may occur by detachment of small portions of the material surface, phenomenon known as pitting; surface damages because of abrasive wear; the appearance of local welding between surface parts, due to the lack of lubrication and the thermal stresses, phenomenon called scuffing.(2)

Figure 2. Types of tappets wear (5)

THE VIRTUAL MODEL

With CATIA V5R16 software, the component parts were made as 3D bodies. After that the mechanism was assembled using the Virtual Lab Motion software (6). In VL the connections between elements were made. The figure below presents the dynamic model, a model that consists of 7 rigid bodies which were assigned with material properties.

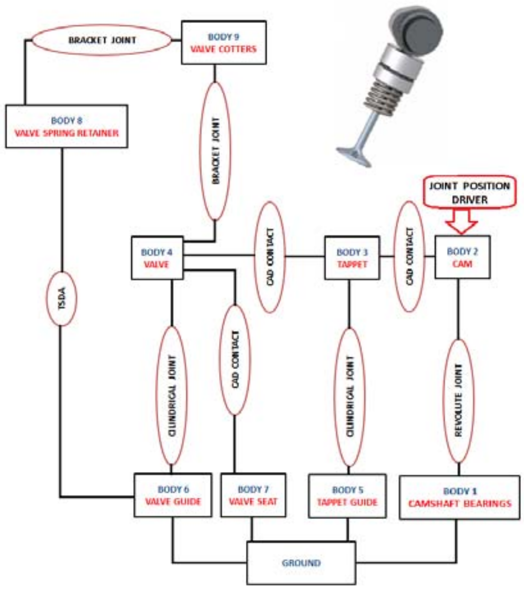

Figure 3. Design of the virtual model of the valve train

The link between the camshaft and ground, is represented by the sliding bearings of the camshaft, which is achieved through a rotation joint. In this joint, a motion driver was introduced. The joint driver induces the rotation movement of the camshaft and can control its speed.

The contact between the camshaft and tappet, tappet and engine valve, valve head and valve seat are made using CAD Contact element. This type of contact allows simulation of the contact between rigid bodies with arbitrary geometry. The bodies for which contact is to be calculated are selected, and the solid geometry associated with each body is tessellated based on user-specified parameters, the spring damping and friction coefficients characterize the contact force.

The cotters and the spring retainer are mounted on the valve with a bracket joint, the same command is use for fixing the valve guide and seat to the ground. A bracket joint prevents all relative motion, translation and rotation, between two bodies. Using the bracket joint the two bodies behave as a unified body. The same joint is used between hydraulic tappet components, so the hydraulic tappet acts like a mechanical tappet.

The valve spring was replaced by a TSDA element. The TSDA element represents the abbreviation from translational spring damper actuator and defines a spring damper actuator force element between two bodies. TSDA is a force defined by a value of: stiffness, damping and actuation torque.

In the joints between valve and its guide, tappet and its guide, CAD Contact elements, friction forces were introduced to simulate the lubrication process.

RESULTS

The tests with the virtual model were carried considering different value of the cam eccentricity position. The value of the cam eccentricity was varied from 1.5mm up to 3mm. Also was investigated the influence of the friction coefficient between moving parts. For this, the friction coefficient value was set to 0.05 for the first case and to 0.1 in the second case. All the tests were carried at different engine speed, starting from the engine idle speed, 600rpm (300rpm for the camshaft) to maximum engine speed, 7200rpm (3600rpm for the camshaft).

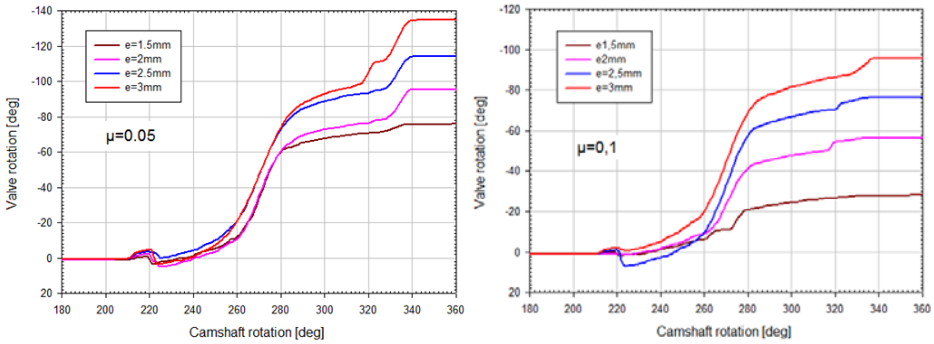

Figure 4. Comparison between valves rotation for different values of the cam eccentricity and different friction coefficients [300rpm camshaft speed]

At lower engine speeds the valve, the value of the cam eccentricity influence the valves rotational movement. It can be seen that increasing the value of the cam eccentricity lead to a pronounced rotational movement of the valve, but if the friction coefficient double it value then the valve rotate less whit almost 25%.

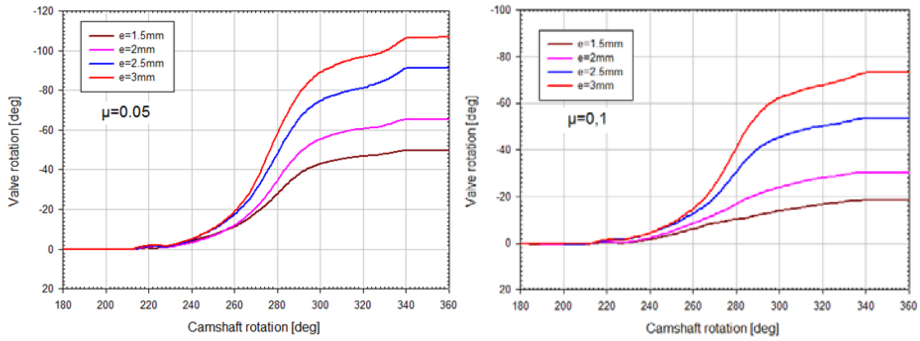

Figure 5. Comparison between valves rotation for different values of the cam eccentricity and different friction coefficients [1250rpm camshaft speed]

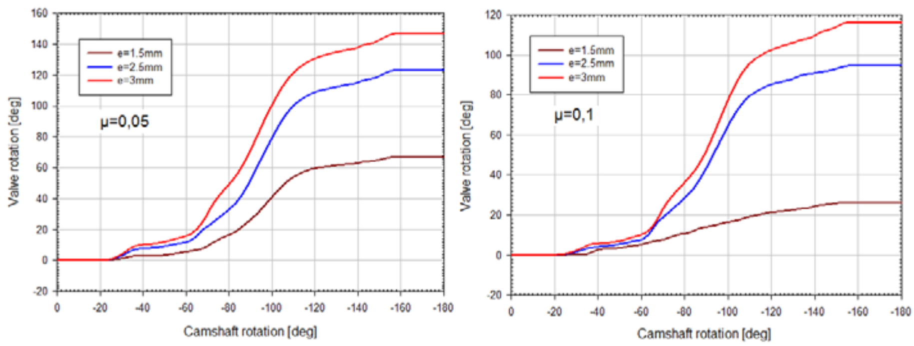

Figure 6. Comparison between valves rotation for different values of the cam eccentricity and different friction coefficients [1600rpm camshaft speed]

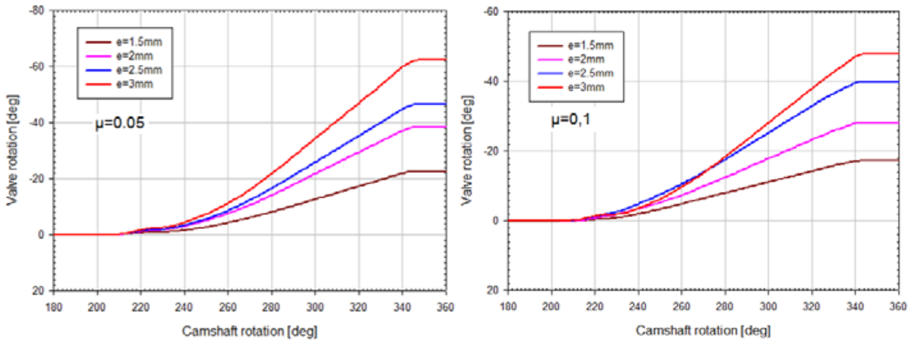

Figure 7. Comparison between valves rotation for different values of the cam eccentricity and different friction coefficients [3600rpm camshaft speed]

As it can be seen for the rest of the tests, the results seem to have the same evolution when the values of the cam eccentricity increase.

An unexpected results were obtained when the engine speed was increased, the valve rotation decrease. This thing may occur due the fact that the CAD Contact parameters were not good defined or their value varies as a function. The same phenomenon occurs in the tappet rotation dynamics.

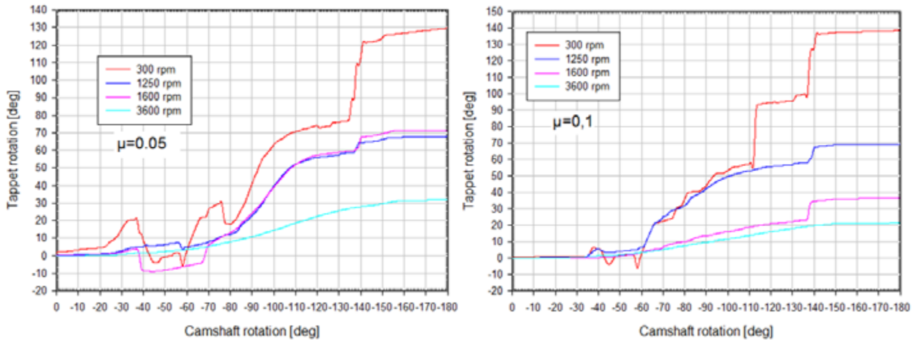

Figure 8. Comparison between tappets rotation for different friction coefficients and different camshaft speeds [1.5mm cam eccentricity]

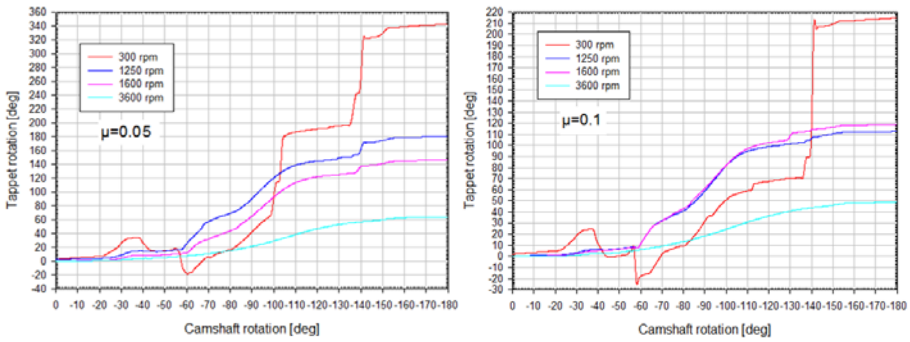

Figure 9. Comparison between tappets rotation for different friction coefficients and different camshaft speeds [2.5mm cam eccentricity]

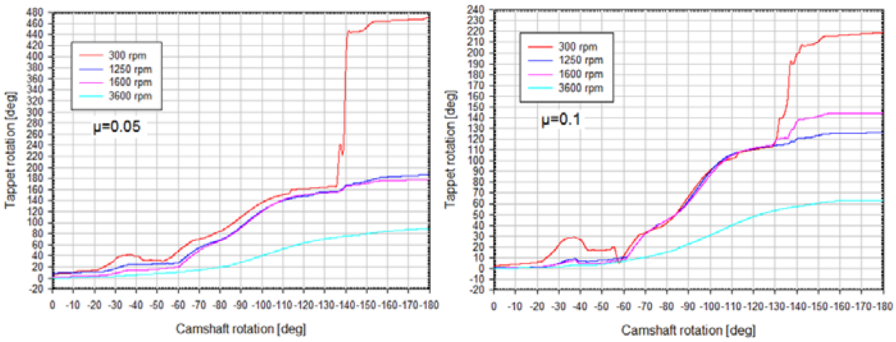

Figure 10. Comparison between tappets rotation for different friction coefficients and different camshaft speeds [3mm cam eccentricity]

CONCLUSION

A 3D model of the direct acting valve train system for internal combustion engines has been developed, using Virtual Lab from LMS software.
By increasing the value of the cam eccentricity, the rotational movement of the tappet is amplified what entails a pronounced rotational movement of the engine valve.
In this study case, the engine speed has a negative effect on the rotational movement of the tappet and valve. When the engine speed increases, the tappet and the engine valve rotates slowly. This is a cause of type how the contact between moving elements was model.
The same negative effect upon the rotational movement of the tappet and valve is obtained when the value of the friction coefficient increases from 0.05 to 0.1.
Currently the virtual model of the direct acting valve train system is pending validation by experimental work.

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