Bulletin of the *Transilvania* University of Braşov
Series I: Engineering Sciences • Vol. 4 (53) No. 2 - 2011

STATE OF THE ART OF ENGINE VALVE AND TAPPET ROTATION

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Abstract: *The paper presents some aspects regarding the importance of the engine valve and tappet rotation during engine functioning. Types of different configuration of the valve trains that are used in internal combustion engines, auxiliary solution for valve rotation and parameters that influences the valve and tappet rotation are also described. In conclusions the advantages of valve and tappet rotation as a function of life cycle and wear reduction are presented.*

Key words: *internal combustion engines, valve train, valve rotation, tappet rotation, wear.*

1. Introduction

The valve train represents one of the most important systems from an internal combustion engine. The main role of the valve train is to ensure the gases exchange process between engine cylinders and environment, to fill up the cylinders with fresh charge and to evacuate the burned gases. This function is accomplished by periodically opening and closing the intake and exhaust valves [3].

Knowing this thing we can conclude that the valve train system directly affect the engine performance. So for designing new types of valve train, keeping account of demands, the manufactures must resolve one major problem. They must find a compromise between fast opening and closing the valves at fixed moments, involving high acceleration values, and the loads that shouldn't exceed the limits, small acceleration values. This problem might be solved by reducing the weight of the valve train components, by optimizing the kinematic and dynamic feature of the components [9].

Thus, depending on engine type, spark ignition engine or compression ignition engine, and the imposed requirements, five types of valve train system were designed (Figure 1). Each has its constructive features, advantages and disadvantages.

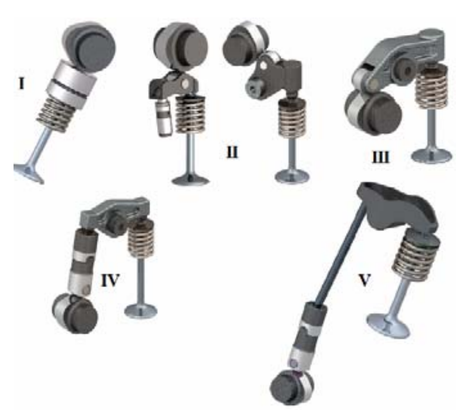

Fig. 1. *Types of Valve Train System* [12]

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The first type of configuration is the Direct Acting OHC Valve Train (Figure 2) which is the most common type used in internal combustion engines. The main characteristics of this type are: high rigidity during functioning which enable to be used at high engine speeds, high friction as a result of contact between cam lobe and tappet surface, high values of inertial masses [1], [12].

The second type is represented by the End Pivot Rocker Arm OHC Valve Train, also an important type defined by low friction because of rolling contact between cam and rocker arm, high friction for sliding contact, high sensitivity at rocker arm oscillation, small values of acceleration due to cam concavity which doesn't permit to be used at high engine speeds, small cam profile due to rocker ratio [1], [12].

Type III is Center Pivot Rocker Arm OHV Valve Train, system characterised by low friction for rolling contact between cam and rocker, high sensitivity at rocker oscillation, low stiffness as a function of rocker ratio [1], [12].

Type IV, Center Pivot Cam Follower OHV Valve Train which has similar characteristics with type III.

And the last one, the Pushrod OHV Valve Train. This type is very flexible because of the length of the pushrod and can't be use at high engine speeds, facts which confer small rigidity value [1], [12].

Based on the characteristics of this types of valve trains and considering the engine loses it can be conclude that the friction due to valve train system represent 7.5-21% of total engine friction loss [1].

So the valve train system remains an important element in engine performance.

2. The Rotational Movement

The main motion of the tappet and valve is the translational movement. But in some cases considering some condition this two elements have an additional motion: the rotational movement.

Analysing the valve train system like a mechanism can be see that between valve and its guide is a translational joint. The geometrical configuration of the valve guide is like a cylinder fact which allowed the valve to have a rotational movement around its axis of symmetry. Similar conditions are for the tappet [6].

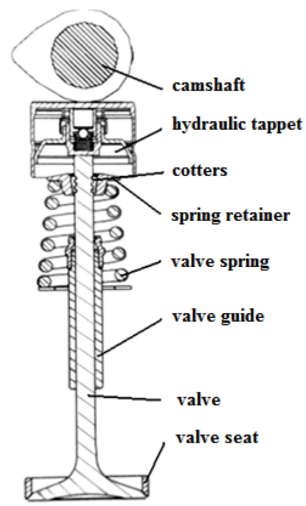

Fig. 2. *Components of Direct Acting Valve Train System* [6]

The valve and tappet might rotate as a result of valve train configuration or by using auxiliary system which force the valve to rotate.

2.1. The importance of valve rotation

The main scope of the valve and tappet rotation is to reduce the wear, the friction and to increase the life period of the components. To maintain the conical valve face and seat clean of carbon or soot deposit that might appear on surfaces during valve opening. To uniform the thermal stress of the valve head because of the asymmetry exhaust manifold and uniform the wear of the conical face, providing a good sealing of the cylinder [4].

If the valve is rotating the contact point between valve head and seat will varying and in this way the wear marks or cracks can be avoided. Also another unwanted phenomenon it is avoided, the valve burning [4].

Another important result of the valve rotation is the uniformity of the oil film in the valve guide and on the valve stem.

The wear caused by the contact between valve and rocker arm is reduced by varying the contact point [8].

2.2. The importance of tappet rotation

The tappet rotation is important because it reduces the wear caused by the contact with the cam, improves the lubrication of those two surfaces and increases the tappet life. Also for the Direct Acting Valve Train systems ensure the valve rotation if there aren't used any auxiliary solution [8].

2.3. Auxiliary rotation system

This auxiliary system are devices more or less simple replacing the spring retainer. The main purpose of those systems is to rotate the valve during opening or closing period. On those systems we can mention: Rotocap, Turnomat, Rotocoil, Rotomat, Duomat.

2.3.1. Rotocap

The Rotocap (Figure 3) systems rotate the valve during opening period. This system can be mounted below or above the valve spring, the most used configuration. The valve rotation is realised by the ring on which inclined tracks are processed. On those channels balls and springs are mounted. The valve spring is based on the spring retainer. Between spring retainer and ring a spring washer is mounted. When the cam attacks the valve, the valve spring force is transmitted to the spring washer forcing the balls to move in channels, this movement creates a friction force that causes the rotational torque around valve axis. When the valve is released by the cam action, the device is restored to its original position under the spring washer and the springs from channels [2].

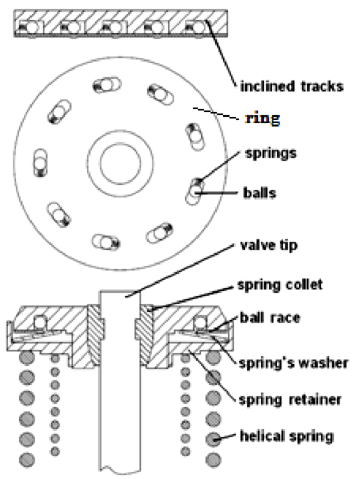

Fig. 3. *Rotocap components* [2]

The Rotocap stops at engines loads smaller than 25%, also depending on engine speed and spring washer rigidity, the valve rotates more or less (Figure 4) [4].

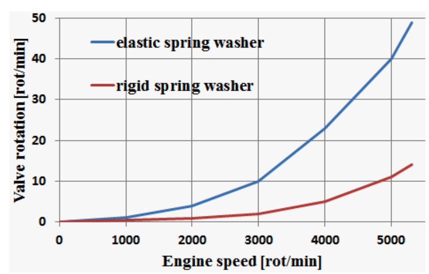

Fig. 4. *Influence of engine speed under the valve rotation* [4]

The main disadvantage of this system is represented by the presence of impurities in the lubricant. This thing leads to deposit formations on the ball race and thus the abnormal functioning of the system. Also the engine price is higher than without those devices [4].

2.3.2. Turnomat

The Turnomat system (Figure 5), also known as Rotomat, represent an optimization of Rotocap system. This device isn't sensitive at impurities presence in lubricant. With this device the valve is rotated during closing period [2].

The main component of the system is represented by the element which contains the tilted grooves. The element is fixed with the valve cotters. In the tilted grooves are placed two balls, one for each side, which are related to a rotating cylinder. The entire assembly is mounted on a bearing which is part of the valve spring retainer.

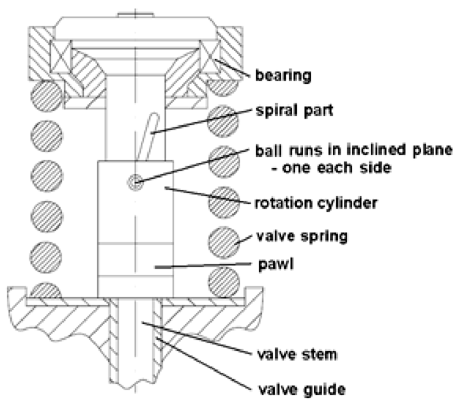

Fig. 5. *Turnomat components* [2]

When the valve opens, the piece that contains the grooves starts to move. The piece will enter in the rotating cylinder and the balls will go up in the groove. When the balls reach the end of the channel occur the rotation of the cylinder, but the valve will not rotate because the pawl is in free position. When the valve closes, the balls move down and produce a new rotation of the cylinder, the ratchet lock and in the same time with cylinder rotation the valve rotation occurs.

In the Figure 6 a comparison between the Rotocap and Turnomat is presented. It can be seen that the valve rotates more when it's using the Rotocap [2].

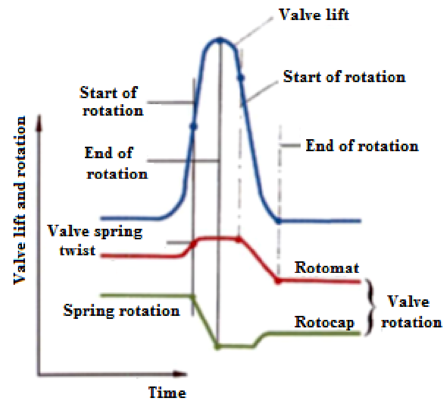

Fig. 6. *Comparison between Rotomat and Rotocap*

2.3.3. Rotocoil

The Rotocoil (Figure 7) is a simple device for valve rotation which replaces the valve spring retainer.

Fig. 7. *Rotocoil system* [2]

In comparison with Rotocap, in this system the tilted grooves and balls were replaced by a spiral channel within which there is a spiral spring. The role of the spiral spring is to rotate the valve under the cam action.

2.3.4. Other devices

Some particular device can be used but only for heavy duty diesel engines or marine engines.

One of those is the device used by Wärtsilä (Figure 8). This system involves the mounting on the valve stem a propeller and during the exhaust stroke under the action of kinetic energy of burned gases the valve rotates [11].

By using this device there is a changing in dynamic behaviour of the valve because of the added mass, which gave rise to inertial forces.

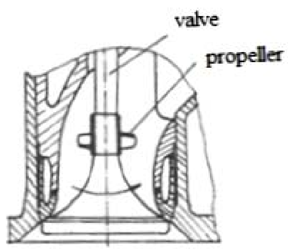

Fig. 8. *Valve with propeller* [11]

2.4. Valve train configuration

To obtain the valve rotation using only the valve train configuration, the contact between valve tip and cam or rocker arm must be slightly offset [5].

For the Direct Acting Valve Train type, the cam is mounted with an eccentricity to the tappet axis, for a flat tappet, or the cam profile is manufactured with an angle fact which gave an offset contact point, for a large radius tappet (Figures 9 and 10).

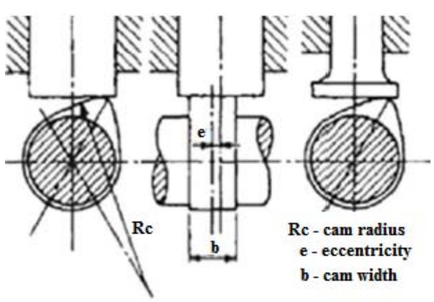

Fig. 9. *Contact with a flat tappet*

The rotational motion of the engine valve is strongly influenced by the tappet rotation which in its turn is influenced by the friction between the cam surface and the tappet surface.

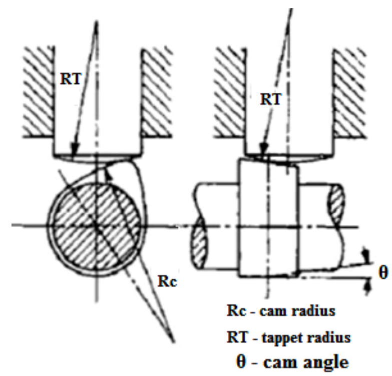

Fig. 10. *Contact with a round tappet* [4]

Also it is influenced by the friction between the tappet and guide from the engine head. So the film of lubricant between two surfaces is crucial. When the oil has a lower viscosity the contact force between cam and tappet will be bigger and the tappet will have a higher rotation speed. The same effect occurs when the pressure of the oil from hydraulic tappet increases [7].

In case of the valve trains with rocker arm, the valve rotation it is generated by the offset position of the rocker in relation with the valve axis (Figure 10). When finger followers are used with hydraulic lash adjuster the offset constrain can't be used because of the high sensibility at oscillation of the valve train system [10].

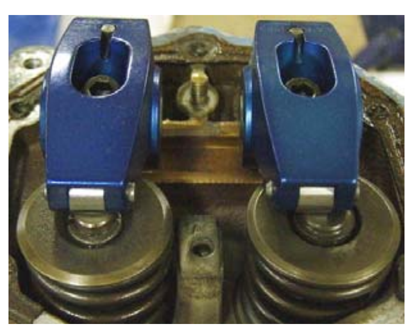

Fig. 11. *Ford Roller Rockers position* [10]

3. Conclusions

The valve train system represents an important part of an engine, and by increasing the life period of the valve, the engine service period increase.

By ensuring the rotational movement the valve durability increases by 2-5 times and in some cases up to 10 times [4].

The valve rotation is as a function of engines speed. At high engine speeds the valve rotational movement amplifies. Because of this phenomenon, a major problem appears at low engine speeds when the valves stops rotating or its rotation isn't constant.

Using auxiliary devices to ensure the valve rotation assume increasing the engine total costs but it obtained a constant variation of valve rotation.

Depending on valve train design, the valve rotation might be obtained by using the cam or rocker offset position or by using angled cam.

The contact between cam and tappet, the friction coefficient and the film thickness influence also the valve rotation.

Acknowledgement

This paper is supported by the Sectoral 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 and POSDRU/6/1.5/S/6.

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