INVESTIGATING THE EFFECTS OF OIL PRESSURE ON VALVE ROTATION FOR A DIRECT ACTING VALVE TRAIN

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Abstract. This paper investigates the influence of oil pressure on the engine exhaust valve rotation for a direct acting valve train. In introduction, a short presentation of the direct acting valve train is made and the necessity of the valve rotation is described. The test rig and the equipment used for measuring the influence of the oil pressure upon valve rotation are described in the main section of the paper. The results obtained revealed the fact that the oil pressure represents an important parameter which influences the valve rotation.

Keywords: internal combustion engines, valve train, valve rotation, oil pressure

1. Introduction

Internal combustion engines are complex systems, found in a continuous improvement. One of those improvements refers to increasing the service life up to 250,000 km with a minimal mechanical intervention during this period. This facts cause an increasing of impurities level from engine oil and also an increasing of components wear [1].

The valve train system represents one of the most important components of an internal combustion engine. The proper functioning of the valve train influences the gas exchange process and also the engine performances [2].

Today, five types of valve train systems exist, each of them having its advantages and disadvantages, as shown in Table 1 [3, 4].

Table 1.Comparison between valve trains

Mechanism / Feature	Type 1	Type 2	Type 3	Type 4	Type 5
Natural Frequency (Hz)	2000 -3000	1200 -1500	900 -1400	900 - 1400	400 - 700
Effective Mass @ Valve (gr.)	140 - 160	80 - 120	120 - 160	130 - 170	240 -290
Maximum RPM	6500 ++	6500 +	6000 +	6000 +	4000 - 6000
Friction (A-E)	E	A	B	C -D	C - D
Overall Engine Packaging (A-E)	D - E	D - E	B	C	A

*A= Best , E= Worst

One of the most used types is the direct acting valve train. In Figure 1 the components of direct acting valve train are presented.

The spread of this type is due to the high stiffness during functioning, simple design and small number of moving components. It also has a few disadvantages caused by the sliding contact between cam profile and tappet, which determines a high level of friction losses, and the high level of the inertia forces [4].

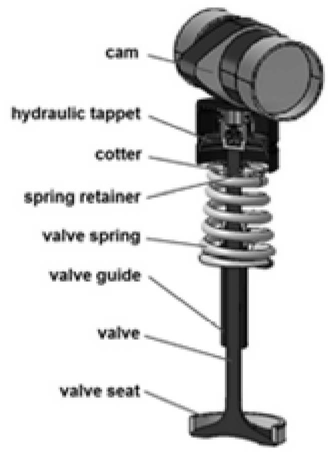

Figure 1. The direct acting valve train components

The valve motion is generated by the cam profile trough a hydraulic tappet. Analyzing this motion, it might be observed that beside its translational movement, the valve also might rotate around its own axis due to the cylindrical configuration of the valve guide. This rotational movement might appear due to valve train configuration or it might be generated by using auxiliary systems like Rotocap, Turnomat or Rotocoil [4, 5].

The main purpose of the valve rotation refers to increasing its life by reducing wear, carbon deposits and the risk of cracks appearing due to uneven distribution of temperature [2, 4, 5, 6, 7].

However, if the valve rotation is too big, the usage of the valve head conical facet and valve seat increases significantly.

2. The test rig

The test rig, shown in Figure 2, was build starting with the cylinder head of a SAAB 900 spark ignition engine which has a direct acting valve train.

Figure 2. The test rig

The camshaft was driven by an electric motor and its position and speed was monitored using an AVL 364-C01 encoder. Those five camshaft speeds used in tests, were set by modifying the electric motor speed using a frequency converter. The gear ratio between electric motor shaft and camshaft was 1:1.

The oil circuit, shown in Figure 3, used for lubrication of moving parts and for filling the hydraulic tappet, it consist from a 20 liters oil tank filled with 10W40 oil, an electrically operated oil pump, a pressure relief valve, an oil filter, the pipelines and a pressure valve used for varying the oil pressure. The oil pressure was measured using a manometer and a piezoelectric transducer from Keller PR-11/80059.2-20.

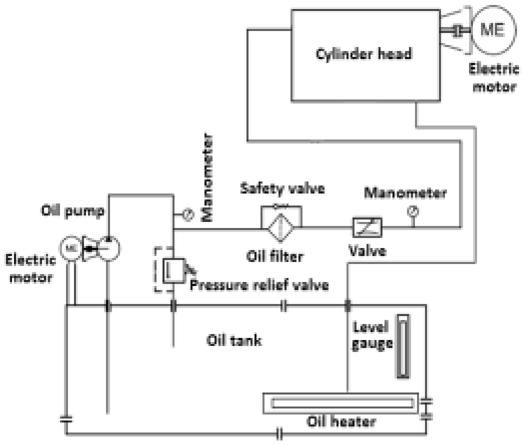

Figure 3. The oil circuit

Using an electric heater, the oil temperature was set to 60°C and to 70°C, this value of temperature being measured using a Pt100 sensor and a digital thermometer.

For measuring the valve rotation, on the valve head, markers were placed as shown in Figure 4. The markers were filmed using a FASTCAM SA3 high speed video camera. The videos were taken at 1000 frame/second, with a length of five seconds.

Figure 4. Markers positioned on valve head

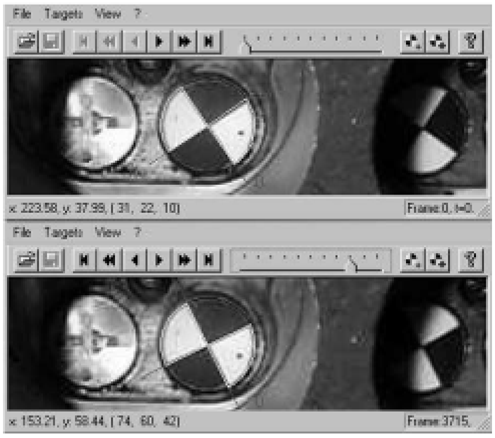

Figure 5. The Target Tracking v1.1 software

The next step was to analyze the obtained videos using Target Tracking v1.1 software from DSD (see Figure 5). This software analyzes the video frame by frame and gives the marker coordinates and angle of rotation in a text table, so that the desired values can be extracted and displayed on graphics.

3. Results

For determining the influence of oil pressure on valve rotation, an experimental procedure was established. Four values for oil pressure were chosen: 0.3 MPa, 0.35 MPa, 0.4 MPa, 0.45 MPa. Those values of oil pressure were analyzed as a function of four different camshaft speeds. Also, for a better understanding of the phenomenon, the oil temperature was modified from 60°C to 70°C.

The results of the first test can be seen in Figure 6. The conditions for those tests were: 0.3 MPa oil pressure, 60°C oil temperature and camshaft speed starting from 1875 rpm up to 2375 rpm.

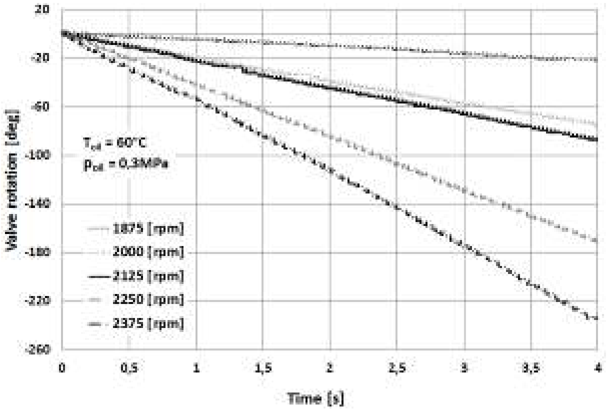

Figure 6.Valve rotation at 0.3 MPa oil pressure

After four seconds of recording the valve head, when the camshaft speed increases, the valve rotational angle increased randomly.

Keeping the same oil temperature and the same camshaft speeds, but modifying the oil pressure up to 0.35 MPa, as it can be observed in Figure 7, the valve rotation was modified.

When the camshaft speed was set to 1875 rpm, 2125 rpm and 2250 rpm, the valve rotation angle was increased with more than 10 degrees. But for 2000 rpm and 2375 rpm the valve rotation decreased with 20 degrees.

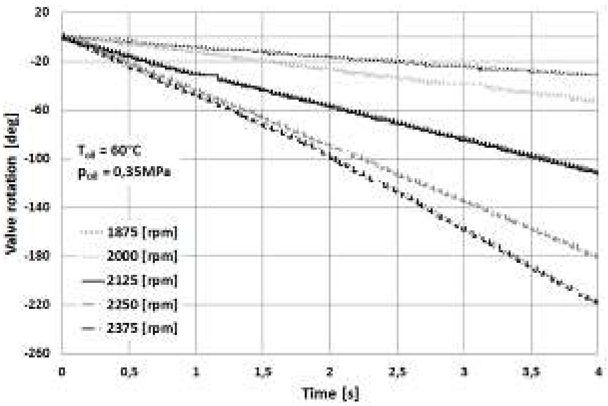

Figure 7. Valve rotation at 0.35 MPa oil pressure

The next approach was to keep the same oil temperature and the same camshaft speeds, but to set the oil pressure to 0.4 MPa. The results obtained are presented in the figure above. It can be noticed that for 1875 rpm, the valve rotation angle doesn't modify, it remains the same. When the camshaft speed was set to 2125 rpm, the rotational angle decreased, until 89 degrees. Also an interesting behavior of the valve rotation appeared for the rest of the camshaft speeds, when the angle of rotation had a small increase.

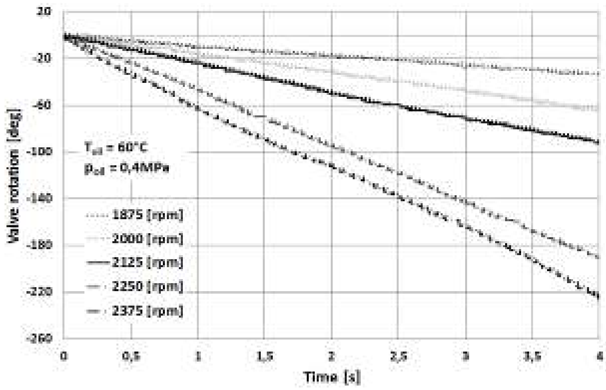

Figure 8. Valve rotation at 0.4 MPa oil pressure

The last tests were carried out at the same conditions but at 0.45 MPa oil pressure. It might be observed, in next figure, that the trend of rotational angle of the valve is to decrease for all camshaft speeds with a single exception: at 2000 rpm the valve rotational movement remains the same as in tests carried out at 0.4 MPa oil pressure.

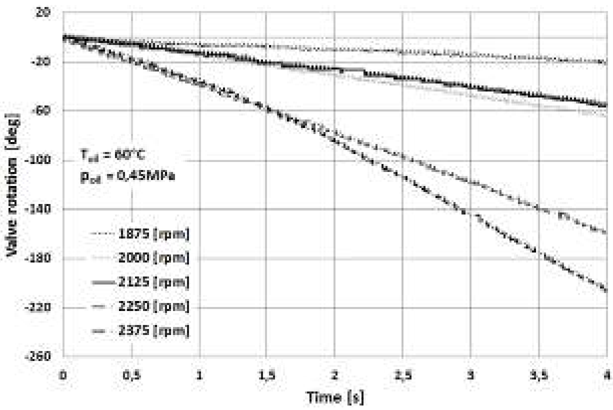

Figure 9. Valve rotation at 0.45 MPa oil pressure

For better understanding the influence of oil pressure on valve rotation, two additional tests were carried at 0.3 MPa and 0.4 MPa, for a different oil temperature.

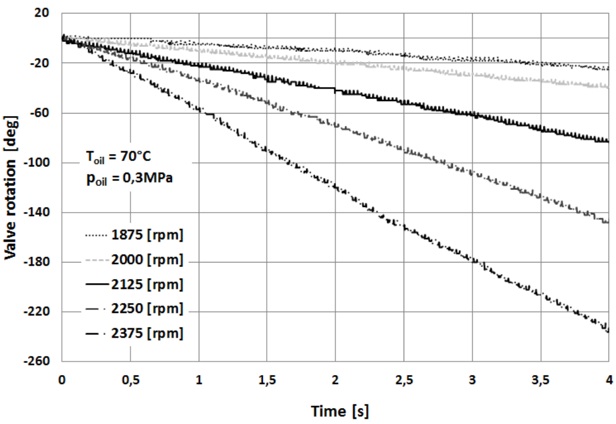

Figure 10. Valve rotation at 0.3 MPa oil pressure

Using the electrical heater placed in the oil tank, the oil temperature was increased until 70°C. The results obtained during those tests are presented in Figure 10 and Figure 11.

The first tests were carried out at 0.3 MPa. If the figure below is compared with Figure 6 two things can be concluded. For 1875 rpm and 2375 rpm, the angle of valve rotation increases with five degrees, but for the rest of camshaft speed, the angle of rotation has decreased.

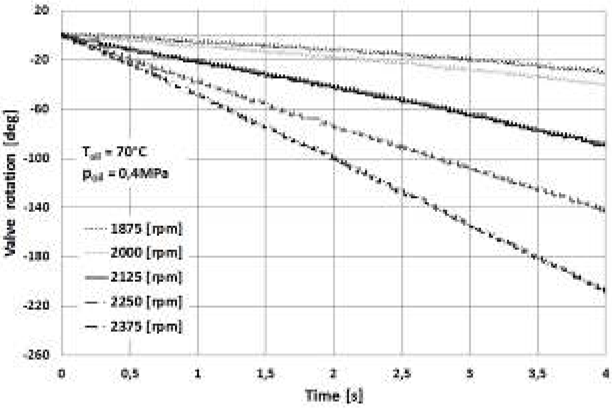

Figure 11. Valve rotation at 0.4 MPa oil pressure

After that, the oil pressure was set to 0.4 MPa. The results obtained were compared with the results presented in Figure 8. A decreasing trend in valve rotation can be observed. For four camshaft speeds, the difference between valve rotation is small, only a few degrees, but for 2250 rpm the difference between those two oil temperatures was more than 50 degrees.

4. Conclusions

The level of carbon deposits and temperature distribution on valve might be improved by ensuring a rotational movement of the valve. Also, it reduces the risk of cracks on valve head.

A test rig necessary for analyzing the valve rotation was build.

The valve rotation was measured using a high speed video camera which records the markers placed on the valve head.

The experimental results obtained, revealed an interesting behavior of the valve motion during its functioning. For all testing approaches, when the camshaft speed was increased, the valve rotational angle increased with a single exception: at 0.45 MPa oil pressure, 60°C oil temperature and 2125 rpm. In this case the angle of rotation was smaller with eight degrees than at 2000 rpm.

By modifying the oil pressure, a significant influence upon the angle of valve rotation can be observed. At some camshaft speeds, when the oil pressure was increased, the angle of rotation decreased, but on the other hand for other speeds the rotational angle of the valve decreased.

It can be concluded that besides the oil pressure and camshaft speeds, the oil temperature influenced the valve rotation. When the temperature was increased with ten degrees, the amplitude of valve rotation decreased.

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