Experimental Study on the Valve Gap in the Gasoline Engine

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ABSTRACT. The influences of the installations of the camshaft support, and timing system and the heat release on the valve gap of the gasoline engine were analyzed in the present. The experiments were carried out on 50 4-cylinder 4-stroke gasoline engines, and the results indicate that to tighten the camshaft support has a great impact on valve gap, the indicated mean there was an obvious deformation in cylinder head after the camshaft support was tightened. The timing system also has a significant influence on the valve gap because it produces a downward force to the camshaft, leading to a smaller valve gap near the timing system and a bigger valve gap on the other side. It was also found that with the increase of temperature the valve gap was 0.1mm larger than that in the normal state.

1 Introduction

The inlet and exhaust valves are the important parts of the engine valve train. Its function is to ensure the engine can absorb as much inflammable gas as possible during the intake stroke and to seal the combustion chamber during the compression power strokes. Curves of torque curve, brake power and indicator power can be improved by controlling the valve timing [1-3]. A number of studies have demonstrated that the variable valve timing technology can potentially improve engine torque and power, reduce automotive emissions and fuel consumption [4,5]. For engines, a small valve lift at a low engine speed will increase the negative pressure in cylinder and intake eddy, which helps improve the fuel-air mixing and fuel economy and increase the torque at the low speed. A large valve lift at high engine speed elevates the charging efficiency, which is beneficial for improving power performance of engines at high speed. In addition, if a multi-cylinder engine is operated at low loads, then the valve lift of a few cylinders can be reduced to zero to realize cylinder deactivation technology [6]. This approach effectively decreases the fuel consumption.

During the working processes of the engine, the valve tappet is inflated by the temperature of the combustion. In order to ensure that the valve can be sealed reliably in any cases, the engine needs to reserve a certain amount of valve gap. The valve gap has significant effects on the combustion process in the engine and the design of the inlet valve assemblies [7,8]. The opening and closing timings of the valves have a huge impact on the engine cycle efficiency, and the variable valve timing technology has been utilized to enhance the engine performance of the engines[9-11]. Although the literature on valve timing and valve lift is abundant, relatively few papers have been published on valve gap for gasoline engine. In [12] a four cylinder diesel engine was mounted four accelerometers on the cylinder head to test the tables of feature measurements for the different fault levels. The valve gap of this engine was induced into 0.15mm, 0.6mm, 0.9mm, 1.2mm and 1.5mm, which normal valve gap is 0.3mm. The valve gap was also studied on one cylinder of a four cylinder diesel engine in [13]. A probabilistic neural network was used to classify the Wigner-Ville distributions of the vibration signal. The valve gap was range from 0.06mm to 0.50mm, while the normal valve gap was 0.30mm.The experimental results show that the diesel trains faults can be classified accurately by the proposed method. In [14] a crank shaft angle sensor, two accelerometers and four in-cylinder pressure sensors was equipped on a four cylinder diesel engine to analysis the valve gap faults. The valve gap was induced into 0.25mm and 0.70mm on the intake valve of one cylinder. The results show that the two abnormal valve gaps can be distinguished from the normal state, but no classification accuracy values were reported. They also proposed a valve fault detection and diagnosis technique based on empirical mode decomposition and the instantaneous variations of the crankshaft's speed. The valve gap on a similar internal combustion engine was study in [15] used two acoustic mission sensors. The normal valve gap was 0.38 mm. They induced an exhaust valve gap of 0.8mm in one of the cylinders. The valve gap fault could be obviously distinguished from a healthy engine by the frequency domain analysis of the acoustic emission signals.

As so far, the majority articles of the valve gap are focus on the engine fault diagnosis, there is no published papers study the valve gap when the engine is wording and the effects of the other parts on the valve gap during assembling. The objective of the present study is to investigate the effect of the installations of the camshaft support, and timing system and the heat release on the gasoline engine valve gap. Through the investigation of the camshaft support and timing system influences, the

tappet selection can be corrected by KA to ensure the valve gap is in the middle of the acceptable range, which is important to improve the passing rate of the tappet selection. Meanwhile, the measurement of the valve gap in thermal and normal states can predict the variation of the valve gap efficiently; it can make a great contribution to the design of the valve gap and the quality control in production. The paper is organized as the following: the test bed and mathematical model is described in detail in Section 2. Section 3 presents the influence of the tightening of the camshaft support, the installation of the timing system and the temperature on the valve gap, along with the discussions of the experiment results. Conclusions are provided in Section 4.

2 Experimental setup

In the present work, the valve gap was measured in the MARPOSS tappet selection machine. Shown in Figure 1 was the mathematical model employed in the present study. The model was originally developed for SOHC, in-line 4-cylinder engines. In this type of engine, when the nose of one cam is upward (i.e. in the position for measuring the gap), there are usually several other cams which correspond to the opening valves.

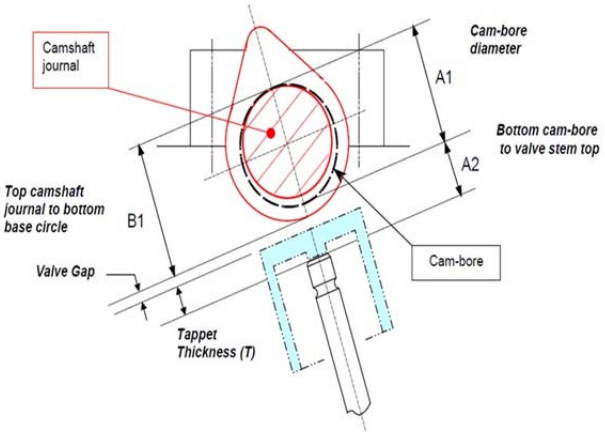

Fig. 1. The mathematical model.

Subsequently, the tappet thickness was derived from the following formula. The KA in the formula is the empirical correction factor.

$$T=A1+A2-B1-Gap+KA \quad (1)$$

At the start of the experiments, 50 engines, which were of 4-cylinder 16-valve DOHC structure, including intake VVT system, were selected to measure the valve gap. According to the design requirements, the inlet valve gap in the normal state was 0.17±0.04mm, while the exhaust was 0.28±0.04mm. The valve gap of the test engine was assembled according to this condition. Then the valve gap was measured after the timing system was installed. The valve gap in the front end of the engine was affected by the downward force from the timing system. After those engines were assembled, the hot test was done to investigate the effect of the temperature increase due to the heat release from the combustion processes in the cylinder on the valve gap. The hot test lasts 5 min, including 1 min under the idle condition, 2 min at 2000-3000r/min and then 2min under the idle condition. At last, the cylinder head cover was dismantled quickly to measure the valve gap in thermal state.

3 Results and discussion

3.1 Influence of the tightening of the camshaft support

Engine camshaft support mainly provides camshaft installation position for the engine cylinder head. Two camshaft supports were used to fix the camshaft in the experimental engines, i.e., the upper and lower camshaft supports. During the assembly process, the upper camshaft support should be taken down first, followed by tightening the camshaft. In order to investigate the impact of tightening force on the valve gap, the valve gap was measured three times in the present work. First, measure the valve gap after the camshaft support was tightened to the fitted state (9 N· m). Then tighten the camshaft support to the final moment 22 N· m, and the valve gap was measured at this time. To ensure the cylinder head deformation was not affected by the camshaft support, the valve gap was measured for the third time after the cylinder head bolts were tightened.

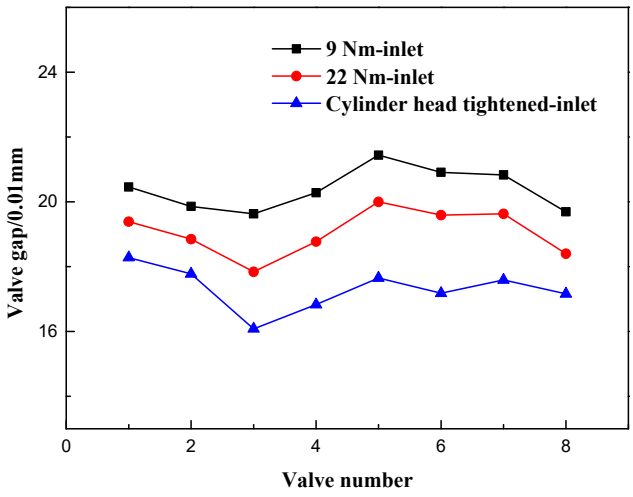

Fig. 2. Average changes of the inlet valve gap when tightening the camshaft support.

Shown in Figure 2 is the inlet valve gap before and after the camshaft support was tightened. The inlet valve gap is 0.01-0.02mm smaller after the camshaft support was tightened, and continues to decrease by 0.01mm after the cylinder head was tightened. The result shows that the camshaft support and the cylinder head are deformed by the tightening processes, but the tightened influence can be corrected by KA in the above formula.

3.2 Influence of the installation of the timing system

In this paper the timing system in the test engine consists of the timing chain, the fixed guide, the crankshaft timing chain wheel, etc. During the installation processes of the timing system, the timing chain will produce a downward pressure on one side of the engine, resulting in a smaller valve gap near the timing system and a larger valve gap on the other side. Variations of the inlet and exhaust valve gaps before and after the timing system was installed are shown in Figure 3. As shown in the figure, the gaps of inlet valves 1 and 2 and exhaust valves 1 and 2 were 0.01mm smaller than the values before, while the gaps on the other side were 0.01mm larger than those before. The middle valves were not affected by the installation of the timing system, and therefore there were no obvious changes in the valve gap before and after the timing system was installed.

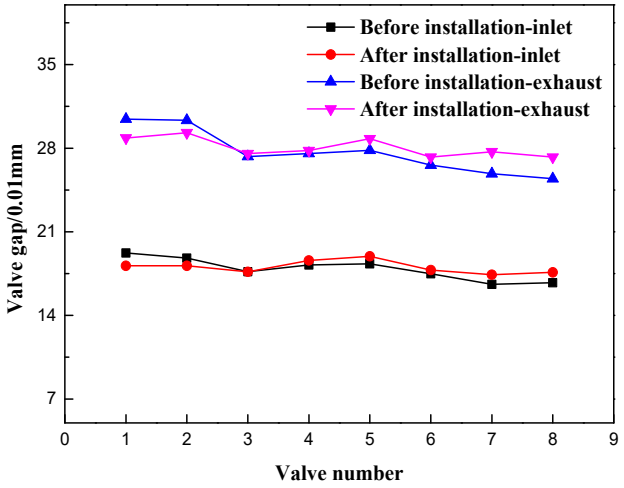

Fig. 3. Comparisons of the valve gap between before and after the installation of the timing system.

3.3 Influence of the temperature

Combustion is a very complicated physical and chemical process, and the heat energy released from the fuel combustion is delivered to the valve, leading to its thermal expansion. The valve gap is assembled in normal state, which is not measured during the engine operating processes before. To investigate the valve gap in thermal state, the experiment was taken to explore the valve gap when the engine was working.

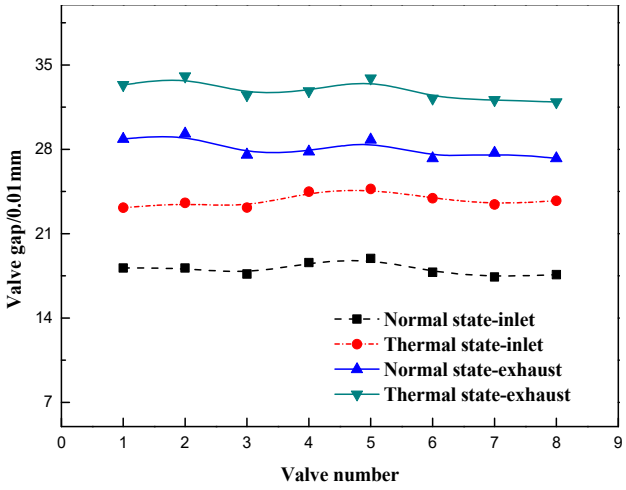

Fig. 4. Comparisons of the valve gap between the thermal and normal states.

To derive the effect of engine temperature, the gaps of the inlet and exhaust valves in the thermal state with the machine oil of 338K were measured, respectively, and the result is shown in Figure 4. As a result of the heat expansion, the valve gap in the thermal state was generally 0.05mm larger than that in the normal state. Then, the valve gap was measured again after the engine cooled down into the room temperature of 298K, and it is observed that the gap was generally consistent with that before. The detailed result is shown in Figure 5. That is to say, when the engine was working, the effect of the rising temperature on the valve gap disappears when the engine cools down, and the valve gap was mainly influenced by the heat release in the cylinder.

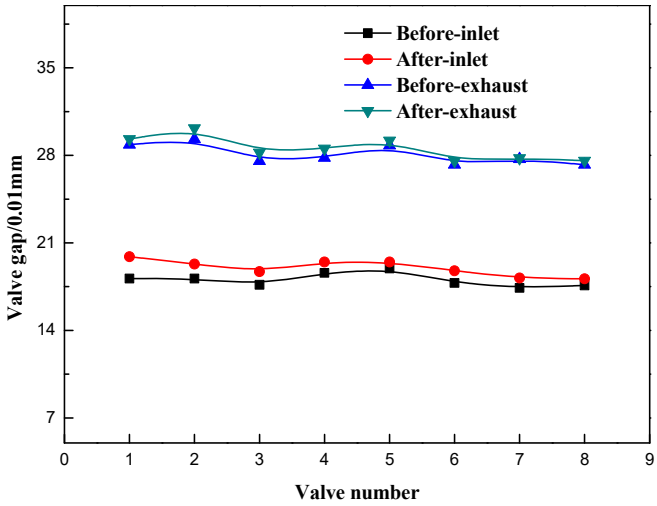

Fig. 5. Comparisons of valve gap between before and after the hot test.

4 Conclusions

Valve gap of inlet and exhaust on diesel engine were experimental studyed by using MAPOSS tappet selection

machine. The tightening of the camshaft support leads to a 0.01-0.02mm smaller in valve gap, which would continue to decrease by 0.01mm after the cylinder head was tightened. The influence of the installation of the timing system was also presented in this paper, the results show that the valve gaps on both side were influenced by 0.01mm, while the middle valves were not affected by the installation of the timing system. However, the effects of the camshaft support tightened and the timing system installation can be corrected by compensation, which can guarantee the valve gap in the normal range under normal temperature. On this basis, an experimental study considered the influence of the temperature was also taken in this paper. The valve gap of inlet and exhaust were both 0.05mm larger than the normal state at the machine oil was 338K. Compared to the tightened of the camshaft support and the timing system installation, the increase of temperature has strong effects on the valve gap of the gasoline engine. At last, according to the variations of the valve gap with the temperature effect, the valve gap should take into account the temperature of the engine working state to ensure the intake of the engine at the design phase.

References

1. U. Kramer, P. Philips. Phasing strategy for an engine with twin variable cam timing[C]. SAE World Congress& Exhibition. **1**(2002):1101.
2. T. Kohany, E. Sher. Using the 2nd Law of thermodynamics to optimize variable valve-timing for maximizing torque in a throttled SI engine [J]. Training. **1**(1999):0328.
3. E. Sher, T. Bar-Konany. Optimization of variable valve timing for maximizing performance of an unthrottled SI engine- A theoretical study [J]. Energy. **27**, 8 (2002):757-775.
4. E.D. Mohamed. Design and experimental investigation on an electromagnetic engine valve train[C]. SAE World Congress& Exhibition. **1**(2011):0365.
5. H.B. Lee, H. Kwon, K. Min. Effects of various VVA systems on the engine fuel economy and optimization of a CVVT-VVL SI engine using 1D simulation [J]. Automotive Technology. **8**, 6(2007):675-685.
6. S. Diana, B. Iorio, V. Giglio, G. Police. The effects of valve lift shape and timing on air motion and mixture formation of DISI engines adopting different VVA actuators[C]. SAE International Fall Fuels& Lubricants Meeting& Exhibition. **1**(2001).
7. A.F. Bicen, C. Vafidis, J.H. Whitelaw. 1985, Steady and unsteady air flow through the intake valve of areciprocating engine [J]. J FLUIDS ENG. **107**(1985):413.
8. C. Arcoumanis, C. Validis, G. Varropoulos, J. H. Whitelaw. Correlation between valve and incylinder flow in a motored reciprocating engine[C]. ASME Automotive Engine Technology Symposium, Dallas, Texas, 1987.
9. B. Khalighi, S.H. EI Tahry, W.R. Kuziak. Measured steady Bow velocity distributions around a valve/seat annulus [J]. SAE Transactions. **86**, 04(1986):62.
10. M. Haghgooie, J.C. Kent, R.J. Tabaczynski. Intake valve cylinder boundary flow characteristics in an internal combustion engines [J]. COMBUST SCI TECHNOL. **38**(1984):49.
11. E.M. Paul. Numerical prediction of fluid motion in the induction system and the cylinder in reciprocating engines [J]. SAE Technical Paper. **87**, 05(1987):94.
12. S. Liu, F. Gu, A. Ball. Detection of engine valve faults by vibration measured on the cylinder head [J]. Proc. Inst. Mech. Automob. 220(2005).
13. C. Wang, Y. Zhang, Z. Zhong. Fault diagnosis for diesel valve trains based on time–frequency images [J]. MECH SYST SIGNAL PR. **22**(2008):1981-1993.
14. Y. Li, P.W. Tse, X. Yang, J. Yang. EMD-based fault diagnosis for abnormal clearance between contacting components in a diesel engine [J]. MECH SYST SIGNAL PR. **24**(2010):193-210.
15. F. Elamin, Y. Fan, F. Gu, A. Ball. Diesel engine valve clearance detection using acoustic emission [J]. ADV MECH ENG. **2**(2010):1652-1660.