Chapter 49
Experimental Study on the Application of Hydrogen Detector in Engine Leak Detection

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Abstract The use of hydrogen detector and leak testing equipment is a new technology to leak location. The paper summed up advantages and disadvantages between methods soap-bubble and hydrogen detection to find leaks. Analysis of influences the mixture gas of nitrogen and hydrogen on the leak testing equipment and theoretical analysis. Hope to help others.

Keywords Three leaks · Leak detection · Hydrogen detector · Soap-bubble

Three leaks is a big problem in the production. In order to reduce the rate of leakage of the engine, engine manufacturers layout many leak detection stations in the production line. And it can effectively reduce the leakage and repair cost. In the leak detection process, to find the leak is the key to solve the problem of leakage. But with usual soap-bubble leak detection, part of engines with leakage rate exceeds permissible limit were unable to locate the leak, which increases the cost of repair. Therefore, to find new ways of leak location is still of great significance.

49.1 Introduction and Test Arrangement

The mixed gas of nitrogen and hydrogen is used as a tracer gas in hydrogen detection to locate the leak. The inspection equipment is hydrogen detector, as shown in Fig. 49.1. When looking for the leaks, the workpiece must be filled with mixture gas of nitrogen and hydrogen (Generally 95% nitrogen and 5% hydrogen mixed gas [1], 4% hydrogen in this paper, and the mixed gas is not combustible [2]), and maintain the pressure within a certain range (about 0.2 Bar), then find the possible leak points. If there is a leak, the handheld probe will be able to inspect the leakage of hydrogen and locate the leakage area. If the leak is large enough,

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Fig. 49.1 Hydrogen detection device

the hydrogen detector alarms. In this paper, the hydrogen detection device model is INFICON ISH2000, as shown in Fig. 49.1.

49.2 Experimental Arrangement

Generally, under the same conditions, nitrogen and hydrogen mixture gas does not cause additional damage to the leak test equipment. In the experiment, filling, keeping and exhaust of the mixed gas are controlled by a leak test device. Adjusted the pressure of the mixture gas to about 5 Bar.

Select engines as follows:

(a) Oil passage: the leakage rate is greater than 600 cm^3/min and cannot find the leak. If there is no engine exceeds 600 cm^3/min, reduce the requirement.
(b) Waterway: the leakage rate is greater than 15 cm^3/min and cannot find the leak.

49.3 Experimental Study on the Hydrogen Detection Equipment with the Use of the Whole Engine Leakage Test Device

49.3.1 Effectiveness Analysis of the Hydrogen Detection Equipment

A total of 88 engines were tested with mixture gas, from which found 43 waterway leak and 45 oil leak, as listed in Table 49.1.

Table 49.1 Test result of hydrogen detection

	Total number	No leak found	The average leakage rate (cm^3/min)	Remark
Waterway	43	4	23.5	1 engine retest and qualified
Oil passage	45	3	1036.4	1 engine retest and qualified

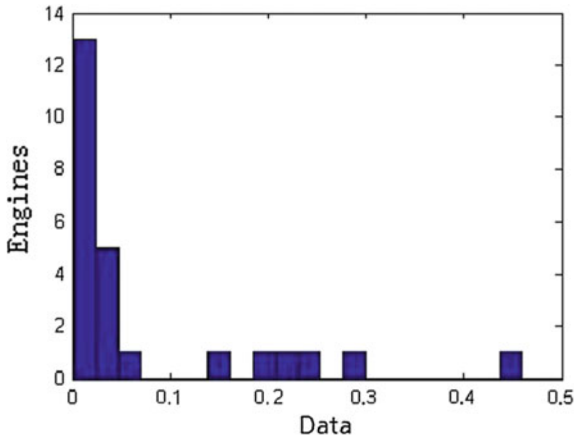

Fig. 49.2 Hydrogen detection data distribution of cylinder cover

Through the hydrogen test data and corresponding soap-bubble method data analysis, the advantages and disadvantages of hydrogen detection technology as follows.

The ability to locate leaks: 157 leaks were found by hydrogen detection, involving 35 different leaks, and at the same time 17 different leaks were found by soap-bubble in a total of 21,228 diesel engines. Hydrogen detection can find more locations. And only 3 engines are still unable to locate the leaks in 45 oil leakage engines, 4 in 43 for water leakage engines. So the sensitivity of hydrogen detection is higher.

Analysis of the hydrogen test data: Take the cylinder cover as example, as shown in Fig. 49.2, the hydrogen data is discrete widely. Because of the hydrogen detection data is the leakage data of point, but the actual leak is line or area, it is difficult to get the actual value of the leak. So it is not recommended to set limits for engines rework.

Cost analysis: Hydrogen detection cost less than ¥2.5 per engine and about ¥4 to ¥5 for soap-bubble. Application of hydrogen detection has lower cost.

Production rhythm analysis: Compared with hydrogen detection and soap-bubble, the former takes more time. Hydrogen detection requires a distance and moving speed when working. It is about 15–20 min per engine and too long to production.

Comparation of hydrogen detection and soap-bubble method are shown in Table 49.2.

Table 49.2 Comparation of hydrogen detection and soap-bubble method

	The ability to locate leaks	Location requirements	Operation time	Operating environment	Cost
Hydrogen detection	High	No	Long	Clean	Low
Soap-bubble method	Usual	Liquid must be attached	Short	Liquid residue	High

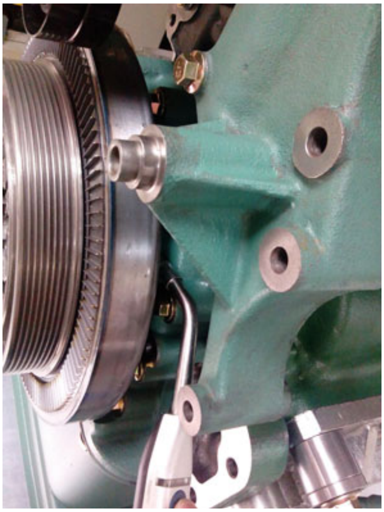

Fig. 49.3 Front oil seal detection

In addition, the external power supply limits the working space of the device, and inconvenient. Therefore, rechargeable batteries should be equipped in future.

49.3.2 Feasibility Analysis of Online Hydrogen Detection

49.3.2.1 Online Operability Verification

Hydrogen detection not only find all locations that soap-bubble method can, but also find the following 6 kinds of leak that soap-bubble method cannot or difficult to find.

(a) Oil pan: Since linear and small leak at the oil pan, it is not easy to form a bubble, but hydrogen detection device is able to detect the slight leakage.
(b) The cylinder cover: The condition to cylinder cover is similar with oil pan, small surface leakage is not easy to be found by soap-bubble method.
(c) Front oil seal: Due to the block of shock absorber, the soap-bubble method does not work. But hydrogen detector can be placed to locate the leak, as shown in Fig. 49.3.

Fig. 49.4 Rear oil seal detection

Table 49.3 Experimental data of effect of residual mixture gas of hydrogen and nitrogen

Leak point	Non blowing (10^{-3} cm^3/min)				Blowing (10^{-3} cm^3/min)			
Oil pan gasket	02	18	31	28	6	7	7	3
Cylinder cover bolt	28	32	62	71	150	140	170	130

(d) Rear oil seal: It is inside of oil pan, and cannot reach and observe. The hydrogen detector can be placed in the hole of the speed sensor to inspect as shown in Fig. 49.4.
(e) Plug at bottom of pump: It is unable to liquid adhesion, and the operator is difficult to observe.
(f) Oil level gauge tube: The leakage is mostly caused by welding, the large leak prevents the formation of air bubbles.

In summary, the online hydrogen detection has many advantages. But it cost too many time to production. It should be improve the quality of parts and assembly, optimize the process and so on, then the online hydrogen detection may be feasible.

49.3.2.2 Effect of Residual Mixture Gas on Hydrogen Detection

As online hydrogen detection, the engines stay at a fixed station, gas accumulation may impact on the results of the hydrogen detection. Therefore, the effect on hydrogen detection is verified. In the experiment, a leakage position was tested several times. Plan A: in the case of non blowing, Plan B: air blowing before test.

As shown in Table 49.3, in the case of non blowing, there are some fluctuations to the hydrogen detection data. And there is no readings and no alarm in the vicinity of the residual gas. In the case of blowing, the data fluctuations too, but the values greater than these of non blowing. Residual mixture gas has little impact on hydrogen detection values. The fluctuations partly due to the changes in direction and position of the handheld sensor and the formation of air bag during inflation. This condition can be improved by increasing inflation time or using vacuum equipment.

49.3.3 *Effect of Residual Mixture Gas on the Whole Engine Leakage Test Device*

Using mixture gas of nitrogen and hydrogen as a leak testing medium during online test can do leak detection and location at the same time, which helps to reduce the test time. Carried out the test take mixture gas instead of compressed air as an medium gas. In the experiment, 2 diesel engines were selected. The test data are shown in Table 49.4.

As shown in Table 49.4, leakage values with the mixture gas are lower than compressed air. Since the whole engine leakage test device use mass flow sensor to measure the leak, the readings is the volume flow, and the relationship between volume flow and mass flow is $Q = \frac{nRT}{mP} \cdot \hat{m}$, here, Q is volume flow, P is pressure, n is molar mass, R is molar gas constant, T is kelvin temperature, m is mass, $\hat{m}$ is mass flow. P, R, T can be regarded as constants, $\frac{n}{m}$ is the reciprocal of the molar mass. The molar mass of the gas is proportional to the density ρ. So the volume flow rate can be expressed as: $P = \frac{C}{\rho} \cdot \hat{m}$, here C is a constant.

Take mixture gas instead of compressed air, the medium density changes but the coefficients of the instrument does not change. Thus, the relationship between volume flow Q_H measured by mixture gas and volume flow Q_A measured by the

Table 49.4 Mixture gas of nitrogen and hydrogen and compressed air leak detection data

No.	Engine				Medium gas
	A		B		
	Waterway (cm^3/min)	Oil passage (cm^3/min)	Waterway (cm^3/min)	Oil passage (cm^3/min)	
1	4.03	49.64	4.77	−2.6	Compressed air
2	2.3	51.27	4.64	−10.5	
3	1.78	51.42	3.85	−5.61	
4	0.15	53.22	1.57	−8.62	
5	−3.25	25.85	−0.42	−25.85	Mixture gas
6	−2.39	35.42	−0.37	−26.21	
7	−2.72	39.17	−1.83	−16.63	
8	−4.91	40.37	−0.53	−20.62	

Table 49.5 Conversion leakage rate data

Engine	Compressed air	Mixture gas	Compressed air	Mixture gas
	Waterway	Waterway	Oil passage	Oil passage
A	1.49	0.74	7.65	7.04
B	1.74	1.23	3.69	2.83

compressed air as follow: $\frac{Q_H}{Q_A} = \frac{\rho_H}{\rho_A}$, that is $Q_H = \frac{\rho_H}{\rho_A} \cdot Q_A$, here ρ_H and ρ_A is the density of mixture gas and air.

Calculating the mean leak rate at the flow sensor according to coefficient and offset settings of the test device. And the absolutely leak rate of compressed air multiplied by $Q_H = \frac{\rho_H}{\rho_A} \cdot Q_A$. The test results of the two medium gas are closely and compared in Table 49.5. Thus, the method can be used to calculate an initial coefficient and offset settings of the leakage test device. That is the original coefficients multiplied by $\frac{\rho_A}{\rho_H}$ and offset settings minus $(\frac{\rho_A}{\rho_H} - 1)$. It is conducive to fast the whole engine leakage test device calibration, and the limits are almost constant.

49.4 Summary

Through application study on hydrogen detector, the advantages of hydrogen detection are verified. To the poor performance of soap-bubble method in leak location, the hydrogen detection still has a good performance. It can effectively improve the accuracy of leak location and repair efficiency. Through technology experiments, it demonstrated the online hydrogen detection program and laid the foundation for batch production applications in future. The new method of calculation of coefficients and offsets with mixed gas is useful to the calibration of the test device. And also explained the values change caused by density changes of medium gas. Others can learn from this article or carry out in-depth study.

References

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