# Study on the Technology of Improving Working Condition of Small Diesel Engine

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**Abstract** Small diesel engines, specially S195 type diesel engines, are widely used in rural areas of China. According to the results of investigation and inspection of 21000 engines, it is found that the working conditions of the engines in use are relatively bad in general. The average specific fuel consumption increased by 25.6% and the average power decreased by 18.2% compared with the rated specific fuel consumption and the rated power respectively. A new suitable technology, i.e., optimal adjustment and inspecting technology was put forward to improve the working conditions of small diesel engines in use. The test showed that the average specific fuel consumption decreased 11.21～29.47 g/(kW·h) and the average power increased 0.18～0.97 kW respectively after the engines were inspected and optimally adjusted. This technology has been listed as one of the major popularizing projects of state commission on science and technology of China. It was estimated that over 939.8 thousand tractors in use have been inspected and optimally adjusted and 97.7 thousand tons of fuel have been saved and 959 thousand kilowatt of power have been regained from 1991 to 1994.

**Key words** diesel engine, working condition, inspection and adjustment

## 1 Introduction

To find the reason why the working conditions of small diesel engines in use are so bad, more than 400 engines were inspected and the power data and eight technical parameters were obtained. Through analysis, the main factors influencing the working condition of the engine were found out. Then the optimal adjustment technology and data for the main parameters were put forward through theoretic analysis and tests.

## 2 Analysis of Main Influencing Parameters on the Engine Working Condition

Through inspection and investigation, it was found that the working condition of the engine in use is interrelated to the technical parameters such as intake and exhaust valve timing, fuel delivering angle, fuel injection pressure, cylinder pressure and so on. Technical state parameters (fuel-delivering angle, $X_1$; exhaust-valve-opening angle, $X_2$; intake-valve-

Received date: 1999-03-17 (Mar. 17th 1999)

* Supported by China Agricultural Ministry

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closing angle, $X_3$; idle rotation speed, $X_4$; intake-valve-opening angle, $X_5$; exhaust-valve-closing angle, $X_6$; the number of flywheel sweeping just after the engine out of ignition, $X_7$; injection pressure, $X_8$) and power and specific fuel consumption ($y$) of more than 400 diesel engines of S195 type were inspected randomly at Zhuji in Zhejiang Province in order to find out the internal relationship between the parameters and the power and specific fuel consumption. Path coefficient analysis is used to analyze the relationship[1]. With the help of computer, the direct path coefficients: were obtained as follows $P_{1y} = -0.162$, $P_{2y} = 0.506$, $P_{3y} = 0.414$, $P_{4y} = 0.217$, $P_{5y} = 0.114$, $P_{6y} = -0.034$, $P_{7y} = -0.037$, $P_{8y} = -0.119$. Indirect path coefficients can also be obtained. The total decision coefficient $d = 0.807$, which showed that almost all influencing factors can be covered by the selected eight parameters. Path coefficients showed that the order of influencing the working condition of the S195 type diesel engine will be successively exhaust-valve-opening angle, intake-valve-closing angle, idle rotation speed, fuel-delivering angle, injection pressure, intake-valve opening angle, the number of flywheel sweeping just after the engine out of ignition and exhaust-valve-closing angle.

## 3 Optimal Adjustment of Technical State Parameters

In general, the adjusting data of main technical state parameters were provided for each new engine. Adjustment of new engine according to those data can make the engine reach the best work condition. The wear of engine parts will increase with the time. If the parameters of an engine were still adjusted by the original data, the engine would not be in the best technical state. Optimal adjustment technology was an aimed adjustment according to different wear conditions.

### 3.1 Principles and Method of Optimal Adjustment of Valve Timing

It is important to select a suitable valve timing angle in order to make the time-section of valve opening larger and improve the air exchange effect. The valve timing has four angles, that is, intake-valve-opening angle, intake-valve-closing angle, exhaust-valve-opening angle and exhaust-valve-closing angle. As for a definite type of engines, only two angles of the four can be adjusted because the shape and position of cam shaft are fixed. The valve timing of engine in use will be changed with the wear and the variation of the valve clearance, which make technical state of an engine bad. If the engines were adjusted using traditional methods, that is to adjust the valve clearances by the data of specification of manufacture, the technical state of the engines will be improved little and even made worse. That is because the cam, tappet and other valve mechanism parts have been worn, if they are still adjusted according to the valve clearance standard data, the valve timing can not be kept correct. The relationship between valve timing and valve clearances were shown in Fig 1. When the valve clearance is correct, $oh_1$ stands for cam lift height for eliminating the clearance of valve. When the cam rotates to $t_1$, the valve clearance is just eliminated and valve begin to open. The more the cam rotates, the larger the valve opens. The maximum effective lift height of the cam is $H_1$. The valve will be closed when the cam rotates to $t_1'$. If the valve clearance is increased to $h_2$, the lift height of the cam that eliminates the valve clearance is $oh_2$, the valve begins to open when the cam rotates to $t_2$. On this condition, the maximum effective lift height of the cam is $H_1 - \delta$. The valve was closed when the cam rotates to $t_2'$. So, the increase of valve clearance will make the valve open late and close early and the effective lift height of the cam will decrease. For the same reason, the decrease of valve clearance will make the valve open early and close late and the effective lift height of the cam will be increased. If the valve clearance is still adjusted to standard data by specification when the cam has been worn, the valve timing can not be kept correct. The lift height of the cam that eliminates the valve clearance was $oh_1$ before the cam was worn, as shown in Fig. 1. After the cam was worn, if the valve clearance keeps unchanged, the valve opens when the cam rotates to $t_3$ and closes when the cam rotates to $t_3'$ and the maximum effective lift height is $H_1 - \delta_1$. That means that the valve was opened late and closed early and the effective lift height of the cam will be decreased when the cam has been worn. If the valve clearance is reduced suitably to make the lift height of the cam that eliminates the valve clearance decrease to $oh$, that is, the valve will be opened when the cam rotates to $t$ ($t_1$) and closes when the cam rotates to $t_1'$ and the effective lift height of cam is $H_1 - \delta_1 + \delta_2$. That means that the suitable decrease of valve clearance can make the valve open early and close late and the effective lift height of the cam will be increased. Therefore, suitable decrease of valve clearance can make up the wear of the cam. It is known from above path coefficient analysis and theoretic analysis that the exhaust-valve-opening angle and intake-closing angle are the main factors influencing the working condition of the engine. So, when adjusting the valve clearance is changed to keep the exhaust-valve-opening angle and intake-valve-closing angle correct, and the valve clearance must be more than 0.02 mm for heat expansion. This method can not completely make up the wear of the cam, but it can make up the wear partly and is effective for engine in use.

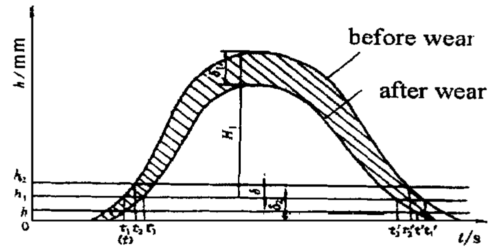


Fig. 1 The relationship between the valve clearance and valve timing

### 3.2 Optimal Adjustment of Fuel Delivering Angle

The results of inspecting the 227 diesel engines of S195 type showed that only 27% fuel delivering angles of the engines fit standard value and ones of most engines are too late. The reason for causing fuel delivering angle late are as follows: a) wear of parts of fuel pump, b) the inspecting and adjusting method are not correct. There are many methods to inspect the angle, but different inspecting methods will obtain different results. A lot of experiments have been done and the relationship was gained among different inspecting methods[2]. As usual, overflow-fuel-method is widely used. On the basis of our experiments, the optimal fuel delivering angle of S195 type diesel engine is 18°±5.°

### 3.3 Optimal Adjustment of Fuel Injection Pressure

The fuel injection pressure is much higher for most engines in use. The effect of fuel injection pressure on the working condition of engine is not as sensitive as that of valve timing and fuel delivering angle. If the seal of fuel pump is good, the fuel injection pressure needs to be adjusted to 12.25～13.23 MPa. If the seal of fuel pump is not good because of wear, the fuel injection pressure needs to be adjusted to 10.29～11.76 MPa.

## 4 Period and Effect Analysis of Optimal Adjustment

In order to survey the changing rules of main technical state parameters when the engine was optimally adjusted and to decide the period of optimal adjustment, 14 diesel engines of S195 type fixed on walking tractors were selected randomly to test for one year. For the first time, all the 14 engines were optimally adjusted, and then every month power and specific fuel consumption and 8 technical state parameters were inspected and not readjusted. The results were shown in Fig. 2～Fig. 5. Supposing a S195 type diesel engine consumes 1000 kg fuel in one year. Half a year later, the average power of engine has been decreased by 12 % and the average specific fuel consumption has been increased by 12 %. Of all the 8 technical state parameters, valve timing and fuel delivering angle are changed most quickly.

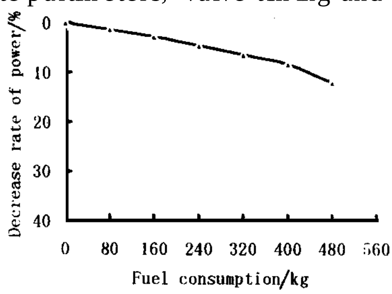


Fig. 2　Curve of engine's power changing rate with fuel consumption

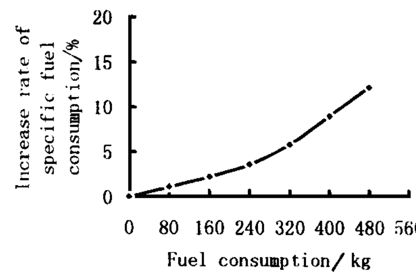


Fig. 3　Curve of engine's specific fuel consumption changing rate with fuel consumption

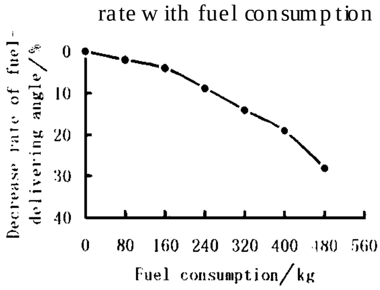


Fig. 4　Curve of engine's fuel-delivering angle changing rate with fuel consumption

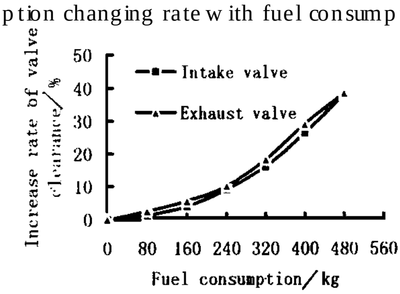


Fig. 5　Curve of engine's clearance changing rate with fuel consumption

Average value of valve timing was changed about 5° after 500 kg fuel was consumed by an engine. So the valve timing should be inspected and optimally adjusted after the engine runs 3～6 months. Average fuel delivering angle decreased 1.5° after 250 kg fuel was consumed by an engine. So the fuel delivering angle should be inspected and adjusted after 3 months. The engine power will be affected greatly by the cylinder compression pressure at the end of stroke. Experiment shows that when the pressure decreases by 10 % the specific fuel consumption will rise evidently. So every half a year it should be inspected. In order to verify the optimal adjustment effects, 10 diesel engines of S195 type were selected randomly in Jiangshan in Zhejiang Province. First they were adjusted according to the data of the specifications of the engine and the power and the specific fuel consumption were measured, then they were readjusted according to the data and method of the optimal adjustment. The tested results of effects of optimal adjustment were showed in Fig. 6 and Fig. 7. Through statistical analysis[1], it was showed that the power increased by 0.18～0.97 kW and the specific fuel consumption decreased by 11.12～29.47 g/(kW·h) after optimal adjustment. The confidence level of the estimation was 99 %. The method and principle of optimal adjustment can also be used on new diesel engine to compensate the manufacture tolerance of the cam.

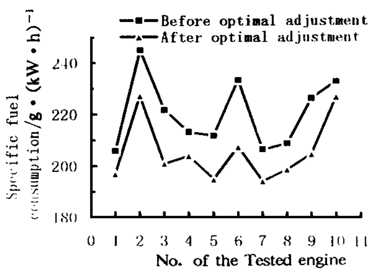


Fig. 6 Specific fuel consumption of engines before and after optimal adjustment

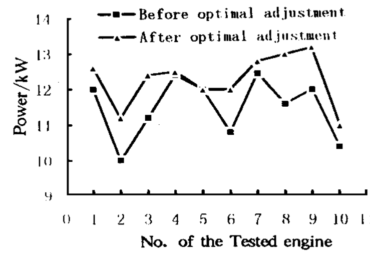


Fig. 7 Power of engines before and after optimal adjustment

## 5 Conclusion

The inspected data of 400 engines of S195 type were analyzed by using path coefficient analysis method so that the main factors that cause the working condition of the engine in use to be bad were found out. They are exhaust-valve-opening angle, intake-valve-closing angle, idle rotating speed, fuel delivering angle and fuel injection pressure.

Optimal adjustment is that the engine is adjusted according to the practical state of the engine to obtain the best working condition, which is much more effective for the engine in use compared with traditional adjustment method according to the tests and theoretic analysis. The principle and method of main influencing parameters-valve timing, fuel delivering angle and fuel injection pressure were analyzed and worked out. Experiments showed that the technical conditions of the engine were improved greatly after the engines were optimally adjusted and the inspecting and adjusting period of the main technical state parameters of S195 type diesel engine were determined.

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# 小型柴油机优化调整节能技术的研究

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**摘 要** 针对中国农村广泛使用的小型柴油机技术状态普遍较差这一现状, 通过试验研究和主成分分析等方法找出了影响技术状态的主要因素。通过理论分析和试验研究, 确定了各主要技术状态参数在发动机不同工况和磨损状况下的变化规律和最优调整值及调整周期, 提出了柴油机的优化调整节能技术。对柴油机进行针对性的检测和优化调整后, 可提高功率 0.18～0.97 kW, 降低油耗 11.21～29.47 g/(kW·h), 取得了较好的效果。

**关键词** 柴油机 工作状况 检测和调整