ISSN 1009 - 3095 *Journal of Zhejiang University(SCIENCE)* V.2, No.2, P.192 - 195, Apr. - June, 2001
http://www.chinainfo.gov.cn/periodical; http://www.zju.edu.cn;
http://lib.zju.edu.cn/English; http://www.zjupress.com

STUDY ON THE RELATIONSHIP BETWEEN ADJUSTABLE OPERATIONAL PARAMETERS AND NOISE OF SINGLE-CYLINDER DIESEL ENGINE*

HE Yong(何 勇)†, BAO Yi-dan(鲍一丹)
(*Dept. of Agricultural Engineering, Zhejiang University, Hangzhou 310029, China*)
† E-mail: yhe@zju.edu.cn

Received Nov.21, 1999; revision accepted Sept.3, 2000

Abstract: A Model S195 (8.8 kW) single cylinder was used in this study to determine the effect of four operational parameters, i.e. intake valve close angle, exhaust valve open angle, fuel delivery angle and fuel injection pressure on noise. Single factor and multi-factor quadratic regressive orthogonal methods were adopted in the experiments to find the relationship between the four parameters and noise. By means of optimization technique, the optimum operational parameters for two working conditions of the engine were selected and the test results showed that optimum adjustment could reduce noise by 2 - 4 dB.

Key words: diesel engine, noise, working condition, optimum adjustment
Document code: A **CLC number**: S219

INTRODUCTION

Type S195 diesel engines are widely used in rural areas of China. The total number of the engines used in agriculture is about 8 million sets. Our investigations showed that the working conditions of the engines in use are relatively bad in general. The noise level is very high. Tractor operators are exposed to noise and vibration that are hazardous to human health, due to their long-term effects. Optimal Adjustment and Inspecting Technology (OAIT) (He, 1995; 1996) was found useful for improving the working conditions of S195 diesel engines in use. The objective of this experimental research is application of OAIT to decrease the noise of type S195 diesel engine.

NOISE ANALYSIS OF DIESEL ENGINE

There are various studies to clarify the mechanism of noise and vibration in diesel engines and to identify and pinpoint various sources of noise and their contribution to the total engine noise composed mainly of combustion-induced noise and mechanically-induced noise.

1 Combustion-induced noise

The mechanism of combustion-induced noise is triggered by the cylinder pressure acting on the engine structure, then causing deflection of the structure (Naoya, 1989). The structural impedance of an engine structure is dependent on engine stiffness, mass and damping. Combustion noise is caused by the direct exciting force of the engine (Hiroshi, 1990). The characteristic noise of diesel combustion is generally known as diesel knock.

2 Mechanically-induced noise

Mechanically-induced noises result from indirect forces that are dependent on the direct exciting force in some linear manner, such as the impacting forces produced by pistons, bearings, and timing gears. These secondary forces cause the mechanically-induced noises (Gerhard, 1973). Bad maintenance, wear, as well as maladjustment cause changes in engine performance and noise. So the optimal adjustment of the operational parameters can decrease the noise.

MATERIALS AND METHODS

Used in this study was a Model S195 single

* Project supported by Agricultural Ministry of China

cylinder, four-stroke cycle diesel engine with rated power 8.8 kW, 2000 r·min^{-1}, and with swirl chamber. Noise was measured by means of a pressure-sensitive microphone. The noise metering instruments was a Model ND10 that could read in the range of 43 – 140 dB at frequency from 31.5 Hz to 8 kHz. Noise was measured according to Chinese standard measurement procedure (GB1859 – 80).

The four parameters under study (intake valve close angle α, exhaust valve open angle β, fuel delivery angle θ, and fuel injection pressure p were measured by a simple device developed especially for the engine. The China patent number of the device is No.87201917.9.

EXPERIMENT RESULTS AND ANALYSIS

Tests were designed to provide data on diesel engine performance under controlled conditions, and aimed to study the changing law between the four parameters and noise, and to get the best parameter combinations.

1. Single variable test

(1) Exhaust valve open angle

Adjust intake valve close angle, fuel delivery angle and fuel injection pressure to standard value (according to the specification of the engine), and keep them constant. Adjust the exhaust valve open angle to 10°, 20°, 30°, 36°, 43°, 50°, 60°, 70°((Before Bottom Dead Center, BBDC), and measure the noise separately. Fig.1 shows eight exhaust valve opening angles at five different ranges of power (0, 4.4, 5.9, 7.4, 8.8 kW) at constant rated engine speed of 2000 r·min^{-1}. Fig. 1 shows that the engine noise increased with increase of load. The noise curves dip steeply for exhaust valve opening angle of 10° to 43°, from which point they rise rapidly to maximum height at about 50°, from where they all dip again.

(2) Intake valve close angle

Adjust exhaust valve opening angle, fuel delivery angle and fuel injection pressure to standard values (according to the specification of the engine), and keep them constant. Adjust the intake valve closing angle to 26°, 31°, 36°, 40°, 43°, 46°, 51°, 56°, 61° (BBDC), and measure the noise separately. Fig.2 shows that with the increase of load, the noise increases. The noise is the lowest at about 43°, and has no considerable change at other angles.

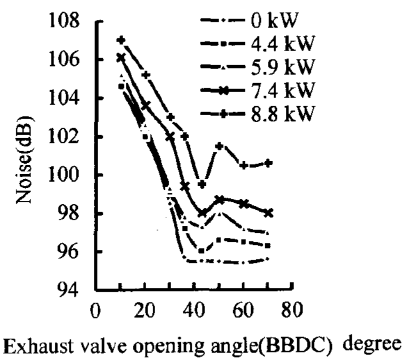

Fig.1 **The relationship between noise and exhaust valve opening angle at various loads**

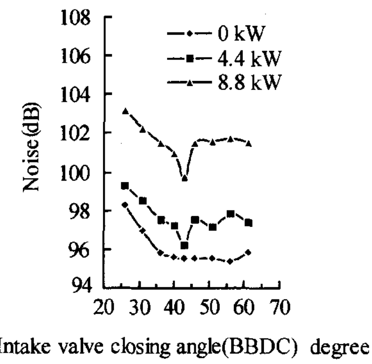

Fig.2 **The relationship between intake valve closing angle and noise at various loads**

(3) Fuel delivery angle

Adjust intake valve closing angle, exhaust valve opening angle and fuel injection pressure to standard values (according to the specification of the engine), and keep them constant. Adjust the fuel delivery angle to 2°, 6°, 9°, 12°, 15°, 17°, 20°, 23°, 35° (Before Top Dead Center, BTDC), and measure the noise separately. Fig. 3 shows that with the increase of load, the noise increases. The curves dip from 0° to 17°, after which do not change much.

(4) Fuel injection pressure

Adjust intake valve closing angle, exhaust valve opening angle and fuel delivery angle to standard values (according to the specification of the engine), and keep them constant. Adjust the fuel injection pressure to 5.886, 7.848, 9.810, 11.772, 13.734, 15.696, 17.658

MPa, and measure the noise separately. Fig.4 shows that with the increase of load, the noise increases. The change of noise level with different fuel injection pressure is not significant.

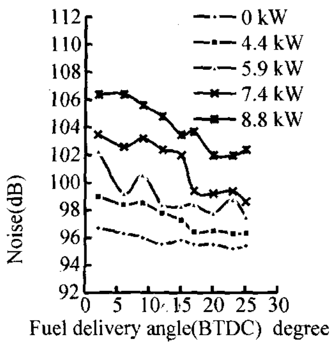

Fig.3 The relationship between fuelde livery angle and noise at various loads

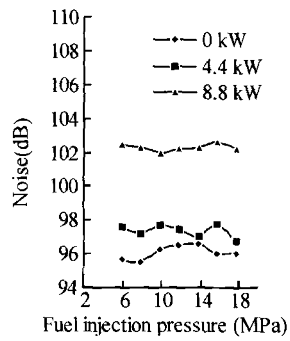

Fig.4 The relationship between fuel injection pressure and noise at various loads

The above results show that the main factors influencing noise are exhaust valve opening angle and fuel delivery angle.

2. The quadratic regressive orthogonal test

The quadratic regressive orthogonal design method was adopted to get the main adjustable working parameters influencing the noise and find the optimal parameter combinations for minimizing the noise. Four parameters were arranged in the tests (Table 1). After each test was over, the working parameters were readjusted according to the test arrangement. After significance tests to obtain the regression coefficients and regression formula, the equations of the four working parameters' relation to noise under two working conditions can be written as follows:

Table 1 The design level of the four variables

Variables	Changing interval	Design level of the variables ($m_0 = 2$, $r = 1.483$)				
X	Δ_j	$-r$	-1	0	$+1$	$+r$
X_1 (intake valve closing angle)	6.743	33	36.257	43	49.743	53
X_2 (exhaust valve opening angle)	6.743	33	36.257	43	49.743	53
X_3 (fuel delivery angle)	2.697	14	15.303	18	20.697	22
X_4 (fuel injection pressure)	1.32	10.30	10.94	12.26	13.59	14.22

working condition 1 (idling condition: 0 kW, 2000 $r \cdot min^{-1}$, $F_e > F_{0.01}$):

$$Y = 95.696 - 0.289X_1 - 0.289X_2 - 0.119X_2X_3 - 1.213X_3X_4 - 24.211X_4^2 \quad (1)$$

working condition 2 (8.82 kW, 2000 $r \cdot min^{-1}$, $F_e > F_{0.10}$):

$$Y = 100.52 - 0.277X_1 - 0.419X_2 - 0.363X_1X_2 + 2.681X_3X_4 + 0.373X_1^2 + 0.327X_2^2 + 0.828X_3^2 + 38.759X_4^2 \quad (2)$$

The variable analysis and regression equation show clearly that the exhaust valve opening angle and fuel delivery angle are the most important among the four working parameters influencing the noise.

OPTIMUM WORKING PARAMETERS

The regression equations of the two working conditions are taken as objective functions respectively, and the test range of each working parameter is taken as constraint condition, in the nonlinear programming mathematical models below. Working condition 1 (idling condition: 0 kW, 2000 $r \cdot min^{-1}$):

Objective function:

$$\min Y = 95.696 - 0.289X_1 - 0.289X_2 - 0.119X_2X_3 - 1.213X_3X_4 - 24.211X^2X_4 \quad (3)$$

Constraint conditions:

$$\begin{cases} X_i - 1.483 \leq 0 \\ -X_i - 1.483 \leq 0 \quad (i = 1,2,3,4) \end{cases} \quad (4)$$

With the help of a computer, the optimal combinations of the four working parameters under the two working conditions were worked out by using the nonlinear programming, punishment function method (Changkong, 1983; Gan, et al., 1990) to obtain the optimum parameter combinations. The results are shown below:

working condition 1: $Y_{min} = 95.58$ dB, $X_1 = 0.223(\alpha = 44.52°)$, $X_2 = 0.223(\beta = 44.52°)$, $X_3 = 0.02(\theta = 18.05°)$, $X_4 = -0.001(P = 12.26$ MPa):

working condition 2: $Y_{min} = 100.19$ dB, $\alpha = 49.25°$, $\beta = 50.82°$, $\theta = 17.99°$, $P = 12.26$ MPa.

TEST VERIFICATION OF THE OPTIMAL COMBINATION

The objective of field tests was to inspect and measure the four parameters according to the actual condition, to readjust the parameters according to the optimal combination , and to make comparison before and after optimal adjustment. Comparison of 6 Type S195 diesel engines in Jiande City of Zhejiang Province showed that after optimal adjustment, the noise was reduced by 2 - 4 dB, and that the power could be increased by 0.7 - 2.5 kW.

CONCLUSIONS

Tests showed that exhaust valve opening angle and fuel delivery angle were the main factors influencing noise level of Type S195 diesel engine in use.

Optimal combination of four parameters has been worked out. After optimal adjustment according to the optimal combinations, the noise of the engine in use can be reduced by 2 - 4 dB.

Noise in general increased from light to heavy load of engine.

References

Chankong V. and Yacov Y.H., 1983. Multiobjective decision making: theory and methodology. Elsevier Science Publishing Co., Inc. p.130 - 165.

Gan Yinai et al., 1990. Operations research. Tsinghua University Press. p.183 - 190.

Gerhard E. T., 1973. The use of specially designed covers and shields to reduce diesel engine noise. SAE 730214, 955 - 968.

He Yong., 1995. Analysis and improvement of working condition of S195 type diesel engine in use. *Transactions of the Chinese Society of Agricultural Machinery*. **26**(3):5 - 9

Hiroshi K. and Minoru O., 1990. Analysis of noise sources and their transfer paths in diesel engines. SAE900014, p.34 - 41.

Mao Shisong et al., 1986. Regression analysis and test design, Huadong Normal University Press, Shanghai, p. 30 - 50.

Naoya K., 1989. An Evaluation of combustion noise generation in diesel engine structure. SAE890126, p.51 - 59.

Xi Wenbin, He Yong., 1996. Optimal adjustment and inspecting saving energy technology. Chinese Agricultural Science and Technology Press, Beijing, p.134 - 174