Testing Research on Performances of Diesel Engine Fueled with Natural Gas and Diesel Fuel Blends

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ABSTRACT: By means of a technology method which combining diesel pilot injection and natural gas supplied to intake pipe forming gas mixture, engine bench test research has been done on a diesel engine when being fueled with natural gas and diesel fuel blends. On the basis of design natural gas supplying system, effects of natural gas and diesel blends under different alternative ratios on power performance were studied. The results indicate that natural gas combusted on diesel engine can improve torque performance of engine power points, the maximum torque increasing by 6.8%. And when the engine is running at low speed points, combustion efficiency is better using higher natural gas alternative ratio; while at high speed points, lower alternative ratio is suitable. Conclusion can be drawn that reasonable alternative ratio of natural gas co-combusted on diesel engine can improve power performance and economic performance of diesel engine.

1 GENERAL INSTRUCTIONS

Recent studies suggest that natural gas is an efficient, clean energy, its huge storage capacity, the price is relatively low, the engine can be fueled with produce good economic and social benefits.

At present, natural gas, mainly in compressed gas cylinders are stored (CNG) used in gasoline vehicles. Its main application is by using a separate natural gas fuel supply piping system directly in the engine fueled with gasoline, burning this way is simple and practical, but unable to play natural gas as gaseous fuel in the engine fueled with natural Advantage. Therefore, the study and exploration of natural gas has important practical engineering in application mode on the engine.

Our vast mountainous area, transport diesel energy dependence, the use of alternative energy on the part of the natural gas and diesel fueled with diesel engines, both diesel can save valuable resources, diversification of natural gas may also be implemented on the engine application. Therefore, this article studies the calorific value when use of natural gas instead of diesel fuel on the engine part, variation of diesel power and economy, provided that the reference to the natural gas burning mode diesel engine and burning techniques.

2 OVERVIEW OF NATURAL GAS PHYSICAL AND CHEMICAL CHARACTERISTICS

Physical and chemical properties compared to traditional gasoline and diesel fossil fuels, natural gas is different. The main component of natural gas is methane, the main hydrocarbon composed of two elements, the formula is CH4, the standard state density 0.7174kg/m3, less than air, light blue flames emit when burned. Physical and chemical properties of natural gas and diesel fuel such as are shown in Table 1. Due to the low energy density of natural gas, diesel fuel used in compression and storage often used way of compressed natural gas CNG volume before compression is about 1/600.

Table 1. Physical and chemical properties of natural gas.

<table>
<thead>
<tr>
<th>Physical and chemical properties</th>
<th>Natural Gas</th>
<th>Diesel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stoichiometric Air-fuel Ratio/kg/kg</td>
<td>17.25</td>
<td>14.3</td>
</tr>
<tr>
<td>Stoichiometric Air-fuel Ratio V/V</td>
<td>9.52</td>
<td>9.42</td>
</tr>
<tr>
<td>RON</td>
<td>130</td>
<td>20~30</td>
</tr>
<tr>
<td>Cetane Number</td>
<td>&lt;10</td>
<td>45~65</td>
</tr>
<tr>
<td>Mixture Heat Value (MJ/m³)</td>
<td>3.39</td>
<td>3.79</td>
</tr>
<tr>
<td>Low Heating Value (MJ/kg)</td>
<td>50.0</td>
<td>42.5</td>
</tr>
<tr>
<td>Flame Propagation (m/s)</td>
<td>34~37</td>
<td>-</td>
</tr>
</tbody>
</table>
As can be seen from Table 1 compares and gas research octane number higher ignition temperature higher than diesel compression ignition is not easy, so the use of blended diesel on the way, some diesel injection through the injector in the cylinder, in order to pressure from the intake manifold to ignite the fire burning supplied fuel gas and air are mixed, blended with natural gas to ensure viable.

3 TEST METHODS AND EQUIPMENT

Test fuel to 0# diesel and compressed natural gas (composed mainly of methane), on JL4JB1 diesel engine were carried out economic research and experimental than the amount of gas dynamic blending different alternatives. Substitute natural gas ratio is defined as the natural gas heat value and gross calorific value (diesel and natural gas calorific value and heat value) ratio, expressed as shown in Equation (1).

\[ R_{N/D} = \frac{H_{\text{NaturalGas}}}{H_{\text{DieselFuel}} + H_{\text{NaturalGas}}} \]  

Wherein, \( R_{N/D} \) ratio of natural gas alternative, \( H_{\text{NaturalGas}} \) and \( H_{\text{DieselFuel}} \) respectively calorific value of natural gas and diesel units of MJ.

In order to achieve natural gas in diesel engines blended, the engine test bench adds a natural gas supply system, including high-pressure CNG cylinders, regulators, heat exchangers, gas meter and mixers, among mixer installation on the intake manifold to ensure that the supply of natural gas and air to form a homogeneous mixture. Natural gas supply system shown in Figure 1.

![Fuel Supplying System of Diesel Engine](image)

Table 2. Main parameters of diesel engine.

<table>
<thead>
<tr>
<th>Type</th>
<th>Displacement/L</th>
<th>Bore×Stroke/mm×mm</th>
<th>Rated Power/Speed/(kW/r·min(^{-1}))</th>
<th>Maximum Torque/Speed/(N·m/r·min(^{-1}))</th>
<th>Minimum BSFC/(g·(kW·h(^{-1}))</th>
<th>Compress Ratio/(-)</th>
<th>Combustion Chamber</th>
</tr>
</thead>
<tbody>
<tr>
<td>JL4JB1</td>
<td>2.8</td>
<td>93×102</td>
<td>65/3600</td>
<td>221/1800</td>
<td>224</td>
<td>18.2</td>
<td>0</td>
</tr>
</tbody>
</table>

4 TEST RESULTS AND ANALYSIS

4.1 Different alternatives to determine the ratio of the amount of natural gas supply

Diesel engine running on different operating conditions, the fuel injection quantity of each cycle vary, the amount of diesel fuel injection cycle using equation (2) calculation.

\[ m_{\text{Diesel}} = \frac{B_{\text{Diesel}}}{30ni} \times 10^6 \]  

Wherein, \( m_{\text{Diesel}} \) diesel engine diesel injection amount per cycle, in units of mg/str; \( B_{\text{Diesel}} \) is diesel fuel an hour, the unit is kg/h; \( n \) is the engine speed, the unit r/min; \( i \) is the number of cylinders.
In the diesel cycle fuel injection amount is calculated based on the combination of natural gas than the alternative definition, you can determine different substitution ratio per cycle diesel engine to determine the amount of natural gas supplied to the respective operating conditions needed using equation (3).

\[ m_{\text{NaturalGas}} = \frac{m_{\text{Diesel}} \times h_{\text{Diesel}} \times R_{\text{ND}}}{h_{\text{NaturalGas}}} \times 10^6 \]

Where, \( m_{\text{NaturalGas}} \) for the diesel-cycle gas injection quantity per unit of mg/str; \( h_{\text{NaturalGas}} \) and \( h_{\text{Diesel}} \) respectively low calorific value gas and diesel fuel, the unit is MJ/kg. Combining Equation (1), (2) (3) calculate the diesel engine is run in different conditions, different alternative than burning natural gas and - a hybrid diesel fuel supply amount per cycle, natural gas and diesel, as shown in Table 3.

4.2 Variation of different alternative diesel engine performance

Made diesel engine fueled with a different alternative than natural gas - in 800r / min, 1400r/min, 1800r/min, 2400r/min, 3200r/min and 3600r/min and dynamic study of a hybrid diesel fuel to run. During the experiment, always keep natural gas - diesel mixed with diesel fuel heating value of each of the original machine mode cycle fuel injection quantity of heat equal to the value. Test results are shown (dashed line in FIG original diesel engine torque level at the external characteristic of the rotational speed) in Figure.2.

(a) n=800r/min

(b) n=1400r/min

(c) n=1800r/min

(d) n=2400r/min

(e) n=3200r/min

(f) n=3600r/min

Figure 2. Fueled with a different alternative than gas - torque characteristics of diesel.
As can be seen from Figure 2, the diesel engine fueled with natural gas - diesel blended fuels in certain alternative ratio, torque within the test speed range can exceed the original diesel engine levels of external characteristics (torque curve portion is located above the dashed line); at the same time with the speed increases, the torque characteristics than the original machine level when gas substitution ratio decreases; and low-speed alternative than small, high-speed alternative to large poorer than the burning efficiency; torque rises highest at 1800r / min, an increase of 6.8%.

Above diesel engine fueled with a different alternative than gas - diesel fuel blends performance analysis of different conditions torque variation of the view that (1) certain natural gas to replace diesel fuel with more than Replacement part, it is possible to improve the maximum combustion temperature of the cylinder to expand power stroke of the combustion cycle the temperature of the ladder, and the diesel combustion full extent improved, thereby improving the thermal efficiency, and therefore under the same heat value of the fuel supply condition, natural gas - diesel mixed fuel of torque will be higher than diesel original machine level; (2 ) when the engine low speed operation, the cylinder air movement is relatively weak, and lower power, lower average cylinder temperature, then replace the smaller lean mixture formed in the incomplete combustion is not easy to slit, whereas when the high-speed air movement is strong, resulting in high power average cylinder temperature, improve the natural gas mixture for complete combustion, the role of these factors make the rotation speed increases, natural gas - torque characteristics of diesel blended fuel exhibits exceed the original machine when the level of alternative ratios in reduced; (3) However, due to the diesel engine high speed, high load operation, the excess air ratio is relatively small, and is larger than the stoichiometric air-fuel ratio of natural gas and diesel, and therefore as the speed continues to rise, than the alternative increasing, and natural gas - diesel blended fuel excess air ratio will further decline, occur due to insufficient supply of oxygen content appear incomplete combustion phenomena, resulting in high speed, large alternative than burning efficiency is poor, torque down; (4) medium speed diesel engine is running, the cylinder air movement reasonable, pneumatic and thermal efficiency are high, in favor of diesel - natural gas mixed fuel combustion, and therefore the maximum torque rise.

4.3 Diesel engine fueled with natural gas - the best alternative to diesel ratio

Extraction of natural gas corresponding to the maximum torque from the experimental data of Fig. 2 - diesel hybrid alternative fuel ratio, and with the external characteristics of the original diesel engine torque contrast, as shown in figure 3.

Diesel blended fuel and diesel economy comparison Figure 4 shows the external characteristics of the diesel engine is running, the best alternative fuel than natural gas.

![Figure 3. Best alternative than gas - torque characteristics of diesel.](image)

From Figure 3 can know, by choosing natural gas - the best alternative to burning fuel than diesel hybrid, it can make external characteristics of the diesel engine torque rise in the speed range of all trials, suggesting that natural gas in diesel engines blended with diesel engines can improve power, degree of enhancement of the diesel engine strengthened; and the best alternative to exhibit higher than the low-speed, high-low speed variation. Because keeping the total calorific value of the fuel supplied to the respective conditions in the same experiment, power enhancements will improve the economy of the engine, the effective fuel consumption rate variation presented in Figure 3.
Firstly, diesel to natural gas in the intake manifold mix blended way, can effectively improve the performance of diesel engine torque external characteristics. At different speeds, the best alternative fueled with natural gas is different than

Secondly, diesel engine is running at low speed for high replacement ratio at high speed for low replacement ratio.

Thirdly, at medium speed diesel engine fueled with natural gas sharpest increase in torque, compared to the original diesel engine maximum torque increased by 6.8%.

Fourthly, natural gas in diesel engines at a reasonable replacement for blending, can enhance engine power and economy, enhance the degree of enhancement of diesel engine.

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