Analysis and Study of Methanol-Containing Diesel in the Accelerating Condition

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Abstract: This paper analyzes the influence of methanol-containing diesel in the accelerating condition on the performance of diesel engine. The more the methanol is, the greater the changes of \( \Delta t \) and \( \sigma_{\Delta t} \) and the worse the dynamic performance is. At the same time the soot emission increases, which mainly generates in the initial stage of fuel acceleration. The emission of NO\(_x\) goes up after dropping, then slightly decreases and tends to be stable.

Keywords: Diesel engine, dynamic performance, fuel, methanol.

1. INTRODUCTION

With the development of economy and society, our country has become a high energy consumption country. The energy shortage has become an urgent problem. Thus, finding new energy, especially renewable energy has been an important strategic significance. Methanol is an oxygenated fuel, which has a huge latent heat of vaporization and extensive resources. It can be made by fully using natural gas, coal and biomass. The use of methanol in the diesel engine can both alleviate the scarce problem of energy and lower the gasoline price. In this big environment, this paper analyzes the influence of methanol-containing diesel in the accelerating condition on the performance of diesel engine. When burning different blend fuels which have different content of methanol, the combustion condition, emission status and steady-state condition are different. The main reasons are the influence of movement, quality and moment of inertia of diesel engine, the damage of internal heat balance, the formation of gas mixture and the change of cylinder charge, and the change of fuel physicochemical property [1-2].

2. COMPARISON OF ACCELERATING CONDITION AND CORRESPONDING STEADY CONDITION

Due to above reasons, there are many differences between the accelerating condition and the steady condition in combustion. In the accelerating condition, the variation is big. The M10 combustion indication pressure \( P_i \) varies in the range of 0.4-0.6 MPa, the maximum combustion pressure \( P_{max} \) varies in the range of 4-7.5 MPa, the corresponding crank angle \( \theta_{pmax} \) of the maximum combustion pressure varies in the range of 18-20oCA, the combustion constant angle \( \Delta\Phi \) varies in the range of 80-85oCA, [3] while in the steady condition, these are steady. The comparison is showed in Figs. (1-4).

![Fig. (1). M10 comparison of Pi in steady condition and accelerating condition.](image-url)

Pi and Pmax of M10 in accelerating condition decrease slightly comparing with those in the steady condition. The average decrease range can be 16.7%, and in the earlier stage of accelerating, the pressure fluctuates. It is extremely unstable, but becomes relatively steady in the later stage of accelerating. In the accelerating condition, fuel atomization and vaporization are all very unstable, which leads to a constant change of the corresponding angle of maximum combustion pressure, therefore, the combustion duration keeps increasing.
3. ANALYSIS METHOD AND SOLUTION IN THE ACCELERATING CONDITION

Making a comparison between accelerating condition and steady working condition from qualitative to quantitative is the basic analysis method of accelerating condition research. In order to achieve the varying numerical simulation in the process of engine acceleration, each transient point is similarly regarded as a quasi-stabilized state, that is, use small circulation oil supply leading to gradually transforming and changing and then replace the whole acceleration process [4-6]. The whole process of change is regarded as a series of quasi-stabilized state operating points according to the successive sets of time sequences [7]. This is a calculation method that transforms gradually from steady condition to accelerating condition. The steady condition can be calculated for the dynamic property and emission model using CFD software. The results are shown in Fig. (5).

Under the same cycle fuel supply, with the increase of rotational speed, smoke emission will be reduced. The high emission area of diesel soot occurs mainly in the low speed region. This is because the cylinder temperature is low at low speed and the combustion organization is not good with the fuel imperfectly combusted, while the exhaust temperature is not high, so the soot particles are formed [8-10].

Change of fuel delivery per cycle has a great influence on the emissions of diesel soot. At the same speed, the inlet charge and intake swirl are basically unchanged. With the increase of load rate, the fuel delivery per cycle increases, A/F ratio decreases and the overrich area of partial combination gas increases; meanwhile, the combustion temperature of the cylinder rises. Under hyperthermia and oxygen lack conditions, the soot emissions increase as the load increases [11].

The fuel delivery per cycle and rotational speed have an effect on maximum combustion pressure also and the relationship is shown in Fig. (6). With the increase of fuel delivery, the the maximum combustion pressure increases. If the fuel delivery per cycle increases, the liberated heat by combustion will be more, and the power capability of engine will be enhanced. Under the same fuel delivery per cycle, with the increase of rotational speed, maximum combustion pressure also increases, but greatly at low speed, especially the speed varies in 1000—1400 rpm with a quite obvious effect on the maximum combustion pressure, while having a smaller increase at high speeds. Because of the increased speed, the capability of the turbulence in cylinder is strengthened, the fuel-air mixture condition is improved and the combustion effect is enhanced [12].
little changes in the late period which tends to be stable. Comparing the pure diesel with Methanol-containing Diesel, the diesel combustion pressure rises faster, while the Methanol-containing Diesel rises slower.

Fig. (9). M10 working diagram and variation diagram of cycle number.

Fig. (10). M15 working diagram and variation diagram of cycle number.

4. INDICATOR DIAGRAM ANALYSIS OF DIESEL ENGINES IN FREE ACCELERATION WORKING CONDITION

Free acceleration is one of the most complex situations of diesel engines in unsteady working condition, accompanying with rotate speed variation and load variation of diesel engines [13-17] at the same time. Therefore, the mixed fuel with different methanol contents should be analyzed. As shown in Figs. (11, 12) the measured indicator diagram of diesel and M10 in free acceleration working condition.

Fig. (11). Indicator diagram variation of diesel in free acceleration working condition.
The variation curve graph of the maximum combustion pressure variation rate along with circulation. It shows that the diesel variation reacts fast during acceleration and the variation fluctuation of the maximum combustion pressure is smaller. The more the methanol is contained, the larger the fluctuation of the maximum combustion pressure variation rate is, and the longer the accelerating reaction time is.

The comparison of indicated pressure $P_i$ is shown in Fig. (15).

$P_i$ increases while the rotational speed rises and $P_i$ decreases while the methanol contents increase. The diesel $P_i$ is under acceleration working condition, the maximum $P_i$ of M0 is 0.92MPa while that of M10 is 0.88, the maximum variation of M0 is 34% while that of M10 is 37.2%.

The maximum pressure rise rate curve is shown in Fig. (14).

The study, summarize and contrastively analyze the measured indicator diagram the maximum combustion pressure of mixed fuels with different methanol contents, we can get the Fig. (13). The diesel pressure increases quickly, but it becomes steady basically after 17 circulations. The more the methanol contents increases, the slower the pressure rises. The pressure only begins to rise rapidly when M5 is at the 3rd circulation while M15 is at the 5th. Then it becomes steady when reaching the 22nd circulation, after which the maximum combustion pressures of M5 and M10 are slightly higher than that of pure diesel. All the above shows that, in steady state, the thermal efficiency of mixed fuel is slightly higher, but the power performance under acceleration working condition is not as good as that of pure diesel.

The maximum pressure rise rate curve is shown in Fig. (14).

The comparison of measured indicator diagrams of M0 and M10.

Figs. (15-19) is the comparison of measured indicator diagrams, pressure rise rates, heat release rates and accumulated heat release rates in typical circulation of M0 and M10 during free acceleration. The combustion starting point of diesel is earlier than that of M10 mixed fuels, combustion pressure rises faster and maximum combustion pressure also is slightly higher. The accumulated heat release rate is higher, the combustion ends sooner and the combustion duration is shorter. All these lead to the better power performance of diesel under acceleration working condition than that of M10.
CONCLUSION

a. In acceleration working condition, the indicated pressure $P_i$ of Methanol-containing Diesel and the maximum combustion pressure $P_{max}$ are declined compared with those in steady working condition. The $p_\Delta$ and $\sigma_\Delta$ in mixed fuels of methanol-containing diesel are both higher than that of diesel. The more the methyl alcohol is, the bigger are the changes of $p_\Delta$ and $\sigma_\Delta$. The $p_\Delta$ and $\sigma_\Delta$ of M10 is similar to that of diesel, with 8.1% and 5.5% respectively; while the sum of M15 is quite different from that of diesel, with 22.6% and 17% respectively. This makes M15's dynamic property under the accelerated condition obviously weak.

b. Soot under accelerated condition is mainly generated during the initial period of oil supply. During the initial period of acceleration, along with the increase of circling oil supply the soot emission is maximized. Then along with the reduction of circling oil supply and increase of revolving speed, it slightly decreased. For NOx, during the period of acceleration, the NOx emission decreases. As time of acceleration goes by, the fueling is improving gradually until NOx rises to the maximum. Later on, the revolving speed keeps increasing, the turbulence inside the cylinder rises, and the combination gas is well mixed, which make both the NOx emission decreasing.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

ACKNOWLEDGEMENTS

This work was Funding project of National High-tech Research and Development Project (863 Project) (2012AA10A503-4).

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Received: January 6, 2015 Revised: May 20, 2015 Accepted: June 19, 2015

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