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

Huang Jie[1], Zhou Qinghui[2], Li Gang[1], Wang Xuelei[1], Cao Fang[3] and Hou Shulin[1,*]

[1]Engineering College of China Agricultural University, Beijing, 100021, P.R. China

[2]School of Mechanical-Electronic and Automobile Engineering of Beijing University of Civil Engineering and Architecture, Beijing, 100044, P.R. China

[3]School of Science and Engineering of Beijing Geely University, Beijing, 102202, P.R. China

Abstract: This paper analyzes the influence of methanol-containing diesel at the accelerating condition on the performance of diesel engine. The more the methanol is, the greater the changes of $p_{\Delta t}$ and $\sigma_{\Delta t}$, and the worse the dynamic performance is. At the same time the soot emission increases, which mainly generates at 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 of 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 scarcity 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, there is great variation. The M10 combustion indication pressure Pi varies in the range of 0.4-0.6 MPa, the maximum combustion pressure Pmax varies in the range of 4-7.5 MPa, the corresponding crank angle θpmax of the maximum combustion pressure varies in the range of 18-20oCA, and the combustion constant angle ΔΦ varies in the range of 80-85oCA, [3] while in the steady condition, these are steady. The comparison is shown in Figs. (**1-4**).

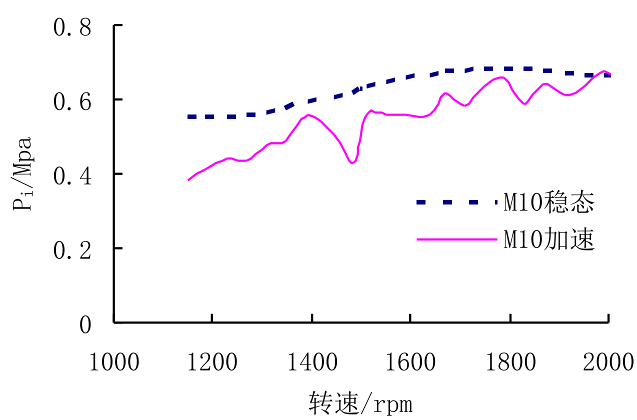

Fig. (1). M10 comparison of Pi in steady condition and accelerating condition.

Pi and Pmax of M10 in accelerating condition decrease slightly compared with those in the steady condition. The average decrease range can be 16.7%, besides at 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.

*Address correspondence to this author at the Communication at the Engineering College of China Agricultural University, East Campus, Block B Princess No. 17 Tsing Hua East Road HaiDian District, Beijing, P.R. China; Tel: +86 13581711364/+86 18611729985; E-mail: h01520@cau.edu.cn

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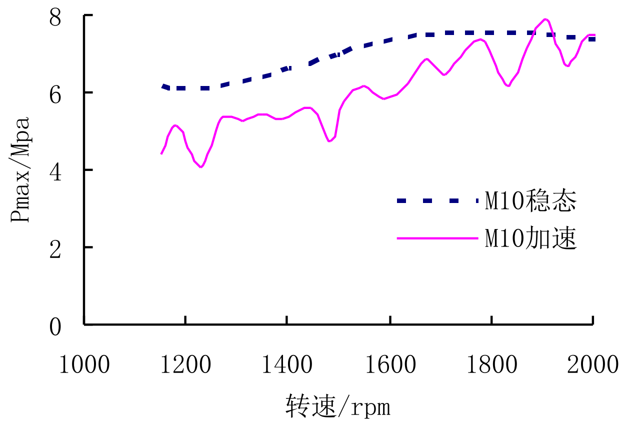


Fig. (2). M10 comparison of Pmax in steady condition and accelerating condition.

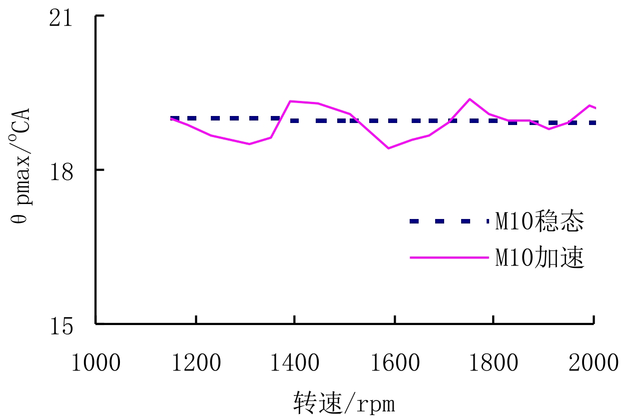


Fig. (3). M10 comparison of θpmax in steady condition and accelerating condition.

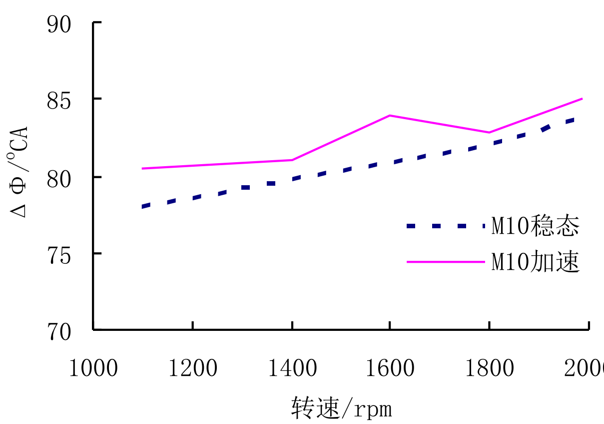


Fig. (4). M10 comparison of ΔΦ in steady condition and accelerating condition.

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, using small circulation oil supply leading to gradual transformation and change 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**).

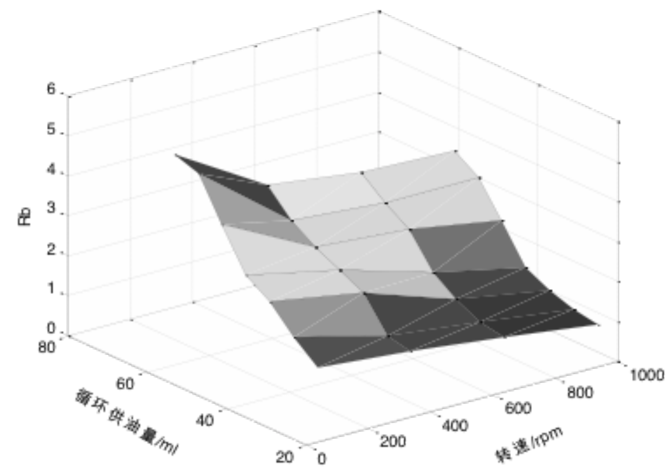


Fig. (5). Relationship between smoke emission, rotational speed and fuel delivery per cycle.

Under the same cycle of 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 that 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 overreach 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 also on maximum combustion pressure and the relationship is shown in Fig. (**6**). With the increase of fuel delivery, the maximum combustion pressure increases. If the fuel delivery per cycle increases, the liberated heat by combustion will be increased, 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].

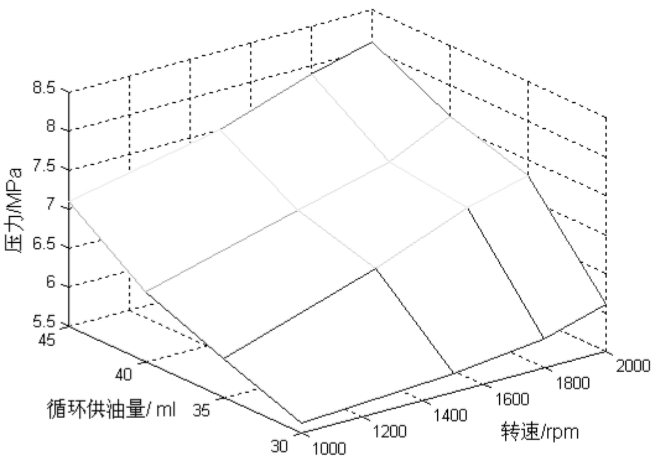


Fig. (6). Relationship between the maximum combustion pressure and the change of fuel delivery per cycle and rotational speed.

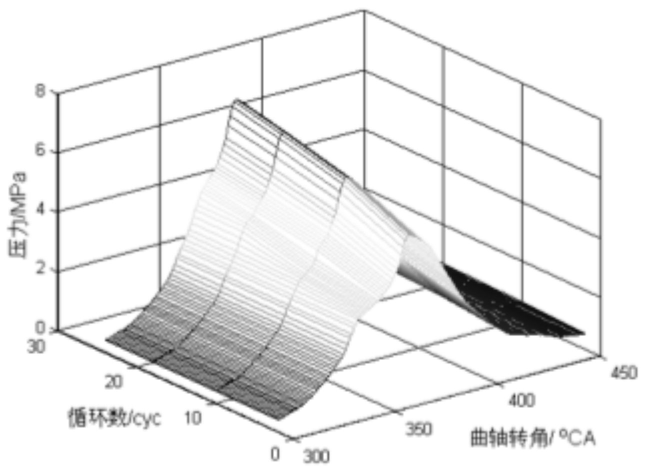


Fig. (7). M0 working diagram and variation diagram of cycle number.

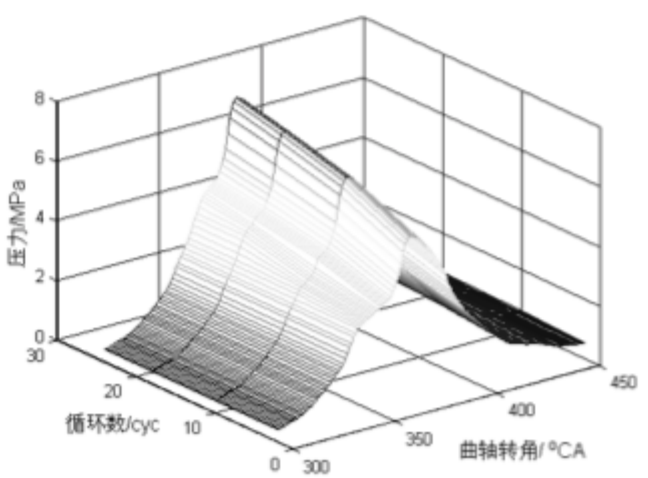


Fig. (8). M5 working diagram and variation diagram of cycle number.

Figs. (**7-10**) are the variation diagrams of different-fuel working diagrams with the changes of cycle numbers. With the increase of the cycle numbers, the maximum combustion pressure is increased. In the earlier period of the acceleration, the pressure increases quickly, while there are little changes in the later 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.

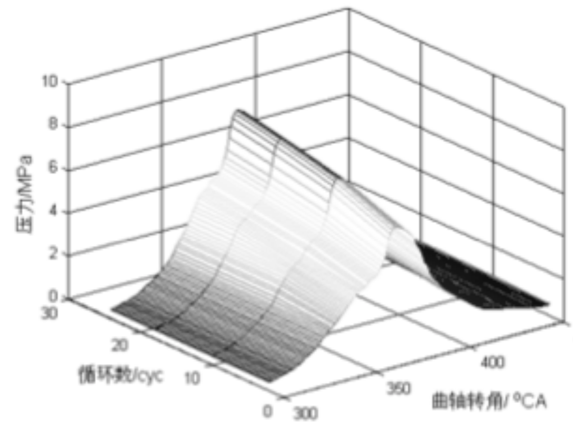


Fig. (9). M10 working diagram and variation diagram of cycle number.

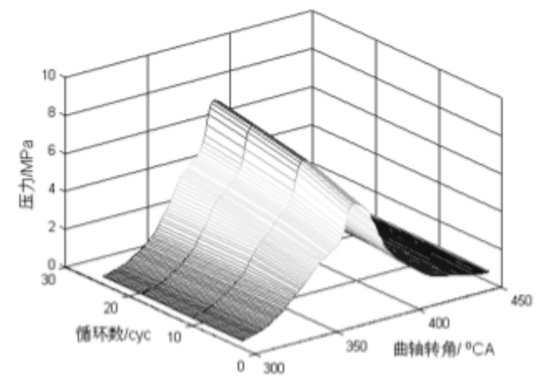
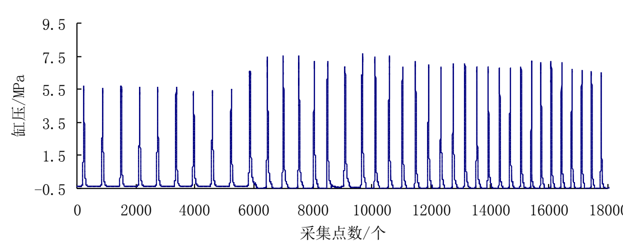


Fig. (10). M15 working diagram and variation diagram of cycle number.

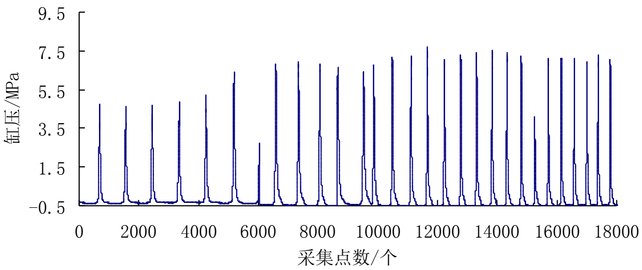
4. INDICATOR DIAGRAM ANALYSIS OF DIESEL ENGINES IN FREE ACCELERATION WORKING CONDITION

Free acceleration is one of the most complex situations of diesel engines in unsteady working condition, accompanying with rotation 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. Figs. (**11, 12**) show the measured indicator diagrams of diesel and M10 in free acceleration working condition.



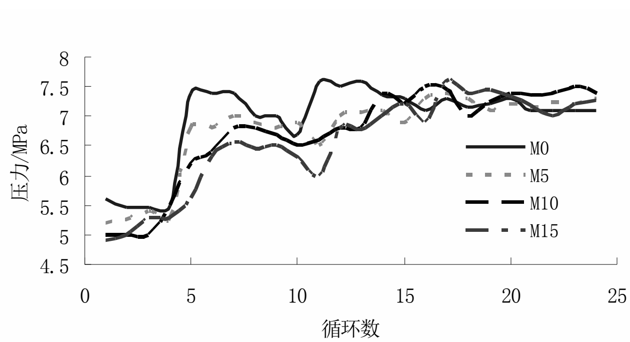
number of collection points

Fig. (11). Indicator diagram variation of diesel in free acceleration working condition.



number of collection points

Fig. (12). Indicator diagram variation of M10 mixed fuel in free acceleration working condition.

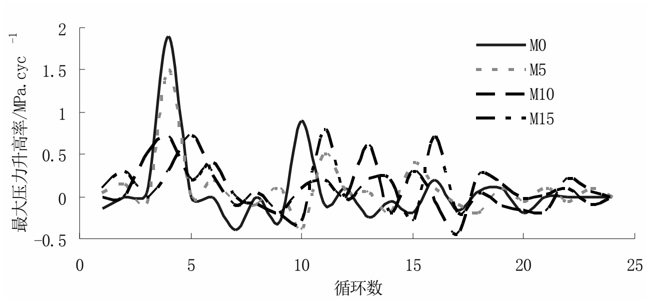


cycle number

Fig. (13). Variation diagram of the maximum combustion pressure along with circulation.

Study, summarize and contrastively analyze the measured indicator diagram of the maximum combustion pressure of mixed fuels with different methanol contents to get the Fig. (**13**). The diesel pressure increases quickly, but it becomes steady basically after 17 circulations. The more the methanol content 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**).



cycle number

Fig. (14). Variation diagram of the maximum combustion pressure variation rate along with circulation.

The variation curve graph of the maximum combustion pressure variation rate along with circulation. It shows that the diesel variation reacts faster 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 Pi is shown in Fig. (**15**).

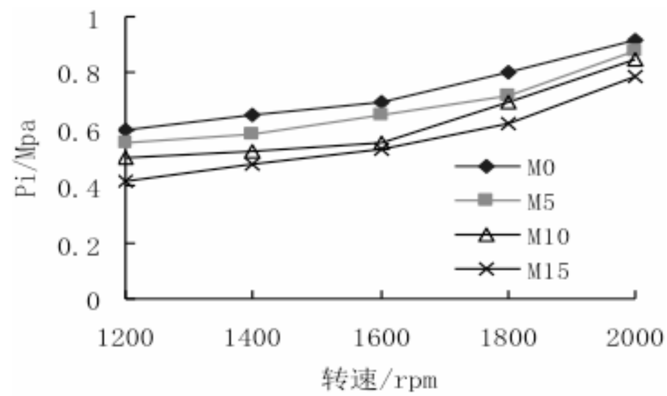
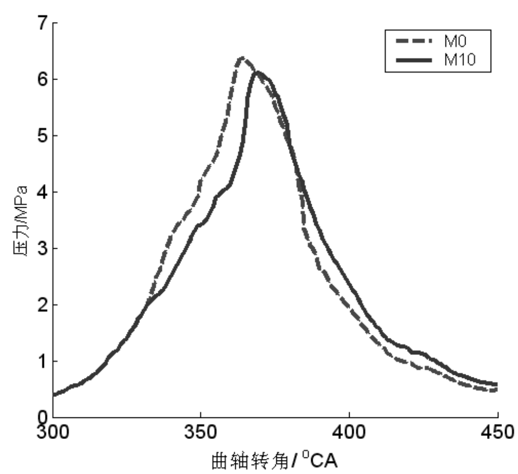


Fig. (15). Variation diagram of P_i along with rotational speed.

Pi increases while the rotational speed rises and Pi decreases while the methanol contents increase. The diesel Pi is under acceleration working condition, the maximum Pi 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%.



crank angle

Fig. (16). Comparison of measured indicator diagrams of M0 and M10.

Figs. (**15-19**) show a 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.

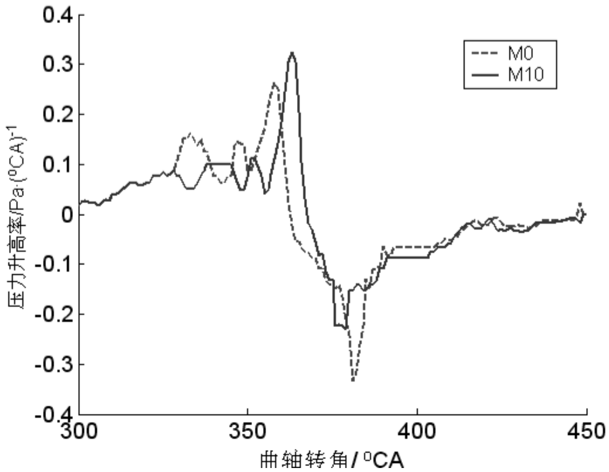


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Fig. (17). Comparison of the pressure rise rates of M0 and M10.

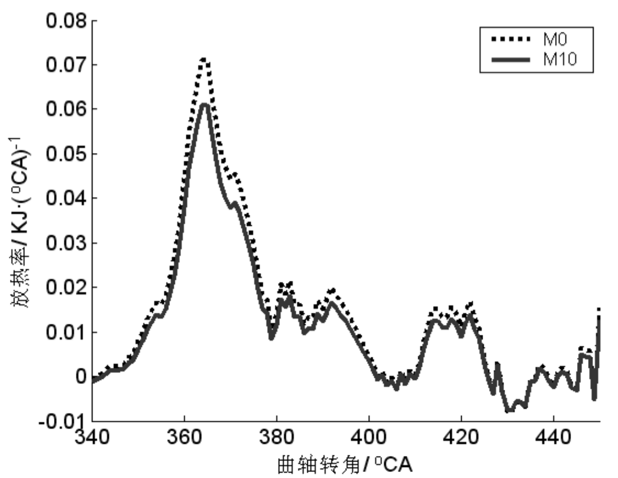

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Fig. (18). Comparison of the heat release rates of M0 and M10.

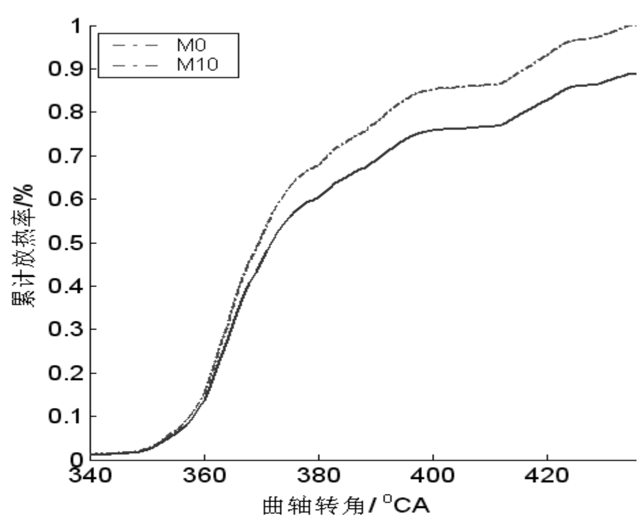

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Fig. (19). Comparison of the accumulated heat release rates of M0 and M10.

CONCLUSION

In the acceleration working condition, the indicated pressure Pi of methanol-containing diesel and the maximum combustion pressure Pmax are declined compared with those in steady working condition. The $p_{\Delta t}$ and $\sigma_{\Delta t}$ in mixed fuels of methanol-containing diesel are both higher than that of diesel. The more the methyl alcohol content is, the bigger the changes of $p_{\Delta t}$ and $\sigma_{\Delta t}$ are. The $p_{\Delta t}$ and $\sigma_{\Delta t}$ of M10 are 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.

Soot under the acceleration 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.

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