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Minimum Ignition Energies and Quenching Distances of Methanol blends

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Abstract

The purpose of this study is to present data on minimum ignition energies and quenching distances for methanol, iso-octane and iso-octane/methanol blends over a temperature range of 100–150°C and at 1 atm pressure.

Minimum ignition energies were measured by means of a conventional automobile ignition system and expressed by the primary current of the ignition coil. The measurement methods of the quenching distances employed the teflon-flanged electrodes technique.

Experiments were performed with methanol, iso-octane and iso-octane/methanol blends over a range of equivalence ratios for several mixture. Quenching distances measured for methane were used to check reliability of the present apparatus and these values practically agreed with other data.

The experimental results indicated that the minimal value of the minimum ignition energies and the minimum quenching distances of methanol and iso-octane air mixtures were attained with a slightly rich mixture. The iso-octane/methanol blend yields larger flammability ranges than those of each in air. The quenching distances of iso-octane/methanol blend depend on that of iso-octane and never become larger than that of either fuel.

1. Introduction

Methanol has been under attention as an alternative energy source to fossil fuel as applied to an internal combustion engine. The use of methanol as an automobile fuel is being examined in two ways. The first way is as a fuel blending component. The second way is as a direct substitute for gasoline. Data on minimum ignition energies are necessarry for the design of ignition equipment of the spark ignition engine of using methanol and the phenomenon of wall quenching in automotive engines, particularly spark ignition engines, is of both experimental and theoretical interest as one of the major sources of hydrocarbons in the exhaust.

There have been many investigations on spark ignitions and quenching distances of various combustible gas mixtures. However, the amount of published data are relatively small on methanol and methanol blends. There are many uncertainties on the flammabilty limits, ignition energies and quenching distances of such fuel blends.

In this study, the flammability limits, minimum ignition energies and quenching

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distances were measured for the static gas mixture of methanol, iso-octane and iso-octane/methanol blends. All measurements were conducted in a constant volume combustion bomb over a temperature range of 100-150°C and 1 atm pressure.

2. Apparatus and Procedure

The schematic of the combustion bomb is shown in Fig. 1. The shape of the bomb is a cylindrical vessel 80 cm in innerdiameter and 100 cm in length. The contents of the bomb is about 525 cc. The test bomb is equipped with two electrodes for spark discharge, a stirring fan for gas mixing, a quartz window for observation and a thermocouple. The electrodes are made of steel of 2.5 mm diameter and are flat at the ends. Two types of electrodes were used, one with a free and the other with a teflon flanged disc of 15 mm diameter and 8 mm thickness. The minimum ignition energies were measured with the former and the quenching distances with the latter. One of the electrodes is fixed and the other can be changed in its position by a gap clearance adjuster. The distance between the two parallel flanged discs can be measured by the vernier scale with an accuracy of ±0.05 mm. Two kinds of ignition units were used. The circuit diagrams of the electrical system are shown in Fig. 2 (a) and (b). The circuits in Fig. 2 (a) are provided for the measurements of ignition energy. The deter-

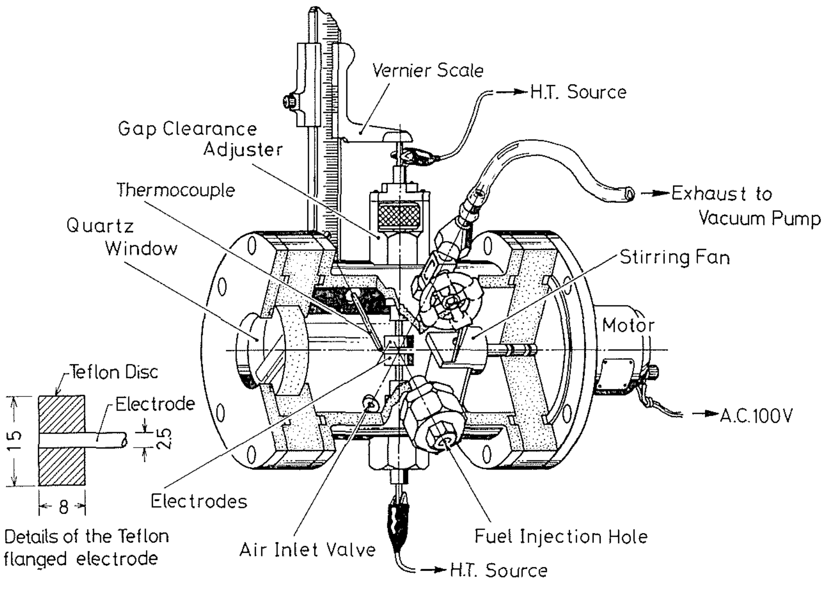
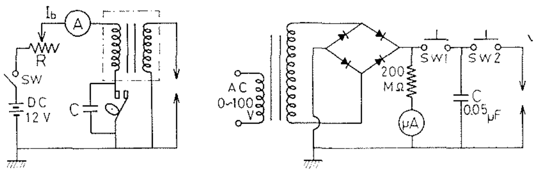


Fig. 1 Schematic of the experimental apparatus



(a) (b)

Fig. 2 Electric circuits of ignition units, (a) for ignition encrgy measurements, (b) for quenching distance measurements mination of ignition energy is obtained by controlling the primary current I_1 which is varied by the variable resister R. The energy E is calculated by the following equation,

$$E=e\cdot(L_1 I_1^2/2),$$

where e and L_1 are the energy conversion efficiency and the self-induction of primary winding respectively. If e and L_1 are assumed to be constant, ignition energy can be represented by the primary current I_1. In this report, the ignition energy was given by the value of I_1 (ampere). The ignition units for quenching distance measurements are shown in Fig. 2 (b). The condenser C ($0.05\,\mu F$) was charged by use of SW 1 and the spark discharge occurred by switching on SW 2. The voltage at electrode Vd is 7.0 kilovolts. The ignition energy calculated by $C\cdot Vd/2$ is 1.225×10^3 millijoule. This value will be sufficient to measure the quenching distance. The combustion bomb is preheated from the outside surface by a ribbon heater. The temperature in the cylinder was measured by a CA thermocouple, 0.3 mm in diameter. An accurately metered fuel was injected into the test bomb maintained at a fixed temperature. The mixture in the cylinder was stirred by the fan for the purpose of the reduction of time that was required for the gases to become homogeneous.

The homogeneity of gas mixture was checked by gas chromatography. Fifteen minutes was expected to be sufficient to attain homogeneity. Accordingly, the mixture has been stirred for 15 to 20 minutes after fuel injection. Experiments were conducted under the static gas mixture.

3. Results and Discussions

3.1 Mixture temperature and ignition energy

The effects of the mixture temperature on ignition energies and flammability limits were investigated with pure methanol air mixture at 1 atm and with a gap distance of 1.0 mm. Fig. 3 shows the results of the primary current I_1 versus the excess air ratio m at $T_m=100$ and 150°C. The flammability limits of methanol air mixtures increase with increasing mixture temperature and at the same time the minimum ignition energies decrease. The temperature dependeney is remarkable in that lean mixture is less temperature sensitive than rich mixture. The minimum ignition energies rise steeply in the rich $m=0.6$ to 0.7 and remains constant in the $m=0.7$ to 1.1 region.

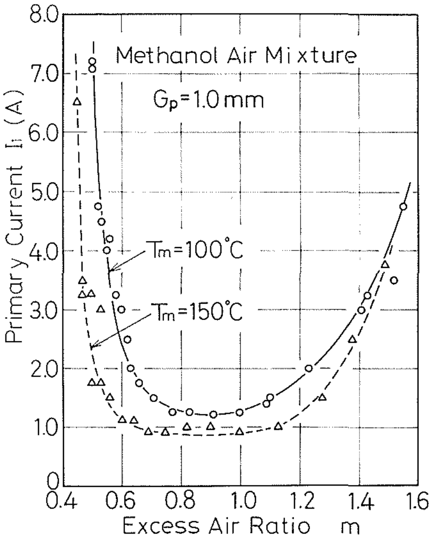


Fig. 3 Effect of temperature on minimum ignition energies for methanol air mixture

3.2 Effects of gap distance on ignition energy

Fig. 4 shows the effect of the gap distance on the minimum ignition energies and the flammability limits for different mixture strength at $T_m=100$°C and with a gap distance of 0.5, 1.0 and 2.0 mm. It is found that, in any case of gap distance, the excess air ratio which gives the lowest value of minimum ignition energy shifts toward richer-than-stoichiometric mixture. The minimum ignition energies increase with increasing gap distance. Especially, in the case of gap distance of $G_p = 0.5$ mm, ignitable mixture region is confined within an extremely narrow mixture strength, furthermore, the bottom of the ignition energy curve becomes higher than that of other gap distance. It is also noted that the measured values are extremely scattered as compared with the cases of other gap distances. This source of error will arise from the irregularity of spark point on the electrodes. It is generally known that the quenching effects are caused by parallel flat plates of which diameter are more than two times larger than the gap distance[1]. In the case of $G_p = 0.5$ mm, this distance marks strongly the flame quenching effect of the solid electrode material and initial flame kernel will be distinguished by narrow-gap-effect, because the minimum quenching distance of methanol is 1.85 mm and electrode diameter is 2.5 mm. But the electrode cooling action on the initial flame is less effective if the spark discharge occurs at the rim of the electrodes. Ignition or no ignition depends on the position of spark generation when the gap distance is under the quenching distance. Therefore, the scattering of the measured values are of high degree in this gap distance condition.

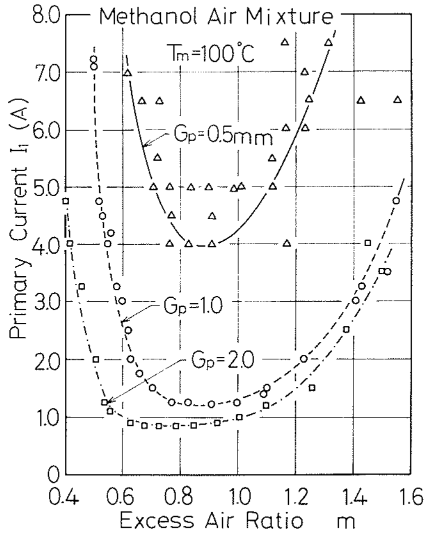


Fig. 4 Effect of gap distance on minimum ignition energies for methanal air mixture

In the case of $G_p = 2.0$ mm, over the minimum quenching distance of methanol, there is less quenching influence on flame propagation even if the spark discharge occurs at any point of the electrodes, so that the ignition certainty is raised. As the gap distance is increased, the flammability limits becomes wide and the ignition energies are also small at rich mixture.

3.3 Flammability limits of methanol blends

Fig. 5 shows the differences of the flammabilty limits and the ignition energies for methanol and iso-octane air mixtures. The ignition regions of both gas mixtures are extremely different for the excess air ratio. When the primary current equals 5 amperes, lean limit of iso-octane air mixture is $m = 1.6$ and the rich limit is $m = 0.4$. For methanol, lean and rich limits are $m = 1.6$ and 0.5 respectively. It is noted that methanol has a wider flammability limit than that of iso-octane, especially at lean mixture side. The minimum value of iso-octane ignition energies shifts to a richer-than-stoichiometric mixture in comparison with that of methanol. These phenomena may be caused by influence of the preferential diffusion[2]. The diffusion coefficients of oxygen, methanol and iso-octane are given in Table 1. From these data, the diffusion coefficients of both fuels are smaller than that of oxygen. Flame front can be enriched with larger diffusion coefficient component, namely oxygen, so that the mixture strength at flame front becomes leaner than that of the ambient initial mixture strength in the test bomb.

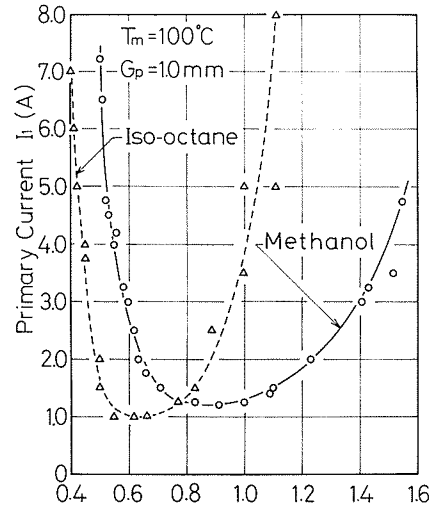


Fig. 5 Minimum ignition enegies for methanal and iso-octane air mixtures

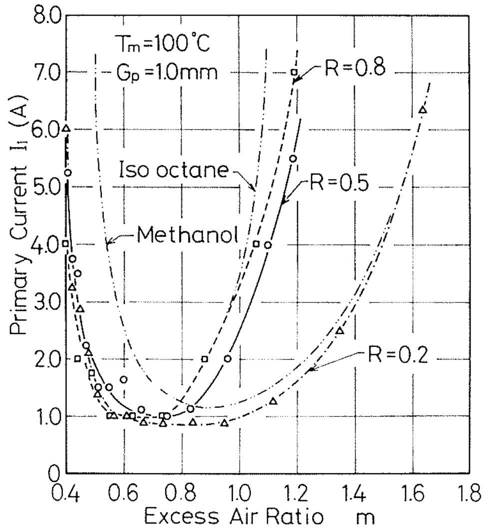


Fig. 6 Minimum ignition energies of iso-octane/methanol air mixtres in comparison with those of iso-octane and methanol air mixtares

Table. 1 The diffusion coefficients of oxygen, methanol and iso-octane

	D (cm^2/sec)
oxygen	0.1780
methanol	0.1325
iso-octane	0.0505

The results of the minimum ignition energies and flammability limits as a function of blending ratio of methanol to iso-octane are shown in Fig. 6. The blending ratio R is calculated by $R = V_0/(V_0 + V_m)$, where V_0 and V_m are iso-octane and methanol volume (liquid) respectively. In the case of $R=0.8$, that is, the volume of iso-octane is much more than that of methanol, the ignition energy curve of the fuel blends is almost identical with that of pure iso-octane. Increasing the blending ratio of methanol to iso-octane, that is, in the case of $R=0.5$ and 0.2, rich limits of fuel blends remain the rich limits of iso-octane, on the other hand, their lean limits approach to those of methanol. The flammability limits of iso-octane/methanol are contained with in those of original fuels. It can be shown that the fuel blending technique is able to increase the flammability limits if fuels with different flammability limits are effectively mixed.

3.4 Quenching distance

The quenching distance is obtainable by means of several different methods and each method gives slightly different values. In order to check the reliability of the present apparatus, initial experiments were conducted with methane-air mixtures at 1 atm and at 80°C. The results are shown in Fig. 7 along with a comparison to the data from Ref. [3] and [4]. The figure shows that quenching

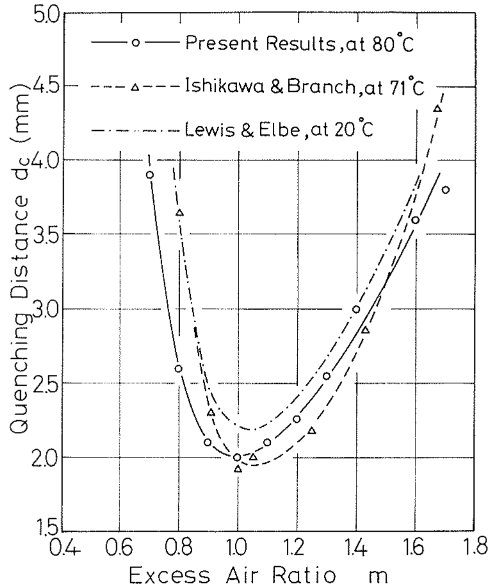


Fig. 7 Comparison of the data of the quenching distance between present results and other results

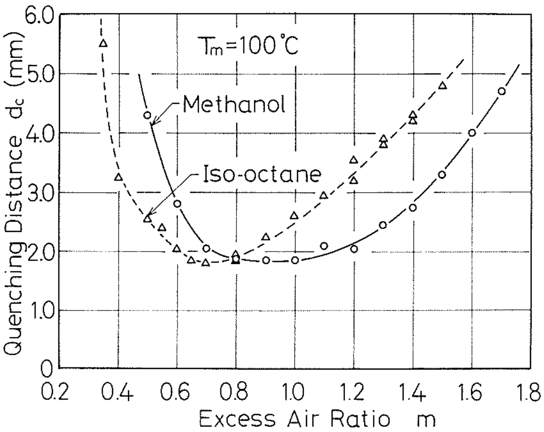


Fig. 8 Quenching distances of methanol and iso-octane air mixtures

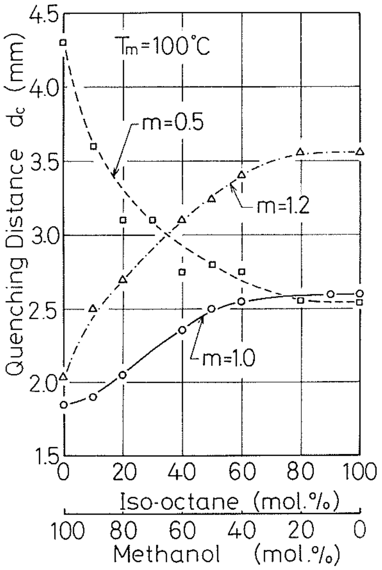


Fig. 9 Effect of iso-octane/methanol mixing ratio (mol %) on quenching distance

distances measured for methane practically agree with other data.

The results for the quenching distances of methanol and iso-octane air mixtures are shown in Fig. 8. Their quenching distances depend on the excess air ratio and are both equal to 1.85 mm. The excess air ratio at the minimum quenching distance is $m=0.9$ for methanol, and $m=0.7$ for iso-octane. The quenching distance curve shows a similar tendency of ignition energy curve for excess air ratio.

Fig. 9 shows the quenching distances of iso-cotane/methanol blends as a function of mixing ratio (mol %) for the excess air ratio $m=0.5$, 1.0 and 1.2. Especially, in the case of $m=0.5$ and 1.0, the distances of fuel blends approach those pure iso-octane as the iso-octane mixing ratio increases. The quenching distance of iso-octane/methanol air mixture depends on that of iso-octane.

These results are different from the results reported by Ishikawa and Branch[4]. They reported that the fuel blends were found to have larger quenching distances than either pure fuel. In their experiments, they arrived at this conclusion from results of 20% methanol in iso-octane by weight alone. In our results, for $m=0.5$, 1.0 and 1.2, the quenching distances of the fuel blends are never larger than that of either pure fuel.

4. Conclusions

The experiments were performed for methanol air, iso-octane air and iso-octane/methanol air mixtures. The following results were obtained:

(1) The flammabilty limits of methanol air mixtures increase with an increae in the gas mixture temperature and the minimum ignition energies decrease with an increase in the gas mixture temperature. The effects of the temperature dependency obtained are extreme at rich side, but slightly at lean side.

(2) There is a optimum gap distance of methanol air mixture for the flammability limits and ignition energies. The range of ignitable mixture strength is confined within an extremely narrow region when the gap distance is under the quenching distance.

(3) The flammability limits of iso-octane/methanol air mixture are contained within those of the original fuels. Blending fuels will be able to increase the flammability limits of fuel blends if the avaiable fuels with different flammability limits are effectively mixed.

(4) The quenching distances of iso-octane/methanol blends mainly depends on that of iso-octane. The quenching distances are never larger than that of either pure fuel.

Acknowledgement

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References

1) Kumagai S.: Nensho (Combustion), Iwanami (in Japanese), (1976), p. 27.
2) Strehlow, R. A.: Fundamentals of Combustion, (1973), p. 220.
3) Lewis, B. and von Elbe, G.: Combustion, Flames and Explosions of Gases, 2nd Ed., (1961), Academic, New York.
4) Ishikawa, N. and Branch, M. C.: Combustion and Flame, 27 (1976), p. 65.