COMBUSTION PROCESSES UNDER STRONG DC MAGNETIC FIELDS

Shoogo Ueno, Hiroshi Esaki, and Koosuke Harada

Abstract - The effects of magnetic fields on the combustion velocities of gasoline and alcohol with platinum catalysis were studied. The place of combustion reaction of gasoline on platinum catalyst was exposed to d.c. magnetic fields with field intensities from 0.1 T to 1.0 T. The combustion velocity was influenced by the magnetic fields. The combustion velocity of gasoline decreased in 5 % - 10 % at 0.2 T and 0.6 T, and increased in 5 % - 10 % at 0.3 T, 0.5 T and 1.0 T. To explain the undulant phenomenon in the curve of combustion velocity v.s. magnetic field, various types of alcohol were burned with platinum catalysis under magnetic fields. The magnetic field effect on the combustion velocity of alcohol was observed to show a minimum at a specific magnetic field; -5.3 % at 0.9 T for methanol, -2.3 % at 0.6 T for ethanol, -16.9 % at 0.6 T for n-propanol, and -73.8 % at 0.7 T for n-butanol.

INTRODUCTION

The question of whether magnetic fields affect combustion processes or not is of considerable interest in fuel engineering and in biomagnetics. Combustion is oxidation reaction which involves both burning with flames in the air and cell respiration in the living bodies. In a series of our studies on biological effects of magnetic fields [1], [2], we are investigating the effects of magnetic fields on the reaction rate of slow-velocity types of combustion to simulate partly the oxidation of organic matter in the body. In the present paper, the effects of d.c. magnetic fields on the combustion of gasoline and alcohol with platinum catalysis are studied.

The relationships between combustion and magnetic fields have been partly studied: Hayashi [3] measured an increased flame intensity of OH radical in magnetic fields. Yoshimura [4] and others applied magnetic fields to flowing gasoline in a pipe conducted to an engine, not to the place of combustion. However, no investigations on measurements of combustion velocities of gasoline and alcohol with platinum catalysis under magnetic fields have been reported previously.

METHODS

Oil-fed pocket warmers made by Hakukinkairo Corp., Osaka, Japan, were used in the experiments. The pocket warmer is a kind of portable body warmer which generates heat by oxidation of gasoline with the aid of platinum catalysis. The combustion is not performed by direct burning of liquid gasoline but by surface reaction of gasified gasoline on the platinum catalyst. Therefore, the combustion rate is very slow compared with burning phenomena.

The samples, 65 mm wide, 100 mm high, and 10 mm thick, were positioned in an airgap of an electromagnet 70 mm gap and 240 mm in diameter. Three types of experiments were carried out:

Experiment (a) The combustion place of oxidation reaction was exposed to magnetic fields with low gradients which were obtained by simply positioning samples in the edges of the airgap. Gasoline of 10.0 cc was poured into each sample, and the samples were ignited simultaneously. Two samples were exposed to magnetic fields for 6 hrs. The other two samples were used as the control. The time course of temperature of samples were measured by a thermistor to obtain the combustion time. The combustion time was measured by detecting the time of rapid decrease in sample temperature. The magnetic field effects on the combustion were evaluated by the mean velocity of combustion over the period from ignition to consumption of the fuel. The experiment was repeated four times, replacing samples in turn under diffrent magnetic fields from 0.1 T to 1.0 T. The magnetic field of 0.5 T generates 5 T/m, and the magnetic field of 1.0 T generates 10 T/m in this experiment.

Experiment (b) Evaporating gasoline before combustion reaction was exposed to magnetic fields with different gradients which were generated by a similar technique used in HGMS. That is, a small space between gasoline tank and combustion place of platinum catalysis was packed with ferromagnetic amorphous fibers with different diameter (20 μm, 50 μm, and 125 μm) which were made by UNITIKA Ltd., Kyoto, Japan. Gasoline of 10.0 cc was poured into each sample, and the samples were exposed to a homogeneous magnetic field of 0.75 T, 0.47 T, and 0.23 T for 6 hrs. Gasoline of 5.0 cc was poured into each sample, and the samples were exposed to a homogeneous magnetic field of 1.0 T for 3 hrs. In this case, the gradient field of 5.0×10^4 T/m was generated around the fiber with 20 μm in diameter.

Experiment (c) The place of combustion reaction was exposed to homogeneous magnetic fields with field intensities from 0.1 T to 1.0 T. 13 samples were used. Gasoline of 10.0 cc was poured into each sample, and the samples were ignited simultaneously. 8 samples were exposed to the homogeneous magnetic fields for 6 hrs, and 5 samples were not exposed to magnetic fields. In order to reduce the temperature variation around the samples, the samples located in both edges of the samples were excluded from the data. Therefore, for each magnetic field strength, the average of the data of 6 samples in magnetic fields was compared with the average of 3 samples of control.

RESULTS AND DISCUSSION

Figure 1 shows the results in Experiment (a). The combustion place of gasoline was exposed to 0.1 T - 1.0 T magnetic fields with low gradients (1 T/m - 10 T/m). The combustion velocity decreased at 0.2T,2T/m and 0.6T, 6T/m, and increased at 0.4T,4T/m and 1.0T,10T/m. The undulant phenomenon in the curve of combustion velocity v.s. magnetic field was remarkably observed.

In Experiment (b), the evaporating gasified gasoline was exposed to high gradient magnetic fields, and the combustion place was exposed to homogeneous magnetic fields. The results are shown in Fig. 2. Each curve was obtained by averaging the results of 4 experiments. The combustion velocity increased in proportion to the gradient of the field in the curves of 0.47 T and 1.0 T. The relationship between combustion velocity and homogeneous magnetic field did not show a linear relationship but showed to be undulant.

In order to investigate the effect of uniform magnetic fields on the combustion velocity, Experiment (c) was carried out. The results are shown in Fig. 3. It was observed that the conbustion velocity was influenced also by homogeneous magnetic fields. The combustion velocity of gasoline decreased in 5 % - 10 % at 0.2 T and 0.6 T, and increased in 5 % - 10 % at 0.3 T, 0.5 T and 1.0 T. That is, the undulant phenomenon was observed in the relationship between combustion velocity of gasoline and uniform magnetic field intensity.

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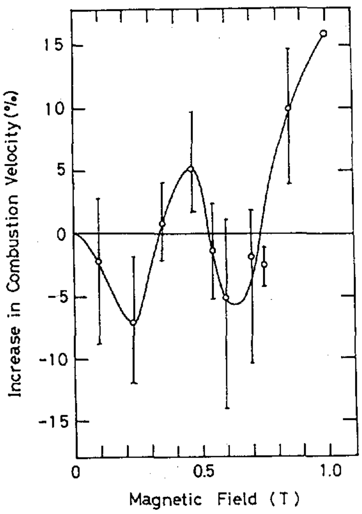

Fig.1 The effect of magnetic fields with low gradients on the combustion velocity of gasoline. The magnetic field of 1.0 T generates 10.0 T/m, and the magnetic field of 0.5 T generates 5 T/m.

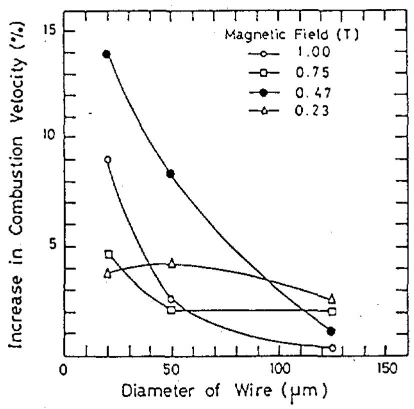

Fig.2 The effect of gradient magnetic fields on the combustion velocity of gasoline. High gradient fields were generated by amorphous wires with different diameter.

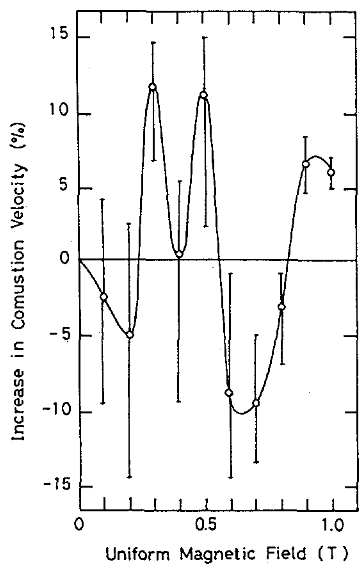

Fig.3 The effect of uniform magnetic fields on the combustion velocity of gasoline.

Since gasoline is a mixed fuel composed of various kinds of hydrocarbons, the combustion processes of gasoline may be complex compared to the cases of pure fuels such as alcohol. To widen the basic understanding of the mechanisms of magnetic field effects on the combustion, various types of alcohol were burned with platinum catalysis under uniform magnetic fields.

Figure 4 shows the effect of uniform magnetic fields on the combustion velocity of methanol. 16 samples were used. Methanol of 10.0 cc was poured into each sample, and the samples were ignited simultaneously. 8 samples were exposed to the homogeneous magnetic fields for 2 hrs, and the other 8 samples were not exposed to the fields. The samples positioned at both edges of the samples were excluded from the data, then, the average of the data of 6 samples in magnetic fields was compared with the average of the data of 6 controls. The magnetic field effect of conbustion velocity of ethanol was clearly observed to show a minimum -5.3 % at 0.9 T.

Figures 5, 6, 7 and 8 show the results of ethanol, normal-propanol, normal-butanol and iso-butanol, respectively. The magnetic field effect was observed to show a minimum at each specific field; -2.3 % at 0.6 T for ethanol, -16.9 % at 0.6 T for n-propanol, -73.8 % at 0.7 T for n-butanol, and -18.9 % at 0.5 T for iso-butanol.

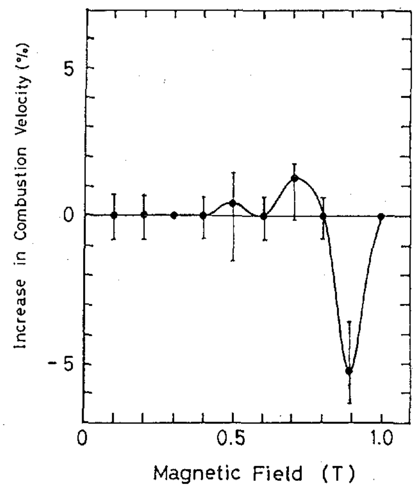

Fig.4 The effect of uniform magnetic fields on the combustion velocity of methanol.

Combustion processes of hydrocarbons and alcohol with platinum catalysis are composed of a series of fundamental reactions. Fundamental reactions might involve various types of radical reactions, although the detailed processes are not clarified well. Radical has unpaired electrons, therefore, its magnetic property shows paramagnetism.

Oxygen is also a paramagnetic molecule.

In combustion processes, photochemical reactions might also occur. In photochemical reactions, the so-called singlet-triplet intersystem crossing can occur in a certain probability.

In magnetic field effects on photochemical reactions in solutions, Hata [5] found an interesting effect; when the photochemical isomerization of isoquinoline N-oxide in ethanol was carried out in either the absence or presence of a magnetic field, the chemical yield of the product (1-isoquinolone) was observed to show a minimum at approximately 1 T. Hata [6] succeeded in interpreting the effect in terms of a hyperfine interaction mechanism including an electron-exchange interaction in the singlet hydrogen-bonded

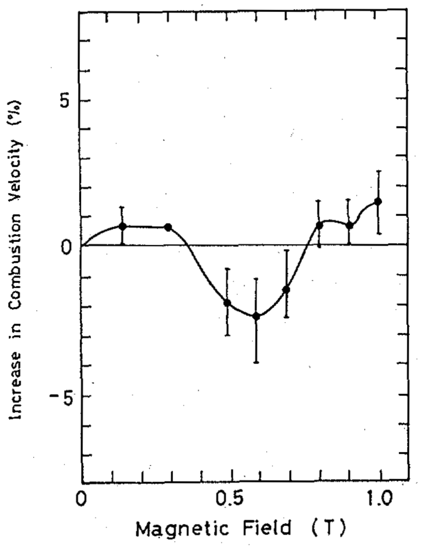

Fig.5 The effect of uniform magnetic fields on the combustion velocity of ethanol.

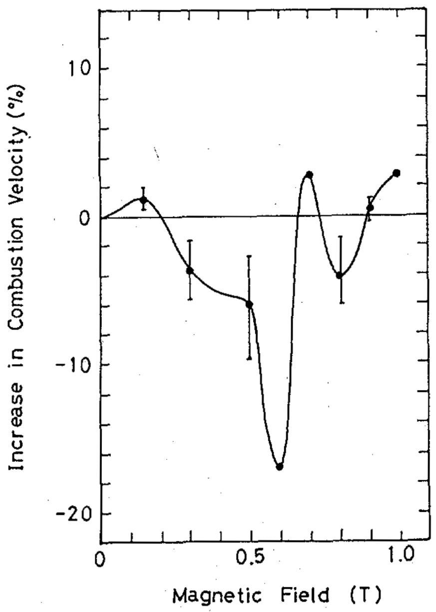

Fig.6 The effect of uniform magnetic fields on the combustion velocity of normal-propanol.

radical-ion pair assumed to be a transient intermediate of this reaction. That is, the triplet level is resolved into three sublevels, T_0, T_+, and T_-, by the application of magnetic fields. The S-T_+ mixing is maximal at the magnetic field in which the singlet level (S) is in resonance with the T_+ level. The chemical yield comes to show a minimum at the resonance magnetic field in which the intersystem crossing of the singlet radical ion-pair is most favorable.

In oxidation reactions of hydrocarbons and alcohol with platinum catalysis, radical reactions might proceed through hydrogen-bonded species on the surface of platinum catalyst. Under a certain condition, each radical reaction could be influenced by each specific magnetic field. The magnetic field effects on the combustion of mixed fuels could be explained by a principle of superposition of pure fuels which have their own resonance magnetic fields. However, the detailed mechanisms for the new phenomena observed in the present experiments are still open to question.

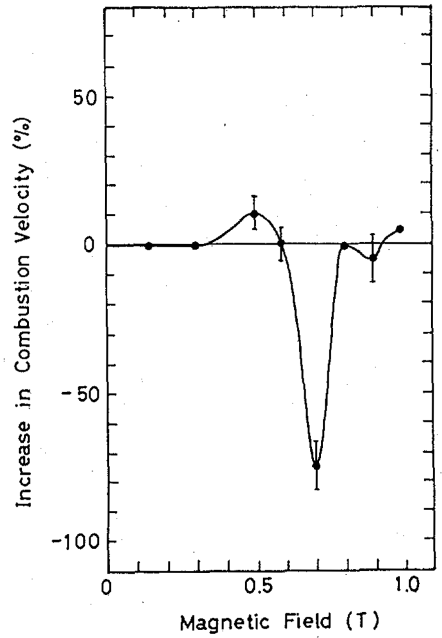

Fig.7 The effect of uniform magnetic fields on the combustion velocity of normal-butanol.

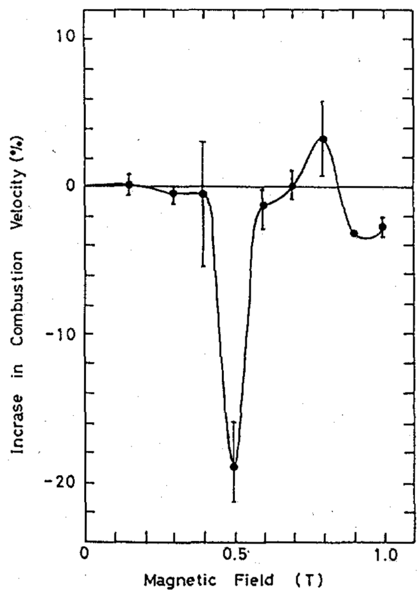

Fig.8 The effect of uniform magnetic fields on the combustion velocity of iso-butanol.

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