短　報

Blue Flame Combustion of a Candle under the Earth's Gravity and at Ordinary Temperature and Atmosphere Pressure

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Abstract

The efficient combustion of biomass is important for reducing CO_2 emissions and to prevent people from inhaling toxic carbonous substance emitted from biomass burning. To investigate the possibility of burning biomass in a cleaner way under the earth's gravity at ordinary temperature and atmosphere pressure, a candle, that is composed of simple constituents and shows a luminous flame with slight blue at the bottom, was used, as a substitute for biomass. Almost complete blue flame combustion was attained by applying simple obstacles to the original candle flame.

***Keywords*:** Biomass, candle, combustion, blue flame, gravity

1. Introduction

The sun shines on the earth and give us many blessings of the sun. Biomass such as firewood is one of them and it is used to produce heat for cooking food and warming houses. However, soot that is generated by the incomplete combustion of biomass is considered to be a cause of health risk. Therefore, many world organizations for example, IEA,(1) WHO(2) and IPCC(3) recommend to use efficient stoves instead of the traditional soot forming three stone type ones for the about 2.7 billion people without the access for clean cooking. For this reason and to decrease the emission of CO_2, one of the green house gases, from burning fossil fuels, developing the methods to burn biomass in an efficient manner without emitting soot is important. The author reports here a simple method to burn a candle, that is used to be made from tallow or resins from trees, with less yellow luminous flame that is a consequence of the light emitted from soot forming carbonous substances in the flame and with more blue flame that is supposed to represent a near complete combustion under earth's gravity, ordinary temperature and atmosphere pressure. Blue flame burning of candles under some special conditions such as in microgravity environment using a free fall experimental facility of NASA,(4) or on the Mir orbiting station and a space shuttle(5) and at reduced pressure(6) using combustion chamber under the earth gravity were reported. The author, however, believes that if the blue flame burning of a candle could be attained under the ordinary conditions, without any forced air supply, it would be more useful and suggestive for the more efficient and less harmful usage of biomass for the people relying on biomass fuel around the world.

2. Experimental

Commercially available paraffin candle (L: 100 mm, OD: 9 mm, melting point: 135 °F, initial wick: L 10 mm, OD ca. 1 mm) was stood vertically and ignited under the earth's gravity, at room temperature and at atmosphere pressure. First, to examine the effect of increasing oxidant supply (air in this case) to the laminar diffusion flame of a candle with natural convection, two stainless steel pipes (L: 200 mm, OD: 2.35 mm, ID: 1.75) were placed with their ends at a distance of 5 mm apart in a line with an elevation angle of 45° toward the flame (Experiment 1, see Fig. 1 and Fig. 2, 1B). Then a candle placed at the center of the two pipes was horizontally slid 7 mm along the right angle direction to the longitudinal centerline of the pipes. In this way, when the candle is most way from the pipes, the distance of the center of the pipes and the candle surface that is closest to the center is 2.5 mm (Fig. 1). The air coming to the flame by the convection through the pipes would be maximized when the candle is at the center of the pipes. To examine the lower air supply from the pipes, they were placed horizontally or with a depression angle of 45° toward the flame (Experiment 2 and 3 respectively. see Fig. 1 and Fig 2, 2B and 3B). In Experiment 4, the pipes were replaced with iron rod (L: 250 mm, OD: 2.5 mm) to examine the effect of no airflow through the pipes but the effect of the obstacles only (Fig. 1 and Fig 2, 4B). Finally in Experiment 5, an effect of additional obstacle to the

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candle flame equivalent to 4B in experiment 4 was investigated by applying two pipes fixed parallel to the longitudinal direction of them with a distance of 3.3 mm in between the outer side of each of them. They were moved upward slightly in the blue part of the flame (Fig. 3). The candle flames were photographed on a CCD digital camera and the vertical length of the flames and luminous and blue parts of the them were measured.

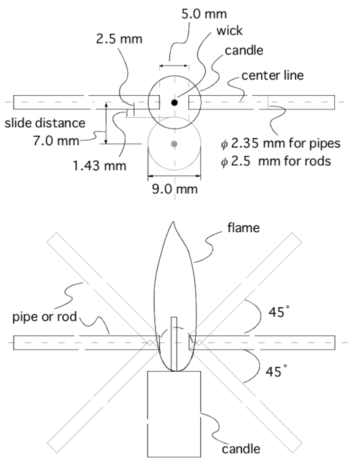

Fig.1 Schematic presentation of a vertical (lower) and horizontal (upper) views of the positions of a candle and pipes or rods.

3. Results and Discussion

As shown in Table 1 and Fig. 1, the appearances of the candle flames and the vertical length of the flames and that of blue and luminous flame parts in each of them changed when the flames were at the center of the pipes or rods. Flames shrunk between 1 – 2.5 mm and blue parts grew 3.5 – 5.1 mm with a similar effect of both pipes and rods. These results show that air supply through the pipes has little or no effect on flame color and length change and that the existence of obstacles is necessarily for these phenomena. The blue frame grew more when further obstacles were located in upper part of the blue flame (Fig. 3 5B) made by rods. The grown blue flame grew more when the additional obstacle was moved slightly upward (Fig. 3 5C-5E).

These results give us an insight that biomass fuel could also be burned with blue flame that give us an expectation of efficient combustion under the earth's gravity and atmosphere pressure.

Table 1 Vertical length of the flames (F) and blue (B) and luminous (L) parts of the flames in each them (mm). Flame numbers are the same as indicated in Fig. 1 and 2.

	1A	1B	2A	2B	3A	3B	4A	4B
F	27.6	26.1	24.1	21.6	25.4	23.4	25.6	24.6
B	4.0	8.0	3.5	8.0	3.6	7.1	4.1	9.2
L	23.6	18.1	20.6	13.6	21.8	16.2	21.5	14.4

	5A	5B	5C	5D	5E
F	22.3	23.9	23.9	23.9	23.9
B	8.6	15.2	16.2	18.3	18.8
L	13.7	8.6	7.6	5.6	5.1

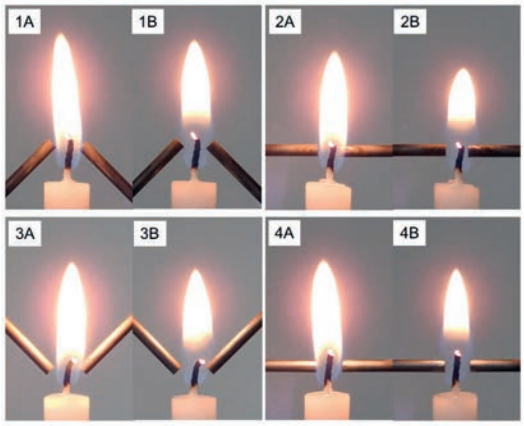

Fig.2 Candles were placed this side of the pipes and then they were slid 7.0 mm to the center of the pipes (with an elevation angle of 45°: 1, horizontal: 2 and with an depression angle of 45°: 3) or rods (horizontal: 4). A and B represent before and after moving candles to the pipes or rods center.

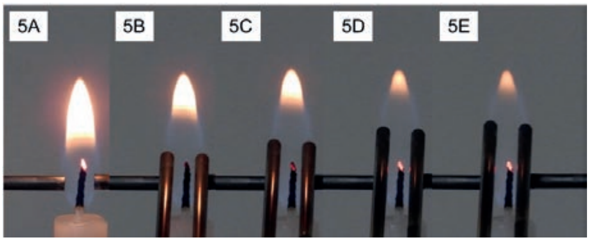

Fig.3 Additional two pipes fixed parallel to the longitudinal direction of them with a distance of 3.3 mm between the outer sides of them were moved upward slightly (5B-5E) in the candle flame (5A) that is in the same condition as in 4B in Fig. 2.

4. References

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