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動画解析による宇宙船内における電線火災のリスク予測法の検討

Study on Risk Prediction Method for Electric Wire Fires by Video Analysis in Spacecraft

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1. Introduction

Combustion of electrical wire sheathing is identified as primary causes of fire in spacecraft. In the past, fires have occurred due to poor contact with the vast number of power cables and wire harnesses carried on board[1]. In this study we attempted to construct a video analysis that enables prediction of expansion after flame detection using visual features of the spreading flame along the electric wire. For this purpose, we utilized the experimental movie data obtained in our laboratory experiments previously, and then extracted features from the flame images.

2. Previous works

A previous study has investigated the flame spread rate and extinction limits of the laboratory wire samples under varied oxygen concentrations and forced flow velocities[2, 3]. Figures 1 (a) and (b) show the experimental apparatus and flame spreading over laboratory wire sample[2, 3]. In the previous study, laboratory wire samples were used for flame spread test to simplify the combustion phenomenon of electric wire. The wire sample consists of a single-core metal wire coated with a thin polymer. Ethylene-tetrafluoroethylene (ETFE) was used as the coating material. In this paper, analysis was performed on ETFE insulated copper (Cu) wire with an outer diameter of 0.8 mm and a core diameter of 0.5 mm.

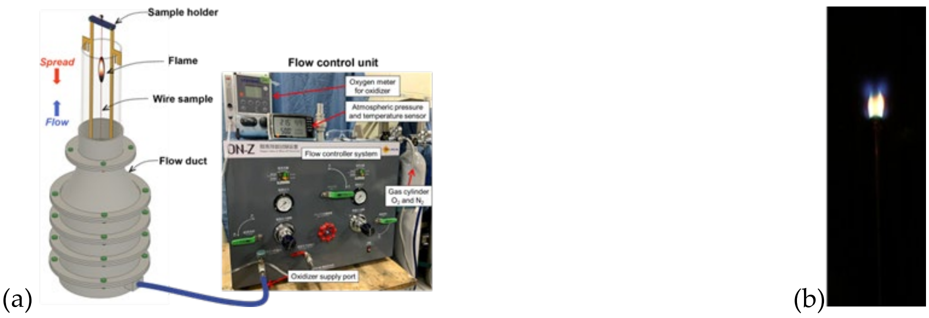

Figure 1. (a) Schematic of the experimental apparatus[3]. (b) Flame spreading over wire sample [2].

3. Analysis method

In this paper, an attempt is made to link flame extinction phenomena using 2-D data of flame color. This makes it possible to discover features related to the extinction phenomenon independent of ambient conditions.

In converting the video image into a 2-D data for analysis every still image with interval of 0.5-second was utilized. As one of the most obvious features during the extinction process was the changes in size and color of the flame, the images were further broken down into three RGB colors. In the following equation r, g and b are the color values of red, green, and blue of each pixel of the image, and R, G, and B are given as follows, respectively. Σ means total sum in terms of whole pixels in one frame.

$$R = \sum r \tag{1}$$

$$G = \sum g \tag{2}$$

$$B = \sum b \tag{3}$$

In the experimental observation, human eyes identify the red area decreases and, instead, the blue area increases in the flame when the flame goes to extinction. Therefore, the following parameter was introduced to quantify the change in flame color with the change in flame size.

$$\tau = \frac{R - B}{R + B} \tag{4}$$

Here, we simplify the interpretation by limiting the data to only two component colors, R and B. Then, correlation between equation (4) and elapsed time was investigated in the next section.

4. Results and discussion

Figure 2 shows the time dependent change in τ for 25 seconds after ignition of the flame for six different conditions with ambient flow velocities of 20 cm/s, 40 cm/s, and 80 cm/s, respectively, and different ambient oxygen concentrations (O2). The dotted line represents the case where the flame continued in the whole experimental period (sustained flame), while the solid line represents the cases when the flame was extinguished in the middle of the experiment (extinction).

The results show that in the pattern of flame continuation (dotted line in Figure 2), the slope of τ with respect to time is approximately constant from the beginning to the end and does not take a negative value. On the other hand, in the case of extinction, the slope of τ with respect to time is relatively large immediately after ignition. The magnitude of the slope has strong correlation with the ambient flow velocity. Furthermore, τ is found to take a negative value about 2 seconds before the flame is extinguished. Thus, a large difference between the cases of extinction and sustained flame were found in the present work, which implies the potential application of flame colors for risk evaluation of fire after any detection of flame in an electric wire harness is promising by combination with machine learning method.

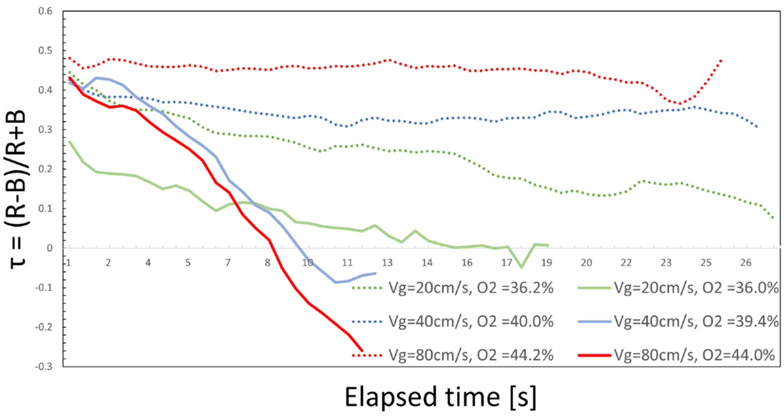

Figure 2. Differences in flame-extinguishing properties under different materials and flow velocities

Summary

In the present study, an attempt to find a feature of the spreading flame over electric wire which results in extinction. The new parameter τ showing the color feature of the flame were introduced and correlated with the probability of extinction. The results showed that time dependent change in τ showed different trend between the cases of extinction and sustained combustion. As the next step we plan to apply the parameter to give better risk assessment after the first detection of flame in combination with machine learning method.

References

1) Hiroyuki Takeuchi, Graduate School of Engineering, Hokkaido University, 2011, "A Study on Non-Stationarity of Flame Spreading Phenomena on Low-Density PE-Coated Conductors in Microgravity," 2010 Master's Thesis, Department of Mechanical and Space Engineering.
2) Muhammad Zhaffri bin Zainal Abidin, Graduate School of Engineering, Hokkaido University, 2020,"Development of a Blowout Test Method to Obtain the Critical Oxygen Concentration of Wire Coated Materials: Observation of Downward Flame Spread under High Velocity Conditions Near the Spread Limit.".
3) Konno, Yusuke, Muhammad Zhaffri Bin Zainal, Nozomu Hashimoto, Osamu Fujita, Proceedings of the 18th HASTIC Annual Conference, March 3, 2021, Online.