Flame spread behavior over combustible thick solid of paper, bagasse and mixed paper/bagasse

Mohd Azahari Razali¹, Sofian Mohd², Azwan Sapit¹, Akmal Nizam Mohammed¹, Ahmad Husaini Ismail², Mohd Faisal Hushim¹, Norrizam Jaat¹ and Amir Khalid³

¹Centre for Energy and Industrial Environment Studies (CEIES), Universiti Tun Hussein Onn Malaysia, 86400 Pt. Raja, Batu Pahat, Johor, Malaysia
²Faculty of Mechanical & Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Pt. Raja, Batu Pahat, Johor, Malaysia
³Advanced Technology Centre (ATC), Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia, 86400 Pt. Raja, Batu Pahat, Johor, Malaysia
Email: azahari@uthm.edu.my

Abstract. Flame spread behavior on combustible solid is one of important research related to Fire Safety Engineering. Now, there are a lot of combustible solid composed from mixed materials. In this study, experiments have been conducted to investigate flame spread behavior over combustible solid composed by paper, bagasse and mixed paper/bagasse. Experimental data is captured by using video recording and examined flame spread shape and rate. From the results obtained, shows that the different materials produce different flame spread shape and rate. Different flame shape is seen between all types of samples. Flame spread rate of 100% paper is faster than the one of 100% bagasse. Based on the result, it is also inferred that the material composition can be influenced on the flame spread shape and flame spread rate of mixed paper/bagasse.

1. Introduction
Fire safety engineering is an application of science to protect human and their environments from the destructive effects of the fire. Researches on the fire safety engineering have been done for many years and it is beginning to focus on the technical capability for fire preventions in complex issues. In order to improve the technical capability for fire preventions, the fundamental approach is required which can be applied at the design stage. Such approach requires detailed understanding of combustion process from an engineering standpoint.

The combustion involves the flame spread phenomenon along the surface of combustible solid [1]. A lot of researches have been done in order to discover the mechanism [1-5]. An understanding of factors affecting the flame spread mechanism is indispensable to discover the mechanism. In other to elucidate the complex mechanism, it is necessary to know about the flame spread mechanism.

There are several researches are conducted to examine the effect of material on flame spread behavior of combustible solid [6-8]. However, all these researches are focused only on the flame spread over fabric. Instead of fabric, the paper is also one of the important factor influences on fire destruction. Nowadays, there are several materials such as oil palm leaf, bagasse or pineapple leaf are used as alternative source in paper fabrication. Some product also fabricated by composed these alternative sources with the paper.
Before flame spread behavior over mixed paper is examined, it would be indispensable to study the phenomenon for pure material since this phenomenon has not been studied in detail. Thus, in this study, the flame spread behavior over paper, bagasse and mixed paper/bagasse is examined.

2. Experimental setup
In this research, the experiments have been conducted for pure paper, pure bagasse and mixed paper/bagasse. The specimen size is 8 cm x 7.5 cm.

Figure 1 shows experimental setup in this research. Before the burning test, the sample is dried in a desiccator for more than 48 hours and the humidity in the desiccator is controlled to below 40%. The sample is clamped to the holder and a burner is used for igniting the sample at a point on its top edge. The surface of the sample is videotaped to observe the flame spread behavior.

3. Results and discussion

3.1. Flame spread shape
In this experiment, the sample is ignited at a point on its top edge. The flame spreads in the downward direction. The sample is videotaped to observe the flame spread behavior. Figure 2 shows shape of flame front for pure paper, pure bagasse and mixed paper/bagasse. It is seen that from Figure 2 (a) to (c), all samples exhibit similar shape of flame front, which is ‘U’ type. However, size of the shape shrinks from pure paper, mixed paper/bagasse to pure bagasse.

Figure 3 shows shape of flame front for every 30s. This figure shows detail propagation of flame shape during the experiments. It is seen from Figure 3 (a), the shape of flame front is in ‘V’ shape at the beginning of combustion. After few minutes, the shape changes from ‘V’ to ‘U’ shape which is remained until the end of sample.

From Figure 3 (b) and (c), significant different of the shape is seen for other samples. It is seen that for paper/bagasse, the shape is in ‘U’ at the beginning. The flame is propagated after the ignition; however, the propagation is limited to the central region only and the flame is retarded after few minutes.

For the case of pure bagasse, the flame is spread after the ignition. However, the flame is retarded in the very short period that the one of paper/bagasse, as seen in Figure 3 (c). Results infer that the type of material and material composition may influence on the flame spread shape.
3.2. Flame spread rate
Flame spread rates are obtained by measuring the position of the most preceding point of the burning front at each time. In order to avoid the influence of the initial transition process after the ignition, the position is measured from $x = 10$ mm, where $x$ is the vertical distance from the top edge of the sample in downward direction.

Figure 4 shows the flame spread rate for pure paper, paper/bagasse, and pure bagasse. Result shows that the flame spread rate for pure paper is highest, which is 0.111 mm/s. It is followed by paper/bagasse and pure bagasse; the former and the latter are 0.093 mm/s and 0.086 mm/s, respectively. From this research, it is inferred that the material has significant influences on not only the flame spread shape, but also on the flame spread rate. However, the additional results are needed in order to examine about the influence of the material composition. This result will be useful to validate simulation works in the future.
Figure 4. Flame spread rate for different type of sample.

4. Conclusion
In this study, flame spread over pure paper, pure bagasse, and paper/bagasse is examined and following results are obtained:

1. Shapes of flame front differ between samples. Pure paper burns and flame spreads in ‘U’ shape. However, flame is distinguished when pure bagasse is ignited. For paper/bagasse, the sample burns and the flame is only spread in the central region during burning process.
2. Flame spread rate for pure paper is highest, followed by the values of paper/bagasse and pure bagasse. Results infer the material has significant influences on not only the flame spread shape, but also on the flame spread rate.

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