

Thread angle dependency on flame spread shape over kenaf/polyester combined fabric

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Abstract. Understanding flame spread behavior is crucial to Fire Safety Engineering. It is noted that the natural fiber exhibits different flame spread behavior than the one of the synthetic fiber. This difference may influence the flame spread behavior over combined fabric. There is a research has been done to examine the flame spread behavior over kenaf/polyester fabric. It is seen that the flame spread shape is dependent on the thread angle dependency. However, the explanation of this phenomenon is not described in detail in that research. In this study, explanation about this phenomenon is given in detail. Results show that the flame spread shape is dependent on the position of synthetic thread. For thread angle, $\theta = 0^\circ$, the polyester thread is breaking when the flame approach to the thread and the kenaf thread tends to move to the breaking direction. This behavior produces flame to be 'V' shape. However, for thread angle, $\theta = 90^\circ$, the polyester thread melts while the kenaf thread decomposed and burned. At this angle, the distance between kenaf threads remains constant as flame approaches.

1. Introduction

Fire safety engineering is an essential science for improving the safety knowledge from the fire destructive. Now, the research starts to focus on the technical capability for fire preventions in complex issues. For improving the technical capability, the fundamental approach in the design stage is essential. Such approach requires detailed understanding of combustion process from an engineering viewpoint.

One of the important technical areas in fire safety engineering is combustion process of combustible solid such as fabric. There are several researches have been done related to the flame spread rate. Bhattacharjee et al. [1] have made an apparatus for flame spread study. The spread rate can be measured by tracking the position of visible edge of flame through video recording. There are several factors influence on flame spread rate. Fernandez-Pello et al. [2] found that the flame spread rate can be affected by ambient and fuel conditions. Ding et al. [3] simulated the fire spread. Results show that spread characteristics have major relation with factors such as material of solid, width, thickness, placed angle and atmospheric pressure. It is also discovered that the increment in oxygen concentration will cause the external radiant flux required for flame spread to decrease. Flame spread



characteristics of many thin materials will be varying with affect from material thickness, external heat flux, oxygen concentration, pressure and forced flow velocity [4]. Higher heat flux results in higher heat release rate and peak mass loss rate and the fabrics will burns more violently. The density of the structure and moisture content also has effects on burning behavior of fabrics. The arrangement order of types of fabrics in increasing fire risk: wollen fabrics > sponge fabrics > cotton fabrics > linen fabrics [5]. It is stated that cellulosic fabrics burn with a yellow flame, light smoke, and have glowing embers. Synthetic fabrics catch fire quickly or shrink from the flame initially. Nylon, lastol, olefin, polyester, and spandex burn slowly and melting. It also can melt and pull away from small flames without igniting. The residue is hot molten and difficult to get rid. The burning of these fabrics can self-extinguish [6].

Nowadays, fabric is always fabricated by using two different type of thread; natural/natural threads, natural/synthetic threads or synthetic/synthetic threads. The natural thread has different flame spread characteristic than the one of synthetic thread; which may have some influence on flame spread of combined fabric. There are several researches have been done to examine the flame spread rate over combined fabric. Mohd Azahari et al. [7] have conducted experiment to study the flame spread behavior over combined fabric of cotton/polyester. Experiment is conducted for several weft trade angles from 0° to 90° . Results show a significant difference in the shape of burning front between $\theta = 0^\circ$ and 90° . It is also found that the flame spread rate decreases as the angle increases. Experiments also have been conducted to study the flame spread behaviour over combined fabric of cotton/polyester and cotton/nylon [8]. For $\theta = 0^\circ$, a significant difference is seen between these two combined fabrics in the shape of burning front. However, the shape of the burning front is the same for both fabrics at $\theta = 90^\circ$. From the research, it is also seen that both fabrics have similar angle dependency; the flame spread rate decreases as the angle increases.

Recently, several industrial have used kenaf as natural thread. Mohd Azahari et al. [9] have been examined the effect of thread angle on flame spread behavior over kenaf/polyester fabric. From the results obtained, it is seen that thread angle have some influence on the flame spread shape of fabrics. However, there is no detail explanation about the influence of the angle on flame spread shape. The data of detail behavior of flame spread is essential to describe this influence. Thus, in this study, the detail flame spread behavior over kenaf/polyester combined fabric is explored.

2. Experimental setup

Fabric samples are made by means of a weaving machine. Plain weave is chosen as the structure of the fabric. The plain weave has warp threads perpendicular to weft threads. The fabric composed of different materials is referred to as a combined fabric. For combined fabric, kenaf is used as the warp thread and polyester as the weft thread. **Table 1** shows the characteristic values of these threads.

Table 1. Size of threads.

	Diameter [mm]
Kenaf thread	0.7
Polyester thread	0.5

Thread distance of all samples have been controlled for approximately 3.0 mm. Samples are cut with different weft thread angle of 0° , 45° and 90° . The weft thread angle is referred to the angle between polyester thread and the horizontal line as shown in **Figure 1**.

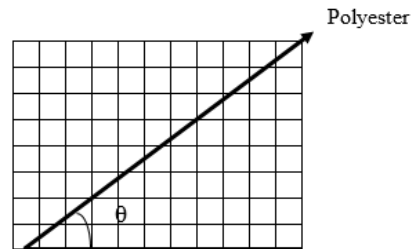


Figure 1. Illustration of fabric angle.

Figure 2 shows the experimental setup. Before the burning test, the fabric sample is dried in a desiccator for more than 48 hours and the humidity in the desiccator is controlled to below 40%. The fabric sample is clamped to the holder and its area of 100 mm x 200 mm is exposed to burn. A burner is used for igniting the fabric at a point on its top edge. The surface of the sample is videotaped to observe the flame spread behavior.

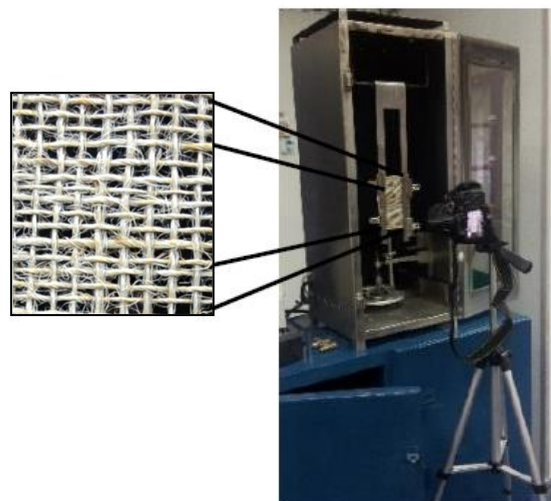


Figure 2. Experimental setup.

3. Result and discussion

This experiment was carried out with a fire lit at the top end of the experiment. This sample combustion is carried out facing down. The fire behavior during the experiment recorded for the purposes of observation and analysis of the data collected.

Figure 3 (a) to (c) show shapes of flame front for $\theta = 0^\circ$, 45° , and 90° . From **Figure 3(a)**, the flame spreading with slightly 'V' shape for $\theta = 0^\circ$. However, the shapes started to change into curvy flat line shape for $\theta = 45^\circ$ and 90° as seen in **Figure 3(b) to (c)**.

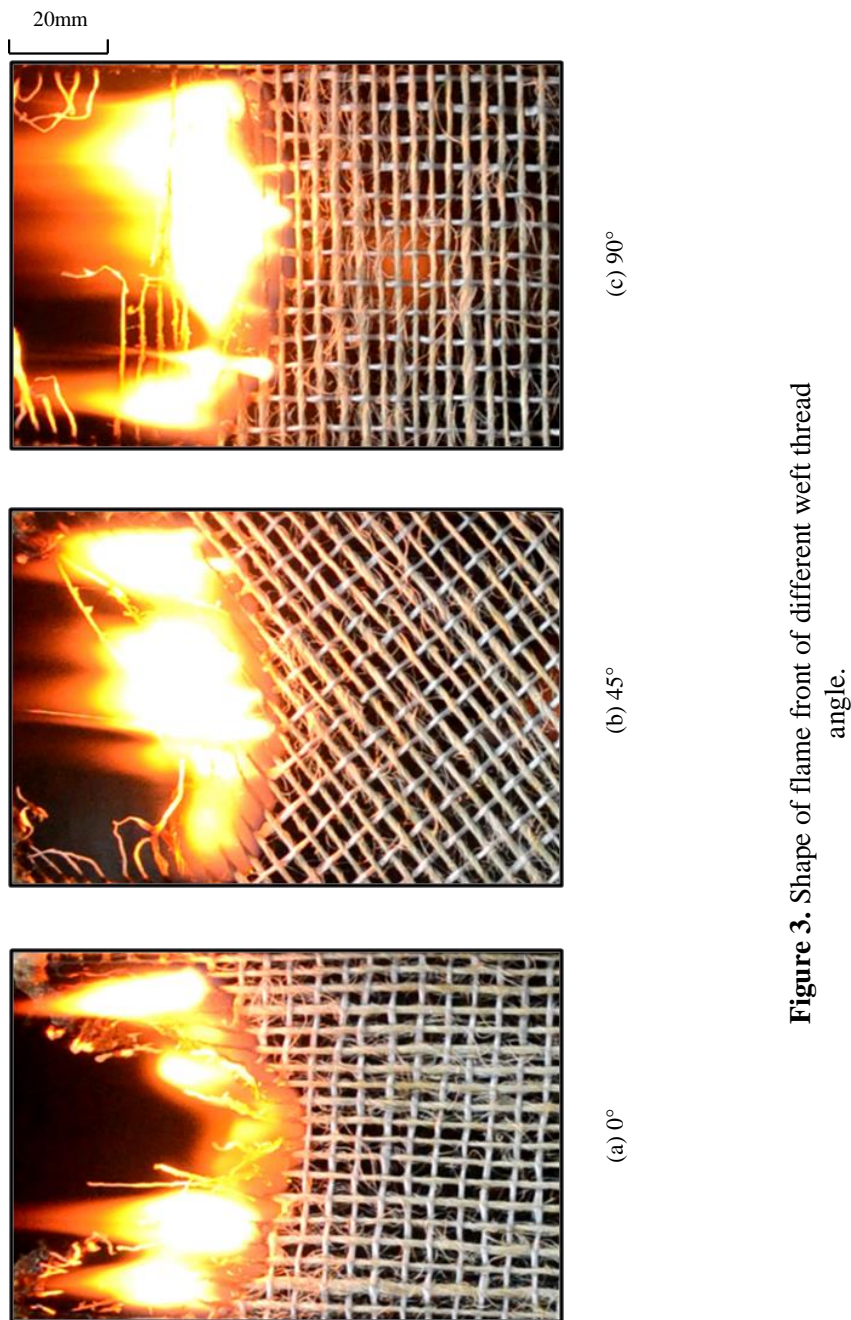


Figure 3. Shape of flame front of different weft thread angle.

Detail observation of flame front for every 5 s is shown in **Figure 4 (a) to (c)**. The flame front is determined at the front edge of discoloration when it decomposes. For $\theta = 0^\circ$, it is seen that the flame front starts with semicircle shape as shown in **Figure 4(a)**. After few second, the shape changes to 'V' shape. The 'V' shape remains as time increases until the fabric completely burn. **Figure 4(b)** shows the shape of flame front of the fabric at $\theta = 45^\circ$. It is seen, the flame front is in the semicircular shape at the beginning of the combustion. Then, the semicircular shape turns into 'V' shape. After that, the flame front becoming flat line until the fabric completely burn. This similar phenomenon is also seen for $\theta = 90^\circ$.

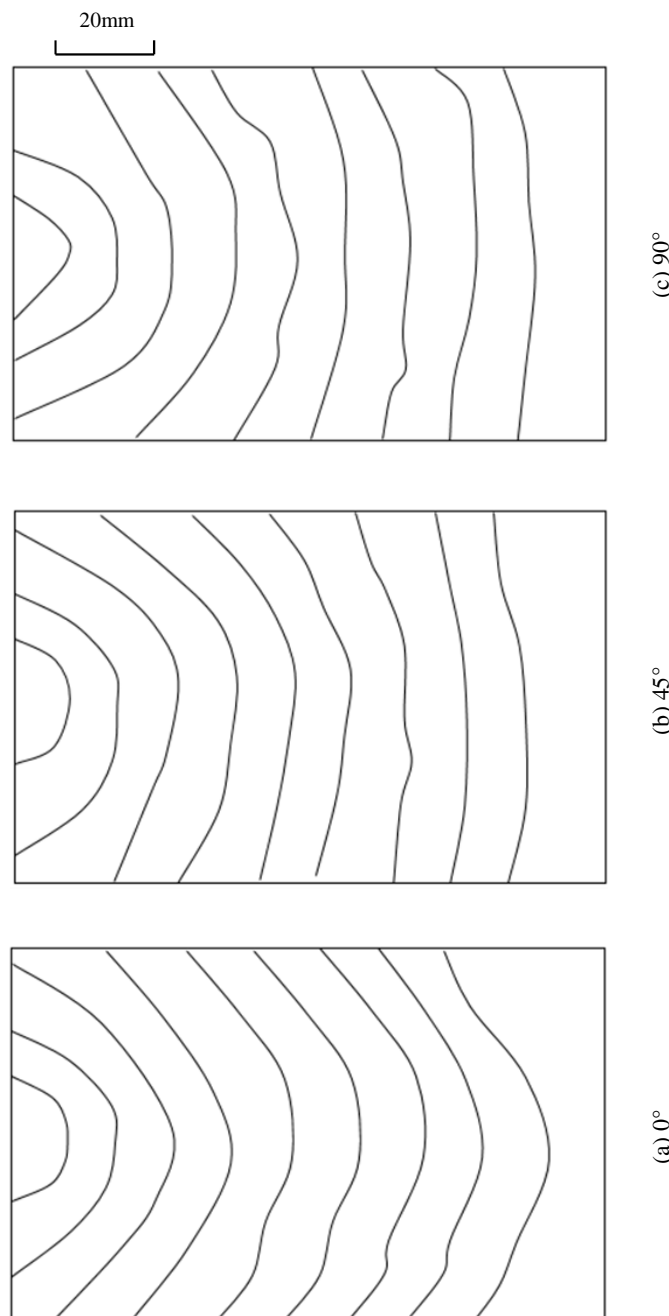


Figure 4. Shape of flame front for every 5 s.

This different of flame spread shape between the weft thread angle may influenced by the decomposition behavior at leading point of combustion. **Figures 5** and **6** show the flame spread behavior at leading edge for $\theta = 0^\circ$ and 90° , respectively.

Figures 5 (a) to (d) show the flame spread behavior at leading edge in every 0.30 s as shown in 'O'. As seen in figure, the polyester thread melts when the edge of discoloration on the cotton thread approaches. The polyester thread breaks into two and it pulls the kenaf thread when it shrinks.

The case is different when the thread angle is 90° . As shown in **Figure 6 (a) to (d)**, shows the different shrinking behavior of polyester thread at $\theta = 90^\circ$. The polyester thread melts gradually in the direction of the thread and attaches to the kenaf thread. However, the distance between kenaf threads remains constant as flame approaches.

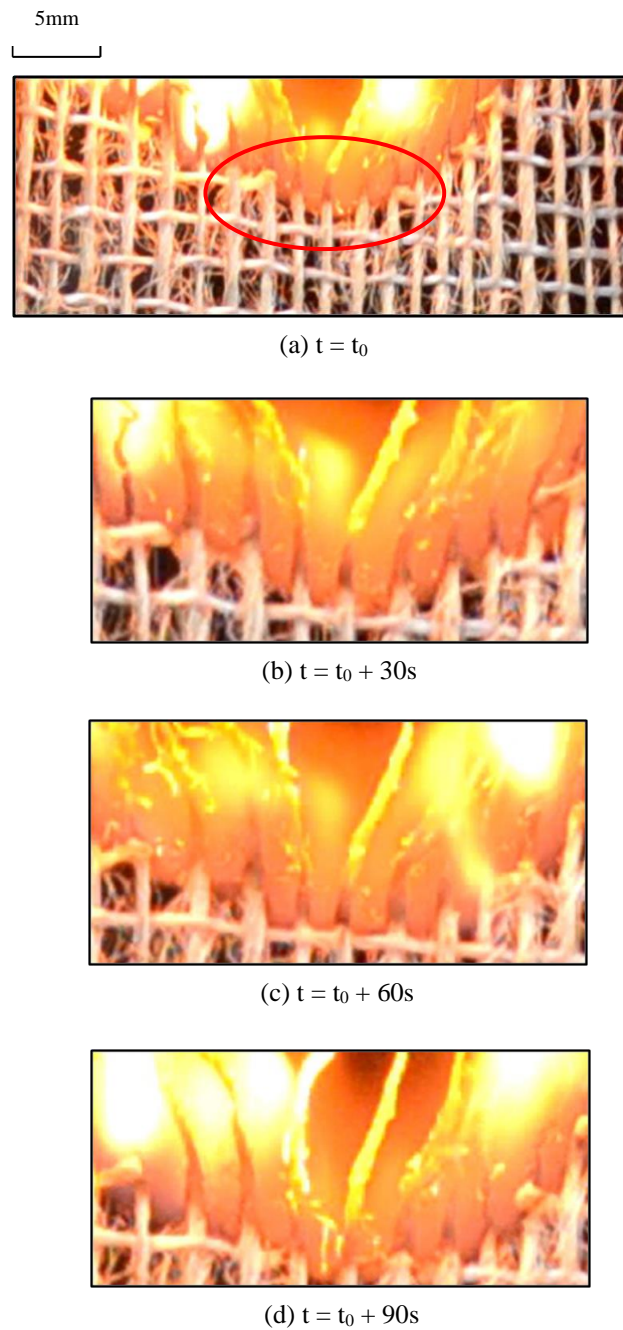


Figure 5. Flame spread behavior at leading edge for $\theta = 0^\circ$.

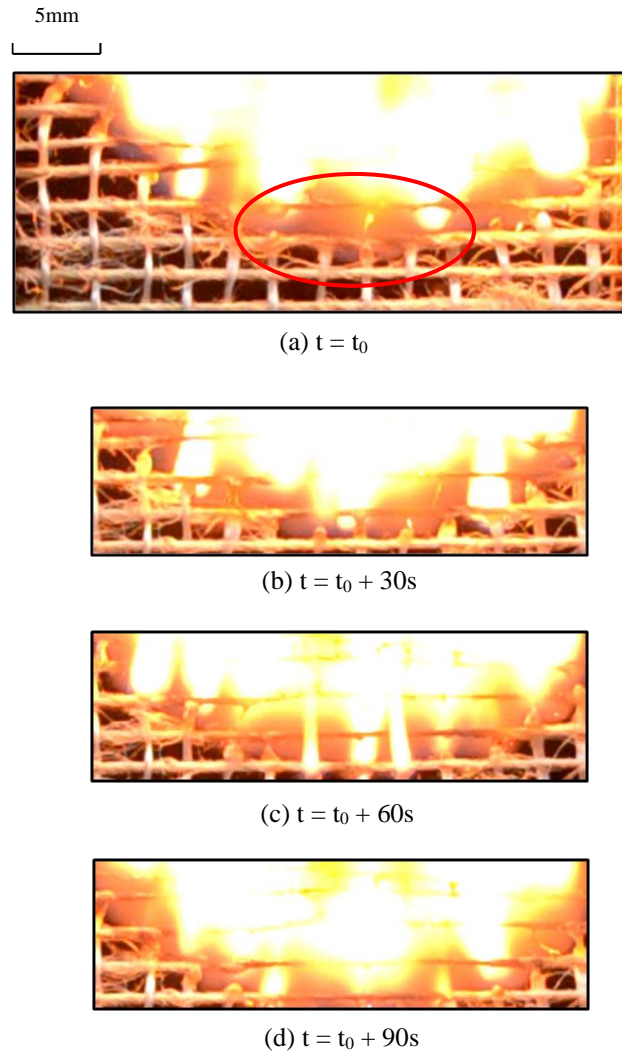


Figure 6. Flame spread behavior at leading edge for $\theta = 90^\circ$.

4. Conclusion

In this study, thread angle dependency on flame spread shape over kenaf/polyester fabrics is examined and following results are obtained:

1. Flame spread shape is differed for combined fabric at $\theta = 0^\circ$ and 90° . For $\theta = 0^\circ$, the shape turns to be in 'V' shape but the flame is in flat shape when $\theta = 90^\circ$.
2. Flame spread shape is influenced by the flame spread behavior at leading point. For $\theta = 0^\circ$, the polyester thread melts when the edge of discoloration on the cotton thread approaches. The polyester thread breaks into two and it pulls the kenaf thread when it shrinks. For $\theta = 90^\circ$, the polyester thread melts gradually in the direction of the thread and attaches to the kenaf thread. The distance between kenaf threads remains constant as flame approaches.

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