Effective factors on the performance of woven wire screens against leaf firebrand attacks

Javad Hashempour[a*], Ahmad Sharifian[b]

[a,b]**Computational Engineering and Science Research Centre (CESRC),**

Faculty of Health, Science and Engineering, University of Southern Queensland, Toowoomba, Australia

[a] javad.hashempour@usq.edu.au, [b] Sharifia@usq.edu.au

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Abstract- Firebrand spotting is the dominant wildfire propagation mechanism. The use of wire screens to prevent firebrand entry into structures is recommended or mandated by many standards. The existing standards address only one feature of screens which is opening size. This experimental study aims to explore several other factors that may influence the performance of wire screens and may need to be incorporated in codes and standards development process for structures located in wildfire prone areas. The results demonstrate a previously unreported shattering mechanism in the case of Eucalyptus populnea (from the Myrtle family) leaf firebrands under a moderate wind speed of 14.5 m/s. The results also show that screen porosity, screen type and wind speed would be appropriate to be addressed in developing standards, but there is no need for concern about screen orientation as long as the screen is placed perpendicular to the wind direction during the experiment.

* Corresponding Author: Computational Engineering and Science Research Centre (CESRC), Faculty of Health, Science and Engineering, University of Southern Queensland, Toowoomba, Australia; Tel: +61 4 10734889; Email: javad.hashempour@usq.edu.au

1. Introduction

Firebrand attacks (or spotting) are the main cause of rapid fire propagation and house destruction during Wildland-Urban Interface (WUI) fires. Lofted firebrands from trees can fly for several kilometres ahead of a fire front, then fall to the ground and start spot fires. These falling firebrands can cause house ignitions during WUI fires by sitting on building components or entering into buildings through openings [1]. A review of three major historical bushfires in Australia has identified the substantial role of firebrands in the destruction of houses [2]. Reducing or containing the effects of firebrand attacks would provide greater efficiency of house protection and avoidance of huge losses.

The Australian Standard for construction of buildings in bushfire prone areas recommends the use of screens with aperture sizes of less than 2 mm on any open-able windows and gutters to block firebrand attacks [3]. From an experimental investigation carried out at a wind speed of 9 $m.s^{-1}$, it was found that glowing wooden firebrands are capable of passing through wire screens once they fit the screen mesh sizes of 1.5 mm, 3 mm and 6 mm [4]. These results led to the updating of the California Building Code for construction in wildfire-prone areas that reduced aperture sizes from 6 mm to between 1.6 - 3.2 mm in 2010 [5,6]. Similar results were also reported later for screens with mesh sizes between 1.04 - 5.72 mm tested in both laboratory and full scale experiments [7,8]. Other standards, such as the International Urban-Wildland Interface Code and the National Fire Protection Association, mandate the use of screens with maximum opening sizes of 6.4 mm and 6.3 mm, respectively.

These current standards are only based on the opening size of screens and do not consider other parameters. This study aims to explore how other geometrical parameters of screens influence screen performance against firebrand attacks, as well as documenting the effects of opening size which is currently used as the leading parameter intuitively rather than through research.

The study addresses several research gaps present in the literature. First, this study addresses leaf firebrands which appear to be the most difficult firebrands for screens to contain due to their inherent structural weakness. Leaves were collected from Eucalyptus Populnea plants, which are an extremely flammable species in wildfires because of their oil content [9]. According to [10] and [11], charcoal, bark, dry moss, leaf and grass firebrands can initiate spot fires. Second, this work focuses on quantifying the behaviours of firebrands during their passage through screens, not simply identifying the behaviours. Third, in addition to opening size, the effects of several previously unstudied parameters such as screen porosity, screen type, opening shape, and the orientation of screens with respect to leaf firebrand showers have been studied. Fourth, this work has been completed at a wind speed of 14.5 $m.s^{-1}$, which represents a higher and a more realistic wind speed [2][12][13] than most prior studies. A higher wind speed presents the worst case scenario in terms of passage of firebrands through screens (due to higher wind force and firebrand fragmentation) but does not necessarily represent the worst case scenario in terms of likelihood of initiating a fire by firebrands. In the latter case, heat is removed quickly and inhibits the temperature rise to the ignition temperature.

The current experimental study has been carried out using an ember shower simulator, five different woven wire screens and four flat screens with different opening sizes, opening shapes and porosities. The ember shower simulator (ESS) was designed and manufactured in-house for the current study and is capable of generating wind speeds up to 21 $m.s^{-1}$ in the unfilled test section.

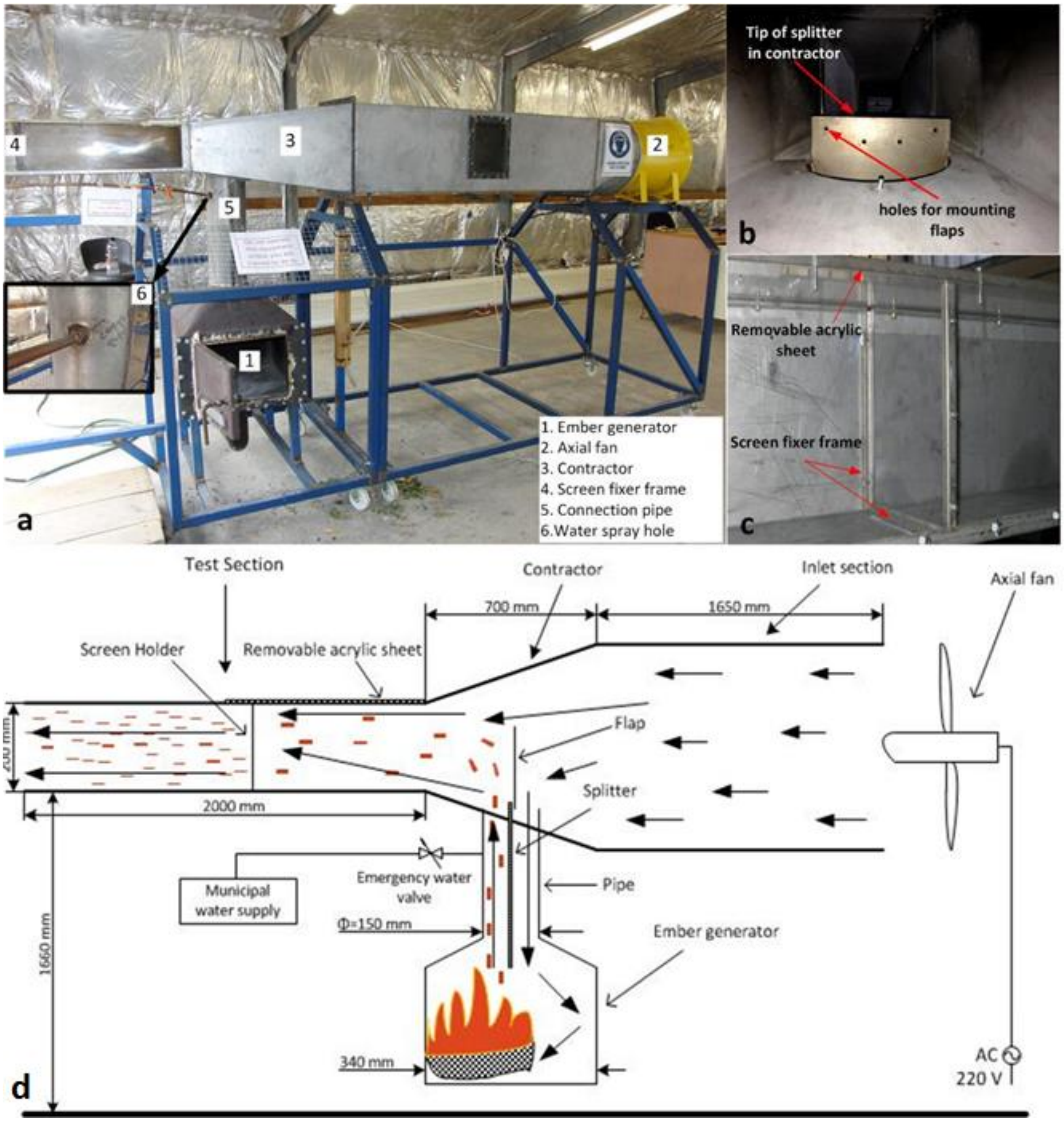

Figure 1 Photographs of the Ember Shower Simulator : a) The complete Ember Shower Simulator; b) Splitter; c) Screen fixer frame, d) Scheme of Ember Shower Simulator [14].

In this work, similar to previous studies, retention time and penetration ratio are used to assess the performance of screens against firebrand shower. Retention time is the time firebrands are delayed behind the screen. The penetration ratio (PR) is the ratio of the number of firebrands that pass through the screen (FB_p) to the number of firebrands approaching the screen (FB_a) in a given time interval (Δt) and is defined as [8]:

$$PR = \sum_{t=0}^{\Delta t} FB_p \,/\, \sum_{t=0}^{\Delta t} FB_a \qquad (1)$$

2. Ember Shower Simulator (ESS)

Figure 1 is a scheme and photograph of the designed and manufactured Ember Shower Simulator (ESS) used in this research. Two important criteria for the new design were the ability to produce wind speeds higher than 10 $m.s^{-1}$ when low porosity screens were placed in the test section, and the capability to create and test different firebrands with various weights and sizes.

The simulator includes an axial fan which blows air at an average speed of approximately 5 $m.s^{-1}$ into the inlet with a cross section area of 1600 cm^2. Wind speed can be adjusted by moving the fan towards or away from the inlet of the wind tunnel. In this study, the average wind speed in the test section was adjusted to 14.5 $m.s^{-1}$, measured using a hot wire anemometer.

The air blowing into the wind tunnel flows to the contractor before the test section. Inside the contractor, a flap directs a portion of air down into the ember generator. The pipe is divided into two sections by a splitter. The splitter is a thin steel sheet which is axially welded inside the pipe. Several flaps were built at different heights. In each experiment, a flap was screwed to the top of the splitter to provide the desired flow distribution (see figure 1b & 1d). The air diverted into the ember generator supplies the required oxygen for combustion as well as helping the firebrands to fly into the other half section of the pipe. After mixing the lofted firebrands with the airflow in the wind tunnel, they enter the test section. The top and one side wall of the test section have been built using acrylic sheets for monitoring purposes. Screens sit in a fixed frame (see figures 1c) that keeps them stretched inside the test section.

The maximum non-uniformity of the flow was measured as 9.5% at the inlet of the test section for the flap at 150 mm, and decreases to 6.3% at the end of test section. The temperature distribution in the test section shows a maximum non-uniformity of 4.3˚C for the flap at 150 mm. Also, the turbulence intensity in the test section increases with the height of the flap and

Figure 2 Dead Eucalyptus tree leaves collected for this study.

reaches a maximum of 3.7% in the middle of the test section for the flap at 150 mm. Details on flow patterns and characteristics of the ESS can be found in [14].

Leaves were ignited in a bucket and delivered into the ember generator once the flaming condition was observed. The leaves were collected from Eucalyptus (E.populnea) trees during autumn (see figure 2). The moisture content and size of leaves were measured in twenty randomly selected samples. The average mass of the sample leaves was calculated as 0.255 g and the average moisture content was 27% using the oven-dry method. The oven-dry method determines the moisture content as a percentage of mass loss of the sample to the sample dry mass. The average length and width of sample leaves were measured as 71.9 mm and 59.1 mm. A high speed video camera was placed outside the wind tunnel next to the test section to monitor and record the flying firebrands during the experiments. The captured videos at a frame rate of 420 frames per second (fps) were imported into MATLAB for video processing and further analysis.

3. Image processing

The counting of the large number of firebrands was carried out using the image-processing toolbox in the MATLAB environment. The developed script counts the firebrands in two strips, one before and one after the screen. The wind speed was 14.5 $m.s^{-1}$ and as the camera was set to take photos at a speed of 420 fps, the maximum width of the strip to avoid double counting should be less than approximately 35 mm. However, firebrand speed is not uniform and not necessarily the same as the wind speed. In addition, the length of firebrands as observed in the photos is around 10 to 20 mm, which may cause double counting of firebrands if the width of the strips is set to 35 mm. In practice, the strips were at a distance of 90 mm to 110 mm from the screen at the approaching and leaving sides, respectively, and the width of each strip was only 2 mm. The observation showed that up to 3% of the firebrands on the upstream side and 5% on the downstream side might pass through the strips without being counted, but as this occurred on both sides of the screen, the error in the penetration ratio was limited to 5%. More details on the image processing are available in [14].

4. Experimental results

4.1. Preliminary experiments

Several preliminary experiments were performed to determine the minimum number of firebrands required for repeatable results and to assess the possible effects of the intensity of the firebrand shower and ambient conditions on the results.

Initial experiments showed that good repeatability could not be achieved only by increasing the time of the experiment or the number of firebrands without adopting a special procedure. In an experiment in which approximately 20,000 firebrands were recorded, the penetration ratio for twenty clusters of 1000 firebrands each were measured and the results demonstrated a variance of ±38.4%. The varying average size of approaching firebrands during the experiment was identified as the main reason for the high variance. It was found that a smaller variance could be achieved if the results for all firebrands produced in an experiment were compared with those of the next experiment. The results of three consecutive experiments in which approximately 20,000 firebrands were produced showed a variance of ±3.0%. Taking into account the uncertainty of 5.0% in the counting process, the procedure was accepted and utilised for the remaining work.

The possible effect of the intensity of the firebrand shower on the measured penetration ratio was assessed at two intensities of 2380 firebrands.m^{-2}.s^{-1} and 6716 firebrands.m^{-2}.s^{-1} (see table 1). The intensity was increased by mounting a higher flap while the wind speed (14.5 m.s^{-1}) at the test section and the amount of leaves (to produce around 20,000 firebrands) at the ember generator section remained unchanged. The comparison of the results of the two successive experiments shows a variance of ±3.3%. Taking into account the uncertainty of the counting and the results of two consecutive experiments with approximately 20,000 firebrands at an identical intensity having a variance of ±3.0%, the effect of intensity of firebrand shower was marked as minor in the intensity range of the experiments.

Table 1 The penetration ratio (fragmentation ratio) of Eucalyptus leaves versus ember shower intensity for a square woven wire screen with porosity of 54% and opening size of 3.15 mm at wind speed of 14.5 m/s.

Exp .No	Intensity ($\frac{firebrand}{second.m^2}$)	Penetration ratio
1	2380	2.62
2	6716	2.80

Four experiments on different days were performed to estimate the possible effects of ambient conditions on the results (see table 2). The air temperature ranged from 17˚C to 24˚C and the relative humidity ranged from 47% to 73.5%. The penetration ratio showed a variance of ±6.8%.

The following main experiments were performed on different days and so ambient conditions could not be controlled. The maximum overall uncertainty of the results was calculated using the square root of mean square values. The maximum overall uncertainty was 8.9% based on 5.0% uncertainty of counting, 6.8% uncertainty of ambient conditions, 2.1% uncertainty of measuring mesh size and porosity, and 2.1% uncertainty related to wind speed measurements.

Table 2 The effect of ambient conditions on penetration ratio (fragmentation ratio) of Eucalyptus leaves for a square woven wire screen with porosity of 66%, opening size of 6.85 mm and wire diameter of 1.54 mm at wind speed of 14.5 m/s.

Date	16 April	10 June	11 June	23 June
Temperature (˚C)	24	18	17	19
Relative Humidity (%)	62.0	73.5	70.5	47.0
Penetration ratio	2.98	2.60	2.95	2.92

4.2. Effect of opening size

The impact of screen opening sizes on the penetration ratio has been investigated and the results are shown in table 3. Figure 3 indicates the experimental results and the best-fit curve which has a maximum relative error of less than 0.7% ($R^2 \approx 1$).

Table 3 The Eucalyptus leaf fragmentation ratio of four square woven wire screens with different porosities, opening sizes and wire diameters at wind speed of 14.5 m/s.

Exp.No	Opening size (mm)	Wire diameter (mm)	Fragmentation ratio
1	0.99	0.54	1.29
2	1.61	0.57	3.07
3	6.85	1.56	2.96
4	11.15	1.51	2.29

The experiments show that no firebrands remain on the arrival side of the screen after terminating the experiment, regardless of the opening size, but the number of firebrands on the downstream side and the retention time change. This observation shows that the approaching firebrands shatter into pieces and produce secondary firebrands, and these secondary firebrands, being smaller than the opening size, pass through the screen. Therefore, the

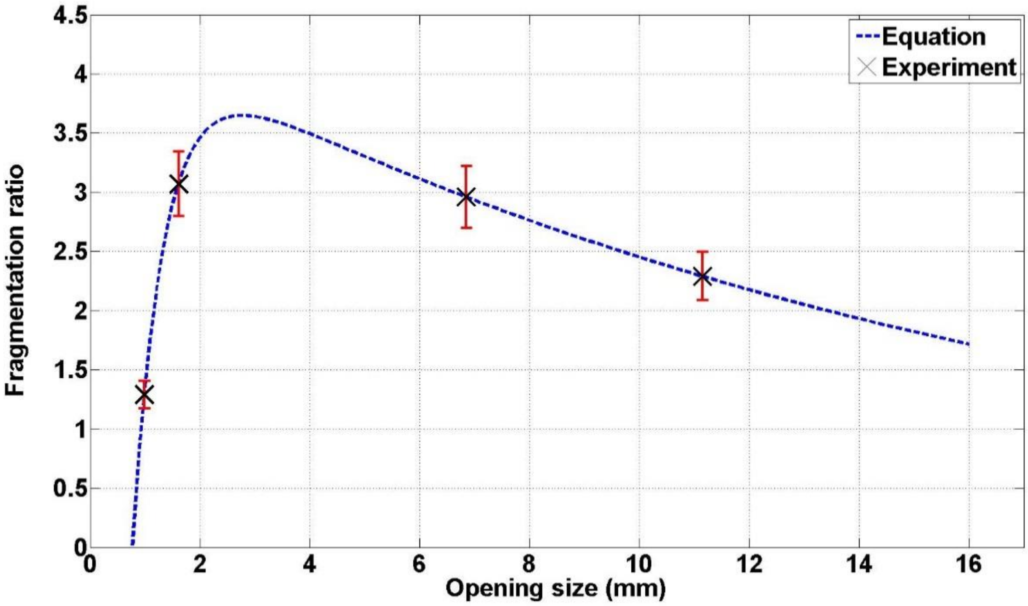

Figure 3 Eucalyptus leaf fragmentation ratio versus opening size of square woven wire screens at wind speed of 14.5 m/s.

penetration ratio exceeds one. The results show that it is more relevant to call the ratio defined in equation 1 a fragmentation ratio rather than a penetration ratio for leaf firebrands.

According to figure 3, the fragmentation ratio of burning firebrands sharply increases from 1.29 at the minimum opening size of 0.99 mm to a maximum value of 3.65 at the opening size of 2.8 mm, and then moderately decreases to 2.29 at the maximum opening size of 11.15 mm. Figure 4 has four snapshots of the videos showing the behaviour of firebrands in the test section for four screens with different opening sizes. The retention time and number of secondary firebrands for the minimum opening size screen of 0.99 mm is highest. Due to the high retention time, which gives sufficient time for a high percentage of firebrands to burn out and quench (see figure 4a), many firebrands passing through the screen are not glowing, thus the fragmentation ratio for burning firebrands is minimum. As the opening size increases, the retention time and the number of secondary firebrands sharply decreases, but a higher percentage of secondary firebrands are still burning (see figure 4b), consequently the fragmentation ratio of burning firebrands increases. By further increasing the opening size (see figure 4c), the effect of the decreasing number of passing firebrands becomes dominant and the fragmentation ratio decreases. It should be noted that the size of firebrands passing through screens always increases as the opening size increases. The results suggest that retention time is negligible for openings greater than 2.8 mm.

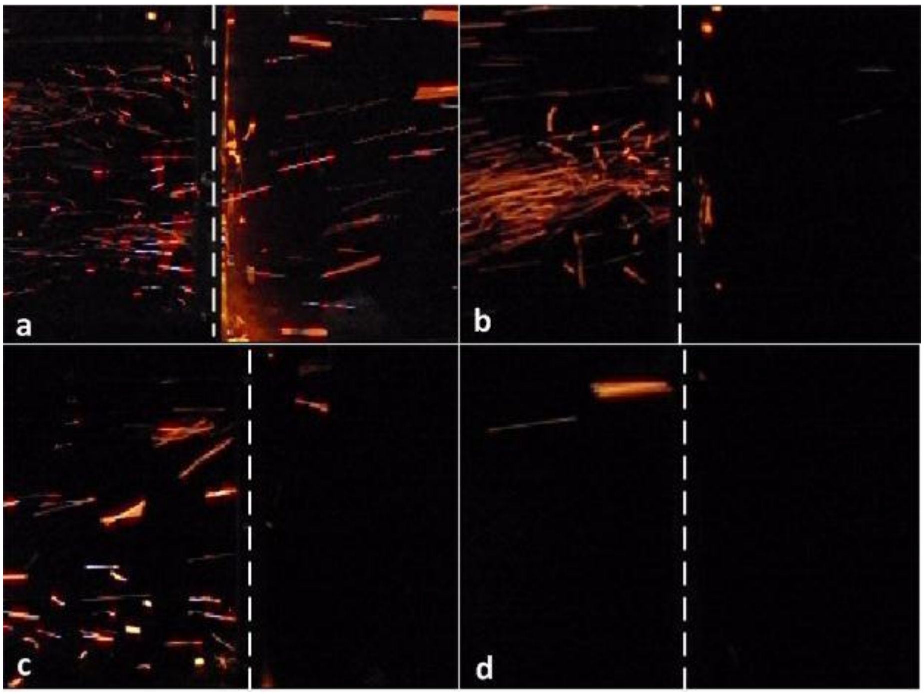

Figure 4 Four selected frames of the captured video showing approaching and leaving Eucalyptus leaf embers during the experiments with square woven wire screens at wind speed of 14.5 m/s ; a) screen with an opening size of 0.99 mm, wire diameter of 0.54 mm and porosity of 41%; b) screen with an opening size of 1.61 mm, wire diameter of 0.57 mm and porosity of 54%; c) screen with an opening size of 6.85 mm, wire diameter of 1.56 mm and porosity of 66%; and d) screen with an opening size of 11.15 mm, wire diameter of 1.51 mm and porosity of 78%.

These results are in agreement with the previous work by Manzello et al [8] that showed the retention time of firebrands (wood mulches derived from Norway Spruce trees) behind screens increases with decreases in opening sizes at a wind speed 7 m.s^{-1}. The increase of retention time leads many firebrands to reach to their burnout time before leaving the wire screen. By decreasing the opening size, firebrands remain longer behind the screen until their size fits the mesh size.

4.3. Effect of wire diameter or screen porosity

The opening size and porosity of common commercial screens increase simultaneously. In the previous section, the effects of opening size have been investigated but it should be noted that the porosity also increased. Therefore, it is not entirely clear that the obtained results are indeed due to opening size. Porosity has been reported as the key factor determining the drag force on the screen [15] and the capability of screens in limiting radiant heat flux of wildfires [16][17][18]. To break the trend between the increase of opening size and porosity, two screens with approximately the same porosity but different opening sizes were tested. The first screen has an opening size of 1.61 mm and porosity of 54.5% and the second screen has an opening size of 3.15 mm and porosity of 53.7% (see table 4). The fragmentation ratio of burning firebrands on the 1.61mm and 3.15mm screens in the conditions described in section 2 are 3.07 and 2.76 respectively.

Table 4 The Eucalyptus leaf framentation ratio of two square woven wire screens with porosity of 54% and different opening sizes and wire diameters at wind speed of 14.5 m/s.

Screen	Opening size (mm)	Wire diameter	Porosity	Fragmentation ratio
1	**1.61**	**0.57**	**54.5%**	**3.07**
2	**3.15**	**1.15**	**53.7%**	**2.76**

This result can be explained by considering the relationship of the wire diameter of screens (d) to porosity (P) and cell size (l) in the following equation:

$$P = (1 - d/l)^2 \tag{2}$$

The first and second screens have wire diameters of 0.57 mm and 1.15 mm respectively. From figure 3, a fragmentation ratio of 3.62 for the second screen could be reasonably expected if its wire diameter was equated with the first screen and consequently the porosity was increased to 71.7%. The difference between the experimental result (2.76) and the expected result (3.62) is 31.1% which is far greater than the estimated experimental uncertainty of 8.9%.

The observation showed that there are two reasons for the decline of the fragmentation ratio from the expected value. A larger diameter wire blocks a higher percentage of the firebrands and considerably increases the retention time. In addition, as their contact surface area with the firebrands is greater, they do not cause breakage of firebrands as much as thinner wires do. Therefore, wire diameter (or porosity) is a key factor influencing the fragmentation ratio.

4.4. Effect of screen type

Screens are categorised based on the way they have been woven or manufactured. The possible effect of screen types on the fragmentation ratio is investigated using two different types of screen. The first type is a woven wire screen with an opening size of 6.85 mm and porosity of 66%. The second screen is a flat screen with nearly the same opening size and porosity. The fragmentation ratios of the two screens were measured as described in section 2. Table 5 lists the details of experiments and results, and figure 5 shows snapshots of the firebrand behaviour during observation.

Table 5 The Eucalyptus leaf fragmentation ratio of two types of screens with identical porosities at wind speed of 14.5 m/s

Screen type	Opening size(mm)	Wire diameter(mm)	Fragmentation ratio
Woven	8.41	1.56	2.96
Flat	8.34	1.52	2.38

The results show that the fragmentation ratio of the flat screen is lower than that of the woven wire screen. The fragmentation ratio of the woven wire screen is 2.96, while this ratio declined to 2.38 (19.6% decrease) for the flat screen. The reason is similar to the explanation for the impact of wire diameter. Flat screens have flat contact surfaces and provide a larger contact area than the woven wire screens and thus lower the contact pressure which leads to less breakage and fewer firebrand pieces.

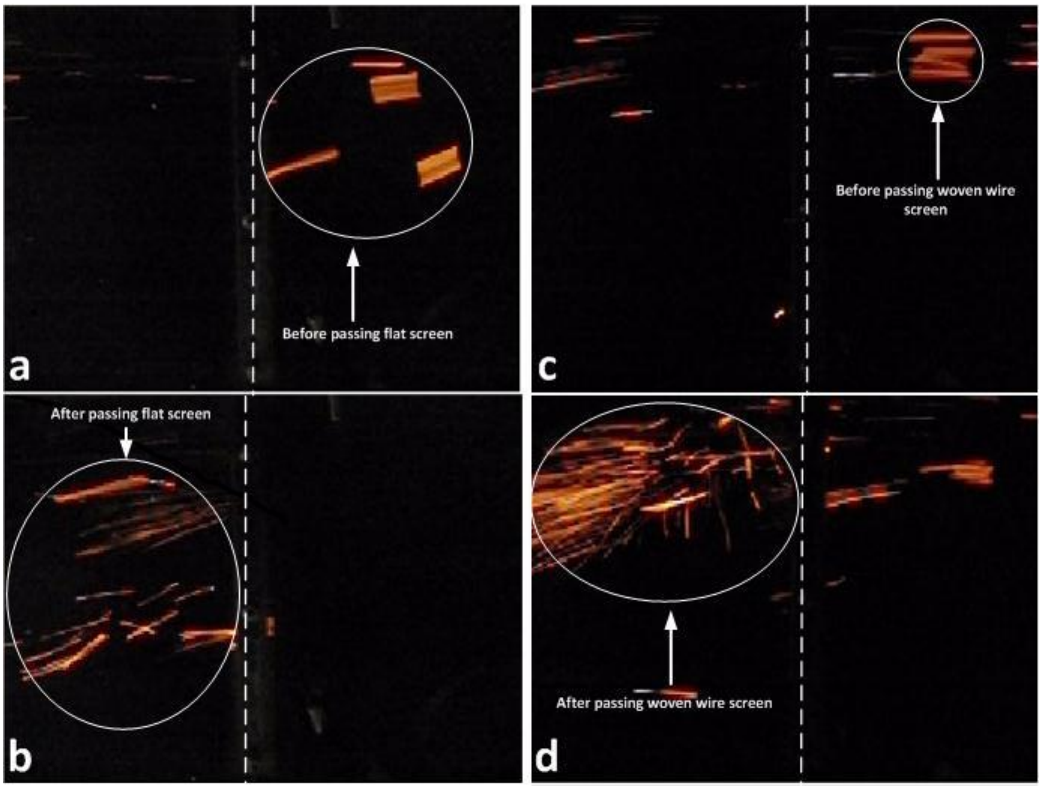

Figure 5 The photos of Eucalyptus leaf embers before and after passing through two types of screens with porosity of 66% at wind speed of 14.5 m/s; a) approaching embers to the square flat screen with an opening size of 8.34 mm and gap size of 1.52 mm; b) leaving secondary embers from the screen described in (a); c) approaching embers to a square woven wire screen with an opening size of 8.41 mm and wire diameter of 1.56 mm; and d) leaving secondary embers from the screen described in (c).

4.5. Effect of opening shape

The possible effect of opening shape on the fragmentation ratio was investigated using three flat screens with approximately the same porosity but different opening shapes: square, circular and rectangular. The square cell shape screen has a mesh size of 8.34 mm and an opening size of 6.82 mm and the rectangular cell shape screen has a mesh size of 10.5 mm × 5.35 mm with an opening size of 8.65 mm × 4.52 mm. The circular cell shape screen has a cell diameter of 9 mm and an opening diameter of 8.30 mm. The porosity of the square, rectangular and circular shape screens are 66.9%, 69.5% and 66.8% respectively. Table 6 lists the screen dimensions and measured fragmentation ratios.

Table 6 The Eucalyptus leaf fragmentation ratio of three flat screens with different opening shapes and sizes at wind speed of 14.5 m/s.

Mesh shape		Opening size (mm)	Gap length (mm)	Fragmentation ratio
Square		6.82	1.52	2.38
Rectangular	Length	8.65	1.85	2.57
	Width	4.52	0.83	
Circular		8.30	0.70	2.42

The measured fragmentation ratios show negligible changes in all three experiments. The fragmentation ratio of the square mesh shape is 2.38, it is 2.42 for the circular screen (+2.1%) and 2.57 for rectangular screen (+7.9%). The change of the ratio is less than the uncertainty of the experiment (8.9%), therefore the results are not conclusive but do suggest an insignificant effect of opening shapes on the fragmentation ratio.

4.6. Effect of screen orientation

Existing standards are set based on experiments in which wind direction is perpendicular to screens. However, in a real wildfire, firebrands do not always approach in a perpendicular fashion to the screen due to the randomness of wind direction and loose fittings of screens. As a result, the effect of screen orientation with respect to wind direction needs to be investigated.

Table 7 The Eucalyptus leaf fragmentation ratio of a square wire woven screen with a porosity of 54%, opening size of 3.15 mm, and wire diameter of 1.15 mm in three different orientations at wind speed of 14.5 m/s.

Orientation (Degrees)	Fragmentation ratio
45	1.63
90	2.76
135	2.04

A screen was inclined at two different angles to implement the experiment. The screen had an opening size of 3.15 mm and porosity of approximately 53.7%. In the first experiment, the screen was 45° leaning forward (45°) while in the second experiment, it was 45° leaning back

(135°). The experiment results are detailed in table 7 and the fragmentation ratios versus angles are given in figure 6.

The results show that tilting the screen has a significant impact on the fragmentation ratio. For the wire screen with the 45˚ orientation (tilted forward), the fragmentation ratio decreased remarkably from 2.76 for the vertical screen to 1.63 (41% decrease). For the wire screen with the 135° orientation, the fragmentation ratio is 2.04 which shows a 25% increase compared to the 45° screen and 26.1% decrease compared to the vertical screen.

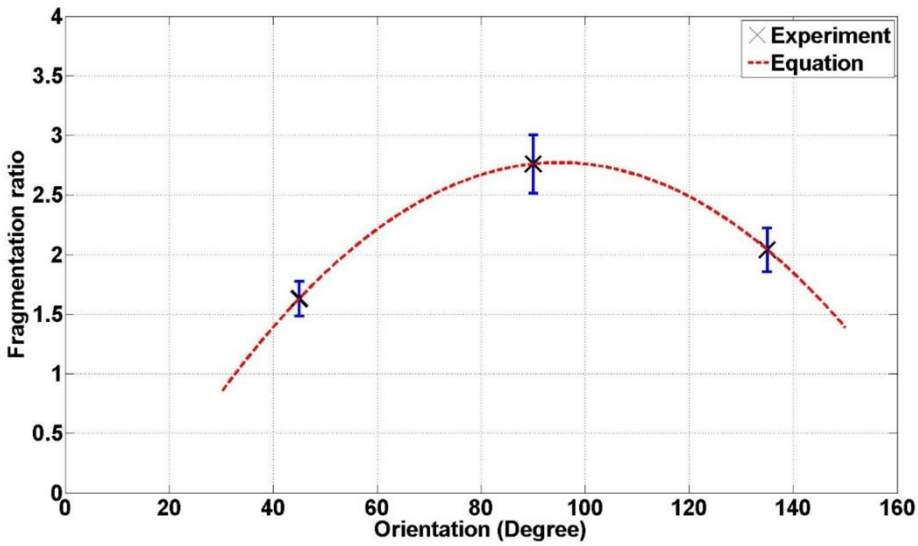

Figure 6 Eucalyptus leaf fragmentation ratio versus orientation angle for a square woven wire screen with opening size of 3.15 mm, wire diameter of 1.15 mm and porosity of 54% in wind speed of 14.5 m/s.

The reduction of the fragmentation ratio for tilted screens was further investigated by reviewing the captured videos. Observations of the 45° screen show that the number of trapped firebrands behind the screen increases in comparison to the vertical screen. The possible reasons are a decrease in the projected area of screen openings and reduction of the perpendicular wind force against the screen to push the firebrands through the screen. In addition, the observation shows that in the case of the 45° screen, some firebrands move downward and accumulate at the bottom of the screen on the upstream side (see figure 7a). These firebrands spend some time behind the screen before passing through the screen. Due to the delay, the retention time increases which gives sufficient time for some firebrands to quench. In the case of the 135° screen, the number of trapped firebrands behind the screen is similar to the 45° screen, but the firebrands are inclined to slip upward on the screen. This slippage on the screen causes some firebrands to shatter and thus find an opportunity to pass through the screen.

5. Summary of experimental results

Eucalyptus (E.Populnea) leaf firebrands show different behaviours during their passage through wire screens at a wind speed of 14.5 m.s^{-1} to wooden firebrands at lower wind speeds. Previous studies showed that wooden firebrands are captured by screens and burn until they fit the size of the opening before passing through the screen. In contrast, this study shows that leaf firebrands can shatter into smaller pieces and so secondary firebrands pass through the screen. Due to this different mechanism, the penetration ratio is interpreted as the fragmentation ratio and this has been used throughout this study. As wind force increases by the square of wind speed, it is fairly reasonable to expect a similar shattering mechanism for wooden firebrands at higher wind speeds.

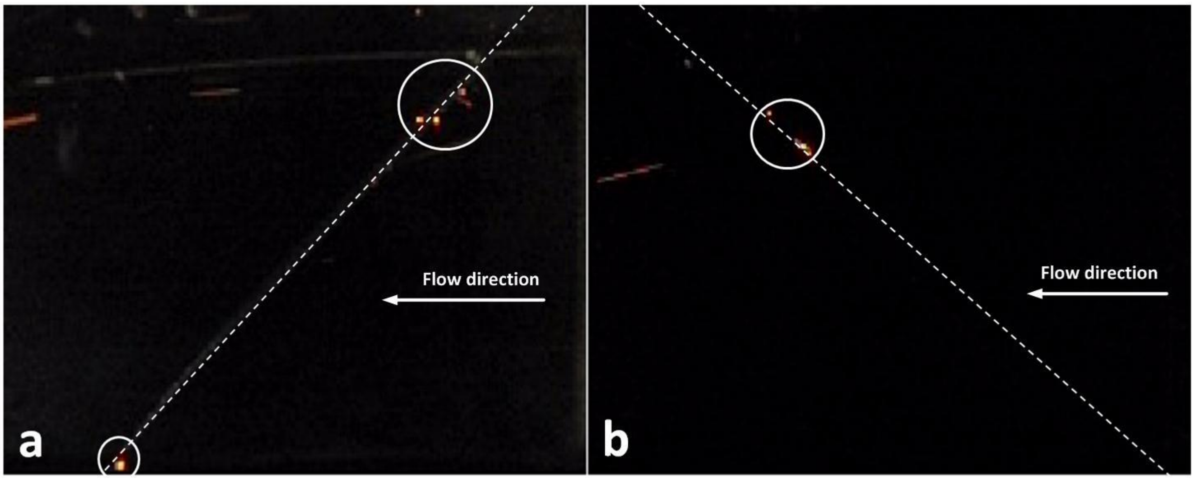

Figure 7 Two captured frames during experiment on a square woven wire screen with opening size of 3.15 mm, wire diameter of 1.15 mm and porosity of 54% in two different orientation angles; a) 45° degree orientation; and b) 135° degree orientation.

The results show that fragmentation ratio depends on two factors: retention time and the number of secondary firebrands generated once a leaf firebrand hits the screen. For screens with opening sizes less than 2.8 mm, retention time has the largest impact on the fragmentation ratio. In this range, retention time decreases as opening size increases, therefore fewer firebrands completely burn out and the fragmentation ratio increases. The retention time becomes approximately zero when the opening size exceeds 2.8 mm, and only the number of secondary firebrands influence the fragmentation ratio. The number of secondary firebrands decreases as the opening size increases and consequently the fragmentation ratio decreases.

The diameter of screen wires (or porosity) and the type of screen can have an impact on the fragmentation ratio. For two screens with the same opening, a thinner wire or a sharper wire with a smaller contact area will produce more secondary firebrands, thus the fragmentation ratio increases. It was also found that the opening shape does not notably affect the fragmentation ratio.

The orientation of firebrands with respect to screens has a considerable impact on the fragmentation ratio. A tilted screen has a smaller fragmentation ratio as the projected area and perpendicular wind force pushing the leaf firebrands through the screen decrease. A screen leaning forward has better performance in terms of fragmentation ratio than a backward leaning screen as this pushes the firebrands downward and increases the retention time. However, there is no need to revise the existing standards to compensate for the orientation of screens as they have been developed based on experiments carried out with screens perpendicular to the wind direction, which is the worst case scenario in terms of the fragmentation ratio.

6. Conclusion

This experimental work aimed to explore the influence of geometrical parameters of metal screens on their performance to reduce firebrand attacks. Eucalyptus (E.Populnea) was selected due to its high flammability and intrinsic structural vulnerability, and the experiments were performed using a variety of metal screens at a wind speed of 14.5 $m.s^{-1}$. The results show that:

1. This work identified a previously unreported mechanism of passage of susceptible leaf firebrands through screens. The shattering mechanism is also expected to occur for other types of firebrands at different wind speeds, depending on the structural strength of firebrands, screen opening size and porosity.
2. The opening size of a screen is the most effective characteristic of the screen geometry to determine its performance against leaf firebrand attack.
3. It is appropriate to include or at least to document screen type, screen porosity (or wire diameter) and maximum wind speed in some existing standards on the performance of screens against firebrand attacks.
4. Screen orientation has a major impact on performance but does not need to be included in the standards.

Screen opening shape does not appear to have a significant impact on performance as long as porosity does not change

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