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Firebrand generator system applied to wildland-urban interface research

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Abstract

The problem of forest fires in the Wildland Urban Interface (WUI) areas is increasing in all countries that have problems with forest fires. This phenomenon is well known and studied in USA, Canada or Australia.
In European countries the problem is identified and studied. In the last 50 years Portugal experienced an unprecedented rural exodus in all its history. Rural areas faced the decreasing of population every year on the one hand emigration, on the other hand young people moved to urban areas. This led to difficulties of management and increased problems related with combat of wildland fires.
The problem of WUI is growing so fast in Portugal in last decade, mainly as a result of the events occurred in 2003, 2005, recently 2012 and 2013. This problems of WUI were identified as a priority, immediately afterwards to personal safety.
Given the importance of spot fires in the context of WUI fires the Centre of Forest Fire Studies (CEIF) developed several studies to increase the knowledge on this problem.
A study of the probability of penetration of firebrands in typical Portuguese house roofs was carried out. Studies on ember aerodynamic transport and on new ignitions inside houses caused by embers. In particularly this second work about ignitions inside houses is being developed with test that involves the generation of embers in a special device designed to create embers, similar to the ones generated in a real forest fire that can transpose structural gaps of the models tested and start a new fire inside of the structure.
In order to carry out this study program a firebrand generator similar to the Baby Dragon developed at NIST by Suzuki and Manzello in 2011 was built. The original device was used in 2013 by Manzello for a similar study.

***Keywords**: wildland-urban interface, spot fire, firebrand generator, firebrand particles, burning particles.*

1. Introduction

The problems of forest fires in the Wildland Urban Interface (WUI) areas are increasing in all the countries that have problems with forest fires (Ribeiro *et al*, 2010). This phenomenon is well known and study in USA (Cohen, 2010), Canada (Cohen *et al*, 2004, 2008) or Australia (Harrap, 2004). In European countries the problem has been identified and studied (Caballero *et al*, 2007).
In the last 50 years Portugal experienced as well other Mediterranean territories an unprecedented rural exodus in all its history (Freire, 2006). Rural areas faced the decreasing of population every year on the one hand emigration, on the other hand young people moved to urban areas. This led to difficulties of management and increased problems related with combat of wildland fires. The problem of WUI is growing so fast in Portugal in last decade, mainly as a result of the events occurred in 2003 and 2005 (Ribeiro *et al*, 2010) and recently in 2012 in the south region of Portugal in Algarve (Viegas *et al*, 2012), and 2013 in Alfândega-da-Fé, Bragança district in the northeast region of Portugal (Viegas *et al*, 2013), as consequence the WUI problem was identified as a priority, immediately afterwards to personal safety (Viegas, 2008).
The situation in Portugal and Mediterranean areas and countries is quite different from the point of view of structures that could be burned. Structures are made of bricks that are not combustible and so in terms of fire the houses of this type of construction are much more resistant although they could be affected if they were not well maintained or have some weakness of constructions as gaps in windows,

doors, roofs and ventilation systems.. In the other hand many places such as USA, Canada have different types of constructions based on wood that are greatly affected by the occurrence of forest fires, despite of this they have some particularities that made is construction attractive as the low price of construction and quick time of construction or reconstruction after a fire.
It is also remarkable that despite of less construction on wood structures is not a synonym of lees problems in an occurrence of a fire many new fuels could appear in a forest fire context as the wastes drooped in the forests.
Given the importance of spot fires in the context of WUI fires the Center of Forest Fire Studies (CEIF) developed several studies to increase the knowledge on this problem. A study of the probability of penetration of firebrands in typical Portuguese house roofs was carried out (Viegas *et al*, 2008). It is not correct believe that wildfires ignite homes by the direct contact of flames on flammable surfaces, Mediterranean structures are not. It is very unusual to have a home ignition this way because of the non flammable nature of the materials.
Studies on ember aerodynamic transport and on new ignitions inside houses caused by embers transposing gaps are being developed. In order to carry out this study program a firebrand generator similar to the *Dragon* developed at NIST by (Suzuki and Manzello, 2011) was built at CEIF by Freitas (Fig.1). The original device was used in Manzello *et al.* (2013) for a similar study.

Figure 1. Firebrand Generator Device

2. **Methodology and Results**

An extensive experimental program to calibrate the equipment and to develop a methodology of test was established by Freitas (2013) for the study we have mentioned before.
The fuel particles used to generate the burning embers were pellets. Pellets were chosen because of their known characteristics of calorific value (not important in these tests), dimensions of weight and volume and their facility to burn and generate large amount of particles. Using this type of initial fuel is the best way to reach a repeatable experiment.
The device was manually fed with given amounts of fuel with initial mass (m_i). The tested quantity was considered at 300g of pellets. Greater amounts of pellets were not reflected in more number of generated particles by the device.

Other test control parameters are the gas burner pressure (p), the flow velocity that is linearly related to the radial fan velocity or frequency (Hz) and different opening gaps. Calibration tests to determine the flow of burning particles mass flow rate dm/dt for various sets of control parameters were performed.
A variation on the opening sizes sample results of the mass flow rate for different values of m_i performed with gas pressure equal to 0.3 bar and fan frequency of 50 hz are shown in figure 2.

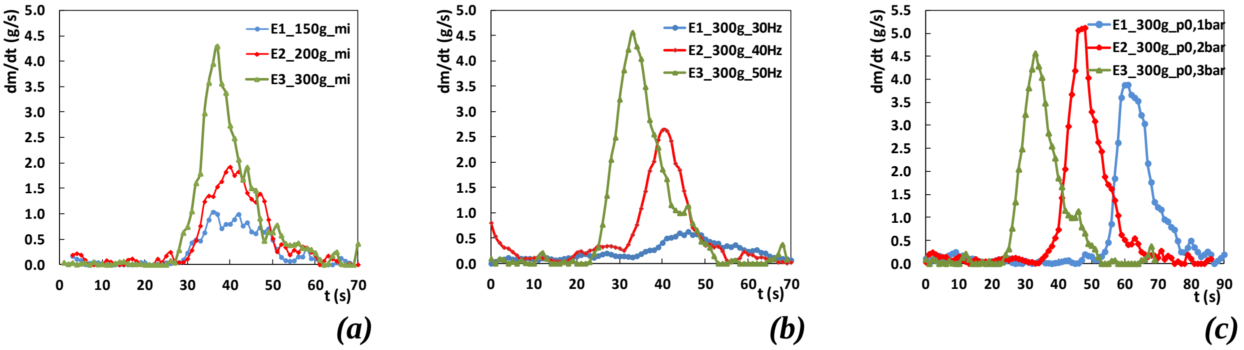

Figure 2. Plot of the rate of ember production dm/dt (g/s) as a function of time t(s). a) varying initial mass; b) varying flow velocity; c) varying gas pressure.

According to figure 2a) the duration of the shower of embers does not depend on the value of $\boldsymbol{m_i}$ but the peak value of *dm/dt* increases with $\boldsymbol{m_i}$. Figure 2b) shows that the maximum value of *dm/dt* increases with flow velocity and occurs earlier in the test. Figure 2c) show that the peak value of *dm/dt* is larger for gas pressure equal to 0.2bar and it decreases for larger or smaller values of ***p***.
In order to analyze the flow of embers through the gap created by a partially closed window or door simulating an opening in a house or building, a special structure that is shown in figure 1 was built specially for this experiment. The results of mass collected in five series of tests with vertical gap values set manually between 0 and 5 cm are shown in figure 3. The reason of choosing 5 cm is the consideration of a small but sufficient size opening to permit a burning particles cross inside the structure. The points corresponding to ***h***=80 cm Standard dimensions of a completely opened window are not shown in the figure but they are very similar to those obtained for h=5 cm A small side opening but wide enough, to the pass of particles. We consider 5 cm as a maximum threshold.
In these tests the following control parameters were kept fixed: *p*=0.3bar, $\boldsymbol{m_i}$ =100g and Frequency=50Hz. During the test the particle generator was placed always in the same position in relation to basis of the gap (from 5 to 80 cm openings). During the ember shower the particles that passed in the gap were collected in a wet surface that would quench immediately the burning particles in order to conserve their mass. After the test these particles were carefully collected and weighted. After that remaining water was eliminated by an oven process drying. The complete evaporating process of water particles took a 24 hours period. The results obtained of completely dried particles in a series of tests in which the gap height ***h*** was varied between 0.5 (almost closed) and 80 cm (completely opened) are shown in figure 3. These results show that the mass of particles collected inside the gap increases sharply for relatively small values of ***h***. For 0<***h***<3 cm the collected mass increases in average from 0 to 7g while for 3<***h***<80 cm it increases in average only to 8g.

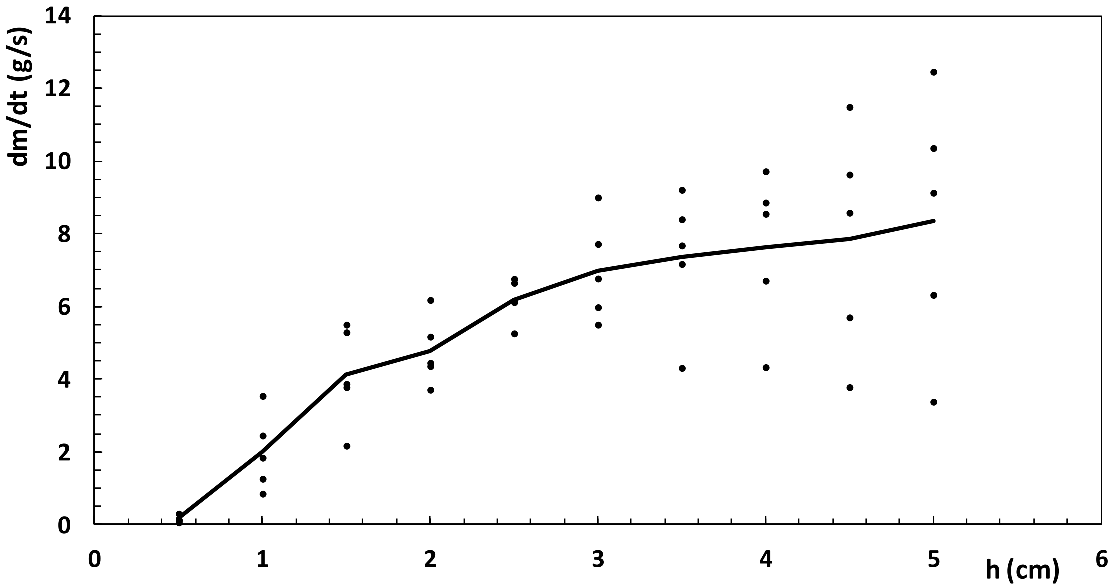

Figure 3. Mass of embers that transposed the gap as function of gap height h (cm). The continuous line is the average of five tests.

3. Further work

It is expected to extend the analysis for other particle sizes different of the ones represented in figure 4.

Figure 4. An example of firebrand dimensions obtained in the tests are showed in a 3 mm x 3 mm grid

To characterize the generated embers as a function of the feed particles properties could be used a new technique applied to the forest fires called PIV that are being used in CEIF laboratory to the study of firebrands generated by the burning of trees as showed in figure 5

Figure 5. An example of firebrand generated by the burning of trees

Particles position inside the structure can be studied as a limit parameter of an Inside Home Ignition Zone (IHIZ), the inside home fuels (curtains, armchairs, carpets) that an ember could find next to an opening like a window or a door and burn them.

We intend also to continue the experiments submitting different real structures to the tests with showers of firebrands like doors, windows and other structural weaknesses or openings that present in a real structure (figure 6).

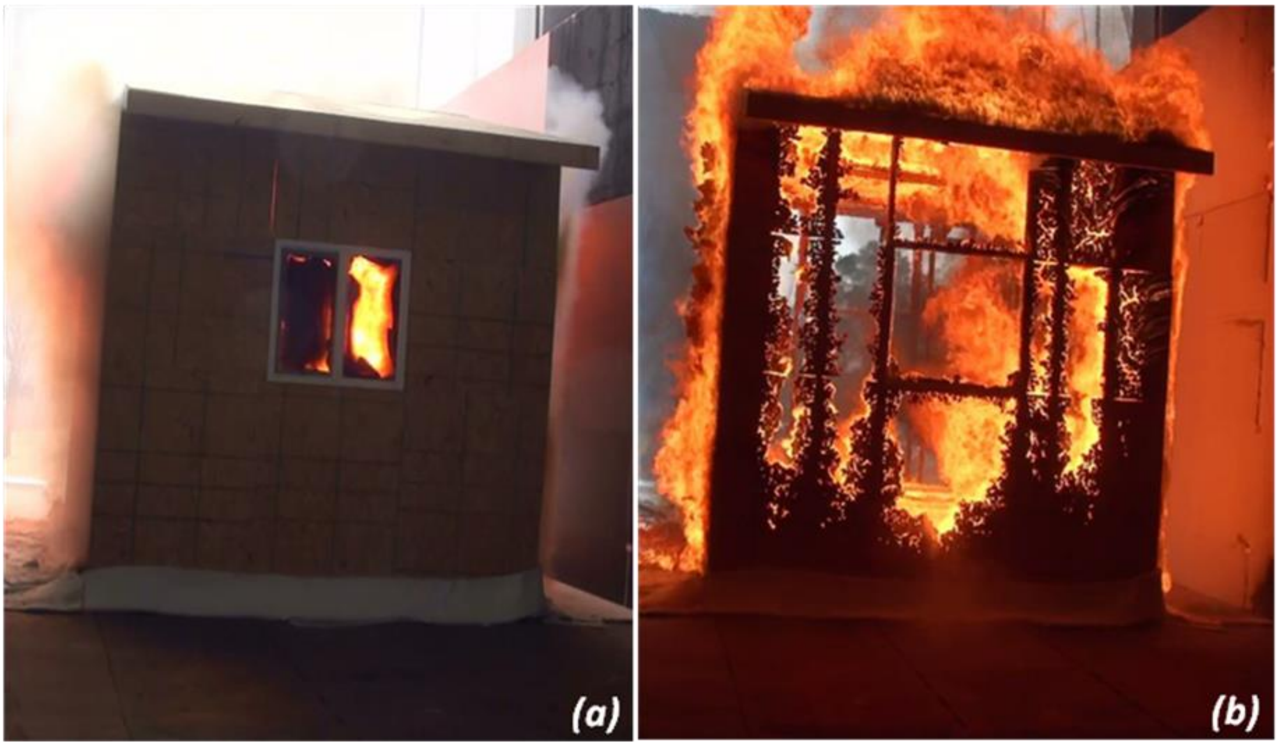

Figure 6. An example of real structures tested used in similar studies (a) after 4 minutes (b) the same structure after 10 minutes (source NIST, 2013)

4. Conclusions

This paper aims to contribute to a better understanding about the houses ignition by firebrands. Recent studies conducted in several countries that have serious problems of house ignition by firebrands allowed us to understanding the risks of houses ignitions in WUI areas.

The embers generator device installed at the CEIF laboratory allows us to lead several projects to propose mitigation measures to decrease the risk of home ignition in Mediterranean areas. This device working together with the PIV system could be a powerful tool to get reliable data about this problem such as the characterization of the generated embers as a function of the burned fuels and consequently the probability of the ignition as function of the type of the s released particle.

More studies should be effected whit the generator device to have more consistent results as gaps in doors or windows and whit real structures to testing different construction materiaisl to mitigate the problems in WUI areas.

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