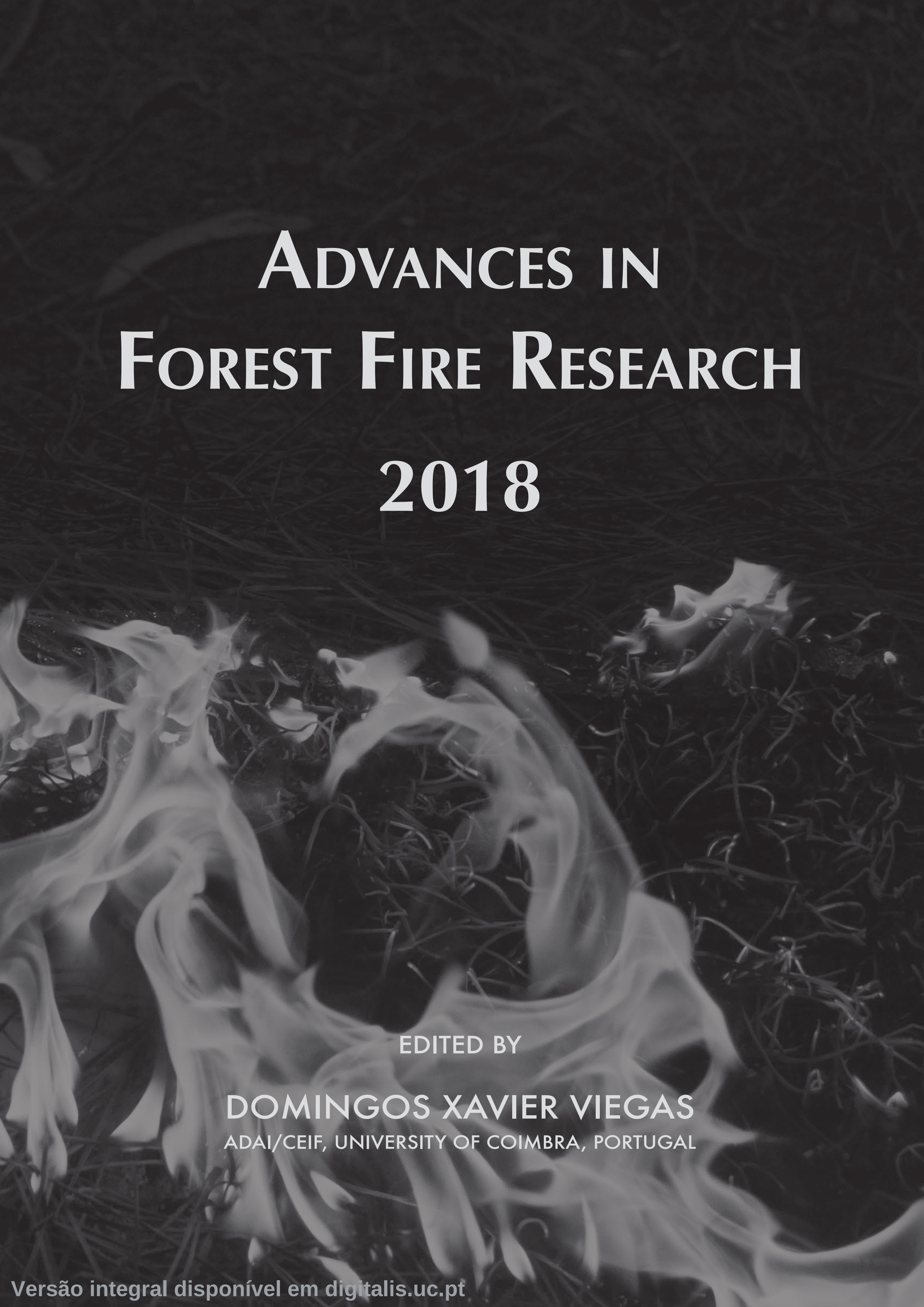

Advances in Forest Fire Research 2018

EDITED BY

DOMINGOS XAVIER VIEGAS
ADAI/CEIF, UNIVERSITY OF COIMBRA, PORTUGAL

https://doi.org/10.14195/978-989-26-16-506_45

Effects of aerodynamic lift on firebrand trajectories: Numerical investigations based on simplified models.

Hangxu Zhou[1]; Yi Li[2]; Yang Zhang*[1]

[1]*Department of Mechanical Engineering, University of Sheffield, Sheffield, S1 4DF, UK, {hzhou1@sheffield.ac.uk, yz100@sheffield.ac.uk*}*

[2] *School of Mathematics and Statistics, University of Sheffield, Sheffield, S3 7RH, UK, {yili@sheffield.ac.uk}*

Abstract

Spotting distance of a firebrand lofted in flow is an important mechanism of fire spread in large scale fires such as forest fires. Many models have been developed to study the propagation of a firebrand, but only a few focused on analyzing the aerodynamic lift on firebrand trajectories. From the modelling perspective, it is important to ascertain the relative importance of the lift compared with the drag force. However, no such study has been reported. In this paper, simplified models are developed to illustrate the effects of the lift on the maximum potential propagation distances of rectangular-shaped firebrands. The effects are firstly demonstrated clearly for non-burning firebrands. The effects of size regression and mass loss on burning-particle are then considered. A variable-thickness-burning model is developed to account for these effects. Two lift coefficient models, suitable for different Reynolds numbers, are considered. The results demonstrate that the lift force can have very significant effects on the firebrand trajectories. Using the high Reynolds number lift model, the spotting distance can be increased up to 14 times of the traveling distances calculated without the lift. Positive effects are found over whole ranges of parameters. On the other hand, when the low Reynolds number model is used, occasionally the lift can have very small negative effects, especially for the firebrands at large ambient flow velocities. By comparing with the results of variable-thickness-burning model, it is obtained that lift effects are sensitive to the inertia of a firebrand at small Reynolds and large flow velocity. Finally, for the parameters involved in this study, attempts are made to compare their importance to the effects of the lift. The main factor is found to be the ambient flow velocity which can significantly enhance or weaken the lift effects. Another main factor is the incident angle. The lift effects are strengthened at negative angles but weakened at positive ones. The lift effects are relatively weaker for higher particle density, whereas they are mostly independent of particle initial velocity. We conclude that the lift force has very significant effects on particle propagations, and should be considered in order to model extreme spotting distances.

Keywords: firebrands, trajectory, aerodynamic lift, numerical models.

1. Introduction

Spotting ignition has been found to be a significant mechanism of fire spreads since at least the 1960s (Tarifa *et al*, 1965). The flaming or glowing pieces of wood, branches, or charcoal etc., commonly called firebrands, are lofted by a fire plume and transported by wind to cause new ignition in large-scale fire. It has been shown that firebrands contribute to the spread of large-scale fires such as the 1666 London Fire, the 1871 Chicago Fire, the 1923 Tokyo Fire, the 2006 Iversen Fire, etc (Koo, 2010). The short-distance spotting firebrands, such as barks, needles, leaves and small wood particles, can continuously keep the fire spreading, while the long-distance spots, such as glowing charcoal, may result in new spot ignition which is kilo meters ahead of the main fire. The latter also is the main cause that decreases the efficiency of forest fire prevention methods used nowadays, such as firebreaks and fire resistance barriers. Predicting the spotting of firebrands is considered one of the most difficult, yet important problems in the study of fire spread, since it involves a board range of physical processes including generation of firebrands, transport, and ignition of fuel at the landing position. To predict