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DOMINGOS XAVIER VIEGAS
LUÍS MÁRIO RIBEIRO

Autonomous wildfire containment tool

Martin Hofmann*[1]; David Zenz[1]

[1]*HoZe Solutions GmbH, Bergisch Gladbach, Germany, {info@hoze-solutions.com}*

**Corresponding author*

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Abstract

Go-to strategies to contain advancing wildfires with water as an extinguishing agent can be differentiated in ground- and air-based techniques. Ground-based techniques rely on man-held nozzles connected to a water reservoir such as the water tank on a fire truck. This approach can only be used for fires with intensities below 2000kW/m above which it is deemed unsafe. For higher intensity water is dropped ahead or on top of burning materials. Recent studies have unveiled how inefficient these approaches can be. Studies characterising aerial drops make use of water rigs fitted with nozzles. We propose to scale up such mimicking devices to a novel type of appliance which can be used to contain a fire front of several hundreds of meters length. We show the typical wetting pattern obtained as well as the effective containment of fires reaching intensities above 2500 kW/m.

1. Aerial drop characterisation

Above a certain wildfire intensity, ground-based operations involving personel presence in proximity of the fire front can not be carried out. Aerial support from planes and helicopters are required. The desired effect of aerial water drops is a reduction in the fire intensity to reach levels allowing for ground crews to intervene. The efficiency of such drops on reduction of fire intensity has become the subject of critical review. Indeed, studies show that such operations are effective in only 30% of the cases.[1] Reasons for this inefficiency can be the poor control over the water distribution on the ground and the “shadowing” effect of leaf cover not allowing for the water to reach the ground with the fire progressing in still dry vegetation. A further aspect which has not been fully investigated is the turbulence occurring around an aerial drop, which can fan the wind and thus be enitrely counter-productive.

Setups have been devised to characterise aerial drops. Arrays of cups have been placed on an airstrip to obtain the wetting pattern of a certain aerial mean. This obviously has been carried out at ideal dropping heights in absence of strong wind, which can make the relationship between these idealised wetting patterns and real wetting patterns in proximity of a wildfire difficult. Models have been proposed in order to provide a basis for water distribution in fire management tools.[2] Linking the water distribution to effective containment can be achieved empirically, highlighting the critical aspect of homogeneous water distribution.[3] Indeed patches which receive less than a critical amount of water still allow for fire progression.

The critical amount of water remains surprisingly an elusive parameter. Little research has been carried out on the critical apparent fuel moisture content required to inhibit fire progression. Lab-scale experiments provide hints at certain species requiring a higher exposure to water before reaching pyrolysis temperature.[4]

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[1] Aerial Firefighting Use and Effectiveness (AFUE) Report
[2] Amorim, J. H. "Numerical modelling of the aerial drop of firefighting agents by fixed-wing aircraft. Part II: model validation." *International Journal of Wildland Fire* 20.3 (2011): 394-406.
[3] Plucinski M., Gould J., McCarthy G., Hollis J. (2007) The Effectiveness and Efficiency of Aerial Firefighting in Australia, Part 1.Bushfire Cooperative Research Centre,Australia. Report A.07.01.
[4] *Stechishen* E (1970) Measurement of the effectiveness of water as a fire suppressant

2. Wetting pattern characterisation in wind tunnel

We take inspiration of such experimental rigs with nozzles to propose a novel containment tool in itself. Such a construction can provide with well-controlled water distribution. With a given flow rate, the running time is the only parameter controlling the amount of water spent on the surrounding vegetation. Knowing the fuel type and density it should be possible to estimate the critical amount of water and thus the required running time of the system.

We carry out similar experiments to the aerial drop characterisation by arranging an array of plastic containers in a wind tunnel. A nozzle is placed laterally to the array and exposed to various wind patterns mimicking real conditions to characterise its wetting pattern on the ground. The nozzle is optimised so as to allow for a homogeneous distribution even in presence of the strongest wind attainable in the facility (3 m/s). Details of the wetting pattern are kept confidential.

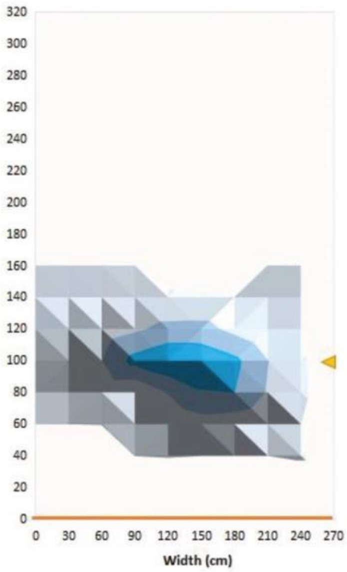

Figure 1: Wetting pattern of nozzle (triangle) over plastic container array in absence of wind.

The droplet dimension distribution is chosen so as to allow for both a wetting of the surrounding vegetation as well as to produce wind-entrained droplets of smaller diameter. This combination will allow the effective wetting of the vegetation, avoiding the “shadowing” effect. Similarly, the entrainment of droplets will allow them to wet vegetation in the general spread direction of the fire and will therefore not be wasted. The effect of increased humidity levels obtained on the extinguishment of flying embers remains to be studied. More detailed PIV analysis in presence of surface-tension modifying agents is also under progress.

3. Effective fire containment in field experiments

A series of selected nozzles is connected by the means of firefighting hoses, forming a closed loop with the single opening being connected to the water reservoir of a fire truck. The hose loop is placed in the top third of a plot of 25meters width and 50 meters length and dubbed Papageno system for the remainder. Water is then pumped at standard operational pressure. After a wetting time of 60 minutes a fire is ignited at the lower section and left to progress towards the system. Infrared images allow for the determination of the rate of spread. Similarly the flame length is recorded. Both indicators (flame lenght of 7 meters and derived fireline intensity of 2500kW/m) place the fire in an intensity regime too high to be safely contained using ground-based approaches. Upon approaching the Papageno system, the fire intensity drops and eventually is contained at the height of the system. The exact dynamics of intensity drop upon approach are still under investigation.

Figure 2: Effective fire containment using the Papageno system

4. Conclusion and outlook

We propose a novel fire containment tool consisting of a hose lenght with bespoke nozzles at regular intervals. The autonomous system allows for the safe retreat of practitioners outside of the danger zone, can operate at night and in presence of strong winds and allows for resource-efficient operations. Further field tests are required to characterise the operating windows of the system. Similarly we strongly recommend to pursue studies allowing for an effective understanding of critical amount of water as a function of fire intensity, which in turn is dictated by fuel type and density.