EXPERIMENTAL STUDY OF FOREST FIRE

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ABSTRACT

The aim of this study is to determine the influence of the four following parameters on a fire spread : voluminal mass and moisture of the fuel, slope and wind respectively in the ranges 8-40 kg/m3, 10-60%, 10-30% and 0-7 m/s for a vegetable fuel and of the wind and thickness for a hydrocarbon.

The results show that in these intervals of values voluminal mass does not play a significant role. The high moisture of a fuel delays and even stops the spread of the fire when there is no wind while the wind and the slope accelerate the spread of the flame front.

All the experiments have been performed mainly in the BEST canal but also in the TEXAID tunnel on excelsior for slight variations of the parameters. Other experiments will have to be carried out in order to verify the fire behaviour for wider intervals of values.

INTRODUCTION

This work has been achieved in the frame of the European MINERVE project.

The aim of the experiments carried out in the BEST test canal is to observe the spread phenomenon of the flame front over a vegetable fuel with respect to several parameters.

During this first study the voluminal mass, the slope, the wind and the moisture of the fuel have been studied separately.

Regarding the spread study according to the density the voluminal mass ranges between 8 and 40 kg/m3.

Regarding the study of the slope effects, four out of the eight carriages have been lifted by means of a frame and five slopes have been worked out : 10; 15, 20, 25 and 30%.

Several wind velocities ranging between 0 and 7 m/s have been tested in the tunnel for a constant mass per carriage.

Different methods for moistening the fuel have been applied to obtain fuel moistures ranging between 10 and 60%.

A study of the spread on a hydrocarbon has also been carried out in order to study the influence of both the pool thickness and the wind on the spread velocity of the flame front.

EXPERIMENTATION

Test facility

The BEST test canal : The BEST is an open test facility made up of an aeraulic module and a combustion one. The combustion module consists of two cellular concrete walls, which are 8 m long, 2 m high and 1 m apart. Between these two walls two containers have been put on rails ; they are 4 m long, 80 cm wide, 20 cm deep and subdivided into 4 comportments.

The TEXAID tunnel (Issartel *et al.* 1989) : It is made up of an aeraulic module, a combustion module whose dimensions are 0.4* 1.2 m² and a shaft module.

Experiment with a homogeneous fuel

The spread measurements have been tested with the TPH+TBP hydrocarbon (hydrogenated TetraPropylene 70+ TriButylPhosphate 30) ; it is a reference fuel for the spread in a homogeneous environment in the BEST canal.

The experimental apparatus consists of thermocouples, fluxmeters, a video camera and a heat camera. The liquid is kept in a steel container (3*0.60 m²). The experiments have been carried out for two different heights of fuel : 0.5 and 1 cm and for three winds whose intensity ranges between 0.2 and 4 m/s.

The flame temperatures are in the order of 800-900°C and do not vary with the thickness. The flame is about 1.2 m high. the flame velocity increases sharply with the wind but is stable with the thickness. The radiated heat fluxes increase markedly with the wind which tends to flatten the flame. The fuel height affects mainly the duration of combustion. The results are given in the table below :

wind intensity m/s	fuel height cm	spread velocity cm/s
0	0.5	3
	1	2.5
2	0.5	6
	1	5
4	0.5	11
	1	17

For 0.5 cm of fuel the spread velocity is slightly higher than obtained for 1 cm concerning the first two winds. However for a wind whose intensity is 4 m/s, the spread velocity obtained for 1 cm of fuel is superior to that obtained under the same conditions for a wind with half this intensity. The difference with regard to the 0.5 cm-fuel experiment is due to the outside conditions. As a matter of fact, an adverse wind of about 2 m/s had disturbed the spread and therefore has markedly decreased the velocity of the flame.

The flame spread over a hydrocarbon pool is sharply accelerated by the wind but seems to be very little affected by the variation of the fuel thickness.

Experiments with excelsior

Excelsior is a dry fuel quickly implemented.

Density (Naville et al. 1994)

Various voluminal masse ranging between 8 and 40 kg/m3 have been chosen to study the spread of the flame front with respect to the density.

The temperatures and the flame height have remained stable during all the experiments, respectively 800°C and 60 cm.

The spread velocity can be considered like the value constant : 1.5 cm/s. This constant kinetics can be attributed to a slight variation of the percentage of air trapped in the curling for the different voluminal masses.

Comparison between TEXAID and BEST

The spread velocities obtained in the two test facilities are constant whatever the voluminal mass can be. Therefore the exterior disturbances peculiar to the BEST do not seem to modify the spread phenomenon.

The velocities obtained in the TEXAID and in the BEST vary by a factor of two. This difference is not attributable to the different dimensions of the two test facilities, if one refers to the experiments carried out in Portugal by the University of COIMBRA. It must be due to the airing in the open test facility, as it contributes to the combustion reaction and consequently increases both the spread velocity and the flame temperatures.

However the flame heights remain appreciably identical.

Considering the elasticity of the curling the voluminal mass does not play a significant role during the spread phenomenon in the range 8-40 kg/m3. Accordingly a necessary mass of about 500g/ carriage has been accepted for the forthcoming experiments.

Slope

In order to study the spread of a fire over an inclined surface, five slopes ranging between 10 and 30% have been worked out by means of a frame which enables the last four carriages to be lifted.

The flame temperature and the combustion duration do not vary with the slope for all the experiments, while the spread velocity increases sharply.

The first four carriages are not lifted, whatever the experiment is. The following carriages are lifted and the spread velocity increases exponentially with the slope in this part.
Throught these velocity measurements the acceleration between the plane section and the inclined one has been calculated and shown in figure 1.
The spread velocity increases sharply with the slope, just as the radiated fluxes recieved by the fuel vary by a factor of two between the plane part and the inclined one.

Comparison BEST-TEXAID

The absolute spread velocities obtained in the TEXAID for a voluminal mass of 16 kg/m3 and a fuel moisture of 12% are similar to those obtained in the BEST.

The spread velocity of an ascending fire increases markedly with the slope.

Wind

For a constant fuel density of 12.5 kg/m3, several experiments have been carried out with winds ranging between 2 and 7 m/s.

There are important variations in the spread velocities according the the day when the experiment was carried out. Therefore the results given are in absolute velocity (figure 2).

The reference velocity is defined for every day by the spread velocity of the fire without any wind or slope for the same fuel density.

Between 2 and 5 m/s, the spread velocity increases markedly then it lessens between 5 and 7 m/s.

The spread of the flame front increases sharply with the ventilation, but there seem to be stages.

Moisture

In order to study the effect of the fuel moisture on the spread of the flame front the non-moistened curling (moisture 10%) has been tested :

. soaking of the fuel : the moisture of the curling reaches 60% (maximum moisture) and through drying it decreases to 40% ;

. night humidity : it allows the fuel moisture to reach about 60% (mainly on the surface) and through drying it decreases to 27% ;

. artificial humidity : low water contents are obtained, between 15 and 20%.

When it is not windy a humidity ranging between 40 and 60% is too high to enable the fire to spread. In order to observe the spread of the flame front with respect to humidity a wind has been added to accelerate the drying of the fuel.

The results given in figure 3 are in absolute velocity (the reference velocity is the spread velocity in the first four carriages).
The spread velocity decreases markedly in 1/x when the fuel moisture increases.

A high moisture of the fuel can strongly slow down and even stop the spread of the fire when there is no wind. This restricting factor connected with an aggravating factor such as the wind looses much of its efficiency. As a matter of fact the wind dries up the fuel on the surface.

CONCLUSION

The study of the four parameters, that is to say the slope, the wind, the density and the moisture of the fuel has shown that :

. in the 8-40kg/m3 range, the voluminal mass of the fuel does not play a significant role,

. in the 0-30% range, the slope increases the velocity of the flame spread,

. in the 0-7 m/s range, the wind accelerates markedly the spread of the flame front,

. when the moisture is 60%, the spread of the flame front stops. By connecting the humidity and wind factors, the flame spreads, even when the moisture is almost at its peak.

The behaviour of the spread velocity according to the wind velocity is similar to that observed with regard to the slope. The effects of the wind and the slope on the flame are practically identical ; they consist of flattening the flame on the fuel, thus increasing the tranfers of radiative energy for the slope case and the tranfers of both radiative and convective energy for the wind case. Therefore the results are in good agreement.

Other experiments on a larger scale of values for these four parameters will be performed in the next series of tests, in order to verify the behaviour observed during these experiments.

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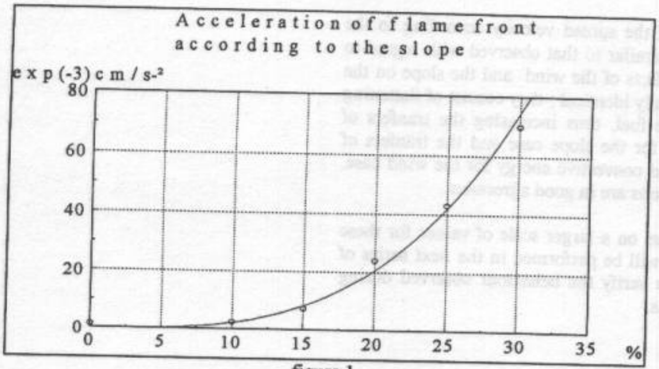

figure 1

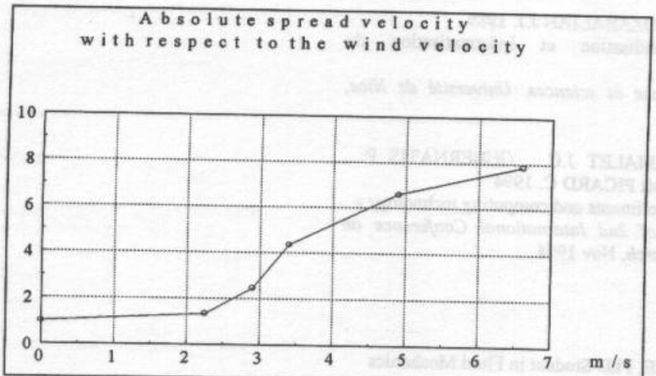

figure 2

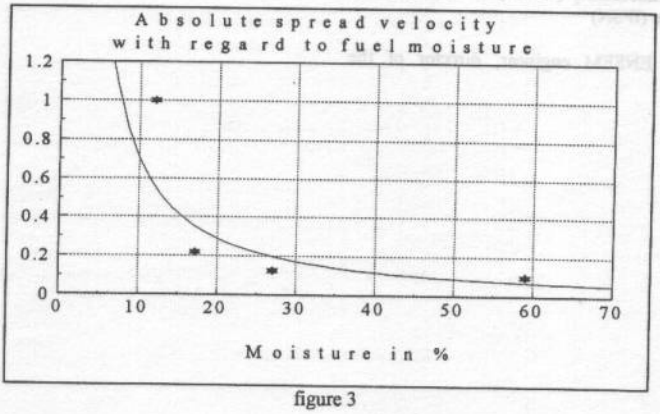

figure 3