VELOCITY MEASUREMENTS BY PARTICLE IMAGE VELOCIMETRY USING A DIRECT INTERCORRELATION ALGORITHM. APPLICATION TO THE INTERACTION BETWEEN A WATER MIST AND A LIQUID POOL FIRE.

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In the last decades, gaseous agents (halons) were widely used to extinguish fire. However, for environmental reasons, the use of Halons was progressively withdrawn and the research of an alternative appears as an important challenge. In this context, fire suppression system based on water mist is now considered as a reliable technique. Studies that were developed since 1950's [1-2] on extinguishing properties of water mist idientified three dominant mechanisms acting together : heat extraction or gas phase cooling, oxygen displacement or dilution and attenuation of radiant heat fluxes.
Although the benefit of radiant heat attenuation to the final pan or to surroundings is evident, this mechanisms has until now received only little attention and its knowledge has to be improved. It is therefore of great interest to study the dynamic interaction between the cloud of droplets and the flame. The objective of the present paper is to describe a method of analysis of tomographic video recording of the flow pattern using a PIV algorithm. The concentration and the size of the droplets entering the flame are deduced.

EXPERIMENTAL PROCEDURE

Experiments were performed with heptane pool fire. Heptane was contained in a circular steel pan 10 cm deep, with a diameter of 23 cm.

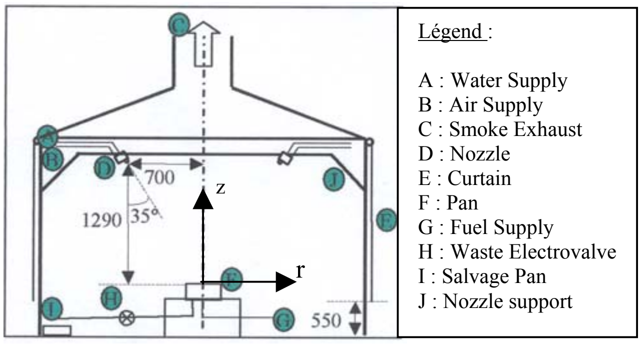

Figure1 : Experimental set-up

The water mist system consisted of three nozzles placed symetrically with respect to the flame axis (120°) and directed toward the fuel surface (Fig. 1). The applied air pressure (1 bar) and water flow (3,5 $g.s^{-1}$/ nozzle) were chosen in such a way that the fire may not be extinguished and may be maintened enough time for experimented purposes. The laser used was a double pulse Yag laser (@532 nm) giving 25 mJ/pulse in 10 ns. The laser sheet, 2 mm deep, passes through the center of the pan. Pictures were obtained with a high resolution CCD video camera (1300×1030 $pixel^2$) fitted with a lens of 50 mm (f/1.2) permitting to visualize a field of 25×30 cm. The time between two successive pictures was 2 ms.

IMAGE PROCESSING

An example of the pictures obtained is presented in Fig. 2a. It is seen that both spots due to water droplets and filaments due to the diffusion of soot particles are evidenced. To obtain information concerning the dynamic of the droplet alone, an original algorithm giving means to isolate the spots is proposed. This pre-processing is applied to all the pictures corresponding to the application of water mist.

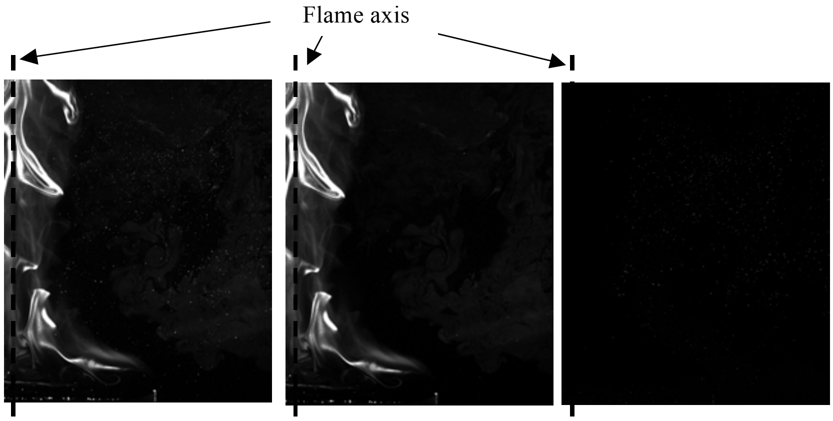

Figure 2a : Initial Image Example

Figure 2b : I_S Image Example

Figure 2c : I_G Image Example

For one of these pictures, it gives two pictures : one showing the filament of soot (cf Fig. 2b), the other only the spots due to the droplets (cf Fig. 2c). The PIV algorithm is then applied to pictures obtained from the the flame without water mist addition (reference picture), to pictures showing the filament of soot (I_S pictures) and finally to pictures showing spots dur to the droplets (I_G pictures).

The PIV calculation used is based on an direct intercorrelation algorithm, previously developed in our Laboratory by Susset and al.[3]. An algorithm is also developed for the purpose of determining the mean size an concentration of the droplets.

RESULTS AND DISCUSSION

Flame without water mist addition (reference flame)

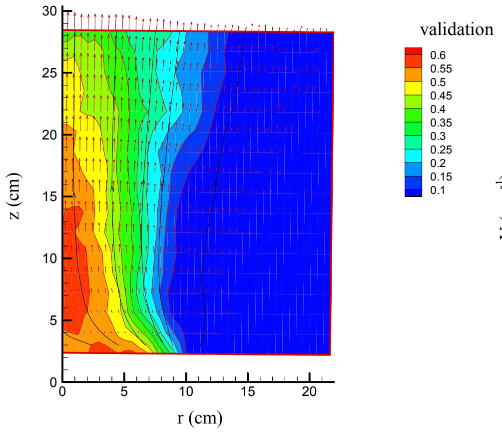

Figure 3 : Soots mean velocity field for the flame without water mist

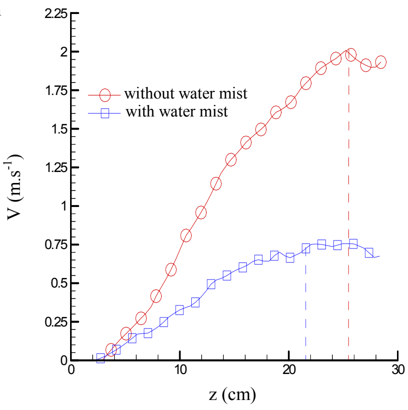

Figure 4 : Soots mean velocity versus the distance above the fuel surface on the flame axis

The overall flow velocity field is shown in Fig 3. The soot aggregates are small enough to make the assumption that the calculate velocities are representative of the gaseous flow velocity. Therefore, from the observed trend of this field, the major characteristics of the flame base structure are evidenced : chemical reaction and air entrainment near the surface of fuel and upward movement of the flame gases created by buoyancy as a result of temperature gradients.

Flame with water mist addition

-Soot correlation.

During the application of water mist, the flame loses its characteristic structure described above. The result of the interaction is a cyclic behaviour involving three steps. During the first step, the overall trend is that of a classical diffusion flame. However, due to the momentum generated by the mist produced the three nozzles, the tip of the flame is flattered. During the second step, the flame seems " explode " with randomness lateral projection of pockets of warm unburnt fuel and products. During this phase of lateral expansion, the flame is absent in its central zone with ponctually total clearance of the fuel surface. The flame looks like an annular flame anchored to the pan edge. It is during the step of expansion that extinguishment can occure : the generation of flammable vapors and the level of temperature must be reduced enough to reduce the vapor/air mixture near the surface to below the flammability limit. If it's not the case, vapor of heptane are reignited and the flame is restored (third step).

It can be seen from Fig. 4 that the soots are clearly slakened by the momentum of the spray. The cyclic expansion of the flame gives rise to an increase of the radial component of the velocity and, therefore, to an inflexion of the corresponding lines that turn on the outside of the pan (Fig.5).

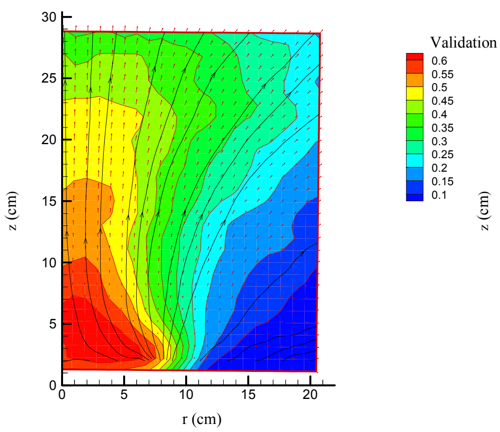

Figure 5 : Soots mean velocity field for the flamme with water mist

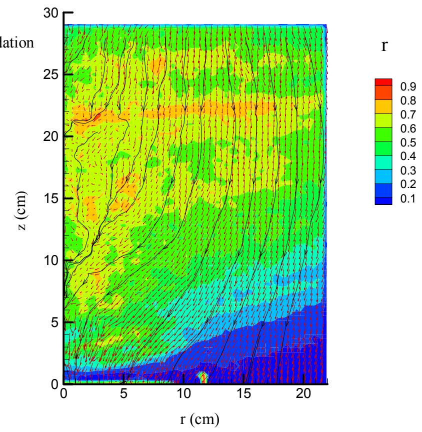

Figure 6 : Droplets mean velocity field and relative concentration of droplets for the flamme with water mist

-Droplets correlation

The overall flow velocity field of water droplet is shown in Fig. 6. It is seen that the direction of the velocity lines of the droplets is inflected outward because the conjunction of two phenomena : the puffs, described above, that add an important positive radial component which compensates partialy the negative radial component of the initial velocity and the effect of the upward movement of the flame gases created by buoyancy that deflects the water droplets from their initial direction. On the Fig.6, a variable, *r*, is showed by colour level. Its definition is $r = C/C_{\max}$ where *C* is the droplets concentration and C_{max} is the maximum of droplets concentration.

CONCLUSIONS

The aim of this work is to have a better characterization of the interaction between a water mist and a diffusion flame of medium-scale size. A PIV algorithm permitted the determination of the flow pattern (with and without water mist) and velocity of water droplet. Two original algorithms are developed : the first to separate spots due to the diffusion of water droplets from the filaments due to the diffusion of soot particles in the pictures of the flow, and the second to determine the concentration and size of the droplets.

REFERENCES

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