Infrared analysis of the interaction between fuel jet and convective hot field in counter flow conditions

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ABSTRACT

The aim of this paper was to study the interaction between fuel droplets and a hot counter air flow. Infrared imaging was employed to better understand what were the mechanisms of heat and momentum transfer that govern the self-sustaining combustion. Working in counter flow and using an IR camera evaporation and mixing, phenomena are analysed . This preliminary work allowed to recover numeric, thermal field and dynamic field in counter flow injection condition.

INTRODUCTION

The exploitation of heavy fuel oils or other not precious liquid combustibles for heat generation through conventional combustion technologies is limited *de facto* by environmental policies, since they contain heavy hydrocarbons and undesired amounts of nitrogen and sulphur, which form NO_X and SO_X during standard combustion processes in an oxygen rich environment.

Nevertheless, they are economical alternatives for power generation due to their low cost, provided that they can be used in compliance with environment protection, heavy oils constitute a major energy source, which could be used for medium/large sized heat/power generation, providing an improved and full exploitation of natural resources.

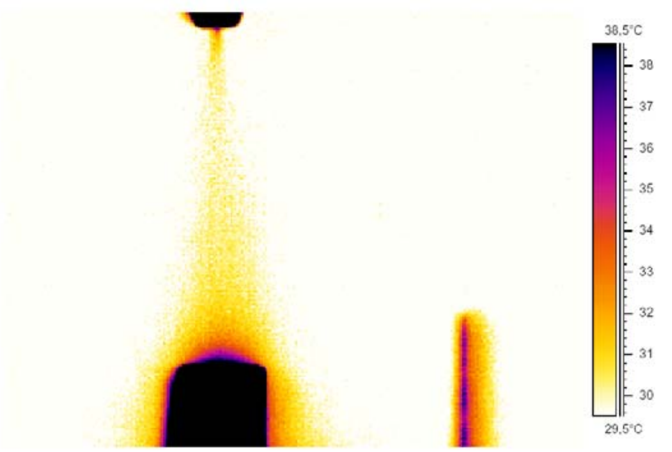

Fig.1

EXPERIMENTAL

In Fig 1 is showed the mouth of the electrical furnace generates hot air in free convection or in turbulent convection in a range of temperature until 1000. K

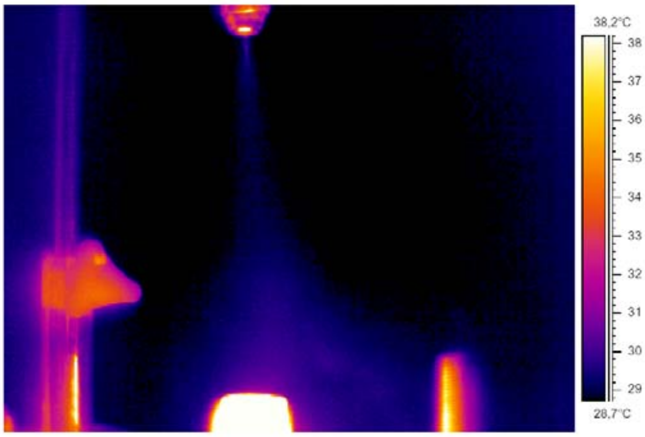

Fig.2

The fuel is injected in a convective thermal flow field generated by the furnace. The gas used in counter flow is nitrogen. This choice has be done to avoid that the thermal field was influenced by some burning phenomena, especially for high gas temperature.

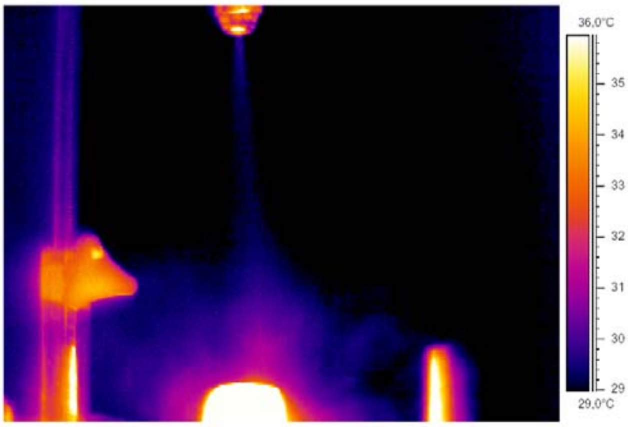

Fig.3

RESULTS

The tests are carried out working with the infrared camera. The range of diameters generated by this nozzle is [0.001/0.005 m The limit conditions of the first test are: fuel temperature T_f = 293.23 and the environment temperature T_e=373K.The pressure conditions of the air is fixed about 2 atm.

In this case the instability of the spray is due only to the stress between the droplets and the external air. The photo in fig 1 shows the behaviour of the spray in the conditions before indicated. It is possible to look the perfectly development of the entire cone spray. It is symmetrical and has an undistorted shape. The droplets arrives undisturbed until the mouth of the furnace. It is possible to notice the profile of the convective field near the mouth of the furnace. The entire jet doesn't fill the thermal convective field and the temperature is the environmental one. It is possible to note a little shadow near the mouth of the furnace In real infrared camera colours it is visible clearly and it has a parabolic profile. The parabolic profile shows that the jet doesn't interact with the thermal field because of the very little difference of temperature between the gas and the liquid phase.

The second photo (Fig 2.) represents the spray visualization with the following limit conditions : T_f = 293°K, T_{in}=723.23 K. The droplets spray now interact with the thermal convective field. The convective profile is still parabolic before of the spray impact. The

droplets spray fill the convective thermal field before than the previous case. The spray near the mouth pf the furnace in less regular. The little droplets interacting with the thermal field and begin to evaporate influencing the superior share of the liquid jet. The jet open quite symmetrically respect the vertical axis and follows the parabolic profile of the convective thermal field. Increasing the furnace temperature the interaction between jet and convective thermal field is more accentuated. The third photo fig 3 represents the behaviour of the spray when T_f = 293°K, T_{in}=800. K. It is possible to notice that the colour of the cloud near the mouth of the furnace is darker than the first one. In infrared colours the cloud the colour is red. The droplets near the furnace evaporate and a influence further the jet. In this case the mixing between the two phases is more evident. The jet begins to lose its symmetrical shape and the vapour phase became very important because influences substantially the behaviour of the spray. The velocity of the hot air due to the free convection flow field is now of 5 m/s. So the droplets are strongly applied by the counter air hot stream. The evaporation or stagnation region is 0.1 m far from the mouth of the furnace. The little droplets evaporate and begin very reactive.
Increasing the temperature of the furnace until 1000°K the presence of the convective flow field begins more important. In fig 5 the velocity of air vs. air temperature is reported

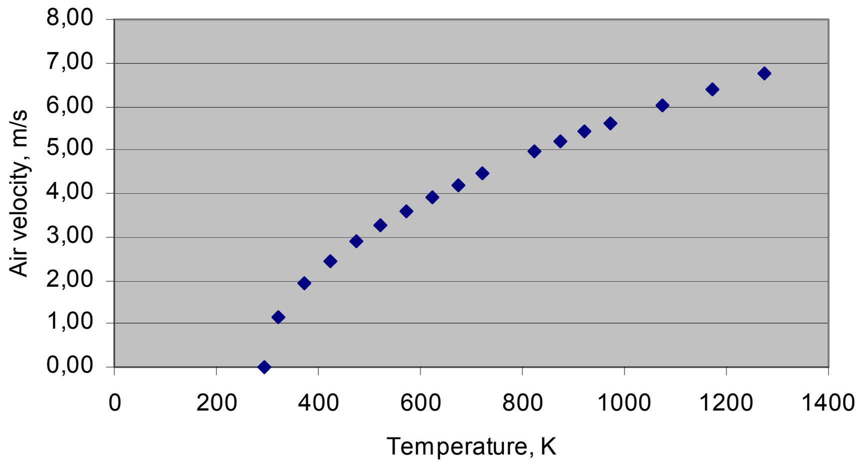

Fig.4

Near the 1000°K the air velocity is 5m/s approximately. The convective thermal field influences strongly the behaviour of the spray. Fig 5 put in evidence the new velocity profile of the thermal field. The spray fill the new conditions until the nozzle. The liquid jet increase completely its temperature. The little droplet evaporates quickly and also the big droplets begin to fill the thermal field.

REMARKS
The paper put in evidence the behaviour of the spray when injected in a free convective counter flow. Also if the application , especially in general industrial applications are few, has been considered that this analysis can be very explanatory to

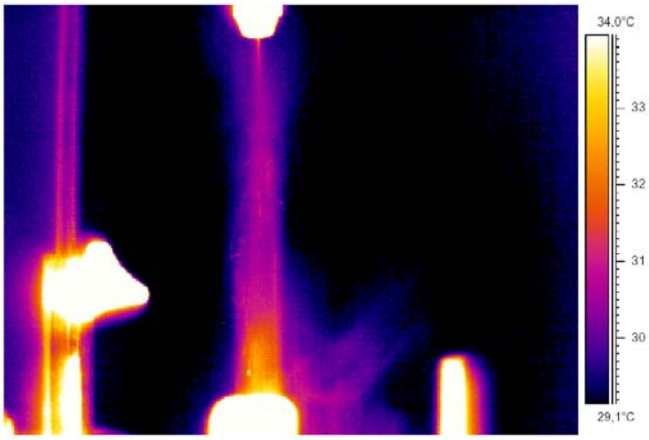

Fig.5

understand what are the mechanisms that govern the free combustion and the importance of the heat and mass fluxes inside these mechanisms. Working in counter flow conditions it is possible to reduce the area of the evaporation and burning phenomena and verify with fine precision the condition of ignition and burning phenomena. The extension of this initial work foresee to recover numeric information about size droplets, thermal field, and dynamic field, to support the choices especially in the applications for mild combustion with heavy fuel. Further more the infrared analysis put in evidence the interaction between the spray and the convective thermal field. In fig 4 is enhanced this behaviour .The spray is very sensitive to convective thermal field generated from the furnace and it is put in evidence because of the red color of the liquid injected.
This particular approach by means infrared camera is very interesting to visualize the mixing zone of spray. The infrared approach gives very important information about nixing phenomena but to follow the real develop of the interaction between spray and gas it is important to follow the typical times of the phenomena. This is possible using the high frequency infrared camera. This kind of systems will visualize also locally the interaction in spray mixing with or without flame production.

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