FLAME PROFILE IN A POROUS RADIANT BURNER USING 1/2" AND 1/4" ALUMINA'S SPHERES

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ABSTRACT

Porous burners are known by their high efficiency and low polluting gases emissions. Their high efficiency is given by the great thermal radiation potential, whereas differently a normal burner, the process of combustion happens in the inner of the porous medium, which is compound by spheres of alumina, and the mix air-fuel goes through the preheating zone, potentializing the combustion. The burners are usually used in the industry, in the process of drying of paper and wood, plastic coating, food cooking and ambient heating. In this article, it was studied the behaviour of the flame in a porous radiant burner with alumina's sphere of 1/2" and 1/4", using LPG as fuel, compressed air as oxidizing agent and ceramic wool as thermal insulation. The burner was divided in three essential sections with a type K thermocouple in each one, which are: base, middle and top. The flame profile encountered was a floating one, however it is almost stable, presenting low variations of temperature and according to previously tests, less consuming of fuel.

Keywords: porous burner, Alumina, LPG

NOMENCLATURE

°C degree Celsius

INTRODUCTION

The heating by thermal radiation has been widely used in industrial processes, such as, drying of paper, glass processing, coating treatment, room heating and food preparation (CATAPAN, 2005). The oil shortage and the environmental pollution are the biggest problems in the use of fossil fuels on large scale. While energy saved has become more important than generated, the demand for more efficient and greener energy management regimes to be deployed in industries, commerce and households has increased day by day. The porous burner has been shown to be a promising option to reduce the above-mentioned problem in both the technical and economic perspective. (MUJEEBU, 2009). According to Howell (1996), radiant porous burners offer high potential for thermal radiation and low emissions of polluting gases, such as nitrogen oxide and carbon monoxide. The burners are characterized by the high speed of the flame and great generation of thermal radiation. One difficulty of the process is the stabilization of the flame within the porous matrix by a moderate range of air / fuel mixtures, resulting in a limited relationship. Another problem to be considered is the durability of the ceramic material, which tends to break down and degrade over repeated thermal cycles.

The porous matrix of the burners is mostly built of metal or ceramic structures, the second one being the most used, and it is precisely at this point where combustion occurs. The presence of this high thermal conductivity material causes preheating of the air-fuel mixture, i.e., the mixture will be preheated before the combustion reaction actually takes place inside the burner, thereby promoting an increase in the reaction zone, which can reach values above the adiabatic flame temperature and lower emission of pollutants. (Howell, 1996). Trimis and Durst (1996) state that the reduction of pores tends to hamper the propagation of the flame through the porous medium. Knowing this, an interface between ceramics of different diameters in porous burners is used to form a barrier to the passage of the flame front. (Apud CATAPAN, 2005, page 2).

Conduction can be evaluated as the transfer of energy from the most energetic particles to the less energetic ones of a substance due to the interactions between the particles. Molecular energies are linked to temperature, so the higher the temperature, the higher the molecular energy. The molecules of a neighborhood constantly clash, and in that shock there is a transfer of energy between them, always moving from the more energetic to the less energetic ones. Convection occurs through two mechanisms, thermal energy transfer by diffusion (random molecular motion) and through the global, or macroscopic, movement of the fluid. This fluid movement (collective or as aggregates), when in the presence of a temperature gradient, contributes to the heat transfer. The random motion of the molecules in the aggregates is maintained, so the total heat transfer is a result of the superposition of the energy transport by the random motion of the molecules with the transport due to the overall movement of the fluid. Thermal radiation is the energy emitted by all matter that lies at a temperature different from zero. The energy present in the radiation field is carried by electromagnetic waves, and this in turn, does not require the presence of a material medium for its transport. (Incropera, 2014).

The heat transfer inside the burner takes place from the top to the base, at the beginning, the flame at the top of the burner radiates thermal energy to the aluminas and the metal walls of the burner. The aluminas absorb this irradiated heat and heat up by thermal conduction. After heating, the aluminas and the burner walls transfer heat energy by means of heat convection. In this type of transfer, the air-fuel mixture flows in contact with the heated surface of the alumina and consequently heats its surroundings. This cycle is repeated until there is homogenization of the temperature inside the burner.

EXPERIMENTAL PROCEDURE

The experiment was performed using data from the temperatures captured by the thermocouples, which in turn were connected to a DataTaker, a device whose function is to convert the collected data into information for a software on the computer. After ignition, the burner remained so until the flame stabilized inside it, the temperature x time graph was lifted and thus the first analysis was made. The second analysis was performed after the stabilization of the flame, and this time the objective was to observe for 1h (one hour) its stabilization. In figure 1 we have: porous burner 'a', top, middle and base type K thermocouples 'b', 'c' and 'd', gas and air flow meters 'e' and 'f' and DataTaker DT800 'g'.

Figure 1. Layout of experiment.

In Figure 2 it is possible to see which aluminas were used in the burner's inner, and their diameters on 'A', 'B' and 'C' are: 1/8", 1/4" and 1/2" respectively.

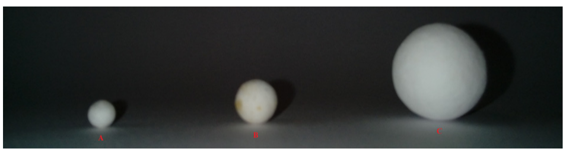


Figure 2. Diameter of the aluminas.

In Figure 3 it is possible to see a schematic of the distribution of the porous matrix inside the burner. As Hsu (1996) proposes the addition of an extra layer of smaller pores above the Flame Stabilization Region (FSR). This new layer, known as the Radiation Reflection Region (RRR) functions as a barrier, it redirects the heat radiation from the high temperature reaction zone back into the FSR. The addition of this layer of smaller pores above the FSR creates a second region of flame stability, thus causing the combustion reaction to remain in the FSR. This proposed configuration presents the upper limit of stability with higher flame velocity values than in a configuration without the RRR. (Apud CATAPAN, 2005). With this in mind, the author opted for the use of an extra layer of alumina on the top of the burner, so that there would be an increase of thermal efficiency in the region of flame stabilization.

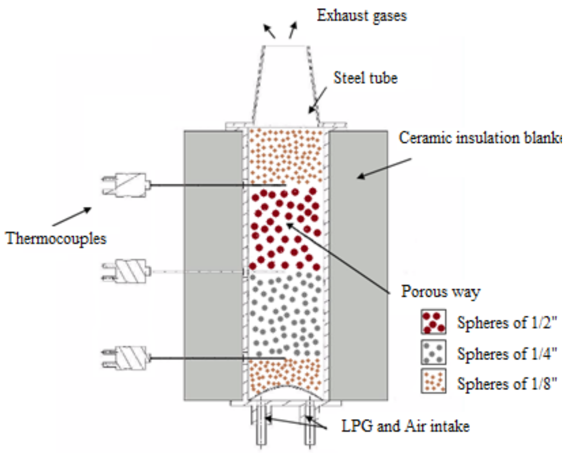
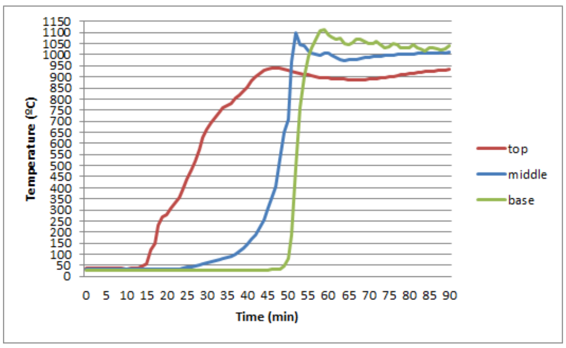


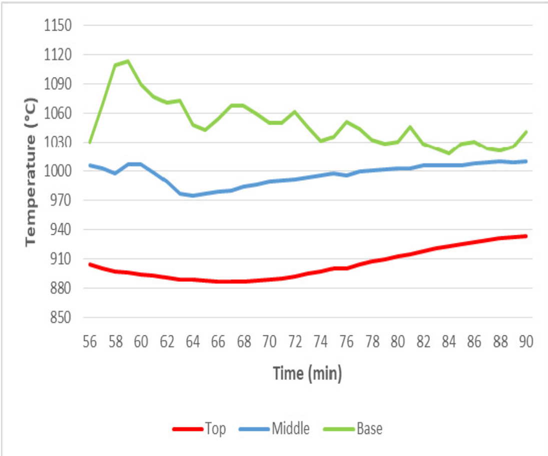
Figure 3. Porous matrix distribution adapted from REGO, 2016.

RESULTS AND DISCUSSION



Graph 4. Temperature variation in the porous medium.

Graph 4 shows the temperature variation inside the porous burner over a period of 90 minutes. The flame begins at the top of the burner, remaining for 40 minutes, after which it is immediately transferred to the middle of the burner, the temperature at the top begins to decrease, and in contrast, it is possible to see in the graph the exponential rise of the temperature in the middle of the burner. After the temperature in the middle reaches its maximum (1097 °C) and stabilizes, the same process as before occurs, the temperature in the base of the burner increases and the middle decreases, it reaches its maximum temperature (1114 °C) In a very short period of time (approximately 7 minutes). From the 65 minutes of test, the three points begin to take an equilibrium state, where the heat transfer becomes minimal, and remain so until the end of the test with low variations.



Graph 5. Temperature variation on the stabilization zone.

The most important step for this work is that of flame stabilization, Graph 5, with this graph it is possible to evaluate more precisely the temperature variations in the three points of the burner. At first sight, it seems that there is no stabilization of the flame in the burner, and in fact there is not, but the flame enters in a state of fluctuation, a state in which the heat transfers are minimal, thus being able to be said that the flame is stabilized.

The greatest difficulty of this work is from the moment the flame is ignited, where the flame is at the top of the burner and above the aluminas, until the flame enters the burner (approximately on the 16 minutes of test). The difficulty of this stage lies in the combination of the air-fuel mixture, because at first it is necessary that there is more fuel than air for the burner to ignite, and after ignition, it is necessary to have a precise control of this mixture so that the burner do not extinguish, therefore the porous burner works with a very short range of air-fuel combinations.

A thermal camera was used during the test so that it was possible to visualize the propagation of heat inside the porous burner as shown in figure 6. As mentioned above, the flame starts at the top of the burner until the 1/8” aluminas get warmer. After heating, the flame begins to migrate to the lowest point of the burner under the influence of the increase of the aluminas, following the opposite direction of air-fuel flow, until reaching the lower limit of the burner. At the end of this process, the combustion happens just above the point of injection of the air-fuel mixture, and consequently, the temperature has its apex at that point, as shown previously in graph 4.

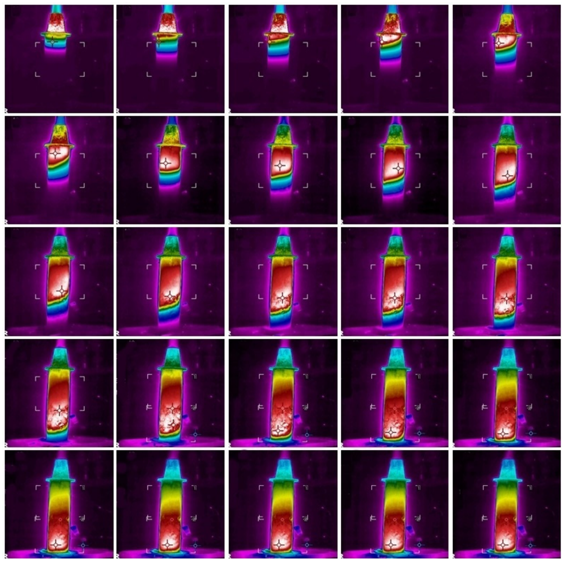


Figure 6. Heat movementation along the burner.

CONCLUSION

Therefore, it is concluded that the flame has a floating behaviour, that is, it does not stabilize in fact. However, once the heat reaches the three points of the burner, there is a very low temperature variation at these points, and such variation, with time, becomes negligible. The burner, in the current configuration, shows a great thermal potential, as it reaches high temperatures, low variations and using a rich mixture of air-fuel, thus generating a fuel economy.

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