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Thermal comparison between a domestic oven with and without alumina.

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Abstract. *This study aims to analyze the heat transfer characteristics in a Saoma Inox 5005 model, modified for the use of aluminas in its oven. According to studies related to porous burners, the use of the ceramic porous media consisting of spheres of alumina, results in a better use of the energy of irradiation of the furnace. This is due to the properties of the alumina that allow a better utilization of the irradiated thermal energy. In the test a thermal camera was used to record the heat transfer. The duration of the test with this setup was 20 minutes with the flame on and proximally 40 minutes cooling it down. It was noted that after cutting off the fuel supply to the furnace, the aluminas stored the heat supplied by the combustion for a longer time than the flat plate, therefore, proving to be a better thermal solution.*

Keywords: Alumina, LPG, Domestic oven, Porous media.

1. INTRODUCTION

1.1 Heat transfer

Thermodynamics is the science that studies the changes of systems and their related phenomenons. Some of the main variables observed by this area are pressure, temperature and conditions related to the fluid flow of systems. The temperature is, in an elementary sphere, the energy of movement of the particles, bodies with high temperatures have its molecules moving more than bodies with low temperatures. A branch of thermodynamics that focuses most on the variations of its greatness is the study of heat transfer. This area studies the transfer of thermal energy in three ways: conduction, convection and radiation.

1.1.1 Conduction

Conduction heat transfer is commonly characterized as the form of heat propagation in solids. In other words, the transfer of thermal energy between adjacent particles in the same body of mass m . One of the most widely used ways to calculate the rate of heat transfer by conduction is nothing more than interpretation of Forrie's Law.

1.1.2 Convection

Convection is the transfer of thermal energy in a system caused by the movement of the particle itself. That is, a particle of matter does not pass its energy to other adjacent to it, but rather moves itself into another position and, trivially, carries with it the energy of movement which it had with it to another location in the system. Therefore, this form of heat occurs only in fluids, because the particles that compose it can move around.

1.1.3 Radiation

The thermal radiation is the form of propagation of thermal energy in the vacuum. Also referred to as irradiation, this flow of thermal energy that occurs by means of electromagnetic waves starts from any body with temperature above absolute zero. The rate at which energy flows by radiation depends mainly on the emissivity of each body, and this

variable is directly proportional to the intensity of the flow of thermal energy transferred. The temperature of the body is another important variable to determine your radiated energy.

1.2 Porous Media

The oil shortage and the environmental pollution are the biggest problems in the use of fossil fuels on large scale (CATAPAN, 2005). 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 problems such as oil shortage and pollution from fossil fuels use 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. One difficulty of the process is the stabilization of the flame within the porous matrix by a moderate range of air / fuel mixtures. 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, this happens before the combustion reaction actually takes place inside the burner, thereby promoting an increase in the reaction zone (Howell, 1996). Trimis and Durst (1996) state that the reduction of pores tends to hamper the propagation of the flame through the porous media.

2. METHODOLOGY

For the tests carried out, the oven Samoa Inox 5-burner model 5005 from the manufacturer Esmaltec was used. For this study, none of the stove nozzles were used, only the specified oven. The valve allowing the passage of LPG to the furnace injector remained open for the entire test time, maintaining a stable flame.

Still in the oven, the plate directly above the flame was modified by opening a rectangular tear of approximately 37x30 cm in its center. First the heating and cooling tests were done with original cutted steel plate. The sheet was held in place by wires in contact with its underside. The first test was then started with the plate at room temperature. The intensity valve of the oven was kept at maximum for 20 minutes, then allowed the oven to cool to a room temperature of approximately 30°C. Next, a steel screen was installed to contain the 1/4 "diameter alumina spheres at the location where the tear was opened. To prevent excessive conformation of the web forming valleys and therefore concentration of aluminas, a steel wire of diameter of approximately 1.5 mm was woven to keep the surface of the screen as flat as possible. The tests were performed in the same way; keeping the oven at maximum power for 20 min and then observing the temperature of the aluminas until the temperature of 56 °C, when the camera battery discharged.

The pressure of the LPG line in the Combustion Technology Nucleus is approximately 3 bar or 300 kPa. Since the operating pressure of the furnace is 2.8 kPa, a pressure regulator has been installed to equalize the pressure of that fluid with the operating pressure indicated by the manufacturer. Then a pressure gauge was positioned so that the pressure of the LPG injected into the furnace could be checked.

For data collection, an infrared camera model E95 of the manufacturer Flir was used. The camera has been positioned to capture the entire exposed area of the alumina in the field of view of the equipment.

3. RESULTS

According to the values obtained during the tests, the following table was obtained:

Time (minutes)	Temperature of the flat plate (°C)	Temperature of the plate with alumina (°C)	Time (minutes)	Temperature of the flat plate (°C)	Temperature of the plate with alumina (°C)
0	30	30	31	64	191
1	232	92	32	59	180
2	377	259	33	56	170
3	403	320	34	54	161
4	407	391	35	51	152
5	426	427	36	48	145
6	456	432	37	45	138
7	457	464	38	41	132
8	433	474	39	38	126
9	458	479	40	35	119
10	462	484	41	32	115
11	461	490	42	29	111
12	455	495	43	30	106
13	439	497	44	30	101
14	461	499	45	31	98
15	460	499	46	30	94
16	460	500	47	30	90
17	447	499	48	29	86
18	442	498	49	30	84
19	447	503	50	30	81
20	448	501	51	29	78
21	289	432	52	29	75
22	221	375	53	30	73
23	177	333	54	30	70
24	145	309	55	30	68
25	122	284	56	30	66
26	105	263	57	31	64
27	93	245	58	30	62
28	83	229	59	30	60
29	76	215	60	29	59
30	70	202	61	29	58

Table 1 – Results of the plate and alumina trays temperatures Author

Table 1 shows that both plates were heated for 20 min, done that, the oven was turned off and the plates were naturally cooling for another 40 minutes. The flat plate reached a maximum temperature of 462 °C at 10 minutes of test, but remained unstable until the 20 minutes of test. After the oven was switched off, there was a drop of 159°C and the plate was allowed to cool to ambient temperature of 32°C at 41 minutes of testing. The plate with aluminas began to stabilize its temperature (495°C) at 12 minutes, reached its maximum temperature (503°C) at 19 minutes and remained high until the oven was switched off. After the oven was turned off, its temperature dropped to 69°C and the plate was allowed to cool until the end of the test (61 minutes), but did not completely cool down, the test was finalized with the temperature above room temperature (58°C).

With the values obtained in table 1 the graph "temperature x time" (graph 1) was set up, in which it is clearer to observe the values obtained in the tests. The temperature curve of the flat plate had its rise in less time, however it fell with less time, when compared to the curve of the plate with alumina. On the other hand, the modified plate reached higher temperatures, remained more constant and declined over a long period of time.

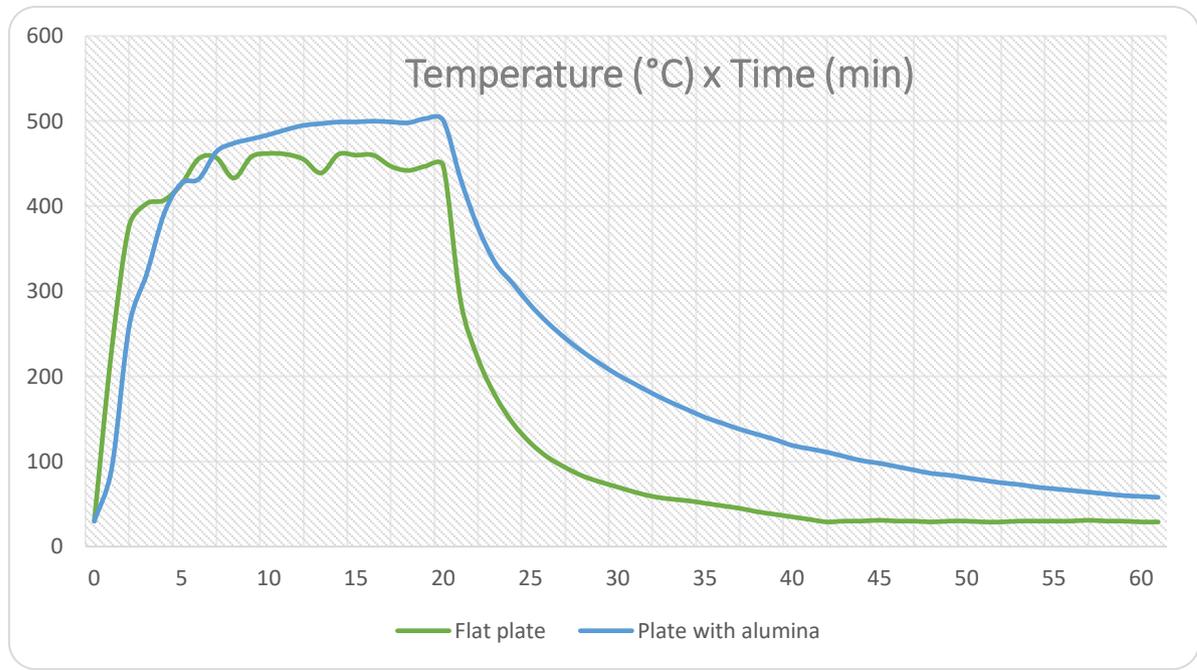


Chart 1 - Cooling of the flat plate and tray with alumina

From the test in laboratory using a thermal camera, the following heat transfer patterns were found inside the oven (Figure 1).

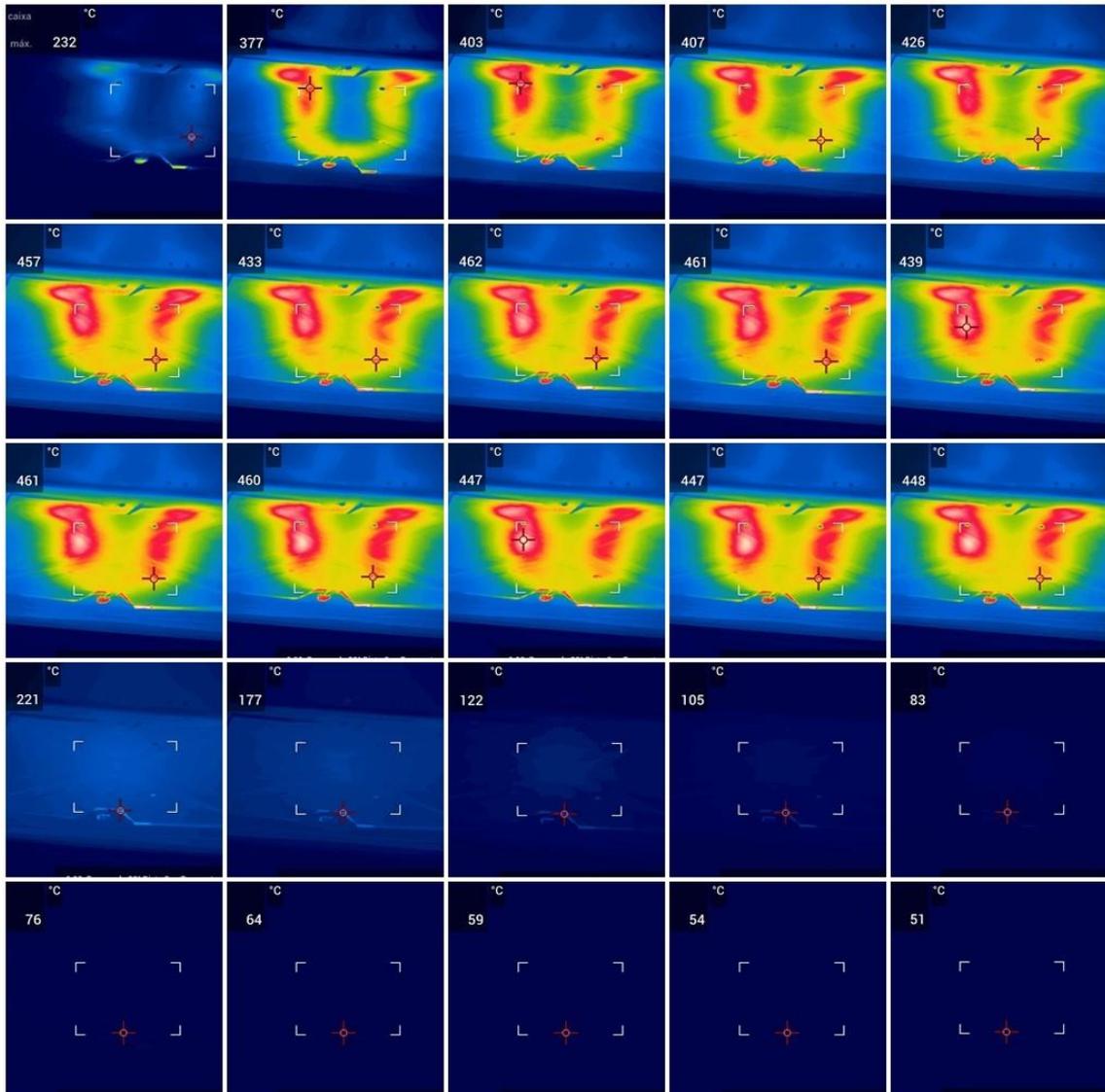


Figure 1 – Heat transfer on the Flat plate

Figure 1 shows the heat transfer into the oven using a flat plate. In it we can see the moment when the plate reaches its maximum temperature of 462°C and then it cools until it equals with the ambient temperature. It is possible to see that heat spreads over much of the sheet, due to the high thermal conductivity of the sheet steel.

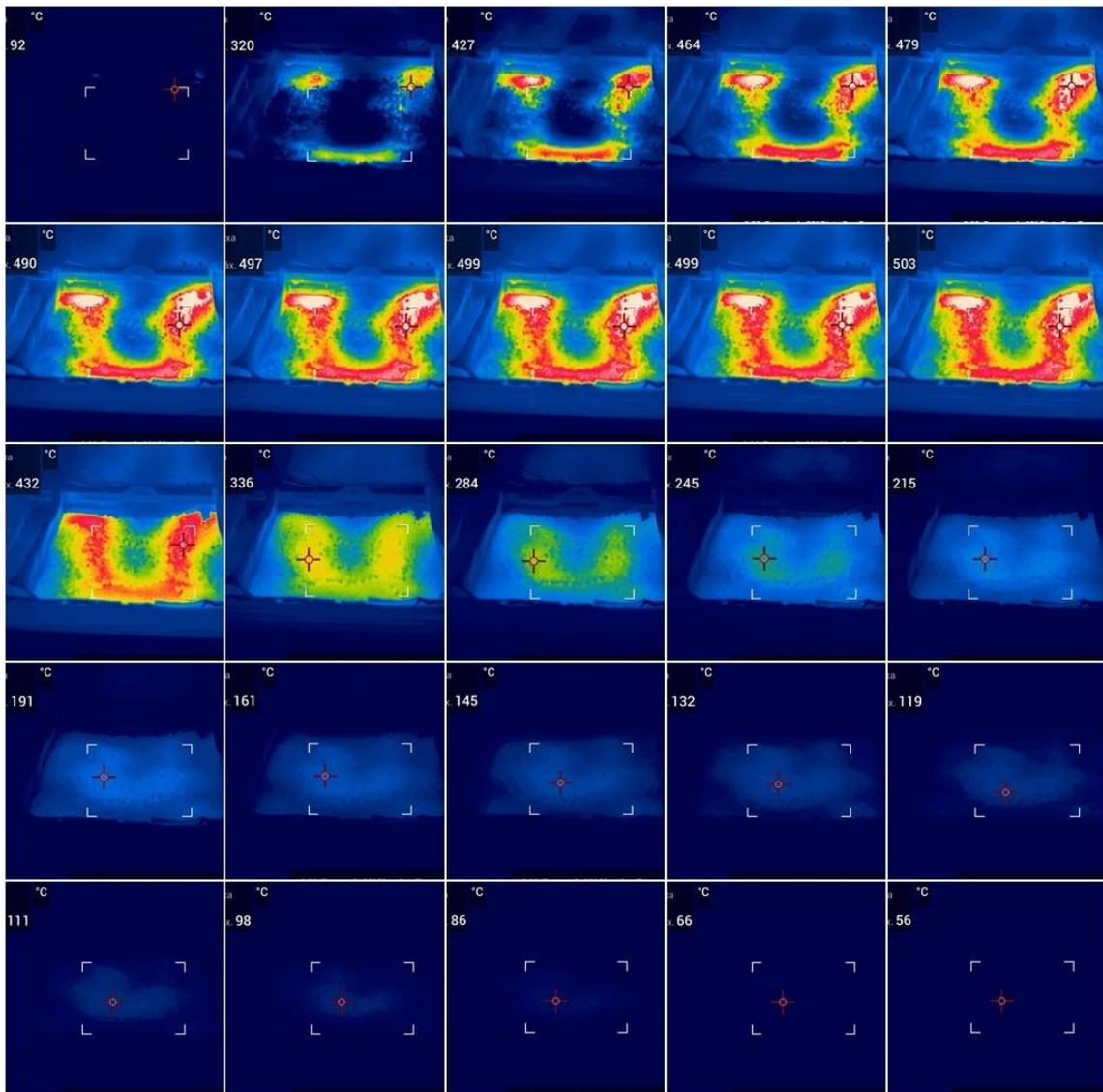


Figure 2 – Heat transfer on the tray with aluminas

In figure 2 is shown the heat transfer inside the furnace, using a plate with alumina spheres. The plate reaches its maximum temperature of 503°C and then cools (not completely) until it reaches the temperature of 56°C. In the photo you can see that the heat is concentrated in an area (above the oven's burner), and after the oven is switched off, heat is transferred by conduction to the borders of the plate.

4. DISCUSSION

The alumina is a ceramic material and stores more heat than a steel plate, therefore, the tests were realized already knowing the superiority of the oven with the aluminas. This became clear from the results found during the tests, the internal temperature of the aluminas at the 20 minutes of test was 501°C and after the oven was switched off, they remained at a high temperature for a long period (reached 101°C after 44 minutes). Elseways, the oven with the flat plate after being switched off had its temperature reduced by 159°C and reached the base temperature of 100°C after 26 minutes of test, that is, less than 10 minutes after the oven was turned off. The plate with alumina reached the same parameters as the flat plate only 24 minutes after the flame was extinguished. There is a significant increase in the total amount of thermal energy kept in furnaces with alumina, when compared to furnaces without alumina.

Another point to be discussed is the centralization of heat inside the furnace, as shown in Figure 1, we see that the higher temperature points of the aluminas are in the center of the furnace and thus remain until the end of the test, therefore the transfer properties of heat from the oven were not changed. The only difficulties encountered during the tests were the fixation of the alumina in the steel tray of the oven and the use of the thermal camera, because the tests with the camera had to be made with the oven door opened, otherwise it would not be possible to capture the images of the interior

of the oven, this caused a loss in the maximum temperature of the aluminas and an acceleration in the cooling of them, but nothing that compromised the test.

5. CONCLUSION

Taking into account the higher temperatures in the results obtained in the alumina test, its better performance, thermal and energetic utilization, it was concluded that the oven with aluminas was thermally better than the conventional oven. The thermal properties of the furnace were not altered, the zone with the highest heat concentration remains the center and the heat transfer media continues to be by thermal radiation. The adaptation of these domestic furnaces becomes an exit feasible to reduce fuel costs; small adjustments are necessary in the oven, more precisely in the steel sheet of the oven and in the temperature sensor, but the physical structure of the oven remains the same, therefore the viability of this oven is high.

6. REFERENCES

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