MELTING OF ALUMINIUM IN PULSED COMBUSTOR FIRED FURNACE

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Abstract

The paper presents an experimental investigation of the use of a locally fabricated SNECMA-Lockwood type Pulsed combustor to fire a metallurgical furnace designed for melting low melting point metals. The fuel used for firing the combustor is Liquefied Petroleum Gas (LPG) sold in Nigeria. The working space of the furnace is 290mm by 290mm by 485mm. The exit port of the pulsed combustor was fired into the Metallurgical furnace. Results showing the variation with time of the Furnace space Temperature and inner wall temperature of the furnace when loaded with aluminum scraps and when it is not loaded are presented. Also presented is the variation with time of the pulsed combustor exit port temperature. Temperature of 680°C was attained in the furnace when it was empty while a maximum temperature of 667°C was attained when it was loaded with aluminum scraps. The aluminum scrap was melted in about thirty five minutes and the molten aluminum was used to cast two small objects. The result shows that a metallurgical furnace fired with pulsed combustor could be used to melt low melting metals like Aluminum and Lead.

Keywords: Pulsed Combustor, Metallurgical Furnace, Liquefied Petroleum Gas

Introduction

The present experimental investigation uses a Pulsed combustor as a burner to fire a metallurgical furnace. Low melting point metals have been melted with furnaces using conventional burners for decades; the choice of pulsed combustor emanate from its advantages over conventional burners. Pulsed combustor is a device that uses intermittent combustion of fuel and resonance in the burner system which is in contrast to continuous combustion in conventional burners[1,2,3,4]. Such periodic combustion generates pressure, velocity and to a certain extent temperature waves propagated from the combustion chamber via the tailpipe [1,4]. One of the advantages of pulsed combustor over conventional burners is the much lower emission of NOx, CO, SOx; this results from oscillatory nature of pulsed combustion and extremely high rate/short time heat transfer process [1,4,5]. It has wide applications in the field of engineering. Its use has been recognized in propulsive devices and in generating lift required for operation of vertical take-off and landing (VTOL) aircraft [1]. Pulsed combustor as also been used for space heating in buses, tents and residences, in domestic water heating units and in hot gas generator for food drying where drying rate as much as ten times faster than those of conventional drying systems have been reported [1,4,5,6,7,8]. It has also been recommended for use in gas turbine plants because of the improvement in thermal efficiency due to a gain in stagnation pressure[1,7]. Olorunmaiye [9] in his paper recommended that SNECMA-Lockwood type pulsed combustor running on LPG gas available in Nigeria can be used as hot gas generator in drying and heating applications and probably melting of low melting nonferrous metals. This serves as the basis for the present work. Zbicinski *et al*[10] submitted their paper on pulse combustion: an advanced technology for efficient drying while Oshodi [11] worked designing a metallurgical furnace fired with pulsed combustor. Other contributors in this area are Ohiwa *et al*[12] and Salubi [13].

3. Experimental Set- Up

The set-up of the experiment is composed of:

(i) The source of hot gas

The source of hot gas for the furnace was a SNECMA-Lockwood type valveless pulsed combustor fabricated locally (Figure 1). It has an inlet diameter of 35mm and a combustion chamber diameter of 76mm. The tail pipe is 944mm long. The pulsed combustor was fabricated from stainless steel sheet of 1.5mm thickness. The combustor uses LPG gas from a cylinder which is supplied into the combustion chamber of the pulsed combustor through two multi-directional jets via pressure hose and a valve. The schematic diagram of the pulsed combustor is shown in Figure 1

(ii) The Air compressor

A two stroke reciprocating internal combustion engine (I.C.E) drives a compressor which supplies compressed air into the inlet of the combustor. The internal combustion engine compressor was manufactured by VILLIERS LTD of England with serial number 96503 and model number C.12.07.53. It supplies the initial compressed air for starting the pulsed combustor. The pulsed combustor sucks in its own air after the initial supply. The compressed air is supplied through a pressure hose.

(iii) The Furnace

The experimental rig also consists of a locally fabricated furnace. The external shell of the furnace which is made of 3mm thick mild steel, is of dimension 550mmx550mmx550mm. It was lined with insulating bricks first and then followed with refractory bricks such that the internal dimensions of the furnace are of 290mmx290mmx485mm. More details on the construction of the furnace can be found elsewhere [14]. Figure 4 shows the furnace in operation. A hole is provided at one side for the tailpipe of the pulsed combustor to supply hot gas into it.

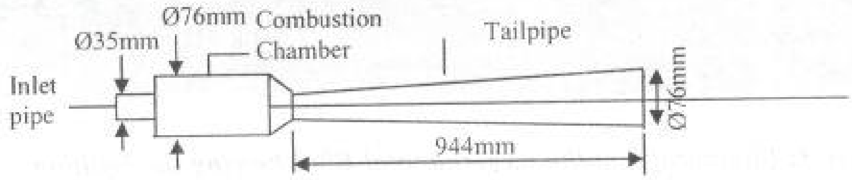

Figure 1: Schematic Diagram of the SNECMA-Lockwood Type Locally Fabricated Pulsed Combustor

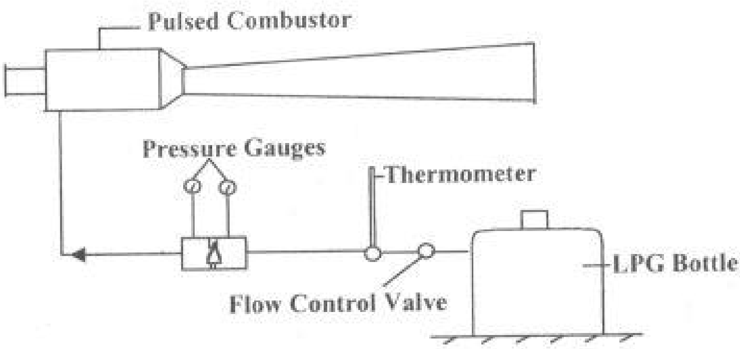

Figure 2: Schematic Diagram of the Fuel System of SNECMA-Lockwood Type Pulsed Combustor

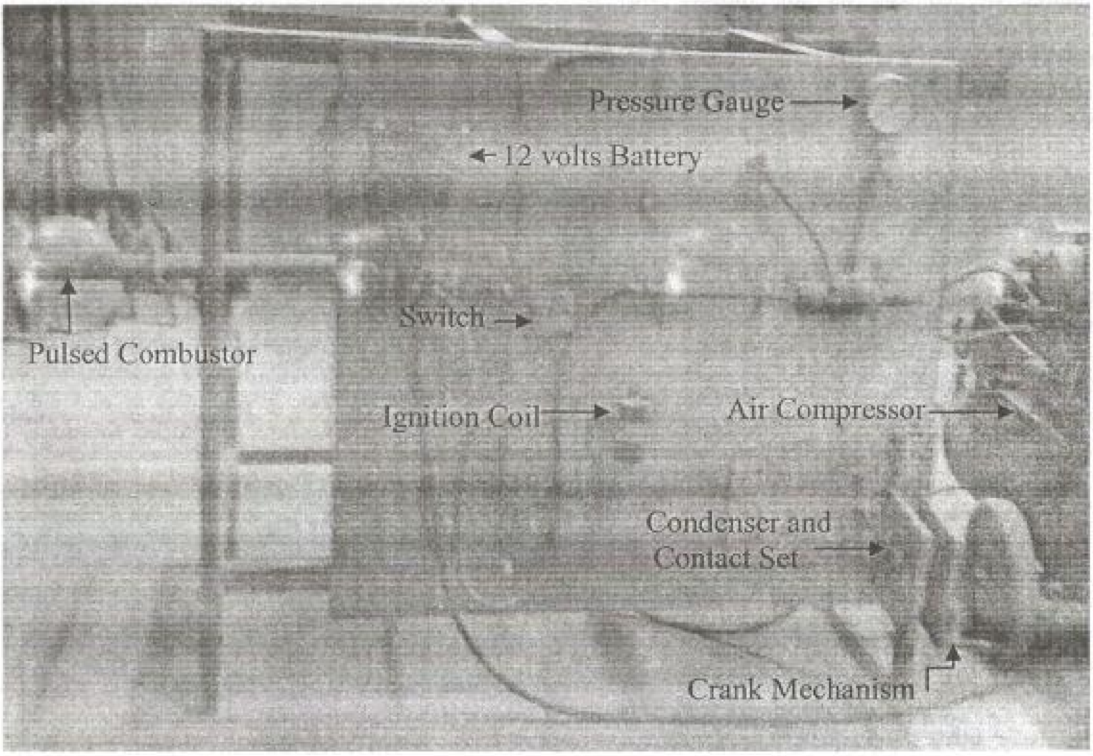

Figure 3: Photograph of the Experimental Rig Showing the Ignition System

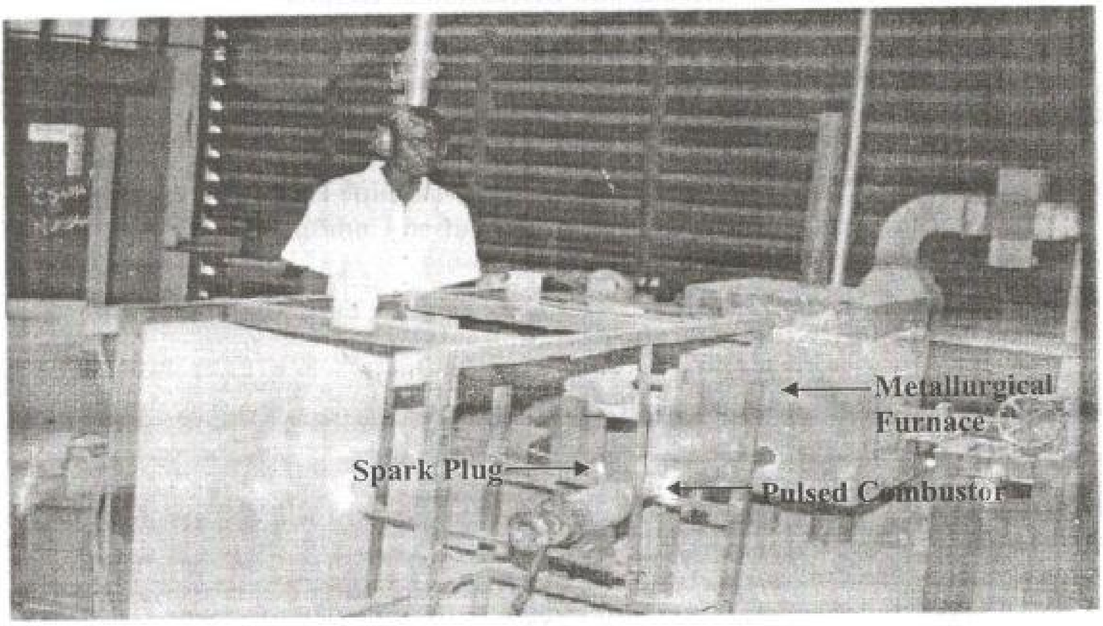

Figure 4: Photograph of the Experimental Rig Showing the Pulsed Combustor and Furnace in Operation

4. Procedure for Experimental runs

Aluminium scraps were properly cut into small pieces before they were put into the crucible of the furnace. The free end of the tailpipe of the pulsed combustor was put in the furnace before starting the pulsed combustor. The pulsed combustor was started by building up the pressure in the air cylinder to between 6-8 bars and then opening the valve of the cylinder to allow air to enter the inlet of the pulsed combustor. Spark was supplied by sparking [plug through a battery, an ignition coil and a crank which through a step-up gearing turned a six-lobed cam which opened and closed the contact set of the ignition system. In firing the pulsed combustor the first thing done was to ascertain if the sparking plug was giving out sparks as this was a safety precaution in making sure that immediately there is fuel injected into the combustion chamber there will be combustion. Fuel was the last thing introduced after the introduction of compressed air and spark. For each experiment, the weight of the fuel cylinder was measured before and after the experiments. The LPG cylinder was put in a hot water bath to keep the temperature from falling so that the pressure in the cylinder will be high enough to supply fuel to the pulsed combustor. The ignition system consists of a 12-volt YB4L – B NIKUN battery, a single standard switch, a sparking plug (long reach type), a car ignition coil, a condenser, a contact set and a mechanical cranking mechanism for opening and closing the contact breaker points. The temperature measurement was done using standard two way HH12A Chromel – Alumel Omega thermocouple with a temperature range of -5oC to 1300oC with serial number IE C 8F32 made in

Taiwan. Though pre-calibrated, it was recalibrated by exposing it to fixed points environment such as melting points of ice and boiling point of water and the melting point of lead at 327oC. The weighing was done with standard weighing scale with a range of 0-25kg with serial number 51395 manufactured by Hemel Laboratory Equipment Limited, England. The temperature of the

tailpipe gas of the pulsed combustor with respect to time was taken at the exit when it was not connected to the furnace, while variation with time of the inner wall temperatures of the furnace when loaded and when unloaded with Aluminium scraps were taken.

5. Results and Discussion of Results

The pulsed combustor was used to fire the furnace a number of times, and various readings were taken. From the readings taken it was found that the upstream pressure of the choked nozzle ranges between 1.2bar and 1.4bar while the downstream pressure ranges from 0.12bar to 0.18bar.

Table 1: Variation with Time of Temperature at the Tailpipe Exit and Inlet of the Pulsed Combustor when the Pulsed Combustor was Fired into the Atmosphere.

Time(min)	Temperature (C) at tailpipe exit	Temperature (C) at the inlet
0	28	28
2	700	470
4	710	474
6	720	520
8	728	521
10	740	523
12	743	529
14	752	530
16	779	533
18	791	540
20	804	548

Table 2: Variation with Time of Furnace Space Temperature and Furnace Inner Wall Temperature when the Furnace was Empty(unloaded)

Time(min)	Temperature (C) of Furnace Space	Temperature (C) of inner wall
0	28	28
2	559	538
4	649	615
6	652	622
8	659	632
10	660	637
12	676	642
14	676	655
16	677	656
18	678	658
20	680	660

Table 3: Variation with Time of Furnace Space Temperature, Furnace Inner wall Temperature When Melting Aluminum Scrap in the furnace

Time(min)	Temperature (C) of Furnace Space when loaded with Aluminum	Temperature (C) of inner wall of the Furnace
0	25	25
5	602	476
10	617	492
15	626	498
20	637	527
25	659	549
30	664	550
35	667	553

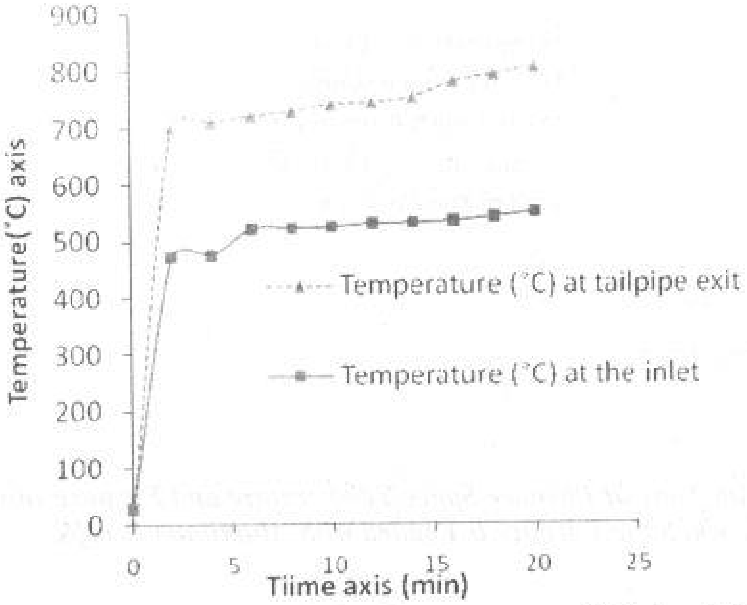

Figure 5: Variation with Time of Gas Temperature at Tailpipe Exit and Inlet Pipe of the Pulsed Combustor.

Figure 5 shows that the higher the exit temperature from the exit of the tailpipe the higher the temperature at the inlet port of the pulsed combustor. The graph also shows that the gas temperature at the tailpipe exit far exceed the temperature at the inlet.

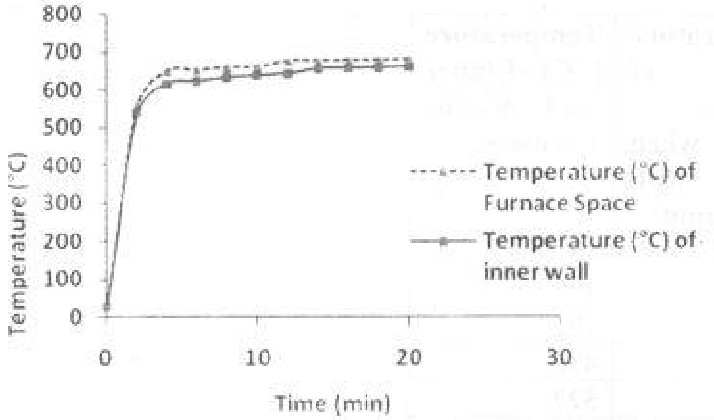

Figure 6: Variation with Time of Furnace Space Temperature and Furnace Inner Wall Temperature when the Furnace is not Loaded.

Figure 6 shows that the temperature of the furnace space is higher than temperature of the inner walls of the furnace; this is due to the fact that some of the thermal energy of the hot gas is convected away from the furnace through the furnace exhaust and the hot gas is not able to reach thermal equilibrium with the wall.

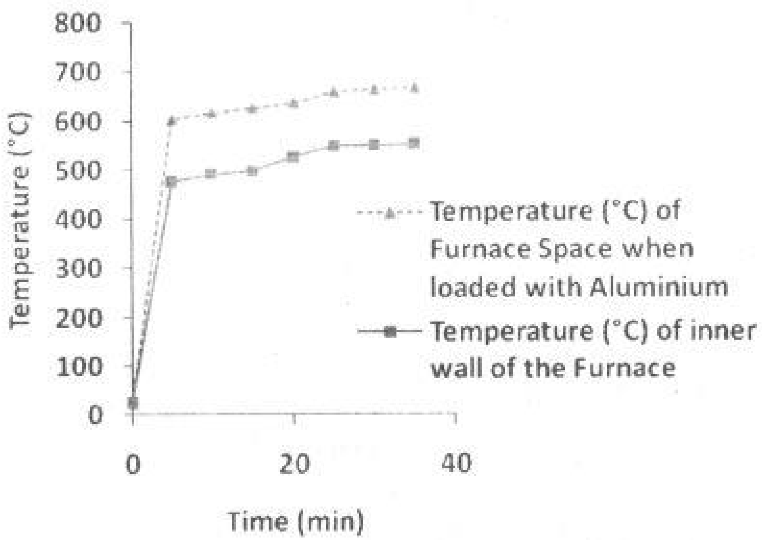

Figure 7: Variation with Time of Furnace Space Temperature and Furnace Inner Wall Temperature when the Furnace is Loaded with Aluminum Scraps.

Figure 7 also shows that the temperature of the furnace space is higher than temperature of the inner walls of the furnace when the furnace is loaded with low melting point metal. The disparity between the two is as a result of part of the heat coming into the furnace being absorbed by the crucible and the metal being melted and some of the remaining thermal energy available is convected out through the chimney of the furnace. The remaining thermal energy of the hot gas is conducted away through the walls of the furnace. It is noteworthy that the inner wall surface temperature when the furnace is loaded are lower than when the furnace is unloaded (see Figures 6 and 7).

6. CONCLUSION

A furnace that is compatible with pulsed combustor was designed and constructed. Maximum temperature attained in the furnace was 667°C when the furnace was loaded with 1 kg of aluminium scrap and 680°C when empty (unloaded). The pulsed combustor can be used in conjunction with the constructed furnace to melt low melting point metals for example, aluminium and lead. Application of load to the furnace was found to affect the temperature distribution of the walls and that of the furnace space. The application of load reduces the temperature of the furnace space and the temperature of the walls. The temperature in both the furnace space and furnace inner wall was found to vary positively with time. With a temperature of 548°C attained at the exhaust of inlet pipe, exhaust gas from the inlet can also be used to melt low melting point metals like lead.

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