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Optimization of Performance Characteristics in a Gas-Fired Furnace by Using Oscillating Combustion

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Abstract: - In this paper mainly the results of some of the heat transfer characteristics of aluminium processed in a specially designed crucible furnace at three levels of air-fuel ratios below and above stoichiometric air-fuel ratio are discussed. The tests are conducted at 90^0 of amplitude at 3Hz, 5Hz and 7Hz frequency of oscillating valve. It was designed and developed by the author describes the thermophysical characteristics of the conventional combustion as well as oscillating combustion of furnace working under normal efficiency can be improved considerably by installing new energy-efficient technologies. Oscillating combustion technology is an essential technology not only the impact of the aluminium to undergo a phase transformation in the furnace but also the potential to improve thermal efficiency. Oscillating combustion improves both in specific energy consumption (SEC) and thermal efficiency of the furnace. Energy conservation measure is a foremost phenomenon in the heat transfer industries.

Keywords: - Specific Energy Consumption, Heat Transfer, Thermal Efficiency, Oscillating Combustion Technology.

INTRODUCTION

In recent years a pretty number of research investigations have been performed while dealing with heat transfer of furnaces, particularly in oscillating combustion technology. The scientific research in the oscillating combustion technology mainly includes few parameters such as utilization of different frequencies, air-fuel ratios, loads, and amplitudes to improve the heat transfer of furnaces. In view of the economy and environmental impacts of energy utilization, most of the heat transfer industries such as glass plants, steel mills, foundry processes, forging shops, and furnaces are focusing on energy-efficient strategies and implementing new technologies [1]. High-temperature, natural gas-fired furnaces, especially those fired with preheated air, produce large quantities of NO_x per ton of material processed. Regulations on emissions from industrial furnaces are becoming increasingly more stringent.[2]. Oscillating combustion is divided as autonomous pulsating combustion and forced oscillating combustion of oscillating fuel flow rate using an oscillating control valve. Autonomous pulsating combustion has the limits of high noise and narrow turndown ratio. However, forced oscillating combustion can be controlled the oscillating frequency, amplitude, and duty ratio and so, it can overcome the limits of autonomous pulsating combustion [3]. Oscillating combustion technology is an innovative and simple process employed to study its influence on the thermal boundary layer, requires an oscillating valve to be incorporated on the path of fuel flow to create oscillations. [4]. Approximately 65-90% of total refineries energy for heating is provided by furnaces [5]. Investigation of melt flow characteristics is nearly impossible even in pure Aluminium due to a lack of velocity probes able to work reliably at increased temperatures. A model experiment with relatively low power consumption and in the low-temperature range has been carried out with liquid Sodium as a liquid metal. [6]. Natural gas is an indispensable resource in today's world which is used in many different ways in a multitude of end-use applications all over the world. It is used to provide heat for residential buildings and serves as a fuel for power generation in gas turbines and engines. In the chemical industry, natural gas is used as a feedstock (for example in hydrogen or ammonia production), while many thermal processing industries (e.g. the metals, glass or ceramics industries) rely on gas to provide process heat for manufacturing processes. [16].

EXPERIMENTAL PROCEDURE

Experimental investigations on the oscillating and steady-state combustion were carried out on gas-fired crucible furnace. A butterfly valve was used to oscillate the fuel by which alternate fuel-rich and fuel-lean zones in the flame were created during oscillating combustion. The air-fuel ratios were varied by adjusting the pressure regulator of the CNG gas. The air-fuel ratios were calculated at different velocities of the gas, and by keeping the air, velocity kept constant. Initially, the experiments were conducted on the conventional (steady-state) mode of combustion. The data recorded during both conventional and oscillating combustion modes of experiments were used to evaluate the temperature distribution, heat transfer, fuel consumption, specific energy consumption, melting time and efficiency for the air-fuel ratios of 16:1, 17:1 and 18:1.

METHOD OF OPERATION IN THE FURNACE

Experimental investigations were conducted in a medium-sized crucible furnace at 5kg, 10kg, and 15kg of loads. Test set-up consisting of the compressed natural gas (CNG) cylinder with pressure regulator, butterfly valve, blower with DC motor, manometer, and temperature indicator with thermocouples. The CNG cylinder pressure is of 200 bar, and it can be reduced by a regulator to 0.7. The butterfly valve would operate at 3 Hz, 5 Hz and 7 Hz by adjusting the DC motor speeds by the assistance of the pulse width module (PWM). With the help of Manometer readings, we can calculate the velocity of air, blower running with constant speed. The air-fuel ratios which are 16:1, 17:1 and 18:1 measured by varying the fuel velocity.

RESULTS AND DISCUSSIONS.

PERFORMANCE OF THERMAL CHARACTERISTICS IN THE FURNACE

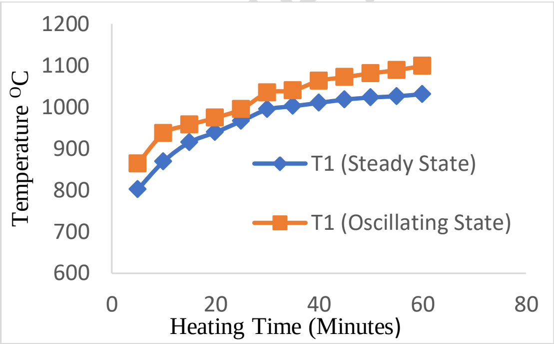

Figure 1. The plot of Heating time and Temperature for T_1

Fig. 1 shows the temperature distribution during melting operation of loads inside the furnace at point T1. Oscillating combustion mode of operation shows an increase in the temperature magnitude than the steady-state mode of operation. It is showing maximum difference prevails to the point the furnace attains steady-state and high radiant condition.

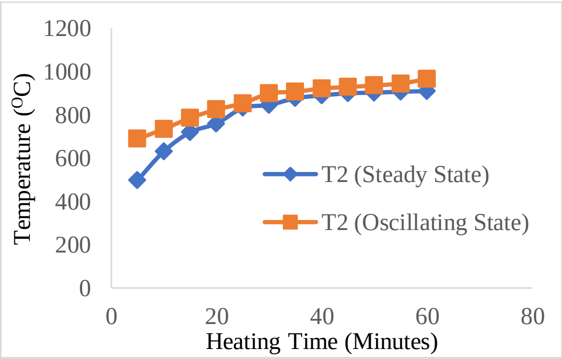

Figure 2. The plot of Heating time and Temperature for T_2

Fig 2. Shows the graph between heating time and rise in temperature at different intervals. For the oscillating mode of combustion it can be seen clearly that rise in temperature at short duration is more than steady state and falls in line almost at later stages. However, the temperature recorded in an oscillating combustion mode must have to confirm that the process operation of melting the aluminum due to increased heat transfer and thermal conductivity in the load.

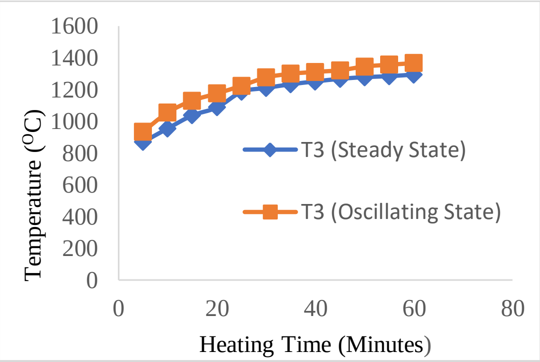

Figure 3. The plot of Heating time and Temperature for T_3

The Fig 3 shows there is small variation in temperatures for T3 during both modes of combustion. This may be due to the optimum absorption of heat energy by the load during melting process and the exit flue gases containing less thermal energy.

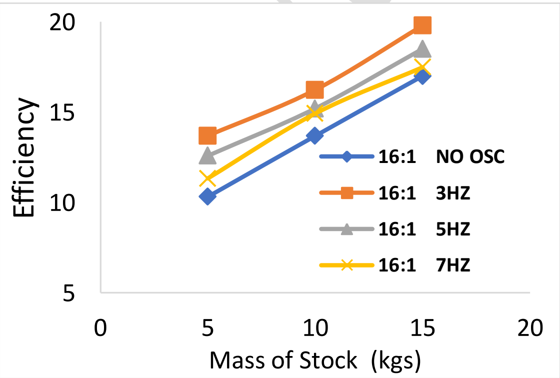

Figure 4. The Relationship between the Mass of the Stock and Efficiency.

The plot between the mass of the stock and efficiency, as shown in Fig 4. The Figure shows steady-state and oscillating combustion at 90^0 amplitude and at different frequencies such as 3Hz, 5Hz, and 7Hz, and at a rich air-fuel ratio is at 16:1. It has been noticed that the efficiency of the oscillating combustion technology is a little bit more than the steady-state combustion from the above-cited observations. In oscillating combustion technology, the valve, which creates the fuel-rich and fuel been zones causes the breakup of the thermal boundary layer, due to its thermal energy transfer to the load significantly more than the steady-state mode of operation.

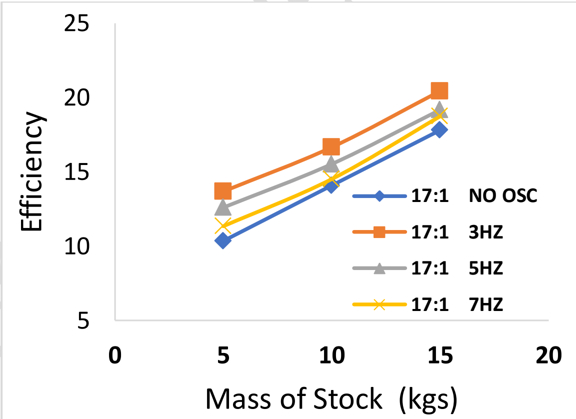

Figure 5. The Relationship between the Mass of the Stock and Efficiency.

The plot has been drawn at steady-state and oscillating combustion at 90^0 amplitude and at different frequencies, such as 3Hz, 5Hz, and 7Hz, and at a stoichiometric air-fuel ratio of CNG is at 17:1. It has been noticed that the efficiency of the oscillating combustion technology is a little bit more than the steady-state combustion. In oscillating combustion technology, the valve which creates the fuel-rich and fuel-lean zones, which are imperative essential to the breakup of the thermal boundary layer due to it, thermal energy transfer to the load significantly more than the steady-state mode of operation.

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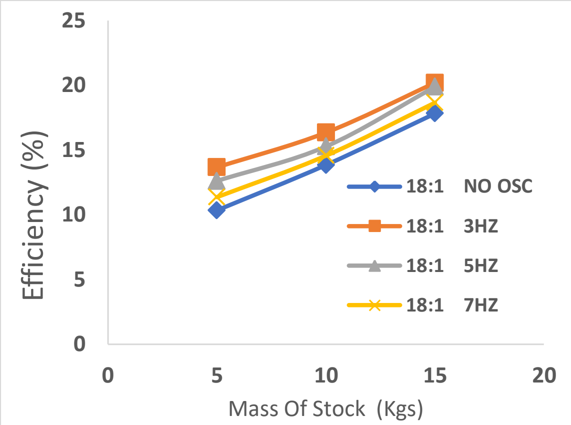

Figure 6. The Relationship between the Mass of The Stock and Efficiency.

The plot between the mass of the stock and efficiency, as shown in fig 6. It shows at steady-state and oscillating combustion at 90^0 amplitude and at different frequencies, such as 3Hz, 5Hz, and 7Hz, and at a lean air-fuel ratio of CNG is at 18:1 air-fuel ratio. The efficiency found to be greater in oscillating combustion technology as compared with the steady-state combustion mode. This is a slight increase in efficiency at lower frequencies as compared with the higher frequencies the efficiency is less and reaches the steady-state combustion mode (conventional combustion). The efficiency of the furnace is found to be more, which is higher than all the efficiency at different frequencies and the air-fuel ratios and all the loads.

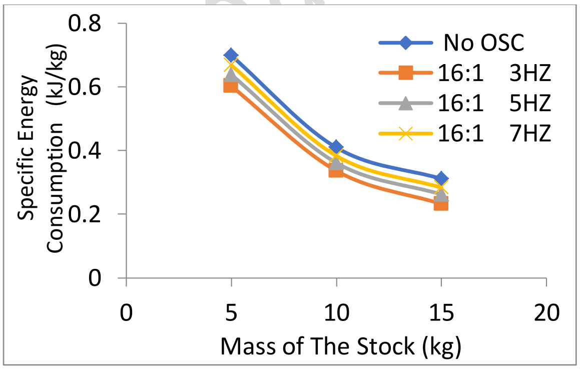

Figure 7. The Relationship between the Mass of the Stock and Specific Energy Consumption.

Fig 7 describes the relation between the specific energy consumption and the mass of the stock during the operation in the furnace at 90^0 amplitude and 16:1 air-fuel ratio. The lowest specific energy consumption is the result of maximum absorption of heat energy by the load due to oscillating combustion. At lower frequencies, the amount of fuel consumed will be slightly lower than the higher frequencies and steady-state combustion.

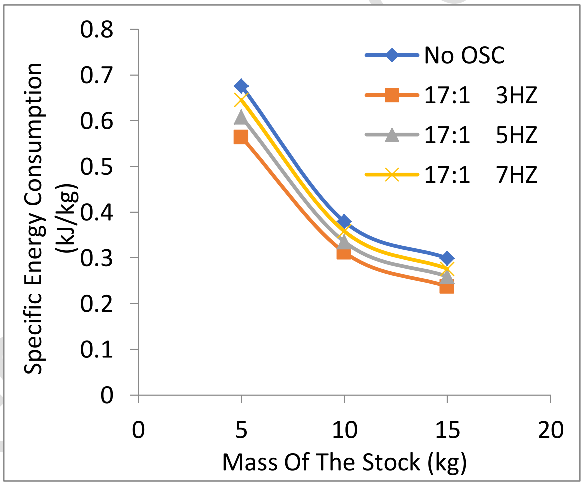

Figure 8. The Relationship between the Mass of the Stock and Specific Energy Consumption.

Fig 8 explains the specific energy consumption at 90^0amplitude at 17:1 air fuel ratio.. It is precisely indicating that Specific Energy Consumption depends on the amount of fuel consumed and the amount of material processed at different frequencies and loads. The specific energy consumption is slightly more compared with the higher frequencies and more loads. Which is maximum value as compared with the all oscillating combustion frequencies and at 3Hz and 15Kg. Which are minimum values as compared with all the oscillations combustion frequencies and load.

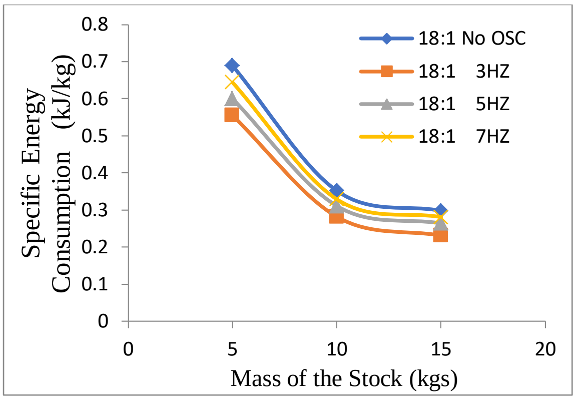

Figure 9. The Relationship between the Mass of The Stock and Specific Energy Consumption.

Fig 8 depicts the relation between the effect of the mass of stock and specific energy consumption at 18:1 air fuel ratio at 90^0amplitude. The specific energy consumption value to be higher for the entire air-fuel ratio and at the mass of stock in steady-state combustion with compared to oscillating combustion technology. It is precisely evident that specific energy consumption is low at lower frequencies and increasing the frequency of oscillations due to its proportionality. It is indicating that at higher frequencies the combustion slowly leads to steady-state combustion. It is precisely seen that the Specific Energy Consumption is more and it is indicating that the fuel consumption at above-cited conditions are more.

CONCLUSION

The intention of the paper is to examine the temperature distribution, efficiency and specific energy consumption inside a furnace using study state conditions and oscillating combustion state. Since the enhancement in temperature using oscillating combustion state was found to be fairly good there by useful for heat transfer industries to replace study state conditions with oscillating combustion technology.

- The temperature values of study state conditions at different points are high compared to the oscillating combustion state.
- The efficiency is an improvement is varied from 2% to 5.1%
- The energy-saving is varied from 3% to 33.6%.

By referring to all the above-mentioned characteristics, the oscillating combustion state concept is more efficient technology compared to steady-state combustion technology with refractory fire bricks. This is currently being used in heat transfer industries to increase the fuel and time savings, as well as significantly helps to increase the efficiency of the furnace.

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