Energy Improvement in Natural Gas Furnace using Oscillating Combustion Technology with Variation of Amplitudes

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ABSTRACT- *Thermal energy is one of the essential input aspects in the heat transfer industries that need an innovative concept for dexterous execution of controlled fuel consumption and diminished processing (melting) time. Energy conservation measure is a foremost phenomenon in the heat transfer industries. The furnaces working under optimum efficiency can be improved by installing new energy-efficient oscillating combustion technology. Fuel-saving and melting time are prime factors while using the furnace for aluminium melting operations. The furnace needs to optimize for constructive make use of fuel consumption, melting time. In this work, experimental results have presented at three levels of air-fuel ratios that are 16:1, 17:1 and 18:1, amplitudes 30^0, 60^0 and 90^0 and 3Hz, 5Hz and 7Hz frequency of oscillating valve. Oscillating combustion technology is a requisite technology to study not only the impact on the furnace but also the potential to the diminished fuel consumption and controlled processing time of the furnaces. The specific energy consumption and thermal efficiency are the functions of numerous variables, of which most of them are beyond the influence of the processing systems.*

Key Words: oscillating combustion, processing time, fuel consumption, mass of the stock, frequency, amplitude.

1. INTRODUCTION

In recent years, many 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 a particular proficiency, like utilization of different frequencies, air-fuel ratios, loads, and amplitudes to improve the heat transfer of furnaces. Given the economy and environmental impacts of energy utilization, most heat transfer industries such as glass plants, steel mills, foundry processes, forging shops, and furnaces focus 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. Self-sustaining 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 straightforward process to study its influence on the thermal boundary layer. It 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 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 many 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. Natural gas is used as a feedstock (for example, in hydrogen or ammonia production). In contrast, many thermal processing industries (e.g., the metals, glass, or ceramics industries) rely on gas to provide process heat for manufacturing processes. [16].

2. 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 alternate fuel-rich and fuel-lean zones in the furnace 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, fuel consumption, and melting time for the air-fuel ratios of 16:1, 17:1 and 18:1.

3. THE VITAL ROLE OF EXPERIMENTAL WORK

The crucible furnace was fired with various levels of air-fuel ratios (AFR), frequency, amplitudes, and the data recorded at every level of the experiment for the betterment of the furnace. This article has been covered on the increased emphasis on the ability of research to perform a conventional and oscillating combustion analysis of the research work. The oscillating combustion studies and solutions have, at particular times, seemed to deserve more emphasis. Experimental work becomes more sophisticated in the modern engineering curriculum. Conventional experimental practices have consistently been changed to include new technologies like oscillating combustion. These methods, including electronic and mechanical instruments of the computer-based data acquisition system.

4. INFLUENCE OF OCT ON PROCESSING (MELTING) TIME ON FURNACE PERFORMANCE.

The new oscillating combustion technology takes into account all the real-time furnace parameters determined from the experimental data. Another possible outcome is to decrease the processing time at different intervals. This would be partially associated with the Aluminium load, which is placed in a crucible for experimental investigating purposes. It improves the fuel savings, production rate and these two were the functions of the manufacturing cost of the final product. The processing time and temperature of the molten metal during the oscillating combustion technology was influenced by the various parameters such as frequencies, amplitudes, the mass of the stock and above and below the stoichiometric air-fuel ratios of the compressed natural gas (CNG). Ultimately, we can be believed that these benefits will undoubtedly contribute to decreasing fuel consumption and higher the production rate in Heat transfer industries. The performance of the oscillating combustion technology is compared to a steady-state (conventional) combustion model. This leads the main thrust at this is to evaluate a generalized dynamic combustion model. The melting time and furnace temperature are selected locations during this operation have also been influenced by the oscillating combustion technology, which is operated at specific frequencies, amplitudes, the mass of the stock and at below and above the stoichiometric air-fuel ratio.

5. INFLUENCE OF OCT ON FUEL CONSUMPTION ON FURNACE COMBUSTION.

The fuel savings is an essential criterion due to the depletion of fossil fuels at an alarming rate and increasing of pollution level from various combustion processes, such as furnaces, boilers, kilns and furnaces. The researchers are focusing on various technologies to control fuel consumption, pollution and emissions. Fossil fuels energize melting furnaces and heat transfer industries. High energy consumption costs, tight pollution control regulations, and severe competition amongst heat transfer industries and melting furnaces have resulted in the exposer of several methods to control the fuel consumption of these melting furnaces. Presently there is still an advanced technique to achieve the ultimate goals of heat transfer industries to enhancing thermal efficiency, controlled specific energy consumption, and fuel consumption. Most of the issues are existing heat transfer industries operating in poor thermal and operating conditions worldwide. Most of the researchers are developing new methodologies and techniques to improve thermal efficiency and controlled fuel consumption.

The influence of the fuel consumption in the industrial furnaces is directly proportional to the weight of the stock but deviates at different Situations of the experimentation implementation process. It has been noticed that the fuel consumption is relatively high in steady-state combustion mode as compared with the oscillating combustion mode. It is also seen that minimum fuel consumption of the oscillating mode was found than compared to that of steady-state combustion technology. Genuinely the fuel consumption is marginally more for the higher loads more significant amount of load was processed. The consumption of fuel was low in an oscillating combustion technology as compared with the steady-state combustion mode.

6. INFLUENCE OF OCT ON FUEL CONSUMPTION IN FURNACE COMBUSTION.

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7. RESULTS AND DISCUSSIONS.

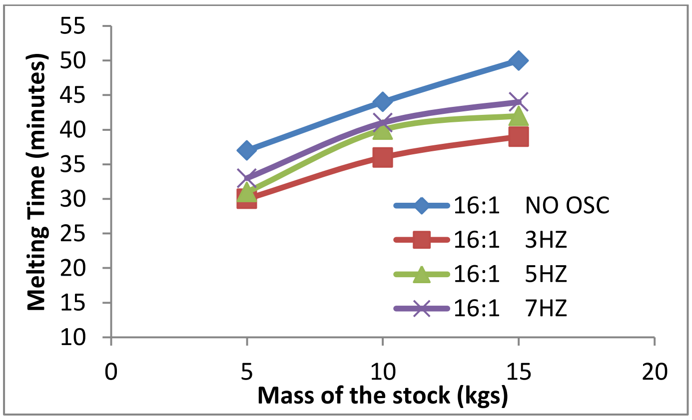

Figure 1 The plot between the load (MOS) and processing time

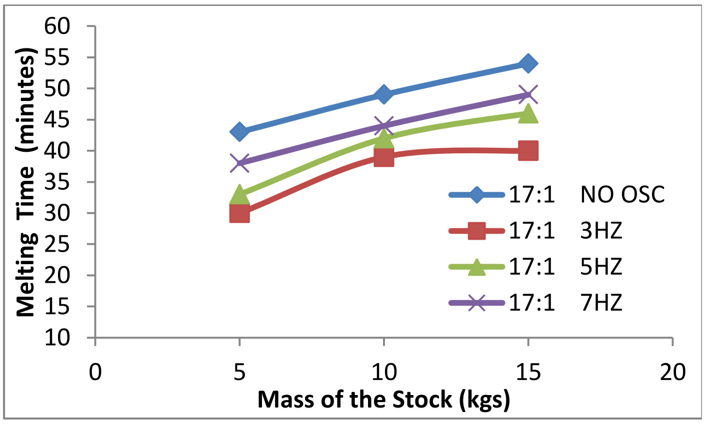

Figure 2 The plot between the load (MOS) and processing (melting) time

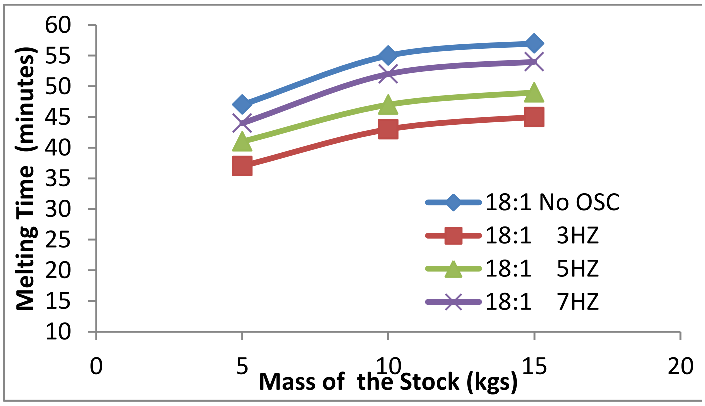

Figure 3 The plot between the load (MOS) and processing (Melting) time.

The plot between the mass of the stock and processing time at 30^0 amplitude, at 16:1, 17:1, 18:1 AFR and at different frequencies such as 3Hz, 5Hz, and 7Hz and above and below stoichiometric air-fuel ratios no oscillating state were drawn in the Figure 1, 2 and 3. After experiments at rich air-fuel mixture, which is low excess air level at 16:1 air-fuel ratio, the Figure 1 shows that at this stage, the processing (melting) time can be reduced from 44 minutes to 41 minutes, which is 7% time saving and it is least value of time-saving at this stage, the melting time can be reduced from 50 minutes to 39 minutes, which is 28% of time-saving and it is topmost time processing time-saving at this juncture. After experiments at stoichiometric air-fuel mixture, which is optimum excess air level at 17:1 air-fuel ratio, the Figure 2 shows that at this stage, the melting time can be decreased from 54 minutes to 49 minutes, which is 10% of the melting time saving and it is least value of time-saving at this stage. The melting time can be minimized from 54 minutes to 40 minutes, which is 35% of time-saving and it is topmost time processing time-saving at this stage. After experiments at lean air-fuel mixture, which is high excess air level is at 18:1 air-fuel ratio, the Figure 3 shows that at this stage, the melting time can be decreased from 57 minutes to 54 minutes, which is 5.5% of the melting time saving and it is least value of time-saving at this stage, the melting time can be minimized from 57 minutes to 45 minutes, which is 26.6% of time-saving and it is topmost time processing time-saving at this stage.

It is depicting the melting time is slightly high in steady-state combustion as compared with the oscillating combustion mode of operations for all conditions. It is also revealing that processing time taken for a different mass of the stock (loads) is further reduced due to oscillations that are created by a butterfly valve at different frequencies and amplitudes. According to instinctive phenomena, the melting time is directly proportional to the weight of the stock it has been noticed that the melting time in all the loads in oscillating combustion technology is very low when compared with the steady-state combustion and it is varying at different frequencies of the oscillations. This is happened because of the oscillating mode of operation; the butterfly valve can open and close steadily at higher amplitudes and lower frequencies. It is facilitating to increase heat transfer, which reduces the heating time.

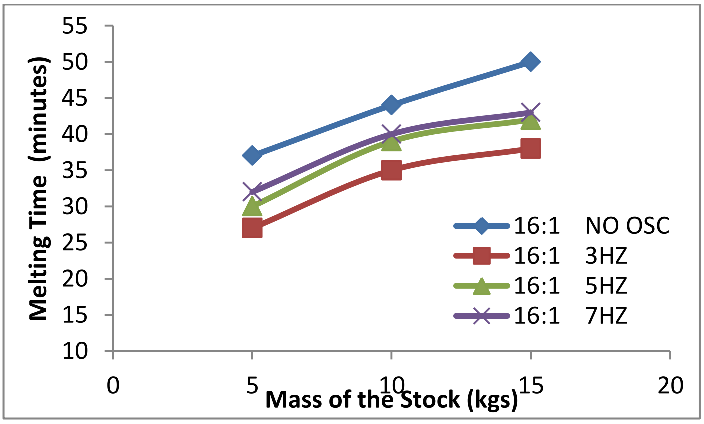

Figure 4 The plot between the load (MOS) and processing (melting) time.

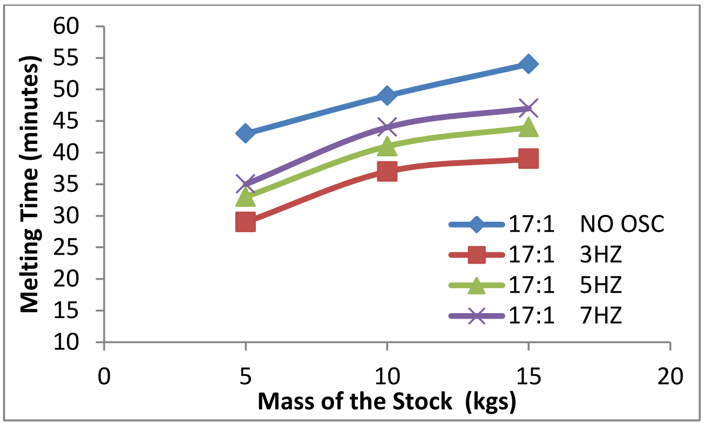

Figure 5 The plot between the load (MOS) and processing (melting) time.

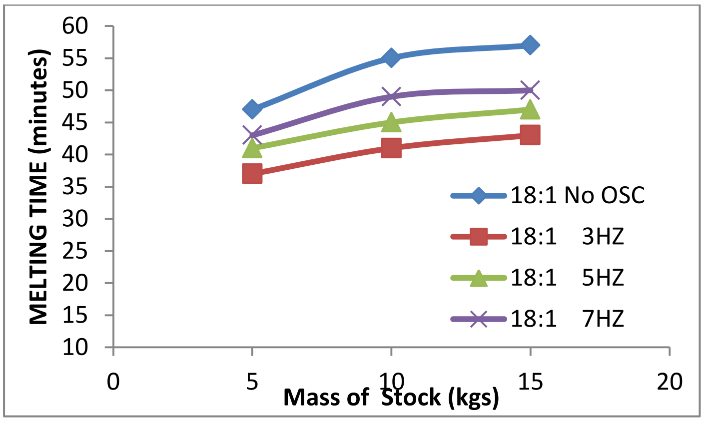

Figure 6 The plot between the load (MOS) and processing (melting) time.

The plot between the mass of the stock and processing time at 60^0 amplitude, at 16:1, 17:1, 18:1 AFR and at different frequencies such as 3Hz, 5Hz and 7Hz, and no-oscillating (steady) state were drawn in the Figure 4, 5 and 6. It is depicting the melting time is slightly high in steady-state combustion as compared with the oscillating combustion mode of operations for all conditions. It is also revealing that the processing time taken for different loads is further reduced due to oscillations that are created by a butterfly valve at different frequencies and amplitudes. After experiments at rich air-fuel mixture, which is low excess air level at 16:1 air-fuel ratio, the Figure 4 shows that at this stage, the melting time can be reduced from 44 minutes to 42 minutes, which is 4.76% time saving and it is least value of time-saving at this stage, the melting time can be reduced from 50 minutes to 38 minutes, which is 31% of time-saving and it is topmost time processing time-saving at this juncture. After experiments at stoichiometric air-fuel mixture, which is optimum excess air level at 17:1 air-fuel ratio, the Figure 5 shows that at this stage, the melting time can be decreased from 49 minutes to 44 minutes, which is 11.36% of the melting time saving and it is least value of time-saving at this stage. The melting time can be minimized from 54 minutes to 39 minutes, which is 38% of time-saving and it is topmost time processing time-saving at this stage.

After experiments at lean air-fuel mixture, which is high excess air level is at 18:1 air-fuel ratio, the Figure 6 shows that at this stage, the melting time can be decreased from 47 minutes to 44 minutes, which is 6.8% of the melting time saving and it is least value of time-saving at this stage, the melting time can be minimized from 55 minutes to 41 minutes, which is 34% of time-saving and it is topmost time processing time-saving at this stage. It is evident that the processing time decreased in OCT as compared with the steady-state (conventional) combustion technology. The processing time is less at lower frequencies as compared with other (remaining). The processing time is less in the oscillating combustion technology as compared with the steady-state due to the breakup of the thermal boundary layer. It has been pointed out that the melting time taken for the various mass of the stock is further reduced (controlled) due to oscillations which are created by the butterfly valve at different frequencies. The melting time taken for the different loads is further reduced due to oscillations by the oscillating valve at different frequencies and amplitudes.

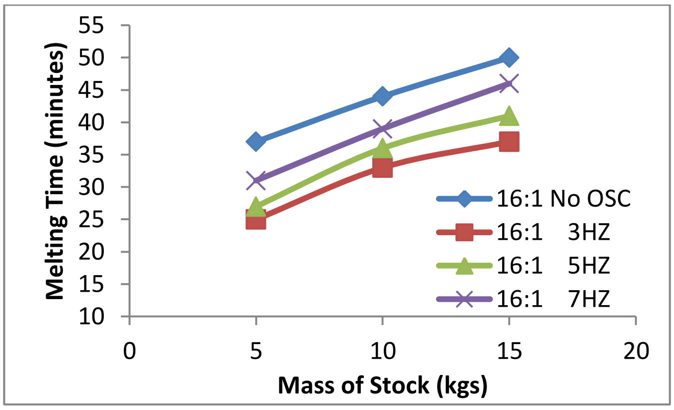

Figure 7 The plot between the mass of the stock and processing time.

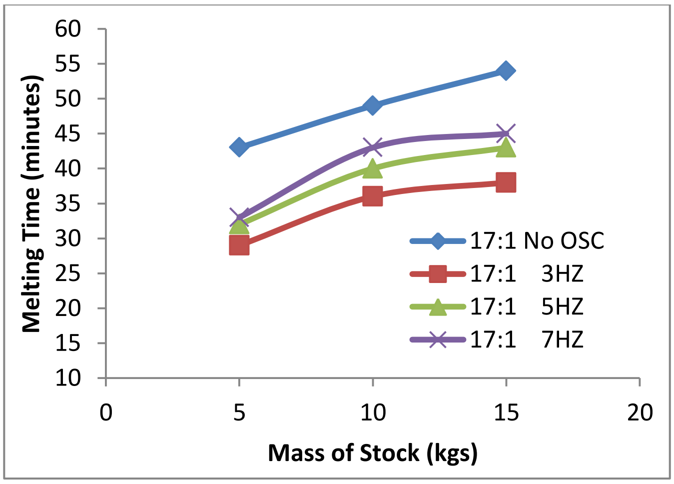

Figure 8 The plot between the mass of the stock and processing time.

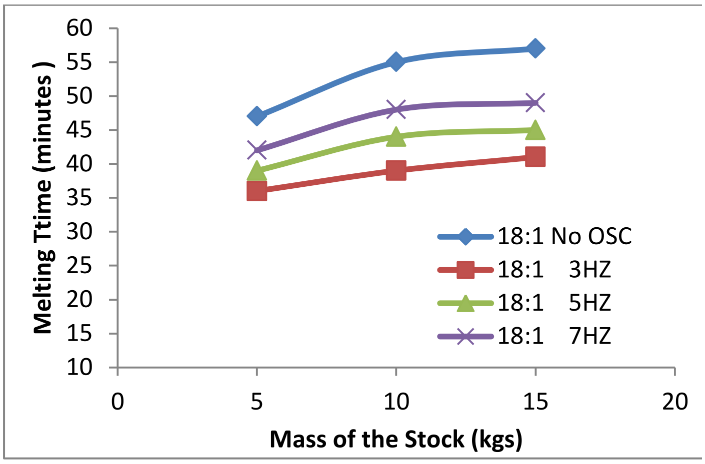

Figure 9 The plot between the mass of the stock and processing time.

The plot between the mass of the stock and processing time at 90^0 amplitude, at 16:1, 17:1, 18:1 AFR and at different frequencies such as 3Hz, 5Hz and 7Hz and no oscillating state were drawn in the Figure 7, 8 and 9. It is depicting the melting time is slightly high in steady-state combustion as compared with the oscillating combustion mode of operations for all conditions. It is also revealing that processing time taken for different loads is further reduced due to oscillations that are created by a butterfly valve at different frequencies and amplitudes. After experiments at rich air-fuel mixture, which is low excess air level at 16:1 air-fuel ratio, the Figure 7 shows, at this stage, the melting time can be reduced from 50 minutes to 46 minutes, which is 8.69% time saving and it is the least value of melt time-saving at this stage. The melting time can be reduced from 50 minutes to 37 minutes, which is 35% of melt time saving and it is the topmost processing time-saving at this juncture. After experiments at stoichiometric air-fuel mixture, which is optimum excess air level at 17:1 air-fuel ratio, the Figure 8 shows that at this stage, the melting time can be decreased from 49 minutes to 44 minutes, which is 11.36% of the melting time saving and it is least value of time-saving at this stage. The melting time can be minimized from 54 minutes to 38 minutes, which is 42% of time-saving, and it is topmost time processing time-saving at this stage. After experiments at lean air-fuel mixture, which is high excess air level is at 18:1 air-fuel ratio, the Figure 9 shows that at this stage, the melting time can be decreased from 47 minutes to 42 minutes, which is 11.9% of the melting time saving and it is the least value of melting time-saving at this stage. The melting time can be minimized from 57 minutes to 41 minutes, which is 39% of time-saving and it is the topmost time processing time-saving at this stage. It is being noticed that the processing time with respect to the load. It is possible to predict the processing time of the furnace using the new model. The new model enables us to reduce the processing time and maximize the production rate and also improve energy savings. It could be observed that the processing time is lower in oscillating combustion technology as compared with steady-state (conventional) combustion in all the conditions. Processing time is significantly less at lower frequencies as compared with the other. It is possible to predict the processing time of the load inside the furnace using improved furnace models. It shows that the time taken for melting time was increasing as the mixture turns leaner for with and without oscillations. It has been predicting that the time taken for a given air-fuel ratio at 90° amplitude with 3Hz frequency was less for all masses and also less for 16:1 air-fuel ratio at the 3Hz frequency for all masses.

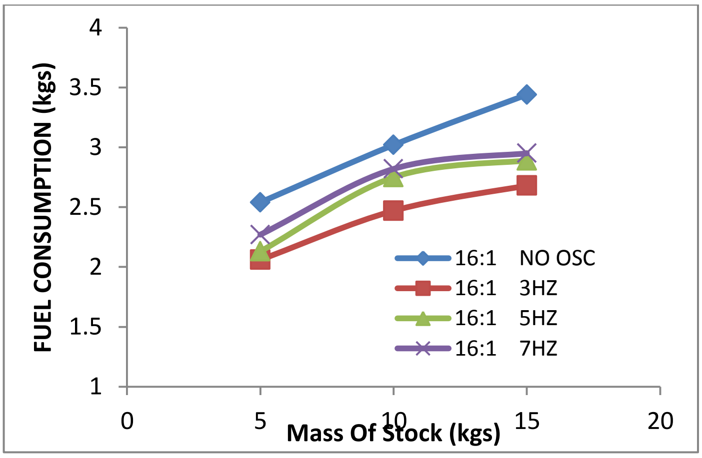

Figure 10 The Correlation between the load (MOS) and Fuel Consumption.

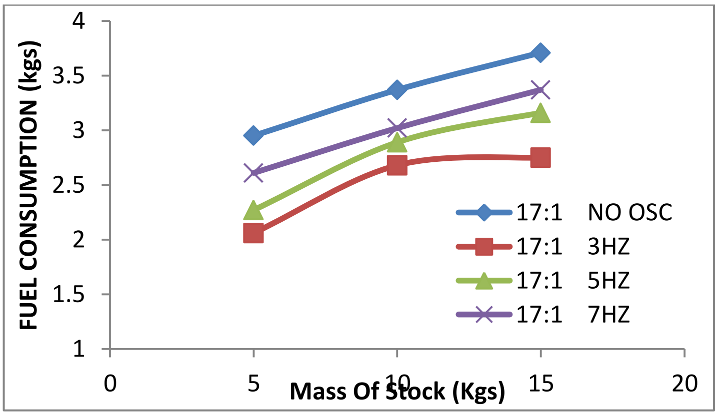

Figure 11 The Correlation between the load (MOS) and Fuel Consumption

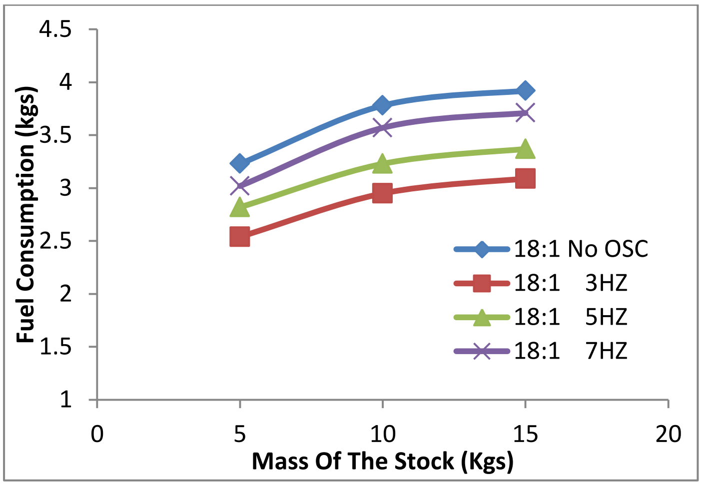

Figure 12 The Correlation between the load (MOS) and Fuel Consumption.

The plot between the mass of the stock and fuel consumption at 30^0 amplitude, at 16:1, 17:1, 18:1 air-fuel ratio, and at different frequencies such as 3Hz, 5Hz, and 7Hz and steady-state as well as oscillating combustion technology were drawn in the Figure 10 , 11 and 12. The influence of fuel consumption in the furnaces is directly proportional to the mass of the stock but also varies at different scenarios of the experimental process. At the end of experimental investigations at rich air-fuel mixture, which is low excess air level at a 16:1 air-fuel ratio, the Figure 10 shows, at this stage, the fuel consumption can be reduced from 3.02 kg to 2.82, which is 7.09% fuel saving and it is least value of fuel-saving at this stage. The fuel consumption can be reduced from 3.44 kg to 2.95 kg, which is 28.3% of fuel-saving and it is the topmost fuel saving at this juncture. After experiments at stoichiometric air-fuel mixture, which is optimum excess air level at 17:1 air-fuel ratio, the Figure 11 shows that at this stage, the fuel-saving can be decreased from 3.71kg to 3.37 kg, which is 10.08% of the fuel-saving and it is least value of fuel-saving at this stage, the fuel-saving can be minimized from 2.95 kg to 2.06 kg, which is 43% of fuel-saving and it is topmost time fuel saving at this stage. After experiments at lean air-fuel mixture, which is high excess air level is at 18:1 air-fuel ratio, the Figure 12 shows that at this stage, the fuel-saving can be decreased from 3.92 kg to 3.71 kg, which is 5.66% of the fuel-saving and it is least value of fuel-saving at this stage. The fuel-saving can be minimized from 3.92 kg to 3.09 kg, which is 26.86% of fuel-saving and it is the topmost time fuel saving at this stage.

The fuel consumption is slightly less in the oscillations combustion as compared with the steady-state (conventional) combustion technology in all the cases. This is due to the breakup of the thermal boundary layer around the crucible due to the breakup of the thermal boundary the crucible due to boundary more substantial the heat transfer from the flame to load is more as compared with the steady-state combustion technology. The fuel consumption was observed less at the lower frequencies of respective loads. This is due to oscillating consumption technology mode, within a short period of time, the furnace surface temperature reaches uniforms due to the time scale of the flame propagations is less and it's flame velocity is faster due to the turbulence created due to the oscillations resulting more luminous flame from the fuel-rich and fuel-lean zones which are created by the butterfly valve at different frequencies. The fuel consumption tends to become low due to less time is taken for the load to melt the Aluminium. It was possible to predict fuel consumption using the new model (oscillating combustion technology). The new model which enables to reduce the fuel consumption and maximize the production rate and improves energy savings.

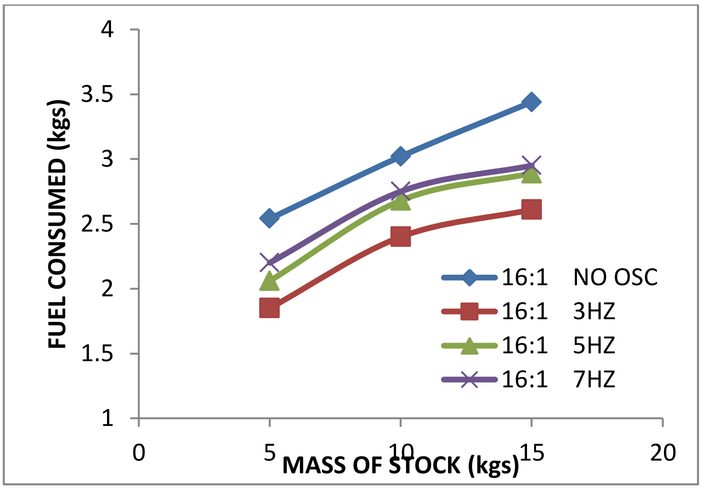

Figure 13 The Correlation between the load (MOS) and Fuel Consumption

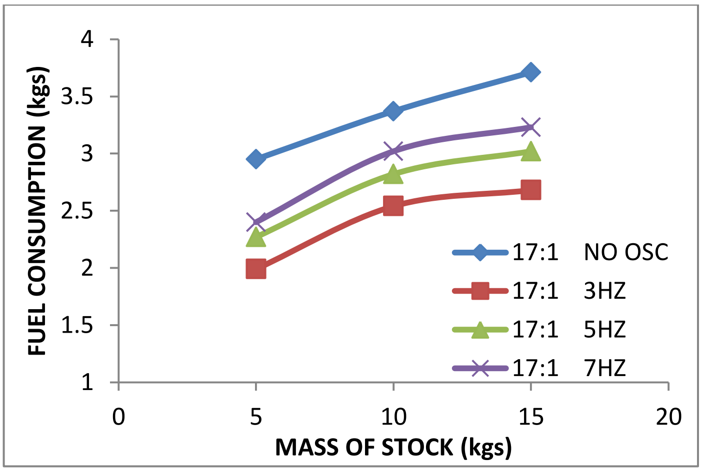

Figure 14 The Correlation between the load (MOS) and Fuel Consumption

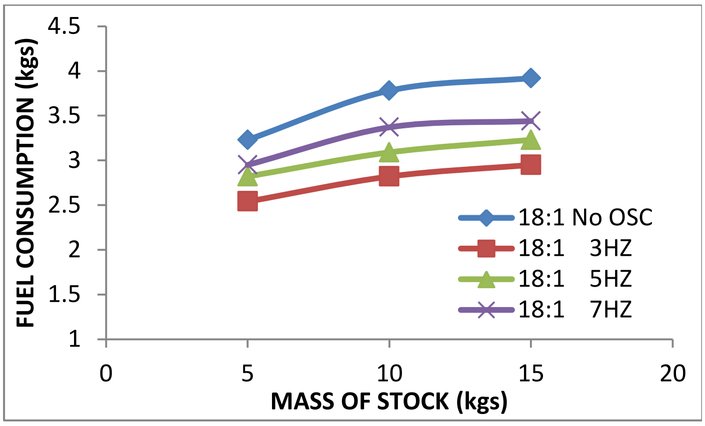

Figure 15 The Correlation between the load (MOS) and Fuel Consumption.

The plot between the mass of the stock and fuel consumption at 60^0 amplitude, at 16:1, 17:1, 18:1 AFR, and at different frequencies such as 3Hz, 5Hz, and 7Hz. Here the plots were drawn between steady-state and oscillating combustion displayed in Figure 13, 14 and 15. It is depicting the fuel consumption is slightly high in steady-state combustion as compared with the oscillating combustion mode of operations for all conditions. It is also revealing that fuel consumption taken for different loads is further reduced due to oscillations which are created by the butterfly valve at different frequencies and amplitudes. At the end of experimental investigations at rich air-fuel mixture, which is low excess air level at 16:1 air-fuel ratio, the Figure 13 shows, at this stage, the fuel consumption can be reduced from 3.02 kg to 2.75 kg, which is 9.8% fuel saving and it is least value of fuel-saving at this stage. The fuel consumption can be reduced from 2.54 kg to 1.85 kg, which is 37.2% of fuel-saving and it is the topmost fuel saving at this juncture. After experiments at stoichiometric air-fuel mixture, which is optimum excess air level at 17:1 air-fuel ratio, the Figure 14 shows that at this stage, the fuel-saving can be decreased from 3.37 kg to 3.02 kg, which is 11.5 % of the fuel-saving and it is least value of fuel-saving at this stage, the fuel-saving can be minimized from 2.95 kg to 1.99 kg, which is 48.2 % of fuel-saving and it is topmost time fuel saving at this stage.

After experiments at lean air-fuel mixture, which is high excess air level is at 18:1 air-fuel ratio, the Figure 15 shows that at this stage the fuel-saving can be decreased from 3.23 kg to 2.54 kg, which is 9.4% of the fuel-saving and it is least value of fuel-saving at this stage. The fuel-saving can be minimized from 3.78 kg to 2.82 kg, which is 34 % of fuel-saving and it is the topmost time fuel saving at this stage. The fuel savings plays a vital role in Heat transfer industries and steel mills. It is indicating that the fuel consumption is low in an oscillating combustion technology as compared with the steady-state combustion. This new technology (OCT) is preferable for us to reduce the fuel savings, but it possible only by reducing the processing time. It is revealing the fuel consumption is moderately high in steady-state combustion as compared with the oscillating combustion mode of operations for all conditions. It is also revealing that the fuel consumption taken for varying loads is further reduced due to oscillations that are created by a butterfly valve at different frequencies and amplitudes.

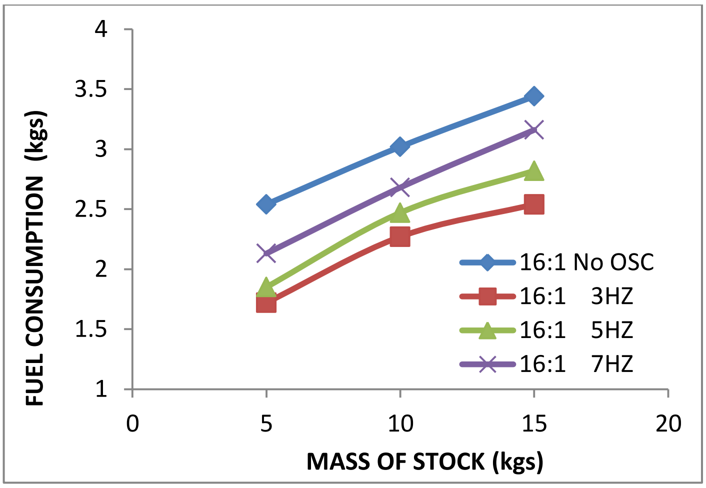

Figure 16 The Correlation between the load (MOS) and Fuel Consumption

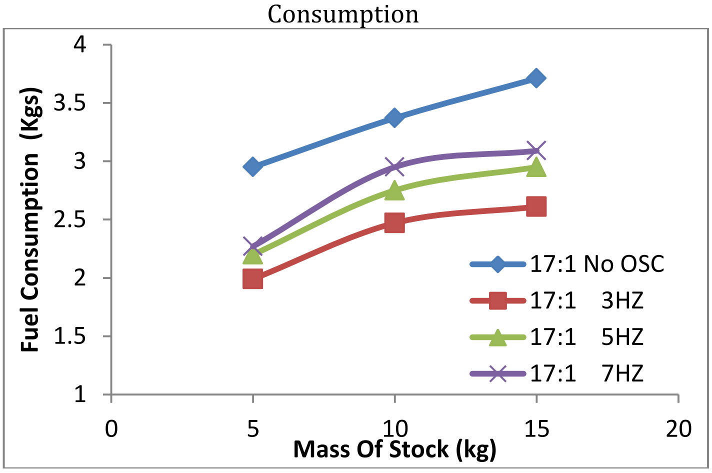

Figure 17 The Correlation between the load (MOS) and Fuel Consumption.

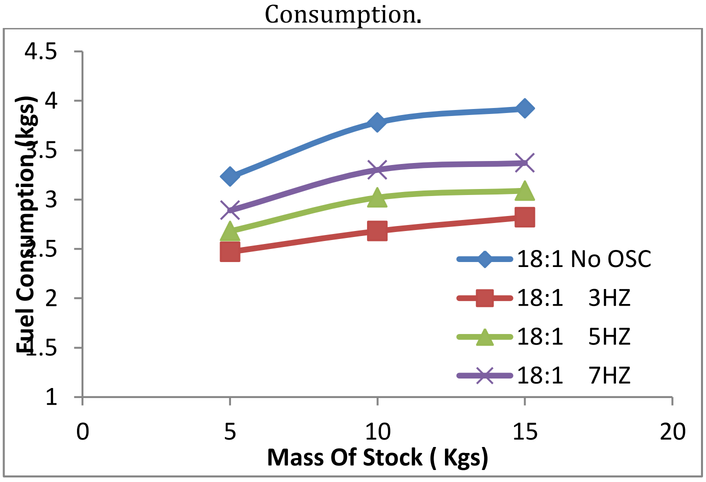

Figure 18 The Correlation between the load (MOS) and Fuel Consumption.

The plot between the mass of the stock and fuel consumption at 30^0 amplitude, at 16:1, 17:1, 18:1 AFR and at different frequencies such as 3Hz, 5Hz and 7Hz and steady-state as well as oscillating combustion state were drawn in the Figure 16, 17 and 18. It is representing the fuel consumption is slightly high in steady-state combustion as compared with the oscillating combustion mode of operations for all conditions. It is also illustrating that fuel consumption taken for different loads is further reduced due to oscillations which are created by a butterfly valve at different frequencies and amplitudes. At the end of experimental investigations at rich air-fuel mixture, which is low excess air level at 16:1 air-fuel ratio, the Figure 16 shows, at this stage, the fuel consumption can be reduced from 3.44 kg to 3.16 kg, which is 8.8 % fuel saving and it is least value of fuel-saving at this stage. The fuel consumption can be reduced from 2.54 kg to 1.72 kg, which is 47.6% of fuel-saving and it is the topmost fuel saving at this juncture. After experiments at stoichiometric air-fuel mixture, which is optimum excess air level at 17:1 air-fuel ratio, the Figure 17 shows that at this stage the fuel-saving can be decreased from 3.37 kg to 2.95 kg, which is 14.2 % of the fuel-saving and it is least value of fuel-saving at this stage, the fuel-saving can be minimized from 2.95 kg to 1.99 kg, which is 48.2 % of fuel-saving and it is topmost time fuel saving at this stage.

After experiments at lean air-fuel mixture, which is high excess air level is at 18:1 air-fuel ratio, the Figure 18 shows that at this stage the fuel-saving can be decreased from 3.23 kg to 2.89 kg, which is 11.7 % of the fuel-saving and it is the least value of fuel-saving at this stage. The fuel-saving can be minimized from 3.78 kg to 2.68 kg, which is 41.0 % of fuel-saving and it is topmost time fuel saving at this stage. Since the butterfly valve is able to operate at different frequencies and amplitudes. It facilitates the rate of Heat transfer, which shortens the processing time and it directly. The fuel consumption is lower in an oscillating combustion technology as compared with the steady-state combustion model. It is facilitating that heat transfer being increase from the flame to load is increased. When the heat transfer increases, then the processing time will decrease automatically. It is being observed that the processing time was controlled at different frequencies and amplitudes. It is having been noted that, in order to lower the fuel consumption and to increase the performances such as efficiency, Heat transfer of the crucible furnace, the heat being transferred to the load has to be enhanced.

8. CONCLUSION

The intention of paper was to examine the temperature distribution, fuel consumption and processing time 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, thereby useful for heat transfer industries to replace study state conditions with oscillating combustion state. Fuel consumption and production rates are the functions of the processing time. The processing time and melting temperature of the aluminium during the oscillating combustion technology was affected by the oscillating combustion technology and depended on different frequencies, amplitudes, the mass of the stock, and above and below the stoichiometric air-fuel ratios of the compressed natural gas.

Here, at 30^0 of amplitude melting time saving is 57 minutes to 54 minutes, and it is 5.5%, which is the least value among all the conditions. The melting time saving is 54 minutes to 40 minutes and it is 35%, and it is the maximum possible obtained processing time.

Here, at 60^0 of amplitude melting time saving is 44 minutes to 42 minutes, and it is 4.76%, which is the least value among all the conditions. The melting time saving is 54 minutes to 39 minutes and it is 38%, and it is the maximum possible obtained processing time.

Here, at 90^0 of amplitude melting time saving is 50 minutes to 46 minutes, and it is 8.69%, which is the least value among all the conditions. The melting time saving is 54 minutes to 38 minutes and it is 42%, and it is the maximum possible obtained processing time.

The fuel economy (fuel saving) is a prime criterion due to the depletion of fossil fuels at an alarming rate and increasing emission levels from different combustion operations such as furnaces, boilers, kilns and furnaces.

Here, 30^0 at the fuel consumption is saved from 3.92kg to 3.71kg and it is 5.66% of fuel-saving, which is the least fuel saving at this juncture. The second most fuel-saving ranges from is 2.95 kg to 2.08 kg and it is 43 % of fuel-saving and it is maximum possible.

Here, 60^0 at the fuel consumption is saved from 3.23kg to 2.54kg and it is 9.4% of fuel-saving, which is the least fuel saving at this juncture. The second most fuel-saving ranges from is 2.95 kg to 1.99 kg and it is 48.2 % of fuel-saving and it is maximum possible.

Here, 30^0 at the fuel consumption is saved from 3.44kg to 3.16kg and it is 8.8% of fuel-saving, which is the least fuel saving at this juncture. The second most fuel-saving ranges from is 2.95 kg to 1.99 kg and it is 48.2 % of fuel-saving and it is maximum possible fuel saving in this work.

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 help to increase the efficiency of a furnace.

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