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Experimental Research on Heat Transfer Performance of Honeycomb Heat Regenerator[1]

ZHANG Xinsheng[2] XIONG Lihong[3] WANG Xitang[4]

Abstract: Heat transfer characteristics of honeycomb ceramic regenerator has been examined experimentally. The influence of switching time, flow rate of air and fuel gas on temperature distribution under unsteady heat transfer process in regenerator has been investigated. The results obtained are of some reference value for application of high temperature air combustion (HTAC).
Key words: honeycomb ceramic regenerator; heat transfer; HTAC technology; molten steel container

1. INTRODUCTION

[1] **Aided financially by NSFC (NO. 50446022)**
[2] Associate professor, School of power and mechanical engineering, Wuhan university, China.
E-mail: ewind999@126.com
[3] Associate professor, School of power and mechanical engineering, Wuhan university, China
[4] Professor,Wuhan university of science and technology, China.
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High temperature air combustion (HTAC) technology has been widely applied at home and abroad since 1990s especially in metallurgical industry, glass and cement manufactures, and heat treatment process. It has been proved to help to save energy and decrease the exhausting of NOx and some other toxic gases. As a key part of HTAC technology, honeycomb ceramic regenerator is characterised by larger specific surface area, less pressure drop in gas flow and good heat-resistant capability. Several works [1-4] pertaining to numerical and experimental investigations on heat transfer performance of honeycomb heat regenerator are available in the literature. LI Wei and QI Haiying[5] have obtained the distribution of temperature and velocity in regenerator by numerical simulation. Yu Juan[6] has established the mathematical model to investigate the relation between the level of caloric value in fuel and reduction of NOx in flue gas. And WANG Jieteng[7] and XU Xuchang[8] have investigated the heat recovery rate and pressure drop experimentally.

The present work deals with the further experimental study based on a device used to roast molten steel container involving HTAC technology to research into the heat transfer feature of honeycomb heat regenerator.

2. EXPERIMENTAL APPARATUS AND PROCEDURES

Aided financially by NSFC, the experiment is carried out on a small steel container roaster as shown in Figure.2. The experiment apparatus contains molten steel container, cover, honeycomb heat regenerator, switching valve, blower fan, exhaust fan and temperature detecting system. The air inlet, liquefied petroleum gas (LPG) inlet and flue gas outlet are set in the cover.

As Figure.1 shows, air forced by the blower fan is rapidly heated to a high temperature when flowing through the honeycomb regenerator at one side. When LPG gas is mixed into the hot air, it bursts into flames to roast the wall of the steel container by convection and radiation. Then the flue gas with high temperature flows into the honeycomb regenerator at another side to store most of the remanent heat in it before being drawn out by the exhaust fan. The above-mentioned process can be reversed by the switching valve to make air and flue gas flow through the honeycomb heat regenerators at different sides to accomplish heat absorbing and storing processes alternatively.

The heat retainer used in the experiment is of 300mm long with a sectional area of 225mm by 225mm which shown in Figure.3. Each hole is of hexagon structure with its every side being 1.5mm long and 0.8mm thick. To detect its temperature distribution, eleven thermocouples are fixed into the regenerator in advance as Figure.4.shows. Other three thermocouples are buried at different height in the wall of the experimental steel container.

In Figure.4. the hot end (point 8) is very next to combustion area while the cold end (point 4) is relatively far from it. A special software is used to detect online the temperatures of the above points based on a configuration software named Fameview. Apart from displaying the value of temperature, it functions to show temperature distribution curves and chang

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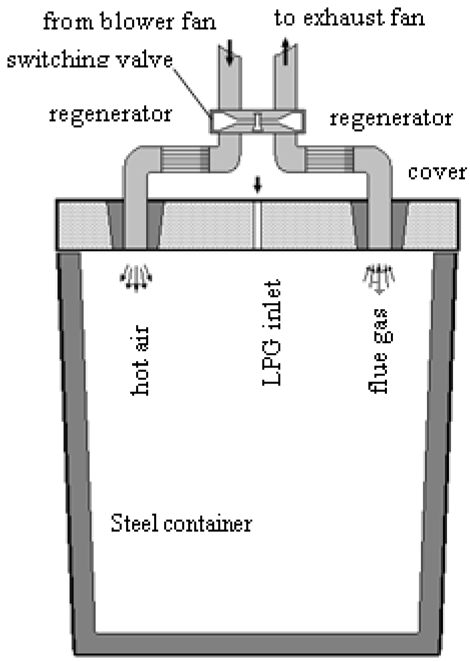

Figure 1. Steel container roaster

Figure 2. Experimental apparatus

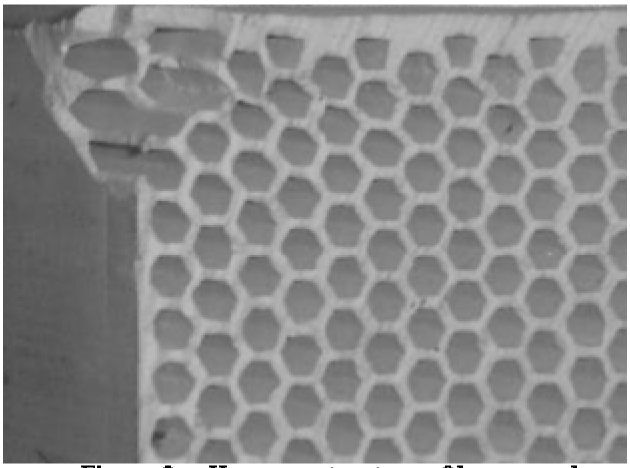

Figure 3. Hexagon structure of honeycomb

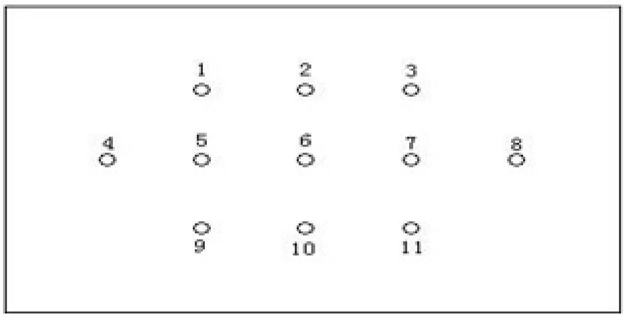

Figure.4. Location of thermocouples in regenerator

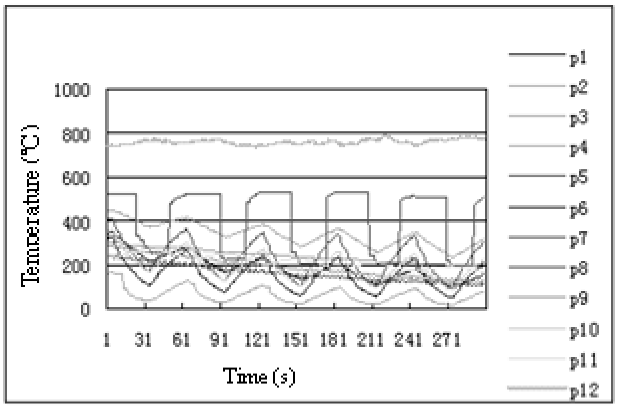

Figure 5. Switching time 60s, LPG flow rate 14m³/h

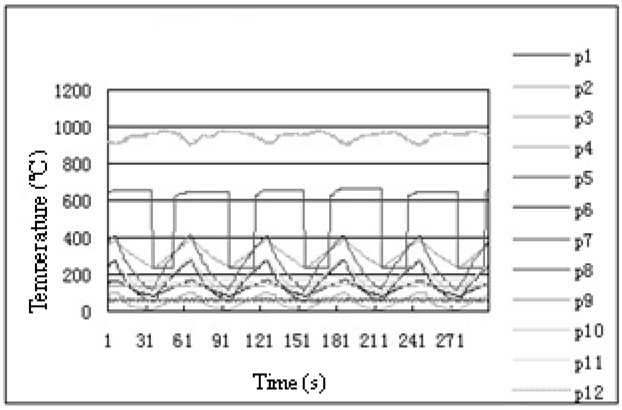

Figure 6. Switching time 60s, LPG flow rate 18m³/h.

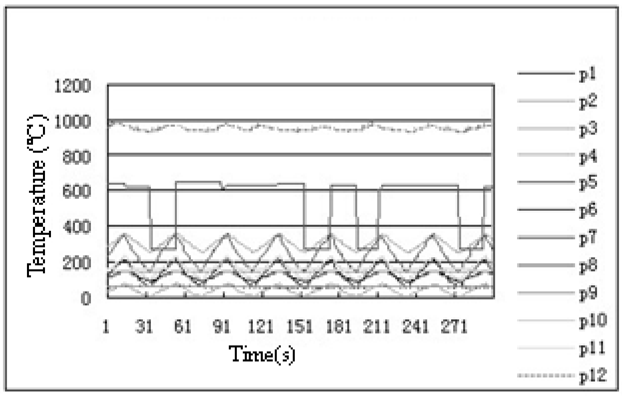

Figure 7. Switching time 20s, LPG flow rate 14m³/h

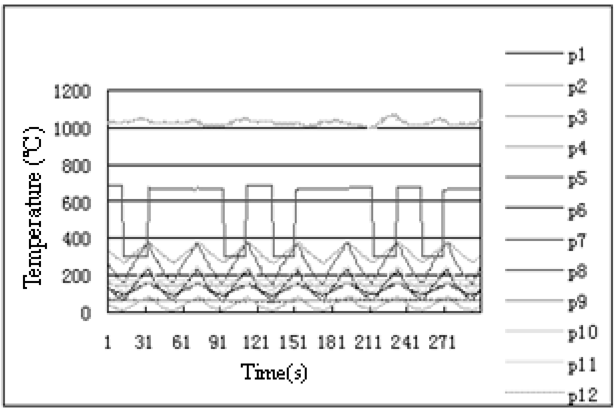

Figure 8. Switching time 20s, LPG flow rate 18m³/h

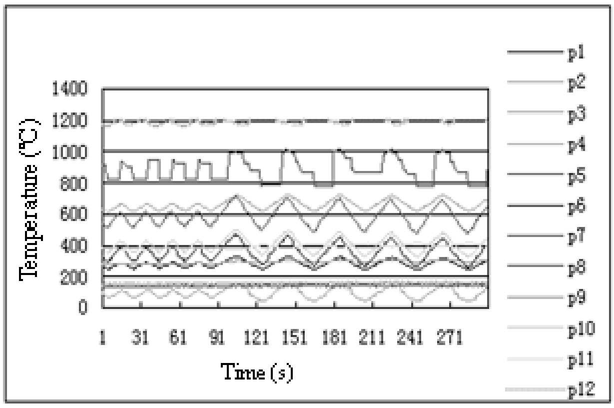

Figure 9. Switching time change from 15s to 30s

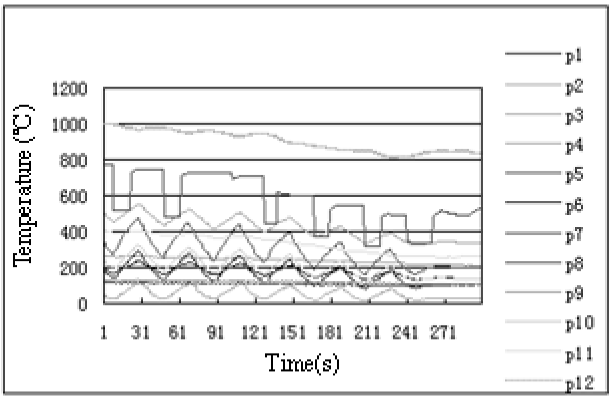

Figure 10. Temperature decreasing process

3. EXPERIMENTAL RESULTS

The experiment has tested the heat transfer performance under different conditions when air flow rate, LPG flow rate and switching time changed respectively. To ensure full combustion, the air flow rate is adjusted with LPG simultaneously according to proper ratio.

Figure.5 to 10 show the temperature variation within 5 minutes. The highest temperature is associated with point 12 where the thermocouple is fixed near the flame region. When the temperatures of other points respond periodically to the switching valve action, temperature at point 12 changes little, which indicates that the temperature fluctuation within the regenerator has little influence on the temperature of being heated region. Point 8 near the hot end is different from others in that its temperature jumps up and down sharply between the flat top and bottom of the curve while the remain points wave between peaks and valleys.

Comparing Figure.5 with 6 and Figure.7 with 8, it is easily to find that the LPG flow rate has less influence on the shape of temperature curves than it has on value of temperature.

Figure.9 shows the temperature variation within the regenerator when switching time changing from 15s to 30s. It tells that with the increase of switching time, the amplitude of temperature vibration becomes more obvious.

Figure.10 records the process of temperature decreasing. It shows that the points with high temperature experience greater temperature drop than those points near the cold end when fuel feeding is stopped.

4. CONCLUSIONS

● From the above experimental investigation about heat transfer performance of honeycomb regenerator, the following conclusions can be obtained:

● Switching time, air flow rate and fuel flow rate have different influences on temperature distribution of regenerator. Switching time mainly influence the frequency of temperature vibration while air flow rate influences its amplitude.

● With the increase of switching time, temperature vibrates obviously. But too short switching time may prevent the regenerator from retaining or releasing heat fully.

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