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Research Article

Experimental Investigation of a Novel Condensing Boiler[#]

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Abstract: A novel laboratory type condensing boiler was developed and a data acquisition system was set up in order to measure physical magnitudes related to the performance of the developed boiler. A closed circuit water circulation system was included in the experimental setup in order to circulate water as the energy carrier fluid. The boiler was operated according to the predetermined parameters and data acquisition system collect the data from electronic transmitters placed in the probes at the certain points in the experimental setup. All these results were presented in graphical form and they are interpreted in terms of physics related to the phenomena. The temperature increase in the boiler changes in a parabolic manner. At the beginning of the incident, convection dominantly occurs in respect of heat transfer even though radiation also exists. However radiation contributes more with elapsed time in the experiment and temperature rise curve deviates from the linear path. Numerical analyses can contribute to the findings as well as design parameters.

1. Introduction

Porous medium as an alternative to conventional burners attracts industrial and scientific communities. Their compact and complex inner structure leads to efficient burning of the fuels while its general geometry from outside can be adapted literally to any volume. Metal gas burners having porous structures with flame and radiation essentials have been developed and put into use instead of conventional systems due to their compact sizes and low emission values. Various sizes are available for specific needs.

There are remarkable studies in the literature about porous combustion mediums and recent researches are going on to identify these aforementioned characteristics. Altınışık et al. conducted a simulation for a semi spherical burner in FLUENT software. They investigated combustion in respect of fluid density, viscosity, flow rate, pressure and temperature [1]. Numerous experiments were done for PPI 10, PPI 20 and PPI 30 sizes of SiC ceramic foam filter by Altınışık et al. And convenient radiant burning was observed in PPI 20 [2].

When it comes to combustion in porous mediums, Mujeebu et al. should be emphasized. There are several reports about the topic by these researchers. For instance they performed investigations on combustion in porous mediums and their applications [3]. They also worked in order to improve energy efficiencies of porous medium burners and hidden combustion chambers [4]. The developed two compact premixed LPG burners based on hidden and surface combustion in porous medium and compared to a conventional burner. The thermal efficiencies of the two developed burners and the conventional burner were found to be 71%, 59% and 47% respectively at the end of the study. In 2011, another report of Mujeebu et al. provides information about stable combustion based premixed burner development for a separated porous medium [5].

In this study, porous metal matrix radiant premix gas burner in cylindrical form was developed, manufactured and experimentally investigated. Present study should be regarded as an experimental evaluation of a novel design. It is not a parametrical one and a performance assessment was carried out.

Results may inspire related audience about potential of the similar designs. Detailed content can be found in the PhD thesis of Ali H. Abdulkarim [6].

2. Experimental Setup and Methodology

The principal scheme of the experimental setup and the cross section of the boiler used in the present study are given in Figure 1. The surface temperatures of the burner for unsteady and steady conditions are approximately 900ºC and 950ºC respectively. The closed circuit experimental setup contains a condensing boiler which is consisting of two main parts. The lower part is the combustion region and the upper part is the condensing region. Measurements were taken with 1 second intervals and fuel flow rate was tried to be fixed during the experiments.

Fuel air mixture was prepared prior to the combustion system and this setup is called premixed. The guide baffles direct air fuel mixture to the burning surfaces homogenously. When the mixture passes through the first stage, it gets ignited and starts to burn. The combustion in the first region has a temperature below 700ºC and has a blue color. The actual and effective combustion takes place at the second region which is called infrared combustion. Here, the surface temperature can reach up to 960ºC.

These kinds of facilities are of interest in respect of exergy analyses [7]. Exergy analyses are useful in order to evaluate system components and the harmony among them. This work lacks such a work; however, a similar investigation is planned for the future.

Experimental analyses are always a major tool for the scientific research. Thermocouples are very important in these works, especially for heat transfer studies. Special care is paid on thermocouples for assessing interfacial heat transfer coefficient in [8].

Another important aspect of the experimental works for the heat transfer studies is the turbulence for the examined flow domains which also enhance the heat transfer. Capturing turbulence structures with experimental tools is a hard task and study of Günal and İsmael [9] is a good example of it. Again, flow structures in the burner will be considered in the future for the designed burner.

The present burner can be regarded as a compact heat exchanger. A good counterpart or an alternative in compactness is the plate heat exchangers. There are lots of optimization studies in the literature for the plate heat exchanger. So one can infer from these studies, considering the present work, present burner design should be optimized. A good instance for the optimization of compact heat exchangers is [10].

There are important dimensionless numbers for evaluating results from the current study. Especially exhaust gasses have an important effect on the heat transfer because the condensing part of the boiler exists for the further harnessing of the energy. Aforementioned dimensionless numbers can be exemplified by Prandtl Number, Rayleigh Number and etc. An example study can be given by Arıcı et al. [11].

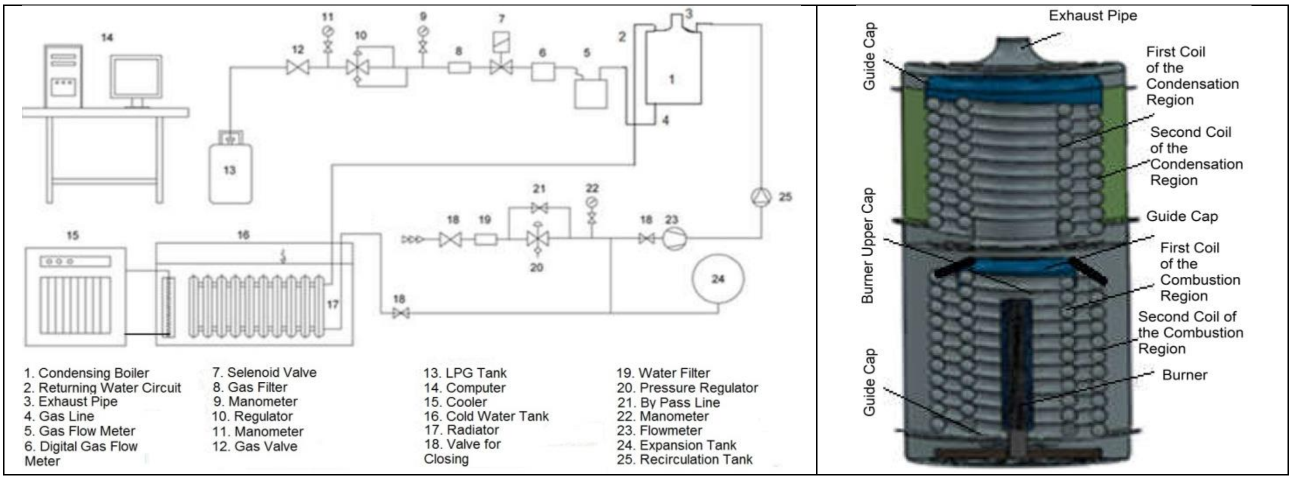

Figure 1. *Experimental setup schematics on the left and boiler cross section on the right.*

3. Results

Figure 2 contains data for water inlet temperatures changing versus time and Figure 3 contains data for water outlet temperatures changing versus time. Water outlet temperature change is not linear and it exhibits a parabolic trend. This can be inferred as the radiation heat transfer mechanism is not effectively exists at the beginning of the incident. So the only major contribution to the heat transfer is done by the convection heat transfer mechanism. However, radiation heat transfer gains ground by time and the heat transfer increases parabolic by time. Water inlet temperature on the other hand also exhibited a similar curve however the response time was higher since the circuit was cooled. Again, the cooling system has a capacity and hence the inlet water temperature increases by time similar to the outlet temperature.

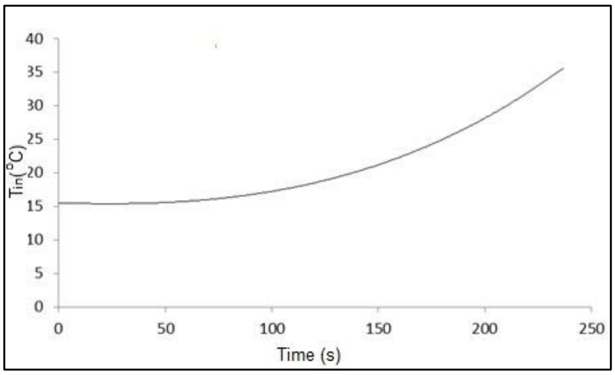

Figure 2. *Inlet water temperatures changing with time.*

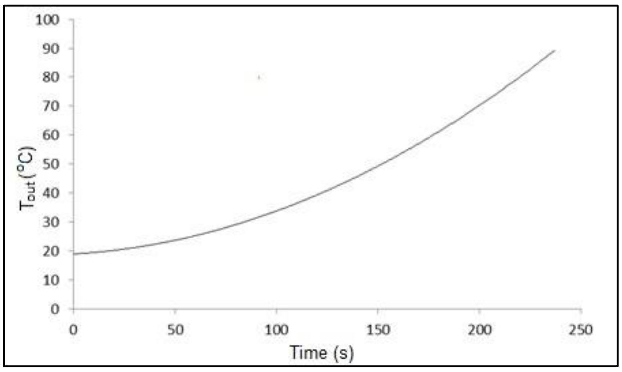

Figure 3. *Outlet water temperatures changing with time.*

Figure 4 is for the pressure change of the system. One can estimate that pressure should not be altered too much since the heat transporting fluid is liquid however pressure increase at the beginning of the experiment slightly. This should be because of the pump in the system since the initiation can yield such a result till system reaches to the steady state. Then pressure values fixed to a value for a while. At the late part of the experiments, pressure sharply increases. This should be due to the partly boiling of the flow because the temperature becomes too close to the boiling temperature at the location where experiments were conducted.

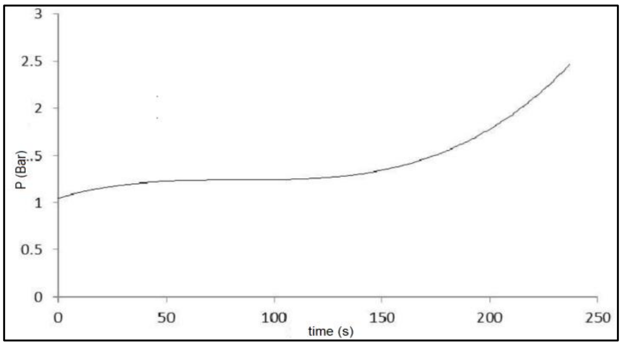

Figure 4. *Pressure at inlet changing versus time.*

4. Conclusions

A novel condensing boiler and porous burner were developed and used in the present work. Additionally, utilizing the burner in the boiler can give instructive data for the related audience. Thus, experimental work yielded results adaptable to the application. At the inner part of the porous metal burner, flame color is blue and at the outer surface, the combustion has a regime yielding infrared heat transfer. The temperature distribution on the porous burner surface is quasi-steady and changes between 900 to 960ºC. Water outlet temperature change is not linear and it exhibits a parabolic trend. Pressure values fixed to a value for a while. At the late part of the experiments, pressure sharply increases. This should be due to the partly boiling of the flow because the temperature becomes too close to the boiling temperature at the location where experiments were conducted.

These experimental results can be used in order to validate numerical studies for similar designs. The results can also give insight for a possible similar design in terms of its potential

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