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For industrial heating furnaces, the recuperative-burner which contains the efficient heat exchanger and contributes to large energy saving and low NOx has been developed.

1. Background

In industry, measures to the issue of global environment and improvement of the productivity have always become the problem. Therefore the installation of equipment realizing energy saving, CO_2-saving and quality improvement is demanded. For measures to the issue of global environment, it is one of the most effective solutions to use natural gas. Because CO_2 emission per unit of heat value of natural gas is smaller than that of heavy oil and coal.

However, heavy oil has so far been used mainly as fuel for an industrial heating furnace in Japan. The main reason is that natural gas is expensive compared with heavy oil, since it is liquefied and imported from overseas as LNG.

Table1 the price of heavy oil and natural gas of each country

	Heavy fuel oil for industry (MWh)	Nat. gas for industry (MWh)
Austria	67.40	58.00
Belgium	61.57	35.99
Canada	61.00	11.90
Czech Republic	47.42	48.82
Denmark	77.50	92.00
Finland	・・・	45.75
France	63.80	51.14
Germany	60.18	51.04
Italy	74.28	68.00
Japan	**80.51**	**92.05**
Korea	77.80	64.80
Netherlands	57.90	38.62
Poland	66.70	43.96
Portugal	92.68	52.70
Slovenia	・・・	64.38
Spain	63.66	43.97
Sweden	124.80	63.32
Switzerland	62.30	71.71
Turkey	104.10	41.15
United Kingdom	77.90	38.45
United States	58.66	12.74

Source: "Key World energy Stayistic 2013" etc

So, in order to expand the sales of natural gas, we need to develop energy-saving burners. By doing so, even if natural gas is more expensive than heavy oil, customers can reduce a running cost and fuel switching from heavy oil to natural gas can be realized.

Osaka Gas performed technical development by ourselves and has so far lengthened the volume of sales of LNG by proposing a user's business solution.

2. Development concept of Recuperative burner

We have developed many kinds of burners for heating furnaces. Especially regenerative burners are the most efficient in the all of burners.

However, the installation cost of regenerative burners may be large and cost effectiveness may worsen. Regarding the heating furnace with a comparatively low temperature that is under 1,000 degree Celsius, the effect of a running cost reduction by energy-saving becomes particularly smaller than with high temperature that is over 1,000 degree Celsius, as a result the influence of an installation cost becomes large. Moreover, since a regenerative burner needs a directional control valve, therefore piping may become complicated.

On the other hand, the recuperative burner which Osaka Gas developed in the past has a lower initial cost compared with a regenerative burner. But, efficiency is inferior and the energy-saving effect is small. If a large-sized heat exchanger is used, preheated air temperature can be higher. However, there are some problems, such as a large installation space's is required and piping becomes complicated.

Then, we started development of a recuperative burner which is more efficient than the conventional one we have, and is less-priced and easier to lay pipes than a regenerative burner.

This time, we developed the recuperative burner jointly with Chugai Ro Co., Ltd., which is a major burner maker, and Osaka Gas mainly took charge of the design of a heat exchanger.

We developed two kinds of recuperative burner of input with the comparatively small amount of combustion; 145 kW and 58 kW. The reason was because there were needs of small input burner in the Osaka Gas area as a result of investigating the data of the customer equipment, and other burner makers didn’t have small input recuperative burners.

3. Structure of a burner

Fig1 shows the outline of a recuperative burner.

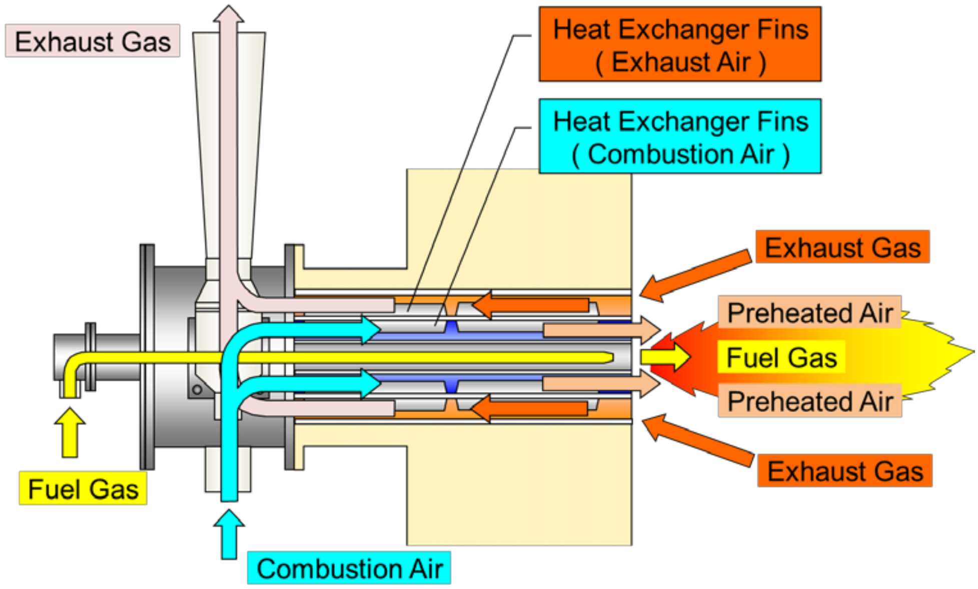

Fig1 outline of recuperative burner

The heat exchanger built in the recuperative burner is inserted in a furnace wall, and this burner is installed compactly as a whole. The combustion air supplied into a heat exchanger is heated by the exhaust gas, and turns into preheated air. The preheated air which blew off from the air nozzle at high speed is mixed with fuel gas in a furnace, and forms a flame. An exhaust gas is attracted by the eductor from inside of a furnace, is heat-recovered at a heat exchanger, and is discharged.

4. Feature of this recuperative burner

① Efficient

When the temperature in a furnace is 1,000 degree Celsius, preheated air temperature turns into over 500 degree Celsius at the heat exchanger, and can realize large energy saving as compared with the non-recuperative burner. Since the preheated air temperature of the conventional recuperative burner is up to approximately 350 degree Celsius, a new recuperative burner serves as over 8% of improvement in efficiency.

Fig. 2 shows the preheated air temperature and temperature efficiency at each exhaust gas inlet temperature.

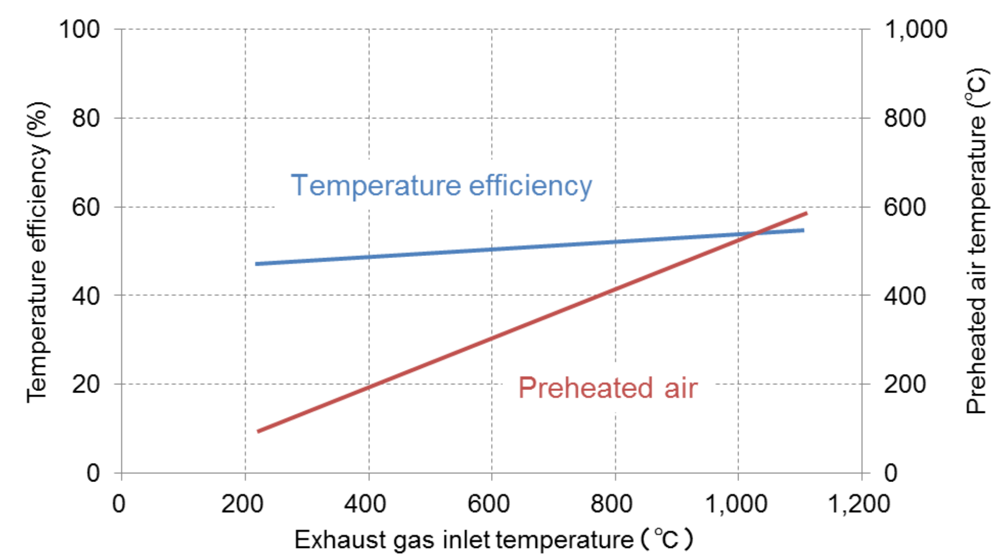

Fig2 relation with exhaust gas temp, efficiency and preheated air temp

② Compact and low pressure loss

When we want to increase the amount of heat exchange, it is effective to enlarge the flow velocity and/or a heat transfer area. However, if the flow velocity is enlarged, an exhaust pressure loss (resistance) will become large. In this case, since there is a limit in the power of absorption by an eductor, sufficient quantity of exhaust gas may be unable to be attracted from inside of a furnace. On the other hand, if a heat transfer area is enlarged, a burner is enlarged and a production cost also increase.

We solved these problems using simulation technology, and we were able to design the efficient, compact, and small pressure loss heat exchanger.

③ Low NOx emission

Preheated air blows off at high speed from the air nozzle moderately separated from the gas nozzle. Before fuel gas burns, the exhaust gas in a furnace is involved in combustion air, and combustion becomes slow. As a result, though preheated air is used, flame temperature is held down relatively low, and NOx emission becomes small.

Fig. 3 shows the relation between the temperature in a furnace, and NOx emission.

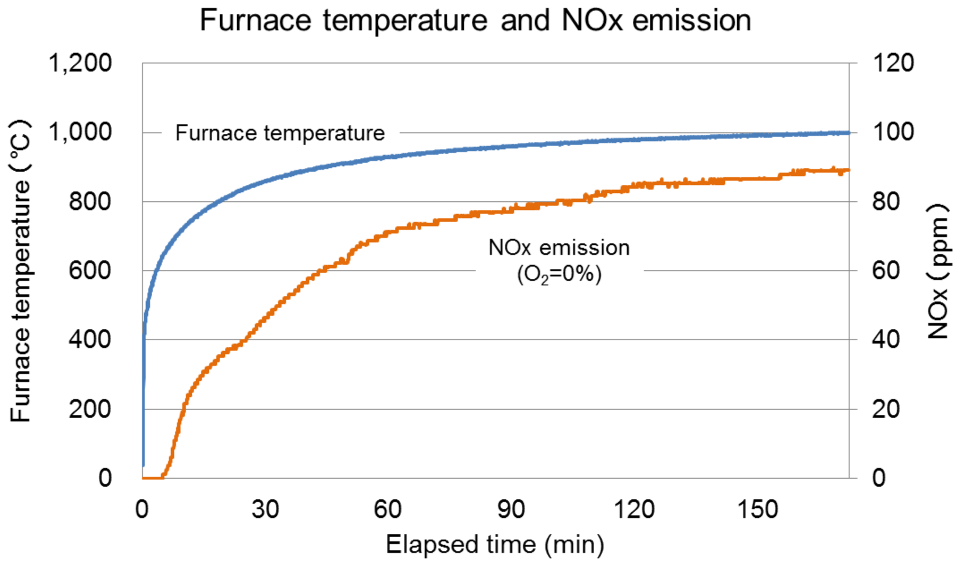

Fig3 relation with furnace temperature and NOx emission

④ High-speed combustion air

The preheated air is injected at high speed (about 80m/s) from an air nozzle of the heat exchanger tip. The high-speed preheated air contributes to the equalization of the temperature distribution to stir the air in the furnace.

5. Specification

Table2 shows specifications of 2 type recuperative burner which we developed this time

Table2 specifications of recuperative burners

Target		Performance	
Input		145kW	58kW
The highest furnace temperature	1,000°C	1,000°C (Checked durability)	
Hot air temperature	500°C	over 500°C	over 500°C
Efficiency	68%	over 68%	over 68%
NOx (O_2=0%)	100ppm	under 100ppm	under 100ppm
Exhaust gas pressure loss	Exhaust blower unnecessary	Eductor use is possible (about 200Pa)	
Main air volume		151m^3N	61m^3N
Premix air volume		6m^3N	5m^3N
Eductor air volume		151m^3N	40m^3N

6. The tool used for development

So that we need to reduce the times of a prototype production and to shorten a development period in this recuperative burner development, the heat exchanger was designed using the simulation technology of Energy Technology Laboratories, Osaka Gas Co., Ltd.

And, in prototype production, we used 3D printing for the purpose of shortening of a production period and reduction of a prototype cost.

I. Simulation technology

In order to attain target performance, prototype productions needed to be repeated many times in the conventional way, therefore the development period was long. Therefore we evaluated the performance of the heat exchanger by simulation and decided the shape that we tested in a real prototype from some plans, so as to reduce the number of times to make a prototype

First, the combustion data of the same kind of burner was collected.
The collected data items are as follows.

- Temperature of combustion air at inlet, outlet and halfway of the heat exchanger
- Temperature of exhaust gas at inlet, outlet and halfway of the heat exchanger
- Temperature of heat exchanger fins

Nest, the heat exchanger form of the primary prototype was determined by simulation. And thermal data was collected similarly. The accuracy of the simulation was further raised with this data, and the heat exchanger form of the secondary prototype was determined. As a result of enlarging the exhaust gas flow velocity within the allowable pressure loss and miniaturizing the heat exchanger, target specification was able to be cleared with the secondary prototype.

Fig4 shows an example of the simulation result. We were able to obtain correct data by improving precision of the simulation.

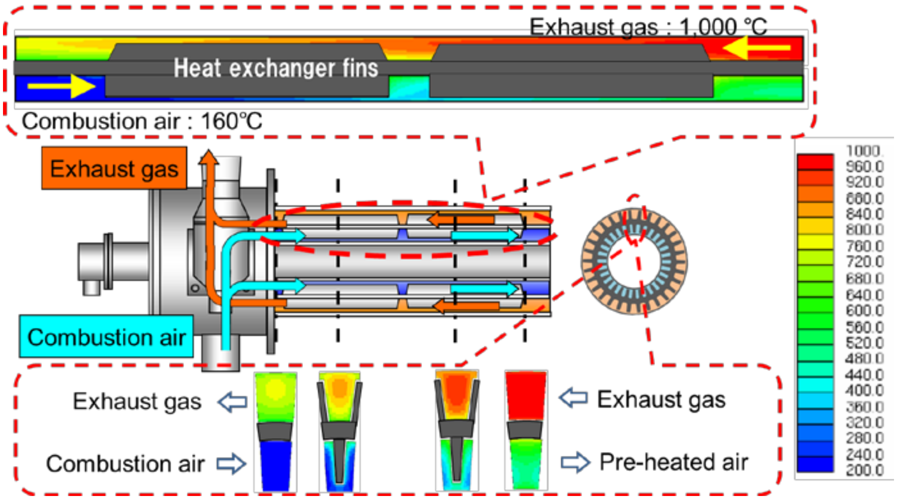

Fig4 one example of simulation results

II. 3D printing technology

Numbers of times of prototype production were able to be reduced by the simulation. However, two problems, period and cost, remained about production itself of prototype. Since casting was not generally used by prototype production, we were using the metal shaving method conventionally. This method can shorten a production period, but it is very expensive. Then, we tackled the new method; 3D printing.

Although the resin model was usually made from the metallic mold in lost-wax casting, we made one by 3D printing this time. By this method, we could product a prototype in time shorter than the conventional lost-wax casting, and could cut down the cost sharply rather than metal shaving method.

Fig5 shows a resin model by 3D printing and a casting article by lost-wax casting. Table 3 shows comparison of each method of fabrication.

 

Fig5 picture of resin model (left) and casting (right)

Table3 comparison of each production method

Method	Casting (Use of resin model by 3D printing)	Casting (Use of metallic mold)	Shaved metal
Production period	3 weeks	12 weeks	8 weeks
Price	$4,000	$10,000	$40,000
Feature	Complicated form Size restriction	Metallic mold Mass production	Conventional method

Although we worried about accuracy of dimension by 3D printing, this resin model was produced correctly. However, since the size which can be produced has restriction, we must be careful in future production. Moreover, 3D printing became cheaper than the conventional prototype production method, but compared with the usual casting in mass production, it is expensive. Therefore, we consider that 3D printing is effective by prototype production.

7. Conclusion

We were able to develop a new burner in short period by combining the simulation technology which Osaka Gas has and 3D printing which is adopted newly. This recuperative burner is the burner which can attain energy saving to various heating furnaces, and it is a simple structure. We would like to continue contributing to customer's energy saving and reduction of CO_2 emission through burner development.