Development of a Highly Efficient Immersion Burner for Aluminum Holding Furnaces

Main author

Tatsuya Moriyama

Commercial Combustion Application Group,
Technical Research Institute, Toho gas Co., Ltd.
Japan

Co-authors

Masataka Yabushita
Shinpei Miura
Masahisa Koizumi

1. Introduction

Toho Gas Co., Ltd. is a city gas provider supplying natural gas to the Tokai region located in the central part of Japan. Many manufacturing companies are located in this region, and the main industry is the automotive industry. The automotive industry is using a large amount of thermal energy for molding and thermal processing to produce metal parts. Thus, energy conservation and reduction of CO_2 emissions in the field of industrial furnaces play an important role in protecting the global environment. Many companies are working to conserve energy and reduce CO_2 emissions in the recent years. Among them, Toho Gas is developing and distributing highly efficient devices while converting fuel to natural gas, which is an environmentally superior fuel and thereby assisting energy conservation and CO_2 reduction activities of our clients.

Under such circumstances, Toho Gas developed a highly efficient immersion burner (Gas Immersion Heater : GIH) as a joint development with Shoei Manufacturing Co., Ltd. (Osaka, Osaka Prefecture, Japan) to realize energy conservation and reduction of CO_2 emissions targeting molten metal holding furnaces which are used in the manufacturing processes of aluminum parts.

This article describes the highly efficient immersion burner (GIH) for molten aluminum holding furnaces as an example of the development of highly efficient devices at Toho Gas.

2. Developmental background

2.1 Molten aluminum holding furnace

Molding is one of the methods for producing aluminum parts in the manufacturing process of automobile parts and mechanical parts (Fig.1). The molding process often uses holding furnaces to keep the temperature of molten aluminum until the aluminum which was melted in melting furnaces is poured into a mold.

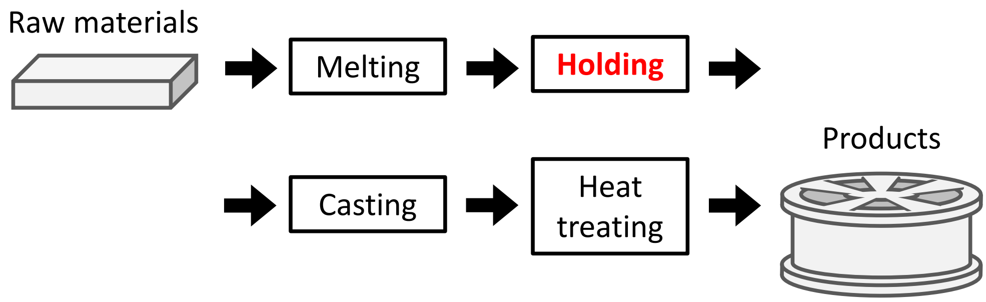

Fig.1 Example of the production process of aluminum parts using molding

Methods for heating molten aluminum in holding furnaces include crucible type, immersion heating type, direct heating type, and radiation type (Fig.2). Among these methods, crucible type and immersion heating type are commonly used.

The crucible type is a method which increases the temperature of molten aluminum by heating a crucible which is holding molten aluminum. Meanwhile, immersion heating type is a method which heats molten aluminum by immersing a ceramic heat-transfer tube in the molten aluminum in a bathtub-shaped furnace and placing a heat source (burner or electric heater) in the tube for heating the molten aluminum. An advantage of these methods is that they degrade the quality of molten aluminum poorly, because the molten aluminum does not directly touch flame, which means less generation of oxides.

GIH introduced in this article is a new type of burner which is developed for immersion heating type holding furnaces.

Immersion heating type includes upper immersion method in which a tube is vertically inserted from the top of a furnace, and lower immersion method in which a tube is horizontally inserted from the side of a furnace (Fig.2). An advantage of the upper immersion method is that the replacement and maintenance of burners and heaters can be easily performed. Meanwhile, there have been reports that oxides appear and grow larger on a tube at the interface between the section which is immersed in the molten aluminum and the section which is exposed to the atmosphere in the furnace, and that the thermal stress associated with these conditions result in the deterioration of the tube. Meanwhile, damages to tubes caused by the above conditions do not occur with the lower immersion method, because the entire tube is immersed in the molten aluminum. The thermal efficiency is also superior to the upper immersion method, because the entire heat released from the tube is transferred to the molten aluminum. There are also disadvantages, however, such as that the molten aluminum may leak out to the outside of a furnace in case a tube is damaged.

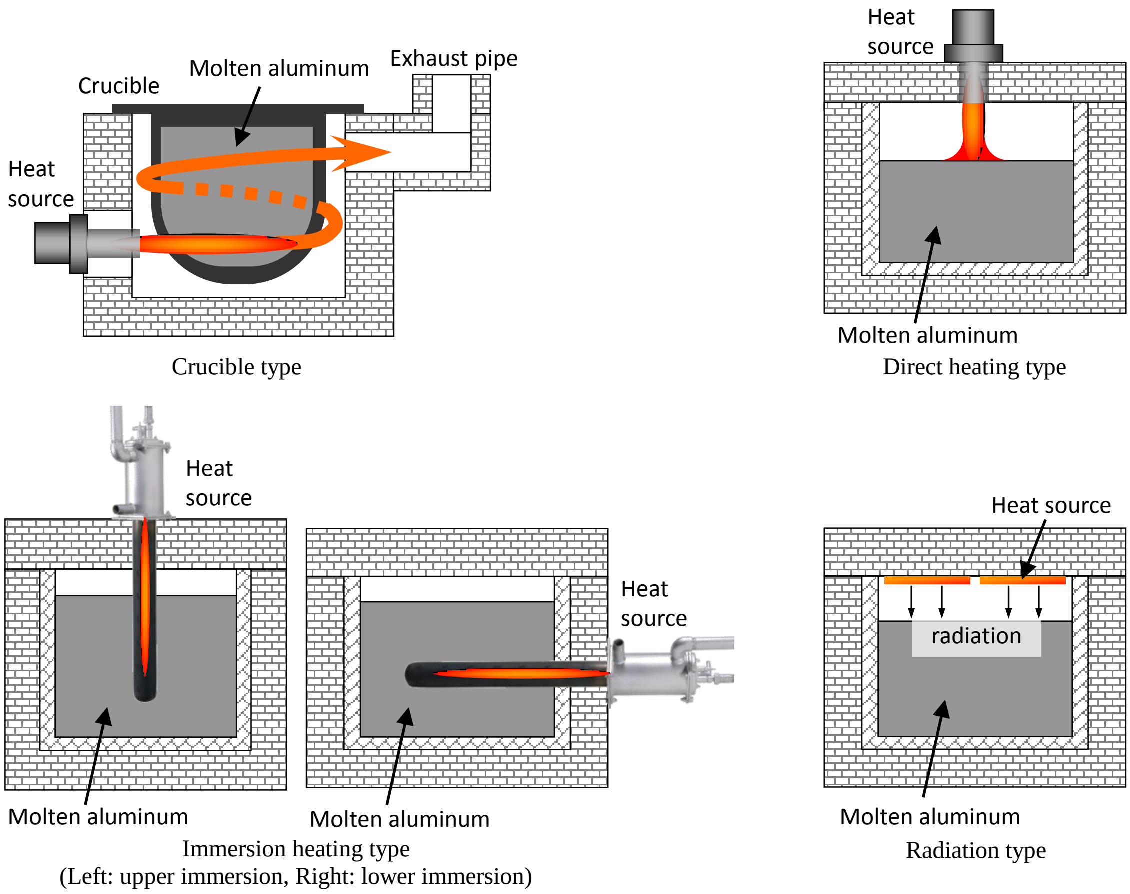

Fig.2 Image of the molten aluminum holding furnace

2.2 Problems of immersion burners to be solved

Conventional type of burners used in immersion heating type holding furnaces today has the following problems to be solved.

1) Improvement of efficiency

The exhaust gas of non-waste-heat-recovery type burners is hot, and the thermal efficiency (based on exhaust loss) is about 60%. This type of burner is superior to electric heaters in its energy efficiency and the amount of CO_2 emissions today, but further improvement of efficiency is expected.

2) Improvement of safety

An important task of the lower immersion method is to secure the safety against the leakage of molten aluminum to the outside of a furnace in case a tube is damaged. When burners are used in the lower immersion method, safety measures must be implemented against the leakage of molten aluminum from pipes of fuel gas or combustion air or exhaust pipes.

3) Size reduction

Electric heaters often use heat-transfer tubes with relatively small diameters. Replacement cost is required when the tube is to be replaced with another tube with a larger diameter when an electric heater is being replaced by an immersion burner.

3. Target specifications

Based on the conditions above, the target specifications are set as follows for the development of GIH.

1) Improvement of efficiency

Drastic improvement of energy efficiency and the reduction of CO_2 emissions compared to conventional non-waste-heat-recovery type burners can be achieved (Fig.4) by using a recuperator or regenerator (Fig.3) to preheat the combustion air using the heat of exhaust gas (waste heat recovery) as a method to improve the efficiency of the burner.

This development adopted the recuperator method by considering the balance between the energy efficiency and the reduction of CO_2 emissions and the initial maintenance cost. The development aimed to reduce the cost by using the structure in which a burner body has a simple heat exchanging structure and to achieve the thermal efficiency of 75% or more (based on exhaust loss) which is higher than the conventional non-waste-heat-recovery type burners.

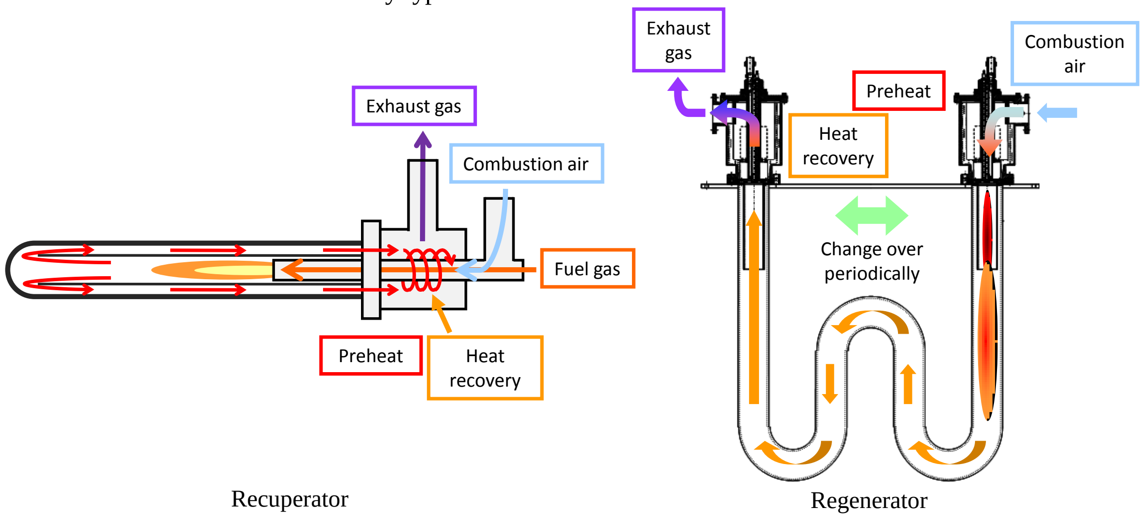

Fig.3 Schematic diagram of waste heat recovery

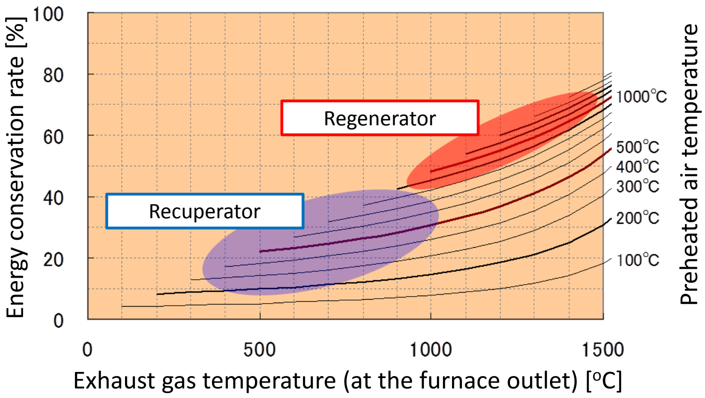

Fig.4 Relationship between the preheated air temperature and energy conservation rate
(When fuel is 13A and fuel-air ratio is 1.1)

2) Improvement of safety

The development aimed to create a structure which prevents molten aluminum from leaking out of a furnace through pipes of fuel gas or combustion air or exhaust pipes even when the heat-transfer tube is damaged while the lower immersion method is in operation.

3) Size reduction

The development aimed to create a relatively small size burner which can be used with small-diameter heat-transfer tubes so that the device can be easily replaced from conventional burners or electric heaters.

4. Features

4.1 Overview of structures and energy efficiency

Fig.5 describes the external appearance of GIH which is developed in this project.
As seen in Fig.5, GIH is used by combining it with a ceramic heat-transfer tube. The burner body has a heat exchanging structure, which realizes improved energy efficiency and the reduction of CO_2 emissions by using the waste heat generated by exhaust gas to preheating the combustion air.

Fig.5 External appearance of GIH

4.2 Size reduction

In addition to the burner body with heat exchanging structure which is described above, the reduced sizes of parts such as nozzles enabled the use of heat-transfer tubes with smaller diameters (the outer diameter of about 100 mm) for an immersion burner designed for molten aluminum holding furnaces. As a result, the replacement from not only existing burners but also electric heaters became easier.

4.3 Safety against the leakage of molten aluminum

A filtering mechanism was developed as a measure against the leakage of molten aluminum in the lower immersion method. This mechanism prevents the molten aluminum from leaking out of a furnace through exhaust pipes or other pipes even when the tube is damaged and thereby improves the safety. The heat-transfer tube destruction test was conducted and confirmed that molten aluminum would not leak through pipes of fuel gas or combustion air or exhaust pipe.

4.4 The use of surface combustion technology with nozzle mixing method

Surface combustion technology with nozzle mixing method which was a new development in this project was used for the burner nozzle of GIH.

Nozzle mixing method mixes the fuel gas and combustion air at the outlet of a nozzle unlike the premixing method which mixes the fuel gas and combustion air at the process before the burner nozzle (Fig.6).

The surface combustion technology with nozzle mixing method which is used for this burner is a technology which produces longer flame (slow combustion) than the flames of conventional burners, which is created by reducing rapid combustion near a nozzle by separately dispersing combustion air and fuel gas to the nozzle surface.

Fig.7 shows the flame created using a surface combustion nozzle with nozzle mixing method. The production of a long flame creates a homogeneous surface temperature of a ceramic heat-transfer tube, which prevents the heating of specific points and is expected to elongate the service life of the heat-transfer tube.

Preheating of combustion air was difficult with the combustion method based on premixing method. The use of the nozzle mixing method which mixes fuel gas and combustion air at the surface of a nozzle enabled the preheating of the combustion air and improved the thermal efficiency.

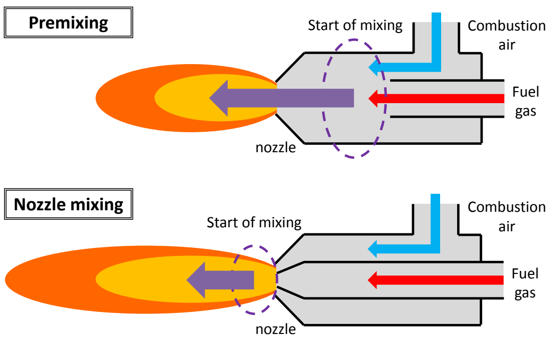

Fig.6 Difference between the premixing method and nozzle mixing method

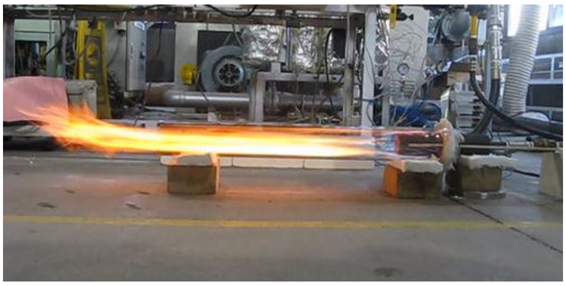

Fig.7 Flame created by a surface combustion nozzle

5. Specifications

Table 1 describes the specifications of GIH.

Table 1 Specifications of GIH

Combustion capacity*	12 to 29 [kW]
Combustion control method	Hi-Lo-Off control or On-Off control
Fuel gas	13A city gas**
Necessary gas pressure (at the inlet of a burner)	5 [kPa] or more
Immersion method	Upper immersion or lower immersion

*The combustion capacity varies depending on the diameters and lengths of heat-transfer tubes.

**In Japan, there are 13 groups of city gas (classified by calorie value and combustion speed), and each group is referred to by a number and letter of the alphabet, e.g., 6C and 13A.

6. Uses

GIH can be used as heat sources of immersion heating type molten aluminum holding furnaces with the retention capacity of one to three tons. GIH can also be used for larger holding furnaces by installing multiple GIHs.

Besides aluminum, GIH can also be used with non-ferrous holding furnaces such as zinc holding furnaces.

7. Performances

7.1 Basic performance of GIH

Fig.8 shows the relationship between the combustion capacity and thermal efficiency of GIH which was measured in a test furnace of Toho Gas. The thermal efficiency of 75% or more (based on exhaust loss) was confirmed in all ranges. This experiment confirmed that GIH has sufficient energy conservation performance in comparison to non-waste-heat-recovery type burners.

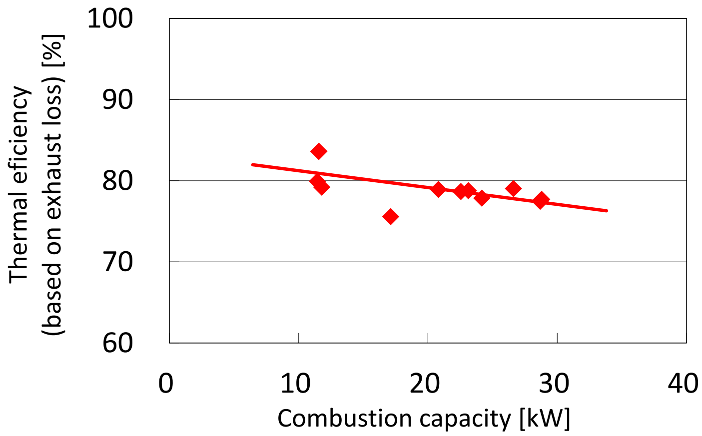

Fig.8 Relationship between the combustion capacity and thermal efficiency of GIH

(With a test furnace of Toho Gas)

7.2 Result of field test

Field test using GIH was conducted at our clients. Based on the result of the field test, the use of GIH reduced the primary energy consumption by 40% or more compared to already operating furnaces with immersion heating type electric heaters (see Table 2). The CO_2 emissions reduction effect was also estimated to be 50% or more.

Table 2 Effect of the reduction of primary energy consumption and CO_2 emissions through the use of GIH

Heat source	Primary energy consumption (reduction rate)	CO_2 emissions (reduction rate)
Electric heater	55.2 [crude oil kL/year] (base)	138 [t/year] (base)
GIH	28.4 [crude oil kL/year] (▲49[%])	56.8 [t/year] (▲59[%])

8. Future prospects

We are working to produce a series of products to be used with heat-transfer tubes in various sizes and to increase the capacity of GIH so that it can also be used for melting purposes.

9. Conclusion

Toho Gas developed a highly efficient immersion burner (GIH) targeting immersion heating type molten aluminum holding furnaces and confirmed the following results.

(1) The use of the surface combustion technology with nozzle mixing method realized slow combustion and enabled preheating of combustion air through the recovery of waste heat. High thermal efficiency of 75% or more (based on exhaust loss) was confirmed with this system.

(2) The safety against the leakage of molten aluminum while the system was being used with the lower immersion method was confirmed.

(3) Field test and other tests confirmed that GIH has sufficient energy efficiency and CO_2 emissions reduction performance.

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