Development of Ammonia Burner at Coal-fired Boilers for Decarbonized Society

TAKATOSHI YAMASHITA[*1] TAKESHI AMARI[*1]
YUICHIRO URAKATA[*2] KEIGO MATSUMOTO[*3]
TOSHIHIKO MINE[*4] AKIMASA TAKAYAMA[*5]

The Japanese government's Green Growth Strategy for carbon neutrality by 2050 presents a "roadmap" for the growth of the fuel ammonia industry. One of the future initiatives is the spread of ammonia co-firing and the increase in the co-firing rate in coal-fired thermal power plants, and the shift to ammonia single-fuel firing. Mitsubishi Heavy Industries, Ltd. (MHI) is developing technologies to enable ammonia co-firing for both circular firing and opposed firing systems of coal-fired boilers in order to respond to the efforts of various customers in Japan and overseas to use ammonia fuel toward the goal of carbon neutrality. This report presents the development of ammonia burners.

1. Introduction

MHI has declared its intention to realize carbon neutrality by 2040 (MISSION NET ZERO), which includes the promotion of the carbon neutrality of existing infrastructure. In order to achieve carbon neutrality in thermal power generation, which generates a large amount of CO_2, it is important to reduce CO_2 emissions from coal-fired boilers. MHI has been developing technologies that enable higher co-firing rates of ammonia, which does not emit CO_2 when combusted. This paper presents the development status of ammonia burners applicable to both the circular firing and opposed firing systems.

2. Concept of ammonia firing

2.1 Approach to higher ammonia co-firing rates

There is a problem that combusting ammonia in a coal-fired thermal power plant generates a large amount of NOx. Since this NOx generation is sensitive to the air ratio, i.e., the ratio of fuel to air, the setting of the amount of air to be fed from the burner is important. In order to increase the ammonia co-firing rate, in addition to controlling NOx, maintaining the combustibility of coal and controlling the increase in unburned combustible are required, so the combustion conditions required for both coal and ammonia need to be maintained at the same time. For this purpose, combusting coal and ammonia in separate burners (single-fuel firing burners) to co-firing them in the boiler can easily control the air ratios of each and reduce NOx emissions even at high co-firing rates. Also, this enables the co-firing rate to be changed as desired by adjusting the number of burners in operation and the burner load.

In combustion tests in a small burner furnace, installing separate coal and ammonia burners and setting optimal combustion conditions for each resulted in the suppression of NOx generation and no detection of unburned ammonia at the furnace outlet, even when the co-firing rate was increased[(1)]. Based on this, the modification to ammonia co-firing adopted the concept of replacing the existing burners with ammonia single-fuel firing burners.

*1 Chief Staff Engineer, Engineering Department, Steam Power Maintenance Innovation Business Division, Energy systems, Mitsubishi Heavy Industries, Ltd.
*2 Engineering Department, Steam Power Maintenance Innovation Business Division, Energy systems, Mitsubishi Heavy Industries, Ltd.
*3 Deputy Senior Director, Combustion Research Department, Research & Innovation Center, Mitsubishi Heavy Industries, Ltd.
*4 Chief Staff Researcher, Combustion Research Department, Research & Innovation Center, Mitsubishi Heavy Industries, Ltd.
*5 Combustion Research Department, Research & Innovation Center, Mitsubishi Heavy Industries, Ltd.

2.2 Selection of ammonia burner structure design based on combustion simulation

In order to modify an existing burner to be an ammonia single-fuel firing burner, several burner structure designs were developed based on the assumption that the burner can be switched to an ammonia burner, and a test burner for a combustion test in a 0.5 t/h furnace was selected by combustion simulation. **Figure 1** shows the simulation results of ammonia single-fuel firing burners. Using a simulation model that improved the prediction accuracy of combustion performance for coal-ammonia co-firing based on the results of basic tests, predictions for ignition conditions, NOx, unburned ammonia, etc., were made, and the burner structure to be used for the combustion test was determined.

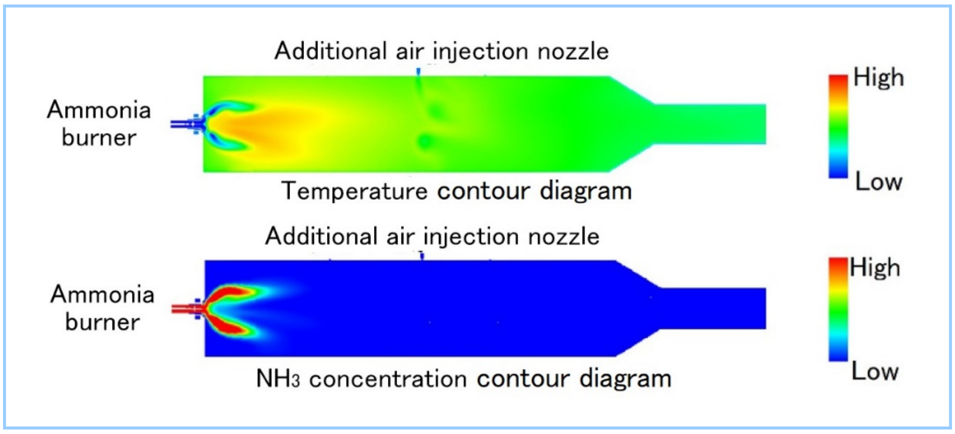

Figure 1 Selection of burner modification design based on combustion simulation

The next and subsequent chapters will describe initiatives to verify the performance through large-scale burner combustion tests to determine the burner structure.

3. Combustion test equipment and combustion test plan

3.1 Combustion test equipment

In order to evaluate combustion stability and exhaust gas performance during coal-ammonia co-firing and ammonia single-fuel firing, combustion tests are conducted in MHI's 0.5 t/h furnace (**Figure 2**). This equipment is capable of developing burners for both circular firing and opposed firing systems. In accordance with the burner arrangement characteristics of the two types shown in **Figure 3**, tests are conducted with two-stage coal burners and an oil burner placed between them for the circular firing system, and with a single ammonia burner for the opposed firing system. This equipment can test both ammonia gas-firing and liquid-firing systems to meet the various needs of our customers. Using this equipment, various exhaust gas concentrations such as NOx, unburned ammonia, nitrous oxide (N_2O), etc., which are of concern in ammonia co-firing, as well as flame temperature and various gas concentrations in the furnace can be obtained from the access port on the side of the furnace and utilized to improve the accuracy of combustion CFD.

Figure 2 Appearance of 0.5 t/h furnace

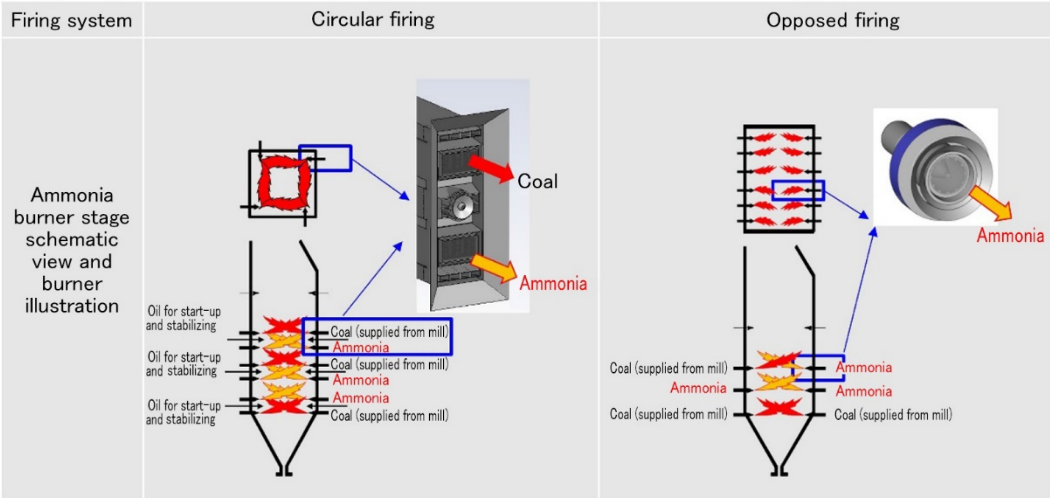

Figure 3 Concept of single-fuel firing burner placement for circular and opposed firing system boilers

3.2 Ammonia supply and storage equipment

This section describes the ammonia supply equipment installed under a project commissioned by the New Energy and Industrial Technology Development Organization (NEDO) for ammonia co-firing and single-fuel firing tests. **Figure 4** shows the appearance of the equipment. The equipment consists mainly of a liquefied ammonia tank, a receiving compressor, a liquid-phase pump, a vaporizer, and an ammonia detoxification tank for purging the system. The ammonia in the tank is saturated at normal temperature and can be supplied in the liquid phase to the test burner by pressurizing with the liquid-phase pump. The vaporizer enables an ammonia supply in the vapor phase as well. The capacity of the ammonia tank is 40 tons, which was selected to allow continuous testing for more than 24 hours in a 0.5 t/h furnace and up to about 8 hours in a 4 t/h furnace.

Figure 4 Appearance of ammonia supply equipment

3.3 Combustion test plan

We have started combustion tests with this 0.5 t/h furnace, and are evaluating concepts and narrow down burner shapes for both circular and opposed firing ammonia burners. Based on this, we will select the basic structure of the burner, aiming for stable ignition and the equivalent levels of NOx and unburned combustible in ash as those in the case of coal single-fuel firing.

After that, we plan to conduct final confirmation tests of the combustion stability and exhaust gas performance in a 4 t/h furnace, which is capable of conducting burner combustion tests with full-scale burner equivalent to actual equipment.

4. Schedule for practical application

With the aim of increasing the ammonia co-firing rate, this development is conducted in developing and demonstrating a technology to increase the ammonia co-firing rate at coal-fired boilers under the Green Innovation Fund program "Fuel Ammonia Supply Chain Establishment" project of NEDO[2]. As shown in **Figure 5**, we plan to develop an ammonia single-fuel firing burner by fiscal 2024 through combustion tests with using full-scale burner equivalent to actual equipment. In addition, we are working with JERA Co., Inc. on a basic plan and feasibility study for an actual-equipment demonstration of an ammonia co-firing boiler, aiming to verify ammonia co-firing at the co-firing rate of more than 50% in two units, one with a circular firing system and the other with an opposed firing system, through demonstrative operation using the actual equipment.

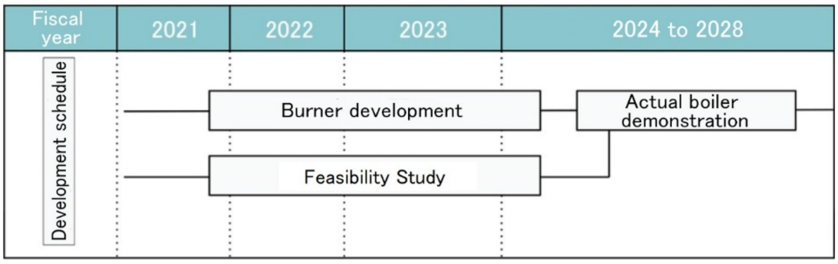

Figure 5 Schedule for practical application

5. Conclusion

This report describes the development status of an ammonia burner, which is being implemented for the carbon neutralization of coal-fired boilers and is intended for modifying existing boilers. We are developing an ammonia single-fuel firing burner to achieve a high co-firing rate, and presented an outline of a 0.5 t/h furnace combustion test facility. We have already started the test and will select the basic burner structure after confirming the abovementioned concepts for the burner regarding the achievement of ignition stability, NOx, and in-ash unburned fuel levels equivalent to those of a coal-fired burner. After that, we plan to conduct final confirmation of combustion stability and exhaust gas performance in a 4 t/h furnace, which is capable of conducting burner combustion tests on a scale equivalent to that of the actual plant. We also presented our initiatives toward future practical application.

This development is being conducted under "JPNP21020 Green Innovation Fund Project / Fuel Ammonia Supply Chain Establishment / Ammonia high-ratio co-firing and single-fuel firing for thermal power generation / High-ratio co-firing and single-fuel firing needed for ammonia power generation/, Development and demonstration of high-ratio ammonia co-firing technology (including single-fuel firing technology) in coal-fired boilers / Demonstration project of high-ratio ammonia co-firing in the commercial coal-fired power plants utilizing ammonia single-fuel burners" of the New Energy and Industrial Technology Development Organization (NEDO).

References

(1) Takatoshi Yamashita et. al, Development of Ammonia Co-firing Technology for Coal-fired Boilers toward Decarbonized Society, Mitsubishi Heavy Industries Technical Review Vol.59 No.4 (2022)

(2) JERA and MHI Start a Demonstration Project to Develop Technology to Increase the Ammonia Co-firing Rate at Coal-fired Boilers (2022), PRESS INFORMATION, Mitsubishi Heavy Industries, Ltd., https://www.mhi.com/news/22010702.html