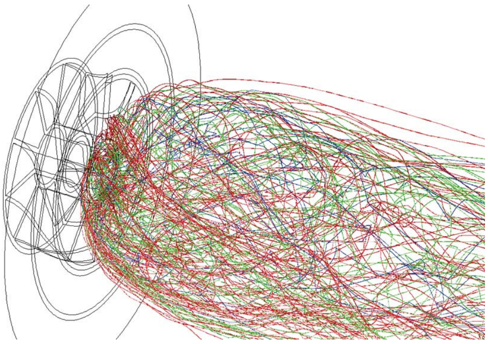
Development of Environmentally-Friendly Heavy Oil Fired Burner



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Aiming at the increase in use of combustion technologies for heavy oil fuel containing a lot of carbon residue and in order to develop heavy oil fired burners having excellent environmental performance, Mitsubishi Heavy Industries, Ltd. (MHI) examined the structure of atomizers and swirlers, which are the main components of the burners, mainly using numerical analysis. It was confirmed that the developed structure attained a reduction in particle size by 38% in a spray test and that the developed swirler remained undamaged even after one year of operation in actual equipment. In this way, the effectiveness of MHI's burner development was verified. This paper describes the analysis technologies that were newly established in the burner development.

1. Introduction

In the environment that surrounds the oil market, the demand for C-heavy oil has been decreasing significantly and a demand shift toward white oil has been advancing in recent years. It is believed that such a trend will steadily continue.

For increase in production of light oil products, some oil refineries have proceeded with introduction of SDA (Solvent De-Asphalting) equipment that uses organic solvent to extract light fractions. In that case, how to utilize heavy oil residue (SDA pitch) that is produced as a byproduct has become a problem(1).

SDA pitch is expected to be used as boiler fuel; however, it contains a large amount of carbon residue, which is comprised of carbon solids, and there is concern over the increase in dust concentration in combustion exhaust gas. Therefore, it is necessary for existing boiler plants to take large-scale environmental measures such as enhancing the dust collection facility.

MHI is promoting the development of heavy oil fired burners by combining numerical analysis technologies and experimental technologies in order to realize low-dust combustion of heavy oil fuel described above.

2. Technological problems of heavy oil fired burners

Figure 1 shows the basic configuration(2) of a heavy oil fired burner and **Figure 2** shows spray combustion process(3). For attainment of low-dust combustion of heavy oil, improvement in the following factors is necessary.

(1) Atomization performance of atomizer

During spray combustion, the heating of droplets, release of combustible gas known as volatile components, and a carbon combustion reaction all occur on the particles. Because carbon combustion reaction is relatively slow among these processes, the burn out time becomes longer when the carbon material is coarser, and the existence of residual cenospheres is one of the factors that causes a significant rise in dust concentration. Therefore, it is expected that the dust concentration can be reduced by improving the atomization performance of atomizers and making droplets smaller.

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(2) Durability of swirler

In front of the swirler, a circulation area is formed. Droplets are heated by combustion gas introduced into the circulation area. Then the released volatile components become a source for ignition and stable combustion is maintained.

At the edge of the swirler, air separation occurs and causes reverse flow. Droplets caught in the reverse flow adhere to the swirler, and the carbon residue burns and generates a high level of heat. Then, corrosion caused by components contained in the fuel, such as vanadium and sulfur, progresses and damages the swirler. Because heavy oil fuel contains a large number of corrosive components, it is necessary to suppress the air reverse flow for enhancement of the swirler's durability.

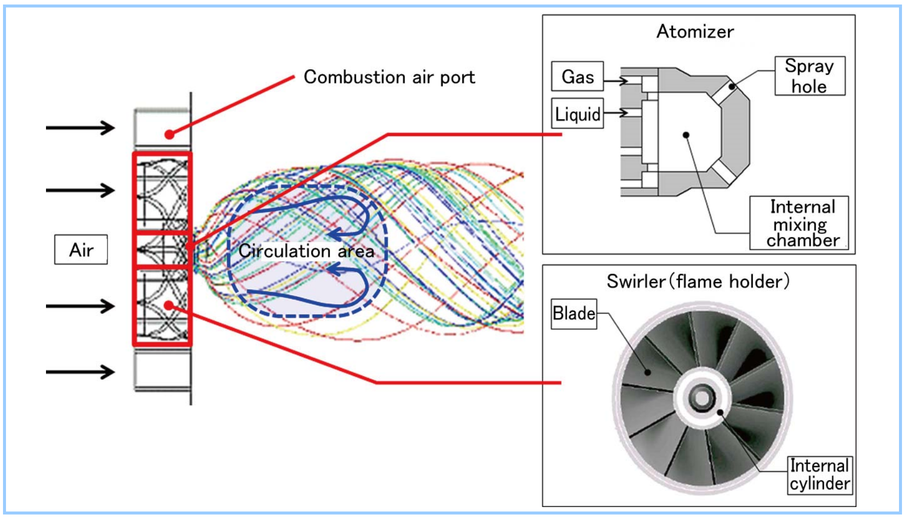

Figure 1 Basic configuration of heavy oil fired burner

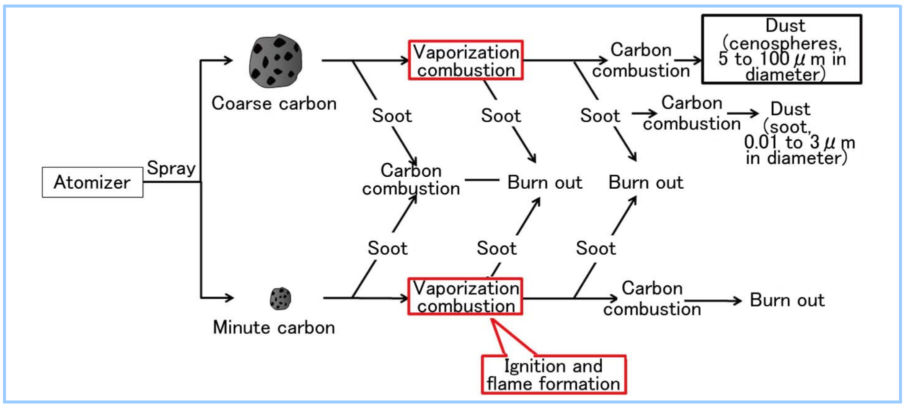

Figure 2 Combustion process of heavy oil fuel

3. Development of atomizer

For development of an atomizer having higher atomization performance, understanding gas-liquid flow inside the atomizer is important. Therefore, we implemented gas-liquid flow analysis inside an internal mixing-type atomizer shown in **Figure 3** using the VOF (Volume Of Fluid) method that is an interface-capturing method for numerical analysis.

3.1 Flow analysis inside internal mixing-type atomizer

Figure 4 shows gas-liquid distribution inside an internal mixing-type atomizer. Liquid that flows into the atomizer from its back face collides with gas that flows from the circumference, disperses, and then flows into spray holes. Because the gas flows from the circumference to the center of the atomizer, the liquid is pushed into the center of the atomizer and forms a liquid accumulation. This shows that gas and liquid in the internal mixing chamber are not mixed sufficiently. **Figure 4**(b) shows gas-liquid distribution in the section A-B of the spray hole entrance in Figure 4(a) and indicates that liquid flow into the spray hole is biased to the center of the atomizer. This is considered to be because of the liquid accumulation described above. Such deviation of the liquid inflow amount is a factor that causes the formation of thick liquid films in the spray hole and creates concerns about the generation of large droplets. Therefore, making the liquid flow into the spray hole more uniform is a development task of an atomizer having higher atomization performance.

To achieve the task, an improvement was added so that the spray holes were arranged on the side wall in addition to the tip in order to increase the length of the wetted perimeter, while keeping the same overall spray hole area. This improvement suppresses deviation of the liquid inflow amount to spray holes and formation of thick liquid films. In addition, because the spray holes on the tip create spray flow toward the front of the atomizer and the spray holes on the side wall create spray flow toward the side of the atomizer, collision of these spray flows hardly occurs, and the droplet size can be reduced.

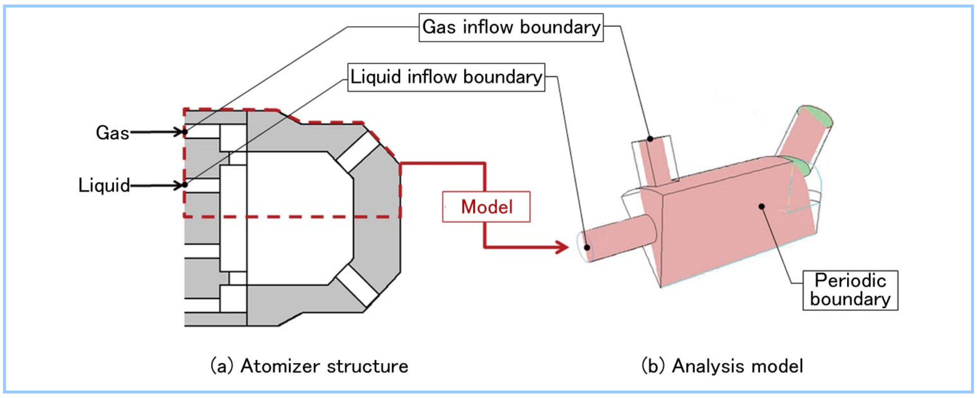

Figure 3 Analysis object

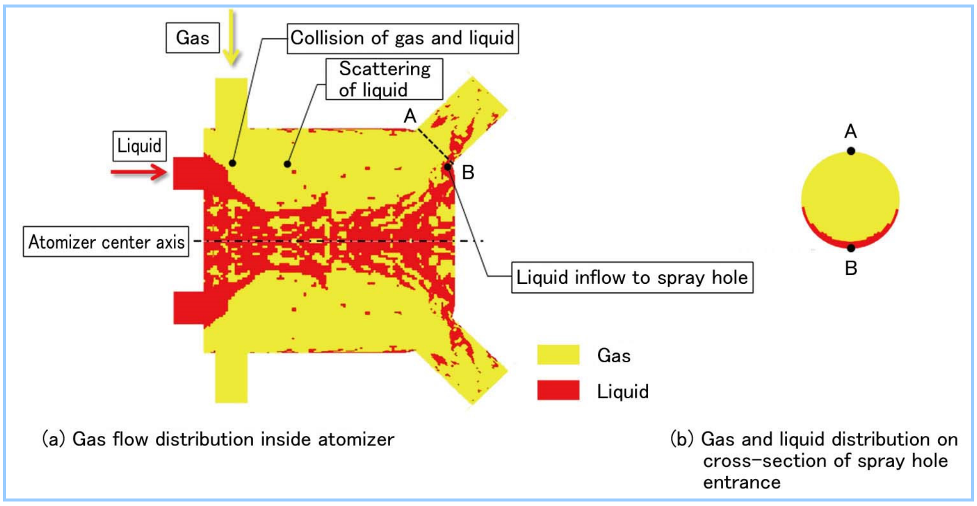

Figure 4 Internal flow analysis result of base atomizer

3.2 Verification with water-air spray test

The atomization performance of atomizers was evaluated with water-air spray tests. Two types of atomizers, a base atomizer that mixes gas and liquid in the fuel hole and is used as the standard for heavy oil fired burners, and an improved atomizer, were used as test pieces. The droplet size and the droplet speed were noncontact-measured using a phase Doppler interferometer (PDI) placed in front of the tested atomizer. A single spray flow was measured as shown in **Figure 5.**

Figure 6 shows the relation between the dimensionless distance from the center of the spray flow, the SMD (Sauter mean diameter), and the droplet speed. In the case of the base atomizer, large droplets exist. In the case of the improved atomizer, however, such large droplets do not exist. The droplet speed of the improved atomizer is characteristically slower than that of the base atomizer. A high-speed droplet has a high penetration power and causes concerns about an increase in dust density due to insufficient mixing resulting from penetration of the droplet through air flow. On the other hand, droplets from the improved atomizer are slow-speed and easily included in air flow, and therefore favorable mixing is expected. The atomization performance of the atomizers was compared using the representative droplet size obtained by weighing the SMD by the droplet speed. The representative droplet size of the improved atomizer is 38% smaller than that of the base atomizer, and enhancement in the atomization performance was confirmed. According to this result, it shows that the flow of gas and liquid in the atomizer improved as expected.

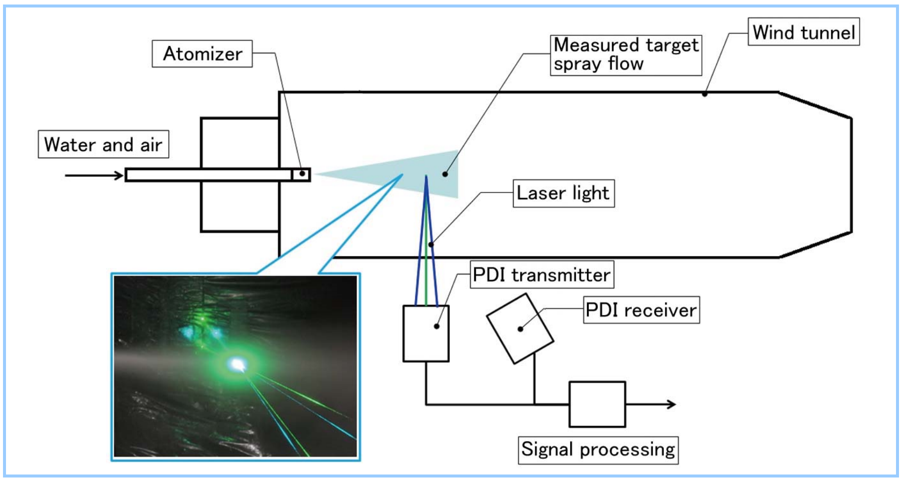

Figure 5　Measurement summary of water-air spray test

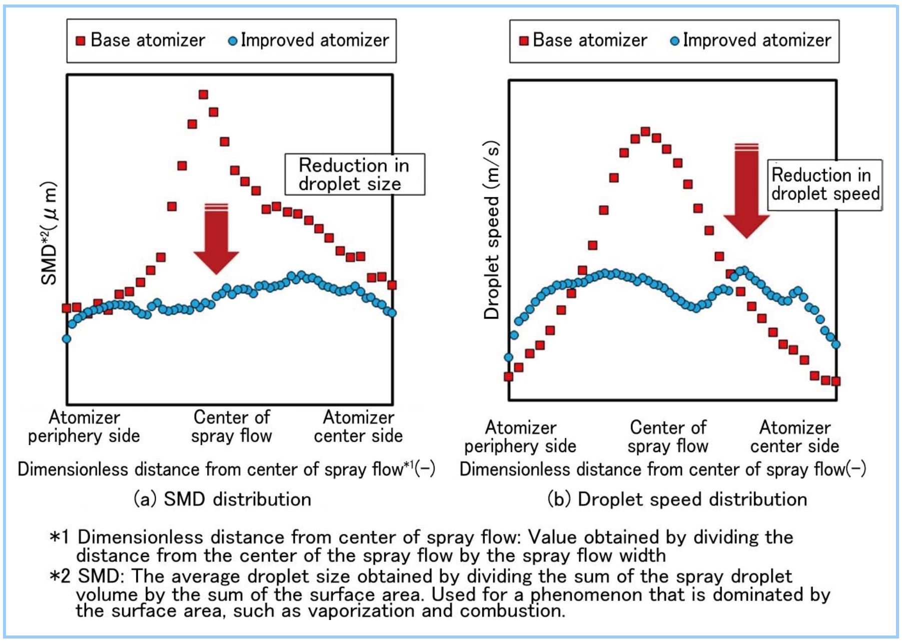

Figure 6　Spray test result

4. Development of swirler

We solved the problem of swirler damages by adopting an improved swirler by optimizing the swirler blade profile. The improved swiler can suppress the separation of air and the adhesion of possible reversing droplets (**Figure 7**).

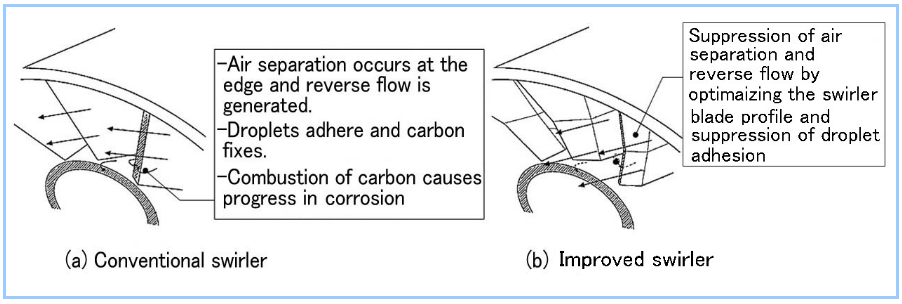

Figure 7　Combustion air flow around swirler

4.1　Analysis of swirler air flow

Figure 8(a) shows the result of air flow analysis using the conventional and improved swirler. No reverse flow occurs in any location, and therefore, it is expected that adhesion of droplets is suppressed. The improved swirler has a flow velocity and a circulating area of the circulating air that are equivalent to those of the conventional swirler as shown in Figure 8(b) and Figure 8(c), and therefore, it is seen that the ignitability is comparable.

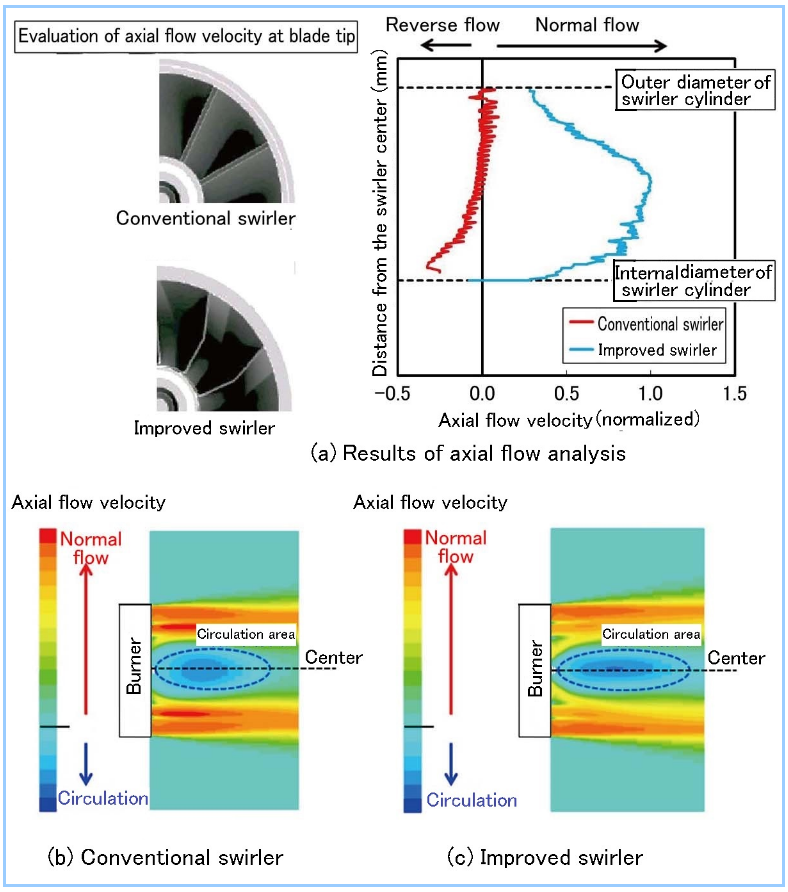

Figure 8 Swirler gas flow analysis result

4.2 Verification of improved swirler on actual unit

As shown in **Figure 9**, it was confirmed in an actual-equipment-scale combustion test that the improved swirler has the ignitability equivalent to that of the conventional swirler. The improved swirler was installed in a domestic unit in order to observe the progress of damage. Almost no damage and reduction in thickness was observed on the swirler blade even after one year of operation. It was verified that the improved swirler can be used for a long period of time even when used with heavy oil fuel.

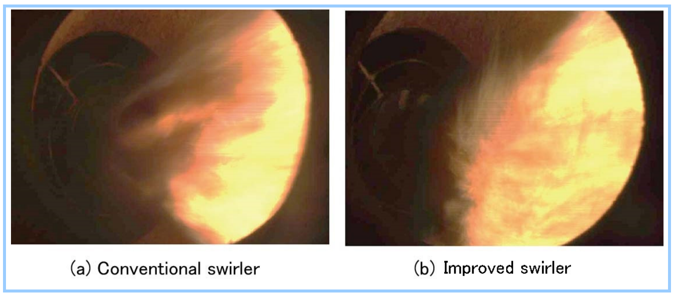

Figure 9 Ignition state

5. Conclusion

In development of heavy oil fired burners, we developed a structure that improves the flow of gas and liquid in the atomizer and combustion air flow around the swirler using numerical analysis technology. It was confirmed that the developed structure attained reduction in the droplet size by 38% and it was verified in actual equipment that the developed swirler remained undamaged even after operation for a long time. We will combine these technologies to increase the use of heavy oil fired burners in the future.

References

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