Inspection Technology for Inside of Power Plant Boilers by Drones

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In recent years, improvement of the operational rate by shortening the shutdown period of thermal power plants has been highly sought after, and in particular, the shortening of forced outage periods and the prevention of failures in boilers have become important issues. During periodic inspections of boilers, temporary scaffolding construction in the furnace becomes an essential task, and the drastic shortening of the shutdown period becomes possible if this temporary scaffolding is eliminated. Accordingly, Mitsubishi Heavy Industries, Ltd. (MHI) and Mitsubishi Hitachi power systems, Ltd. (MHPS) focused on drones, which have recently seen remarkable technical advancement, to develop a drone usable for initial investigations (identification of leaking parts) of unexpected tube leaks, as well as for intermediate inspections, without requiring the installation of scaffolding. This report describes the characteristics of the developed drone and inspection cases carried out in an actual boiler. This technology is expected to be applied not only to boilers, but also to other industries such as in the inspection of indoor facilities in which GNSS (Global Navigation Satellite System) cannot be used.

1. History of development

Typical commercially-available drones use information such as GNSS and magnetic field to control the position and attitude of the drones themselves. However, GNSS cannot be used in a boiler because it is an enclosed space. In addition, the magnetic field is disturbed because the inside of the boiler is surrounded by metal such as the boiler tube, meaning stable flight might not be achieved or the safety equipment cannot perform properly. Therefore, we have developed a boiler inspection drone with the specifications shown in **Table 1**. Since inspection accuracy equivalent to the visual inspection is necessary for the development of a drone for boiler inspection, the defect recognition performance target was set to detect a pinhole of φ1mm or a crack of 1mm width, and one of the requirement specifications was that the drone could be carried in from the standard manhole size.

Table 1 Specifications of boiler inspection drone

Item	Specifications
Size/Weight of drone	590 mm/1.3 kg
Wheel bumper size Spherical bumper size	ϕ 570 mm (Wheel part can be divided into two parts) ϕ 750 mm (Spherical part can be divided into two parts.)
Maximum rising/horizontal peed	5 m/s / 16 m/s
Operating ambient temperature	0 °C to 40 °C
Resistance to soot and dust	At least seven hours of flight
Defect detection capability	Φ1 mm
Continuous flight time	About 10 to 15 minutes per flight
On-board equipment	Inspection camera, LED light

2. Characteristics of inspection drones

Figure 1 presents the flight range of the boiler inspection drone. The flight range is the inside of the boiler furnace (red frame) and the pendant super heater just above the furnace (blue frame), where large-scale temporary scaffolding work is required for boiler inspection. Other areas, such as the rear flue, are not applicable because they can be accessed relatively easily from the manhole of the rear flue and scaffolding can be erected immediately.

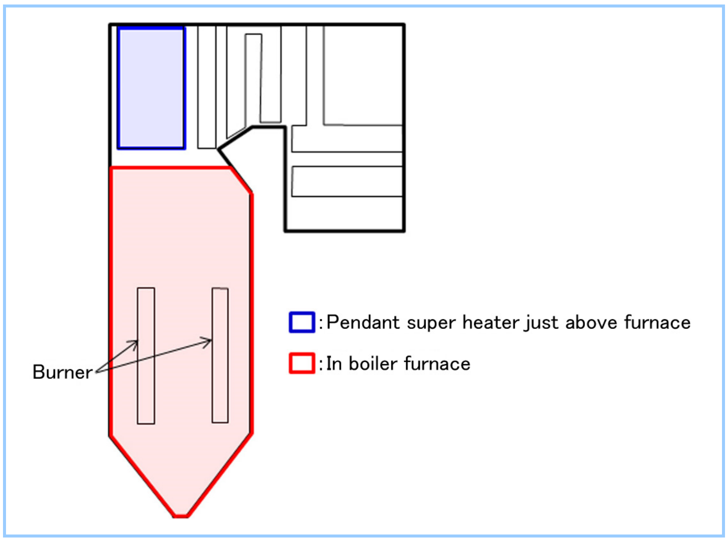

Figure 1 Flight range of boiler inspection drone

It is necessary to approach the subject as closely as possible to distinguish a defect, and two kinds of bumpers – the wheel type bumper for inspection in the boiler furnace (red frame) and the spherical type bumper for inspection of the pendant super heater (blue frame) just above the furnace – have been developed, and the characteristics are shown below.

(1) Wheeled bumper mounted drone

Figure 2 depicts the developed wheeled bumper mounted drone. One major characteristic of this airframe is that a wheeled bumper for collision prevention is mounted on its left and right sides. The hovering property is improved when this bumper comes into contact with the furnace wall, and imaging as close as 250 mm to the subject became possible. This bumper also adopted a slide structure, which can change the interval of the wheel according to the tube pitch of the furnace wall.*

Figure 3 gives the results of an in-house flight test of this bumper. In the test, the bumper was brought into contact with a large panel simulating the boiler furnace wall, and the effectiveness and defect detectability of the bumper were verified by photographing a boiler tube simulating a φ1 mm pinhole installed at the position of 6.5 m in height. As a result, it was confirmed that a pinhole of φ1mm could be clearly photographed by flying with the wheeled bumper against the furnace wall.

(2) Spherical bumper mounted drone

The developed spherical bumper mounted drone is shown in **Figure 4**. It is characterized by the 360° spherical bumper made of carbon surrounding the airframe. This bumper can prevent collisions from all directions, and it can fly in narrow spaces such as the pendant super heater just above the furnace.*

Figure 5 presents the test results of the actual flight test of this bumper. In the test, the drone flies between the burner part and the pendant super heater just above the furnace, and verifies the effectiveness of the bumper and the imaging accuracy of the burner part and heat transfer surface. As a result, it was confirmed that the drone flew without issue between the narrow pendant super heater, and that the conditions of the heat transfer surfaces, etc., were clearly photographed.

*Patent pending

Figure 2 Wheeled bumper mounted drone

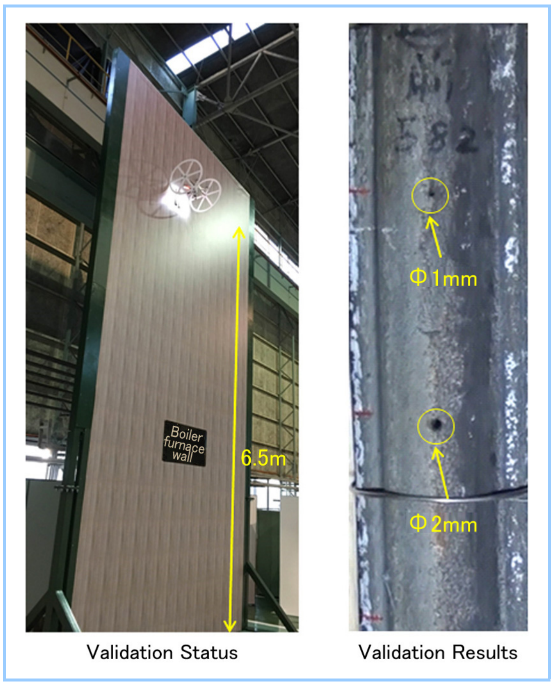

Figure 3 Flight test results of wheeled bumper mounted drone

Figure 4 Spherical bumper mounted drone

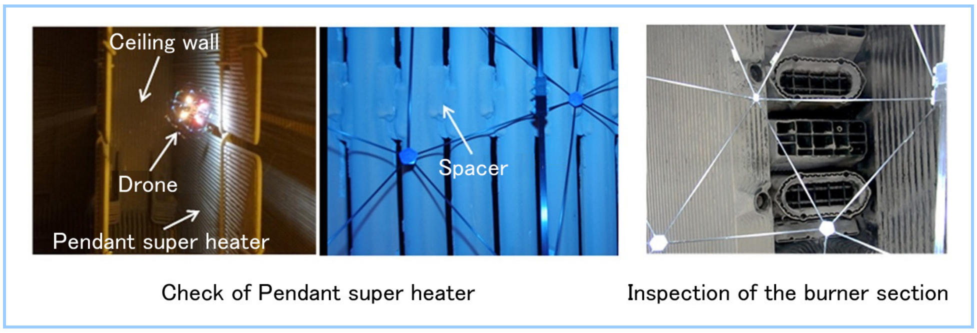

Figure 5 Actual flight test results of spherical bumper drone

3. Customer advantages

The following lists the expected advantages of using a boiler inspection drone reflecting the results of past inspections. (However, the significance of these advantages depends on the local situation.)

- In the case of leakage abnormality, the leakage position can be confirmed before the installation of scaffolding, so that the repair process can be shortened through the early identification of the cause, prior arrangement and manufacturing of the material for repair, and shortening the scaffolding installation period by limiting the areas where scaffolding needs to be installed.
- By having an engineer of MHPS, which is a boiler manufacturer, carry out the drone inspection, it is possible to quickly and accurately draft the inspection range, the cause of

damage (primary evaluation), the inspection plan for the cause investigation and horizontal development, as well as the range of exchange and repair.

- By confirming the conditions in the furnace such as the condition of the burner, furnace wall tube and pendant super heater (wear, deformation, expanding, etc.) and the condition of clinker (the state in which ash has melted and hardened) adhesion during the simple periodic inspection without requiring the installation of scaffolding, it is possible to support the periodic inspection plan with high accuracy from the next time and reduce the leakage risk.

4. Future prospects

The newly-developed boiler inspection drone is operated manually, and it is necessary to remove clinker in advance as a safety measure, because the operator is required to enter the furnace. Therefore, the development of an autonomous flight type drone has commenced, because inspection will become possible at an earlier stage by using a drone that can be remotely-controlled from outside the boiler. The basic technology was verified using a prototype with a mock-up facility in September 2018. Through the verification, it was confirmed that the drone recognized its position and autonomous flight was possible in an environment with a large amount of floating coal ash without using a satellite positioning system such as GNSS. The basic technology was verified using a prototype with a mock-up facility in September 2018. Through the verification, it was confirmed that the drone recognized its position and autonomous flight was possible in an environment with a large amount of floating coal ash without using a satellite positioning system such as GNSS. In fiscal 2019, a miniaturized and lightened practical model was manufactured, and development has been advanced with the aim of practical application and commercialization in fiscal 2020.