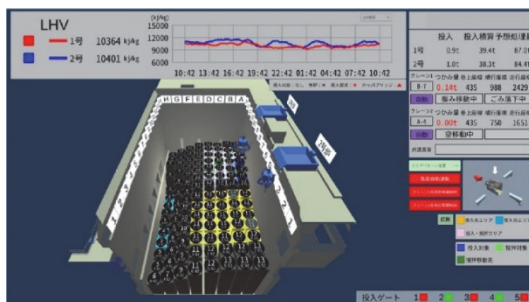


Development of Advanced Automated Crane Operation System to Support Sustainable and Stable Operation of Waste Incineration Facilities



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Mitsubishi Heavy Industries Environmental & Chemical Engineering Co., Ltd. has developed an advanced automated crane operation system for waste incineration facilities. This system considerably contributes to the facility's operational stability and a reduction in manpower, and can mitigate the effect of variable factors related to individual operators regarding waste receiving, feeding and mixing. Requiring hardly any human intervention during waste receiving and feeding processes, this system evaluates waste properties using a comprehensive scoring method based on three variables from three variables: (1) the number of mixings, (2) bulk density and (3) waste storage retention time.⁽¹⁾ Automatic waste mixing is then carried out accordingly. Use of this automatic mixing has been confirmed to lead to a smaller standard deviation of lower heating values (LHV) of waste and less fluctuation of the main steam flow rate. Thus, this crane operation system contributes to stable combustion of the incinerator and can become an indispensable system for sustainable and stable operation of a facility.

1. Introduction

In recent years, a key challenge faced by waste incineration facilities is the simultaneous achievement of stable operations and cost reduction in pursuit of facility sustainability. If stable operation with minimum costs is sought while dealing with a shortage of experienced operators, responding to the spread of infectious diseases, and seeking a reduction in CO₂ emissions to mitigate global warming, an operational support system is indispensable. Mitsubishi Heavy Industries Environmental & Chemical Engineering Co., Ltd. (hereinafter referred to as MHI EC) therefore has developed an advanced automated crane operation system for waste incineration facilities.^{(2), (3)} Using this system, waste receiving and feeding processes can be carried out with negligible human intervention. Moreover, waste properties are evaluated using a comprehensive scoring method based on three variables: (1) the number of mixings, (2) bulk density and (3) waste storage retention time. Automatic waste mixing is then carried out accordingly, leading to a smaller standard deviation of lower heating values (LHV) of waste and less fluctuation of the main steam flow rate. This report describes the results of the verification test of the system using an actual unit and presents the verification test results which have been obtained up to now.

2. Outline of the advanced automated crane operation system

A diagram of the process flow of the advanced automated crane operation system is shown in **Figure 1**. With "plant information" as a given condition, three functions, i.e. "route search," "three-dimensional (3D) registration management (of waste in the storage pit)" and "truck navigation optimization," are integrated to automatically determine the optimal solution to the ever-changing needs of plant operations at any given time. This system can reduce the manpower required for

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processes from waste receiving into the storage pit to feeding into the incinerator, in addition to providing consistent management of waste in the storage pit and stable combustion of the incinerator.

The height of the collected waste is measured by LiDAR (Light Detection and Ranging), covering the entire area of the storage pit. The route search automates the operation of one or two cranes for waste receiving, mixing and feeding into the hopper. Moreover, crane control information is sent to the advanced automated crane operation system (**Figure 2**). This enables monitoring of the following: height of collected waste in the storage pit, calculation status of the registration management system, necessity of feeding into the hopper, and crane operation conditions. In the 3D registration management, the storage pit is divided into sections by coordinates. The quality of waste at each point in the coordinate system is calculated in real time and can be represented numerically by comprehensive score points. This function is therefore regarded as management using a dedicated database that allows waste quality to be assessed quantitatively. The comprehensive score points ($= K1 \times \text{number of mixings} + K2 \times \text{bulk density} + K3 \times \text{retention time}$), as an indicator of the homogeneity of waste, can be obtained by weighting K1, K2 and K3 in the aforementioned formula according to the regional/seasonal characteristics of the waste incineration facility.⁽¹⁾ Truck navigation optimization calculates the appropriate destination of the compactor truck in conjunction with the route search, thereby achieving not only automatic navigation but also the handling of operations which have conflicting challenges, such as maintaining the height of the collected waste level throughout the first storage area and alleviating congestion of the platform. This system is also equipped with an automatic mixing function based on the comprehensive score points for the homogenization of waste in the storage pit, which contributes to stable combustion.

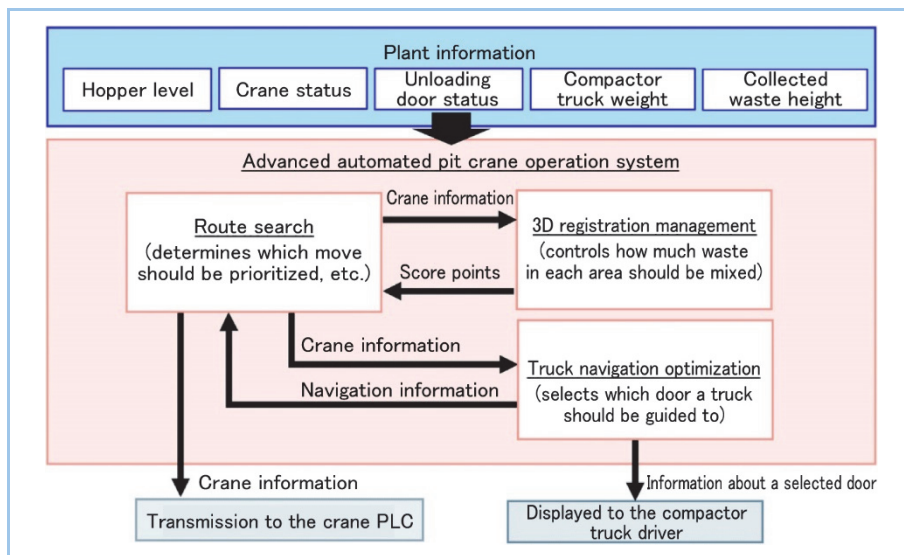


Figure 1 Flow diagram of the system processes



Figure 2 Advanced automated crane operation system

3. Verification test results of the advanced automated crane operation system performance

Sectional divisions of a waste storage pit are shown in **Figure 3**. Waste is received from the compactor truck into the first storage area, then moved to the second storage area by crane and mixed as needed. Waste placed in the standby area is fed into the incinerator on the day, whereas the waste in the second storage area will be incinerated on the next day. The advanced automated crane operation system by MHIEC was introduced into the incineration facility A and was in operation for a week, in order to verify system functionalities for the fully-automated waste receiving/feeding operation and automatic waste mixing. Results are introduced in the following sections. Specifications of incineration facility A are described in **Table 1**.

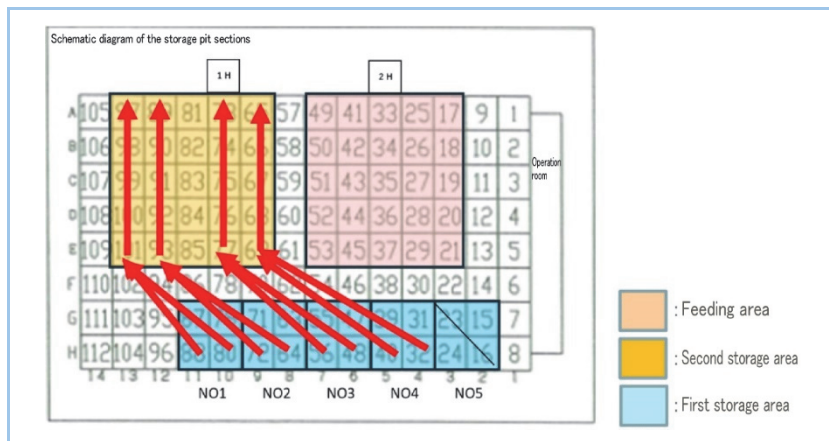


Figure 3 Sectional divisions of a waste storage pit

Table 1 Specifications of the incineration facility

Incineration capacity	182 tons/day
Number of incinerators	2
Incinerator type	Stoker type

3.1 Operational performance of fully-automated waste receiving and feeding

Waste receiving and feeding at the incineration facility are carried out from Monday through Saturday. A cycle is one week, and is repeated throughout the year. Mainly, the compactor trucks collect waste and bring it into the facility. In this environment, the advanced automated crane operation system was tested by operating two cranes simultaneously for waste receiving and feeding for one week. As shown by the test results of automatic waste receiving/feeding operation, the height of the collected waste in the first storage area never exceeded the upper limit. In fact, a margin of approximately 1 m was maintained throughout the week (**Figure 4**). The rate of human intervention in operations was 4.6%, indicating almost fully automated waste receiving/feeding operations (**Figure 5**). The 4.6% intervention is related to the shredding and spreading of oversized flammable items (which are brought in irregularly) inside the storage pit and leveling of the pit area. As shown in **Figure 6**, the waiting time per compactor truck in standby in front of the unloading door was managed within 50-60 seconds despite changes in the number of trucks coming into the facility each day of the week. There were no cases of congestion for the large compactor trucks.

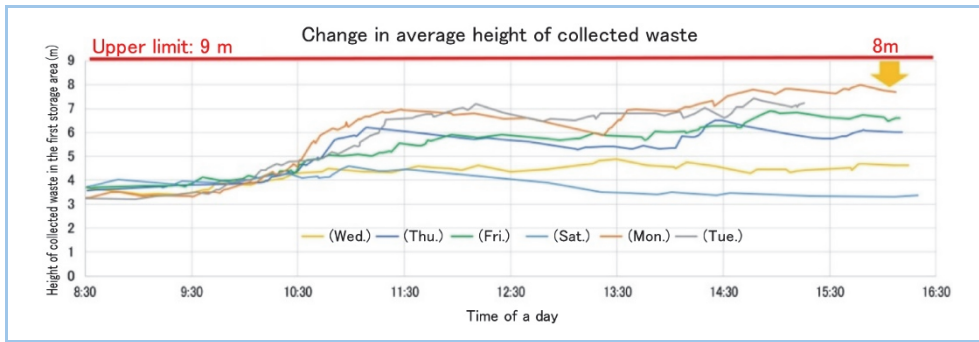


Figure 4 Changes in height of collected waste in the first storage area

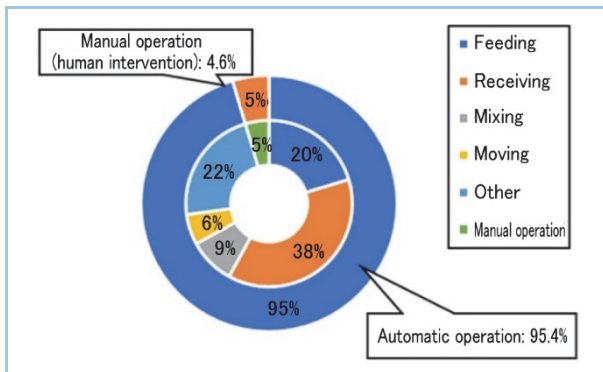


Figure 5 Rate of automatic operations

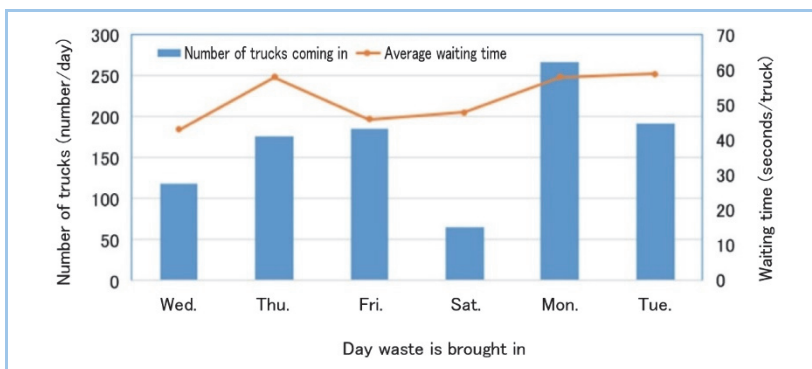


Figure 6 Number of compactor trucks by day of the week and average waiting time in front of the unloading door

3.2 Automatic waste mixing performance

Since sufficiently mixing and homogenizing the waste stored in the pit before incineration leads to smaller fluctuations in the amount of evaporation in the boiler and less variation in the exhaust gas properties, stable performance of the incinerator can be expected. The method of automatic waste mixing is as follows. Based on the comprehensive score for all coordinates of each area, waste is spread within the storage pit from coordinates with a lower score to coordinates with a higher score, before mixing. Mixing is carried out even during the waste receiving and feeding operations. In principle, mixing in the second storage area is prioritized, until the following day when new waste starts to come in and the well-mixed area is designated as the standby area for the day. In this way, waste is automatically mixed for about 24 hours. The mixed waste was used to verify improved combustibility by automatic mixing.

Results are as follows. The relationship between the comprehensive score, LHV variation coefficient, and steam flow rate fluctuation are shown in Figure 7. Mixing to a greater extent leads to a higher comprehensive score, which indicates higher homogeneity of waste as shown by lower LHV variation coefficients ($LHV\sigma/LHV\mu$). Lower LHV variation coefficients indicate that the waste is homogeneous, lead to smaller fluctuations in the main steam flow rate ($((PV-SV)/SV)\sigma$). As a result, combustion becomes more stable. The relationship between standard deviation of the comprehensive score and fluctuation of main steam flow rate is shown in Figure 8. These results highlight the importance of keeping fluctuation of the comprehensive score low while achieving a

higher comprehensive score, when considering factors to minimize fluctuation of the main steam flow rate. Results of the combustion performance assessment under conditions of with or without automatic mixing are shown in **Figure 9**. According to the results, combustion becomes more stable with automatic mixing, and is shown by a reduction in variations compared to cases without automatic mixing (i.e. 16% decrease in evaporation amount, 17% for CO and 40% for NO_x).

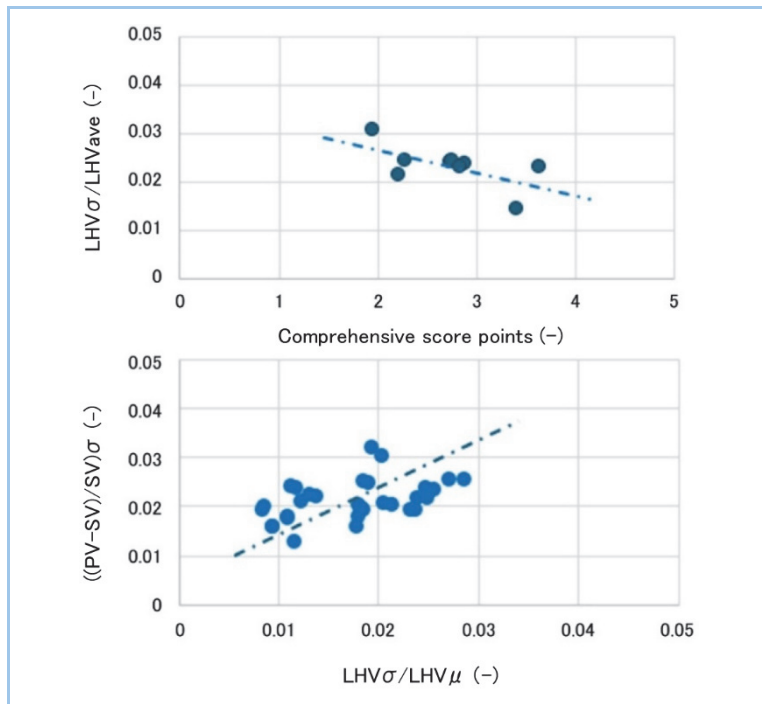


Figure 7 Relationship between the comprehensive score, LHV variation coefficient, and main steam flow rate fluctuation

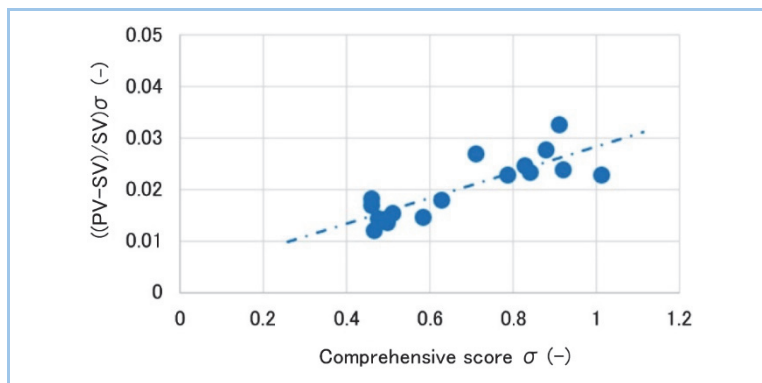


Figure 8 Relationship between the standard deviation of the comprehensive score and fluctuation of main steam flow rate

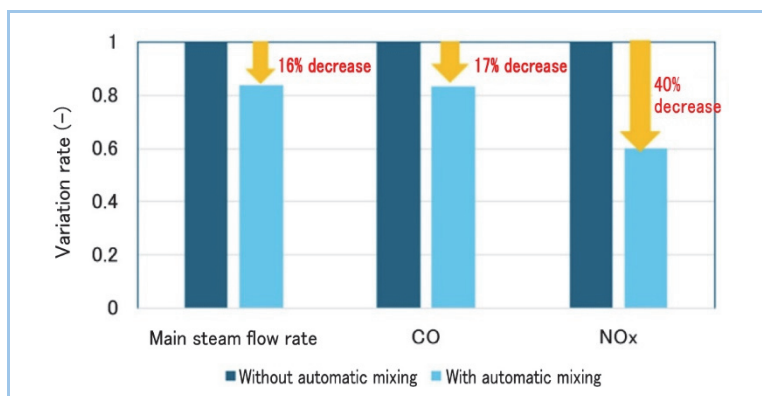


Figure 9 Combustion performance assessment with or without automatic mixing

4. Conclusion

In this report, incorporation of a truck navigation optimization function in the advanced automated crane operation system by on MHIEC has been confirmed to mitigate heavy congestion of compactor trucks at an incineration facility, and achieves $\geq 95\%$ automation of waste receiving and feeding operations in the storage pit. Use of the automatic mixing function was confirmed to contribute to stable combustion by controlling variation of main steam flow rate, as well as a reduction in CO and NO_x. Thus, introduction of advanced automated crane operation system is considered to result in the following critical outcomes in waste incineration facility operations: "reduction in the manpower necessary from waste receiving to feeding into the incinerator processes," "stable management of waste in the storage pit" and "combustion stability of the incinerator." Looking forward, MHIEC seeks to further enhance the reliability of the above-mentioned technologies, and will continue to offer products and services that meet the needs of customers such as plant stability and labor-saving features, while also considering various issues such as CO₂ emission abatement.

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