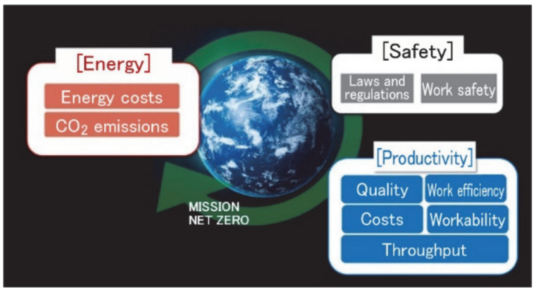
Green Manufacturing Activities for Reducing Factory Power Costs and CO_2 Emissions



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The Mitsubishi Heavy Industries Group is promoting energy saving and rationalization activities regardless of the amount of CO_2 emissions to achieve carbon neutrality by 2040. For these activities, environmentally conscious green manufacturing that reduces equipment energy consumption while maintaining and improving work safety and product productivity is important. This report outlines how green manufacturing was achieved for the production equipment of the Oye Plant, which manufactures aerospace parts, resulting in a 10% reduction in factory power costs and CO_2 emissions.

1. Introduction

In recent years, the Mitsubishi Heavy Industries Group (hereinafter referred to as MHI Group) has declared its goal of achieving carbon neutrality by 2040 and is advancing activities toward it [(1), (2)]. Specifically, the Oye Plant, which manufactures large, high-quality aerospace parts such as Boeing 787 wings, Boeing 777 rear fuselage and tail section parts, and structural components for the domestically produced H3 launch vehicle, is one of the MHI Group's plants with high energy consumption. It also has faced challenges including reduced production volumes due to the COVID-19 pandemic and soaring electricity and gas prices. Therefore, since fiscal 2021, the Oye Plant has been undertaking carbon-neutral activities aimed at rebuilding the manufacturing foundation to recover the production volume and prepare for future production increases.

2. Overview of activities

The Oye Plant currently operates over 500 custom-made equipment units to meet demands for the diverse range of components used in aerospace parts. **Figure 1** shows the energy consumption by equipment type and the main production equipment at the Oye Plant. Equipment requiring stringent precision in temperature, humidity, and cleanliness within large spaces, such as heat treatment, production air conditioning, and surface treatment equipment, consumes large amounts of energy.

Necessary energy-saving activities toward carbon neutrality include actively promoting changes in the conditions of energy-intensive production equipment. However, the manufacturing of aerospace parts requires strict adherence to processes, once established, that ensure high levels of safety, and any changes to these conditions without careful consideration are not allowed.

Table 1 summarizes the timeline of energy-saving activities undertaken by the Oye Plant since fiscal year 2021 in response to changes in the business environment. From fiscal year 2021 to fiscal year 2022, the plant, primarily the Manufacturing Department, worked to eliminate waste in production equipment and processes without affecting product quality and to foster a culture of energy-saving activities involving all employees.

To further promote these activities, starting in fiscal 2023, corporate divisions centered on the Research & Innovation Center have been participating to expand the activities to the entire

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plant and promote efforts for energy saving while maintaining the productivity of aerospace parts from the perspective of overall optimization. Specifically, the activities have been revitalized and advanced by building a system that transcends departmental boundaries and even boldly challenges process changes, establishing a green manufacturing scheme that achieves not only safety and productivity but also energy saving in equipment, and developing a tool that visualizes energy loss in equipment (hereinafter referred to as "energy diagnosis tool"). The next chapter presents the key schemes and energy diagnosis tool used in these activities.

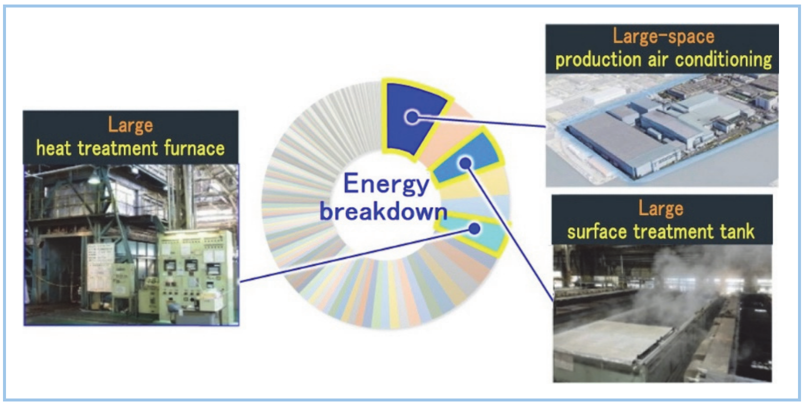

Figure 1　Energy breakdown by equipment type and main production equipment at Oye Plant

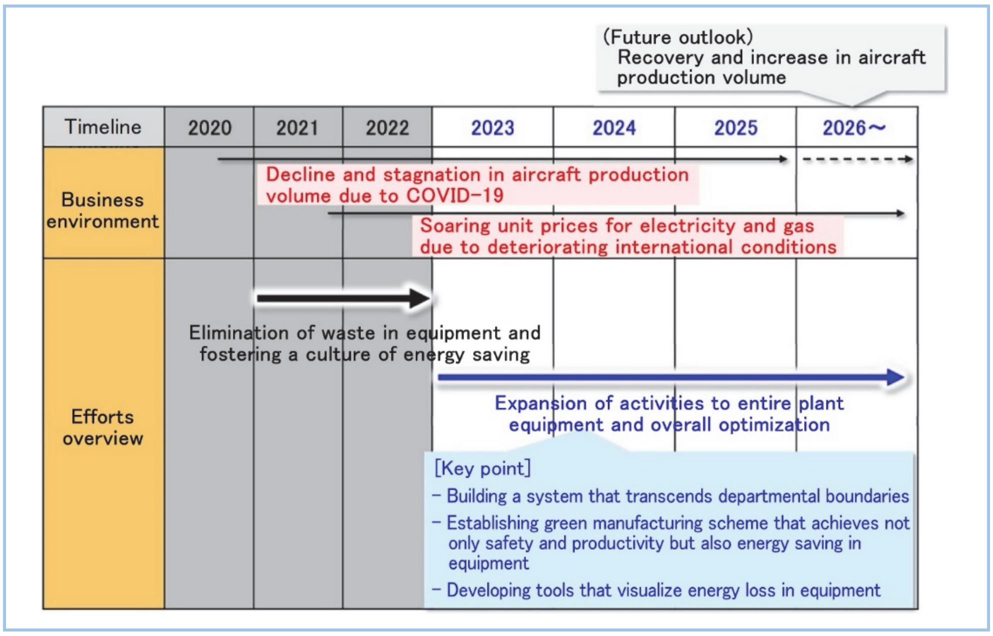

Table 1　Efforts in energy-saving activities at Oye Plant

3. Specific efforts

3.1 Establishment of green manufacturing scheme that achieves productivity and energy saving in equipment

A green manufacturing scheme was established to promote effective energy-saving activities while maintaining high product quality in aerospace parts. As shown in **Figure 2**, the scheme is broadly divided into selection, analysis, countermeasure, and evaluation.

The selection involves identifying the power sources for all of more than 500 production equipment units within the plant and selecting those with high energy consumption. For example, the identification is made possible by visualizing power consumption per process unit and equipment unit using a Pareto chart, as shown in **Figure 3**. Through analysis, equipment with a higher implementation priority was accurately identified.

Figure 2 Steps for considering green manufacturing scheme

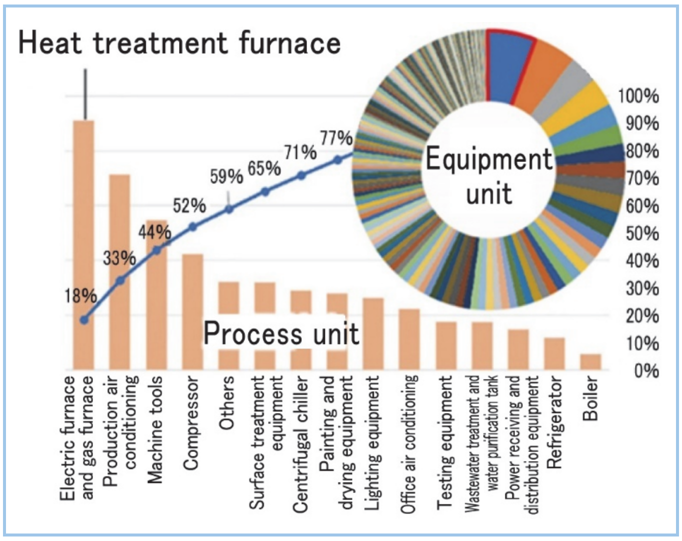

Figure 3 Power consumption per process unit and equipment unit

Next, the analysis is performed to analyze the selected equipment. In addition to analysis using commercially available electricity and gas meters, a self-developed energy diagnosis tool (Section 3.2) was utilized to visualize specific areas within processes and equipment with high energy usage ratios.

The countermeasure involves formulating effective countermeasure plans and numerical targets based on a scientific approach from the Research & Innovation Center. The scientific approach is a methodology for systematically and objectively understanding matters and resolving them, and a key point here is formulating specific countermeasure plans that incorporate the safety and productivity of processes and operations linked to the target equipment. Furthermore, in addition to formulating countermeasures, anticipating checkpoints (concerns) and the implementation difficulty level for realizing the countermeasures to reflect them in the execution plan is also necessary. Therefore, more efficient countermeasure planning was made possible by formulating guidelines as shown in **Table 2**.

The evaluation, the final step, involves examining the applicability of the countermeasures for the equipment and verifying their effectiveness. As previously described, since the manufacturing processes for aerospace parts cannot be easily changed, it is necessary to thoroughly identify all checkpoints (concerns) based on a scientific approach and ensure that all technical verifications are performed without omission. As an example, **Figure 4** shows a case where a commercially available float was adopted as a countermeasure against heat dissipation from the liquid surface in a large surface treatment tank. A relatively inexpensive, chemically resistant resin float available commercially was selected for the countermeasure against heat dissipation from the liquid surface (Figure 4(a)). The benefit of applying the resin float floating on the liquid surface (Figure 4(b)) is that it can reduce the energy consumption of the 90°C surface treatment tank by approximately 48%. On the other hand, the target surface treatment tank is designed for the treatment of aircraft outer panels and reinforcing members, and there are multiple checkpoints (concerns) from a productivity perspective, including the dissolution of the float and temperature uniformity in the tank (Figure 4(c)). The countermeasure was applied after technically verifying and evaluating its effects and scientifically proving that it causes no issues.

Table 2 Standard guidelines for each equipment type to achieve green manufacturing

Equipment	Manufacturing process	Countermeasure			Checkpoints (concerns)
		Method	Effect	Difficulty level	
Production air conditioning	Machining, composite molding, painting, assembly and outfitting	Revision of exhaust volume	-8%	Low	Work environment (ordinance on prevention of organic solvent poisoning), cleanliness requirements
		Revision of set temperature	-10%/℃	Low	Process requirements for each target
		Minimization of equipment warm-up operation	-5 to 10%	Low	Equipment and process requirements, target object temperature surveys, etc.
		LT reduction: Minimization of operating time	(Varies depending on the target)	Low to Medium	Overall manufacturing flow, bottleneck processes
		Building insulation measures	-10 to 15%	Medium to High	(Regulations, building insulation specifications)
		Automated control in accordance with external environment	-30%	Medium to High	(Configuration equipment, intake/exhaust specifications, operating conditions)
Heating furnace	Heat treatment, painting, composite molding	Operating conditions, centralized operation	(Varies depending on the target)	Low	Item to be treated, process requirements
		Tuning of furnace circulation fan	-10 to 40%	Low	Item to be treated, process requirements
		Revision of cooling water temperature (vacuum furnace)	-20%	Low	(Equipment seal heat resistance evaluation)
		Thermal insulation measures	-5%	Medium	Heat loss investigation, equipment management requirements
		Adoption of direct heating process	-15% to 25%	Medium to High	Item to be treated, process requirements
Personnel air conditioning	Non-environmental requirement processes	Revision of set temperature	-10%/℃	Low	Interviews with workers (identifying concerns)
		Utilization of energy-saving components	(-13%)	Medium	Manufacturer survey
Surface treatment tank	Surface treatment, cleaning	Countermeasure against heat dissipation from liquid surface	-20 to 30%	Low	Heat loss survey, equipment management requirements, solubility, etc.
		Lowering liquid temperature	Up to -30%	Low	Process requirements, production control values, etc.
		Utilizing new low-temperature cleaning agent	(Unknown)	Medium	Equipment requirements, process requirements
		Switching from air agitation to convection agitation	-30%	Medium to High	Equipment requirements, process requirements
Machine tools	Machining, forming, A/R (automatic drilling and fastening)	Detailed power visualization, waste reduction	-10 to 20%	Low	Equipment requirements, process requirements
		Rotating load reduction	-18%	Medium	Equipment requirements, process requirements, LT requirements
		Adoption of high-efficiency cutting tools	-10 to 15%	Medium to High	Equipment requirements, process requirements
Compressor	Assembly/outfitting, composite molding	Discharge pressure reduction	-15%	Low	Bottleneck process equipment requirements, process requirements
		Utilization of waste heat recovery equipment	-20%	Medium	(Equipment requirements)
Refrigerator	Forming (aluminum), assembly/outfitting (seal)	Revision of storage temperature	-29%	Low	Equipment requirements, process requirements
		Installation of heat-dissipation prevention cover	-10%	Low	Equipment requirements, process requirements
		Revision of operation through inventory minimization	-70%	Medium to High	Process requirements (only for high-rate production)

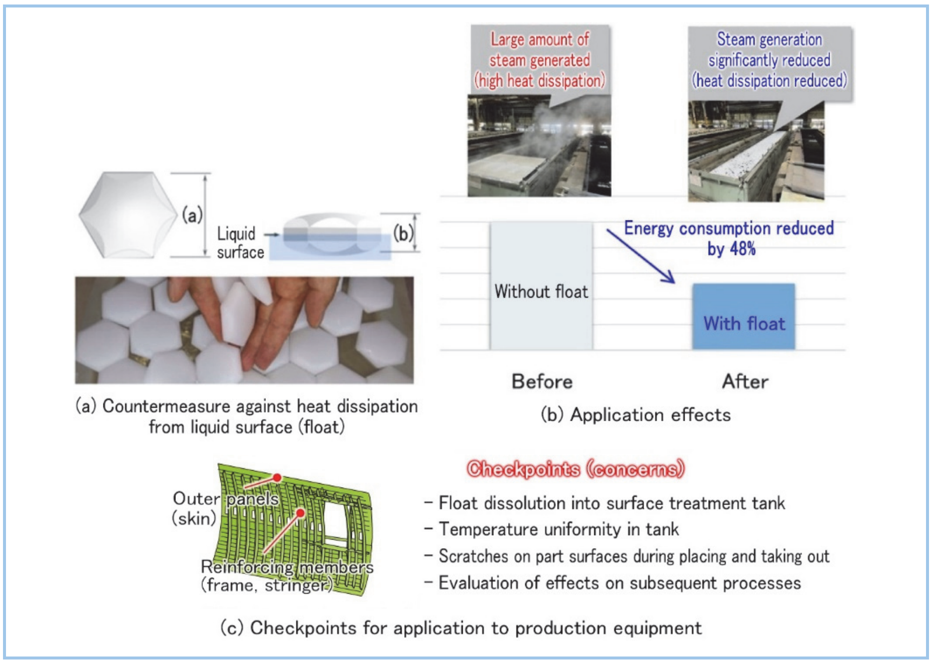

Figure 4　Countermeasure against heat dissipation from surface treatment tank

3.2　Energy diagnosis tool

This section outlines the energy diagnosis tool, a key point for the step "2. Analysis" of the green manufacturing scheme, using the analysis results of a large heat treatment furnace for aluminum alloy parts as an example. **Figure 5** shows a schematic diagram of the heating area of the target furnace. This heat treatment furnace is large-scale equipment designed to treat parts measuring several meters in size, employing a circulation fan to circulate air within the furnace and heat the products.

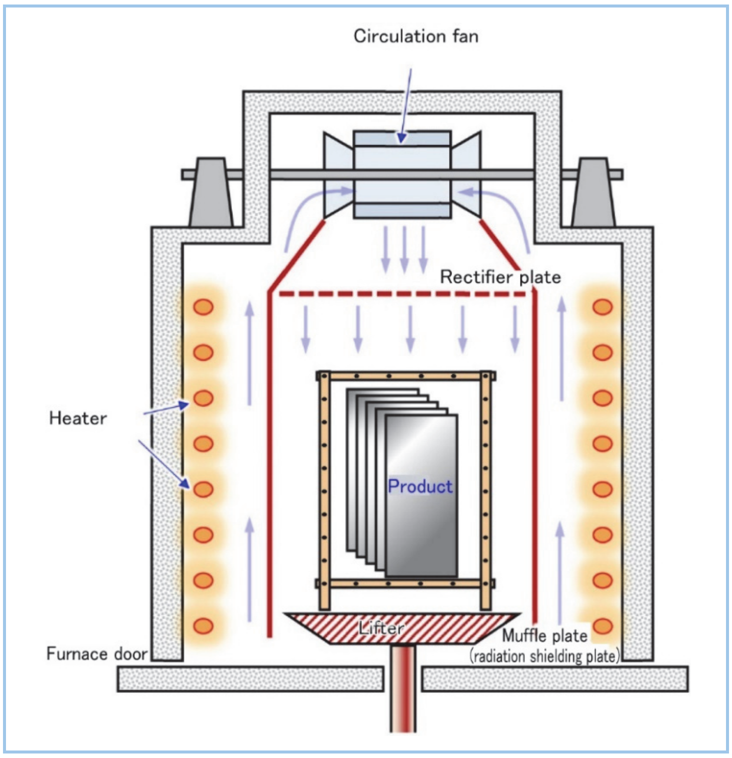

Figure 5　Schematic diagram of heat treatment furnace

The existing measurement tool had an issue of difficulty in identifying effective countermeasure points for thermal utilization equipment such as heat treatment and surface treatment equipment at the Oye Plant. As such, a tool that visualizes the breakdown of energy losses was developed in-house. This energy diagnosis tool automatically performs heat balance calculations based on designated equipment information items (heating conditions, equipment specifications, and specifications of the item to be treated) input as shown in **Figure 6**(a), and provides the energy usage breakdown ratio for the target furnace as shown in Figure 6(b) as output information. This tool not only visualizes the locations of energy loss and clarifies areas which should be improved, but also enables the discovery of points for improvement that had not been previously focused on.

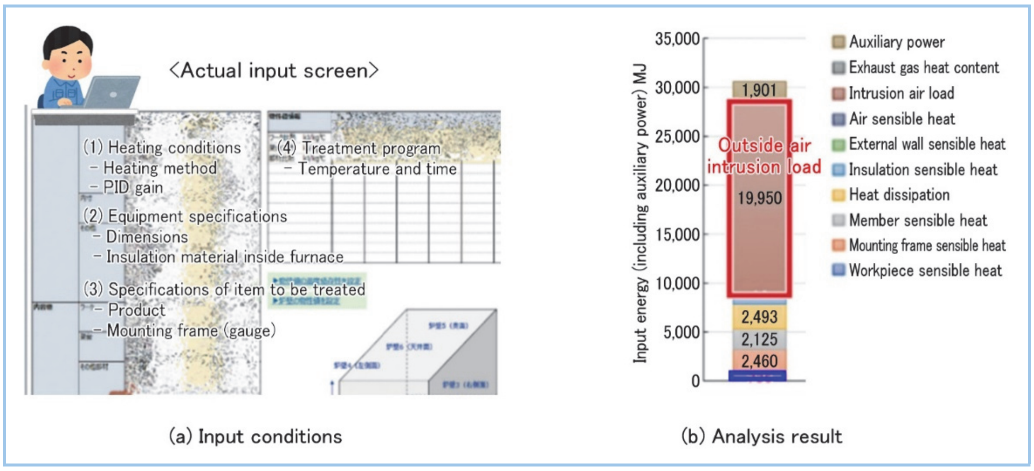

Figure 6 Overview of energy diagnosis tool

4. Achievement and effects

Through energy-saving efforts utilizing the green manufacturing scheme from fiscal 2023 onwards, a total of 64 improvement cases were implemented for various production equipment without large-scale investment. The cumulative CO_2 emission reduction effect achieved was approximately 10% for the entire plant in fiscal 2024. **Figure 7** shows the breakdown of the achieved reduction. Figure 7(a) shows the number of applied cases by equipment category, while Figure 7(b) indicates the breakdown of the reduction effect by equipment category. The number of applied cases by equipment category was highest for heat treatment, followed by production air conditioning, surface treatment, and machining. On the other hand, the effects of application were greatest for production air conditioning, followed by surface treatment, heat treatment, and painting. It was found that production air conditioning achieved a large effect relative to its number of applied cases. In the manufacturing of large, high-precision aerospace parts, production air conditioning is frequently used for temperature and humidity control in assembly, outfitting (seal), and machining processes, which is assumed to be a major factor in high energy consumption. The various production equipment including the production air conditioning systems, which succeeded in achieving energy savings through these activities, is also a high energy consumption equipment in each plant of the MHI Group, and therefore, horizontal deployment will be pursued.

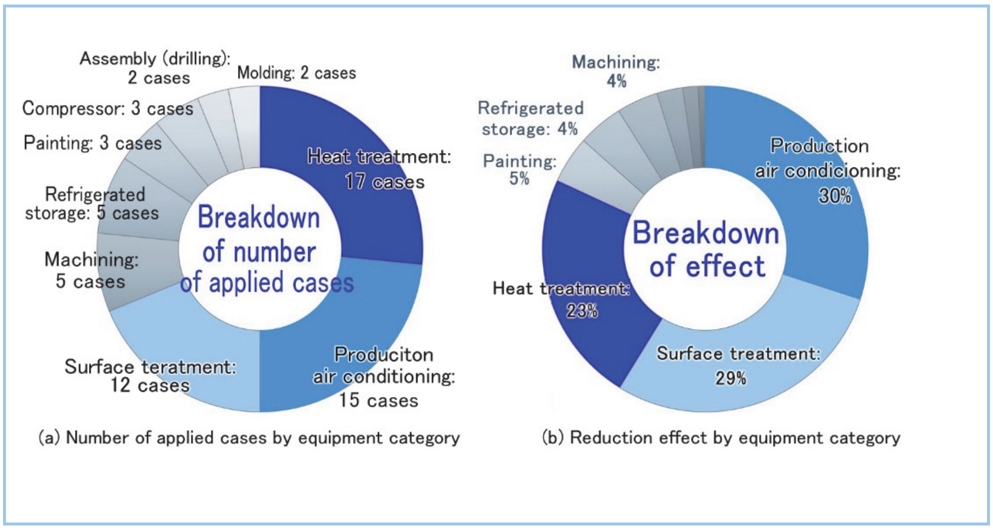

Figure 7 Analysis of cases to which these activities were applied

5. Conclusion

Starting in fiscal 2023, from the perspective of deployment to the entire plant equipment and overall optimization, green manufacturing of high-quality aerospace parts was achieved for production equipment at the Oye Plant, resulting in a 10% reduction in plant power costs and CO_2 emissions. The specific features include building a system that transcends departmental boundaries, establishing a scheme that achieves not only safety and productivity but also energy saving in equipment, and developing an equipment energy diagnosis tool. For efficient horizontal deployment of outcomes gained through these activities within the MHI Group in the future, there is an issue that much of the energy-saving review process and procedures remain tacit knowledge. Therefore, standardization (making explicit knowledge) of the know-how developed through these activities, such as the promotion framework, visualization methods, and schemes, will be promoted to enable third parties to understand and utilize them, further contributing to the MHI Group's carbon neutrality efforts.

References

(1) S. Murakami et al., MISSION NET ZERO: Carbon Neutrality Initiatives at MHI Group toward a Sustainable, Safe, Secure and Comfortable Society, Mitsubishi Heavy Industries Technical Review Vol. 59 No. 4 (2022)

(2) J. Nakatani et al., Carbon Neutral Initiatives for Works and Plants of MHI Group, Mitsubishi Heavy Industries Technical Review Vol. 59 No. 4 (2022)