15TH IEA HEAT PUMP CONFERENCE
MAY 26–29, 2026 | HOFBURG
VIENNA 2026
DECARBONISATION THROUGH INNOVATION

Development of industrial hot water heat pump for mechanical parts cleaning process

Hiroshi Nakayama[a,*] Teruyoshi Kataoka[b], Yoshimasa Kataoka[b], Shigeo Mori[c], Hidenori Fujita[c], Satoshi Kashiwazaki[c] and Toshio Ohara[d]

[a]Chubu Electric Power co., Inc, 20-1 Kitasekiyama Ohdaka Nagoya Aichi, 459-8522, Japan
[b]Fine Machine Kataoka co.,Ltd, 25-2 Ishihara Ishii Anjo Aichi, 444-1223, Japan
[c]Degree co.,Ltd, 773-1 Takaoka Suzuka Mie, 513-0014, Japan
[d]Yumesouzou Lab., Kariya, Aichi, 448-0044, Japan

Abstract

In general, in the cleaning process for mechanical parts, metal fragments and lubricating oil are adhered to the parts in the previous process, so they are showered with a cleaning solution at 60°C. A boiler or electric heater is used as a heat source to warm the cleaning solution. If a hot water heat pump with a plate heat exchanger is introduced into this process, indirect heat exchange between the cleaning solution and hot water is required, which reduces system efficiency. In addition, periodic cleaning and maintenance of the heat exchanger is mandatory, which has been an obstacle to its introduction. In this study, a hot water heat pump with a rated heating capacity of 13 kW and a rated COP of 3.1 was developed using a new coil-type heat exchanger that enables direct heat exchange between the refrigerant and the cleaning liquid, significantly improving system efficiency and ease of maintenance. Assuming a standard cleaning process, the annual primary energy consumption of the developed heat pump can be reduced by 67% compared to an electric heater, 60% compared to a gas boiler, and 11% compared to a conventional indirect heating heat pump system. Furthermore, the system has the lowest CO_2 emissions and running costs, is highly energy efficient, environmentally friendly, and economical. This paper describes the features and performance of this heat pump, introduces the developed heat pump into the cleaning process of mechanical parts, and reports on the system performance and the effect of dirt and cleaning of the heat exchanger on the performance.

Keywords: Industrial heat pump ;Hot water; Heat exchanger, Easy maintenace; Cleaning process

1. Introduction

In the manufacturing process of metal parts, after machining (cutting, grinding, etc.), parts must be cleaned with a cleaning solution heated to approximately 60°C to remove contaminants such as metal powder and oils. Until now, steam boilers and electric heaters have been commonly used as heat sources for heating the cleaning solution. However, as an increasing number of customers aim to decarbonize and save energy in their factories, demand for energy-efficient heating using circulating heat pumps is growing.

Figure 1 shows the installed base of industrial heat pumps in Japan [1]. The combined annual installed base of heat pump water heaters and circulating heat pumps is around 100 to 200 units and has not shown any signs of increasing. Accelerated adoption is needed to achieve a decarbonized society.

There have been several reports of the application of industrial circulating heat pumps to cleaning processes, most of which use plate heat exchangers or immersion heat exchangers [2-5]. In these cases, contamination from cleaning fluid accumulates in the heat exchanger. This accumulation of contamination leads to performance degradation and ultimately to blockage, leading to heat pump shutdown. This necessitates

* Corresponding author. Tel.: +81-80-8663-0975
E-mail address: Nakayama.Hiroshi2@chuden.co.jp

15th IEA Heat Pump Conference 2026 - AIP3.1 - https://doi.org/10.23697/x80n-ky50

backwashing or disassembly and cleaning of the heat exchanger, which is time-consuming and costly, and poses maintenance challenges. Furthermore, integrating a heat pump into an existing cleaning machine poses challenges, including complex system design, extensive modifications required for connection to the cleaning machine, and high installation costs. These challenges hinder the widespread use of heat pumps in cleaning processes.

Therefore, we developed a new industrial circulating heating heat pump that uses an air heat source. This new type of heat pump significantly improves maintainability while resolving issues such as installation considerations and cost.

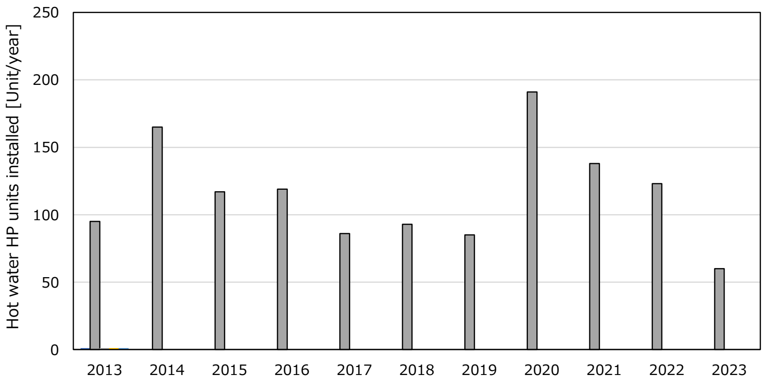

Figure 1. Number of installed industrial hot water heat pumps in Japan

2. Overview of the developed unit

Figure 2 shows the exterior of the developed unit, and Table 1 shows its specifications. While most conventional hot water heat pumps have a heat exchanger inside the device that exchanges heat between the refrigerant and hot water, the unit has a newly developed coil-type heat exchanger located on the outside of the main body, improving heat exchanger maintainability.

So far, when installing a hot water heat pump in an existing cleaning machine, the layout of the control panel, heat exchanger, pump, and piping had to be considered for each customer, requiring time for pre-installation considerations. However, the unit is designed with connection to the cleaning machine in mind, allowing the operation of the unit to be controlled from the cleaning machine. The water supply pump can be installed underneath the unit, and all that is required is connecting the heat exchanger's water piping to the cleaning machine's tank and the power and control cables to the cleaning machine's control panel, significantly reducing the design man-hours required for installation.

2.1. Unit configuration

A refrigeration cycle diagram is shown in Fig. 3, and a schematic diagram of the coil heat exchanger is shown in Fig. 4. The refrigeration cycle is single-stage, uses R134a as the refrigerant, and is designed for indoor installation. It employs an inverter-controlled fan and scroll compressor, and uses hot gas bypass defrost for defrosting.

The newly developed coil heat exchanger has all wetted parts made of stainless steel to enable direct heat exchange between the refrigerant and alkaline cleaning solution. The refrigerant and cleaning solution piping are concentrated at the bottom of the heat exchanger, and the upper part has a removable housing structure with enhanced insulation, improving cleaning and maintenance. To ensure heat exchange area and reduce pressure loss, inside the heat exchanger, the cleaning solution is introduced from the bottom and flows to the top along a screw-shaped rotating plate, where it exchanges heat with two-pass refrigerant pipes formed into a coil. The cleaning liquid flow path is set approximately 4 cm high, preventing clogging even with slightly contaminated cleaning liquid and enabling direct heat exchange between the refrigerant and the contaminated cleaning liquid. Conventionally, heat pumps for circulating heating are often set to a flow rate that results in a temperature difference of about 5°C between the inlet and outlet of the hot water, but in the developed unit, a higher flow rate is set because the circulation pump used in a cleaning machine is used and the increased flow rate improves the heat transfer coefficient. As a result, the temperature difference between the inlet and outlet is small, at about 1°C.

Figure 2. Appearance of developed system

Table 1. Specifications of heat pump

Item	Specification
Rated heating capacity*	13.3 kW
Rated COP*	3.14
Power Supply	3ϕ200V (50Hz/60Hz)
Leaving water temperature	40～65℃
Flow rate	50～250L/min
Ambient temperature	5～43℃
Refrigerant	R134a
Size (W×D×H)	1,975mm×675mm×2,250mm
Weight	417kg

*Ambient temperature 25℃DB/21℃WB, Twi=60℃

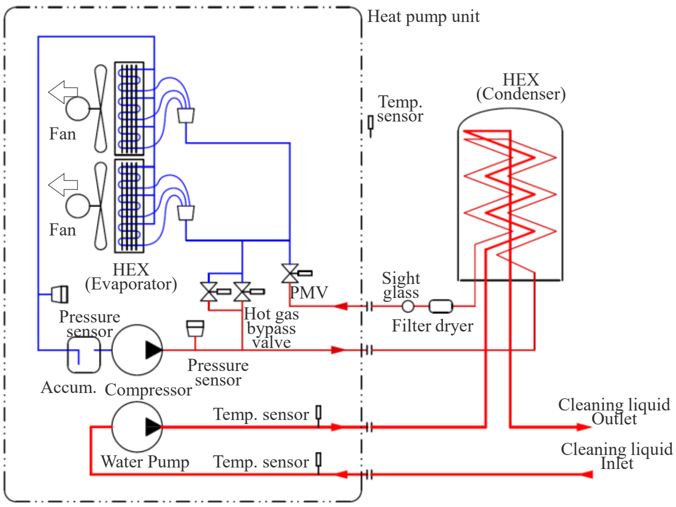

Figure 3. Piping diagram

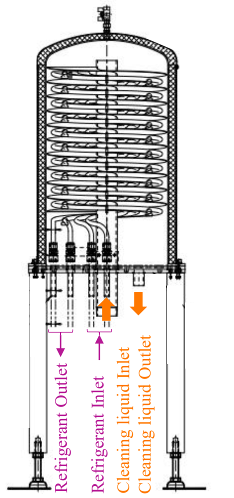

Figure 4. Coil-type heat exchanger

2.2. Unit performance

To evaluate the performance of the unit, heat pump performances were taken in a test room under various conditions, including ambient temperature and water flow rate. Figure 5 shows the relationship between heating COP and water flow rate under conditions simulating indoor installation: an ambient temperature of 25°C DB/21°C WB, and hot water inlet temperatures of 50°C and 60°C. The heating COP tends to increase as the flow rate increases. This is thought to be due to the improved heat transfer coefficient outside the heat exchanger pipe as the water flow rate increases, resulting in a increase in performance. Figure 6 shows the relationship between heating COP and ambient temperature at a rated flow rate of 250 L/min and hot water inlet temperatures of 50°C and 60°C. Both heating COPs increase monotonically with increasing ambient temperature. At the rated ambient temperature of 25°C DB/21°C WB, a COP of 3.78 was achieved at a heating capacity of 13.42 kW with a hot water inlet temperature of 50°C, and a COP of 3.14 was achieved at a heating capacity of 13.32 kW with a hot water inlet temperature of 60°C.

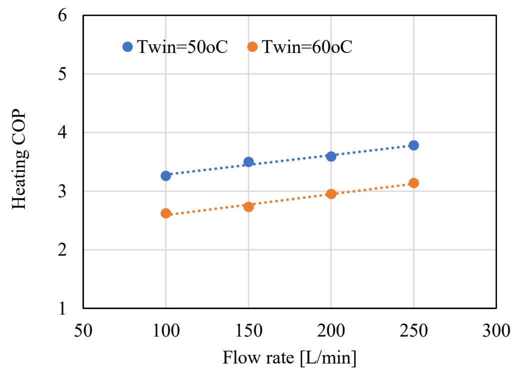

Figure 5. Measured COP and flow rate

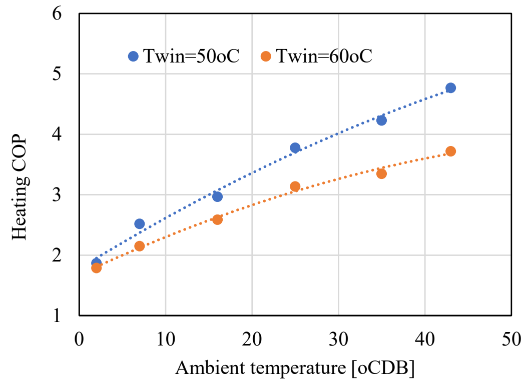

Figure 6. Measured COP and ambient temperature

3. Impact of installation

3.1. System

Currently, the main heat sources used in the cleaning process are boiler steam or electric heaters. When applying an industrial circulating heated hot water heat pump to a cleaning machine, passing the cleaning liquid directly through the heat exchanger inside the machine would cause clogging and breakdowns, so an indirect heating system like the one shown in Fig. 7 is used. That is, an indirect heating system requires a water circulating system consisting of an indirect heat exchanger and water circulation pump to be installed between the heat pump and the cleaning liquid circulation system, and the heat pump's output temperature must be set higher than the target water temperature of the cleaning liquid. In contrast, the direct heating system of the developed unit shown in Fig. 8 makes it possible to directly heat the cleaning liquid using the heat exchanger attached to the heat pump, thereby eliminating the indirect heat exchanger and water circulation pump that make up the circulating water system. The heat pump's output temperature can also be reduced compared to an indirect heating system, resulting in an energy-efficient and inexpensive system.

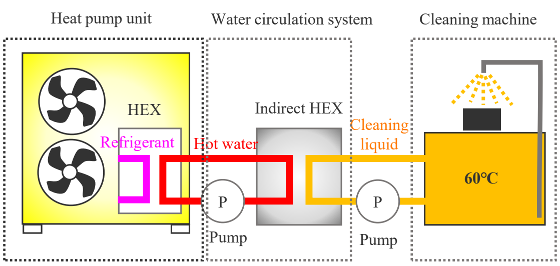

Figure 7. Indirect heating system of heat pump

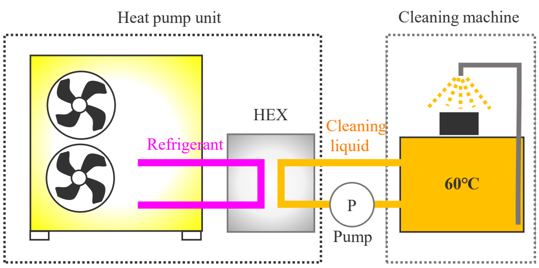

Figure 8. Direct heating system of heat pump

3.2. Calculation results

We compared the energy efficiency and economy of indirect heating heat pump systems using boiler steam, electric heaters, and conventional circulation heat pumps in a simulated machine parts cleaning process. Table 2 shows the calculation conditions. The cleaning fluid temperature was 60°C, the annual operating days were 240, the daily operating hours were 16 hours, the factory temperature fluctuated between 20 and 27°C, and the heat load was constant at 13 kW. The efficiency of a gas boiler system is reported to be approximately 50% of the input energy in a typical steam system due to significant combustion losses, heat losses in the steam piping, and drainage losses, so we adopted this value [6-7]. Furthermore, because the electric heater is assumed to be immersed in the cleaning tank, we assumed that 100% of the input electrical energy is converted into heat. The power conversion factor used was 8.64 MJ/kWh, as stipulated in Japan's Energy Conservation Act. This is a primary energy conversion value that takes into account actual energy losses during power generation and transmission in Japan [8]. The CO_2 emission factor and energy cost were actual values from Chubu Electric Power.

Table 3 shows the results of a comparison of the annual primary energy consumption, CO_2 emissions, and running costs of the developed system (direct heating), the indirect heating heat pump system, the gas boiler, and the electric heater. The annual primary energy consumption of the developed system was 67% lower than that of the electric heater, 60% lower than that of the gas boiler, and 11% lower than that of the indirect heating system. Furthermore, it had the lowest CO_2 emissions and running costs, making it an energy-efficient, environmentally friendly, and economical system.

Table2.　Calculation conditions

Contents	Value
Cleaning liquid temperature	60 °C
Thermal load	13kW
Operation time	16h/day, 240day/year, 3,840h/year
System Efficiency	Electric heater :100%, Gas boiler sytem:50%
Energy conversion factor	Electricity: 8,640kJ/kWh, Gas: 45MJ/m^3
CO_2 emission factor	Electricity: 0.433kg-CO_2/kWh, Gas:2.29 kg-CO_2/m^3
Energy cost	Electricity: 19~20yen/kWh, Gas: about 121 yen/m^3

Table3.　Comparison of system

	Direct heating HP system	Indirect heating HP system	Gas boiler	Electric heater
Primary energy consumption[GJ/year]	144	161	359	431
CO_2 emission [ton-CO_2/year]	7	8	18	22
Running cost [1000yen/year]	423	467	1,049	1,262

4. Field test of developed heat pump

A newly developed unit was introduced to heat the cleaning solution used to wash metal parts as shown in Fig.9. This process uses a weakly alkaline cleaning solution to clean metal parts at a temperature of 50°C. Previously, the cleaning solution was heated using an electric heater, but the newly developed unit was retrofitted to create a hybrid system that also uses an electric heater. The system operates 7-8 hours per day, only on weekdays. The cleaning tank is a single-tank type, and since dirt such as oil and metal chips from metal parts accumulates, we evaluated the impact of dirt on the coil heat exchanger on performance.

Figure 10 shows operating data for a representative day in June 2024. When starting up from a cleaning solution temperature of 25°C, both the electric heater (8kW) and the heat pump were operating, and the temperature reached 50°C in approximately 30 minutes. During operating hours, only the heat pump was operating, resulting in generally stable operation. Figure 11 shows the trend in daily average COP. The COP gradually decreases due to the effects of fouling on the coil heat exchanger, but after cleaning the coil heat exchanger on August 31st, the COP recovered by approximately 0.6 points. It took approximately two hours to clean the heat exchanger.

Even in situations where a typical plate heat exchanger becomes clogged and unable to operate within a few days, the heat exchanger can be maintained for several months without cleaning. The ability to perform cleaning maintenance without significantly affecting operations is considered an important point when applying heat pumps to industrial processes. The development unit also features a function that notifies the customer when it's time to clean via an attached panel, allowing for smart use that ensures the heat pump is always operating efficiently.

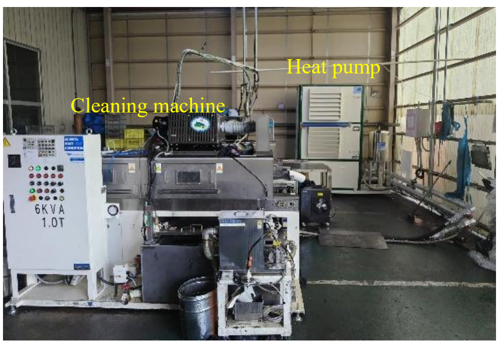

Figure 9.　Installation situation

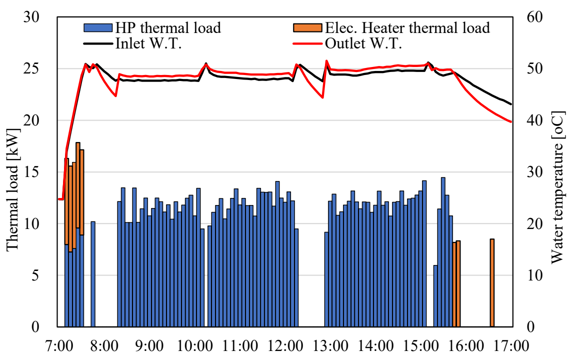

Figure 10.　Operating data for a representative day in June 2024

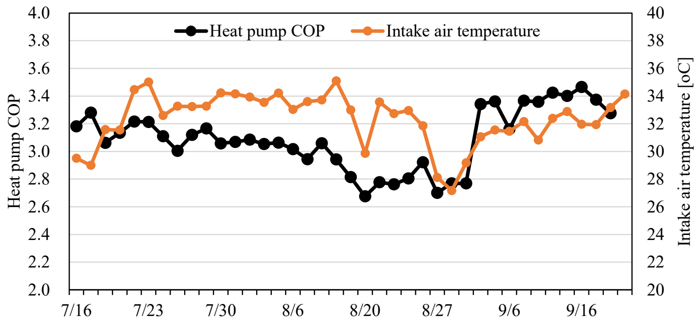

Figure 11. Trend in daily average COP

5. Summary

We have developed an industrial circulation heating heat pump that is highly efficient and offers significantly improved maintainability and installation for machine part cleaning processes. This developed unit can be applied not only to metal part cleaning processes, but also to new and existing facilities for resin cleaning processes, degreasing processes, food heating processes, etc. The adoption of this system, which is highly energy-efficient, easy to install, and highly maintainable, can contribute to our customers' efforts to decarbonize their factories.

References

[1] "Report on the survey results for industrial heat pump installation volume in fiscal year 2023", 2024, Japan electro-heat center, https://sangyo-hp.jeh-center.org/heatpump_library_top.html#data (in Japanese)

[2] Nakayama H.,Zushi T., 2017. "Field test study on the performance of air source heat pump installed at various industrial processes in Japan" 12th IEA Heat Pump Conference. Rotterdam, Netherlad, Paper4.3.6

[3] Shiba Y.,Tanifuji K., Nakayama H., 2012. "Development and introduction of a heat pump for washing process", Proc. 2012 JSRAE Annual Conference, Sapporo, Japan, p.263-266. (in Japanese)

[4] Minea V., 2016, "Advances in heat pump-assisted drying technology", CRC Press, p.10-13

[5] Jakobs R., Stadtlander C., 2021."Annex48 Industrial heat pumps, 2nd phase", Report no. HPT-AN48-1

[6] Hasanbeigi, A., Price, L., 2012."A review of energy use and energy efficiency technologies for the textile industry", *Renewable and Sustainable Energy Reviews*, **16**, Issue 6, p.3648-3665.

[7] "Steam efficiency - a systematic approach to reducing energy wastage", 2011, Energy Efficiency & Conservation Authority (EECA), Technical Guide 13, p.8

[8] Ordinaces and Public Notices for Enforcemnet of the Act on Rationalizing Energy Use, Ministory of Economy, Trade and Industry, https://www.meti.go.jp/press/2022/03/20230331014/20230331014-2.pdf , p.7 (in Japanese)