Cleaning Plant Facilities Using a Low-Pressure Composite Water Flow Cleaner (Cavitation Cleaning)

1. Introduction

A low-pressure composite water flow cleaner physically removes sludge that has adhered to the inside surface of water pipes by using water and air. The cleaning process does not use any high-pressure water, chemicals, or chemical reactions. Previously, such removal required dismantling, liquid-chemical management, and liquid disposal, all of which are costly. Thanks to the cleaner's system, the sludge removal does not involve any dismantling or chemicals, thus achieving low-cost, eco-friendly cleaning.

2. Cleaning method

A hose with a pressure resistance of at least 0.8 MPa is connected to the "IN" and "OUT" ports of the equipment to be cleaned. Water is fed at 0.4 MPa into the hose, while being mixed with fine air bubbles which serve as centers for cavitation. In addition, the direction of water flow is rapidly reversed to create shock waves, which make the fine air bubbles swell and contract, causing cavitation. Also, the air bubbles act as dampers, thus helping to control the cavitation force. Therefore, cleaning can be executed without damaging the equipment to be cleaned.

3. Cleaning effects of resin molding-die water pipes

This section introduces the case of a customer. The customer uses an 850T-class molding machine to mold panel parts, and the mold which we cleaned had been manufactured 7 years ago and then used for production. Cleaning had been performed on-site simply by blowing air into water pipes. Due to clogging since the machine was installed, the product molding cycle of the mold had increased from the initial 113 seconds to 123 seconds or longer. For the analysis, pre-cleaning and post-cleaning conditions were compared as follows:(1) Parts were produced at the mold's passing water flow rate and at the initial condition of 113 seconds. (2) After the mold's temperature stabilized, the temperature was measured using a thermograph. (3) The mold's temperature distribution and defects of molded products before cleaning were compared with those after cleaning.

【Discussion】

The overall flow rate was improved as shown in Table1. Before cleaning, two surface sink marks developed as shown by circles in Figure1. When manufacturing parts, a molding cycle of 123 seconds was required. However, after cleaning, the temperature distribution of the mold improved, the surface sink marks disappeared, and the defects were resolved. Also, the overall temperature was lower. However, the temperature of some areas increased due to changes in the resin flux. Therefore, the molding cycle should be made longer than the initial cycle. Through the extension, the temperature of such areas was lowered. As a result, we showed that parts could be produced without problems at a molding cycle of 115 seconds, which is just 2 seconds longer than the initial condition.

【Results】

The molding cycle was shortened by 8 seconds. We found that regular cleaning of the mold eliminated perforation troubles and achieved stable production. Also, unlike chemicals, the cleaning process is not associated with melting, and thus frequent cleaning does not damage the mold.

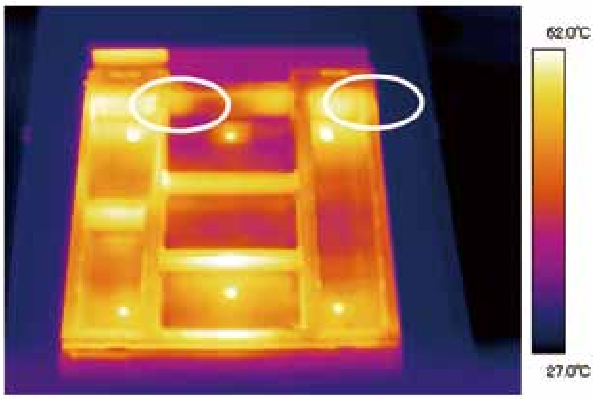

Figure1 Pre-cleaning temperature distribution of the mold and defective areas

Table1 Numerical comparison of pre-cleaning and post-cleaning conditions

Endpoint	Pre-cleaning	Post-cleaning
Overall flow rate (0.2MPa)	59.6L/min	74.6L/min
Circuit 1	1.1L/min	4.2L/min
Circuit 2	8.1L/min	10.3L/min
Circuit 3	3.2L/min	5.3L/min
Circuit 4	5.4L/min	7.0L/min
Circuit 5	10.8L/min	12.5L/min
Sub-circuit 1	16.9L/min	19.5L/min
Sub-circuit 2	14.1L/min	15.8L/min
Molding cycle	123seconds	115seconds
Defective molding (At initial condition)	Surface sink marks developed.	No defect

4. Sales of the cleaning machine

Although we have limited results regarding sales for plants, we have a number of successful sales for the resin-molding industry, and particularly with automobile parts manufacturers. The cleaning machine is applicable to water pipes, not only cast pipes but also those under the molding machine's hopper and in the chiller's heat exchanger. Therefore, the machine can be used for various purposes. Recently, the cleaning machine reduced the cleaning time from approximately 3 days to 24 hours at a PET bottle factory, where previously it was necessary to dismantle pre-form molding dies and the take-out devices' water pipes in order to clean facilities.

In addition, we found that the cleaning machine can be used for cleaning the water pipes of sintering machines for pre-formed screw parts in manufacturing equipment, and rotatory blowing machinery. With these findings, the machine is expected to be used also in the PET bottle industry. Regarding other uses, the machine is used for cleaning the water pipes of castings including aluminum die castings. Although utilization in plants is limited, we have received positive customer feedback. Relative to the effects of chemical cleaning at 100%, the cleaning effect of the machine is 80%. Sometimes, chemical cleaning causes problems for production lines such as chemicals remaining in the lines when production restarts. However, with our cleaning machine, no troubles have been reported. In addition, when cleaning shell- and tube-type heat exchangers (on the side of the shell), only the surface can be cleaned even though a hyperbaric cleaning method is used. However, our cleaning machine can also clean the space between tubes. Such characteristics have been positively evaluated. Since this machine enables plate-type heat exchangers to be cleaned without dismantling, we have received positive feedback such as about the lower cost of exchanging packings.

5. Effects of plant facility cleaning

5-1) Effects for a shell- and tube-type heat exchanger (horizontal-type)

We cleaned a horizontal-type shell- and tube-type heat exchanger shown in Figure2. Before cleaning, a reddish-brown deposit covered the side of the shell as shown in Figure3. The deposit was such that the red deposit could be removed by scratching with a finger. The cleaning machine's "IN" and "OUT" were connected to the handholes and cleaning was conducted without removing the "IN" and "OUT." During cleaning, a large amount of deposit precipitated in the tank as shown in Figure4. This precipitate rapidly clogged the filters as shown in Figure5. A considerable amount of deposit could be removed. In addition, when we confirmed the post-cleaning conditions of the connection outlets, we found that deposit had been thoroughly removed as shown in Figure6, since these areas were exposed to powerful flows.

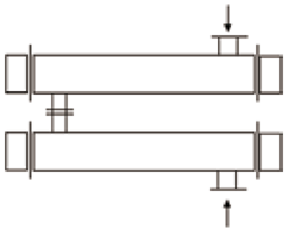

Figure2 Shape of heat exchanger

Figure3 Pre-cleaning condition

Figure4 During-cleaning condition

Figure5 Filter condition

Figure6 Post-cleaning condition

5-2) Effects for a large shell- and tube-type heat exchanger

Before cleaning, as shown in Figure7, the spaces between tubes were clogged with oxide. However, after cleaning, as shown in Figure8, the clogging was removed. The oxide covering the tube surface was not completely removed. However, when the heat exchange conditions during operation were measured, we found that the cleaning was effective.

Figure7 Pre-cleaning condition

Figure8 Post-cleaning condition

5-3) Effects for a large plate-type heat exchanger

As Figure9 shows, the cleaning machine was connected to a large plate-type heat exchanger with a plate number of 410 and a heat transfer area of 391.7m^2 without dismantling. Then, we conducted cleaning for 50 hours on the cooling-water side and for 70 hours on the circulating-water side.

The results are shown in Table2. The flow rate of circulating water was sped up by approximately 45% and the heat exchange amount was increased by approximately 75%. Since the plates were not dismantled, the packing did not need to be exchanged. Customers appreciate such benefits.

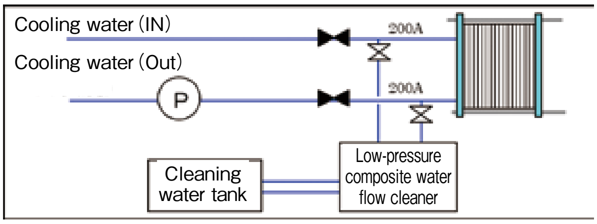

Figure9 Schematic drawing of the connection

Table2 Numerical comparison of pre- and post-cleaning conditions for a large plate-type heat exchanger

	Cooling water temperature (℃)			Circulating water temperature (℃)			Circulating water amount	Heat exchange amount	Heat transmission rate
	IN	OUT	Disparity	IN	OUT	Disparity	m^3/hr	Kcal/hr	Kcal/m^2·h·℃
Pre-cleaning	28.7	35.3	6.6	47.0	42.3	4.7	150	705000	143
Post-cleaning	27.5	36.0	8.5	45.5	39.8	5.7	216	1231200	290

5-4) In-line cleaning of a small plate-type heat exchanger for spa facilities

Although the conditions are different from those of plants, plate-type heat exchangers are also used at spa facilities, which sometimes suffer clogged water pipes. When this happens, they have to dismantle and clean the heat exchangers. Accordingly, we used an in-line cleaning machine (which is less effective than an off-line machine) to clean a small plate-type heat exchanger. During the cleaning, we opened the plates and confirmed the conditions. The cleaning machine was connected to the heat exchanger and the plates were washed for 2 hours as shown in Figure10.

Before cleaning, the entire plates were covered with deposit as shown in Figure11. However, after the cleaning, approximately 80% of the plate surface could be seen, as shown in Figure12. Thus, the cleaning restored the heat-exchange amount and resolved the pressure loss, returning the equipment to normal operation.

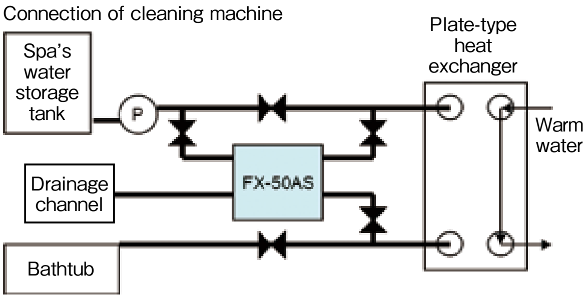

Figure10　Connection of cleaning machine

Figure11　Pre-cleaning condition

Figure12　Post-cleaning condition

6. Conclusion（Expansion to plants）

Until now, plate-type heat exchangers and shell- and tube-type heat exchangers (on the side of the shell) have been cleaned with chemicals or high-pressure water or had to be replaced since such areas could not be dismantled. We have started developing a large cleaning machine (NR-2000) together with VALQUA LTD., which we expect will overcome such problems. Also, when cleaning plant facilities, the channel areas are expected to be large. Therefore, the effects of bubbling through a two-layer fluid and turbulence effects, which develop from switching the flow direction, can exert powerful cleaning rather than with cavitation, which occurs during cast cleaning. Therefore, we need to continue studying physical phenomena regarding cleaning effects.

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