Application of Ceramic Flat Sheet Membranes (CFMs)

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Abstract

We develop overseas markets with ceramic membranes as key technologies, and we conducted basic development and demonstrated field-tests in Japan and its overseas water treatment plants. We commercialized the Ceramic Flat sheet Membranes (CFMs) released in 2011.

Highlights of the CFMs are that they are physically more robust than conventional microfiltration membranes, and they have a high chemical resistance against cleaning chemicals. As a result, a long operational life can be expected. We have been conducting sales and marketing primarily in the industrial wastewater field.

We built a serial production facility for CFMs at Meiden Nagoya Works in Aichi Prefecture and established a system that can supply large quantities of CFMs. As a result, our CFMs were adopted at other sewage treatment plants and drinking water treatment plants where they process several tens of thousands m^3 of water daily. Our CFMs have been supplied primarily in overseas markets.

1 Preface

Currently, there are global issues of chronic water shortages due to rising populations worldwide. Waste water is treated and reused, or the sea water is desalinated to meet these challenges. These measures are popular worldwide. In this connection, various kinds of water filtration membranes are sold by many suppliers. Most membranes are, however, polymeric membranes. Many users commented: “the membrane’s life is too short,” “the membrane filtration needs a lot of power,” or “it cannot be used for oily wastewater or hot water.” These concerns need to be addressed.

By considering such social conditions, the above user requests, and by drawing on our long-standing engineering resources on the ceramic product manufacturing technology, we developed ceramic Microfiltration (MF) membranes for water treatment. Sales of these Ceramic Flat sheet Membranes (CFMs) began in 2011. We received the related specific certificates from the authorities on our CFMs for specific application as they are indispensable for selling our products to many of our customers. This paper introduces some examples of major applications of the CFMs.

2 CFMs

The CFM element comes in a size of W281 × H1046 × T12mm (membrane thickness 6mm) and the nominal pore size of the microfiltration membrane is 0.1μm. A CFM cassette containing multiple CFM elements (CFM cassette) is submerged in wastewater. The water is filtered by a pump to produce clean processed water.

For filtration by means of conventional MF membranes, the membrane itself could be fouled as filtration occurs and clogging is caused. While in the case of the CFM, its surface is hydrophilic and smooth, thus resistant to allow the accumulation of contaminants. Even though foulants are attached, they are easily removed by gusts of air. This is the major feature of the CFM as it is physically robust and can be used at a higher temperature compared with polymeric membranes. In addition, it has resistance against chemicals. It is able to withstand against repeated membrane cleaning by chemicals, it can offer stable filtration for a long duration of time. It does not require special storage like polymeric membranes (that has to be submersed in a preservative solution.) It can be stored for a long time in a dry state. After the end of its operation life,

this ceramic can be reused and processed as other ceramic products.

3 Case Studies of CFM Application

3.1 Industrial Wastewater Treatment Field

3.1.1 Cases for Ceramic Membrane Bioreactor (MBR) Systems

As a method to conventionally reduce organic pollutants in domestic wastewater and industrial wastewater, activated sludge treatment process is widely used. In this method, separation of activated sludge (which is a water treatment microorganism) and treated water is performed by gravity settling. In recent years, by utilizing membranes, a membrane separation activated sludge process, a.k.a. MBR process, has been adopted for customers who want to reuse the treated water as the MBR process can perform the solid-liquid separation in a solid manner. Compared with the other firms' polymeric MF membranes, CFMs are generally more robust and have a longer lifespan. Because of these merits, there are increasing cases that our CFMs are adopted for MBR systems (which is called "ceramic MBR system.")

(1) An overseas case: MBR system for industrial wastewater treatment facility

Singapore is active in the resource recovery of wastewater, known as used water in Singapore. We supplied our CFM cassettes to an industrial used water treatment facility at the Jurong Water Reclamation Plant[1][2]. In the case of industrial used water treatment, the CFM have high resistance to chemical damage and thermal deterioration than conventional polymeric membranes.

This facility consists of a combination of an Upflow Anaerobic Sludge Blanket (UASB) process and ceramic MBR system. With a capacity of 4550m^3/d. The used water received is from industrial sources containing high concentration of Chemical Oxygen Demand (COD), which may serve as an index for organic contaminants. Our CFMs are used as the MF membranes for the MBR installed there. The filtered water passing through the CFMs could potentially be mixed up with the MBR filtered water from the domestic used water treatment facility and reused as a source of industrial water.

This UASB + Ceramic MBR technology realized the reclamation of used industrial water which was considered challenging because of the high organic loading in used industrial water. This UASB + ceramic MBR technology could potentially achieve higher energy efficiencies for treatment of high strength industrial used water. This case in Singapore attracted high attention by such successful results. **Fig. 1** shows the industrial park aggregate wastewater treatment facility. **Fig. 2** shows a treatment flow diagram for the industrial used water treatment facility. **Fig. 3** shows an external appearance of CFM cassette.

Fig. 1 Industrial Used Water Treatment Facility

This facility is installed in the Jurong Water Reclamation Plant.

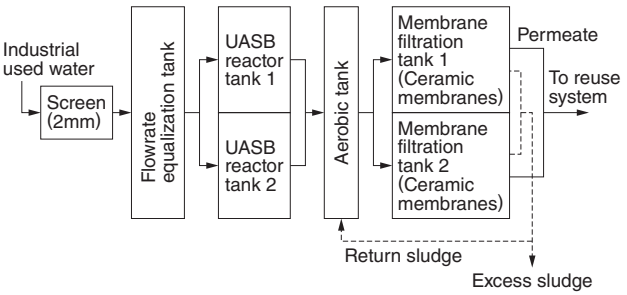

Fig. 2 Treatment Flow Diagram for the Industrial Used Water Treatment Facility

There is an MBR for UASB process installed at the latter stage of organic substance removal. The CFMs are used in this system.

3.1.2 Case of Coagulation Filtration Process

The CFMs are not only applicable to the MBR but are also applicable to general coagulation and filtration processes.

(1) An overseas case: Coagulation, filtration, and reuse of effluent of biological treatment plant for wastewater from a petrochemical plant

This is a case where our CFMs are being used for wastewater recycling systems utilizing the Reverse Osmosis (RO) and MF membrane at Singapore's petrochemical factory[3]. For recycling of wastewater from the factory, in the pretreatment MF membrane

Fig. 3 CFM Cassette for Industrial Used Water Treatment Facility

A CFM Cassette (membrane area 200m²) installed in the membrane tank of the industrial used water treatment facility is shown.

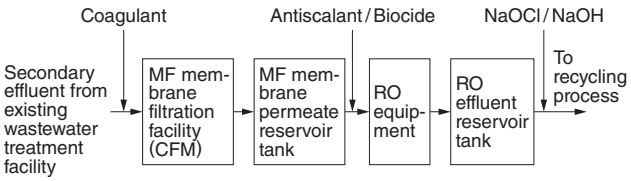

Fig. 4 Treatment Flow Diagram for the Ceramic MF and RO Processes at a Petrochemical Plant

This is a treatment flow diagram where the secondary effluent from an existing biological wastewater treatment facility of a petrochemical plant is processed to recyclable water.

Fig. 5 MBR System at the Changi Water Reclamation Plant

This is the ceramic MBR system where the CFM cassettes were installed in the filtration tank with a deep depth-exceeding 6 meters.

filtration process is required to provide stable water to the RO process against the fluctuating water volume and water quality. This treatment system handles the secondary treated water (5000m³/d) of the existing biological wastewater treatment facility and performs coagulant addition + CFM filtration, supplies the treated water to the RO process, and in the end process, obtains reusable RO treated water.

The secondary treated water in the wastewater treatment facility of the petrochemical factory normally contains an oily ingredient. Because of this, it is considered that under conventional polymeric membranes-based pretreatment MF membrane filtration process, it is difficult to maintain the processing performance for a long term. The CFM, however, can filtrate even oil-contained water; so it is possible to expect stable water recycling. Based on this view, the customer decided to adopt the CFM cassettes. This facility in the plant began to operate in 2016 and the CFM-filtered water quality contributes to the stabile operation of the RO process. The recycled water production has since been continued since then. Before this system introduction, the effluent of biological wastewater treatment facility was discharged into the sea. The wastewater is now recyclable thanks to the introduction of this system. Fig. 4 shows a treatment flow diagram for the ceramic MF and RO system at a petrochemical plant.

3.2 Public Sewage and Domestic Wastewater Treatment Field

3.2.1 An Overseas Case: A Sewage MBR System

We supplied a large-scale ceramic MBR system for the Changi Water Reclamation Plant in Singapore and it began operation in January 2016[4]. Fig. 5 shows an external appearance of the ceramic MBR system.

Public Utilities Board (PUB), Singapore's National Water Agency has been using polymeric membranes in a MBR facility. This time, PUB evaluated ceramic MBR system because of its strong high resistance to chemical damage and thermal deterioration and decided to adopt the ceramic MBR system in its water reclamation plants for the first time. This facility was introduced at the time of expansion work for an existing facility. Part of the bioreactor was retrofitted into MBR tank in order to increase the processing capability without changing the

installation space. As a result, the treated water with high quality and low turbidity was produced. In this case, the system is the world's largest scale as a ceramic MBR system. The processing capability is 15,000m³/d and the permissible peak load is 30,000m³/d. Drawing on this project, we are making technical proposals to public sewage treatment plant operators in Japan for the conversion to ceramic MBR systems.

3.2.2 A Case in Japan: A Ceramic MBR System for Sludge Treatment Center

We supplied our CFMs to a Sludge Treatment Center for the Kinan Environmental Sanitation Facility Office Affairs Associations. This Center was constructed by Hitachi Zosen Corporation. **Fig. 6** shows an external appearance of the Sludge Treatment Center.

The processing capability is 98kL/d (raw sewage 20kL/d + septic tank sludge 78kL/d). Before the introduction of this ceramic MBR system, they adopted and the processing method in combination of pre-dewatering-type high-load denitrification process (handling septic tank sludge) and advanced treatment (activated carbon adsorption). The CFMs were adopted for the solid-liquid separation that maintains the nitrification or denitrification sludge at a high concentration. This time supply of CFM cassettes to the Sludge Treatment Center was our first. With this track record, more introduction of our CFMs in the future to the other sludge treatment centers in Japan is expected with the above-mentioned combined processing methods with such new center construction projects or key part renovation projects of existing sludge treatment plants.

Fig. 6 Sludge Treatment Center

An external appearance of the Sludge Treatment Center where the ceramic MBR system is shown.

3.3 Drinking Water Treatment Field

As a result of verification test with CFM cassettes, we demonstrated that by filtration of our CFM on raw water such as surface water from rivers and underground water, we can obtain relatively high permeate flow from a membrane (membrane flux). Given the aforementioned, we are currently making technical proposals to the local governments, who own the drinking water treatment plants for them to adopt the CFM cassettes there.

As various certificates are necessary for making proposals, we have acquired the certificates in accordance with the "Certification of Modules for Drinking Water AMST-001 (Issue 7)" by The Association of Membrane Separation Technology of Japan and the International Standard of "NSF/ANSI Standard 61 and 419" by the National Sanitation Foundation (NSF). In joint operation with Organo Corporation in 2017, we acquired the "Certification of Water Treatment Equipment" from the Japan Water Research Center.

3.3.1 An Overseas Case: A Membrane Filtration Facility for Drinking Water Treatment Plant

Our large-scale ceramic MF system was supplied to the Chestnut Avenue Water Works (CAWW) in Singapore. This system commenced operation in June 2017. PUB has been using polymeric UF membrane in drinking water plants to produce high quality water whilst requiring a smaller footprint. Submerged polymeric hollow-fiber membrane has been used since 2003 in CAWW. PUB decided to use submerged-type ceramic membranes for enhancement of production capacity at CAWW. The flat-sheet ceramic membrane system was retrofitted into spare empty tanks. The scale of this ceramic MF system is 36,400m³/d and is in two trains. It is the world's largest for a ceramic flat sheet membrane filtration system at a drinking water treatment plant where surface water of a river or reservoir is processed. By adopting the ceramic MF system, the volume of air needed for membrane cleaning can be significantly reduced and system operation can be accomplished with low power consumption. **Fig. 7** shows an external appearance of the ceramic MF system.

Going forward, the ceramic MF system is expected to play a key role in addressing such issues as raw water high turbidity problems or renewal of the sand filtration facilities. Many customers face these issues in waterworks services at home and abroad. We expect market penetration of the ceramic MF systems.

Fig. 7 **Ceramic MF System at the Chestnut Avenue Water Works**

For the effective utilization of existing water tanks, ceramic MF system was introduced to the Chestnut Avenue Water Works.

4 Postscript

In this paper, we introduced the main case studies of CFM application and we showed mostly cases in Singapore. In the water processing industry, the introduction of MF technology is expected to be in further progress in the water shortage areas of the world in order to reuse wastewater. Not only for wastewater treatment but also for drinking water treatment, we view our CFM performance to be sufficiently useful for customers in waterworks services. It is a pleasure to see our CFM cassettes contributing to the water filtration in the drinking and waste water treatment and how we can help in alleviating water processing-related issues at home and abroad.

Lastly, we would like to thank the customers in the case studies for your permission to quote the cases in this paper. We also would like to thank the project-related engineering & construction firms for your cooperation and helps according to us for the projects.

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