The mapping of magnetic force technology to the circular economy

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Recently the Circular Economy CE has been noted. The CE enables the achievement of both economic growth and reduction of environmental burdens by circulating resources and products at various stages of economic activities (production, consumption, disposal, etc.), reducing wasteful resource and energy consumptions, reducing ultimate waste generation and creating additional value within each stage of circulation. International and cooperative efforts have been made to achieve this.

There is a similar concept in Japan called the “Junkan-gata Shakai” (i.e. Recycling-based Society). But the most significant differences between the two economy systems is that the CE does not only promote recycling and the efficient use of resources, but also aims at creating a path to realize “economic development / growth and new job creation”.

So I think that we must consider that the magnetic force technology contributions as to the CE system comparing Recycling-based Society. This paper tried to develop the mapping of magnetic force technology in the circular economy.
The recent development of conduction cooled superconducting 
magnets for magnetic separation in IHEP

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Abstract
Cryocooler directly cooled low temperature superconducting NbTi magnets of different 
sizes and magnetic field intensity are designed, fabricated and tested at the Institute of High 
Energy Physics (IHEP) for high field magnetic separation experiment. One can generated 
6.0 T field in the center of a 400 mm room temperature bore with operating current of 102 A; 
another one can be worked at persistent current mode with superconducting switch, and 
generated 5.0 T field in the center of a 100 mm room temperature bore at 80 A. The 
superconducting magnet systems have been operating stably for several months.
Key Words: Conduction-cooled, Persistent current mode, Superconducting magnet.

1. Introduction

The cryofree conduction-cooled superconducting magnet can generate a high magnetic 
field for a long time operation without use of liquid helium and nitrogen. The reliable GM 
cryocooler with 1.5 Watt at 4.2 K and high temperature superconducting current leads have 
been employed. This kind of superconducting magnet has the advanced characteristics of easy 
operation, no expensive liquid helium or nitrogen is required keeping the running costs to the 
minimum, and also it is very suitable for the industrial system and scientific instruments.

For the testing requirement of large aperture and strong background magnetic field in 
laboratory, an NbTi superconducting magnet cooled by two GM cryocooler has been 
designed and fabricated with available warm bore of 400 mm in diameter and center field up 
to 6.0 T@102 A (design value) in IHEP. The magnet has one solenoidal configuration with a 
copper former, two two-stage 4 K GM cryocooler with 1.5 W second-stage refrigeration 
power are employed to cool the magnet from room temperature to liquid helium temperature 
in 168 hours.

Table I Design Parameters for Φ400mm@6T NbTi Coil

<table>
<thead>
<tr>
<th>Item</th>
<th>Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter of wire, mm</td>
<td>0.85/0.90</td>
</tr>
<tr>
<td>Ic(<a href="mailto:4.2K@7.5T">4.2K@7.5T</a>)</td>
<td>&gt;280A</td>
</tr>
<tr>
<td>Inner dia., mm</td>
<td>450</td>
</tr>
<tr>
<td>Outer dia., mm</td>
<td>560</td>
</tr>
<tr>
<td>Height, mm</td>
<td>400</td>
</tr>
<tr>
<td>Total turn</td>
<td>30056</td>
</tr>
<tr>
<td>Current</td>
<td>102 A</td>
</tr>
<tr>
<td>Center field, T</td>
<td>6.0/7.4</td>
</tr>
<tr>
<td>Inductance, H</td>
<td>324.5</td>
</tr>
</tbody>
</table>

Fig. 1 the field intensity distribution of the
Φ400mm@6T superconducting magnet
At present, due to the influence of excessive leakage magnetic field on GM cryogenic refrigerator, the superconducting magnet test is only charged to 60A@3.55T/4.15T, but no quench. In the next step, the optimal design of the magnetic shielding structure of the refrigerator will be carried out, and the excitation test will be carried out again. Specifications of the superconducting magnet are listed in Table I. Fig. 1 shows the field intensity distribution of the superconducting magnet.

Another One magnet can be worked at persistent current mode with superconducting switch, 5.0T field in the center of a 100 mm room temperature bore with operating current of 80A. The excitation demagnetization time can be controlled within 15 minutes; A two two-stage 4 K GM cryocooler with 1.5 W second-stage refrigeration power are employed to cool the magnet from room temperature to liquid helium temperature in 26 hours.

![Field intensity curve on central axis of Φ100mm@5T SC magnet](image1)

**Fig. 2** a. the field intensity curve on central axis of Φ100mm@5T SC magnet

b. the photo of the Φ100mm@5T SC magnet

![Superconducting magnet test site](image2)

**Fig. 3** the photo of Φ100mm@5T SC magnet test site

Fig. 2 shows the field intensity curve on central axis of magnet and the photo of SC magnet. Fig. 3 shows the photo of superconducting magnet test site. In the last test, the operating current of the magnet reached 92A and the central magnetic field was 5.8T, and closed the loop successfully.

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A superconducting magnetic separation system was installed in the chemical cleaning process to remove the iron oxide scale from the feedwater supply system in a thermal power plant and the obtained results will be reported.

This chemical cleaning was applied to the thermal power plant with AVT (all volatile treatment) for water treatment. The temperature of the cleaning solution during chemical cleaning is 80 to 85 °C., the flow rate is 550 m³/h, and the pH is 2-3. About 1/210 (2.6 m³/h) of this cleaning solution was passed through a superconducting magnetic separation device, and magnetic separation was performed. The applied magnetic field was 0.3 T, the flow rate was 30 cm/s, and the scale concentration was 150-220 ppm. The separation efficiency of more than 80% was targeted and 82.2% was achieved. This separation efficiency can be predicted from the results of small-scale experiments.

The purpose of this project is to protect the decline of the power generation efficiency of thermal power plants and consequently reduce CO₂ emissions. One of the main causes of the decline in efficiency of thermal power plants is brought by the iron oxide scale generated in the water supply system. For this reason, in this study, iron oxide scale is removed using a superconducting magnetic separation system to prevent a decrease in power generation efficiency and suppress an increase in CO₂ emissions.

This project using superconducting separation consists of the following
three steps; i) basic research, ii) application to chemical cleaning process and ii) installation in thermal power plant. The work reported in this paper is the application of magnetic separation technology to the chemical cleaning process.

The generation of iron oxide scale cannot be completely suppressed even with water treatment such as AVT and hence the chemical cleaning process is employed. The power plant is periodically stopped and the generated scale is chemically cleaned. In the process the generated iron oxide scale is partly dissolved and removed from the pipes. The iron oxide scale is transported out of the water supply system and separated from the cleaning fluid. The superconducting magnetic separation was introduced to remove the scale from the cleaning fluid and the separation performance was evaluated.

This work was supported by “Advanced Low Carbon Technology Research and Development Program (ALCA)” of Japan Science and Technology Agency (JST) Grand JPMJAL 1304.
Accurate measurement of the forced or free damped oscillation of a magnetically levitated droplet

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Exciting a levitating liquid droplet and measuring its oscillation frequency is a well-known technique to determine its surface tension, including gas bearing, electromagnetic levitation and diamagnetic levitation. In this study, we observe the oscillation of a magnetically levitated diamagnetic droplet excited by an acoustic device and measure its oscillation with a confocal optical distance sensor.

A liquid droplet (water or ethanol) is levitated in the room temperature bore of a superconducting magnet. The acoustic excitation is generated by a bass subwoofer with frequencies starting from a few Hz. The acoustic wave is transmitted through a long pipe with a reduced section inside the magnet bore. At the end of the line, two nozzles with holes laterally excite the droplet to trigger the L=2 oscillation mode. The oscillation of the droplet is measured by the optical sensor (fig 1), and the frequency is either determined in forced oscillation or free damped oscillation after excitation. In addition, the rate of the decay during free damped oscillation provides information about the viscosity of the droplet.

One of the key parameters in the measurement is the determination of the droplet diameter or its mass. The former is measured optically with a zoom camera outside the field; the latter is obtained by collecting the droplet after the experiment and measuring its mass.

Preliminary results are given for water and ethanol and accuracy of the results are discussed.

**Fig 1.** A levitated water droplet is excited by a low frequency acoustic signal until t = 22s. The frequency and decay constant are determined in the following free damped oscillation.
Potential of Magnetic Biological Wastewater Process and Possibility of That Superconductive Magnetic Application.

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1. Introduction

The United Nations warned that about 700 million people in the world were currently suffering from water shortages, and about 1.8 million children die annually due to untreated drinking water. It is well-known that the water issue is a major problem which should be solved for our sustainable development. The United Nations adopted 17 goals as the sustainable development goals (SDGs) in 2015. The 6 targets in the SDGs is related to water issue, that are G6) clean-water and sanitation, G2) zero hunger, G3) good health-lives, G12) responsible production, G14) life below water, and G15) life on the land. Wastewater treatment technology would be one of important key to approach the goals.

Biological wastewater treatment process is main technique for wastewater treatment process. Activated sludge process which is aerobic bioprocess, is widely utilized to treatment of domestic sewage and organic industrial wastewater. As anaerobic bioprocess, methane fermentation is also widely utilized to treatment sludge and concentrated wastewater. Since these bioprocess are based on natural carbon recycle mechanism, that are reasonable and economical process as compared with other process such as chemical or physical purification process. Still, a few difficult problems remain in these bioprocesses as shown in Table 1.

We considered that these problems can be solved by applying of magnetic separation. In this paper, we introduce research outlines and apparatus of magnetic activated sludge process and magnetic methane fermentation. Additionally, the future application of superconductive magnet in wastewater treatment process is discussed in the large-scale sewage treatment.

2. Magnetic activated sludge

Activated sludge originally is not attracted by magnet but it is easy to give apparent ferromagnetism to the sludge by mixing of magnetite powder. This sludge is called magnetic activated sludge (MAS). MAS is quickly and steadily separated from water by magnetic separator. Since MAS process is operated at steady state concentration under a given organic loading rate, sludge concentration is constant even if there is no excess sludge withdrawal.

Bench-scale test is easily demonstrated using a standard apparatus which is shown in Fig. 1. In spite of the maximum flux density of less than 0.1 T and the volumetric capacity of less than 0.2 L, the separation capability of this process is slow and delicate sludge/liquid separation, instability of sludge settleability, waste sludge treatment and disposal, slow reaction and requirement of large HRT, low settleability and leakage of SS.
magnetic separator is the sludge concentration of 20 g-VSS/L and the flow rate of 200 L/d.

A mobile type MAS apparatus for pilot plant test of MAS was developed a few years ago (Fig. 2). This pilot plant is able to be transported by truck to on-site and to be started soon of demonstration. A commercially available magnetic separator (NEOMAX engineering, Co.Ltd., Japan) is used for the MAS separator, which was set on the aeration tank.

Full-scale MAS separator (proto-type, 17 cmφ×150 cm magnet drum×2, 2-step separation, Fig.3) was developed last year and tested of the separation capacity, which was able to separate MAS at flow rate of 100 m³/d-300 m³/d. A design of full-scale MAS process became possible by using parallel system of this separator. A Pilot-scale test and a full-scale MAS test are prepared to start from this year at a real wastewater plant of a food company.

3. Magnetic methane fermentation

Methane fermentation system is known to consist of acid production bacteria and methane production bacteria. As well as MAS, it is easy to separate magnetically both methane fermentation bacteria by mixing of magnetite powder. The methane fermentation using magnetic separation process was called magnetic methane fermentation (MMF). A standard MMF apparatus (Fig. 4) was made by modification of the standard bench scale MAS apparatus.

4. The future application of superconductive magnet

According to our estimation, it was considered that the MAS process is superior to conventional activated sludge process on the view points of cost and easy operation. In present data, the cost and separation capacity of full-scale MAS separator using permanent magnet are approximately 50,000 dollar and 200 m³/d, respectively. However, the capacities of domestic sewage treatment plant are mainly 10,000 ton or more. If the MAS process was adopted to a sewage treatment plant of the capacity 100,000 ton/d, it will be necessary the parallel system of 500 magnetic separator will be needed, and consequently, the cost will be estimated 2,500,000 dollar. If the superconductive MAS separator is invented, and the cost of the separator is 2,000,000 dollar or less, it is considered that the superconductive MAS process will be widely utilized for domestic sewage treatment method in the world. Then, the MAS process will be able to contribute to the achievement of SDGs.
Application of superconducting HGMS coupling technologies in the fields of resource & experiment

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Abstract

Compared with the traditional magnetic separation, superconducting HGMS technology has many advantages, such as small covering area, high efficiency, low operating cost, low energy consumption, without secondary pollution and so on. Some of the findings on application of superconducting HGMS technologies are as follows.

(1) Application in wastewater treatment and recycling

- Converter dedusting wastewater treatment by superconducting-HGMS technology. The removal of SS is up to 99.5% without flocculants.
- Acid heavy metal ion wastewater treatment by superconducting-HGMS coupling process. The removal rate of arsenic ion is up to 99.06%.
- Removal of Cu\(^{2+}\) from electroplating wastewater by superconducting-HGMS coupling process. The removal rate of Cu\(^{2+}\) can be up to 99.77%.
- Application in open circular cooling water treatment. The hardness removal rate can reach 75%, most of ion Ca\(^{2+}\) and Mg\(^{2+}\) can be removed that scales are not easily formed on the inside surface of devices and pipes. The removal rate of SS is more than 99.5% with flocculants, and the algo-fungus was killed completely. It is difficult to form biofilms without SS and algo-fungus, so formation of bio-slime can be avoided relatively. In addition, superconductivity can also induce lattice distortion, change the nucleation mechanism such as calcium carbonate, and reduce scale formation.

(2) Application in resource utilization of solid waste

- Separation and extraction of Fe\(_2\)O\(_3\) from hematite, the content of TFe is above 65%.
- Preparation of iron oxide red (α-Fe\(_2\)O\(_3\)) from LT fine dust by superconducting HGMS coupling process. The content of α-Fe\(_2\)O\(_3\) was more than 91%, the iron oxide red prepared can meets the requirement of Chinese National Standard (A level).
- Separation and purification SiO\(_2\) from iron-tailings. The content of SiO\(_2\) enriched is more than 99%. We can prepare a series of molecular sieves with it, such as 4A, Na-X, ZSM-5, and so on. It not only dispose waste solid but also realize the high value-added resource utilization of iron tailings.

In a word, our studies on application of superconducting HGMS tell us that coupling process is very important in the fields of resource & experiment. It is not only bring us good economic returns, but also get a great environmental and social benefits with very good prospects.
Introduction of MAP

International Workshop on Material Analysis and Processing in magnetic fields
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International Workshop on Materials Analysis and Processing in magnetic fields (MAP) is the scientific meeting that the researchers who use the magnetic field in their work to analyze some properties, to process or to control something. People who develop superconducting or permanent magnets also involved in this meeting.

MAP was first held in 2004 in Tallahassee (USA), based on the agreement with world high magnetic field laboratories. Then, MAP was continuously held in each two years in Grenoble (France, 2006), Tokyo (Japan, 2008), Atlanta (USA, 2010), Grenoble-Autrans (France, 2012), Okinawa (Japan, 2014), Providence (USA, 2016). The last workshop, MAP8, was successfully held in Grenoble in 2018.

Covering research areas are widely spread out in many research fields such as; materials science, physics, chemistry, biology, medical science, engineering, industries and so on. The workshop aims to discuss recent advances of research. Fundamental investigations as well as industrial applications will be discussed.

Topics treated in MAP are as follows;
1. Magnetic field effects on chemical, physical, hydrodynamic and biological phenomena
2. Magnetic processing of materials
3. Diamagnetic effects and Levitation
4. Magnetic field effects on phase transition, crystallization and texturing.
5. Medical application of magnetic fields
6. Development of analytic technique, equipment and high magnetic field generation
7. Environmental application and magnetic separation
8. Other phenomena related to magnetism or magnetic fields

Next meeting, MAP9, will be held in Japan in June 2020. The venue of the workshop is not fixed yet, however, supposed to be Miyazaki in Kyushu island.
Participants of IFMFC are welcome to join MAP9.
Detailed information will be announced in this autumn.
Magnetic Force Assisted Settling of Fine Particles from Turbid Water

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Introduction

When rivers and lakes are contaminated with numerous contaminants, usually the contaminants are finally deposited on the sediments of the waterbody. Many clean up technologies have been developed for the contaminated sediments. Among several technologies dredging is one of the best methods because dredging removes all the contaminated sediments from the water and the contaminated sediments can be completely treated with physical and chemical methods. However the most worried phenomenon is suspension of fine particles during the dredging process. The suspended particle can release contaminants into water and resulted in spread of the contaminants and the increase of risk due to the resuspension of the precipitated contaminants such as heavy metals and toxic organic compounds. Therefore the success of the dredging process depends on the prevention of resuspension of fine particles. Advanced dredging processes employ pumping the sediment with water onto a ship and release the turbid water pumped with sediment into waterbody after collection of sediment solids. Before release of the turbid water into lake or river, just a few minutes allowed to precipitate the suspended particle due to the limited area on a dredging ship. However the fine particle cannot be removed by the gravitational settling over a few minutes. Environmental technology such as coagulation and precipitation could be applied for the settling of fine particles. However, the process needs coagulants and big settling tanks. For the quick settling of the fine particles suspended during dredging process magnetic
separation has been tested in current study.

Experiments

Sediments were collected from Andong-dam in Korea using grab sampler and turbid water sample was made by stirring the sediments in distilled water. The enhanced precipitation of suspended particles was carried out on an electromagnet. The turbidity of water was compared before and after flowing on magnets. Particle size distribution and heavy metal contents of the suspended fine particle were also compared.

Results and Discussion

The turbidity of the turbid water has been gradually decreased by magnetic force enhanced settling process in preliminary tests with a permanent magnet. The removal rate was about 10-30 % with a permanent magnet of about 0.7 Tesla on the magnet surface. By the repeated flowing over the magnet the removal rate was increased up to 60%. The removal rate was increased with a superconducting magnet. The removal rate was affected by several factors such as flow rate (flow depth), magnetic field, and location of the sediment sampled. The heavy metal contents of the suspended particle in water flowing through magnet were less in comparing those of the magnetically settled particle.

Conclusion

The magnetic force assisted settling and precipitation of fine particles from a turbid water generated during dredging of sediment in lakes and rivers were tested with synthesized turbid water and magnets. Magnetic force increased the settling velocity and the increased settling process can reduce the volume of settling tank usually located in a ship for dredging. The magnetic assisted settling also decreased the heavy metal release through the turbid water by precipitating highly contaminated particles with magnetic force.
The Development of Superconducting Magnetic Separation System for Sewage Treatment in TIPC

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Abstract:
Superconducting magnetic separation system is an significant technique for securing water resources. The system can achieve not only high separation efficiency and high processing speed but also significant cost reduction. The core of the system is a high gradient magnetic separation (HGMS) device, usually with a wide-bore superconducting magnet.
We present the developments of a series of cryogen-free superconducting magnets for magnetic separation in our research center, TIPC. Three conduction-cooled superconducting magnets were developed. The diameters of room temperature bore of the SC magnets are ranged from 40mm to 400mm. the maximum center fields are from 2.5T to 6T. Using these SC magnets, we developed SC magnetic separation systems for wastewater treatment. The system scale is from prototype to pilot-plant. The design of this separation systems is also described, especially the exchange and washing of magnetic filters. More applications of SC magnet magnetic separation technology to industrial practices are being implemented.
An industrial practice of superconducting magnetic separation for wastewater purification

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An integrated set of industrial wastewater purification system using superconducting magnetic separation for treating wastewater from coke-oven procedure was designed and built, which was then deployed at Xuansteel Company, HBIS Group. The system has been running steadily for over one year, while all pollutant indicators were below the national standards.
Adsorption Behavior of Heavy Metal Ions in Muddy Water

-The Possibility of Magnetic Separation for Removal of Cd and As-

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1. Introduction

Large-scale civil engineering works discharge a large amount of soil suspension contaminated with natural heavy metals (muddy water). This study proposes a new method for purifying the contaminated soil without any adsorbents by superconducting magnetic separation.

We have previously proposed a method for reducing the volume of Cs contaminated soil in Fukushima by selective separation of paramagnetic vermiculite which strongly adsorbs radioactive Cs ion. This study tries to apply a similar method to the soil contaminated by natural heavy metals. The first process of soil purification is usually soil classification using the difference in adsorption surface area, as well as the case of Cs contaminated soil. The proposed method is applied for the silt and clay after the classification.

The pH adjustment of the contaminated muddy water makes the surface states of the minerals changed, and heavy metal ions can be adsorbed only to the specific minerals. Then, the contaminated soil is separated into the paramagnetic and the diamagnetic materials using a superconducting magnet.

In order to realize this method, the adsorption behavior of heavy metal ions to the soil minerals depending on pH is important. As a fundamental study, the adsorption amount of heavy metal ions on each minute mineral in the soil as a function of pH were investigated. The adsorption behavior under coexistence of anion and cation was also investigated.

2. Experimental methods

Cadmium and Arsenic, which are frequently detected from muddy water as natural heavy metals, were targeted. 100 mL each of 10 ppm Cd and As aqueous solution was prepared, and the fine mineral was added followed by pH adjustment. Here, kaolinite was added as a 1:1 type clay, vermiculite was added as a 2:1 type clay, and hematite was added as iron oxide as representative minerals in the muddy water. The mixture was shaken for 24 hours, suction filtered through membrane filters, and then the Cd concentration and As concentration in the filtrate were measured with an ICP emission spectrometer (ICP-AES).

3. Results and discussions

Cd adsorption amount per unit mass of each minute mineral as a function of pH showed that the adsorption amount of Cd to vermiculite was significantly high among the minerals especially at high pH. It is known that 2:1 type clay mineral such as vermiculite have negative charge called “permanent charge”, because part of the cation in the crystal structure is replaced by another cation with a lower valence. It is assumed that a large amount of cadmium ions (Cd\(^{2+}\)) were adsorbed for this reason.

On the other hand, pH dependency of As adsorption to each mineral confirmed that hematite (Fe\(_2\)O\(_3\)) adsorbed at low pH was larger than that of other minerals. The minerals have the
charge called “variable charge”, whose surface charge changes positively and negatively depending on the solution pH. Only the hematite surface is positively charged in the acidic to neutral solution that can adsorb anions, since the isoelectric point of hematite (pH = 7) is higher than that of layered silicates of 2:1 and 1:1 clay minerals (pH = ca. 2). It is presumed that a large amount of arsenate ions exist as $\text{H}_2\text{AsO}_4^-$, and adsorbed on the hematite with positive charge.

Furthermore, pH dependency of the adsorbed amount of Cd and As in their coexistence was examined, showing that the coexistence of Cd significantly promoted adsorption of As in the neutral to alkaline solution. This will be due to the interaction between these negative and positive ions in the solution or on the surface of the clay mineral.

The results indicate the possibility of volume reduction of heavy metals contaminated soil by selective separation of paramagnetic minerals.

Acknowledgment

This research was partly supported by JSPS KAKENHI Grant Number JP17K00598 “Development of separating method of heavy metal ion without chemical additives using solid catalyst and magnetic separation.”
Cleanability of Semi-Dried Milk Deposition on a Highly-Smooth Internal Surface of Stainless Tubing by Magnetic Abrasive Finishing

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Stainless steel tubing is widely used for process equipment in the dairy industry. The deposition of milk components to internal surface of stainless steel tubing may cause deterioration in quality and food poisoning. Frequent cleaning of the equipment surface is needed to avoid contamination, however, it may cause an increase in energy consumption and environmental impact. Surface roughness is one factor affecting the attachment and removal of food soils. EHEDG (European Hygienic Engineering & Design Group) recommends that large areas of food product contact surface should have a surface finish of 0.8 µm Ra. In this work, we studied cleanability of semi-dried milk components on a highly-smooth internal surface with 0.01 µm Ra of stainless tubing. The highly-smoothed stainless tube was prepared by magnetic abrasive finishing (MAF), which is an internal finishing process by the application of a magnetic field of permanent magnets. Three different levels of surface roughness of stainless steel tubings were tested to evaluate the cleanability. On the deposition test, whole milk was circulated in a tested loops connected with the tested stainless tubings. After the deposition process, deionized water was flushed into the tested loops to clean milk deposition on the internal surface of stainless steel tubings. To evaluate the cleanability of the milk deposition in the tubings, we measured amounts of milk residues and residual proteins on the internal surface of the tubings. The result indicated that the highly-smooth internal surface has a potential to improve the cleanability of semi-dried milk deposition.
Experimental study on strain sensitivity of Internal-Tin Nb$_3$Sn superconducting strand based on non-destructive technology

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Abstract:
Fracture of brittle filaments plays a crucial role in significant degradation of critical current density of multifilamentary Nb$_3$Sn strand. Recent researches of distribution of filament fractures mostly depend on fractographic analysis with SEM or TEM. However, it is hard to obtain spatial distribution of filament fractures in the multilayer filamentary Nb$_3$Sn strand. In addition, almost unavoidable filament fracture is introduced during the sample preparation procedure and it causes deviation of filament fracture distribution. X-ray micro tomography is a non-invasive, non-destructive method, which allows determination and the discrimination of internal features without destructing the sample. It is widely used as a non-destructive test technology for its high penetrability and high resolution. This paper proposes investigation of filament fracture under different tensile strains. The influence of tensile strains on the filament fracture behavior was investigated and the results will be expected to provide reference for optimization of multifilamentary Nb$_3$Sn strand, conductor and magnet design.
Preparation of Ion-Imprinted Magnetic Adsorbent and Selective Removal of Pb from Aqueous Phase by HGMS

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A selective adsorption process to remove certain ions among various competition ions are very useful in engineering. It allows removal of toxic substances only or recovery of valuable resources. The ion imprinting technology has shown great potential in the synthesis of materials that are capable of adsorbing heavy metals selectively. In this study, a Pb⁡2⁺ imprinted magnetic polymer was synthesized by nanoscale surface imprinting technique with Pb⁡2⁺ as template, polyethyleneimene functionalized magnetic Fe₃O₄ as functional monomer and epoxy chloropropane as cross-linker. The prepared Pb⁡2⁺ imprinted magnetic polymer was characterized by transmission electron microscope (TEM), fourier transform infrared spectroscopy (FT-IR), and vibrating sample magnetometer (VSM). Batch selectivity studies were performed to evaluate the influence of competing ions such as Cd⁡2⁺, Cu⁺, and Ni⁡2⁺. The selectivity coefficients of Pb⁡2⁺/Cd⁡2⁺ and Pb⁡2⁺/Ni⁡2⁺ were calculated as 1.9 and 3.6 respectively. Cu⁺ was not competing with Pb⁡2⁺. The synthesized magnetic polymer was recovered from aqueous phase by HGMS system. The synthetic polymer with small particle size and weak magnetic properties showed the result of a significant improvement in recovery efficiency according to the accredited magnetic field of the HGMS.

Key Words: Selective, adsorption, imprinting, heavy metals, HGMS

Acknowledgement
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Strain response of curing epoxy matrix composites using embedded strain gauges

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In this work, the implementation of residual strains in epoxy resin during its curing process with an operational range of 300 K-400 K and cooling process with an operational range of 15 K-300 K was studied using embedded strain gauges. This represents a significant reduction in the lowest usable temperature of epoxy resin as well as a significant increase in sensitivity of residual strains in curing epoxy resin compared with previously reported solutions. This was accomplished by embedding strain gauges in the epoxy resin before it cured. The measurement of residual strains in epoxy resin gives us a more comprehensive understanding of the mechanical properties of epoxy resin so that we can make a full prevention of warping, loss of mechanical properties caused.
DC surface flashover characteristics of ZnO/EP nano-composites at room temperature and 77 K

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Epoxy resin is widely used in cryogenic superconducting magnets, functioning as the insulating and support structures. Appropriate doping of inorganic nano-particles in epoxy resin can improve its mechanical and insulating properties. In this study, the DC surface flashover characteristics of ZnO/EP nano-composites at both room temperature and 77 K were studied. The samples were made by dispersing ZnO nano-particles into EP resin with weight percentages of 0%, 1%, 3%, 6% and 10%, respectively. The experiment was carried out in a cryostat in which DC high voltages ranging from 0 kV to 100 kV were supplied. The results showed that the surface flashover voltages increased with the increase of ZnO content at 77 K, and the surface flashover voltages at 77 K were higher than those at room temperature for composites with the same ZnO content.
Proposal of Sludge Treatment by Magnetic Assisted Dewatering and Drying (MSDD) Method and Consideration of the Treatment Process

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1. Introduction
Activated sludge (AS) method is widely used for wastewater treatment. More than half of the biodegraded organic matter is converted to microorganisms, and a large amount of sewage sludge is generated in exchange for sewage purification. This sewage sludge is reported to be more than 70 million ton/y in Japan and it is treated by thickening, dewatering, drying and incineration. Conventionally, in thickening process, sludge is concentrated to 98% moisture with 0.5-2 day. Therefore it requires long time and large space. And in dewatering process, the concentrated sludge is mechanically squeezed to 80% moisture. It is difficult to obtain the sludge of less than 80% moisture by conventional dewatering process. In the case of almost industrial wastewater treatment plants, the dewatering sludge is consigned to a waste-disposal vendor. This sludge consigning cost is approximately 30,000 yen/ton in Japan, which is said to occupy more than 40% of running cost of wastewater treatment plant operation. Reduction of sludge moisture and volume is important to reduce operating costs.

In our investigation of magnetic activated sludge process, it was known that, after magnetite powder added to activated sludge, the sludge can be easily lifted up by magnet from water and dewatered to 95% moisture quickly. A magnetic dewatering process was proposed and examined to save cost and energy in sludge treatment process as advanced application of magnetic separation of activated sludge. In the process, magnetite powder was added to activated sludge, and the sludge was lifted up from sludge suspension by magnet plate, dewatering by gravity and dried by air blowing. This method was named Magnetic Assisted Dewatering-Drying (MSDD) method. Since magnetite powder became recently available at low cost, MSDD method is considered to be able to be utilized for waste sludge treatment commercially. The purpose of this paper is proposal of new sludge treatment process assisted by magnetic force, and the cost evaluation.

2. Experimental
Five rubber-magnet plates (10 cm × 10 cm × 0.2 cm; Bmax, 80 mT) which was set in parallel at intervals of 2 cm were used as a basic apparatus for demonstration of MSDD method (Fig. 1). Magnetic activated sludge was prepared by adding magnetite into acclimated activated sludge. The ratio of activated sludge/magnetite was adjusted to 1/0.2. The basic apparatus was dipped in MAS suspension for 3 minutes, and pulled up at the constant speed. The apparatus was put on an electronic balance, and the weight change was measured continuously under blowing cool or hot air until the constant weight. The effect of sunk time (1 s - 3 min), blowing-air temperature (24℃ - 76℃) and pull-up speed (0.67 cm/min - 10 cm/min) to the sludge drying time were investigated.
3. Results and Discussion

1) Pull-up speed

When the basic apparatus was pulled up with at the speed of 0.67, 1, and 10 cm/s, the amount of sludge pulled up was 17.3, 17.3, and 14.5 g-WS, respectively. It was considered that the sludge attached on the surface of the magnet was washed out by fast water flows on the magnet surface. Therefore, the apparatus needs to be pulled up at the speed of 1 cm/s.

2) Sunk time

The relationship between sunk time and amount of attached sludge was investigated at pull-up speed of 1 cm/s. The amount of attached sludge increased with increase of sunk time and was saturated at 30 s or more. Therefore, it was considered that sunk time was enough at 1 minute.

3) Drying performance of MSDD method and that cost estimation

Drying performance of MSDD method was investigated at the pull-up speed 1 cm/s and the sunk time 30 s. The sludge volume pulled up by basic apparatus was 2.5 g-VSS. The moisture content of the sludge after drying was 2.9%, and the dried sludge was easy to fell off from magnet plates. Table 1 shows the influence on the drying performance at various temperatures. If the apparatus size is 1 m ×1 m × 1 m, the magnet area is 1000 times, and the amount of pull-up sludge is 2.5 kg-VSS/m³. The drying performance is 3.6 kg-VSS/(h · m³) in case of using the 76℃ air. Therefore it can dry from 3600 kg (moisture 99%, 36 kg-VSS) of sludge to 48 kg (moisture 10% or less) in a day, in case of using 1 m³ MSDD device for 10 h/d. On the other hand, when the same amount of sludge is treated by the conventional dehydration method, 180 kg (moisture 80%) of dewatering sludge is obtained. Therefore MSDD method can reduce sludge to about 1/4, therefore, the sludge disposal cost can be about 1/4. In spite of magnetite cost, it was estimated that 60% disposal cost could be saved by MSDD method as compared with conventional dewatering process such as filter press, etc.

4. Conclusion

It was considered that Magnetic Supported Dehydration-Drying (MSDD) method is potentially a compact and economic process as sludge treatment process.
Study on Irradiation Effect of Insulating Materials for Superconducting Magnets ~ Change in Mechanical Strength at Cryogenic Temperature ~

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1. Introduction

In ITER, the insulating materials of superconducting magnets are used under severe conditions such as electromagnetic forces, cryogenic temperatures, and radiation environments. Since the polymeric insulating materials show high sensitivity to radiation and brittleness at low temperature, the mechanical strength together with the insulation performance could be decreased. The insulating material in ITER is a hybrid composite made of glass cloth and polyimide film laminate. The materials are often broken in interlaminar shear mode because interlaminar shear strength of GFRP should be much smaller than tensile strength. It means in flexural mechanical test, the interlaminar shear failure might be brought rather than flexural (tensile) failure. Therefore we focused on the interlaminar shear strength in this work. Many studies using liquid nitrogen were conducted to investigate the low-temperature effect on the insulating materials[1]. However, studies using liquid helium, which is close to the actual usage environment, for irradiated specimens have hardly been conducted.

In this study, Glass Fiber Reinforced Plastics (GFRP) consisting of glass cloths and epoxy resin were made and Interlaminar Shear Strength (ILSS) was measured after irradiation at low temperature.

2. Experimental method

The GFRP was fabricated as follows. 32.2 g of curing agent (Baxxodur EC 301, Mitsui fine chemicals, Inc.) is added to 100 g of Bisphenol A epoxy resin (JER-828, Mitsubishi chemical), and were stirred in vacuum for 1 hour. 45 laminated boron-free S-glass cloths (Arisawa Manufacturing. Co., Ltd.) were impregnated with the resin, and then heated for 2 hours at 70 ℃ and for 3 hours at 110 ℃. GFRP were processed into double-notch specimens for measuring ILSS. These specimens were irradiated with 60Co gamma-ray up to the absorbed dose of 10 MGy at dose rate of 42 kGy/h at room temperature in air atmosphere. ILSS tests were conducted under three temperature conditions, that is room temperature (RT, 300 K), liquid nitrogen temperature (LNT, 77 K), and liquid helium temperature (LHeT, 4.2 K). ILSS was calculated by dividing the stress, where the specimen is broken, by the cross-sectional area of the fracture surface.

3. Result and Discussion

ILSS at low temperature was larger than that at room temperature, regardless of an absorbed dose as shown in the figure. ILSS of non-irradiated GFRP (0 MGy), was the largest at LNT, and decreased slightly at LHeT. This indicates the difficulty of stress relaxation since the molecular motion was frozen at lower than LNT. On the other hand, ILSS of GFRP irradiated with 5 or 10 MGy were the largest at LHeT.

![Figure](image.png)

**Figure.** Relationship between ILSS and temperature at 0, 5, 10 MGy.

Reference


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Sustainable Synthesis of ZSM-5 Zeolite from Iron Ore Tailings

Pre-treated by HGMS

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Abstract

Iron ore tailings (IOT) are mineral waste obtained from the process of Iron ore mining. The IOT usually is rich in SiO$_2$ and Al$_2$O$_3$, which can be used as a raw material in producing zeolite materials. It will have substantial benefits from both economic and environmental aspects. High gradient magnetic separation (HGMS) was a new kind of magnetic separation technology that can be effectively applied to the separation and purification of silica in IOT. Herein, we report a novel and green method for preparing the ZSM-5 zeolite used IOT that pre-treated by HGMS as sole silica source.

The experimental results indicated that the optimal magnetic separation parameters were as shown in figure 1, magnetic flux intensity of 3.70 T, pulp density of 30 g/L. Under this condition, the content of SiO$_2$ was up to 86.55% from 63.87%.

![Fig.1 Effect of magnetic flux density (left) and pulp density (right) on SiO$_2$ and yield rate](image)

The ZSM-5 zeolite is successfully synthesized from IOT that pre-treated by HGMS via a novel solvent-free method. The BET surface area is estimated to 319.81 m$^2$/g, and the external surface area is 92.69 m$^2$/g, which indicate the as-synthesized ZSM-5 is a good hierarchically porous material. The synthetic route proposed in this work provides a novel green alternative for the synthesis of ZSM-5 from IOT.

![Fig.2 XRD patterns of the samples (left); Physicochemical properties of the Sample (right)](image)
Separation on Purification of Iron Oxide from Converter Dust

by Superconducting HGMS Technology

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Abstract

Iron oxide red is a significant color inorganic pigment, which is prepared by chemical reagents usually. However, the high cost of the chemical reagents blocks the further industrial application of iron oxide red. Thus, greener and cheaper raw materials for the production of iron oxide red are preferably desired. As a waste byproduct of iron and steel smelting, converter dust usually is rich in iron oxide, which could be used as a raw material for the synthesis of iron oxide red. Therefore, using converter dust synthesis iron oxide red not only solves environmental problems but also creates huge economic benefits.

Due to the magnetism of $\alpha$-$\text{Fe}_2\text{O}_3$ is so weak that cannot be separated and purified by conventional magnetic separation technology. Consequently, the superconducting high gradient magnetic separation (HGMS) is a new kind of magnetic separation technology that can be effectively applied to the separation and purification of weak magnetic materials.

Based on X-ray diffraction pattern of converter dust (Fig.1), we can know that the dust mainly magnetite, hematite, iron olivine, hedenbergite diopsidite phase and so on. By superconducting HGMS, substances contained iron can be separated and enriched mostly.

The effects of magnetic flux intensity, dispersing agent, slurry concentration and slurry flow velocity on the magnetic separation were investigated. The experimental results were shown in Fig.2. The content of iron was increased from 51.31% to 55.73% under the optimal process parameters: magnetic flux intensity of 2.0 T, a slurry velocity of 500 ml/min, a slurry concentration of 15 g/L and a dispersing agent of 30 mg/L. The iron oxide red is successfully synthesized from converter dust prepared, which can approach the Chinese national standard requirements (A level).

Fig.1. Physical photo and X-ray diffraction pattern of converter dust

Fig.2. The effect of magnetic flux intensity, dispersing agent, slurry concentration and flow velocity on separation efficiency
Poly (Lactic acid) –layered sheets were 3D printed using Ultimate 3D printer using the Fused Deposition Modeling (FDM) method. Samples were irradiated in the Co 60 gamma irradiator located at Jordan Atomic Energy Commission (JAEC) at an average dose rate of 307 Gy/hr. Samples were irradiated to different doses in the range of 0-175kGy. The effects of gamma irradiation on the different properties of the 3D-printed PLA were evaluated. Mechanical properties were assessed using tensile measurements. The results show that tensile strength of the irradiated PLA decreased with increasing dose of irradiation due to irradiation enhanced oxidative degradation and chain scission. Thermal properties observed by Differential Scanning Calorimetry (DSC) showed differences in the crystallization energy and temperature due to changes in the crystalline structure and some changes in glass transition temperature and energy. The microstructural properties of the irradiated PLA were characterized by X-ray diffraction (XRD). The results revealed various crystal structures based on the PLA color. While an amorphous morphology was observed in both irradiated and non-irradiated blue samples, semi crystalline structure was observed for white samples and crystalline structure was observed for green 3D printed PLA. Chemical structure was examined by Fourier transform infrared (FTIR) spectroscopy. FTIR spectra showed no detectable changes in intensity or any wavenumber shift of the irradiated 3D-printed samples that was induced by gamma irradiation. Finally, external morphology and fracture behavior of irradiated PLA were investigated using Scanning Electron Microscopy (SEM), showing brittle fractures at high doses, while ductile fractures were observed for unirradiated samples.
Study on manipulation of substance using magneto-Archimedes effect in a horizontal direction

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Magneto-Archimedes levitation is a phenomenon in which a substance levitates stably at a specific position due to the balance between magnetic force and gravity. By utilizing this phenomenon, it is expected to separate and selectively recover specific substances. However, the "horizontal direction magneto-Archimedes effect" that applies this in a horizontal direction has not been sufficiently studied. In this study, with the aim of showing the proposal and usefulness of the horizontal magnetic Archimedes effect as a new magnetic application technology, we have studied manipulation of several kinds of substance using the split magnet and a ferromagnetic cylinder array. The horizontal direction magneto-Archimedes effect has the advantage that the material can be manipulated with a smaller magnetic field than that for the vertical direction magneto-Archimedes effect, because it does not use gravity but balance between the friction force and the magnetic force.

Fig. 1 shows the experimental apparatus. The magnetic field between the poles of the split magnet is almost uniform. Therefore, we have succeeded in creating a larger magnetic field and magnetic field gradient by inserting a ferromagnetic cylinder array between the magnetic poles. Fig. 2 shows that teflon, glass, and copper moved and separated by the horizontal direction magneto-Archimedes effect, respectively. It was confirmed that the behavior of each material depends on its magnetic susceptibility and friction coefficient.

This indicates that there is a possibility of material manipulation due to the horizontal magnetic Archimedes effect.

![Experimental setup](image1)

![Material moved and separated](image2)

Fig. 1 Experimental setup.  Fig. 2 Material moved and separated.

Reference
1. Introduction

Advanced classification using a selection pipe was investigated as a method of reducing the volume of cesium contaminated soil caused by the accident of Fukushima Daiichi Nuclear Power Plant. A selection pipe is a device that can sort the particles depending on particle size by the relationship between buoyancy, drag force, and gravity acting on suspended particles upward in the pipe. This method is based on the fact that the amount of cesium adsorbed is approximately proportional to the surface area of the soil particles. We plan to apply the selection pipe to silt and clay (less than 75 µm in diameter) after the classification. It can also be used as a pretreatment for soil volume reduction technology by high gradient magnetic separation (HGMS).

To put this technology into practical use, it is necessary to improve the classification accuracy of the advanced classification. The objective value of radioactive concentration after classification is 8000 Bq/kg or less, which is the standard value for recycling.

Firstly, a fundamental experiment was conducted with non-contaminated soil. The classification accuracy was improved using a flow straightening plate, in order to make the flow velocity distribution in the cross-section of the pipe uniform. Based on the results, advanced classification was performed using actual cesium contaminated soil in Fukushima Prefecture, and the reduction rate of radioactive concentration was investigated.

2. Experiment

Here, the experiment using actual cesium contaminated soil in Fukushima Prefecture is shown. Advanced classification experiments were conducted for the soil less than 75 µm in diameter by wet sieve classification under five conditions shown in Table 1.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Experimental condition</th>
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<tr>
<td>A</td>
<td>Number of FSP</td>
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<td>B</td>
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FSP … Flow Straightening Plate, $V_t$ … theoretical velocity

When the classification point is set to 20 µm, the theoretical value of the flow velocity is 0.28 mm/s. The solid-liquid ratio of the soil suspension was about 1:144, and the radioactive concentration of soil components of less than 75 µm (silt and clay) before advanced classification was 56000 Bq/kg. After the experiment, the particle size distribution of the remaining suspension in the selection pipe was measured using a laser diffraction scattering particle size distribution measuring device (LA-920, HORIBA, Ltd).
Also, the suspension remaining in the selection pipe is dried by centrifugation and suction filtration, and then the radioactive concentration was measured by NaI(Tl) gamma-ray spectrometer (EMF211, EMF Japan Co., Ltd.)

3. Results and Discussion
   The classification accuracy of the soil residue was highest in the condition E showing 78.1% among 5 conditions in Table1. It shows that the sufficient water well removed the particle less than 20 µm from the pipe. The classification accuracy of the soil residue was second highest in condition B showed 72.6%, indicating that the experimental optimal flow velocity is higher than the theoretical value.
   However, in case the classification point is 20 µm, the radioactive concentration was about 40000 Bq/kg even in the condition E. It indicates that it is necessary to study the appropriate classification point corresponding to the radioactive concentration of each particle size components. To increase the classification accuracy of the soil residue, we are planning to improve the shape of the selection pipe and consider pretreatment of the soil.

4. Conclusion
   Advanced classification experiments using a selection pipe for actual contaminated soil in Fukusima prefecture was conducted. As a result, the radioactive concentration could not be reduced sufficiently and the target value for recycling was not achieved. It indicates that the examination for appropriate classification point and pretreatment or shape design to improve the classification accuracy is required.

5. Acknowledgment
   Part of this study is supported by Kikuchi Seisakusho.Co.Ltd.
Improvement of Treated Water Quality and Reduction of Excess Sludge by the Combination of Magnetic Activated Sludge Process and Settling Tank

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1. Introduction

At 2015, United Nations adopted 17 goals for sustainable development (SDGs). Safety of water resource is one of issues. It is thought that the development of an easy maintenance water treatment process is one of the solutions.

We have been researching to apply magnetic separation to water treatment process for innovation of an activated sludge process which is used for the major process. By mixing with magnetite powder, concentrated activated sludge can be separated magnetically from activated sludge suspension. The biological water purification process using magnetic separation is called Magnetic Activated Sludge (MAS) process. By introducing magnetic separation, activated sludge process became simple drastically on the process maintenance and operation. Because magnetic separation can keep sludge concentration in the aeration tank high, the excess sludge production can be balanced to the cell-decay of sludge microbes. Therefore, MAS process was able to be operated without excess sludge withdrawal. However, small amount of hard-biodegradable suspended solids (hb-SS) are remained after full biodegradation, and it was observed the hb-SS leak to effluent from MAS process. Most hb-SS cannot adsorb the magnetite powder, so the magnetic separator cannot catch those SS. The removal method of hb-SS in the effluent is necessary to be utilized in the severe effluent standard area.

Utilization of the settling tank was thought to be the one of the solutions for the hb-SS problem. Additionally, the phosphate removal procedure was thought to make a merit of additional settling tank system for SS removing increase.

The purpose of this study is to examine the effect of improving the treated water quality by the combination of settling tank and the comparison the process with the conventional method on excess sludge production.

2. Methods

The magnet drum is a diameter of 10 cm, a width of 10 cm, and a maximum magnetic flux of 0.08 T. COD$_{Cr}$ loading rate was 1200 mg/(L·d) for the all experimental period. The concentration of COD$_{Cr}$ was 300 mg/(L·d) and the flow rate of influent was 20 L/d from 1 to 185 days. After 186 days, the concentration was 4 times and the flow rate was 1/4. A batch test was conducted to confirm the usefulness of simultaneous removal of SS and phosphate by coagulation sedimentation.
3. Results and discussion

(1) SS removal by settling tank

The results are shown in Fig. 1. New sewage treatment plants in Tokyo have the strictest waste water standard for SS concentration in Japan (10 mg/L). The SS concentration after magnetic separation often exceeded the standard value, but the SS concentration after the settling tank achieved the standard value throughout the period. Hence, the utilization of a settling tank solved one of the problems of MAS process.

(2) Reducing excess sludge by MAS process

Fig. 2 shows the accumulation curve of calculated excess sludge generation from AS process under same condition as MAS process and hb-SS generation from MAS process. The hb-SS from MAS process means the excess sludge from AS process. In this case, the total amount of excess sludge produced in 80 days was 0.93 g for the MAS process and 135 g for the AS process. It was suggested that MAS process was able to significantly reduce the excess sludge compared with the conventional AS process.

(3) Consideration of removal effect of simultaneous phosphate and SS by coagulation

The PO₄-P of MAS effluent was 11.7 mg/L and could be removed to 0.04 mg/L with SS by coagulation sedimentation. From this result, the cost was calculated under PO₄-P removal from 10 mg/L to 0 mg/L. The flow rate of influent was assumed to be 100 m³/d.

The amount of coagulated hb-SS generation is 17.0 t/y containing SS, Fe(OH)₃, FePO₄ and water. As a result of the calculation, the sludge disposal cost was 0.51 million yen/y. The required cost of flocculant was 0.59 million yen/y. As a result, the total hb-SS disposal cost was 1.1 million yen. On the other hand, in the conventional method, excess sludge generation and the sludge disposal cost were 61.6 t/y and 1.8 million yen/y, respectively.

Therefore, it was found that even if both the excess sludge treatment and phosphate removal were performed in MAS process, the cost was lower than the excess sludge treatment cost of the conventional AS process. In addition, 365 kg/y phosphorus was removed with hb-SS. Since phosphate is a finite resource, this process can contribute to the realization of a sustainable development society.

4. Conclusion

The combination of MAS process and the settling tank solved hb-SS removal, which was one of the problems of MAS process. Compared with the conventional AS process, the excess sludge was significantly reduced. By adding flocculant, phosphate and SS could be removed simultaneously at low cost.
Magnetic levitation experiment of plastic using magnetic Archimedes effect in high gradient magnetic field

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This research is about the magnetic levitation of plastic using the magnetic Archimedes effect. Through this research, we will seek to construct a new separation method for plastics with lower environmental load and lower cost. Currently, plastic separation experiments are being conducted, and finally plastic separation and recovery tests are to be conducted.

All three types of plastic balls (described later) were immersed in an acrylic pipe filled with a paramagnetic medium, and various experimental conditions were considered based on the levitation height when a magnetic field was applied. Split-Magnet was used as a magnet, and the paramagnetic medium was used MnCl₂ (wt20%). The floated plastics were three types of PC, PTFE and POM, and the shapes were sphere in diameter of 2 [mm] to 2.4 [mm]. Under these conditions, the optimum combination of the installation position of the acrylic pipe, the pole of the Split-Magnet, and the presence or absence of the ferromagnetic arrangement were examined.

As a result, we succeeded in optimizing the combination of various experimental conditions to conduct three types of plastic separation experiments.

**Fig.1** Experimental set up. **Fig.2** Materials were levitated and separated.

**Reference**
Screening of Bisphenol A Degrading Bacteria from Acclimatized Magnetic Activated Sludge

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1. Introduction
The importance of biological removal of soil polluted with biologically persistent chemicals is increased. In contaminated site, the pollutant degrading bacteria consider to play a significant role in effective biological removal and the isolation of these bacteria from the polluted environment was required to perform bioaugmentation which is the addition of pollutant degrading bacteria cultures to speed up the rate of pollutant degradation¹. On the other hand, magnetic activated sludge (MAS) can be operated efficiently by solid-liquid separation using magnetic separation in the culture of activated sludge. The aim of this study is to isolate bacteria, which degrade bisphenol A (BPA) as model pollutant, from activated sludge acclimatized with artificial wastewater containing BPA as a sole carbon source by using MAS.

2. Methods
A standard activated sludge sampled from aeration tank operated in municipal wastewater treatment plant (Utsunomiya city, Tochigi pref.) was used as seed culture, and then equal mass of magnetite was added in 5L volumes of MAS cultivation vessel. Initial MLVSS of sludge was 3,880 mg/L. Artificial wastewater contained with 120 mg/L BPA as carbon source was added continuously which is given HRT as 24 h. TOC, CODcr, MLVSS and pH were measured during MAS cultivation at regular intervals. BPA degradation was estimated from the TOC value and UV absorbance.

Total DNA was extracted from 500 mg of wet MAS and used as template DNA for polymerase chain reaction (PCR) amplification of 16S rRNA gene. Diversity of microbial flora in acclimatized MAS was investigated by using both detergent gradient gel electrophoresis (DGGE)² analysis and gene amplicon sequencing analysis.

3. Results and discussion
The effluent quality was not stable for 15 days after the start of operation and a slight sludge wash-out was observed due to the high viscosity of the culture and MLVSS decreased to 1,100 mg/L. However, after the 20 days of cultivation, the TOC in effluent showed 7.4 mg/L, and the BPA degradation rate was maintained at 90% or more for 60 days in cultivation (Fig. 1). DGGE analysis also showed that the number of detected DNA bands significantly decreased by the 15 days after the start of cultivation, and the
intensity of a small number of detected DNA bands increased after the 46 days of cultivation. These results indicate that BPA-utilizing bacteria proliferated and predominated instead of bacteria that could not degrade BPA.

In order to isolate BPA-degrading bacteria, dispersed and diluted acclimatized MAS was spread onto agar plate consist of BPA containing artificial wastewater. After one-week incubation at 30 °C, six different types of bacterial colonies were observed. Both molecular phylogenetic analysis of isolated bacteria and 16S rRNA gene amplicon sequencing analysis of acclimatized MAS revealed that the Sphingomonadaceae are the major family of bacteria group in BPA-acclimatized MAS.

4. Conclusions

We successfully acclimatized activated sludge with BPA by using MAS method. DGGE analysis showed the dynamic change of microbial flora even after BPA acclimatization has achieved, and we confirmed the presence of many kinds of BPA-degrading bacteria in the sludge.

One of the significant features of MAS is that it separates effluent using a powerful magnetic force than gravity sedimentation. Under such circumstances, it is considered to be a more severe condition for microorganisms due to nutrient depletion and anaerobic reasons. We believe that MAS has the marked potential to enhance selection of microorganisms which should be survive. We are currently investigating possibilities of MAS as a unit for selecting pollutant degrading bacteria from activated sludge constituent bacteria.

5. References

Application of superconducting HGMS-chemical coupling technology in river water treatment

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Abstract

Circulating cooling system consumed a lot of water, which usually obtained from river. However, it contained large amount of calcium, magnesium and suspended solids, resulted in high hardness and turbidity of the water. Moreover, the water also contained large amount of bacteria and algae. It would form scale on the surface of the heat exchanger and pipe, which could reduce the heat transfer efficiency, and affect the life of heat exchanger. Superconducting High Gradient Magnetic Separation (HGMS) technology was a new separation technology developed on the basis of traditional ferromagnetic technology. It had the advantages of low investment, energy saving, low operating cost, simple operation, and automatic control, so it had been widely used in the field of water treatment in recent years.

Fig.1 XRD analysis of scale in circulating cooling system

Superconducting HGMS-chemical coupling process was used in high hardness river water treatment. The results showed us that hardness removal rate was up to 71.3% and a large floc formed after treatment. The turbidity change rate of river water was much larger than non-superconducting HGMS after treatment, and the turbidity was reduced below 0.4 NTU.

Fig.2 Effect of superconducting HGMS treatment on scale
a:non-superconducting HGMS treatment
b:superconducting HGMS treatment

Fig.3 Effect of different methods on turbidity
Development of a new water purification method using magnetically separable functional microbial floc, magnetic activated sludge

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1. Introduction

The earth is called a water planet, but, water of 97.5% is seawater. Fresh water of remained 2.5% exists mostly as ice. River and lake water, which is easy to use, is only 0.01% of all water on the earth. The United Nations warned that about 700 million people in the world were currently suffering from water shortages, and about 1.8 million children die annually due to untreated drinking water. In the water shortage areas, it becomes difficult to obtain agricultural and drinking water enough. The United Nations adopted SDGs for sustainable development in 2015. The SDGs is a universal international 17 targets for all countries, and the water issue are related to the 6 targets; that are G6) clean-water and sanitation, G2) zero hunger, G3) good health-lives, G12) responsible production, G14) life below water, and G15) life on the land.

The activated sludge method of biological water purification process is utilized widely as a basic process for conservation of water resource at every developed country. In this process, organic pollutants in wastewater is decomposed by aerobic microorganisms (activated sludge), and separated from purified water at settling tank. However, it is known to be difficult to maintain activated sludge plant at desired performance against delicate and unstable sludge settleability. Typical trouble in activated sludge operation is sludge bulking, which causes insufficient separation and leakage of sludge. Since there are many factors causing bulking, it is difficult to completely prevent it against loading and influent composition changes.

In addition, activated sludge ordinarily grow by 10%-20% everyday because about half amount of organic pollutants which have been decomposed is assimilated to the activated sludge as nutrient. Therefore, the growth amount of activated sludge called excess sludge must be treated properly as industrial waste, which processes are condensation, dewatering, incineration and final disposal. There is Japanese statistical report that the sludge waste (as 97% moisture content) is generated from domestic sewage treatment by about 75 million tons per year. Additionally, it is estimated that the comparable amount of sludge waste is generated, from industrial wastewater treatment. A large amount of cost and energy are consumed for sludge treatment due to the high moisture content of excess sludge. For improvement of these demerits of activated sludge process, we proposed introduction of magnetic separation.

Magnetic separation is the process of separating components of mixtures by using magnets to attract magnetic materials. This technology is capable of high-speed and large-scale treatment compared with existing technology, but its use in the water treatment field was limited. However, in recent years, magnetic powders are available at low cost, and the process of adding magnetic powders to various non-magnetic contaminants has become economically
competitive with conventional methods. And most of the substances capable of undergoing agglutination separation can achieve magnetic separation.

2. Magnetic activated sludge process

Activated sludge is no ferromagnetic and is not attracted by the magnet, but when mixed with ferromagnetic magnetite, the floc becomes attracted to the magnet because activated sludge adsorbs magnetite quickly. The magnetic activated sludge process combines the advantages of activated sludge process and magnetic separation, and at the same time improves the disadvantages of the activated sludge method.

In the magnetic activated sludge method, magnetite is ordinarily added to the activated sludge at a ratio of 1:1. The schematic diagram of the magnetic activated sludge process is shown in Fig. 1. Wastewater comes into aeration tank and is biodegraded to CO₂ and H₂O by magnetic activated sludge. In conventional activated sludge process, it is said that a half of degraded organic compounds generally assimilates to microorganisms. However, in magnetic activated sludge process, activated sludge concentration in aeration tank is maintained at maximum concentration limited by organic compounds supply in influent. Maximum concentration is so high that magnetic separation is necessary to separate the sludge. The sludge concentration is likely reached to more than 10g/L MLVSS. The sludge suspension in aeration tank is sent to the magnetic separator. In the magnetic separator, the magnetic sludge is attached to the rotating magnetic drum, lifted from water, scraped off from the magnet drum and returned to aeration tank all. On the other hand, the separated water comes out from the separator as purified water. The settling tank is not necessary for magnetic activated sludge process. (Fig. 2).

Additionally, magnetic separation has a merit of selectivity. Magnetic separator collects flocculating bacteria and passes inorganic SS or hard-biodegradable SS. This property enable to operate the magnetic activated sludge process without excess sludge waste.

As a new method, the magnetic activated sludge method has the advantages of suppressing the generation of a large amount of sludge by water treatment, alleviating the shortage of final disposal sites, and reducing the amount of carbon dioxide and energy consumption. Furthermore, since it is a simple and inexpensive water purification process, this process eliminates solid-liquid separation problems and can be operated in developing countries.

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1. Introduction
The digested sludge used in methane fermentation can be magnetically separated by adding magnetite just like the MAS (magnetic activated sludge process; activated sludge process using magnetic separation), and can be maintained at high concentration in the reaction tank (1). This process is called magnetic methane fermentation (MMF). The MMF was able to be operated at the volumetric loading rate 6 kg · m^{-3} · d^{-1}, which means to save 80% or more biodegradation tank volume. Additionally, the process recovers organic carbon in wastewater as methane gas. Moreover, microbe growth rate is about 1/10 as compared to MAS process, therefore, excess sludge production is able to control remarkably.

The MMF cannot purify of wastewater to less than effluent standard, but it was considered that the energy and space saving process might be able to be achieved by a combined system of MMF and MAS process. The purpose of this paper is to propose a new MMF and MAS combined process, and to demonstrate the purification capability of synthetic wastewater by bench scale experimental apparatus.

2. Methods
A bench scale experimental apparatus was shown in Fig. 1. Synthetic wastewater of 2 g-COD/L as influent was poured into the MMF reactor by a tubing pump continuously. In the combination of MMF + MAS + CO (Contact oxidation reactor), the microbes in the MMF reactor was collected and returned to the MMF reactor by magnetic separator and only separated liquid was sent to next MAS stage. In the MAS stage too, the microbes in the MAS reactor was separated and returned to the MAS reactor magnetically, and only separated liquid was sent to the CO stage. In the CO stage, the remained organic compounds

![Fig. 1 Apparatus for Bench Scale Experiment](image)

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<th>Table 1 Comparisons of MMF, MMF+MAS, MMF+MAS+CO and Other Conventional Process on COD Loading and COD Removal</th>
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<td>COD Loading [kg/(m³·d)]</td>
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<td>MMF</td>
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<td>MMF+MAS</td>
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in the influent was finally decomposed by biofilm on the support media of cubic sponges. Aeration was carried out in the MAS and CO reactor.

3. Results and discussion
The concentration of digested sludge can be increased to 27 g/L (about 2.7 times of conventional methane fermentation) and the volumetric loading rate was 6 kg • m$^{-3}$ • d$^{-1}$. This performance was same as that in previous paper(1). At this condition, sludge withdrawal as excess sludge was 0.6 kg in total for 450 day of the experimental period. If the activated sludge process is applied under same loading condition, excess sludge production is calculated about 8 kg for 450 days by using ordinary BOD-sludge conversion rate, 0.5(2). From this estimation, it was considered that the MMF can control the excess sludge production to 1/13. The MMF effluent quality was 240 mg-COD/L, black suspension, and hydrogen sulfide odor.

Therefore, MAS and CO process was combined for improvement of water purification. The comparison of the MMF, MMF+MAS, MMF+MAS+CO, and conventional methods were shown in Table 1. The organic substance removal rate was 91% by the MMF alone process. That removal rate was improved to 92% by the MMF + MAS combined process. In addition, the removal rate was able to be increased to 97% by the MMF + MAS + CO combined process. The total volume loading rate of MMF+MAS+CO combined process was about 3 times higher than that of the conventional AS process. It means that the MMF + MAS + CO combined process potentially can reduce the desired space to 1/3. The results suggested CO process was effective for improvement of MMF effluent purification performance. The final effluent quality were about 70 mg-COD/L, transparent water (SS: 16 mg/L), and no hydrogen sulfide odor.

4. Conclusion
The MMF, MAS process and CO combined process achieved COD removal rate of 97% at a volume load of 2.6 kg • m$^{-3}$ • d$^{-1}$. The final treated water was purified until less than Japanese effluent standards.

References
Application of magnetic activated sludge process for treatment of a milking parlor wastewater containing antibiotics of livestock

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1. Introduction
In the preliminary study of magnetic activated sludge, we found that by adding magnetic powder, the activated sludge can be magnetically separated. Moreover, the MAS process can achieve the balance of microbial growth and cell decay, and effectively reduce the residual sludge. Additionally, the SRT (Sludge Retention Time) of the MAS process is close to infinity. And also, the sludge concentration of the MAS process is much higher than that of the ordinary sludge process. In this extremely low-load treatment system, the decomposition of organic matter is accelerated. A good treatment effect is achieved in a short time.

The tetracycline involved in this experiment is a common antibiotic used in animal husbandry, but this nutrient can be secreted into the milk, discharged into the circulatory system of the natural water body through the discharge of waste milk from the livestock industry, and finally enters the human body. It has microbial toxicity and multiple carbon-carbon double bonds and a ring structure, so it is difficult to be degraded by ordinary activated sludge.

In order to explore more possibilities, we have tried to treat synthetic milking parlor wastewater containing tetracycline (TC) by magnetic sludge process, to analyze the effect of magnetic sludge process on the treatment of TC and milk parlor wastewater.

2. Experimental.
Experiments were carried out on the biodegradation of milk parlor wastewater using a continuous MAS-CO process. Fig. 1 shows an overview of the equipment for continuous processing experiments. Diluted solution of commercially available milk (4500 mg/L COD) was used as the synthetic wastewater which simulated milking parlor wastewater.

The seed sludge obtained from municipal sewage treatment plant of activated sludge process made to acclimate to the synthetic milking parlor wastewater. To use magnetic separation, magnetite (Fe₃O₄) was added to the same concentration as MLVSS. The reaction tank of the MAS unit is 5 L, the CO unit is 2.5 L, and the flow rate is 1.0 L/d. In addition, after 53rd day, 10 mg/l of TC was added to the influent to decompose antibiotics.

3. Results and Discussion
At the entire stage of the MAS-CO process, the sludge concentration steadily increased, and reached to plateau of 22 g/L (Fig. 2). It was unnecessary to remove excess sludge for MLVSS concentration control. In this process, the excess sludge disposal was considered to be controlled completely.

The changes of effluent COD concentrations of MAS and CO process are shown in Fig. 3. From approximately 40 day after beginning of operation, the total COD removal of the MAS-CO process reached to more than 99.5% (22 mg/L COD). After beginning TC addition, the COD concentration increased quickly and fluctuated temporarily. However, the COD concentration recovered to stable state after about 50 day from beginning TC addition. The COD removal maintained more than 99% (less than 45mg-COD/L) until the end of the experiment. The COD removal of MAS process alone was more than 97%.

To confirm the TC removal of the MAS process, we used spectrophotometry to compare the absorbance of effluent in different treatment periods (Fig. 4). From this result, TC did not appeared over time, which shows that the MAS process can decompose TC, not just adsorbing.

4. Conclusions
Treatment efficiency of 4,500 mg-COD/L a milk parlor wastewater by MAS process can reach to 97% or more. No excess sludge and no need to manage sludge concentration. This process is operated easily and stable. This process can be utilized for milking parlor wastewater treatment including antibiotics.