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Development of Newly Proposed Drying System for Sludge Treatment

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Abstract

With rapid industrialization and urbanization, wastewater treatment plants have been steadily constructed to prevent water pollution in public waters. In addition, the amount of sewage sludge generated is increasing every year. [1-2] In this study, we derived basic operating conditions by applying high temperature heating element and microwave drying to the conventional hot air drying method, and calculated moisture content according to time based on the foregoing data, and then calculated the correlation of time and optimal operating conditions based on the foregoing water content. To measure the temperature change in the drying chamber, the temperature inside the dryer was fixed 240°C, 290°C and 340°C by operating hot air inside and microwave at the same time. It was judged that as the fixed temperature of the hot air circulated in the dryer and the power of the microwave were used simultaneously; the drying efficiency was higher compared to when only the microwave power was operated. Therefore, as the drying temperature increased, the average moisture content decreased and the drying time of sludge and the time of critical moisture content became shorter. In this study, to evaluate the optimal treatment technology for the industrial sludge, we focused on the method of recycling the dried materials using conveyor type drying technology with hot air/microwave from the perspective of environment and economy and the method of reducing moisture content remarkably by applying hot air in the sludge generation state.

Keywords: Hot Air Dryer, Microwave, High-Temperature, Heating Element, Conveyor, Drying

I. INTRODUCTION

It is important to select a high efficiency dryer in the sludge drying process. Considerations for selecting dryers are the properties and generation of sludge, environmental aspects (dust, odor, etc.), technical reliability, operational aspects, maintenance and economy. The dryer is classified according to the type of heat source and can be classified into heat source, heat medium (steam, oil, etc.) or a combination of heat source and heat medium [3-4]

It was found that the drying time of the industrial sludge was prolonged, because rapid evaporation of moisture occurred when the hot air was applied to the surface of sludge and the microwave power was operated simultaneously. However, for the dried materials contaminated by harmful organisms in the industrial sludge, further studies on evaporation and diffusion to remove by applying the surface area energy of the dried material using high temperature hot air are required. [5-6] Furthermore, as a result of evaluating the cost-effectiveness of the optimum temperature of the moisture content using hot air-microwave, it was found that in the conventional method, heating medium oil and power were used to calculate cost. But for the hot air-microwave conveyor drying system used in this study, hot air injection and the microwave propulsion power was powered electrically and there was no additional cost compared to the existing fusion process, so it can be more cost-effective. [7]

II. EXPERIMENTAL MATERIAL AND APPRATUS

II.I Experimental Materials

Sample A and B used in this study were collected continuously from the industrial waste sludge generated at the industrial complex S and the industrial complex G in A city during the experiment period, and to check the transit time and optimum moisture content of each process, the first dehydration pretreatment was performed. The average moisture content of Sample A was 49.8% and the average moisture content of Sample B was 78.5%. Properties of the feed subjected to the experiment were analyzed according to the waste process test standard and the results are shown in Table 1. [8] In order to prevent the deterioration of the samples, the experiment was performed immediately after collecting samples and extra samples were stored at constant temperature or discarded.

The dried materials were put into the conveyor type dryer equipped with high temperature heating element using hot air / microwave and then heated. And then the moisture content change according to time was measured until there was no moisture content change (i.e. time of attaining critical moisture content), and the temperature inside the sample was measured with thermometers (e.g. ALMEMO 2390 -5 model, Ahlborn Co., Germany).

Table 1. Analysis of Characteristics

Parameter	sample A	sample B
Moisture contents(%)	49.8%	78.5%
Microwave power(kw)	0 ~ 3kw	
Conveyor belt speed(rpm)	5 ~ 60rpm	
Hot-Air Supply temperature(℃)	80 ~ 320℃	

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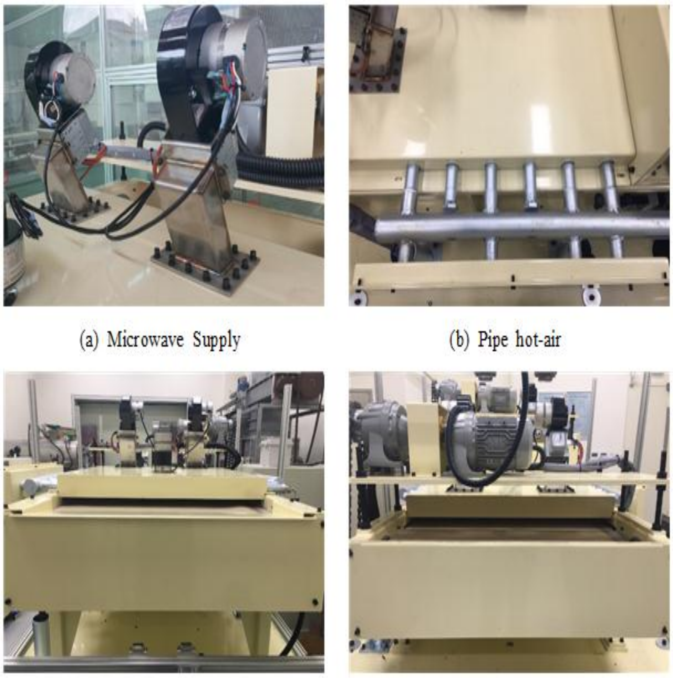
II.II Experimental Materials

In this experiment intended to improve the drying efficiency of the dried material, a continuous two-stage conveyor dryer system equipped with the microwave-hot air and the high-temperature heating element were used. The process system was designed to generate the speed 60 rpm max. at 5. The designed capacity was 1,000 kg / day and the system had the form of a two-stage conveyor belt dryer with a size of 1,400 (W) × 2,700 (L) × 1,900 (H).

The conveyor type dryer equipped with high temperature heating element using hot air/microwave had a straight inlet and outlet, 4 microwaves, 8 hot air, 2 heating elements, temperature sensor and control device and was designed to dry the dried materials fed into the main unit. Fig. 1 shows the detailed structure of the belt-type conveyor drying system, where 8 heaters and 3 kW microwave power were used for the supply of heat source, and 70 ~ 90 kW of power was generated. The new material was installed to dry and discharge the sample at a temperature of 80°C to 320°C and the intake and exhaust pipes were installed at the bottom of the dryer to integrate the exhaust of each zone and discharge it. In addition, at the bottom of the supply unit, temperature control, power control, and speed control device were installed and the basic design specifications of this experimental apparatus are shown in Table 2.



(a) Microwave Supply (b) Pipe hot-air

(c) Dryer inlet (d) Dried product outlet

Fig. 1. Reaction Sintering Method

Table 2. Material Development(Sample A)

No.	Actions	Operating conditions
1	Device Type	Multistage two-speed belt conveyor
2	Application Scope	Sewage sludge, etc.
3	Application Scope	1,000 kg/day
4	Control Power	AC380V x 60HZ x 72Kw
5	Device Speed	10 ~ 60 RPM
6	Heating element	1,100 ~ 1,420℃

III. RESULTS AND DISCUSSION

III.I Optimum speed according to sample throughput

The results of optimum RPM according to the sample throughput are shown in Fig 2. Sample A showed the sample output of 5.9 kg/hr at 10 rpm, 16.5 kg/hr at 20 rpm, 26 kg/hr at 30rpm, 37.7 kg/hr at 40 rpm, 48.7 and 49.5 kg/hr at 50 and 60 rpm, respectively. Sample B showed the output of 4.2 kg/hr at 10 rpm, at 13.8 kg/hr at 20 rpm, 24.9 kg / hr at 30 rpm, 35.8 kg/hr at 40 rpm, 46.9 kg/hr and 49.7 kg/hr at 50 and 60 rpm, respectively. The optimum values when 40 rpm was maintained with treatment capacity was designed to be 1 ton/day was derived.

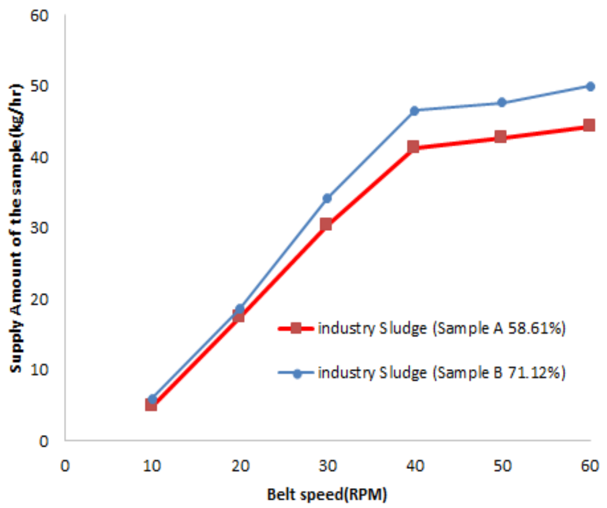


Fig. 2. Results of Optimal RPM According to Sample Throughput

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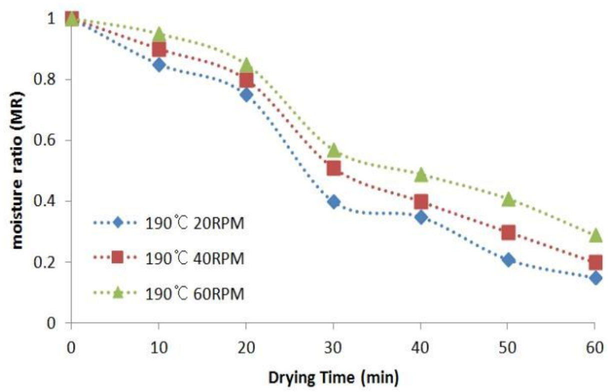
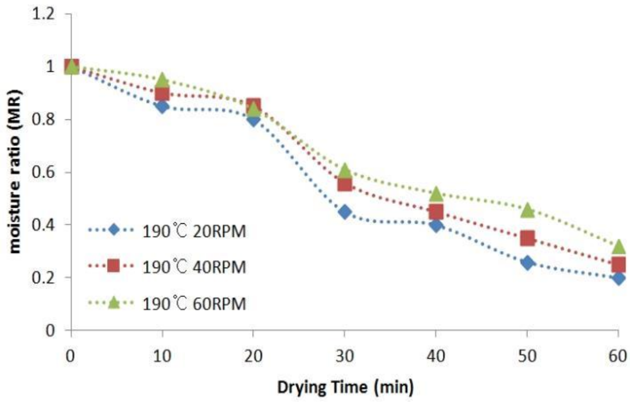
III.II Evaporation rate of moisture inside the conveyor drying system equipped with hot air-high temperature heating element

The conveyor transportation of the sample with high moisture content affects critical moisture content, etc, according to the moisture and properties of the sample. The changes of moisture content after sample input according to the hot air supply amount in the dryer are shown in Fig. 3. For the drying of the sludge, as Me = (equilibrium moisture content, % db) was close to 0 in the overall drying temperature, it was calculated as Me = 0 of the moisture ratio (MR).



(a) sample A



(b) sample B

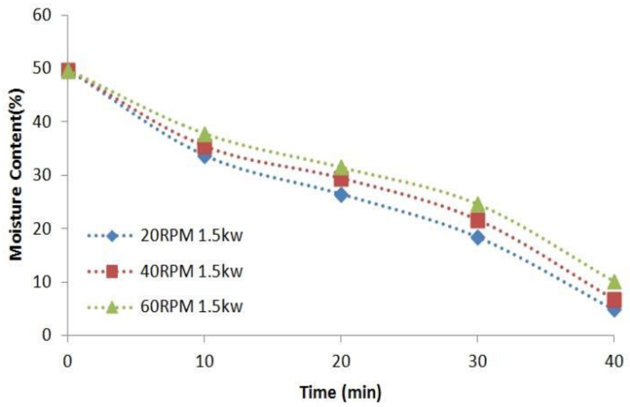
Fig. 3. Change in Moisture Content After Sample Introduction According to Hot Air Supply Amount Inside the Dryer

Therefore, the sludge dried curve is expressed by the relationship between MR = M / Mo (M = moisture content, % db, Mo = initial moisture content, % db) and drying time t (hr). In the Sample A and B shown in Fig. 3, the moisture content decreased proportionally from 10 min after the sample input at a drying time of 40 min at 190° C and the moisture content decreased slightly for 20 minutes of drying time. The prolonged drying time of the industrial sludge was considered to be caused by rapid evaporation of moisture after 20 minutes during hot air supply to the surface of the industrial sludge, which varies depending on the drying condition of the sample.

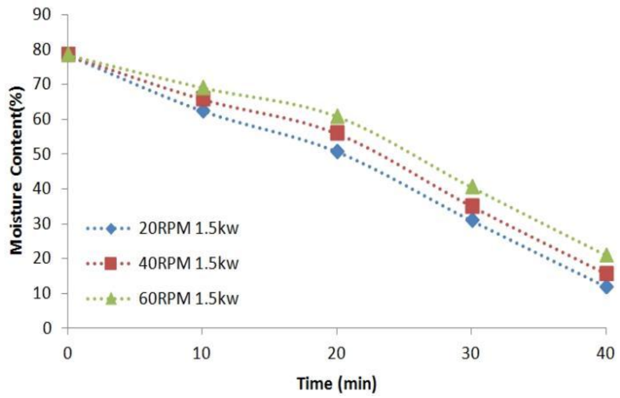
This indicates that the conditions of the decrease of the critical points of moisture are needed to ensure efficient drying and it is thought that it happened because the heat energy was supplied continuously due to the supply of hot air to keep the temperature inside the dryer steadily in addition to the sample input during the operation of the dryer. It was also found that the water content inside the dryer was kept uniformly.

III.III Evaporation rate of moisture in the conveyor drying system equipped with microwave

To dry the sludge from reach industrial complex, one of the four microwave power devices was operated to generate 1.5 kW of power. The results of moisture calculated at 20, 40 and 6 rpm are shown in Fig.4.



(a) sample A



(b) sample B

Fig. 4. Evaporation Rate of Moisture in Microwave Mounted Conveyor Drying System

It took 40 minutes to generate 1.5kW of power using microwave. Sample A with the initial moisture content of 49.8% showed a moisture content of 33.78% at 10min, 26.57% at 20min, 18.54% at 30min, and 4.98% at 40 min when 1.5 kW of power was operated at 20 RPM. Sample B with the initial moisture of 78.5% showed the moisture content of 62.48% at 20min, 50.78% at 30min, 30.98% at

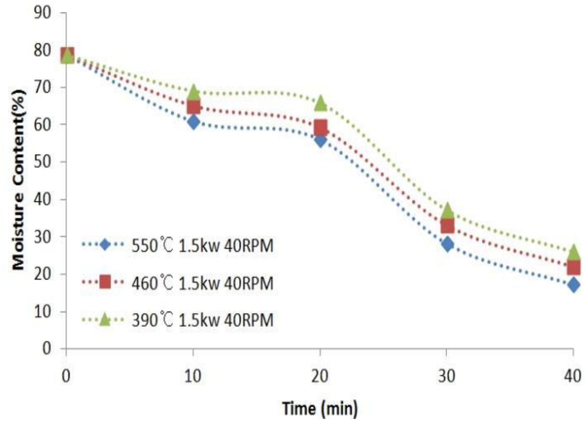
30min, and 11.98% at 40min at 10min when 1.5kW of power was operated at 20 RPM. Sample A showed the moisture content of 35.47% at 10min, 29.48% at 20min, 21.69% at 30min, and 6.78% at 40min when the power of 1.5kw was operated at 40RPM. Sample B showed moisture content of 55.98% at 10min, 55.98% at 20min, 35.11% at 30min, and 15.69% at 40min when the power of 1.5kw was operated at 40 rpm. Sample A showed moisture content of 37.84% at 10 min, 31.54% at 20min, 24.69% at 30 min and 10.25% at 40 min when the power of 1.5kw was operated at the speed of 60RPM. Sample B showed moisture content of 69.11% at 10 minutes, 60.88% at 20 minutes, 40.51% at 30 minutes, and 20.94% at 40 min when the power of 1.5kw was operated at 60 rpm. As a result of drying that sample at the speed of 20, 40, and 60 rpm, it was found that the maximum moisture content was reached at 25 min and optimum value was obtained thereafter and drying efficiency could be calculated.

In the removal of moisture by microwave, moisture is abruptly removed at the initial stage of heating. This is because the pressure suddenly increases at the initial stage of heating. As the solid particles are dried, the internal particle pressure rise rate is determined by the difference between the water vapor generation rate and the flow rate to the surface, and this result is caused by the interaction of various operating conditions including particle size. Therefore the optimum condition of industrial sludge is 20 rpm, which is considered the best when considering the necessary energy during the operation of microwave power.

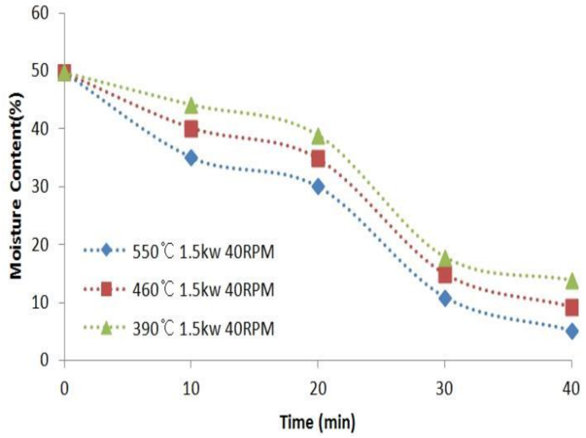
III.IV Evaporation rate of moisture in the conveyor drying system equipped with microwave-high temperature heating elements

The changes of the moisture evaporation rate in the conveyor drying system with hot air/microwave are shown in Fig. 5. When the experiment was performed at 40rpm using 390°C hot air and the microwave power of 1.5 kw at the same time, Sample A with the initial moisture content of 49.8% showed a moisture content of 44.23% at 10min, 38.98% at 20 min, 17.88% at 30min, and 13.87% at 40 min. Sample B with the initial moisture content of 78.5% showed the moisture content of 68.91% at 10min, 65.78% at 20min, 37.18% at 30min, and 25.97% at 40min. When 460 ℃ hot air and the microwave power of 1.5kw were operated at the same time, Sample A showed a moisture content of 40.22% at 10min, 34.95% at 20min, 14.98% at 30min and 9.23% at 40min, and Sample B showed a moisture content of 64.97% at 10min, 59.16% at 20min, 14.98% at 30min, and 9.23% at 40min.

When 550°C hot air and the microwave power of 1.5kw were operated at the same time, Sample A showed a moisture content of 35.18% at 10min, 30.18% at 20min, 10.97% at 30min, and 5.19% at 40min and Sample B showed a moisture content of 60.84% at 10min, 55.97% at 20min, 28.19% at 30min, and 17.18% at 40min. Looking at the results at 390°C, 460°C and 550°C, the sample was rapidly dried after 25 minutes depending on the temperature.



(a) sample A



(b) Sample B

Fig. 5. Microwave - Evaporation Rate of Moisture of Conveyor Dryer with High-Temperature Heating Element

It is thought that this happened because the temperature of the circulating fixed hot air and the power of the microwave were used simultaneously, resulting in higher drying efficiency compared to when only microwave power was used. Therefore, it was found that as the drying temperature increased, the average moisture content decreased and the total drying time and the time of critical moisture content became shorter. In general, as the drying temperature increased, the drying time decreased. The drying curve of all the samples tended to increase as the hot air supply increased after the microwave of 1.5kw was operated. It was found that the prolonged drying time of industrial sludge was due to the rapid moisture evaporation because the sludge surface was heated by hot air and microwave power were operated at the same time. According to this study, it is considered that the moisture content decreased by the heat supply inside the drying system, and the deposition of the sludge by the fly ash mixing caused the decreased moisture content.

IV. CONCLUSION

In this study, to evaluate the optimum treatment technology for the industrial sludge, we conducted experiments using conveyor type drying technology with hot wind / microwave and high temperature heating element, from the perspective of environment and economy. The conclusions are as follows.

1. It was found that heat energy was supplied continuously due to the supply of hot air to maintain the temperature inside the dryer constantly in addition to the sample input during the operation of the dryer. It was also found that the moisture content in the dryer was maintained uniformly.

2. As a result of drying using microwave power at 20, 40 and 60rpm, the critical moisture content was reached and the optimum value was obtained after 25 min thereafter. The accurate drying efficiency per hour was calculated according to the experimental apparatus.

3. As the temperature of circulating hot air in the dryer and microwave power were used simultaneously, the drying efficiency was higher compared when only microwave power was operated. And as the drying temperature increased, the average moisture content decreased and the overall drying time and the time of critical moisture content became shorter.

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