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Study on Microwave Drying Characteristic for PET Materials

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***Abstract*-In this paper, we studied characteristics of material PET (Polyethylene terephthalate) by the microwave vacuum drying technology, which was performed in a resonant cavity. The test was conducted in -92 kPa to study the relation between power, drying time and moisture content for low moisture content substance during the process of microwave vacuum deep drying. Using moisture tester, moisture content of sample was determined during drying. In vacuum, microwave drying time is restricted to 1 hour. Results shows drying PET with microwave is easy to cause thermal runaway. After a lot of experiments, the lowest moisture content of PET reached 0.01% by microwave when the energy consumption only 1 kWh and drying time is only 30 min for 2 kg PET sample. There is a balance between power and efficiency in this experiment, which provided data for industrial application of microwave energy in drying PET.**

I. Introduction

As fiber raw materials and engineering thermoplastic, PET has good stability for electronic appliances, medical, food packaging and other industries, which is widely used in industry[1-2]. However, the product quality is related to moisture content of PET, when traditional dry technology consumed amount of energy and time[3]. In order to adapt PET production capacity increasing, the research of microwave vacuum deep drying applied in PET drying process is necessary.

Compared to microwave vacuum drying technology, the traditional heat conduction technology relied on the thermal conductivity of materials to be dried, which caused low efficiency[4]. Because of the poor thermal conductivity and high thermal property of PET, direct heating characteristic of microwave is suitable for those materials. Simultaneously, the drying efficiency is related to microwave energy distribution, which reflected in hot spots and cold spots in the temperature distribution[5]. Consequently, effectively solving the problem of uneven microwave heating can improve the progress of microwave vacuum deep drying for PET materials[6].

In this paper, we proposed a new microwave frequency adjusting drying technology for PET materials to solving deep drying and uneven heating problem which will probably make PET melt. The test system consists of vacuum pump, microwave source and resonant cavity, which performed the process test of 2kg PET particles through microwave vacuum deep drying technology. Evenly, frequency adjusting way change microwave energy distribution with time, which made PET absorb energy evenly. The result shows that the frequency variation period influenced the efficiency of drying, which provides experimental data for PET via microwave vacuum drying and the solution to the hot issues in the drying process.

II. Experiment

A. Equipment

The experimental system is shown in figure 1, which consists of 3 parts. In order to increase Q-factor of the resonant cavity, power capacity and negative high pressure bearing capacity, the 63.8mm×47mm×48.2mm rectangular cavity was designed. Meanwhile, BJ-26 waveguides were set on the tow sides vertically, which reduced the coupling between ports. Besides, the bleeding point was placed in the back of cavity to create the negative high pressure environment inside the cavity which makes max at -98kPa by the vacuum pump. For obtaining temperature, the observing window was arranged in the middle of upper face of cavity. What's more, ports on the two sides that were fed by solid state source achieved the microwave energy inputting and the transformation of parameters.

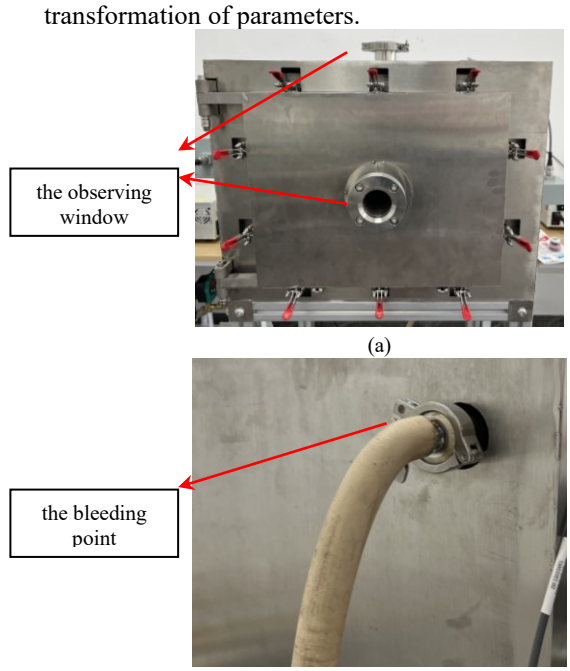

Figure 1. Microwave vacuum deep drying resonant cavity (a)the observe side of cavity(b)the back side of cavity.

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B. *Variable power test*

Based on microwave vacuum deep drying technology, we measured moisture content variation trend of PET particles with 100W, 150W, 200W and 250W. For variation of power, experiments over time were performed. The corresponding change trend for different power is shown in the figure 2. With drying time increasing, moisture content decreased under variable microwave power. Meanwhile, by controlling the source, power improving for the same mass PET caused the drying efficiency raised.

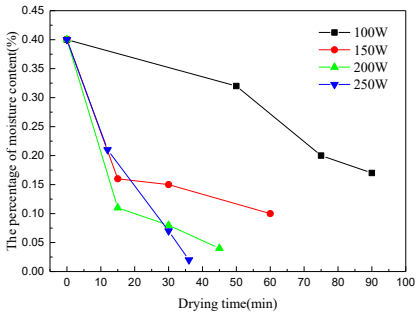

Figure 2. Trend of moisture content with time under 100W, 150W, 200W and 250W.

Temperature is an important parameter to monitor the process of drying, which can avoid the possibility of melt. Furthermore, through temperature distribution, the microwave energy distribution can be measured by infrared thermometer. Because PET has low moisture content, at the meantime, the ability of absorbing microwave is lower than water, the thermal runaway may occur during drying. For observing the microwave energy distribution, the temperatures were measured as shown in figure 3 and figure 4 respectively.

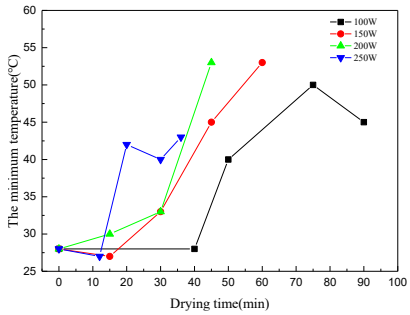

Figure 3. The minimum temperature with time under 100W, 150W, 200W and 250W.

The figure 3 shows the minimum temperature in whole area, which is positively correlated with time mostly. Analogously, the regulation between time and the maximum temperature is shown in figure 4. The figure 4 illustrates that drying efficiency can be improved by increasing the input power. However, under 250W, the minimum temperature existed abnormal point. According to analysis, it is possible for drying time that microwave energy is absorbed by PET poorly. But for 100W, the energy is absorbed more sufficiently, which caused temperature increased suddenly. From the figure 5, the maximum temperature is 156℃ in the middle area.

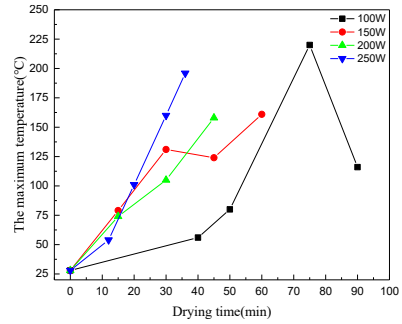

Figure 4. The maximum temperature with time under 100W, 150W, 200W and 250W.

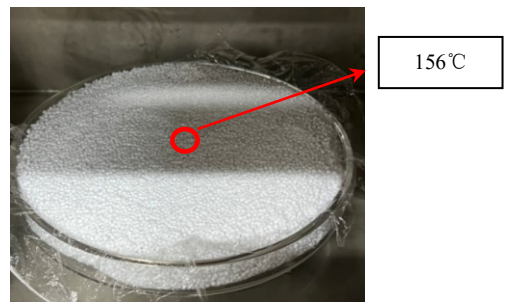

Figure 5. The max temperature under 150W and 70min.

C. *The melting test*

The highest temperature points that were measured under variable power and frequency varying group are presented in table Ⅰ. From table Ⅰ, the power and time will influenced the temperature. When power is increasing, for avoiding melt, time should be shortened. Therefore, this way can achieve balance between efficiency and stabilization. For the sake of avoiding thermal runaway, the temperature was controlled behind 160℃. Furthermore, the test is repeatable, where temperature difference is less than 10℃.

TABLE I
THE TEMPERATURE FOR FREQUENCY GROUP

Power(W)	Temperature(℃)	Time(min)
100	116	90
100	220	75
150	126	60
150	112	60
200	101	30
200	105	30
250	160	30
250	101	20

According to test in vacuum, 160℃ is threshold value of temperature. As figure 6 shown, when the temperature is 168℃, caking was appeared. With temperature increasing, the melting area mostly focuses in the hot point, where the moisture content is 0.12% at this moment. It is available for

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PET drying to use microwave technology in industry production, when the maximum temperature is controlling by adapting microwave parameters.

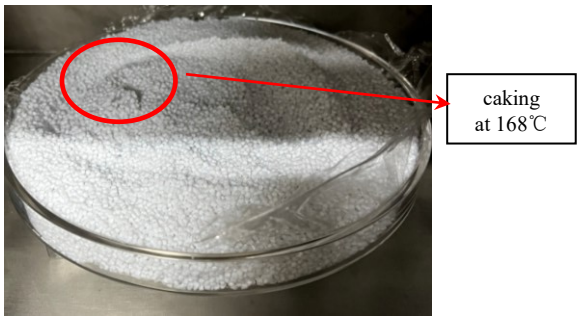

Figure 6. The picture of PET caking.

D. *The reflection test*

In order to improve efficiency and stability, reflections at different frequency was restricted to -10dB. As shown in table Ⅱ, power is 250W to 200W, when PET materials were dried by microwave. The reflection result illustrated that 90% microwave energy was feed into cavity. Compared to fixed power, at the same time, the melting situation was disappeared.

However, at some point in the heating process, the distribution of microwave energy will change, simultaneously, the permittivity of PET will alter. Ultimately, cavity impedance is equivalent to a load, which caused mismatch. In addition, before thermal runaway, PET has low ability of absorbing microwave energy. It means that if the material is less the energy will be consumed by cavity. Consequently, based on microwave vacuum drying technology, reflection monitor can raise efficiency further for high power production.

TABLE II
THE POWER GROUP OF SMALL SINTERING

Power(W)	Ref.(W)
250	2.1-4.3
250	14.3-14.9
250	35.1-32
250	8.7-5
250	1.8-1.1
250	13.6-23.3
200	2.7-0.7
200	9.4-12.7
200	8.4-10.9
200	17.9-19.1
200	17.5-15.5
200	5.3-6.1
200	1.2-2.9
200	22.6-30.1
200	8.6-6.3

III. CONCLUSION

The experiment that drying PET materials by microwave vacuum drying technology provides a new way to dry PET material in industry production. According to those test, the process of drying can be obtained. For guarantying the process of stability and speediness, the melting threshold value was defined at 160℃. Meanwhile, drying time which belongs to low moisture content materials is restricted to 1 hour. Results show that it is feasible to use this technology to solve the problem of drying PET inefficiently in future and there is a negative correlation between power and time. Above all, the test data provide guidance for drying PET, which can promote the industry application process of microwave energy.

ACKNOWLEDGMENT

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