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Microwave Characteristics During PET Material Microwave Vacuum Drying Process with Dual-channel

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***Abstract*—PET(polyethylene terephthalate) is widely used in daily life. With food packaging production steadily increased all over the world, traditional drying for PET materials shows weakness. This work is based on dual-channel microwave power input, which realized PET drying with the minimum at -92kPa and microwave power range is 200W to 500W. Moreover, by means of program, adapting the solid state source to the drying chamber eventually obtains the connection between microwave characteristics and material properties. When the phenomenon of thermal runaway was prevented, the inhibition of reflection power made drying better and the highest temperature corresponds to the best point of moisture content.**

***Index Terms*—PET, food packaging, dual-channel, solid state source, drying chamber, thermal runaway, reflection power, moisture content.**

I. Introduction

PET is abbreviation of polyethylene terephthalate, which is a semi-crystalline polyester with many advantages, for instance, good balance of thermal, mechanical properties and low cost, etc [1]. In modern society, PET is widely used in medical devices, food package and industrial application, such as water (ca. 26%), carbonated soft drinks (CSD, ca. 26%), or other drinks/juices (ca. 18%), in the shape of sheets/films (ca. 14%), in the food industry (ca. 9%), as well as in non-food uses (e.g., cosmetics, ca. 6%) [2]. What's more, with the development of production industry and demand for package, it is an objective phenomenon that 90% of single-use plastic bottles have to be collected separately by 2029, which is related to 16.7 million tonnes of plastic packaging waste [3].

During the process of production, PET materials drying is one of the most important steps before PET flake extrusion, that means, drying efficiency is directly proportional to yield and it is necessary to avoid hydrolytic degradation of polymer molecules [4]. Meanwhile, due to the hygroscopic characteristic of PET and the formation of intermolecular bonds between water molecules and the polymer chain, the removal of humidity from the polymer needs to be appropriate for the adjustment of the PET drying process [5].

Compared to traditional drying for PET, microwave vacuum drying technology can increase efficiency and realize real-time control with artificial intelligence technology. This paper illustrated that the relationship between microwave parameters and material properties, which provides data support for network training when PET microwave vacuum drying technology is applied in industrial production, through program control. Because test system is based on dual-channel source, it is basic multi-port, while the time-varying nature of the energy distribution is unclear. This manuscript shows the results from these experiments.

II. Microwave Vacuum Drying Test

Based on dielectric and physical properties of PET, the resonant cavity is designed as cube which has multi-port for energy synthesis, and the volume is 63.8mm×47mm×48.2mm. As Fig.1 shows, port 1 and port 2 are perpendicular to each other, which achieves the effect of reducing reflection. Both ports adopted the structure of BJ-26 waveguide fed by coaxial.

Fig. 1. Port 1 and port 2 fed by solid state source.

Used program control, the microwave parameters can be adjusted in real time, that is to say, the microwave energy absorption capacity of PET varied over time. In order to increase power and reduce drying time, the reflection power is monitored. The mass is fixed at 2kg, and the vacuum degree of vacuum pumps is set at -90kPa, that is benefit for avoiding thermal runaway.

A. Reflection Power

As a result of low absorption capacity of PET, reflection power reflected that microwave inputting situation, which determined the efficiency of energy use and judged the port match. In drying process, material and cavity is equivalent to load, furthermore, it is affected by frequency. As Fig. 2 shows, when each input power is 100W, reflection power variation range is 4.7W to 80W, and the trend is roughly consistent at both ports. It means that matching situation of port can be control in drying to adjust microwave parameters.

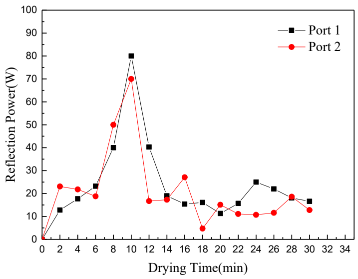


Fig. 2. The relationship between drying time and reflection power when port 1 and port 2 are fed at 100W each port.

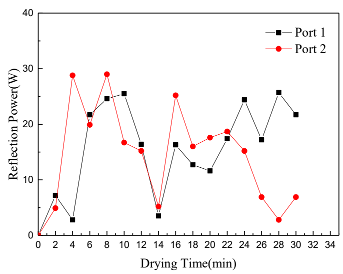


Fig. 3. The relationship between drying time and reflection power when port 1 and port 2 are fed at 150W each port.

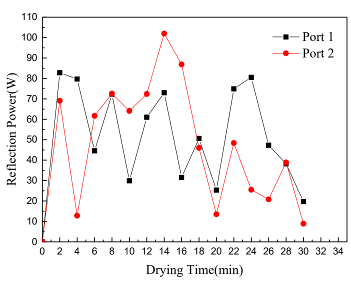
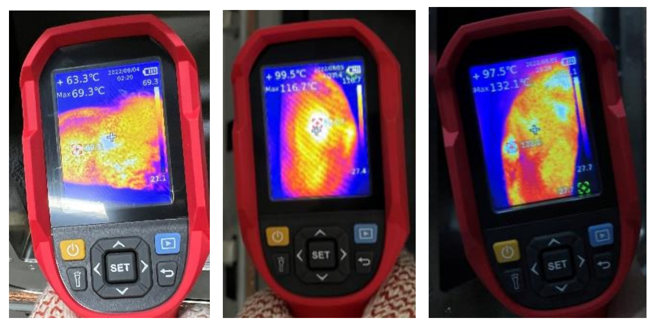


Fig. 4. The relationship between drying time and reflection power when port 1 and port 2 are fed at 200W each port.

With power increased, we monitored reflection power at 150W, 200W each port in 30min. The correlation between reflection and drying time is illustrated as Fig. 3, Fig. 4. It is obvious to see that reflection power varied nonlinearly during drying. In addition, when each input power increased from 100W to 150W, reflection increased from 4.7W to 102W, which means that the way to improve power for promoting will increase energy consumption by power synthesis.

B. Temperature Distribution

Further, in order to verify the microwave energy distribution, we measured temperature distribution after drying at different input power by infrared imager (UNI-T UTi260B). From Fig. 5, the maximum temperature is separately 69.3℃, 116.7℃ and 132.1℃ at 100W, 150W and 200W each port. Considered the compatibility issues of industrialized continuous production and quality, the inner temperature should be limited less than 140℃ for the purpose of thermal runaway preventing. It is worth mentioning that the distribution of absorbing is uneven and the maximum is on the inside.



(a) (b) (c)

Fig. 5. The temperature distribution when port 1 and port 2 are fed at (a)100W, (b)150W, (c)200W.

C. Vacuum Degree

Through vacuum pump, vacuum degree in cavity is controlled from -90kPa to -92kPa. On the one hand, continuous pumping can remove the water vapor produced by consumed microwave energy, on the other hand, this way can accelerate drying process.

However, inner vacuum degree is not fixed as pump one. By using vacuum gauges in top test port, as shown in Fig. 6, we obtained the curve in Fig. 7, which indicated that the internal air pressure increases initially, and then, decreases over time at 200W each port.

Fig. 6. The vacuum gauges for monitoring internal vacuum degree.

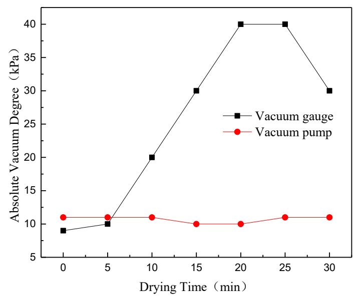


Fig. 7. The relationship between vacuum degree and time at 200W.

D. Moisture Content

As the most important reference indicator, moisture content of PET after drying shows the balance between time and quality with microwave vacuum drying technology. We measured moisture content by moisture determination meter (OHAUS MB27ZH). Fig. 8 shows that moisture content is negatively correlated with drying time when each input power is 100W and 150W respectively. Yet within half an hour, there is not necessarily related between increased power and shorten time.

Consequently, we studied the regulation of temperature and moisture content. As shown in Fig. 9, the maximum temperature is corresponding to the lowest moisture.

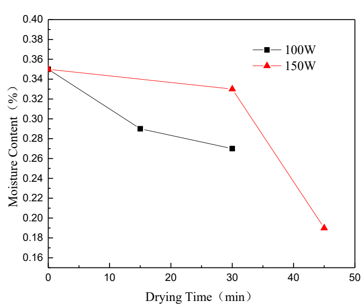


Fig. 8. The curve about moisture content at 100W, 150W each port.

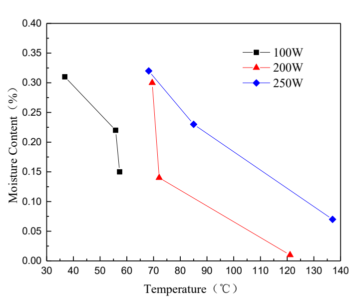


Fig. 9. The regulation between moisture content and temperature at 100W, 200W and 250W each port.

III. Conclusion

In this experiment, all PET material samples are homogeneous cylinders, which facilitates uniform absorption of microwave. According to research, moisture content intensely depends on reflection power and temperature using dual- channel system. That is to say, in industrial application of PET microwave vacuum drying process, reflection power will hinder efficiency. Besides, maintaining the right temperature with dynamic approach can realize steady and speedy drying. Therefore, these experiment data provide support for industrial application of microwave power-synthesizing, which is suitable for PET drying with increasing capacity.

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No acknowledgment is allowed for the initial paper.

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