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Experimental Study on the Recovery of Lignin from Black Liquor by Blade Dynamic Cross-Flow Filtration Device

Hao Wang
College of Electromechanical Engineering
Qingdao University of Science and Technology
Qingdao, China

Xinyuanrui Wang
College of Electromechanical Engineering
Qingdao University of Science and Technology
Qingdao, China

Junfei Wu
College of Electromechanical Engineering
Qingdao University of Science and Technology
Qingdao, China

Abstract: The separation and recovery of lignin in black liquor is a hot topic in current research. Ceramic membrane technology has become the main method of lignin separation in black liquor due to its advantages of green environmental protection, high efficiency and high recovery rate. However, in the separation process, the problem of ceramic membrane fouling has always existed and has become the key to hinder its continuous separation. Aiming at the problem that the existing filtration methods can not meet the continuous separation of lignin in black liquor, this paper proposes to apply the blade dynamic cross-flow filtration device to the separation process of lignin in black liquor, and the influence of blade rotation speed on the separation performance is studied experimentally. The results showed that increasing the rotating speed of the blade could effectively reduce the accumulation of filter cake on the membrane surface and achieve the purpose of improving the filtration flux.

Keywords: black liquid ; lignin ; dynamic cross flow ; blade speed

INTRODUCTION

Traditional dead-end filtration and cross-flow filtration systems are difficult to meet the needs of continuous separation of lignin in black liquor by ceramic membrane technology due to their filtration methods and structural characteristics, so it is urgent to seek a better measure to improve membrane surface hydrodynamics conditions and shear force strengthening mechanism[1, 2]. Vane-type dynamic cross-flow filtration device is a new type of filtration device. By installing blades in the filtration chamber to better realize the improvement measures of hydrodynamic conditions on the membrane surface and the strengthening mechanism of shear force, it can effectively eliminate membrane fouling and significantly increase filtration flux, so as to achieve continuous production[3-5]. However, the blade-type dynamic cross-flow filtration device started late, and is currently only used in the ocean (extraction of green algae and separation of suspended fine particles in seawater) and food (purification of protein in milk). In the paper industry, it is still blank[6, 7]. In order to solve the problem of continuous production of lignin in black liquor by membrane separation, a blade dynamic cross-flow filtration device was applied to the extraction process of lignin in black liquor.

In this paper, the recovery of lignin from black liquor by blade dynamic cross-flow filtration device was studied experimentally. The influence of blade speed on filtration flux and filter cake weight was studied, and the filtration mechanism was understood in detail, so as to find out the best operating conditions, and provide theoretical and technical support for the improvement and perfection of the subsequent blade dynamic cross-flow filtration device and the continuous separation of lignin in black liquor.

MATHEMATICAL MODEL

The filtration flux in the experiment was calculated by Formula (1)[8] :

$$q = \frac{V}{St} \tag{1}$$

Where: q is instantaneous filtration flux, $m^3/(m^2 \cdot s)$; V is the volume of liquid through, m^3; S is membrane area, m^2; t is filtering time, s.

EXPERIMENT SETTINGS

Experimental Materials and Filtration Membranes

The materials used in the experiment were black liquor provided by a paper mill, which was diluted at a ratio of 1 : 20 in the experiment. The filter membrane used in the experiment is a plate ceramic membrane with a pore size of 50 nm and a thickness of 4 mm.

Experimental Equipment and Process

The blade dynamic cross-flow filtration experimental device used in the experiment is shown in Fig.1. The whole filtration process is driven by nitrogen pressure. The filtrate is collected by a conical flask and measured by an electronic balance, which is recorded in a computer for the calculation of filtration flux. In addition, the speed of the blade can be controlled by changing the speed of the magnet stirrer.

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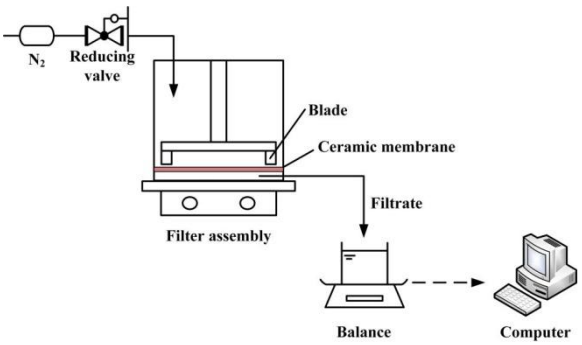


Figure 1. Vane type dynamic cross-flow filtration experimental device

RESULTS AND DISCUSSION

In dynamic cross-flow filtration, blade rotation is the most important part of providing membrane surface shear force and preventing filter cake growth. Therefore, it is particularly important to study the effect of blade speed on filtration flux. In this study, the effects of two different speeds of 0rpm and 600rpm on filtration flux and cake weight were investigated. Fig.2 shows the effect of two different speeds of 0rpm and 600rpm on the filtration flux at a transmembrane pressure of 0.1MPa. It can be seen from the diagram that the filtration flux at 600 rpm decays rapidly at the initial stage of filtration, and the filtration flux has reached a steady state at 2000 s. The filtration flux at 0rpm decays slowly, and the filtration flux reaches a stable state at about 8000s. In addition, the steady-state filtration flux at 600 rpm is higher than that at 0 rpm. This is due to the operation at high speeds, the membrane surface shear force makes the lignin particles not easy to deposit on the membrane surface, resulting in limited growth of the filter cake, so it can quickly reach a stable state. At 0 rpm, the leaves are in a static state and cannot provide shear force for the membrane surface, so the lignin particles continue to accumulate in the membrane area, resulting in a slow attenuation of the filtration flux.

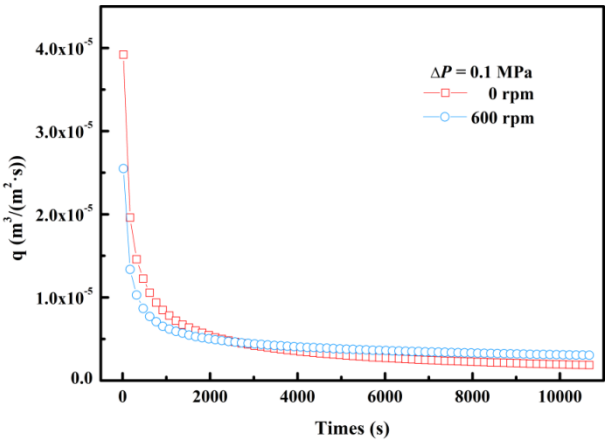
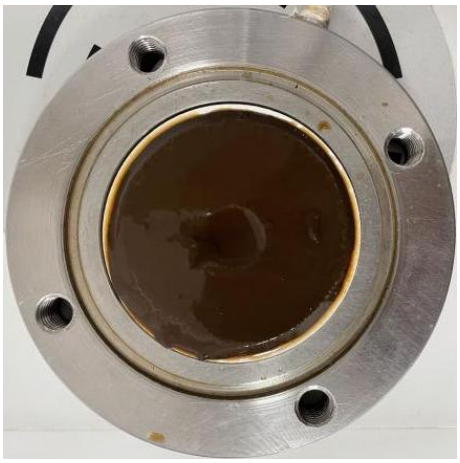


Figure 2. Influence of different rotational speeds of 0rpm and 600rpm on filtration flux when the transmembrane pressure difference is 0.1MPa.

Fig. 3 shows the morphology of the filter cake formed by lignin particles on the membrane surface at two different speeds of 0rpm and 600rpm. It can be seen from the figure that when the operation is at 600 rpm, the lignin particles are taken away from the membrane surface under the shear force of the membrane surface, so the formed filter cake layer is very thin. On the contrary, a thick filter cake layer was formed on the membrane surface operated at 0rpm. In order to further illustrate the effect of blade speed on the filter cake layer, we measured the weight of the filter cake at two different speeds of 0rpm and 600rpm. The weight of the filter cake operated at 0rpm was 3.610g, and the weight of the filter cake operated at 600rpm was only 0.045g. In other words, the operation at high speed is beneficial to eliminate the filter cake and improve the filtration flux.

600rpm



0rpm

Figure 3. Morphologies of filter cakes formed by lignin particles on the membrane surface at two different rotational speeds of 0rpm and 600rpm

CONCLUSION

In this paper, the dynamic cross-flow filtration device is applied to the extraction process of lignin in black liquor, and the influence of blade speed on filtration flux and filter cake weight is studied experimentally. The experimental results show that the filtration flux at 600 rpm is higher than that at 0 rpm, and the filter cake weight at 600 rpm is only 0.045 g, which is much smaller than 3.610 g at 0 rpm. Therefore, increasing the blade speed can effectively reduce the weight of the filter cake and improve the filtration flux.

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