The Study on Paper Porosity Using the Image Processing Method

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Abstract: Porosity is one of important structure parameter for paper. In this study a novel image processing method is developed. Related porosity formula of paper is also deduced by introducing area porosity which derived from three adjacent sides of paper according to the structural feature of paper and the corresponding program developed with Matlab is given. Experiments were conducted by choosing three kinds of food packaging papers as samples and the influencing factors on new method were also analyzed. The results demonstrated that this new method is simple, convenient and accurate and it can determinate porosity from microcosmic aspects.
Keywords: Porosity; Food Packaging Paper; Digital Image Processing

1 Introduction

As an important structural parameter, paper porosity is extensively used in much research, especially in pollutant migration analysis, ink absorption analysis, paper properties evaluation and so on. Paper porosity is defined as a ratio of the total volume of pore of paper to the total volume of paper. Currently the main methods measuring the porosity are the gravimetry method, the Mercury porosimetry method, the nitrogen adsorption method, the liquid permeating method and the digital image processing method.

R.W. Johnson [1] and M. J. Moura et al [2] used the mercury intrusion technique to evaluate the porosity and related information of paper sheets. However, the mercury pressure of the analysis process may cause deformation of paper and collapsed and then affect the accuracy of the analysis result, and moreover, this method need special apparatus and the mercury do great harm to the bodies. Birgit Aurela[3]analyzed paper porosity with the liquid permeating method and chose silicon oil as medium, but this method need remove solvent from surface of paper after immersion and it is difficult to control as a consequence the significant errors would be introduced. Rafik Allem[4] utilize SEM to process images of paper and analyze porosity using the digital image processing method. This method is greatly improved the accuracy and can analyze porosity from microcosmic aspects. However this method can only obtain the area porosity and can not analyze the volume porosity.

The aim of the present work is to develop a novel image processing method. The volume porosity is calculated by introducing area porosity which derived from three adjacent sides of paper. Experiments are conducted by choosing three kinds of food packaging papers as samples and then the influencing factors on new method are taken into consideration.

2. Theory

The images of three adjacent sides of paper were obtained by scanning electron microscopy (SEM), then the area porosity of those images were calculated by Matlab program which was edited in this study. The values of the area porosity were substituted in the porosity formula to calculate the volume porosity.

The porosity formula is deduced as follows:

The paper sample can be approximately regarded as cuboid. It assumed that the height, width. length are L_{length},L_{width},L_{height}, respectively. So the volume formula is:

$$V_{paper}=L_{length}\times L_{width}\times L_{height} \quad (1)$$

And it also assumed that the area of three adjacent sides are A_1、A_2、A_3 respectively. The square of volume formula is:

$$V_{paper}^{\ 2}= L_{length}\times L_{width}\times L_{height}\times L_{length}\times L_{width}h\times L_{height}$$
$$= L_{length}\times L_{length}\times L_{width}\times L_{width}\times L_{height}\times L_{height}$$
$$=A_1\times A_2\times A_3 \quad (2)$$

Therefore the equation(1)can transformed to:

$$V_{paper}=\sqrt{A_1A_2A_3} \quad (3)$$

According to equation(3) If we regard the area of pore in one side of paper as the area of a side of a cuboid, the volume porosity can calculate as follow:

$$V_{pore}=\sqrt{A'_1A'_2A'_3} \quad (4)$$

Where A_1 is the area of pore in the paper face; A_2 is the area of pore in the side next to the paper face; A_3 is the area of pore in another side next to the paper face.

According to equation (3)and equation(4) The ratio of V_{pore} and V_{paper} is the volume porosity.

As a result, if we know the area porosity of three adjacent sides, the volume porosity can calculate according to

$$\varphi = V_{pore}/V_{paper} = \sqrt{A_1'A_2'A_3'}/\sqrt{A_1A_2A_3} = \sqrt{\varphi_1\varphi_2\varphi_3} \quad (5)$$

Where φ_1 is the area porosity of the paper face calculated by Matlab; φ_2 is the area porosity of the side next to the paper face calculated by Matlab; φ_3 is the area

porosity of the another side next to the paper face.

3. Experiments

3.1. Materials and instruments

Kraft paper were obtained from Guangxi Guofa Forestry & papermaking Co., Ltd., China; Imitation parchment paper were obtained from Hangzhou Fuerdun Industry Co. Ltd.;White cardboard were obtained from Nanning Meishi paper industry Co. Ltd.

The Scanning analysis was performed with Hich S3400N Scanning electron micrograph. The image processing analysis was performed with software Matlab and Photoshop.

3.2. Methods

3.2.1. Sample preparation

Experiments are divided into three groups. Choosing Kraft paper, imitation parchment paper and white cardboard as samples, and every group have five duplicate samples. The sizes of 1mm^2 paper samples are cut by razor, and then metal praying on the surface, wait for SEM analysis.

3.2.2. Images analysis

Images were obtained by SEM under different magnifications.

The measurement error of image information would be bigger with a larger magnification, on the contrary, the information of images can not be collected with a smaller magnification. Thus the best magnification is 100 times for paper surface observation after experiments, and the best magnification for side observation is 500 times.

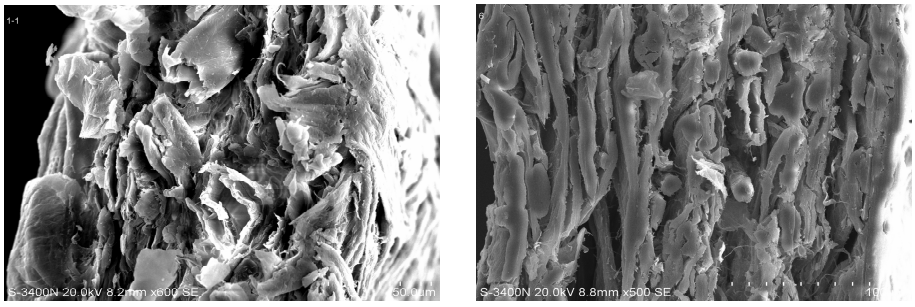
The images are processed by Matlab program. First the image noise is eliminated by median filter, then binarization are performed, separating the pore from the fiber through selecting a suitable threshold, The value above the threshold are expressed by one value, and zero value replace the value which are below the threshold. Thirdly, every regional of the object in the image is labeled and calculated its' pixel number. So the area porosity of paper is the ratio of the pixel number of pore to the pixel number of total area, the range of images can be chosen by software Photoshop.

The mean value of area porosity is calculated through choosing five duplicate samples.

4. Results and discussion

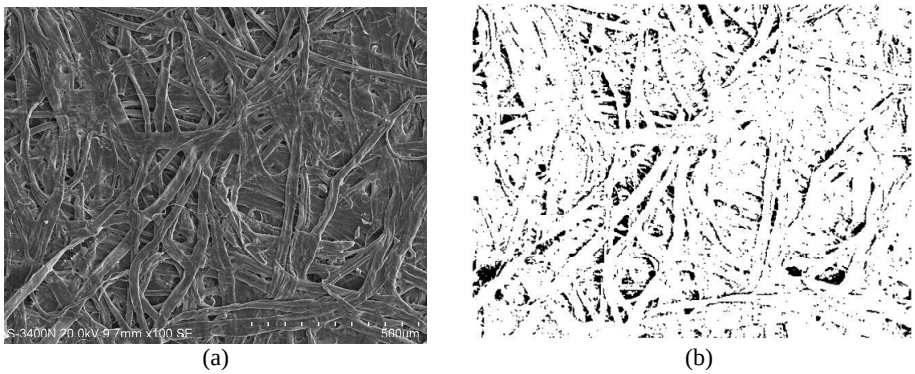
4.1. The impacts of samples preparation on experiment results

The samples should be cut sharply in order to gain the images of pore distribution. Fig. 1(a) the cross section of paper are cut by regular knife; Fig. 1(b) the cross section of paper are cut by sharp razor. Through comparison we found that the origin structure of the paper can be retained by sharp razor.



(a) (b)

Figure 1. Cross section of paper clipped by different knives.



(a) (b)

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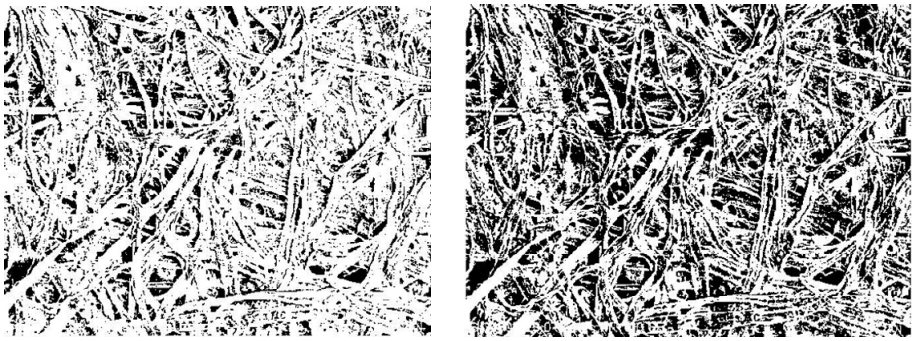
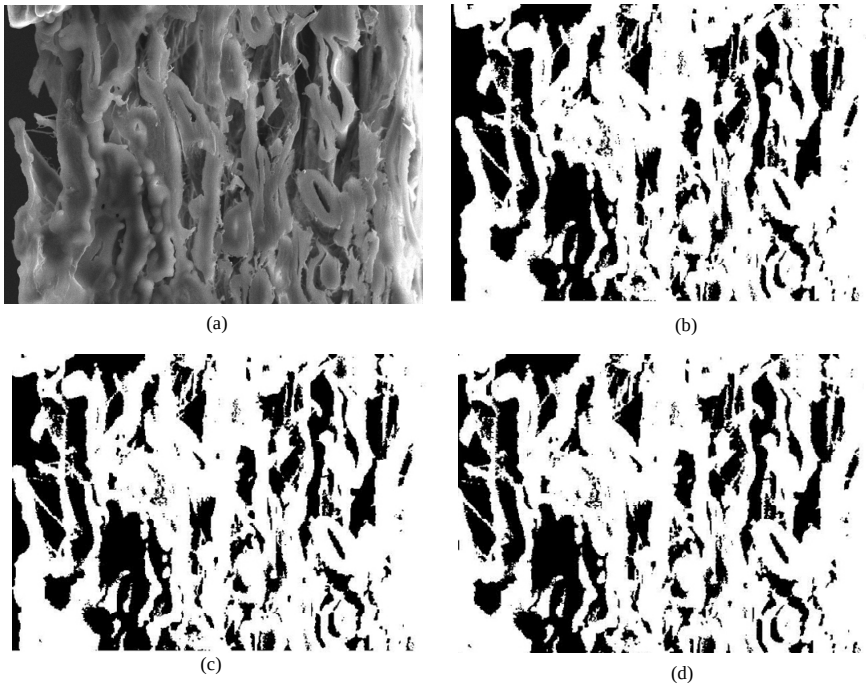


(c) (d)

Figure 2 Comparison original paper image with binary images (a)the image of original kraft paper；(b)the binary image choosing 57 as threshold，the area porosity of this binary image is 9.94%；(c)the binary image choosing 67 as threshold，the area porosity of this binary image is 20.5%；(d)the binary image choosing 77 as threshold，the area porosity of this binary image is 38.39%.



(a) (b)

(c) (d)

Figure 3 Comparison of cross section of paper under different areas conditions; (a) the original image of the cross section of paper；(b)the area porosity of paper side calculated according to the original image of the cross section of paper is 31.57%;(c)the area porosity of paper side calculated after range selection is 30.38%;(d)the area porosity of paper side calculated after range selection is 29.33%.

4.2. The impacts of different selection of threshold on experiment results

The porosity of paper is different with the different selection of threshold during binarization. The area porosity increased an average of 1.4% with the 1 gray value difference.

So when the binarization is performed the threshold should be selected for many times so as to get binary image nearest to the origin image of the paper. As is shown in the Fig 2, the original paper image is compared with the binary images. As can be seen from the diagram the binary image choosing 57 as threshold can not display the micro pore of paper and the binary image choosing 77 as threshold would wrongly express partial fiber as pore, so the most appropriate threshold is 67 and the area porosity should be 20.5%

4.3. The impacts of different selection of image range on experiment results

The open pores of paper are distributing on the surface of paper so the image range of paper must be selected

appropriately for calculating area porosity precisely. The selection range of image should be the same as the thickness of the paper when calculating the area porosity of cross section of paper. The different calculated results of area porosity with different selective range are shown in Fig. 3.

As can be seen from Fig. 3，the area porosity of paper calculated in Fig 3(b) is bigger than that of paper in Fig 3 (c) as a result of the too large range selection；(d)because of the too small range selection, the calculating might be ignore the open pores. The range selection in Fig 3 (c) is corrective and the area porosity of this cross section of paper is 30.38%.

4.4 The precision analysis

The result showed that the volume porosity of kraft paper is biggest, that of white cardboard is less, and imitation parchment paper is the least. The volume porosity of three kinds of food packaging paper is shown in Table 1.

Table 1 Porosity of paper analyzed by new image processing technology

experiment	Kraft paper	White cardboard	Spooling parchment
porosity	15.7%	10.36%	3.27%
RSD	4.6%	3.9%	3.5%

As can be seen from Table 1, the smaller porosity is, the smaller RSD is. The reason of this phenomenon might that the threshold selection in small porosity paper is easier than bigger porosity paper.

5. Conclusion

(1) when the binarization is performed the threshold should be selected for many times so as to get binary image nearest to the origin image of the paper.
(3) The selection range of image should be the same as the thickness of the paper when calculating the area porosity of cross section of paper.
(3) The results demonstration that this new method is simple, convenient and accurate and it can determinate porosity from microcosmic aspects

6. Acknowledgment

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