THE POROSITY CALCULATION OF VARIOUS TYPES OF PAPER USING IMAGE ANALYSIS

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ABSTRACT

The paper porosity study has been done by observing microscopically.The purpose is provide airborne porosity data on various paper types, so that we can rank the ability of liquid absorption on the same paper type. This porosity analysis is done by using ImageJ, with converting the image to binary, set the threshold limit, and clarify the watershed limit. The result of the porosity of filter paper A=51,50586 , B=18,30719 ,C=21,68076 ,D=29,72028 ; tissue paper A=9,174071 ,B=20,96931 ,C=32,76454 ; HVS paper A=23,31616 ,B=27,70944 . So it can be concluded that the ability of filter paper absorption A > filter paper D > filter paper C > filter paper B. Absorption ability tissue paper C > tissue paper B > tissue paper A. Absorption ability HVS B paper > HVS paper A. In general can be inferred that the higher the porosity value of the paper the greater ability to absorb liquids on paper.

ABSTRAK

Penelitian porositas kertas telah dilakukan dengan mengamati secara mikroskopik. Tujuan penelitian ini memberikan data porositas pada berbagai jenis kertas, sehingga dapat dibuat peringkat kemampuan serap cairan pada jenis kertas yang sama. Analisa porositas ini dilakukan dengan menggunakan ImageJ, mengubah gambar menjadi biner, menentukan batas threshold, dan memperjelas batas pengamatan (*watershed*). Hasil porositas untuk beberapa jenis kertas sebagai berikut: kertas saring A=51,50586 , B=18,30719 , C=21,68076 , D=29,72028 ; kertas tissue A=9,174071 , B=20,96931 , C=32,76454 ; kertas HVS A=23,31616 , B=27,70944 . Sehingga dapat disimpulkan bahwa kemampuan serap kertas saring A > kertas saring D > kertas saring C > kertas saring B. Kemampuan serap kertas tissue C > kertas tissue B > kertas tissue A. Kemampuan serap kertas HVS B > kertas HVS A. Secara umum yang bisa ditarik kesimpulan bahwa semakin tinggi nilai porositas kertas maka semakin besar kemampuan serap cairan pada kertas.

INTRODUCTION

Parameters of porosity are very important, because porosity is the primary variable to determine the magnitude of a backup of fluid contained in a mass (Bergaya,1995). Material available in the nature had a pore or a different air cavity, this can be seen with the difference between the ability of absorbing water by the material (Ebaretonbofa & Evans, 2002). Each material has a different porosity depends on the material structure. The high ability of material absorption makes the material absorbs water continuously during and after the process of absorption.

In previous research observation between porosity and permeability on a material performed (Zhaoqi, 2017) have been done, about the influence of the grain measurement against the porosity and permeability sandstone, indicates that there are linear relationship between permeability porosity and rocks (Haffen, Géraud, Rosener,& Diraison, 2017). As the results of the study, there is linear relationship between the cavity of the air and

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absorption ability (Li, Goldstei, & Franseen, 2017). Based on the importance of porosity calculation research to the ingredient's determine the material absorbent, this research is made. Because each paper has different uses and effectiveness. This should be noted. For example filter paper, filter paper has several types of variations / types that have their usefulness, eg tissue type A suitable for oil, filter paper type B suitable for plain water. It was on the ability to absorb paper against liquid fluid.

Another purpose of the research is to calculate the porosity of different kinds of paper, since the same kind of paper does necessarily has of absorption ability different variations.

The outcome of this research is an air cavity (porosity) data base on different variations on paper, such as different kinds paper tissue of, HVS paper, and filter paper which will be analyzed with image processing.

This research emphasizes the analysis of paper pore calculation using image processing. Image processing can be used to accurately analyze the quality of an

image (Ningtias, Suryono & Susilo, 2016). Image processing techniques in addition to generating accurate data also produce data precision (Susanto, 2009). Therefore the image processing system is very appropriate to calculate the small porosity of paper that have a size in millimeter .

The word of paper (paper) derived from the Egyptian language; papyrus, which is a material used by the Egyptians towrite on. Paper was found in China for the first time by Cai Lun. It is manufactured by the process of fiber compression was derived from the fiber separation and fibrous raw materials that has been dried before hand, and some additional ingredient that sticked and connected to each other being added (Ding, Hung, Lee,& Wang, 2017). The results of compressing, drying and adding other material determine the weight of, the paper thickness and quality. The Microscopic image of paper can be seen as in Figure 1.
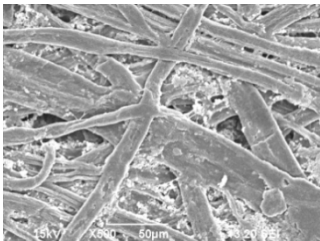

Figure 1. Filter paper pores with 500 times under the scanning of electron microscope.

(https://www.ndsu.edu/em_lab/images/sem_images/papers/)

ImageJ is a software that can be accessed in general. National Institute of Mental Health, Bethesda, Maryland, USA. The software was developed by Wayne Rasband and now in research branches of the National Institute of Mental Health, Bethesda, Maryland, USA. The software can run on various systems supported by Java 1.1 or version software. This software can be downloaded for free from the website http://rsb.info.nih.gov/ij/. Downloaded ImageJ can be paired with a computer by running the program package. In this case, there are three versions of the 8-bit version, 32-bit version and 64-bit version, in this research use 8-bit version, which in the ImageJ software contains sub-files that we can select as needed. ImageJ Software can we upgrade the latest version by opening ImageJ then clicking Help> Update or by opening link http://rsb.info.nih.gov/ij/upgrade/.

Porosity is important physical nature to declare the characteristic of the texture and the of material quality (Cui, Huang,& Liu, 2017). Porosity is an empty space between material and the small part of the empty volume space within the total volume. The value of porosity defined the amount of fluid contained in the material which is very important to making paper. By means of mathematics, porosity is a comparison between the volume pores percentage and the total material volume as present in equation:

$$\varnothing = \frac{V_p}{V_{tot}} \times 100$$

where Φ is porosity, V_p is volume pore, and V_{tot} is volume total.

METHOD

The methodology is conducted by observing the pores of paper under the light of the microscope, various paper was filter sed in this work are HVS paper , tissue and filter paper. The paper to be observed will be cut into several thin sheets before doing the observations from the microscope. The results of the analog images observed on the microscope are converted into digital images to be analyzed using ImageJ. ImageJ program will be used to measure porosity or extent image of air cavities for various types of paper used. The process of image processing can be seen in Figure 2. The

first step was done with the scale of the image of the arrangement, to adjust the scale of the image of the scale with basically implemented by clicking on straight; and draw, a line in accordance with long image pictures the scale that we want to know. Analyze; set scale, to see how pixels that reads within a range of 1 mm.

The next step is the stage of image clarification. The stage of image clarification is done with the purpose of getting a black white image (binary) (Collins, 2007). This process will get through several stages: first set the limit of the analysed image beforehand (find edge) (Haeri, 2015). Then, sharpen the image of the process of thresholds, change into 8 bits, binary. The purpose of this process was to achieve the level of firm overcast on image observation. The surface analysis is made out of the imagery result (Grove & Jerram, 2011).
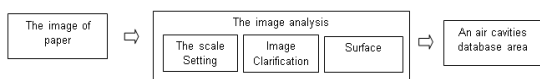

Figure 2. The calculation image of paper

RESULT AND DISCUSSION

From the image of arrangement of scales obtained the value of size pixels, 14100.0000 pixels /mm. This scale is obtained by analyzing a line image that has been known to measure along 0.14 mm. By converting the length of the line image still in mm by the number of pixels read in the digital image that has been enlarged 100 times, get the value of the scale. This scale will be used to analyze all images of 100 times the magnification of the light microscope. Process analysis of the image of the pores of the paper is done in stages which can be seen in below.

Stage of paper image clarification
The original image of the paper before being analyzed.

Figure 3, is an original image filter paper C of true paper pores and wood fibers, which have not been analyzed by image processing

The image clarification
This step is done by changing the image to binary (binary or automatic threshold) with a view at figure 4 to clarify the paper image to be measured.

Figure 4, shows an image filter paper C with an 8 bit brightness level to start analyzing. The next step is to clarify the holes measured.

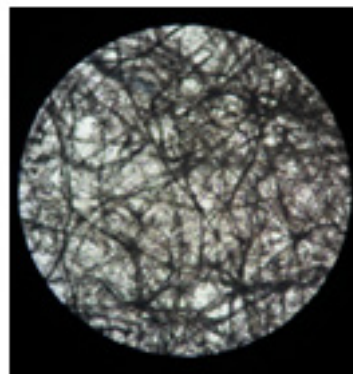Process binary fill holes what needed to be done in Figure 5.
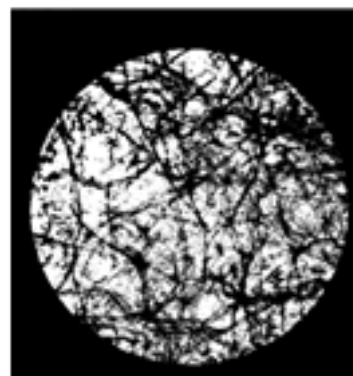

Figure 3. Original image filter paper C

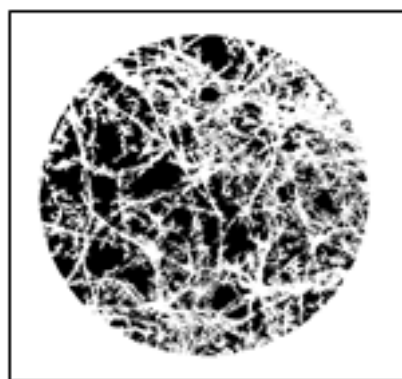**Figure 4**. Binary Image filter paper C

Figure 5. Binary image fill holes filter paper C

The next step is wathershed used to clarify the limit to be measured, so it forms segmentation. Binary image had wathershed what needed to be is. The result in Figure 6.

Analysis image
The next stage is the analysis in Figure 6. Figure 7 is the magnification of some of the image area of Figure 6 to further clarify the ob-
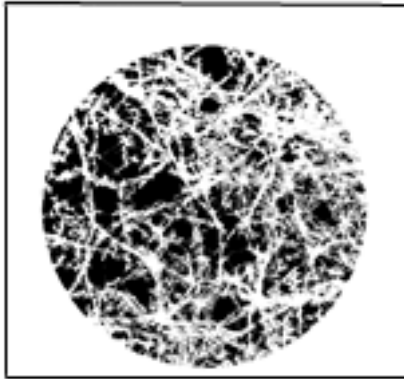
servation

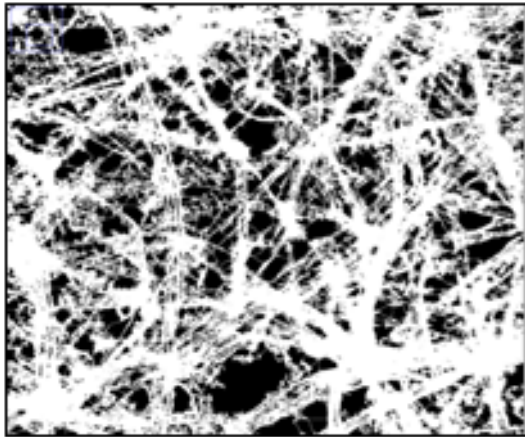**Figure 6**. Image filter paper C after wathershed step

Figure 7. Before image analysis filter paper C

Using the scaling that have created, it is 14100.0000 pixels / mm and calculates the number of pixels contained in each black image. The resulting image as in figure 8
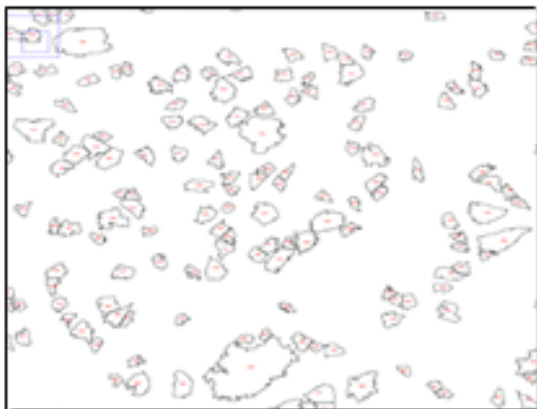

Figure 8. After image analysis filter paper C

From Figure 8 it is seen that each cavity

has been identified by numbering. To see more clearly Figure 8, will be magnification 75% and give the result like figure 9 and figure 10.
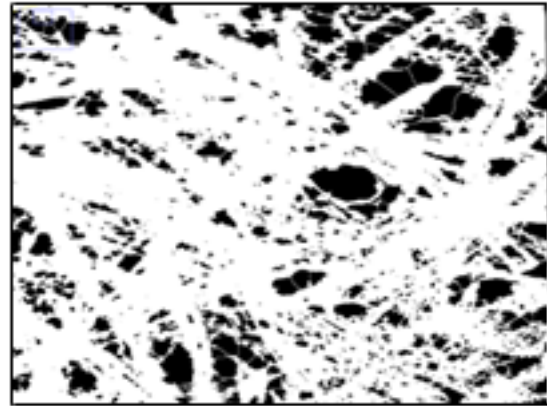

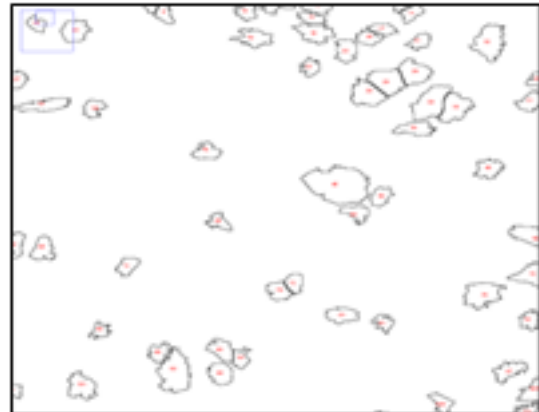
Figure 9. Before image analysis filter paper C

Figure 10. After image analysis filter paper C

The image area is read in Figure 10. Table 2 is a table of each piece of image analysis results in each piece of paper.

The area of the paper pores is the area of the air cavity on the paper. While the wide area is the whole area of the image observed both the pores of paper and wood fiber.Thick paper each piece was measured using a micrometer. By multiplying the area of the air cavity with the thickness of the paper then get the volume of each piece of paper cavity. By multiplying the area of image of both fiber and cavity with the thickness of paper, then get the total volume of paper cut. The total volume of cavities of each paper type can be calculated by summing the volume of each piece of paper. The total volume of paper both cavities and fibers is calculated by summing the cavity and paper volumes of each piece for the same type. So get the volume of paper cavity and total paper volume

as Table 3. The results of the analysis porosity image on obtained value as Table 3, of various sample.

Table 2. The Total Volume of Hole

Paper	Pore Area Vp (mm²)	Total Area V_{tot} (mm²)	Thick (mm)
Filter Paper A			
Slice 1	0.008		0.03
slice 2	0.017		0.01
slice 3	0.019		0.01
slice 4	0.019	0.133	0.02
slice 5	0.022		0.005
slice 6	0.027		0.005
slice 7	0.011		0.04
slice 8	0.01		0.03
Filter Paper B			
Slice 1	0.02		0.005
slice 2	0.019		0.005
slice 3	0,019	0.086	0.005
slice 4	0.015		0.005
slice 5	0.006		0.005
slice 6	0.007		0.05
Filter Paper C			
Slice 1	0.013		0.005
slice 2	0.025		0.005
slice 3	0.014		0.005
slice 4	0.012	0.136	0.01
slice 5	0.014		0.005
slice 6	0.027		0.005
slice 7	0.022		0.005
slice 8	0.009		0.03
Filter Paper D			
Slice 1	0.02		0.015
slice 2	0.026		0.005
slice 3	0.031		0.005
slice 4	0.024		0.005
slice 5	0.017	0.201	0.005
slice 6	0.025		0.016
slice 7	0.023		0.005
slice 8	0.027		0.005
slice 9	0.008		0.06
Tissue A			
Slice 1	0.007	0.007	0.06
Tissue B			
Slice 1	0.016	0.016	0.01
Tissue C			
Slice 1	0.025	0.025	0.015
HVS A			
Slice 1	0.005		0.045
slice 2	0.01		0.02
slice 3	0.017	0.066	0.01
slice 4	0.024		0.02
slice 5	0.01		0.02
HVS B			
Slice 1	0.008		0.03
slice 2	0.006		0.04
slice 3	0.012	0.034	0.005
slice 4	0.008		0.025

Table 3. The porosity for different types of paper

Paper Type	The Total Volume Of the Hole (mm³)	Volume Total (mm³)	Porosity (%)
Filter Paper			
Filter A	0.001965	0.003815	51.50586
Filter B	0.000745	0.004069	18.30719
Filter C	0.000965	0.004451	21.68076
Filter D	0.001920	0.006460	29,72028
Paper Tisssue			
Tissue A	0,000420	0,004578	9.174071
Tissue B	0,000160	0,000763	20.96931
Tissue C	0,000375	0,001145	32.76454
Paper HVS			
HVS A	0.001275	0.005468	23.31616
HVS B	0.000740	0.002671	27.70944

Table 3 presents the results of porosity for the same type paper that has a different porosity. If we want to use a kind of paper with a good absorbent ability, filter paper a the other, paper is tissue C better than is the best amongst paper tissue A and B, and HVS paper B is better than HVS paper A. It's just that in the conducted research, for the type of paper tissue the pores not are being seen per slice (the thin part again) but seen as anintact unity under the light of the microskop because of the nature of the tissue it self is indeed very thin and hard to split into thinner parts.

The nature of porosity material affected each other and being affected by another fisis

and the nature of termal. For example porous material which has low density, larger surface area, low heat conductivity and forth. Porosity comes because the pores are open, closed and the space between particles. In addition, there are the relationship between the material density and porosity (Li, Goldstei,& Franseen, 2017). The bigger the density, the smaller the material porosity. The bigger the density means having large density. The rapid the material, the less the pores within the material. Because of that, it is concluded that the connection between density and porosity is the reverse (Cui, Huang, & Liu, 2017).

It can be concluded that the filter papers absorption A > filter paper D > filter paper C > filter paper B. For the tissue paper absorption tissue paper C > tissue paper B > tissue paper A. Absorption HVS paper B > HVS A. General conclusions that can be giving a result on research, the higher the porosity value of the paper the greater the ability to absorb fluid on paper.

CONCLUSION

The author has done research on porosity calculation of various types of paper, the results of research is the higher the porosity value of the paper the greater the ability to absorb fluid on paper ,it means paper had large air cavities and has more fluid than other types of paper, but have the lowest density.

REFERENCE

Bergaya,F.(1995). The Meaningof Surface   Area andPorosity Measurements   of Clays and Pillared   Clays. *Journal ofPorousMaterials*,2(1),91-96.

Collins, T. J. (2007). Imagej For Microscopy. *Bio-Techniques, 43(1),pp. S25–S30*.

Cui, Z., Huang, Y., & Liu, H. (2017).Predicing the Mechanical Properties of Brittle Porous Materials with Various Porosity and Pore Sizes. *Journal of the Mechanical Behavior of   Biomedical Materials.*

Ding, C.G.,Hung, W.,Lee, M., & Wang, H. (2017). Exploring Paper Characteristics That Facilitate The Knowledge Flow From Science To Technology. *Journal of Informetrics*, 11, 244–256.

D.R. Ningtias, S. Suryono, Susilo. (2016). Digital Image Quality Measurement Computed Radiography Using Image Processing Program-Jurnal Pendidikan Fisika Indonesia 12 (2), 161-168

Ebaretonbofa, E.,&Evans, J.R.G. (2002). High Porosity Hydroxyapatite Foam Scaffolds For-Bone Substitute. *Journal of Porous Materials*, 9, 257–263.

Grove, C.,& Jerram, D.A.(2011).jPOR: An ImageJ Macro to Quantify Total Optical Porosity From Blue-Stained Thin Sections. *Computers & Geosciences,*1850–1859.

Haeri, M., &Haeri, M.(2015). ImageJ Plugin for Analysis of Porous Scaffolds used in Tissue Engineering. *Journal Of Open Research Softwar.*

Haffen, S., Géraud, Y.,Rosener, M., & Diraison, M. (2017). Thermal Conductivity And Porosity Maps For Different Materials: A Combined Case Study Of Granite And Sandstone. *Geothermics* 66, 143–150.

Li, Z., Goldstei, R.H., & Franseen,E.K. (2017). Meteoric Calcite Cementation: Diagenetic Response To Relative Fall In Sea-Level And Effect On Porosity And Permeability, Las Negras Rea, Southeastern Spain. *Sedimentary Geology*, 1–18. doi : https://doi.org/10.1016/j.sedgeo.2016.12.002

Susanto. (2009). DSM Decreasing Technique Being DEM From Alos Satellite Images For Highland Region With Smallest Parameter Parameters Flattening Calculation Count. *Jurnal Pendidikan Fisika Indonesia* vol 5. 129-133