Image Analysis of Heat-Affected Zone of Laser-Cut Heat-Resistant Paper using Otsu Thresholding Technique

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Abstract*—Since ancient times, natural fibers have been essential in paper production and packaging fabrication. However, beauty-marring carbonization, or a heat-affected zone (HAZ) generated during the laser cutting process of paper materials led to an intriguing discussion on the possibility of reducing this defect zone. Thus, paper loaded with aluminum hydroxide [$Al(OH)_3$] (AH) was prepared and tested with laser cutting. There were two input parameters of laser processing: the ratio of laser power to a maximum and the cutting speed. The study discussed the HAZ area of the paper with AH loaded at 0–40% on a dry pulp basis. The HAZ area was measured through image processing software. The Otsu thresholding technique (OTT) was applied to HAZ area determinations. The results from the image analysis signified that the smallest HAZ area was successfully achieved on samples with AH loaded at 40%. The optimal condition for the sample with 40% AH loaded was 60% power ratio and 20 mm/s in cutting speed. Based on the results, the cutting speed was the most significant parameter to produce the smallest HAZ area; therefore, the laser processing parameters were optimized to achieve a minimum HAZ area, and it was possible to reduce its dark color appearance of the material surfaces. Based on this study, it was found that the application of the Otsu thresholding technique was of significance to the HAZ area determination and reduction of the time consumption for the image analysis.

***Keywords*—Heat-affected zone; image analysis; image processing; laser cutting; thresholding**

I. Introduction

The digital image may be described as the two-dimensional function which refers to f (x, y). To make it easy to understand, pairs of x and y are plane or spatial coordinates, and the amplitude of function f at any coordinates of x, y is called gray level or scale. Thus, when x, y, and f are all finite, we call the function f a digital image. The digital image processing is performed with a computer [1] its techniques has been widely thriven and they are now used for all kinds of tasks in various areas such as image recognition technology along with computer vision and thresholding techniques [2]. Image analysis is an area related with image processing and the extraction of useful information from an image is beneficial to various fields ranging from computer vision applications to medical bioimaging analyses. Vision is the most advanced human senses; however, our vison is limited to the visual band of the electromagnetic spectrum. Thus, imaging machines such as electron microscopy, and computer-generated images used to operate on images [1]. Thus, digital image processing and analysis so popular nowadays and encompasses a varied field of applications. There is almost no technical area that is not impacted by the digital image processing. In our case, it is crucial to extract useful information from images that can help determine the HAZ and improve the laser cutting process. In the laser cutting process, image processing techniques and image analysis are helpful for HAZ determination.

The laser cutting process has recently become a fascinating element in paper-based product fabrication. This is because of the wide range of applications from cutting to engraving [3], perforating, and designing complex geometrics [3]–[8]. Moreover, due to the growing personal needs as well as product quality and high productivity, it is convenient to apply laser cutting technology. However, carbonization and heat-affected zone (HAZ) seem to lead to an intriguing discussion on whether reducing the HAZ in the laser cutting process is possible. Laser cutting is an efficient method for cutting materials as it can be operated readily. Through understanding, high-quality cutting optimal parameters can be obtained. Even though laser cutting has been applied since the 1990s for cutting, perforating, and creasing paper materials, unfortunately, only a few works in literature have been discussed using the laser process of paper products. The mechanisms of laser cutting for paper or other wood-based materials are a thermochemical decomposition [8][9]involving vaporization, meaning the paper material reacts to heat generated by laser beam irradiation and evaporates from the surface.

The study of laser cutting quality focused on two laser processing output which are HAZ and kerf of the cuts. However, in this study, only the HAZ output will be discussed. To analyze the HAZ quality, image analysis needed to determine the optimal setting of the laser process. Over the years, image processing and image analysis studies in the laser cutting has been grown [10] [11]. Even there was various image processing techniques reported in the literatures, this study focused on the Otsu thresholding. In computer vision and image processing, Otsu thresholding technique (OTT) which is named after Nobuyuki Otsu, is performed to obtain automatic image thresholding. It is a simple form of algorithm. The algorithm returns a single threshold intensity that can separate pixels into two regions: foreground and background [12]–[14].

This paper is of significance on the study of HAZ and the laser cutting field. By analyzing the HAZ images and determining its HAZ area, the determination of laser cuts can be done faster and cost effectively. The use of digital image analysis has been widely thriven in laser cutting studies [15][16]. However, the literatures only reported the HAZ measurement values by measuring the mean HAZ width without any further discussion on how to determine the HAZ area. Thus, this study aimed to explore and investigate the image processing and image analysis of HAZ using ImageJ global thresholding techniques. This study reported the image processing technique and image analysis used to improve HAZ image analysis that beneficial to the laser cutting field.

II. Literature Review

In the laser cutting, especially during the heating and vaporizing processes, the paper material absorbed heat energy, carbonized, and produced a HAZ. Thus, when laser cutting is performed, the process of material degradation will cut cellulose molecular chains to its shorter elements comprised of small chains of polysaccharides, carbon dioxide, carbon, and water vapor [17] [18].

Paper materials are used in packaging development because they are environmentally friendly materials because of no carbon emission and play roles as alternatives to petroleum-based plastics for packaging. The application of paper-based packaging has become widespread in alignment with a campaign to zero single-use plastics consumption and goals. For understanding the application of paper in packaging and its fabrication using laser cutting, the nature of paper must be understood first. A natural and renewable resource like plant fibers is eco-friendly, low cost, and has soft features and properties [19]. The composition of plant fibers is mainly cellulose, hemicellulose, and lignin. These three components determine the plant fiber properties. Plant fibers are a significant raw material that influences the thermal properties of paper. Some paper products, such as heat-resistance label paper and heat-resistance release paper, require fiber with high thermal stability [20]. In the thermal analysis conducted by Soares et al. 2001 [21][4], the pyrolysis of hemicellulose and cellulose readily happened. It has been reported that the loss of hemicellulose occurred between 220ºC and 315ºC, while that of cellulose occurred between 250ºC and 400ºC. However, lignin degrades at a wide temperature range from 160ºC to 900ºC, meaning it is more difficult to decompose. Consequently, plant fibers have poor heat-resistance, and its decomposition begins at 220ºC, limiting its application at high temperatures. The mechanism of laser cutting for paper or other wood-based materials is a thermochemical decomposition process [18]. The cutting mechanism is vaporizing, which means the paper material will react to the laser beam and evaporate when the heat of the laser beam reaches the surface. Thus, when laser cutting is performed, the process of material degradation will reduce cellulose from large cellulose molecules to its small elements, which are small chained of hydrocarbon, carbon dioxide, carbon, and water vapor [9]. Recently, natural fiber has become essential in paper-based product fabrication and laser cutting applications.

Aluminum hydroxide [$Al(OH)_3$] (AH) is known as a green inorganic flame-retardant [22] and has been applied as a heat-resistance compound used in flame retardant systems [23] for years. For instance, AH is used in the making of heat-resistance and flame-retardant papers [20]. Many methods have been proposed to modify the paper with AH. One of them was a placement of AH on the surfaces and inside walls of fibers. By implementing the method, AH was successfully distributed evenly on the inside and surfaces [24]. During exposure to high temperatures, AH starts to decompose while absorbing heat sourced from the radiant energy of the laser and eliminating water. Then the emitted water molecules absorb heat to evaporate and decrease the temperature around the HAZ. This mechanism leads to the improvement of the thermal properties of the modified fibers and paper. Based on the Yang, F. et al. study [24], the paper samples modified with AH content succeeded in resisting the heat by determining its thermal properties using the thermal gravimetric analysis (TGA). However, their study did not link with the application of laser irradiation process or discussed any thermal process [16].

Generally, the basic mechanisms of laser cutting are exceptionally easy to understand. Infrared light contained in a high-intensity beam is generated by a laser [25]. The beam focuses onto a material surface through a lens. The focused beam functions to heat the material and caused it to melt in case of plastics and vaporized [17]. Then, the molten material will be ejected from the area by pressurized gas. The schematic of laser cutting can be seen in Fig. 2. This study also discussed the effects of various combinations of laser power ratio and cutting speed on the area of HAZ. The samples with different contents of AH loaded were tested. The laser cutting process has been applied to them, including the control sample (without AH loaded) to determine whether it resists the heat and reduces the HAZ production during the laser cutting process. The laser cutting process has been applied to them, including the control sample (without AH loaded) to determine whether it resists the heat and reduces the HAZ production during the laser cutting process.

Based on the literature, in determining the optimal setting of HAZ, the cutting speed should be maximized to prevent excessive heat transfer depending on this parameter [26]. It also highlighted that laser power variations show less impact, and cutting speeds show more impact on HAZ. Furthermore, based on previous literature studies, the quality of a cut can be obtained by determining one of the outputs which is HAZ [27]. The significant reason that those two parameters were chosen has been discussed in literatures [4][5][8]. In this study, laboratory-made paper sheets loaded with AH were cut using CO_2 laser processes at different laser power ratios and various cutting speeds. These processed samples were micrographed with a focus on the HAZ to analyze it using image processing software ImageJ [28]. Even though many methods were presented in the literature using various software tools, ImageJ was chosen because it is the most popular open-source software provided with a detailed manual and tutorials [22].

In image processing, there is no general agreement among authors regarding when and where the image processing stops. Also, in other related areas such as image analysis and computer vision, and when it starts. However, it is important to highlight that in image processing there are types of computerized processes involved; segmentation, classification (recognition) of individual objects, extracted edges and contours [1]. Image segmentation refers to the algorithms class that can partition the image into different pixel groups or segments. In that case, image thresholding is the best and simplest image segmentation as it partitions the image into two pixels groups which are foreground and background [29].

Thresholding is an essential application, especially in any field of study that relies on image detection, inspection, and classification. The thresholding performance depends on the object-background difference in gray level, noise, and the size and position of the object [30]. The process of selecting the optimal thresholding algorithm is the most important step in image processing and analysis. Image processing has been applied in many fields with computers to process digital images through basic operations or advanced algorithms. Thus, we can extract various information from the original images through image processing and analysis. However, the manual threshold process was not preferable in the image analysis for its several limitations. Especially with a high possibility of high bias while performing the image processing [31]. It is also time-consuming to perform a manual threshold for analyzing many images. Therefore, the most crucial part of binarization is identifying the best threshold algorithms and comparing them with a least-biased comparison [23] [24].

There are 16 universal thresholding algorithms offered by ImageJ, which are Huang, Huang2, Intermodes, IsoData, Li, Mean, MinError(1), Moments, Otsu, Percentile, RenyiEntropy, Shanbhag, Triangle, and Yen. However, this study focused on the Otsu thresholding technique (OTT) based on its advantages in terms of simplicity, robustness, and the most widely applied thresholding algorithm [30] [32]. Apart from those reasons, we mainly chose OTT because we focused on determining the HAZ by identifying the optimal thresholding that is highly capable of detecting the area and edge of HAZ. In our case, HAZ images need optimal thresholding to avoid erroneous detection of an edge, dark pixels in the background, and an excessive number of pixels for the edge [33]. Therefore, in our case, OTT was the best option because of its performance in detecting edges and the HAZ area properly. The equation and demonstration of OTT application has been discussed in literature [33]. The OTT is based on the histogram of grayscale images, the main idea is to maximize the between-class variance (foreground and background region) in the histogram. By using OTT, we get the best threshold value that maximizes the variance of HAZ area and background.

OTT was proposed by Nobuyuki Otsu [12] in 1975. Since then, Otsu's technique has become the most widely used in image thresholding algorithms. The concept of OTT can be simplified into the following steps: (1) processing the input image, (2) obtaining image histogram (pixels distribution), (3) computing the threshold value (t), and (4) replacing the pixels obtained from the image by partitioning white and black regions. One of the advantages of OTT is its simplicity in calculating the threshold values because it only involves single-dimensional intensity data; therefore, the process helps in reducing the time for computational processing. OTT is useful in performing image segmentation because it involves a simple mathematical expression in its algorithm. Thus, it requires less computational time compared to other thresholding techniques. Owing to the advantages, the improvement of OTT has been discussed in Kalathiya et al. study [34]. The OTT (iterative and custom approaches) modified by them are also demonstrated in their study.

Over the years, the scientific community has explored the thresholding techniques in image processing. Apparently, Otsu technique appeared as the most prominent for this purpose. ImageJ Otsu global thresholding algorithms is an implementation of the OTT [12]. The histogram is classified into two classes and the inter-class variance is minimized. The Otsu thresholding can be found in ImageJ software under Auto Threshold options. Gonzalez and Woods have been discussed the Otsu method in depth in the literature. The Otsu's algorithm summarized as; (1) computation of the normalized histogram of the input image, (2) computation of the cumulative sums, (3) computation of the cumulative means, (4) computation of the global mean, (5) computation of the between-class variance term, (6) Obtaining the Otsu threshold and (7) computation of the global variance [1].

However, our study mainly focuses on applying the OTT for extracting HAZ. Although many studies in the literature have discussed the characteristics of HAZ generated in a laser cutting process, most of the recent literature mentioned more about the use of image processing to measure the HAZ area without any further discussion on how it is done. Therefore, this study is useful for the laser cutting process field of study in terms of image detection and analysis. Through this kind of study, HAZ can be easily determined, optimizing the laser process and its relations to input parameters, and minimizing the HAZ can be achieved.

III. Materials and Methods

A. Paper Sheet Preparation

The material used in the experiments was laboratory sheets prepared from pulp fibers and loaded with AH to reinforce heat resistance. The fiber materials used were commercially available hardwood pulp (Eucalyptus species). AH in the special grade was purchased from Fujifilm Wako Chemicals, Osaka, Japan. Alkyl ketene dimer (AKD) (AD1608, Seiko PMC Corporation, Tokyo, Japan) as a sizing agent and polyamine polyamide epichlorohydrin (PAE) (WS4030, Seiko PMC Corporation) as a cationic polymer for retaining the size. To prepare laboratory sheets, a 1.0% AKD emulsion was first prepared by weighing 1 g of AKD emulsion stock solution (25% solids) and diluting it 25 times. Next, a 1% cationic polymer solution was prepared likewise from the PAE stock solution (25% solids). A total of 27 g of air-dried hardwood pulp was weighed and disintegrated in 1.6 L of water using a disintegrator specified in the ISO standard for 5 min and poured into a sieve for drainage. Then, the pulp was squeezed to 10% solids and beaten to 5000 times on a PFI mill. The pulp beating process swells pulp fibers, and therefore improves fiber flexibility and mechanical strength[35]. Next, the beaten pulp slurry was diluted to 1.6 L of water and disintegrated at 3000 rpm with the disintegrator for 1 min. Then, the suspension was diluted to 11.25 L of water, and 7.5 ml of sizing agent (1.0 % AKD) was added and stirred for 1 min, followed by adding AH (10%, 20%, and 40%) and 7.5, 15, and 30 mL of retention aid solution (PAE), respectively for sample B, C, and D as shown in Table I. It was then mixed for 1 more min. AKD works as a sizing agent, and PAE works as a retention aid when the pulp is mixed with the AH component. Paper sheets with a targeted basis of about 100 g/m^2 were prepared using a standard sheet former (ISO 5269-1:2005), pressed with the hydraulic press at 0.34 MPa, set between metal rings, and stored in a controlled environment (23ºC) for restraint air drying.

TABLE I. THE COMPOSITION OF SOLUTION

Sample	**Composition of solution for hand sheet paper making**		
	AH to dry pulp mass ratio (%)	***AKD (mL)***	***PAE (mL)***
A	0	0	7
B	10	7.5	7.5
C	20	7.5	15
D	40	7.5	30

B. Laser Processing Setup

The experiments were conducted with a CO_2 laser cutting machine (PODEA 20W ZERO Corsa, PODEA Co. Ltd, Saitama, Japan) with a maximum output power of 20 W with a spatial resolution of 1000 dpi. A schematic of a laser beam head and cutting mechanism is shown in Fig. 1. The vector cutting speed is 20 mm/s at a maximum. One straight cut, each of 5 mm in length (Fig. 2a and 2b), was performed for each experimental run. Then, the results of the laser cuts were evaluated in terms of the HAZ area.

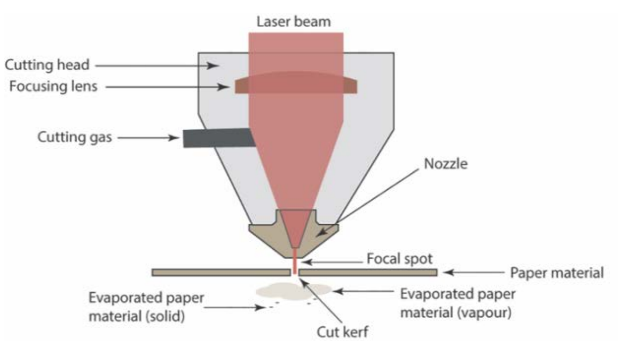

Fig. 1. A Schematic of a Laser Beam Head and Cutting Mechanism.

C. Cutting Parameter Choice

There were two laser parameters chosen: (1) laser power ratio expressed in percentage and (2) cutting speed (mm/s). The laser power ratio was chosen from 20%, 40%, 60%, 80%, and 100% to the maximum and the cutting speed was chosen from 4, 8, 12, 16, and 20 mm/s. The process parameters were performed for each paper condition. The laser cuts with the smallest areas of HAZ were chosen for optimization [16].

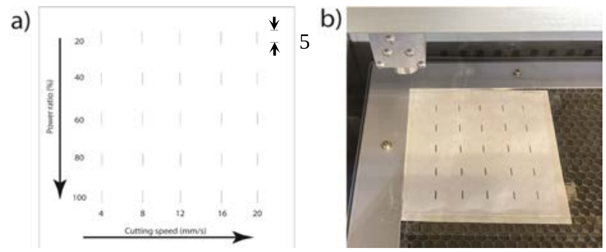

Fig. 2. (a) Illustration of Laser Cut Design (b) Laser Cutting Process.

D. Scanning Electron Microscopy (SEM) and Optical Microscopy

SEM images of heat resistance paper samples were taken using Hitachi Tabletop Microscopes (TM4000Plus). An industrial stereo microscope OLYMPUS SZX10 (Olympus Corporation, Tokyo, Japan) was used to observe the boundary of HAZ. First, optical images were captured using a digital single-lens reflex camera (EOS Kiss X8i, Canon Inc., Tokyo, Japan). Then, the image processing and analysis were performed using ImageJ software to identify and measure the HAZ area by performing binarization and thresholding algorithms.

E. Image Segmentation and HAZ Area Measurement

The identification of the area and edges of HAZ followed the procedure in Table Ⅱ. First, original HAZ images were converted to the grayscale format via the RGB format. Next, image segmentation was performed with the thresholding values (*t*) determined using OTT.

TABLE II. THE IMAGE PROCESSING AND IMAGEJ COMMANDS

Image Processing	**ImageJ Commands**
Grayscale conversion	Image > Type > 8 bit
Thresholding	Image > Auto (global) Threshold > Select method (All 16 global threshold methods have been tested and optimal thresholding selected.)
Particles analysis	Analyze > Analyze particles

IV. Result and Discussion

A. Scanning Electron Microscopy (SEM) and Optical Microscopy

Samples were coated with platinum (Pt) using a spatter before observation with Hitachi Tabletop Microscopes (TM4000Plus). Fig. 3a-d shows the SEM images of the laboratory sheets with and without AH. Fig. 3a shows no particles in Sample A with no AH loaded. Obviously, AH particles are observed to be distributed increasingly in order of increasing AH dose from Samples B (10%), then C (20%) until D (40%).

Fig. 4 shows a HAZ area clearly. The clear definition of HAZ can be defined and referred to the dark burn area that clearly visible under the optical microscope. By analyzing the image, we can determine the HAZ area for each laser process parameter and setting. Each image resulted from the various setting of the laser power ratio percentage and cutting speed can be studied through image processing and image analysis.

B. Image Segmentation

Among the results of image segmentation available with ImageJ for the HAZ images, OTT outperformed the other 15 methods (Fig. 5) in terms of sensitivity and accuracy in detecting the intended areas in the foreground from the background obviously even by visual comparison to the original image. The OTT algorithm is one of the most used methods in binarization [31] [36]. The OTT algorithm refers to the bi-modal image histogram. We focused on OTT not just because it is used widely in many computers vision applications but also because its performance on image segmentation was by far the highest. In this case, the pixels of a HAZ became the foreground. The purpose of thresholding was to separate the HAZ as the foreground from the background. All pixels of a HAZ with intensity lower than a threshold value are considered as the background. After the binarization process, the HAZ area was identified and measured. Based on these values, HAZ was studied for each batch of samples (A to D in Table Ⅰ). In the field of laser process study, it is crucial to determine and understand the HAZ. Moreover, it is important to understand the HAZ area and its correlation with the laser process parameters. Through this process, accurate extraction of HAZ has become possible using the image analysis data. The results showed the smallest values of HAZ area achieved in the condition of optimal laser process parameters for each sample (Table Ⅲ).

As digital image processing is an important tool to analyze the HAZ images. The main step used to perform image analysis in digital image processing through the flowchart is shown in Fig. 6. The process of OTT started with the acquisition of data image, then followed by image segmentation through the Otsu technique. Image segmentation is an essential step in digital image processing to partition the HAZ image into foreground and background regions. In general, there are three segmentation techniques that used in image segmentation which classified as edge-based segmentation, region-based segmentation, and special theory-based segmentation [37]. In our study, we used region-based segmentation using OTT.

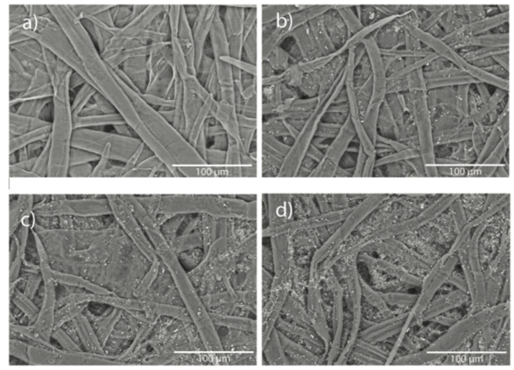

Fig. 3. The Micrographs of the Paper Surface with Different Conditions, (a) Sample A—Control (without Additives), (b) Sample B—10% of AH Loading, (c) Sample C—20% of AH Loading, (d) Sample D—40% of AH Loading.

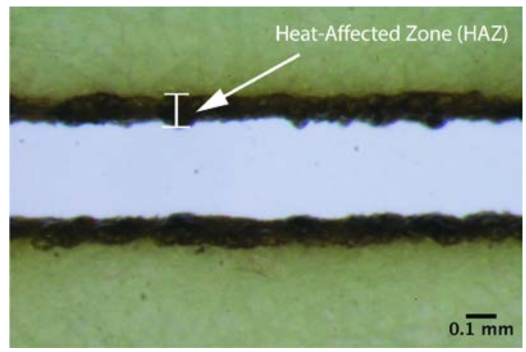

Fig. 4. HAZ Observed through an Optical Microscope.

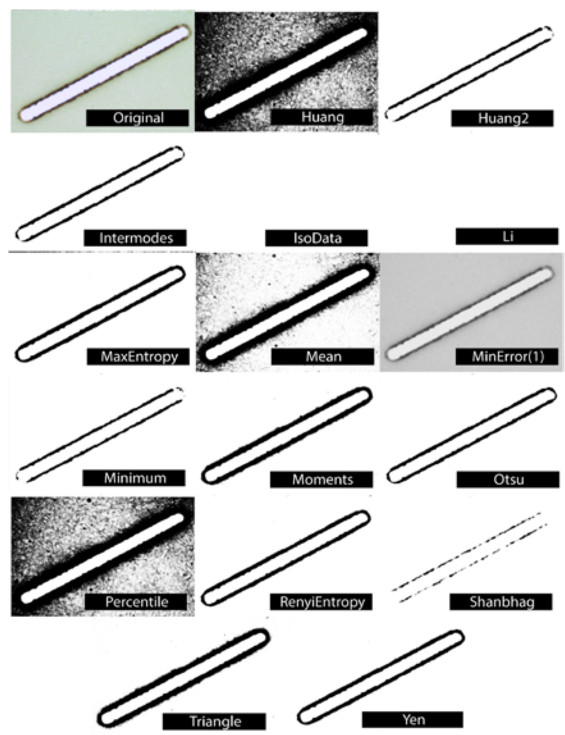

Fig. 5. Original Image and Threshold Images using 16 ImageJ Global Tresholding Techniques.

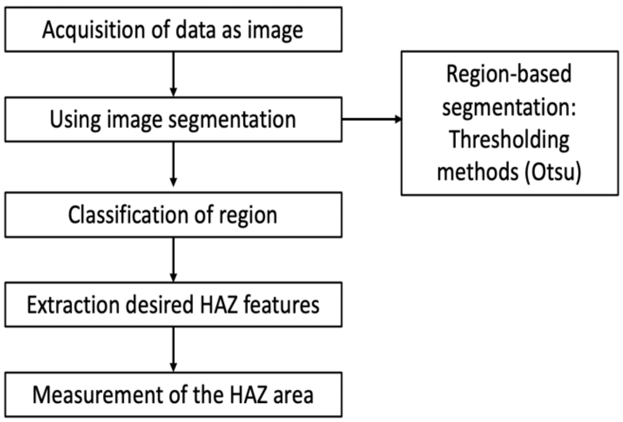

Fig. 6. Main Steps used in Image Analysis in Digital Image Processing.

Meanwhile, Fig. 7 shows some of the overlay images of threshold images on top of original images. The threshold images segmented successfully and unsuccessfully using various thresholding techniques. Fig. 7a shows the grayscale of the HAZ (ground-truth image) and red threshold refers to the detected threshold of HAZ using the mentioned techniques. Fig. 7b shows the successful segmentation of the HAZ using OTT. Fig. 7c and 7d show the unsuccessful segmentation using Shanbhag and Triangle thresholding technique. The criteria that we used to determine the OTT performance by observed the images of original grayscale and threshold images were overlaid on top of each other, and OTT was the best option and optimal thresholding based on its sensitivity in detecting the HAZ area. The OTT-treated image overlapped perfectly with the HAZ.

C. Criteria for Selection of Thresholds

The proposed method makes use some thresholds in HAZ detection for showing the comparison between Otsu and other two examples which are Shanbag and Triangle. As mentioned earlier in Fig. 5, all ImageJ global thresholding performed in identifying the optimal thresholding for the HAZ detection. Thus, in Fig. 7 we overlapped each detected threshold images on top of the original grayscale image. The result of Fig. 7b shown the OTT successfully overlapped accurately compared to the Fig. 7c and 7d which is represent the Shanbag and Triangle technique respectively. However, for another alternative, the detected threshold value of HAZ can be measured or assessed using P-Tile as suggested by Samopa, F. and Akira, A. (2009) and Neogi, N., Dusmanta, K.M., and Pranab K. Dutta (2017) [38][39]. However, the challenges are when it is not applicable when the object area ratio is unknown.

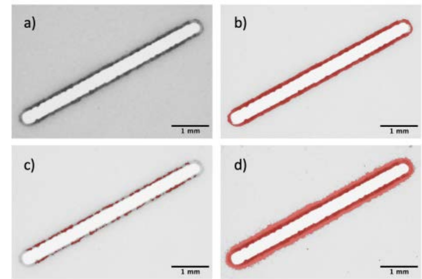

Fig. 7. Some Image Segmentation Results using Different Thresholding Techniques: (a) Original Grayscale Image, (b) Successful Segmentation using OTT, (c) Unsuccessful Segmentation using Shanbhag, and (d) Unsuccessful Segmentation using Triangle.

D. HAZ Analysis

Fig. 8 shows the HAZ area based on various cutting speeds and laser power ratios for Sample A. The low values of HAZ obtained through an optimal laser power ratio of 80% and cutting speed of 20 mm/s gave the optimum desired output of HAZ with the 0.705 mm^2. Secondly, the results of Sample B (Fig. 9) showed that the optimal process obtained the smallest HAZ (0.690 mm^2) through 60% and 100% with a cutting speed of 20 mm/s. However, by considering the power consumption, 60% was preferred compared to the 100% ratio. Thirdly, the results of Sample C (Fig. 10) demonstrated that the highest cutting speed was significant in the smallest area of HAZ. The smallest area value with 0.755 mm^2 was achieved through the highest cutting speed (20 mm/s) and combined with a 100% power ratio. Lastly, the results of Sample D (Fig. 11) showed that the combination of a 60% power ratio with a cutting speed of 20 mm/s successfully obtained the smallest HAZ with 0.629 mm^2. Based on the 100 laser cuts that had been performed, it demonstrated that the modified paper with a different composition of aluminum hydroxide showed resistance to the heat and produced a smaller area compared to the control sample. The smallest area of HAZ obtained through Sample D loaded with the largest amount of AH. The optimal laser process condition of each sample is highlighted in Table III.

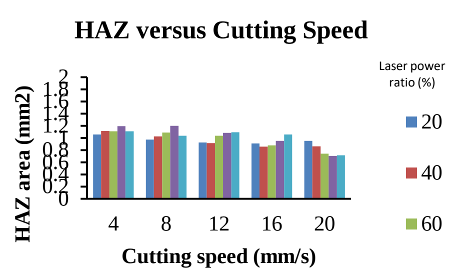

Fig. 8. HAZ Area Compared at Different Laser Power Ratios and Different Cutting Speeds for Laboratory Paper Sheets with no AH.

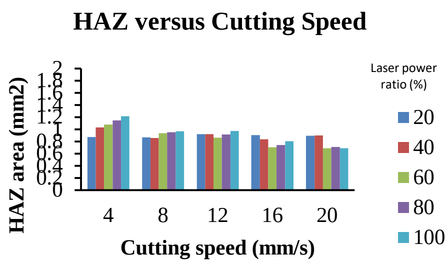

Fig. 9. HAZ Area Compared at Different Laser Power Ratios and Different Cutting Speeds for Laboratory Paper Sheets with 10% AH.

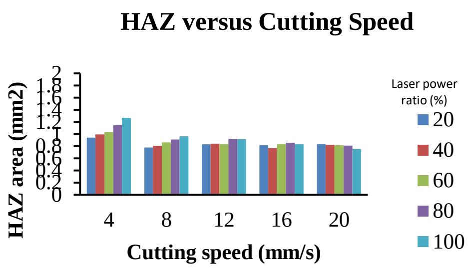

Fig. 10. HAZ Area Compared at Different Laser Power Ratios and Different Cutting Speeds for Laboratory Paper Sheets with 20% AH.

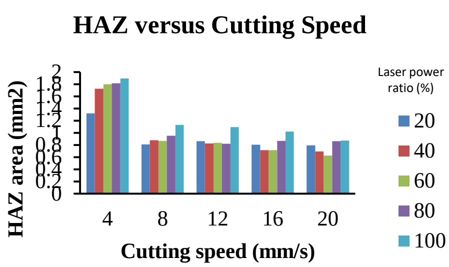

Fig. 11. HAZ Area Compared at Different Laser Power Ratios and Different Cutting Speeds for Laboratory Paper Sheets with 40% AH.

TABLE III. LABORATORY SHEET THICKNESS AND OPTIMAL LASER PROCESS CONDITION FOR EACH SAMPLE

Sample	**Thickness (μm)**	**HAZ area at minimum (mm^2)**	**Optimal condition**
A	140	0.705	80 % power ratio and 20 mm/s cutting speed
B	148	0.609	60 % power ratio and 20 mm/s cutting speed
C	150	0.755	100 % power ratio and 20 mm/s cutting speed
D	183	0.629	60% power ratio and 20 mm/s cutting speed

V. CONCLUSION

In the laser cutting process of paper materials for packaging applications, blackening generation of a HAZ by pulp fiber carbonization mars beauty. However, the characterization and evaluation of HAZ lead to an intriguing discussion on the possibility of reducing this defect zone. Thus, laboratory paper sheets loaded with aluminum hydroxide (AH) were prepared because we highlighted the effect of AH to stabilize heat resistance and carbonization prevention. Laboratory paper sheets with four different amounts of AH loaded were processed by laser cutting. All the HAZ were captured with an optical microscope. The HAZ area was measured by image processing through OTT available with ImageJ. The image segmentation based on OTT permitted to accurately measure the HAZ area. Also, an optimal combination of the laser power ratio and cutting speed providing a minimum of the HAZ area was pursued. We have found that the laboratory paper sheets with the largest amount of AH loaded produced the smallest area of HAZ by a combination of a laser power ratio of 60% and a laser cutting speed of 20 mm/s. Our future work will possibly focus on depth discussion on the other image processing techniques that can be applied in laser cutting image analysis such Gonzalez & Woods technique, and other ImageJ global thresholding techniques.

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