IMAGE ANALYSIS OF CRACKS IN UNDERWATER ENVIRONMENT

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***ABSTRACT*: *Cracking in underwater pipelines are one of the type of disasters difficult to predict accurately. It has high impact in terms of damages to underwater environment and economical loss. Pipelines transport a large amount of fluid but occasionally there exist cracking in the welding pipelines. The objective of this study was to investigate the use of vision sensor in order to capture and analyze the image of underwater cracking in pipelines. In this system, the image processing techniques used to observe the cracking pipelines were greyscale image conversion, Gaussian filter, Simple Thresholding, Histogram and Canny Edge Detection. Moreover, in this paper, the contour method was used to find the coordinates point of the images in area of the cracking path of pipelines. The coordinates of the image can be used to estimate the starting and ending point for welding to repair the crack. The environment studied was clear water and murky water. This indicates that the contour method is viable to estimate the cracking locations on the pipe in several cracking types; Stress Corrosion Cracking (SCC), Hydrogen Induced Cracking (HIC) and Hooks cracking for clear water, and Stress Corrosion Cracking (SCC) and Hydrogen Induced Cracking (HIC) for murky water. However, results for SOHIC for clear water and SOHIC and Hooks cracking for murky water could not be obtained because of the insufficient detail of images*.

Index Terms: Underwater crack, pipeline welding, Gaussian Filter, Simple Thresholding, Canny Edge Detection.

I. INTRODUCTION

The underwater pipeline is an important medium to transport fluid (i.e. oil) from one station to another, in most cases for long distances on sea bed level. Although the pipelines are built from solid materials, one of the problems that may affect the transportation of fluids is underwater cracking since pipelines are being used for extensive periods and subjected to effects from underwater environment.

Events of cracking in underwater pipelines are disastrous, causing accidents and high losses. On 10 June 2014 in Miri, Malaysia, the pipeline exploded incurred financial loss of RM3 Billion to Sarawak Interstate gas pipeline between Lawas and Long Sukang, additionally causing heatwave impact to the villages but luckily without loss of life [1]. Underwater pipelines accident also occurs in Moscow River, Russia which causes a huge black cloud of smoke and a ball of fire engulfed at Moscow River. It causes pollution to the air and three bystanders including a child were taken to hospital for respiratory issues but no fatal injuries were reported [2]. Alaska also was affected from an underwater pipeline cracking incident. A series of oil and gas leaks from underwater pipelines occur in early February 2017, leaking in Cook Inlet from eight-inch pipelines that were used to deliver gas to offshore oil drilling platforms [3].

To attend to the problem of cracks, human or machine inspection is used. However, in most cases, underwater vehicles were the preferred choice since no loss of human life is at stake. Inspection robots employ vision to detect the underwater cracking in pipelines. Human divers are later needed to perform welding on the cracks. Vision inspection faces several challenges to determine the area of the crack, due to unclear images (from the dark underwater environment), sea waves (and other geotechnical or marine conditions) and connection with the server system.

For underwater welding, lethal accidents are also a threat to divers/welders in the underwater environment. The impact of underwater pipeline cracking will cause explosions, drowning and decompression sickness or "the bends". These bends can happen when welders or divers work hundreds of feet underwater and they undergo pressure change and due to this bend, parts of the body like skin, lungs, ears, brain and joint will feel pain [4]. In addition, injuries can occur from the electric shock and cold temperature. Besides that, it will also cause fatal injuries to humans and animals, and water and air pollution. The welders or divers will face numerous complications in deposition rate and bubbling in the underwater welding. No matter how much our technology developed, it affects the strength of welds exposed to the water. A process that called hydrogen embrittlement is a lot of amount of hydrogen is present in the weld region and resulting from the dissociation of the water vapours in the arc region, which causes microscopic fissures, embrittlement and cracks. Cracks can grow and may result in catastrophic failure of the structure.

Navigating in the underwater environment and following the pipeline is not an easy task. It is a great challenge to explore the seabed environment; hence some researchers use online motion planning by using perception sensor by implementing path planning and view planning algorithm [5]. The purpose was to discover the unexplored seabed and to consider safety. For unfavourable conditions in underwater inspection, authors proposed the use of photonic vision for a 3D view [6]. Authors used colour value restoration, image contrast enhancement and depth perception. Attempt to detect defect in tube sheet welding was performed by researchers in [7]. They used a CCD camera as machine vision for quality inspection in the tube sheet. The image could be taken in a clear an accurate view. Infrared thermography and ultraviolet excitation was used to detect the crack on the shiny metal surface [8]. The method could reduce, obtain high signal to noise ratio and free from radiation. Other than computer vision method to detect and track cable pipelines [9], some researchers used ultrasonic surface waves and gel-coupled piezo ceramic (GCP) to detect the crack of underwater concrete beams [10], while others used laser sensor to detect the seam position in underwater welding for S-curve and V-groove types [11].

The various investigations performed on underwater cracking and welding shows that the problem is complex because of the underwater environment. For the purpose of this study, we focus on the computer vision inspection of four types of underwater pipeline cracking in a clear water environment and murky water, in a smaller scale. The types of cracking are; stress corrosion cracking (SCC), Hydrogen Induced Cracking (HIC), Stress-Oriented Hydrogen Induced Cracking (SOHIC) and Hooks Cracking.

II. METHODOLOGY

An experimental setup of the hardware was prepared for use of the experiments in the lab environment, since access to actual underwater pipeline could not be obtained at the moment. A container was used to fill water and pipelines cracks were made manually on the PVC pipes to mimic the four types of cracking mentioned (SCC, HIC, SOHIC, Hooks). Figure 1 show the equipment used

A. Experimental setup

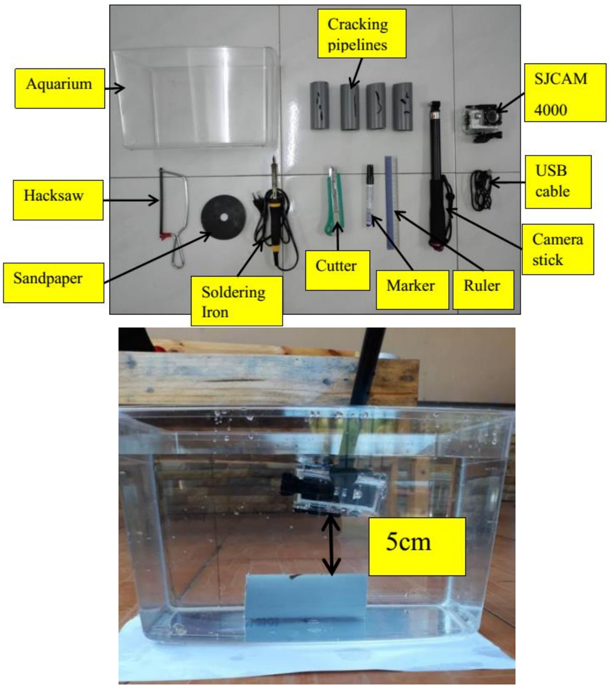


Figure 1: Hardware filled container with the pipe and underwater camera for the experimental setup.

Figure 1 shows the filled container with the cut PVC and camera. The camera is placed at a distance of 5cm. This value is just to ensure that the camera could obtain a sufficient view of the pipe (and crack) and the height of the container.

Figure 2 below, depicts the four types of pipeline cracking investigated. The segments of the pipe were placed in the container with two different environment; clear and murky water. After acquiring the image via the vision sensor (camera), the image is sent to the PC via Wifi transfer, for image processing using OpenCV libraries.

(a) (b)

(c) (d)

Figure 2. Four types of cracking investigated; (a) Stress Corrosion Cracking (SCC), (b) Hydrogen Induced Cracking (HIC), (c) Stress-Oriented Hydrogen Induced Cracking (SOHIC) and (d) Hooks Cracking.

B. Image Processing on Acquired Snapshot

Figure 3 represents the image processing applied on the acquired image. It consists of a few processes. Firstly a Histogram is made for the RGB and Gray-scale converted image. This is for the purpose of assessing the pixel intensity of the colours.

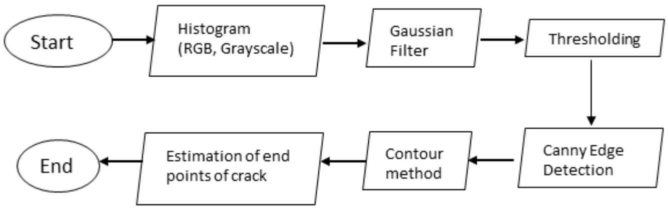


Figure 3: Process of vision inspection for the pipeline cracking

Next, the image undergoes Gaussian filter, to reduce the image noise and detail which may disrupt the image processing later. The Gaussian filter is a linear filter, and functions to blur the image and remove noises for the next process which is thresholding. Thresholding is later applied to convert the Grayscale image to binary, to focus on objects or areas of particular interest. Two different thresholding methods were performed; simple thresholding and Otsu's thresholding, for comparison.

Canny edge detection was also performed from the binary image, to determine whether it is feasible to estimate the points of cracking for both clear and murky water environments. The Contour method was also implemented on the image to estimate the area of the cracking pipelines path. Next, the end points were estimated from the area of the crack, by using the middle point of the rectangular area. The start/end point is not necessarily from the left or right side of the rectangle, and could also be on the top or bottom side of the rectangle. The path of the welding is then by forming a line between the start and end point.

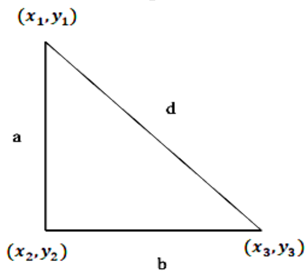


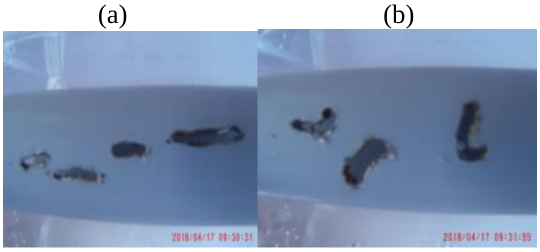
Figure 4: Three possible coordinates of start and end point of the crack.

Note that the estimated position of start and end points could be any two of the three coordinates shown. If the start and end points are point (x3,y3) and (x1,y1), there would be an angle, and the distance is calculated as d. If the start and end points are points (x1,y1) and (x2,y2), it would mean a vertical path, there is no angle and the distance is calculated as the difference between y coordinates. The other possibility is if the start and end points are points (x2,y2) and (x3,y3), it would mean a horizontal path, there is no angle and the distance is calculated as the difference between x coordinates.

III. RESULTS

The snapshots of the underwater images are shown in Figure 6. These snapshots represent Stress Corrosion Cracking (SCC), Hydrogen Induced Cracking (HIC), Stress-Oriented Hydrogen Induced Cracking (SOHIC) and Hooks cracking.

(a) (b)

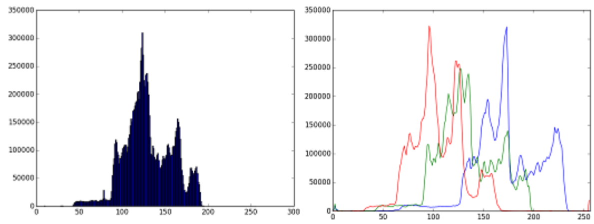


(c) (d)

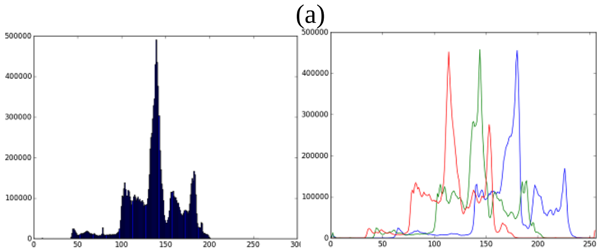
Fig.6. Underwater images of the four cracking types; (a) Stress Corrosion Cracking (SCC), (b) Hydrogen Induced Cracking (HIC), (c) Stress-Oriented Hydrogen Induced Cracking (SOHIC) and (d) Hooks Cracking.

A. Histogram

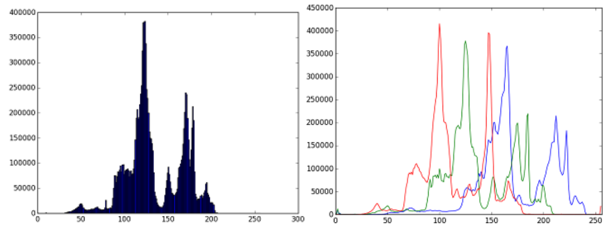
.The Histograms for the four cracking types in clear water are shown in Figure 7. From the observation, the Hydrogen Induced Cracking (HIC) has a highest number of pixels in image rather than other cracking types in clean water. This is because the Hydrogen Induced Cracking (HIC) has higher intensity distribution compared to other cracking types.



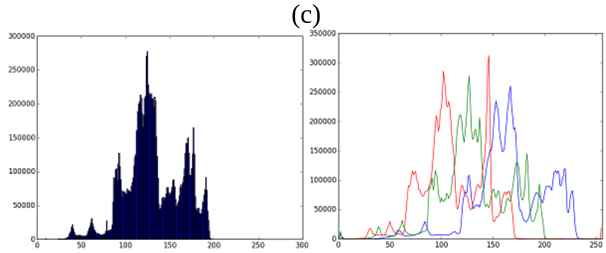
(a)



(b)



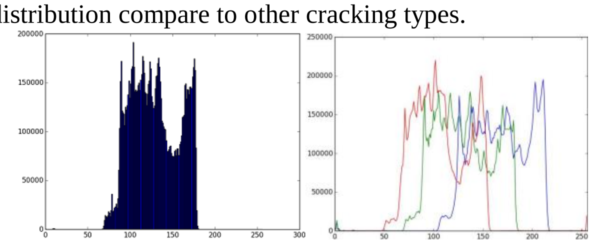
(c)



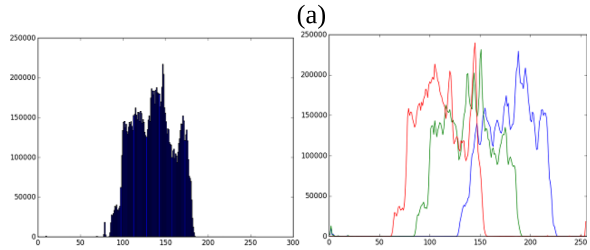
(d)

Figure 7: Histogram for four cracking in clear water, (a) SCC (b) HIC (c) SOHIC (d) Hooks cracking in grayscale (left) and RGB (right).

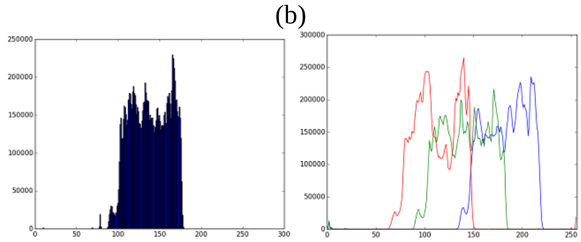
The Histograms for the four cracking types in murky water are shown in Figure 8. It can be seen that the Hydrogen Induced Cracking (HIC) and Stress Oriented Hydrogen Induced Cracking (SOHIC) has a highest number of pixels in image rather than another cracking in clean water because the Hydrogen Induced Cracking (HIC) and Stress Oriented Hydrogen Induced Cracking (SOHIC) has higher intensity distribution compare to other cracking types.



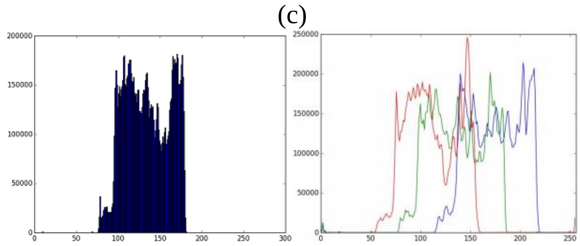
(a)



(b)



(c)



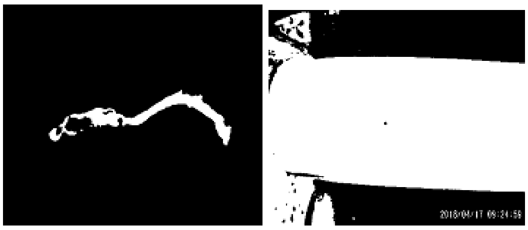
(d)

Figure 8. Histogram for four cracking in murky water, (a) SCC (b) HIC (c) SOHIC (d) Hooks cracking in grayscale (left) and RGB (right)

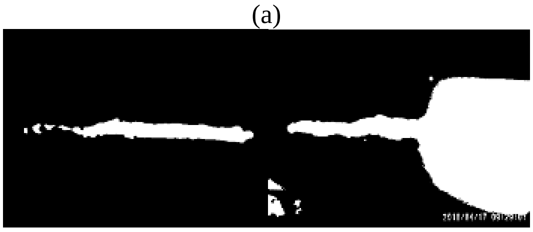
By comparing histogram for clear and murky water, it is evident that the maximum values for Red, Green and Blue are 25000 or less for murky water, but clear water could reach maximum values of 30000 to 40000. This is expected because the picture in clear water shows a clear view of the cracks on the pipes. In murky water however, it is less clear, thus showing lower results of maximum values. The actual underwater environment would be more close to the murky water experiments.

B. Thresholding

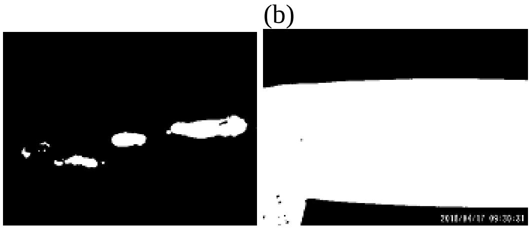
For thresholding results (Simple and Otsu's thresholding) in clear water, the results are depicted as in Figure 9(a)-(d). Left images of the figures show Simples Thresholding results with the right images show Otsu's Thresholding Results. The threshold value of 85, 90 and 95 were used. These values of threshold were used as these values were tried and provided the a clear distinction between cracks and the background. The Simple Thresholding method showed better results than Otsu's. For murky water, results are shown in Figure 10. Similarly, images on the left side shows Simple Thresholding while the right images shows Otsu's Thresholding results. The letters (a), (b), (c) and (d) represents the four cracking types; SCC, HIC, SOHIC and Hooks.



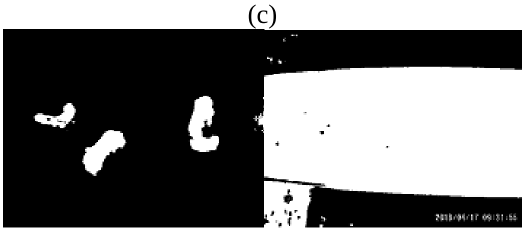
(a)



(b)

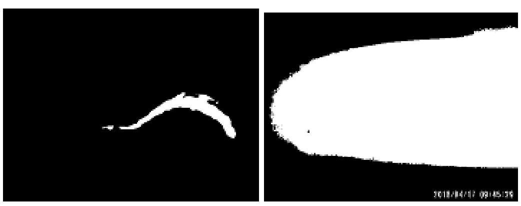


(c)

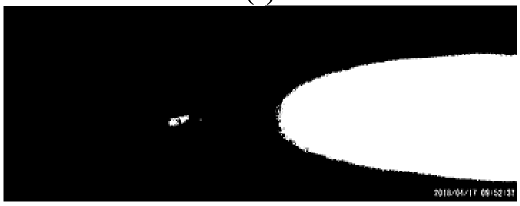


(d)

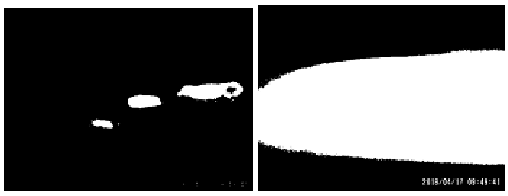
Figure 9: Simple and Otsu's Thresholding in Clear Water; (a) SCC (b) HIC (c) SOHIC (d) Hooks cracking



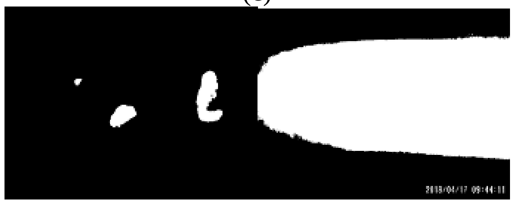
(a)



(b)



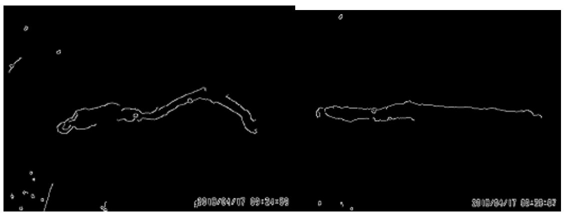
(c)



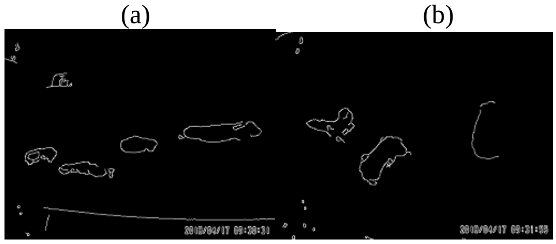
(d)

Figure 10: Simple and Otsu's Thresholding in Murky Water; (a) SCC (b) HIC (c) SOHIC (d) Hooks cracking

Figure 11 shows the Canny Edge detection results for clear water. The results of murky water was not shown because it failed to detect edges since the images are not clear.



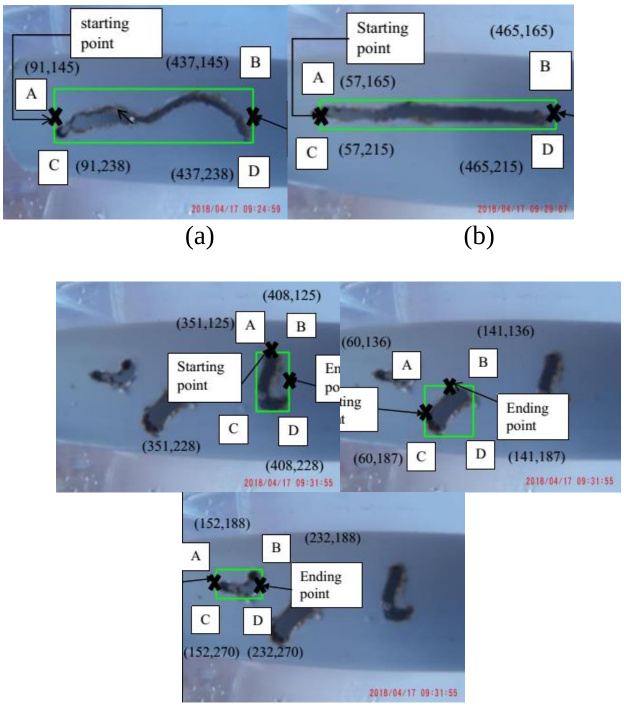
(a) (b)



(c) (d)

Figure 11: Canny Edge Detection in Clear Water; (a) SCC, (b) HIC, (c) SOHIC and (d) Hooks

The results for the estimation of area of cracking (by using the contour method) and its corresponding start and end points (for welding) is shown in Figure 12. Labels A, B, C and D represents the corner coordinates of the constructed rectangles. Table 1 shows the results for the coordinates and angle.



(a) (b)

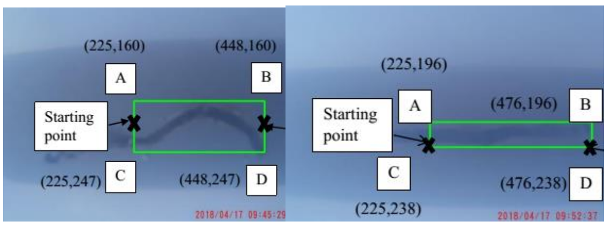
(c)

Figure 12: Contour method in Clear Water (a) SCC (b) HIC (c) Hooks with three different cracks detected

TABLE I: CRACKING IDENTIFICATION RESULTS (CLEAR WATER)

Type	Start point	End Point	Start angle	End Angle
SCC	(91, 192)	(437, 145)	85°	72°
HIC	(57, 190)	(465, 190)	45°	33°
SOHIC	None	None	None	None
Hooks	(380, 125)	(408, 177)	45°	45°

The images in Figure 12 shows the result of the contour method for three types of cracking. The result for SOHIC is not available because the region could not be identified. For Hooks cracking (c), the three separate cracks were identified, with both start and end points. Figure 13 shows the results for countour method in murky water environment.



(a) (b)

Figure 13: Contour method in Murky Water (a) SCC (b) HIC

In Figure 13, the contour method managed to identify the cracking area for only SCC and HIC cracking. The other two cracking types could not be identified due to the images that did not exhibit enough detail. Table II shows the results in murky water.

TABLE II: CRACKING IDENTIFICATION RESULTS (MURKY WATER)

Type	Start point	End Point	Start angle	End Angle
SCC	(225, 224)	(448, 204)	16°	45°
HIC	(225, 217)	(476, 217)	20°	41°
SOHIC	None	None	None	None
Hooks	None	None	None	None

IV. CONCLUSION

Although the results from histogram, simple thresholding, Canny edge detection and Contour method showed possible features that can be used for identification of the crack, it is not proven that the methods are successful for all the cracks in both conditions (clear and murky water). This is due to the uncontrolled environment (lighting, non-clear water) which requires further investigation on the factors that affect the image processing.

The lab experiments are indications that more uncertainties will affect image acquisition and processing in the real underwater environment, which is more prone to lack of lighting, waves and other geotechnical factors. It is recommended, as a further study, to attach a fixed lighting on the area of image acquisition for a more reliable reading, especially in darker underwater environments. It is also desired to perform the experiments on actual pipeline segments with cracks, with more accurate water conditions (murky water) to the actual depths in the ocean.

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