Characterization of Defects in Magnetic Flux Leakage Images

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ABSTRACT
One of the most challenging scientific industrial problems in recent years is automatic defect detection and characterization. Automatic defect detection can replace human operators who locate and identify defects. Detection of defects in the steam generating tubes through periodic in-service inspection is one of the most significant issues of the fast breeder reactors. Among various pipeline inspection technologies, Magnetic Flux Leakage (MFL) Non Destructive inspection is the most prevalent and perfect one. The image of the pipeline is obtained by MFL technique. The obtained image is undergone preprocessing. Then defect region is identified and detected by segmentation (K-means and Thresholding) techniques. The main aspire of this paper is to characterize the defects. A simple and efficient algorithm was developed to characterize the rectangular notch and flat bottom hole defects in MFL image. The length and width of the defect were obtained using the characterization algorithm.

Keywords
Characterization, K-means Segmentation, Magnetic Flux Leakage, Thresholding.

1. INTRODUCTION
High temperature pressure pipelines are extensively used in petrochemical plants and Power Stations [1]. Leakage of pipeline often takes place due to media corrosion and material deterioration. Hence it is necessary for pipeline's security evaluation and maintenance to detect the defects in pipeline regularly and obtain the characteristic features of the defect. Magnetic Flux Leakage (MFL) nondestructive testing is the most commonly used in-line inspection method [2] for metallic pipeline defect assessment. This inspection involves the detection and characterization of defects in the pipe wall with greater accuracy [3] for the evaluation of the severity of these defects. By MFL technique the leakage flux of pipeline is detected by a magnetic sensor [4] and, then an image is constructed.

The images are obtained from Magnetic Flux Leakage (MFL) testing. These images are used for this work to characterize the defect. The defect region of the image will be usually come into view as brighter region. The image is subjected to preprocessing. The preprocessed image ought to be examining for defect detection process [5]. When the defect is discovered then, subsequently segment the defect region for characterization. The existing simple thresholding based segmentation was not efficiently segment the defect region. So, the defect region is segmented by K-means segmentation algorithm [6, 7]. It is an algorithm to classify or to group the objects based on features in to K number of groups. This type of segmentation method is used to become aware of the defect in an object by make out the flawed region in an image [8].The segmented defect region is thus characterized by proficient algorithms. The algorithm furnishes a better result.

2. MFL TECHNIQUE
There are many methods to review the uprightness of a pipeline. In-line-Inspection (ILI) tools [1] are built to travel inside a pipeline to collect data. The In-Line Inspection (ILI) , one among the most commonly used pipeline inspection technology, is the magnetic flux leakage In-Line Inspection tool (MFL-ILI). MFL-ILIs detect and assess areas where the pipe wall was damaged by corrosion.

The Magnetic Flux Leakage Testing is used for detection and characterization of defects in pipeline. The basic principle of MFL technique is that, a powerful magnet is used to magnetize the pipeline. At place where there is corrosion or missing metal in the pipeline there will be leakage in magnetic field. The leakage field is detected by magnetic detector. Analyses are performed based on the recording of the leakage field to identify damaged areas and hopefully to estimate the depth of metal loss.

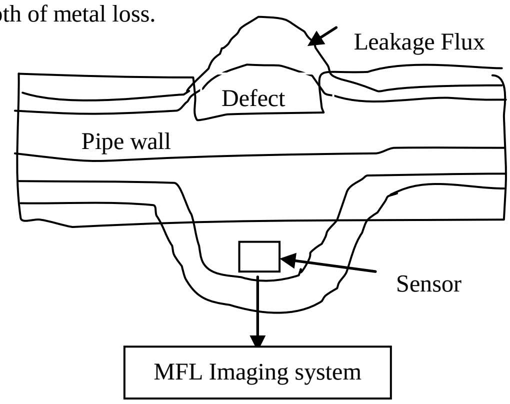


Figure 1: MFL Imaging System

In the MFL technology system, the inspection tools include a magnet, sensors and imaging system to detect the metal loss corrosion defect and any other damages of the oil-gas pipeline. The Figure 1. shows the MFL imaging system. Permanent magnets are used to temporarily magnetize the steel pipe and the magnetic field changes are recorded and examined. When there is no flaw in the pipe wall there is no leakage of magnetic flux. In case if internal or external flaws are present, like corrosion or any other damage, there will be leakage of magnetic flux around the defect region and this is precisely measured by Hall effect sensors.

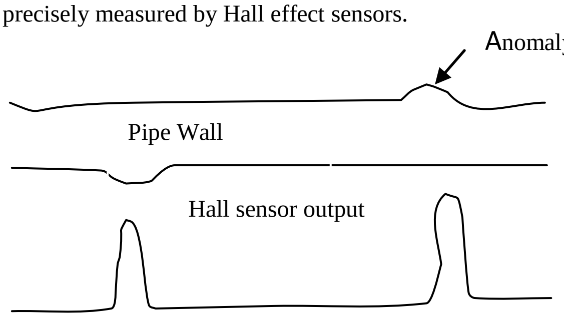


Figure 2: Hall Sensor Output for Pipe damage

Thus the surface leakage flux occurs at defect regions is then gets picked up by the MFL sensors before passing to the imaging system for processing. The Hall sensor output for pipe damage is depicted in Figure 2. Then the Hall sensor output is subsequently reconstructed as an image.

3. PROPOSED METHODOLOGY

3.1 Proposed Approach for Defect Detection and Characterization Process

In this paper, methods for defect detection and characterization of defects in pipeline are presented. Initially by MFL imaging system the pipeline is entirely scanned and hence MFL image was reconstructed. The obtained image is undergone a defect detection process. When any defect is encountered on image then progression of operation such as image preprocessing, segmentation of defect region, characterization of defect are performed. The flow chart of the proposed-automatic-defect detection method is shown in Figure 3.

3.2 Defect Detection Process

Before characterization, the defect detection process is discretionary one. If there is no defect in the image then there is no need for characterization that's why the defect detection process is a simple time consuming process [5]. According to the algorithm, the image of pipeline with very small defect is taken as reference image, I1 and image obtained from MFL processing is taken as Test image, I2.Both the image should be converted to binary image.

When the image is symbolizing in binary form its white pixels signify defect region. From now estimate the number of white pixels in the reference image as D1and in the test image, as D2. The flow chart for defect detection process was illustrated in Figure 4.When the number of white pixels D2 is greater than D1 then it is understood that the test image consists of defect region. Thus the image has to be characterized.

3.3 Image Preprocessing

After the confirmation of presence of defect the image which we obtain from MFL technique is subjected to image preprocessing step. The MFL color image is converted to gray image. The image will unquestionably consist of noise. When the noised image is second-hand for characterization it will lead to untrue result. And so, the filtering is supposed for noised image. To remove noise there are many filtering techniques [10] were adopted.

The grouping of pixel is done based on the minimum distance attribute. After the pixels are allocated to the clusters, the

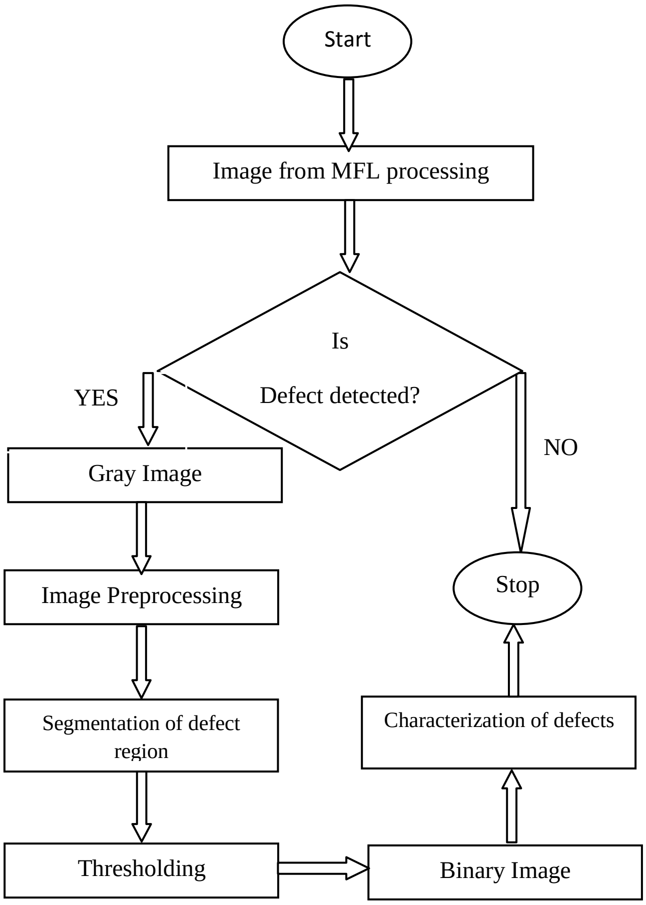


Figure 3: Flow chart for proposed method

One among is Low Pass Filter but when this filter is used it only declines the salt and pepper noises instead of getting free of them entirely. The main negative aspect is that it will blur the edges in the image. Hence preference of filter is important. Mostly median filter is adopted to completely eliminate the noise [5, 9]. The median filter works for each pixel in image by sorting of neighboring pixels into an order based on pixel intensities. Then the original pixel value is replaced with the median value from the sorted list. Thus Median filter is good at conserve details of an image.

3.4 Segmentation

Segmentation usually results in assemblage of adjacent pixels which are akin in some sense. K-means Clustering is a segmentation technique which is used to segment an image into k different clusters. This segmentation technique is foot on resemblance property of intensities. Region of interest (ROI) extraction is an important step in the process of segmentation.

From the k clusters the region of interests are identified. K-means is one of the simplest unsupervised learning algorithms that solve the clustering problem. K-means clustering is considered to be quite fast segmentation method [8]. This algorithm is to begin with determining the number of clusters, K. (K can be chosen random or based on some condition) then centre will be assigned to each and every cluster of the image. Every pixel in the image has got to any one of the k clusters.

centers are re-determined and these steps are repeated until convergence is achieved.

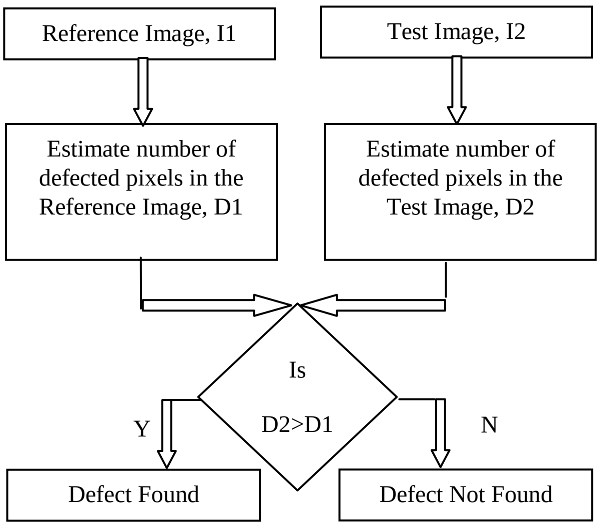


Figure 4: Flow chart for Defect Detection Process

3.5 Thresholding

By means of K-means algorithm the defect region is segmented. For characterization, the segmented region should be binarized. Hence by the way of Otsu's thresholding method binary image of the defect region is obtained.

3.6 Characterization of Defect

The characterization algorithms developed here are relevant only for binary defect image.

3.6.1 Flat bottom hole Defect

The main worsening of the MFL approach is its helplessness to exact sizing. To improve sizing accuracy, defect characteristics need to be quantified with greater exactness. Once a defect has been detected and defect region is segmented, the defect region must be characterized. The reason for flaw or defect formation in pipeline is due to metal corrosion. Mostly the metal loss corrosion will be like flat bottom hole. The Flat bottom hole defect image is shown in Figure 5.

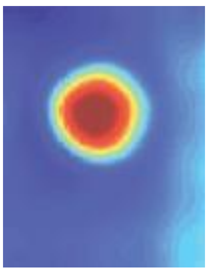


Figure 5: Flat bottom hole Defect Image

The flat bottom hole is virtually equal to the shape of circle. Hence the circle detection algorithm will be appropriate for characterizing flat bottom hole defect. The flat bottom hole is characterized based on the foundation of geometric principle of the circle [9]. According to the feature of the circle the perpendicular bisector of two chords will meet at centre of circle. Flow chart for flat bottom hole characterization algorithm is put in plain words in Figure 6.

The algorithm is comprehensive as initially horizontal chord A is drawn which can originate from any point in the flaw region. The originated point is noted as W (x_1, y_1). The chord A is drawn by a way of touching the two edge points as A1 (x_2, y_1) and A2 (x_3, y_1). In the same way the vertical chord B is drawn from the same originate point W (x_1, y_1) till the two edge point as B1 (x_1, y_2) and B2 (x_1, y_3).

The midpoint of chord A and B is estimated as M1 and M2 respectively.

M1 as $m_{x1} = x_2 + \frac{x_3 - x_2}{2}$, $m_{y1} = y_1$ (1)

M2 as $m_{x2} = x_1$, $m_{y2} = y_2 + \frac{y_3 - y_2}{2}$ (2)

Through the midpoint M1 and M2, a perpendicular bisector is drawn. This bisector will meet at a point C. The point C is

C= ($x_2 + \frac{x_3 - x_2}{2}$, $y_2 + \frac{y_3 - y_2}{2}$). (3)

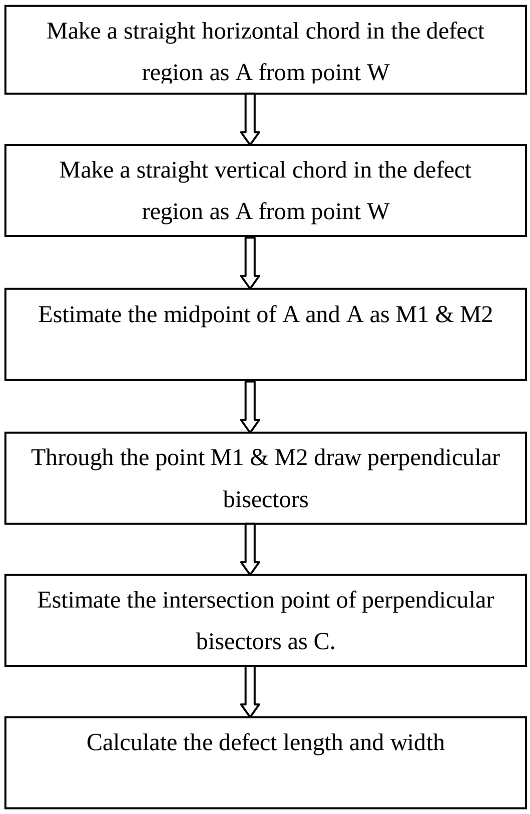


Figure 6: Flow chart for Flat bottom hole characterization algorithm

The corresponding point is the centre coordinates of the flaw. From the centre point, a straight line is made until the edge point. This will give the length of the flaw. In this flat bottom hole defect case, the width of the flaw is identical to the length of the flaw region.

3.6.1 Rectangular Notch Defect

The pipeline defect may perhaps also be in the shape of rectangular notch. The rectangular defect image is shown in Figure 7.After segmentation of brighter defect region by K-means algorithm and thresholding technique, the binary image is obtained with white pixel region in place of the defect region.

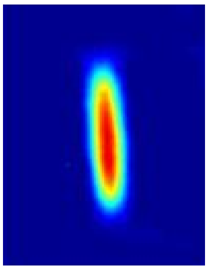


Figure 7: Rectangular Notch Defect Image

The flowchart for Rectangular notch characterization was elucidating in Figure 8. The Defect region coordinates (X, Y) that is, white region coordinates in the segmented image are stored.

$$[X, Y]= [\, x_1, x_{2,} \ldots\ldots x_n ; y_1, y_2 ,\ldots\ldots y_n \,] \quad (4)$$

From the stored coordinate the length and width must be computed. In order to characterize the width the difference between maximum and minimum of stored X coordinate is obtained. Since the width is varied along the X coordinate, the Y coordinate remains constant.

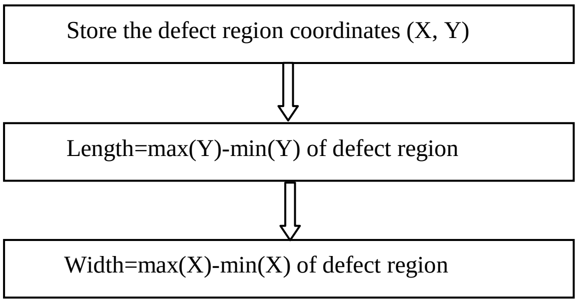


Figure 8: Flow chart for Rectangular Notch characterization algorithm

$$\text{Width}=[x_n - x_1] \quad (5)$$

Similarly the length is characterized by taking the difference between maximum and minimum of stored Y coordinate.

$$\text{Length}= [\, y_n - y_1] \quad (6)$$

Thus, the length and width obtained give the notch dimension.

4. RESULTS AND DISCUSSION

The input image obtained from MFL technique is RGB which is shown in Figure 9 (a to d) & in Figure 11 (a) which is initially preprocessed using median filtering. Then by K-means algorithm the defect region is segmented as one of the K clusters clearly. The segmented defect region is thresholded by Otsu's thresholding method. Thus, the binary image, the white region represents flaw region and black region represents the background, is subjected to characterization.

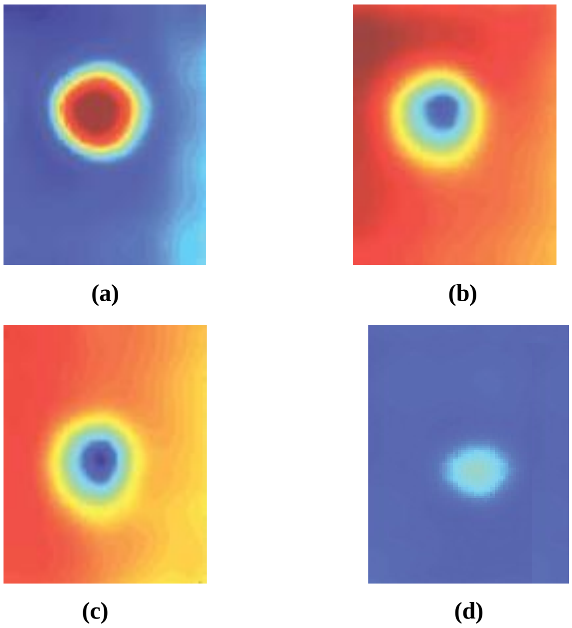


Figure 9: (a) to (d) Original Flat bottom hole defect Images

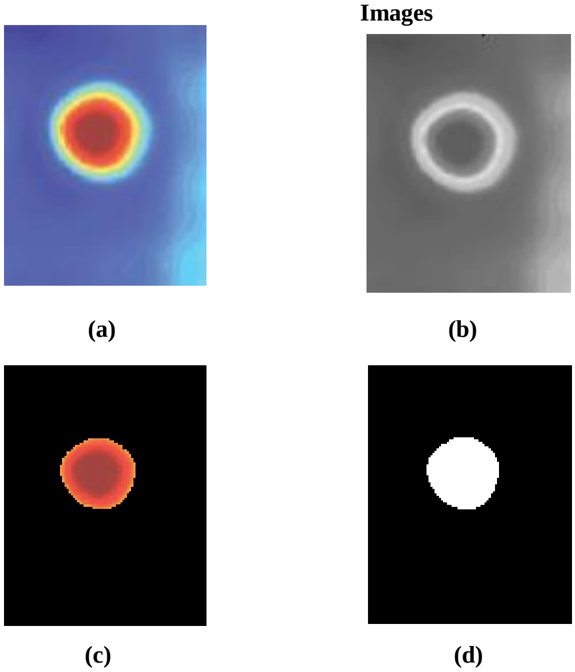
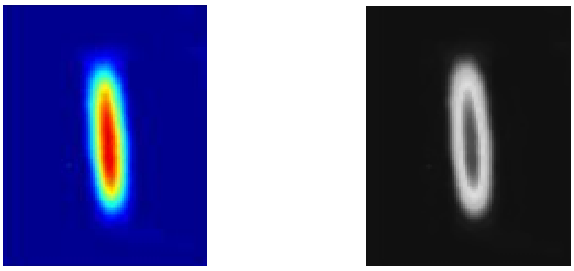
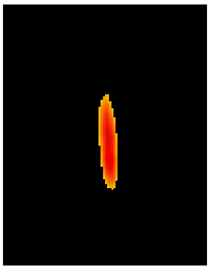


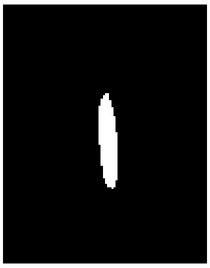
Figure 10: (a) Original Flat bottom hole defect Image. (b) Filtered image. (c) K-means Segmented defect region. (d) Thresholded image.



(a) **(b)**



(c)



(d)

Figure 11: (a) Original Rectangular Notch Image. (b) filtered image. (c) K-means Segmented defect region. (d) threshold image.

By the above discussed characterization algorithms the thresholded image (d) from Figure 10. and (d) from Figure 11. are characterized.

Table 1 & 2 depict the characterization result for Flat bottom hole and rectangular notch defects.

Table 1. Results for Flat Bottom Hole Defect

Fig	Dimensions	Defect Area
Flat bottom hole defect		
Fig 9(a)	Diameter=37 pixels	865 pixels
Fig 9(b)	Diameter=29 pixels	594 pixels
Fig 9(c)	Diameter=32 pixels	736 pixels
Fig 9(d)	Diameter=26 pixels	436 pixels

Table 2. Results for Rectangular Notch Defect.

Fig	Dimensions	Defect Area
Rectangular Notch Defect		
Fig 11(a)	Length=60 pixels Length=14 mm Width=8 pixels Width=1.8mm	373 pixels

5. CONCLUSION

In this paper, the image processing algorithm is proposed for detection and characterization of the defect in Magnetic Flux Leakage (MFL) images. The acquired MFL image is undergone preprocessing stage. In the preprocessing stage the noises in the images were eliminated by the filtering process. Then the filtered image is segmented by K-means algorithm and the region of interest is identified. Otsu's thresholding method is applied to the segmented defect image to separate the image into two regions. The segmented defect region is characterized by different algorithms according to the defect shape. As a conclusion, the proposed technique contributes the characterization of the defects. The considered technique presents the advantage of analyzing non accessible pipes and allows overcoming the main drawbacks of the other techniques.

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7. REFERENCES

[1] Gongtian Shen and Tao Li. 2007. Infrared thermography for high-temperature pressure pipe. Insight Vol 49 No 3 (March 2007).

[2] Lijian YANG, Gang LIU, Guoguang ZHANG, Songwei GAO.2008. Inspection and Identification of Inner-outer Defects on oil-gas pipeline. 17th world conference on Non-Destructive Testing, Shanghai, China. (Oct 2008), 25-28

[3] Neil R. PEARSON, Matthew A. BOAT, Robin. H. PRIEWALD, Matthew J. PATE, John S. D. MASON. 2012. Practical capabilities of MFL in steel plate inspection. 18th World Conference on Nondestructive Testing, Durban, South Africa. (16-20, April 2012), 1-8.

[4] Vit Setnicka, Rudolf Zubal, Mojmir Kollar, Sensing, scanning and Data Acquisition Tools for MFL Testing.

[5] G. M. Atiqur Rahaman, Md.Mobarak Hossain. 2009. Automatic defect Detection and classification technique from image: A special case using ceramic tiles .International Journal of computer science and information security vol 1 No 1.22-30.

[6] Anil Z Chitade, Dr. S.K. Katiyar.2010.Color based Image segmentation using K-means Clustering. International Journal of Engineering Science and Technology Vol 2(10). 5319-5325.

[7] Ali Salem Bin Samma and Rosalina Abdul Salam. 2009. Adaptation of K-Means Algorithm for Image Segmentation. International Journal of Information and Communication Engineering .270-274.

[8] B. Karthikeyan, V. Vaithiyanathan, B. Venkatraman, M. Menaka. 2012. Analysis of Image Segmentation for Radiographic Images, Indian Journal of Science and Technology Vol 5, Issue 11. 3660- 3664

[9] Zhang Mingzhu, Cao Huanrong.2008. A new method of circle's centre and radius detection in image processing. International conference on Automation and Logistics.2239-2242.

[10] Rafael C.Gonzalez, Richard E.Woods, (2005) Digital Image processing, Pearson Education, Inc.,