Crack Detection Using Image Processing

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Abstract: In this paper crack detection using image processing is studied. Image processing technique is an effective tool used for crack detection in engineering materials and there is an increasing interest in image-based crack detection for inspection. Cracks are an important parameter to be identified when it comes to safety of materials or infrastructure. Cracks leads to fracture which in turn leads to failure of material so it is necessary to find a method that is easy to analyze the properties of a material in identifying crack which occurred in a structure due to cycling loading, fatigue stress, internal stress, exposure to high temperatures and to eliminate manual inspection in most of the real time applications, Image processing methods are helpful in determine defectives which leads to automated inspection replacing old manual methods. Thus, industries find a great advantage in identifying defective items by implementing image processing techniques and which substantially leads to their increased production run and image processing finds many more applications in today's technological world like cancer imaging, brain imaging, remote sensing, moving object tracking, defense surveillance etc.
Research also focuses on the various image processing techniques used to detect crack. Based on the review, analysis is done, and a suitable conclusion is drawn. This approach has helped in elevating our control over manual inspection.

Index Terms **- Crack detection; image processing; MATLAB; techniques.**

I. INTRODUCTION

Cracks cause fracture which leads to the detachment of a body into two or more pieces as a result of more stress. Fast fracture occurs when a formed crack in a material suddenly becomes unstable and grows rapidly through the material. This form of fracture is highly undesirable. It is a sudden failure that occurs without warning.

There are two types of fracture occur in most engineering materials, either ductile or brittle. Ductile fracture is characterized by large amounts of plastic deformation before failure. This form of fracture includes large amounts of energy absorption (high toughness). Brittle fracture is characterized by low plastic deformation and small amounts of energy absorption at failure (low toughness). In addition, effects like thermal expansion and contraction, human damage and surface changes transcend material discontinuities which lead to failure. To prevent this damage a Crack detection process is employed. The crack detection can be done using two ways: (1) Manual Inspection (2) Automated Inspection. In standard methods, manual inspection was done by set of skilled inspectors with the help of surveying instruments and visual examination to detect the irregularities and defects in the structure. However, this method has certain drawbacks, as it is impossible for a crew to detect the cracks in unreachable areas such as large dams, monuments, buildings, etc. and the estimation of size, length and width of the crack.

In order to acquire images of the structure in a required manner there is a need of a high-resolution camera to get desired results through image processing method. Because of its accuracy and simplicity in its results many of the image processing techniques were proposed. Image processing techniques such as Morphological approach, Hough transform, Edge detection Dijkstra's algorithm, Neural Network, Statistical approach, image Segmentation are the process that have been focused in this literature. Software's like image processing lab, ImageJ, Open CV and MATLAB Graphical User interface can be developed for easy observation and straight away inspection through which data can be extracted.

Crack detection using image processing: The steps involved in image processing techniques are as follows: (1) Acquisition of an image with the help of a HD camera as a crack image as an input. (2) After acquisition, the collected images go through pre-processing where it undergoes processes such as scaling and segmentation. (3) In color image processing, some of the techniques are used to process the deducted image. (4) Finally, the feature extraction of image is done to obtain the shape of the crack.

II. LITERATURE REVIEW

Putti Srinivas Rao, V. Ramakrishna and N.V.D Mahendra [1] presented procedures of experimental and analytical modal analysis of cantilever beam used for vibration-based damage identification using an artificial neural network (ANN). It is a part of structural health monitoring. A cantilever beam of longitudinal crack at different crack lengths in materials was examined for analysis. The analytical modal analysis was performed using ANSYS 15. The geometric models for analytical modal analysis were developed using software CATIA V5R20.

Putti Srinivasa Rao and Ch. Ratnam [2] have developed an approach for the health monitoring of structures capable of identifying the damage at the earliest possible stage using the acceleration time response data obtained from piezoelectric accelerometers. In this, a unique combination of data-based models to extract the damage sensitive features and Shewhart control charts to monitor the variations of the selected damage sensitive features are presented.

Putti Srinivasa Rao and P. Venkata Sai Chinnaji [3] have proposed dynamic parameters of an inclined rectangular cross-section cantilever beam in transverse vibration are studied. Vibration analysis is an effective tool used for crack detection under non-destructive testing for machinery. The modeled structures for rectangular cross-section beams of different crack depth and crack locations and crack angle were developed using CATIA. Modal analysis and harmonic analysis were parameters and harmonic responses using ANSYS and Modal Analysis using Hyper Mesh. It is seen that due to presence of presence of cracks the stiffness, frequency changes. The Natural Frequencies obtained from model analysis using ANSYS, Hyper Mesh and MATLAB are verified with the harmonic analysis results.

Putti Srinivasa Rao and Ch. Ratnam [4] have developed a health monitoring of weld structures using acceleration time response data. Residual errors are extracted from the measured acceleration time response data using an auto-regressive model. Damage identification is done by monitoring the residual errors using Shewhart and exponentially weighted moving average control charts. The applicability of the proposed method is tested with the welded structure model. Five damage levels are investigated, and the damage is introduced by cutting a slot in the weld using an electrical discharge machine. Acceleration time response data are acquired using piezoelectric sensors for all damage levels. The results show the both Shewhart and exponentially weighted moving average control charts can identify the presence of damage in the welded structure model under consideration. Exponentially weighted moving average control charts are more sensitive in damage identification than Shewhart control charts.

Yiyang et al. [5] have proposed a crack detection algorithm based on digital image processing technology. By pre-processing, Image segmentation and feature extraction [5], they have obtained the information about the crack image. In [5], Threshold method of segmentation was used after the smoothening of the accepted input image. To judge their image, they have calculated the area and perimeter of the roundness index. Then by the comparison, they have evaluated the presence of the crack in the image.

Nguyen et al. [6] have proposed a method based on the edge detection of concrete cracks from noisy 2D images of concrete surfaces. They have observed the cracks as tree-like topology. Then based on the PSCEF non-crack objects were eliminated. After the separation, thresholding filter, and morphological thinning algorithm have been used to binarize the image for the crack Centre line estimation. Then the Centre line was fitted by cubic splines. They have connected the edge points to form the desired continuous crack edge. From the crack edge, the surface of the crack was obtained.

Lee et al. [7] have designed a system for particle crack detection. They used the nearest neighbor and two-point correlation methods for the estimation of the second order micro structural descriptors. Based on the probability function of their corresponding location the crack features were determined. The edge effect was removed by the nearest neighbor estimate from the high-resolution montages.

Shiva prasad K et al. [8] have proposed a simple technique to detect cracks in pavements such as roads and concrete structures. They used normal edge detection algorithm as a primary step as a pre-processing part to detect the false edges of the crack. The false edges were removed by using morphological approach. The drawback of the method was the obtained output images contained false edges which increased noise in the images. Proposed method was well suited for the pre-dominant cracks. As an extension to their method they also used thresholding technique, and the obtained results were good.

Gunkel et al. [9] have designed a crack detection algorithm. The micro cracks are detected using shortest possible path in crack clusters which also follows the darkest parts. They used Dijkstra's edge detection algorithm to detect the crack path which enabled in analyzing kinks and curves of the crack. The method was implemented in C and R programming language package which provided accurate results.

Kammar et al. [10] have proposed a system for road crack detection and characterization to minimize the human involvement. In this type of imaging, they used Hough transformation for crack detection and supervised method for the characterization of crack which is based on block-based image analysis approach. For each pixel the Hough transform determines the straight line of that pixel and calculates the slope of the line by mapping Cartesian coordinate into rotational coordinate system. Based on the obtained results the cracks were classified and this two-step approach proved to be robust.

Pathak et al. [11] have presented a fuzzy logic approach for crack detection which is an alternative for non-destructive test. They used natural frequency of the cracks in a beam as an input to the fuzzy logic. The relative output obtained was the crack depth and relative position of the crack. Accordingly, the fuzzy controller was prepared for varying natural frequencies. At the end, they [8] were able to predict the location of the crack and crack depth within nanoseconds which saved computational time.

Zhang et.al [12] supervised the subway tunnel using Complementary Metal Oxide Semiconductor camera. The captured images were stored in digital images. For extracting the data from the images, they studied and formulated an algorithm using morphological and thresholding technique. The extracted images were compared with grayscale images and they found that over 90% of crack length is preserved in the last output image of binary images. Additionally, the algorithm bottom hat transform proposed by them helped them for the classification and crack detection purpose. The experimental results were based on different parameter settings which showed that high accuracy can be obtained by using different types of classifiers. However, their experiments were subjected to eclectic cracks. These techniques were applicable for the cracks of split width greater than 0.3mm and object length greater than 15cm, which was the drawback of the project.

III. IMAGE PROCESSING TECHNIQUES

This section covers the analysis of the crack detection using image processing techniques. Based on the paper reviewed, it was observed that edge detection method, image segmentation by thresholding and Morphological approach was used in almost all the papers [5, 6, 8, and 9] and [12].

Apart from image processing methods, this section also covered about analysis of crack detection and damage detection using ANSYS and CATIA in [1, 2, 3, 4] papers.
Different analysis and experimental procedures to detect damage in engineering structure were discussed in [1, 2, and 4] papers.

Edge detection method is an image processing technique for finding the boundaries of objects within images. It works by detecting discontinuities in brightness. Edge detection is a method implemented for image segmentation and data extraction in areas such as image processing, computer vision, and machine vision.

Image Thresholding is a simple and effective way of partitioning an image into a foreground and background. This image analysis method is a type of image segmentation that isolates objects by converting grayscale images into binary images. Image thresholding method is most effective in images with high levels of contrast.

Morphological approach makes use of broad set of image processing operations that process images based on shapes. In a morphological operation, each and every pixel in the image is adjusted based on the value of other pixels in its area of neighborhood. By selecting the size and shape of the neighborhood, we can construct a morphological operation that is sensitive to specific shapes in the input image.

The basic morphological operations are dilation and erosion. Dilation adds pixels to the boundaries of objects in an image, while erosion operation removes pixels on the object boundaries. Dilation and erosion operations are often used in combination for specific image preprocessing applications, such as filling holes or removing small objects.

For robust results the Hough Transform was used [9]. Due to its desirable features and real time inspection Hough transform are used for object recognition. Moreover, the statistical approach proved to be efficient and accurate for data analysis and filtering of images.

For reduced computational time, fuzzy logic [10] is suitable method which predicted the cracks in nanoseconds. For easier segmentation of images in pre-processing stage techniques like HSV thresholding were adopted which enhanced the quality of image making it more identifiable. Finally, analysis based on the image processing techniques reviews the fact that the productivity of image processing techniques was introduced only in the post-processing.

IV. RESULT AND DISCUSSION

The output of program in MATLAB for a given input image and process of steps involved is as shown in following figures

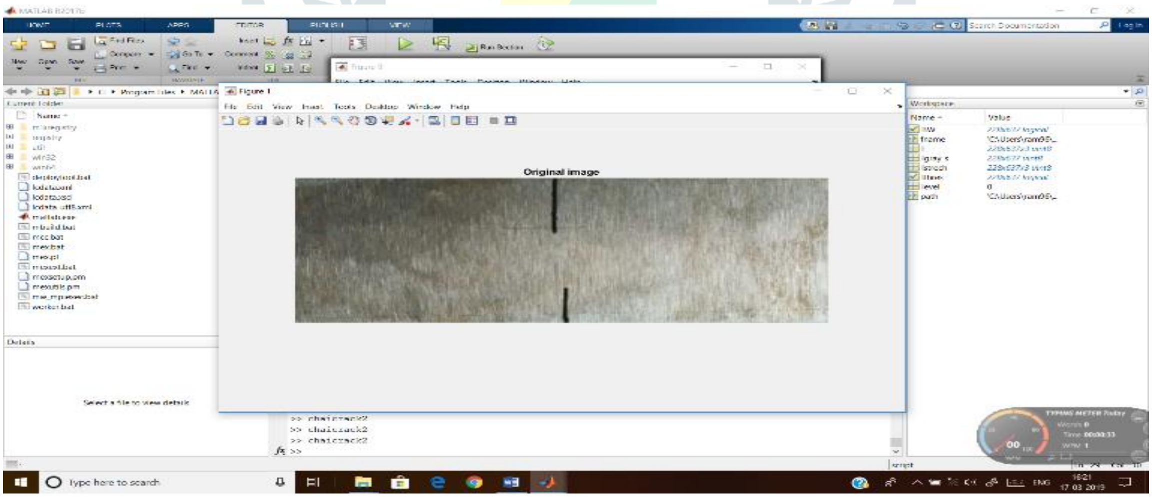

Figure1-Original Image

Figure 1 shows original image that is loaded in MATLAB and displayed using MATLAB function (imshow) as shown in Figure1.Further image filtering operations are performed on this original image to determine crack existing in this input image.

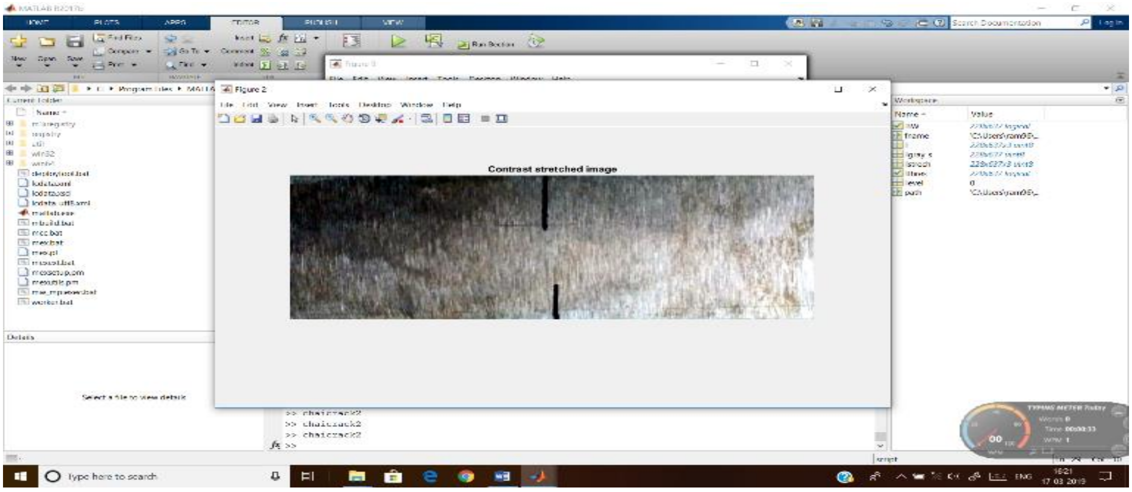

Figure2-contrast stretched image

Figure2 shows a contrast stretched image, Contrast stretching (often called normalization) is a simple image enhancement technique that attempts to improve the contrast in an image by `stretching' the range of intensity values it contains to span of desired range of values.

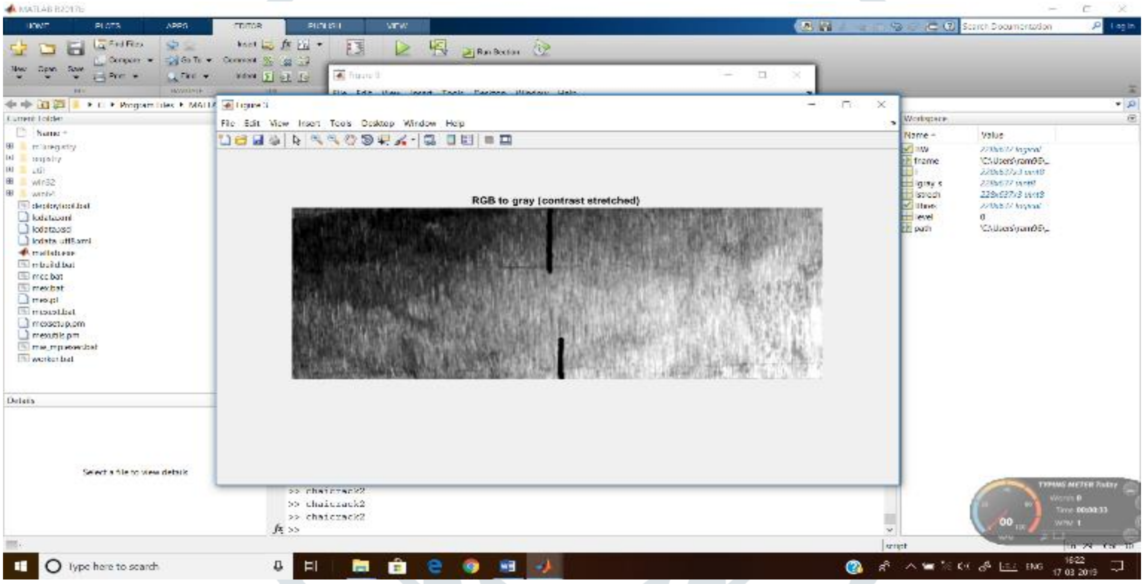

Figure3-RGB to gray image

Figure 3 shows a gray image, MATLAB function I=rgb2gray (RGB) converts the true color image RGB to the grayscale intensity image I. The rgb2gray function converts RGB format images to grayscale image by eliminating the hue and saturation information while retaining the luminance.

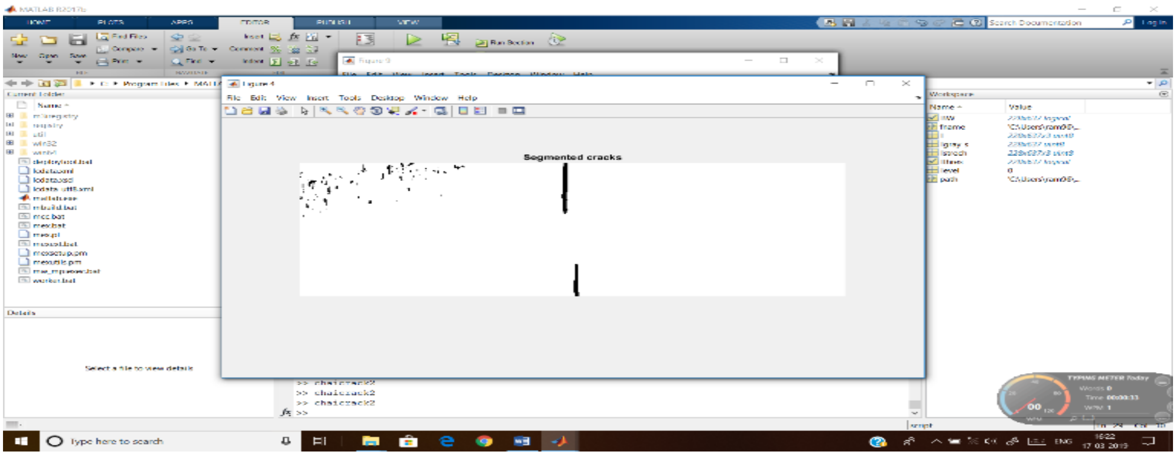

Figure4- Cracks Image –Segmented

Figure 4 shows a segmented image and Image segmentation method is the **process of partitioning a digital image into multiple segments called sets of pixels,** also known as super-pixels. The main goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze.

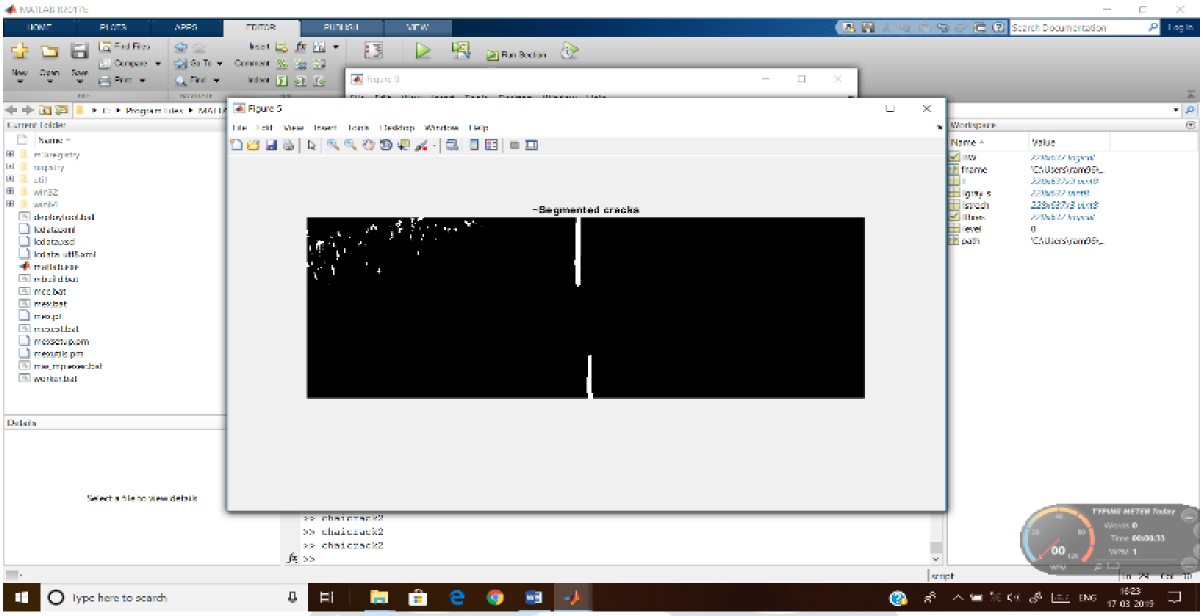

Figure5-segmented cracks image

Figure 5 shows a segmented image like Same as in Figure4 but here in this binary image, crack is indicated in white pixels surrounded by black pixels in remaining portion where as in Figure 4 crack is indicated by white pixels whereas remaining portion of image is in black pixel form.

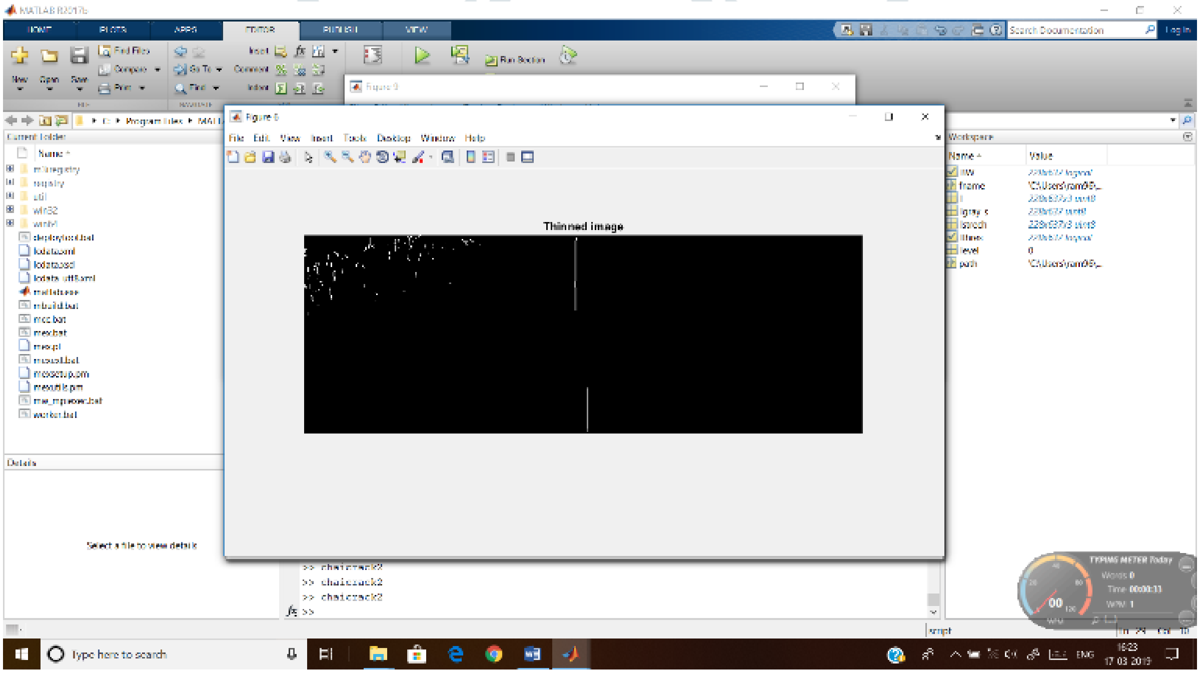

Figure6-Thinned Image

Figure 6 shows a thinned image; Thinning is a morphological operation that is used to remove selected foreground pixels from images.

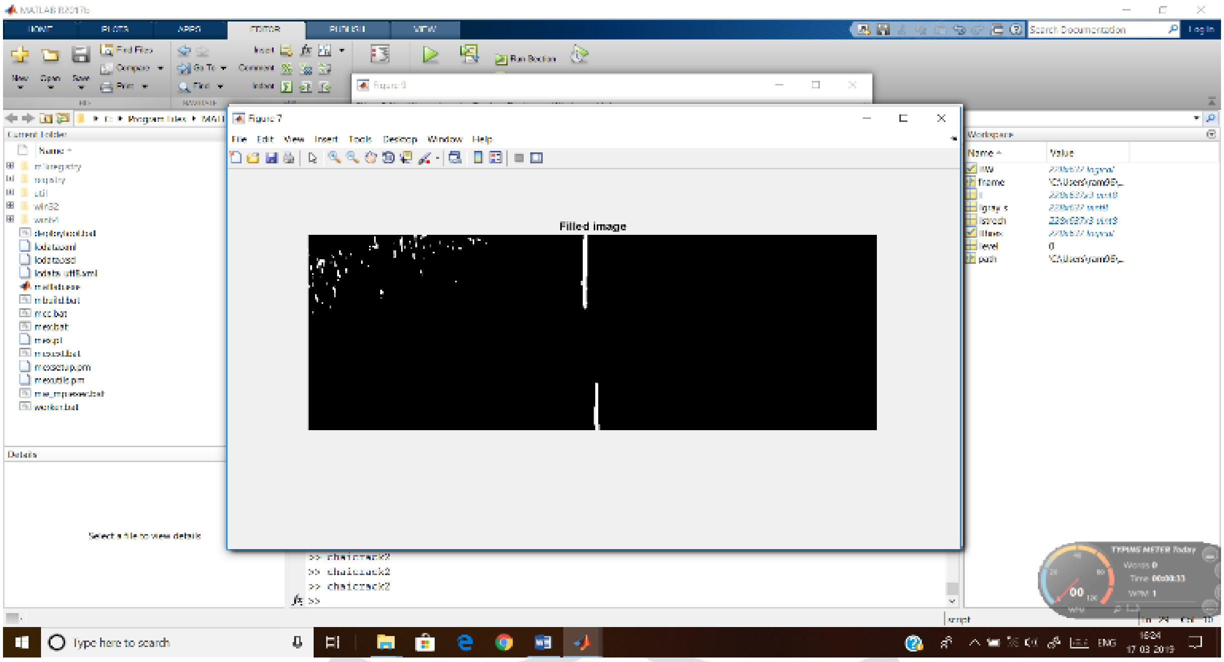

Figure7-filled image

Figure 7 shows a filled image, Using MATLAB function imfill command; it fills image regions and holes. Filling is a Morphological operation to Fill or close Gaps in an Image - Reads a binary *image* into the radius of 10 pixels so that the largest gap gets *filled*. Thereby where large gaps mean we understood that there is a crack in that position.

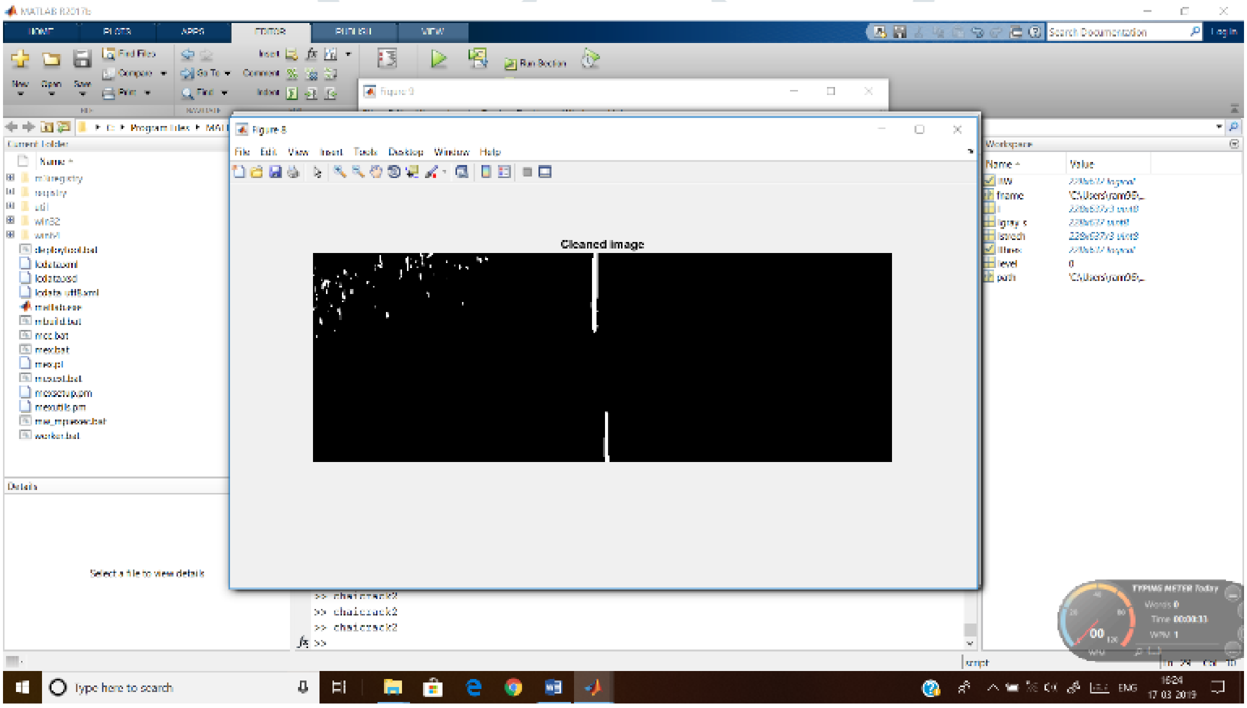

Figure8-cleaned image

Figure 8 shows a cleaned image, cleaning process clears back ground noise from image and maintains uniform brightness all over the image, removes those white pixels which are surrounded by black pixels at a location.

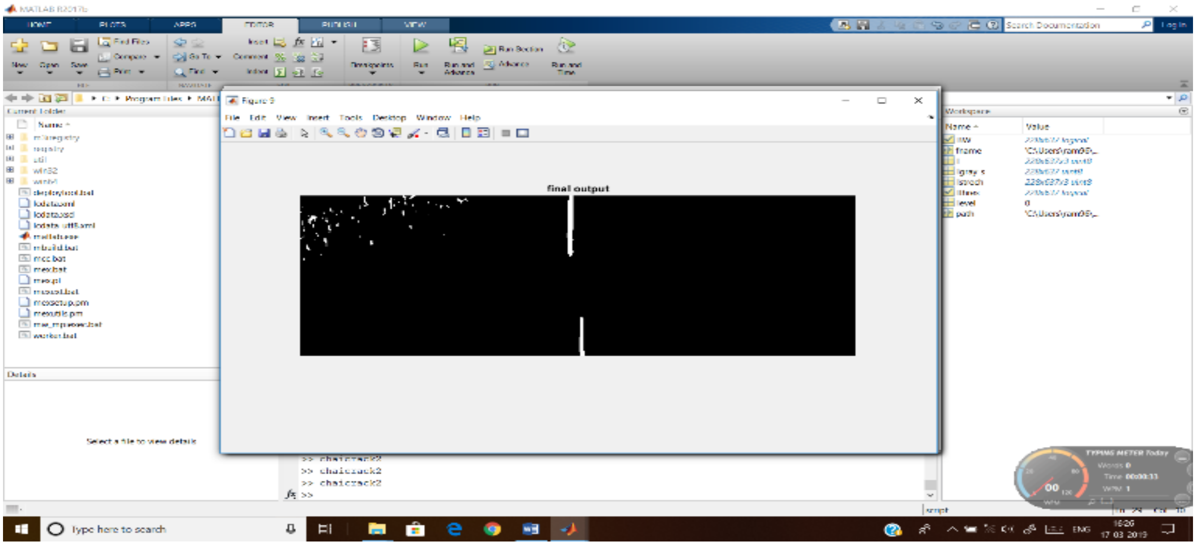

Figure9-final output

Figure 9 shows final output image in which the crack is detected and indicated in white region in the output binary image.

V. CONCLUSION

This paper provides detailed survey of the image processing techniques used to detect cracks in engineering structures. The main aim of the study was to review papers and analyze the best technique that could be used for crack detection. Based on the paper reviewed we conclude that the image processing techniques such as edge detection and image segmentation by Thresholding are the most suitable for crack detection. An automated based inspection based on image processing techniques in identifying cracks in structures proved to be efficient and in real time reducing great human effort and time. This literature encourages studying more on different image processing techniques that can be employed to determine cracks in engineering structures more accurate and error free.

VI. REFERENCES

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