iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL
FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 Issue: IV Month of publication: April 2021

DOI: https://doi.org/10.22214/ijraset.2021.33567

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue IV Apr 2021- Available at www.ijraset.com

Crack Detection and Monitoring of Shaft using Artificial Intelligent Way

Mubashir Ramzan[1], Er. Puneet Bansal[2]
[1]Student, Master of Technology, [2]Assistant Professor, Mechanical Engineering, Desh Bhagat University, Mandi Gobindgarh, Punjab, India

Abstract: In the process of core manufacturing the quality control and its management detection of cracks is one of the fundamental steps of panel products. Old methods used for detection of cracks are quite costly and also takes enough time and maximum of these techniques could only be executed by experts only. So there is need of some fast, accurate and reliable method which should also be automatic so that crack can be detected by without the human intervention.

In this thesis a smart way of detection of cracks is proposed which is relied on image processing. Here images are captured by the camera and then are examined for whether cracks are present in the mechanical panels and not. Crack detection and as well as its exact position cannot be easily examined by human eye but the camera system can easily recognize the hole or some crack present in the image captured of mechanical device. Crack can be holes or it can be a straight or curved line present in the part. So the proposed system should be able to detect all the irregularities present in the mechanical part.

To check and show the capability of the proposed system different mechanical panels and other mechanical parts will be examined and after performing different tests the worthiness of the proposed system will be shown. The system will be evaluated for fast execution time and accuracy of finding the cracks in the mechanical parts.

I. INTRODUCTION

A. Development

Various kinds of mechanical components as well as parts are designed and manufactured by sheet metals with various manufacturing processes in the industry. Along and in amid these processes which have punching, blanking, embossing and other processes the material undergo huge transformations and various deformations occurred in the material as well as in the tool. As a result of it there is various kind of manufacturing defects occurs like cracks, necking and marking lines [1, 2]. So it is necessary to detect these defects. At present crack detection is basically performed by human only. Also this process of mechanical crack detection solely depends on the speed as well as on the skill and also on the experience of human. And also this way of detection is not much reliable as well as unstable in various cases. Due to this reason, there is need of the development and implementation of an automated and accurate crack detection technique. [3-6]

Out of various crack inspection methods for mechanical parts one technique is to monitor the vibrations of pressure signals of a press line. If there is some variation or deformation in shape then it means press line is not working properly. Now the limitation of this method is that it is not efficient for individual panel monitoring. [3-12]

Rotating machineries parts a significant part in all industries. There are various applications of it which include turbine as well as generator in various sectors like power, airplanes, ships, automobile, household etc. For rotating machinery the shaft plays a very critical part as the all power is transmitted with the rotating shaft. If there is various fatigue cracks are present in the shaft then it will lead to a source for their catastrophic failure. With the failure of a machine due to rotating shaft could outcome in the increase in cost of maintenance as well as loss of safety and more of it is the increase in the downtime. Therefore, it is significant to assess the health as well as shaft continuously for its safe working operation. [10]

There are various kinds of crack detection methods and all of these techniques have their own advantages as well as limitations which further depend upon the that situation. At present there are various non-destructive techniques which are also known as NDT are available which are found suitable to detect cracks such as radiographic ultrasonic testing as well as X-ray. Limitation of these methods for detecting cracks in shaft is that the shaft is not easily accessible. Also one of the reasons is that the radiographic testing could be used only for material with small thickness and the limitation of the ultrasound method is that if the crack surface is along the parallel direction to the ultrasonic beam then the system could not detect the crack. [12]

If the cracks are present in a shaft then it varies the flexibility internally and so its dynamic behavior all around. Vibrational method provides a way to identify the cracks in a shaft with the measurement of vibrations in cracked shaft.

Benefit of the vibration relied crack identification method is that it is non-destructive as well as it can be utilized for inaccessible machine components. It is found that the shaft may have more than one or more fatigue crack and so there is a need of some sort of crack detection method to solve this problem.

It is found that in the high-speed rotating machinery there is presence of the high torsional as well as radial loads and together with a high load of rotor motion it can create severe mechanical stress conditions and finally can lead to the introduction of a rotor crack. Among the various mechanical faults like unbalance in a rotor and other reciprocating unbalances, various types of misalignment and other mechanical run-outs, faults in gears, etc., the crack in the rotor is found to be the one of the most serious and fatigue fault. [2-5]

There are various reasons which can lead to generation of the crack in a shaft. One of the reasons can be the fluctuating load in the shaft. Usually, these cracks introduces at the point of stress concentration. So, these types of cracks might produce near the region such as oil holes, keyways, screw threads or also near other abrupt variation in the cross section of the shaft. It includes steps cut on the shaft to mount various mechanical parts like gears, pulleys and it can be bearings also. Various discontinuities like microscopic as well as submicroscopic like inclusion of foreign materials or alloy segregation, and other discontinuity could also produce severe stress concentration. Also there are various circumstances that can accelerate the crack initiation like residual tensile stress, elevation and cycling of temperature and presence of a corrosive environment. [26]

Cracks as well as deformation detection are one of prime indicators when we think about the safety of an infrastructure. Also the cracks are produced due to various effects like cyclic loading, fatigue stress that introduces internal stresses in the structure as well as other effects. Also in addition to it, various effects such as thermal expansion as well as contraction, human damage and surface variations, material discontinuities could generate cracks in the material part. So for preventing this type of damage in the mechanical process a crack detection process should be employed. There are two ways of crack detection:

1) Manual Inspection
2) Automated Inspection.

Figure 1.1: Traditional Machine for Crack Detection [40]

When we talk about traditional methods, manual inspection is performed by various groups of human which are skilled inspectors and which utilize the various types of surveying instruments and by using these instruments persons perform visual examination for detection of various irregularities as well as defects present in the mechanical structure. However, this technique has limitation like maximum times it is not handy for a group of persons to detect and locate the crack in inaccessible regions like inside the mechanical part or downside of the shaft, etc. and not easy to find the estimation of size, length and width of the crack. [20]

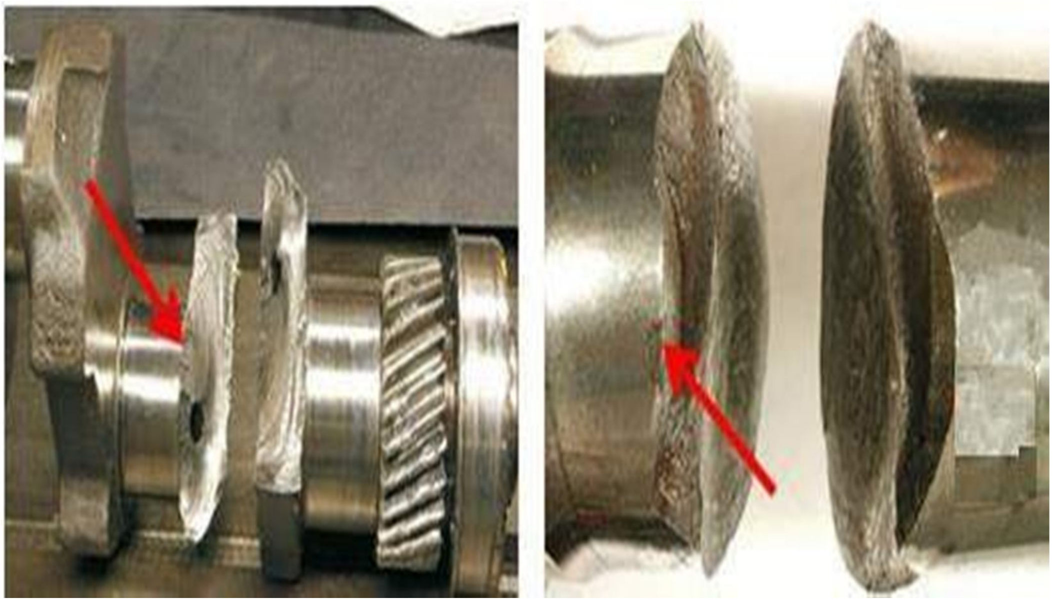

Figure 1.2: Cracked Pieces of Shaft [11]

In contrast to various manual crack detection methods image relied crack detection techniques could provide many benefits over present techniques as this technique is non-invasive, accurate, and could be easily implemented in the manufacturing. So there is need of study on image processing for crack detection in mechanical parts. [9]

From the literate survey it is found that the image processing relied techniques for crack detection in mechanical parts can provide fast inspection of large region of mechanical surface. Also it is found that the stable as well as accurate inspection is possible with this type of an automated process. In order to get digital images of the mechanical part in a required manner there is a need of a high resolution camera to get desired results through image processing.

It is studied that the image processing techniques like Morphological methods, Hough transform, Edge detection, Dijkstra's algorithm, Neural Network and image segmentation are the various methods can be utilized for detection of crack in the manufacturing sector. Various software's like OpenCV and MATLAB Graphical User interface can be utilized for developing techniques which is utilized to monitor as well as for the real time invigilation through which cracks can be extracted. [12-19]

B. Various Types Of Cracks Present In The Shaft

There are various types of cracks which can be present in the mechanical shafts are described below.

1) *Transverse Cracks:* These cracks are always found to be normal to the axis of shaft and are supposed to be general and are found to be very dangerous. This is due to the fact that these cracks can lower the cross-section area of the shaft and that in turn can lead to failure of motor. Also it is found that it occurs due to localization of strain energy at a particular location in shaft. [18]
2) *Longitudinal Cracks:* These particular sort of cracks are always found to parallel or along the axis of a mechanical shaft.
3) *Slant Cracks:* These particular types of cracks are found to be produced at some type of angle to the axis of a mechanical shaft. These cracks are found to affect the torosional nature of the mechanical motor.
4) *Breathing Cracks:* These types of cracks are found to be generated when shaft is under very high tensile stress or any other load. Basically it is found that when the tensile stress is applied then the cracks are widened and upon releasing the stress cracks are closed as a result of it these cracks are known as breathing cracks. Now it is found to be happened when running speed is quite slow and also the radial force is quite high as well as cracks are just tiny in size.
5) *Gaping Cracks:* These cracks are usually open at every time. Their other name is notches.
6) *Surface Cracks:* These cracks are supposed to be appears on the upper layer of the shaft. These cracks can be detected by visual inspection or by using camera intelligent systems.
7) *Subsurface Cracks:* These types of cracks are present on the inner layer or side of the surface of the shaft. Various methods like ultrasonic, magnetic particle and shaft voltage drop are generally utilized to detect these cracks.

C. Various Causes Responsible For Crack Generation In Shafts

Cracking of shafts happened due to various reasons which include various life cycle fatigues as well as any other type of corrosion or many more reasons.

1) *Crack Initiation:* Here cracks are initially started to appear but are not recognized by the system. These initiations can be due to increase in mechanical stress like area of cross-section variations, denting as well as grooving or might be due to porosity as well as presence of voids also.
2) *Propagation of Cracks:* Now when cracks are not analyzed in the starting or initial stage then the discontinuity increases in shape as well as in size. There are various reasons due to which rate of growth of shaft crack increases. Some of them are listed here. [14]

It was found that the various operating faults like sustained surging in various types of compressors, negative sequence current could generates it.

a) Also the presence of various residual stress which also include welding heat affected areas in the rotor material.
b) Various types of thermal stresses
c) Various metallurgical problems like due to hydrogen in steel, increase ductile–brittle transition temperature which is also known as DBTT, due to carbide precipitation in various alloy steels
d) Various environmental effects like presence of a corrosive medium.

D. Matlab Software

Matlab's library has supposed to be including various toolboxes out of which Image Processing Toolbox has mostly found to be usefulness in medical purposes as well as with mathematical problems. This thesis has been utilizing image processing ability of Matlab to have optimized results for detecting cracks in the mechanical parts. [39]

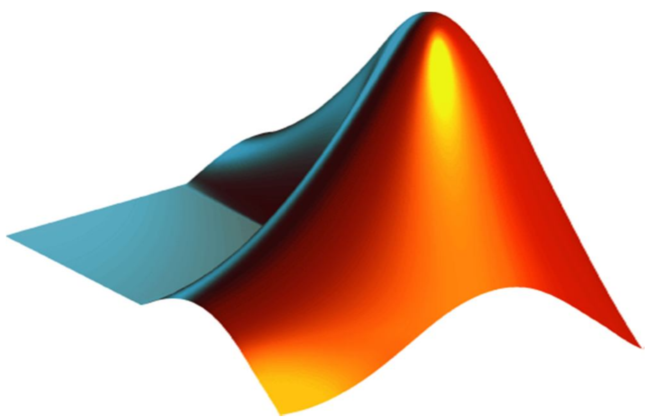

Figure 1.3: Matlab Logo [39]

Matlab comes from two words. First one is matrix and another one is laboratory. The MathWorks which is the parent company of Matlab product is known as a technical computing programming language. This language is utilized mostly for very high performance scientific numeric calculations as well as for the visualization purposes in the real world scenarios. Matlab readily integrates various scientific as well as mathematical concepts like computing, programming, analog as well as digital signal processing and in the field of computer graphics in a very systematic way to use environment. [39]

Matlab is usually widely utilized to analyze every kind of data, its modeling, and its simulation and in the end the statistics also. Matlab high-level programming language finds implementation in other fields of science like biology, chemistry, economics, medicine and many more.

Most valuable feature of Matlab is its easy extensibility. This matlab environment allows creating new applications and becoming contributing author. It has evolved over the last 2 decades and with its long success it now became a perfect tool for research, with optimized development as well as analysis. Matlab also has a vast featured set of specific types of libraries which are known as its toolboxes. These toolboxes can be utilized easily to solve a particular kind of problem in a specific area. Matlab System supposed to be consists of five main parts. First part contains the Desktop Tools as well as the Development Environment and these set of tools are helpful while working with various functions as well as files. [39]

Second part is The Matlab Mathematical Function Library. This is a very wide collection of various types of elementary functions like sum, multiplication, sine, cosine, tangent, etc. Besides these simple mathematical operations, various other more complex arithmetic calculations can be calculated which includes matrix inverses, Fourier transformations as well as approximation functions. Third part is the Matlab language itself which is a high-level array language with various types of functions with data structures as well as object-oriented programming features. This part allows programming of small applications as well as large as well as complex programs. Fourth piece of Matlab System is its graphics capability. It has collection of wide tools for displaying graphs as well as functions. It supposed to contain two as well as three-dimensional visualization, image processing, building graphic user interface and even creation of animation. Fifth and last part of this set is Matlab's External Interfaces. This library helps us to writing code in C and Fortran programs, which can be read and connected with Matlab. [39]

Image Acquisition Toolbox is a very valuable collection of various types of functions that handles receiving image as well as video signal directly from computer to the Matlab environment. This toolbox is utilized to recognize various types of video cameras from various hardware vendors. Matlab has specially designed interface which has lead through various possible transformations of images as well as videos which has acquired thanks to mechanisms of Image Acquisition Toolbox. Image Processing Toolbox is very deep set of various functions and various computer algorithms that work along with computer graphics. This toolbox supports almost any general or other special type of image files. It provides the user various types of suggestions for initial and later processing of pictures. There are various types of integrated functions which are only helpful for performing various kinds of digital image enhancements which has various features like deblurring as well as filtering. After this processing various other operations like reduction of noise, spatial transformations, generating specific histograms and varying the values of given threshold and saturation for adjustment of color balance, contrast, detection of objects and analysis of shapes can be performed. [39]

II. LITERATURE SURVEY

R. Gradzki et al. [1] presented a new rotor fault detection technique. The method was relied on a new diagnostic prototype of rotor signals as well as on the external disturbances.

The model utilized various auto correlated functions to measure vibration of rotor. With the proper processing of the measured vibration data, authors were able to compensate the influence of environmental disturbances completely and were reliably able to dictates the possible rotor faults. The propose method had been tested numerically utilizing the finite element prototype of the rotor. Authorhad performed the experiments experimentally at the shaft crack detection test rig. The results had shown the high sensitivity and strong reliability of the method.

H. K. Jung et al. [2] suggested a digital image processing technique for fast as well as automated crack detection for various pressed panel products.

First of all authors extracted the target part from backgrounds of the digital image by taking into account various color as well as brightness attributes. In the next step author extracted edge line of that part by the help of percolation prototype. But authors found that the percolation method was computationally taking more time so in place of it author used the acceleration methodology which was utilized to lower the processing time for percolation. Finally author was able to get location and position of cracks with the proposed unique edge line analysis method. Further to find the validity of suggested method various experimental researches were also performed.

A. Mohan et al. [3] presented a review on the analysis of various kinds of digital imaging processing methods utilized for crack detection in various materials. Authors performed survey on image processing methods like wavelet transform, median filtering, Hat transform.

Morphological approach, Gabor filtering, Otsu's method Data fusion filtering and Hough transform techniques. Relied on the analysis authors focused their review on just five feature set. Firstly, it was an objective relied attribute that had information of width, length of the crack and as well as the direction of propagation of the crack. Secondly, authors analyzed the data sets utilized in the techniques to calculate the real data and so making it very efficient. Finally, authors performed the analysis of each image processing techniques used in each system.

D. L. Sampaio et al. [5] applied the Approximated Entropy (ApEn) algorithm for detecting cracks in a rotating shaft. This algorithm has a statistical value utilized to quantify irregularities in data series. Authors used patterns as well as correspondences amid samples of the identical series which were searched to find various anomalies. Numerical simulations demonstrated that the feasibility of the proposed methodology for detecting cracks was down to 5% crack depths. Authors stated that the ApEn algorithm could differentiate the presence of crack only for misalignment. Authors found the satisfactory results only by considering the rotor operating under run-up conditions which were nonstationary tests.

E. Balasubramanian et al. [8] proposed a technique which had combined methodology of Hat- transform as well as HSV thresholding to detect cracks. Authors had supposed an algorithm that joined the output of the two image processing filters that had outcome in enhancement of an output digital image. The algorithm was relied on mathematical morphological methodology and the result showed that bottom hat transform was very much effective for detecting the cracks quite comfortably in comparison to the Top-hat transform. It was found that when the bottom hat transform was combined with the HSV thresholding then the combination produced the desired output of the cracks.

A. Patil et al. [13] had presented a fuzzy logic approach for crack detection which could be an alternative for non-destructive test. Authors utilized natural frequency of the cracks in an object as an input to the system working on fuzzy logic. Authors found that the relative output obtained was the depth of crack as well as relative position of the crack. Accordingly, the fuzzy controller was prepared for varying natural frequencies. At the end, authors were able to find the location and position of the crack as well as crack depth within nanoseconds which saved computational time and technique was found to be quite efficient.

W. Zhang et al. [14] proposed the technique and implemented it into supervision of the subway tunnel utilizing Complementary Metal Oxide Semiconductor camera. The captured images were stored in digital images folder. To extract the data or information from the digital images authors studied and formulated an algorithm utilizing morphological as well as thresholding methods. The extracted images were compared with grayscale images and it was found that there was over 90% of crack length was preserved in the final output digital image of binary images. In addition of it the proposed algorithm bottom hat transform could be used for the classification as well as crack detection. The experimental outcomes were relied on various parameter settings which showed that high accuracy could be obtained by utilizing various kinds of classifiers.

A. Kammar et al. [15] proposed a system to detect detection of cracks and tried to minimize the involvement of human. Authors utilized well known Hough transformation for crack detection and supervised techniques to locate crack which was relied on block-based image analysis technique. For every individual image pixel the Hough transform finds the straight line of that pixel and tried to find the slope of the line by performing a one to one mapping the Cartesian points in the coordinate into the rotational coordinate system. Depending on the results the cracks were classified. Authors found that the proposed technique is reliable and fast.

Anders L. Om et al. [18] conducted various experiments on steel slabs to detect cracks which were relied on morphological techniques. The research focused on three dimensional surface profile data which was collected by laser triangulation which was further relied on morphological method. Authors had used two types of groups of A and B of 3D type. The data was processed in various regions in the form of digital images of small size. The overall performance of the proposed method was verified by conducting segmenting as well as classifying a second validation set B, which had total collections of 323 regions of three dimensional surface data collected from four various steel slabs.

C. Gunkel et al. [19] had designed a crack detection algorithm. The micro cracks were detected using shortest possible path in crack clusters which has also followed the darkest parts. Authors used Dijkstra's algorithm to detect the crack path which enabled in analyzing kinks and curves of the crack. The propose method was implemented in C as well as in R programming language package which provided good outcomes.

J. T. Sawicki et al. [20] proposed a crack identification approach which was relied on state observers. The rotor model was augmented by providing an auxiliary way of a single degree of freedom. Various state observers were designed for both the existence of the crack as well as its location. The resulting state variables were considered as crack indicators by authors. Form the numerical simulations authors demonstrated that the efficiency of the proposed methodology to detect as well as locate the crack in the shaft.

III. PROBLEM FORMULATION

In the process of core manufacturing the quality control and its management detection of cracks is one of the fundamental steps of panel products. Old methods used for detection of cracks are quite costly and also takes enough time and maximum of these techniques could only be executed by experts only. Crack detection and as well as its exact position cannot be easily examined by human eye but the camera system can easily recognize the hole or some crack present in the image captured of mechanical device.

So there is need of some fast, accurate and reliable method which should also be automatic so that crack can be detected by without the human intervention. The work was carried on MATLAB 2016a and intel 4^{th} i5 (3.2 GHz) with OS window 10 and 16GB RAM at Davinder Iron and Steel Co. (J&K).

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue IV Apr 2021- Available at www.ijraset.com

IV. RESEARCH GAP AND OBJECTIVES

A. Research GAP

After having a comprehensive literature survey, the various research gaps that were identified are as follows:-

1) Mechanical instruments can have rather complicated structures and may change in shape, size and orientation.
2) Crack can be present on edge, boundaries as well as in interior of the mechanical sheets.
3) Web cam quality should also be noted which can also influence the results.
4) In the acquisitions process of camera, it may possible to introduce a certain amount of noise in the image or video signal.

B. Research Objectives

This research work will be focused to achieve the following objectives:-

1) To design, study and implement a mechanical crack detection framework.
2) The proposed framework depends on the artificial intelligence
3) Main focus on improving the speed of detection of cracks, while providing state-of-the-art detection quality.

V. RESEARCH METHODOLOGY

A. Steps And Pseudocode Of Algorithm

The following steps will be performed to complete this research work:-

1) Set the initial point to start the process with webcam on.
2) Capture the background with the webcam.
3) Check the type of crack present in the system using Matlab interface.
4) Check the line type of crack present in the system using interface.
5) Check the accuracy of result obtained from the proposed system.

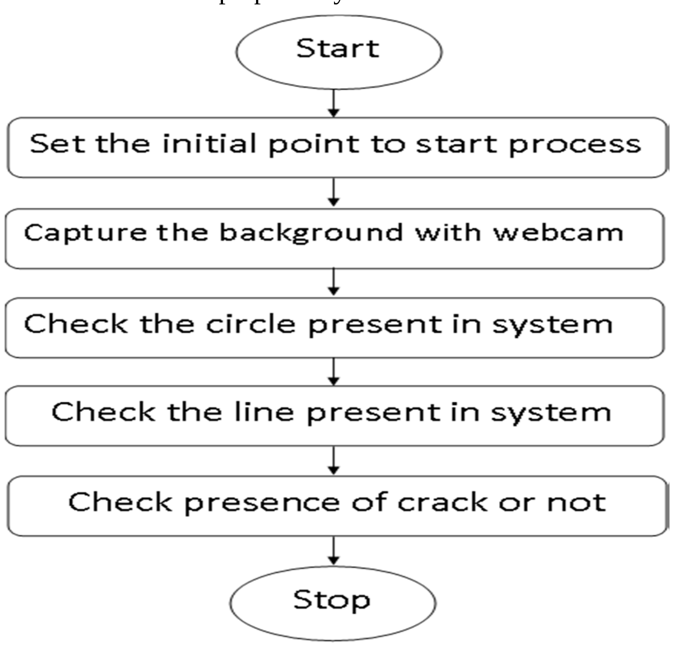

Figure 5.1: Flowchart of Mechanical Crack Detection System

B. Pseudocode Of Proposed Algorithm

1) Read the video of the desired shaft under investigation
2) Convert the video into series of frames.
3) Convert the image into binary form
4) Apply the segmentation on the video frames so that foreground can be extracted from background
5) Check for the transverse cracks and the longitudinal crack in the shaft image
6) Save the cracked image with the label either cracked or not
7) Save the results for the manual visual inspection also for checking the credibility of the proposed system.

C. Facilities Required For Proposed Work

1) Matlab Software or Python framework for simulation purposes
2) USB Webcam
3) USB wire
4) Mechanical materials with cracks or without cracks present.

VI. RESULTS AND CONCLUSION

A. Results

Various experiments had been performed on both the traditional machine and the new image processing setup. In this experiment various mechanical parts were analyzed. MATLAB 2016a and intel 4th i5 (3.2GHz) with OS window 10 and 16GB RAM was utilized with multi core processor. While taking images, a highly calibrated digital camera was used as an image acquisition device.

During the first lab experiment, a cracked bolt is used. In this experiment every image has resolution of 4164 x 2360 pixels.

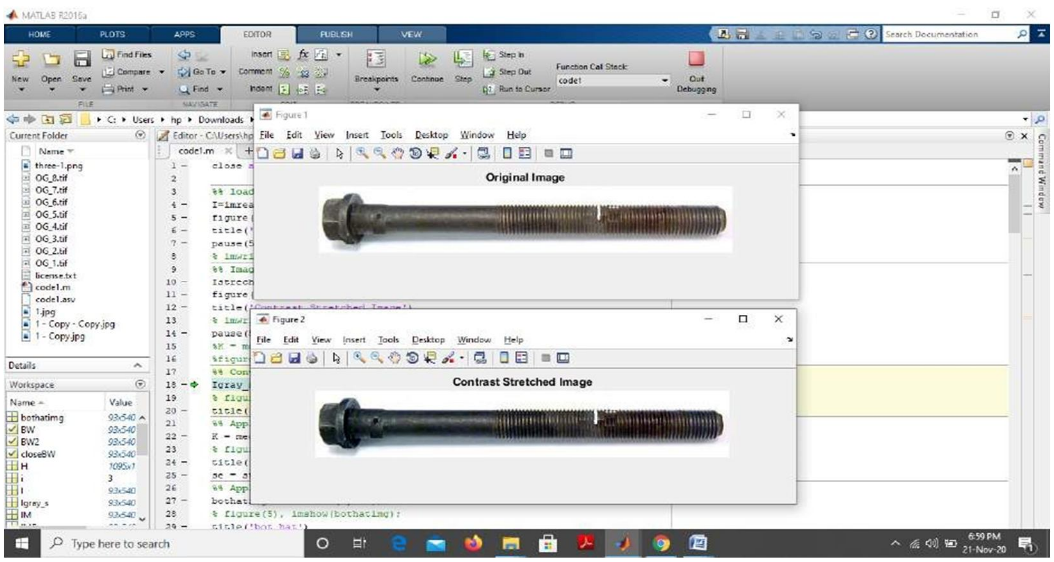

Figure 6.1: Original and Contrast Stretched Images of Bolt

Figure 6.1 shows the Original image and its contrast stretched image of bolt. Contrast stretched algorithm is used to adjust the various features of image like brightness, gain and contrast of the original input image of bolt image.

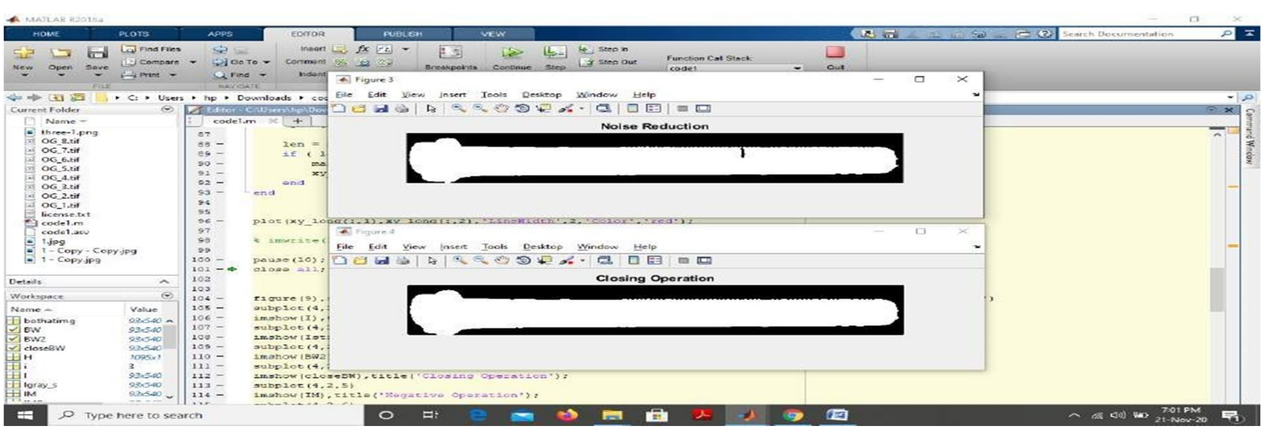

Figure 6.2: Noise Reduction and Closing Operation Images of Bolt

Figure 6.2 shows the noise reduction of the contrast stretched image and then closing operation is performed to find out the image without any crack detection of bolt image.

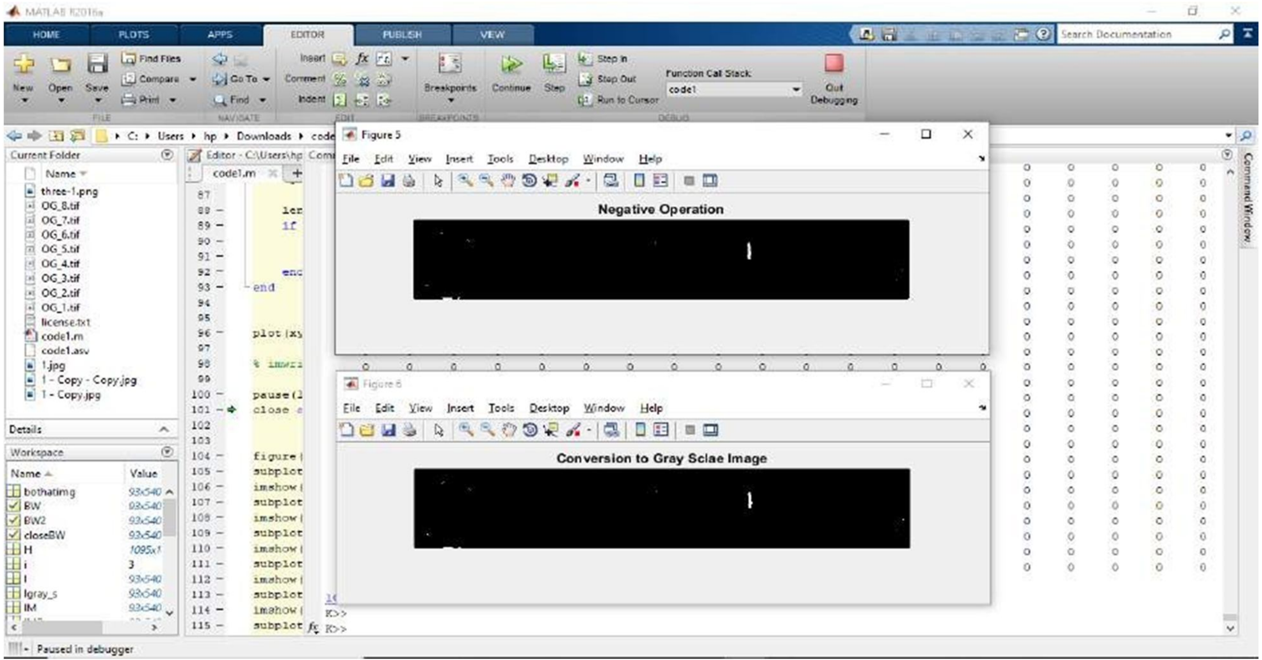

Figure 6.3: Negative Operation and Conversion to Gray Scale Images of Bolt

Figure 6.3 shows the negative operation performed after the closing operation on the image. In the second image binary scale image is get converted into gray scale image of bolt image.

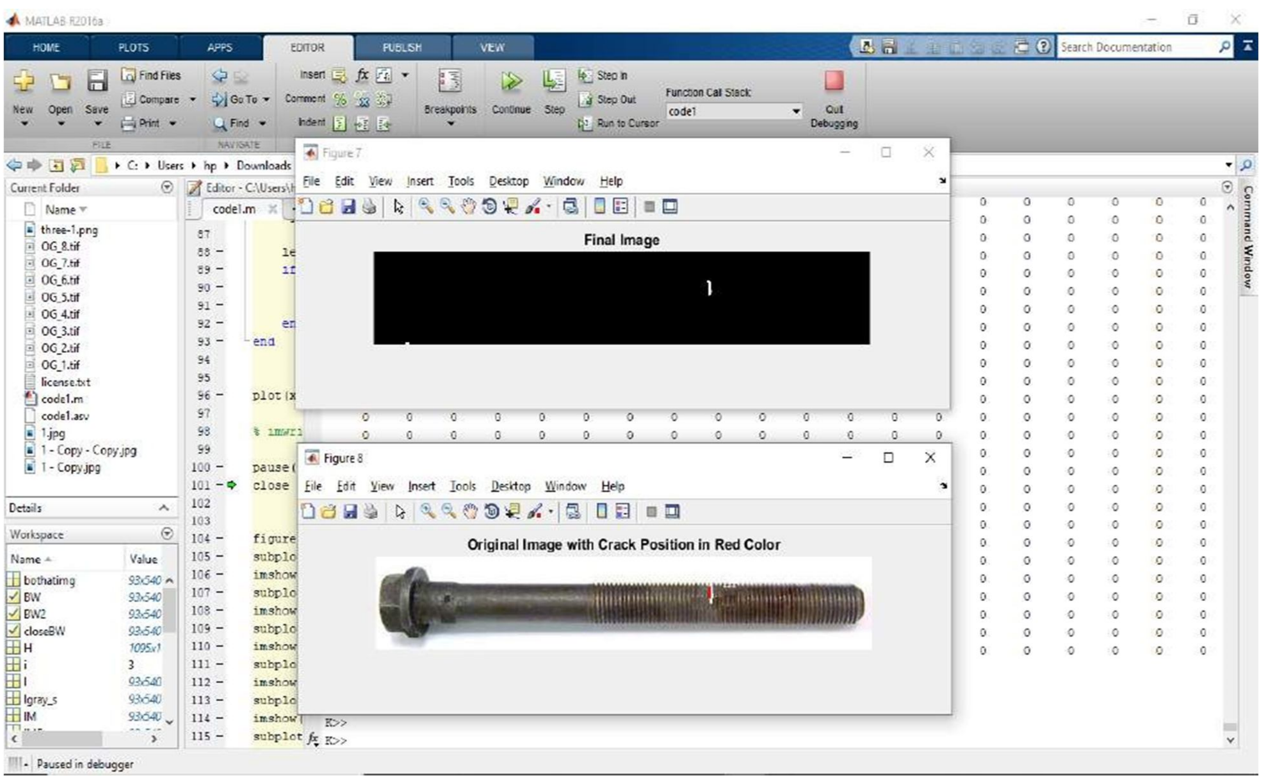

Figure 6.4: Final and Marked Cracked Images of Bolt

Figure 6.4 shows the final image with the cracked position in bolt. Then in the second sub image the original image with the cracked position is pointed by red color line is displayed on the bolt image.

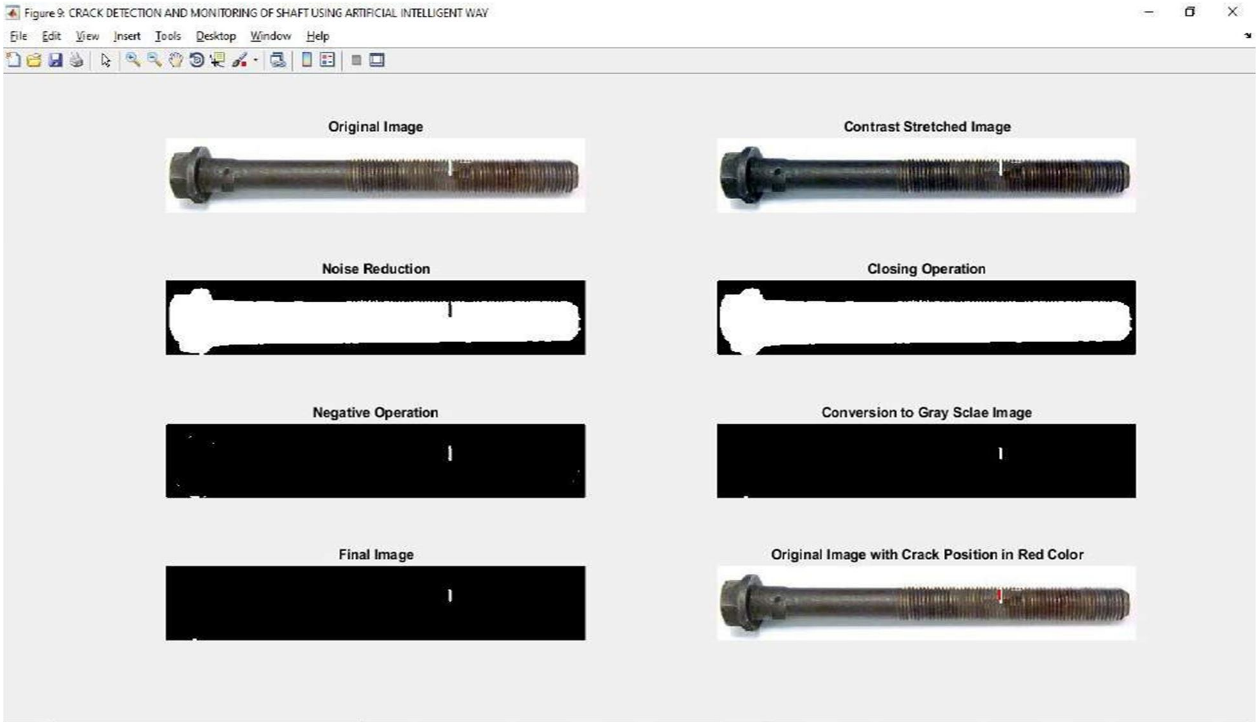

Figure 6.5: Stepwise Operations Performed to Get Cracked Position in Image of Bolt Figure 6.5 showed the all sub steps in detecting the crack present in the original input image of bolt. The steps involved are displaying original image, contrast stretched image, noise reduction image, closing operated image, negative operated image, gray scale image, final image and inlast original image with the cracked location highlighted by red color on the bolt image.

During the second lab experiment, a cracked shaft is used. In this experiment every image has resolution of 4164 x 2360 pixels.

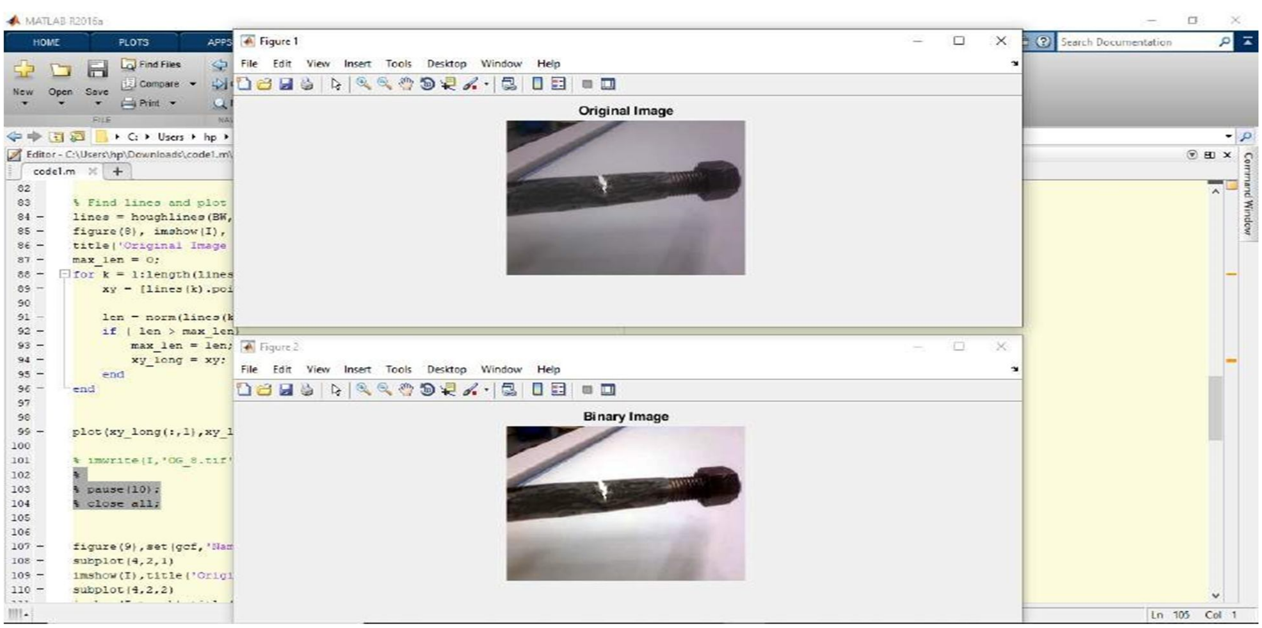

Figure 6.6: Original and Contrast Stretched Image of Shaft

Figure 6.6 shows the Original image and its contrast stretched image of shaft. Contrast stretched algorithm is used to adjust the various features of image like brightness, gain and contrast of the original input image of shaft image.

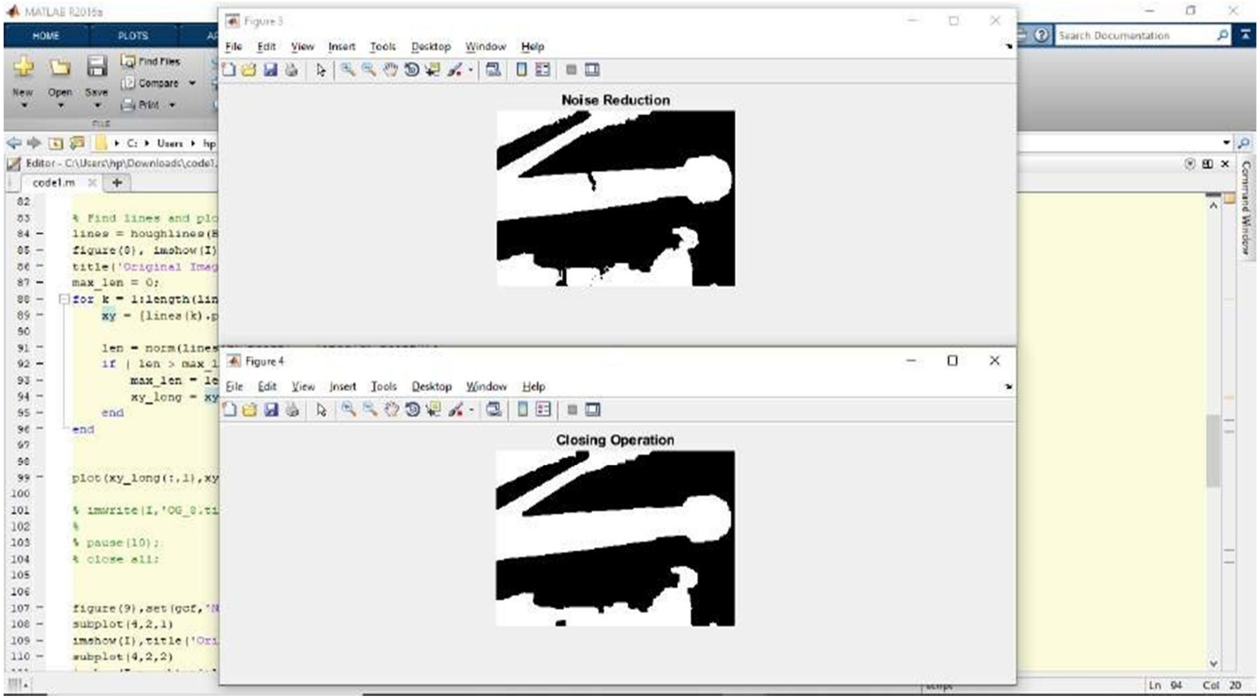

Figure 6.7: Noise Reduction and Closing Operation Image of Shaft

Figure 6.7 shows the noise reduction of the contrast stretched image and then closing operation is performed to find out the image without any crack detection of shaft image.

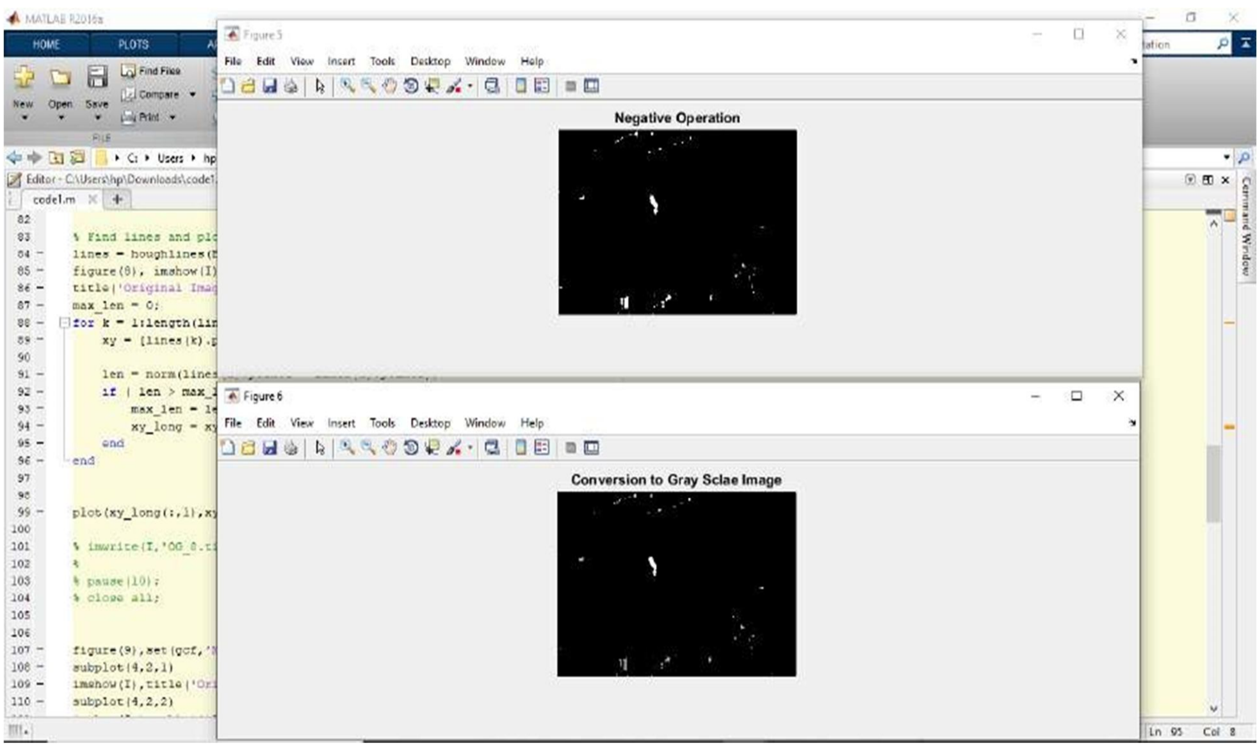

Figure 6.8: Negative Operation and Conversion to Gray Scale Image of Shaft

Figure 6.8 shows the negative operation performed after the closing operation on the image. In the second image binary scale image is get converted into gray scale image of shaft image.

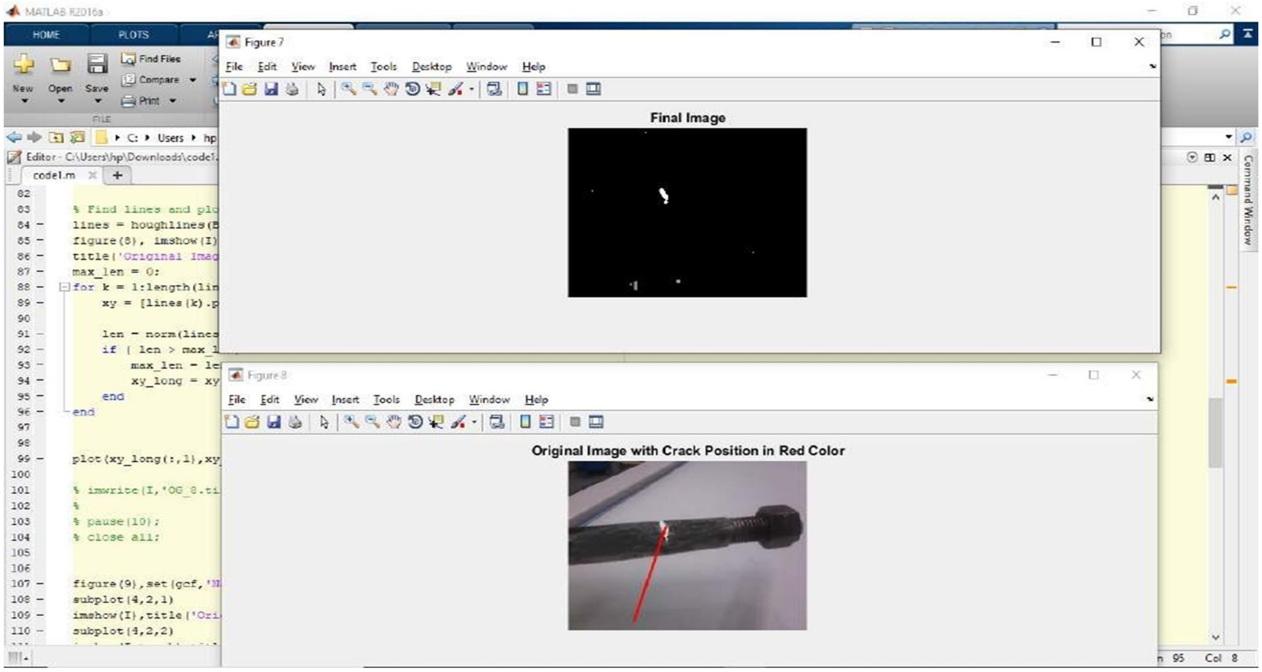

Figure 6.9: Final and Marked Cracked Images of Shaft

Figure 6.9 shows the final image with the cracked position in shaft. Then in the second sub image the original image with the cracked position is pointed by red color line is displayed on the shaft image.

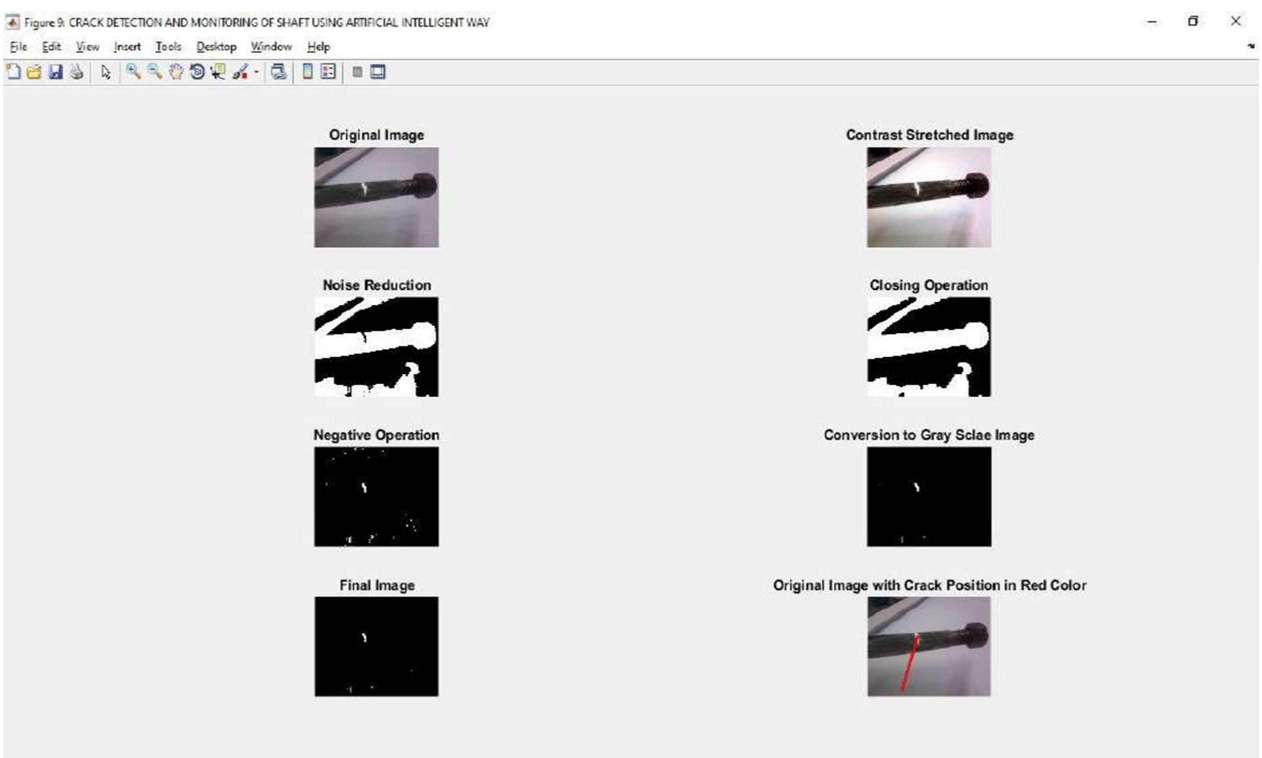

Figure 6.10: Stepwise Operations Performed to Get Cracked Position in Image of Shaft Figure 6.10 showed the all sub steps in detecting the crack present in the original input image of shaft. The steps involved are displaying original image, contrast stretched image, noise reduction image, closing operated image, negative operated image, gray scale image, final image and in last original image with the cracked location highlighted by red color on the shaft image.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue IV Apr 2021- Available at www.ijraset.com

During the third lab experiment, a cracked pipe is used for investigation. In this experiment every image has resolution of 4164 x 2360 pixels.

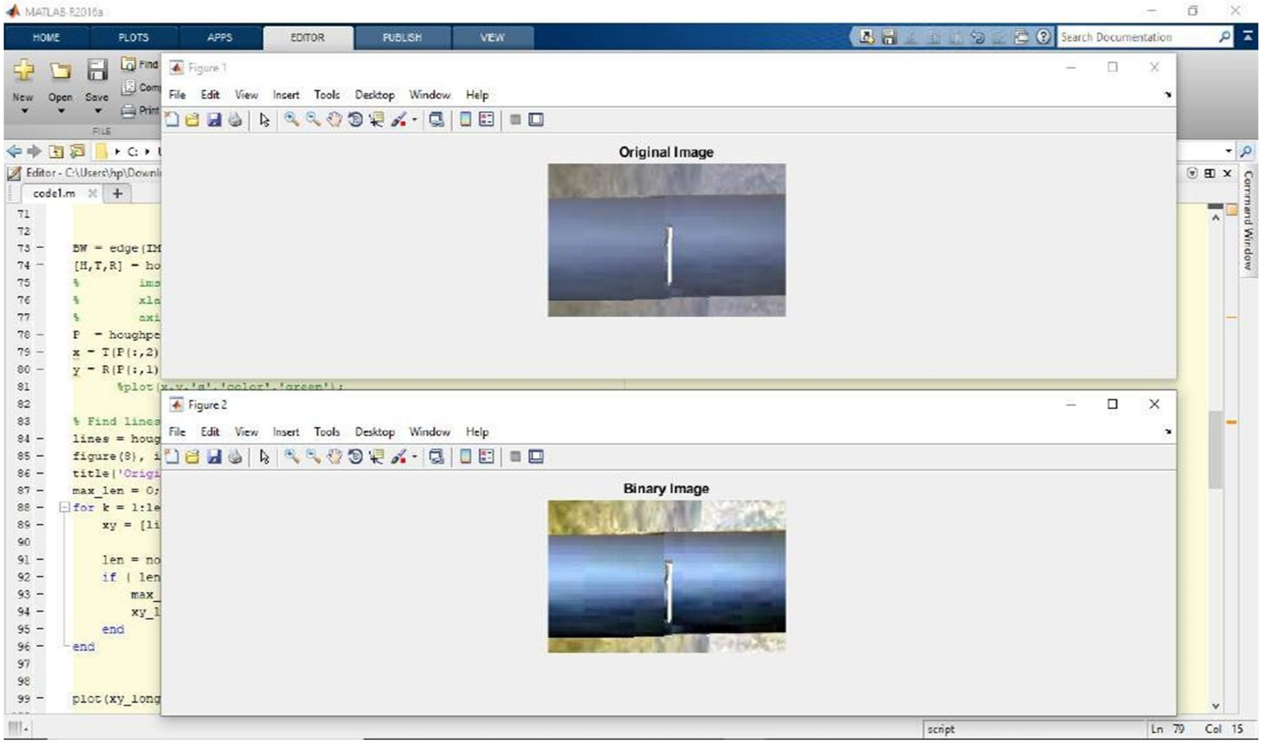

Figure 6.11: Original and Contrast Stretched Image of Pipe

Figure 6.11 shows the Original image and its contrast stretched image of pipe. Contrast stretched algorithm is used to adjust the various features of image like brightness, gain and contrast of the original input image of pipe image.

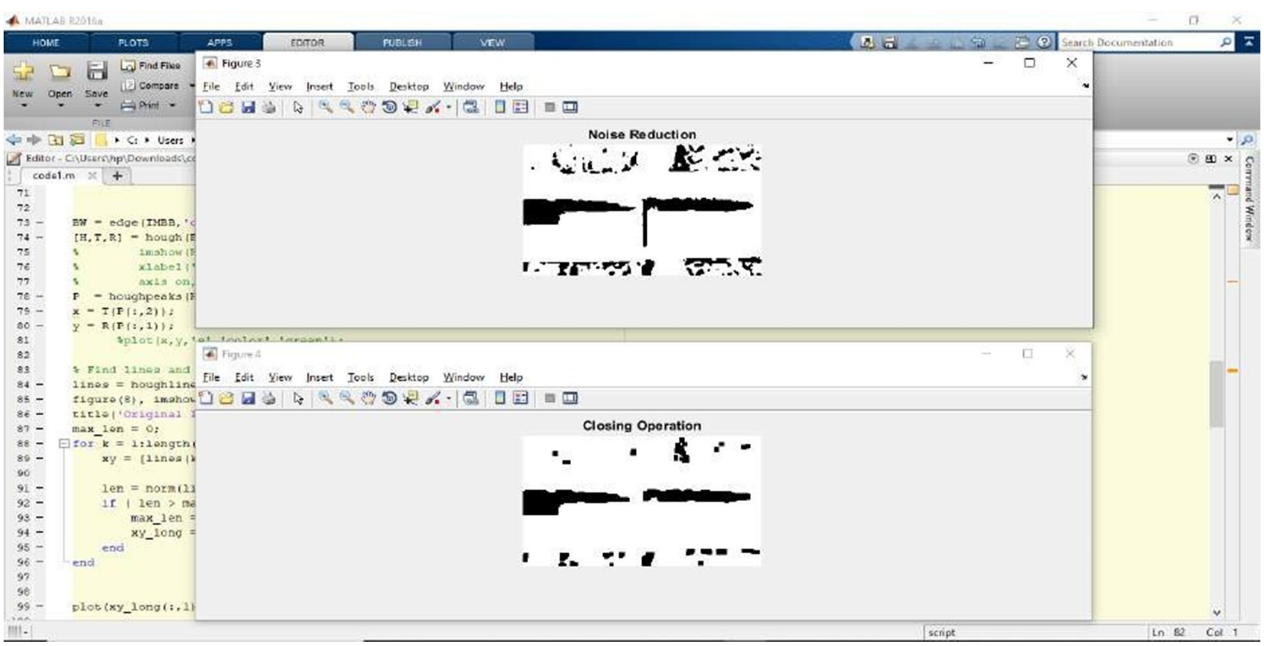

Figure 6.12: Noise Reduction and Closing Operation Image of Pipe

Figure 6.12 shows the noise reduction of the contrast stretched image and then closing operation is performed to find out the image without any crack detection of pipe image.

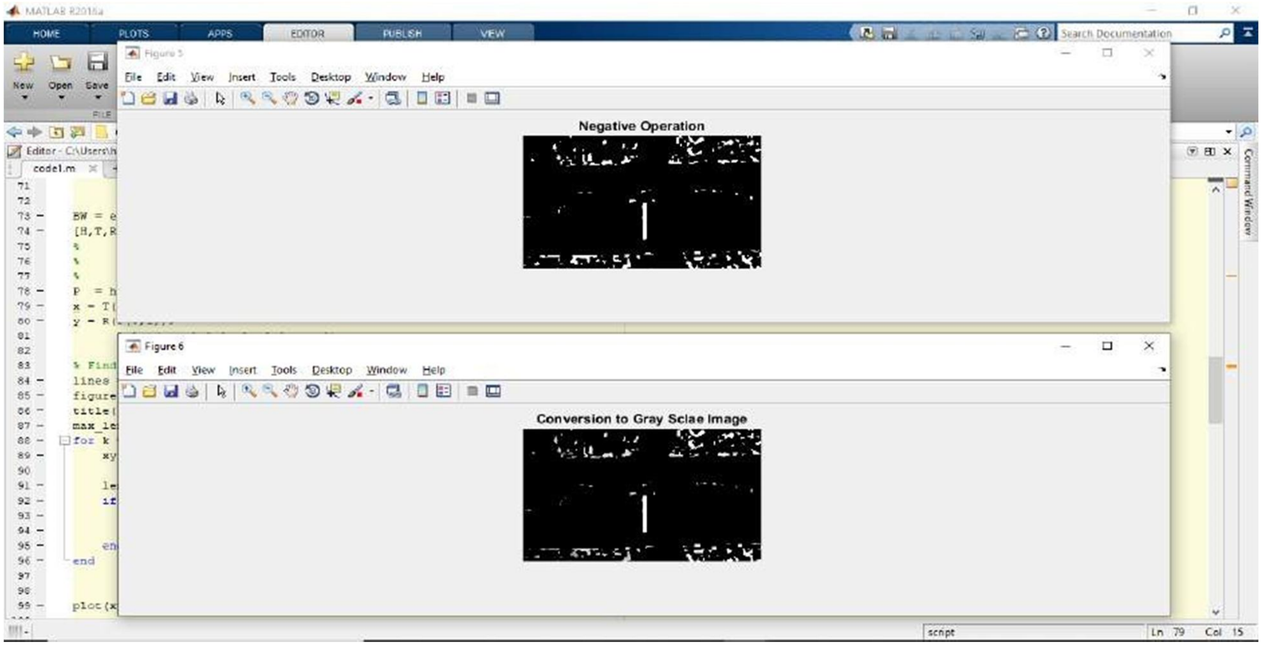

Figure 6.13: Negative Operation and Conversion to Gray Scale Image of Pipe

Figure 6.13 shows the negative operation performed after the closing operation on the image. In the second image binary scale image is get converted into gray scale image of pipe image.

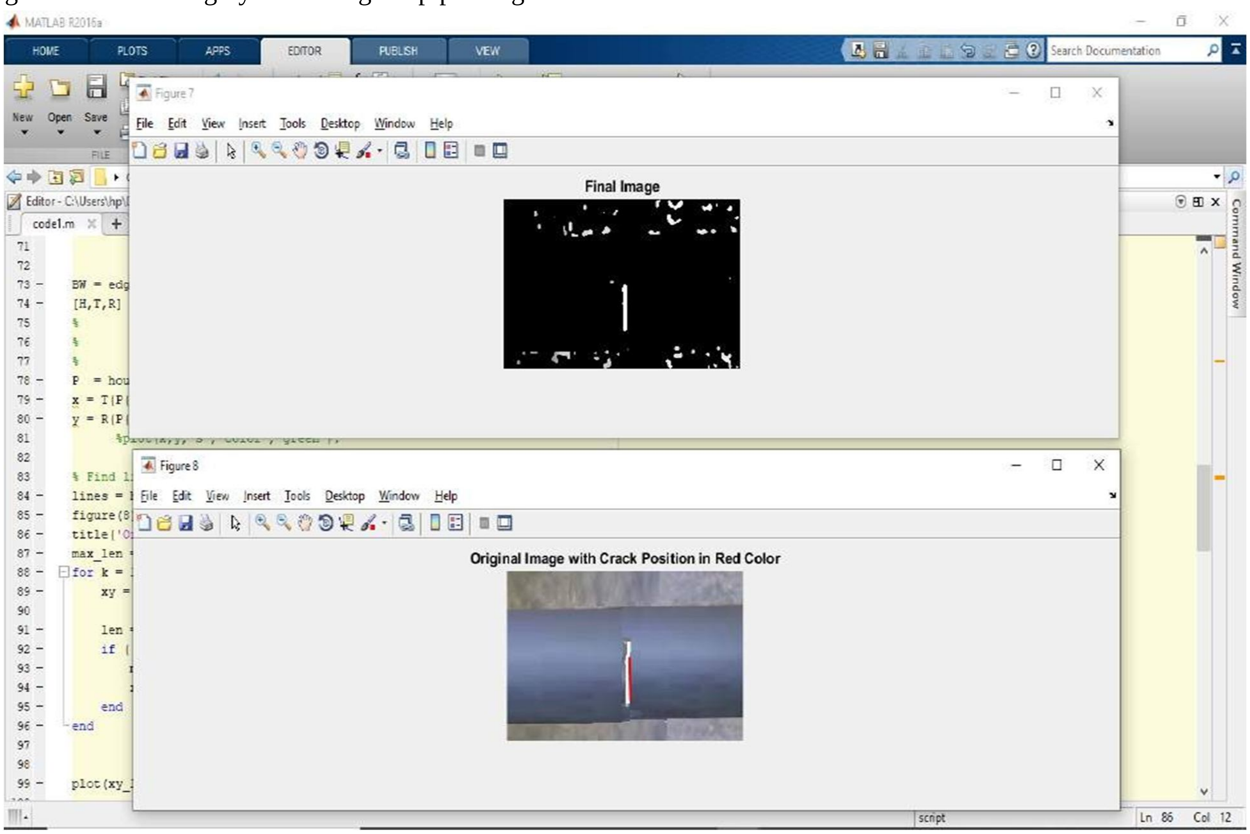

Figure 6.14: Final and Marked Cracked Images of Pipe

Figure 6.14 shows the final image with the cracked position in pipe. Then in the second sub image the original image with the cracked position is pointed by red color line is displayed on the pipe image.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue IV Apr 2021- Available at www.ijraset.com

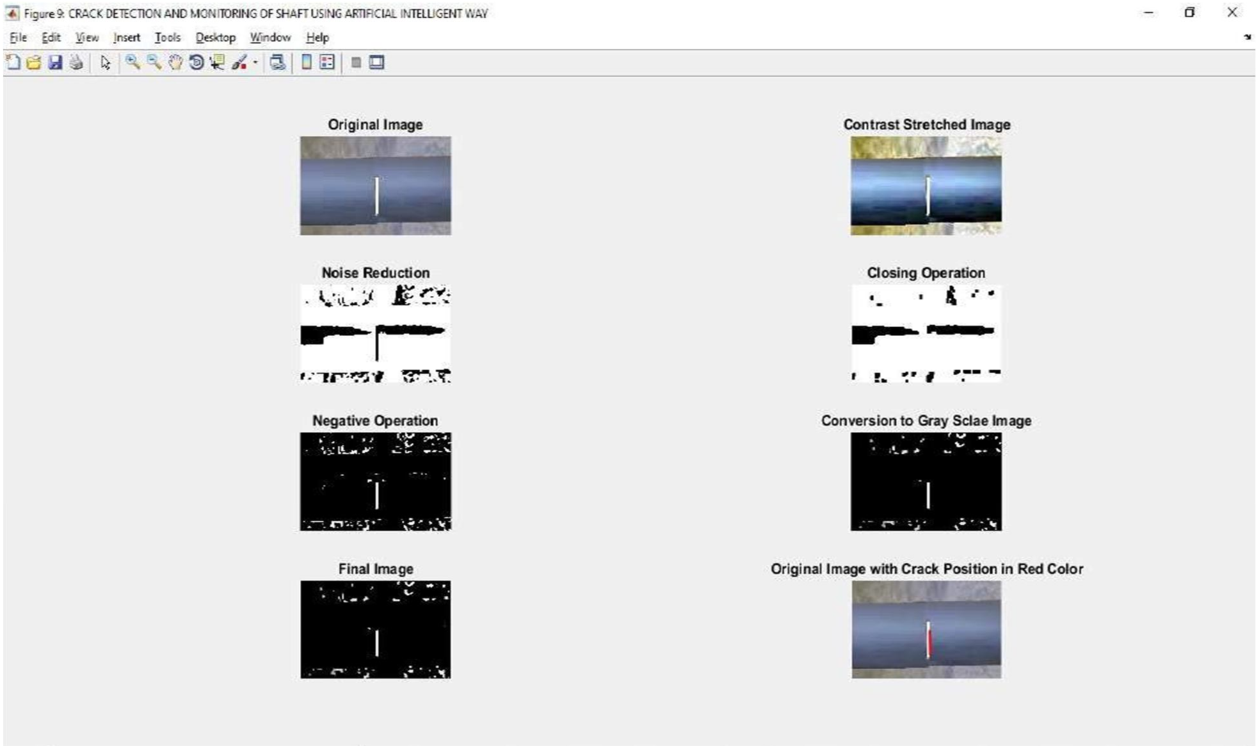

Figure 6.15: Stepwise Operations Performed to Get Cracked Position in Image of Pipe Figure 6.15 showed the all sub steps in detecting the crack present in the original input image of pipe. The steps involved are displaying original image, contrast stretched image, noise reduction image, closing operated image, negative operated image, gray scale image, final image and inlast original image with the cracked location highlighted by red color on the pipe image.

During the fourth lab experiment, a cracked shaft is used. In this experiment every image has resolution of 4164 x 2360 pixels.

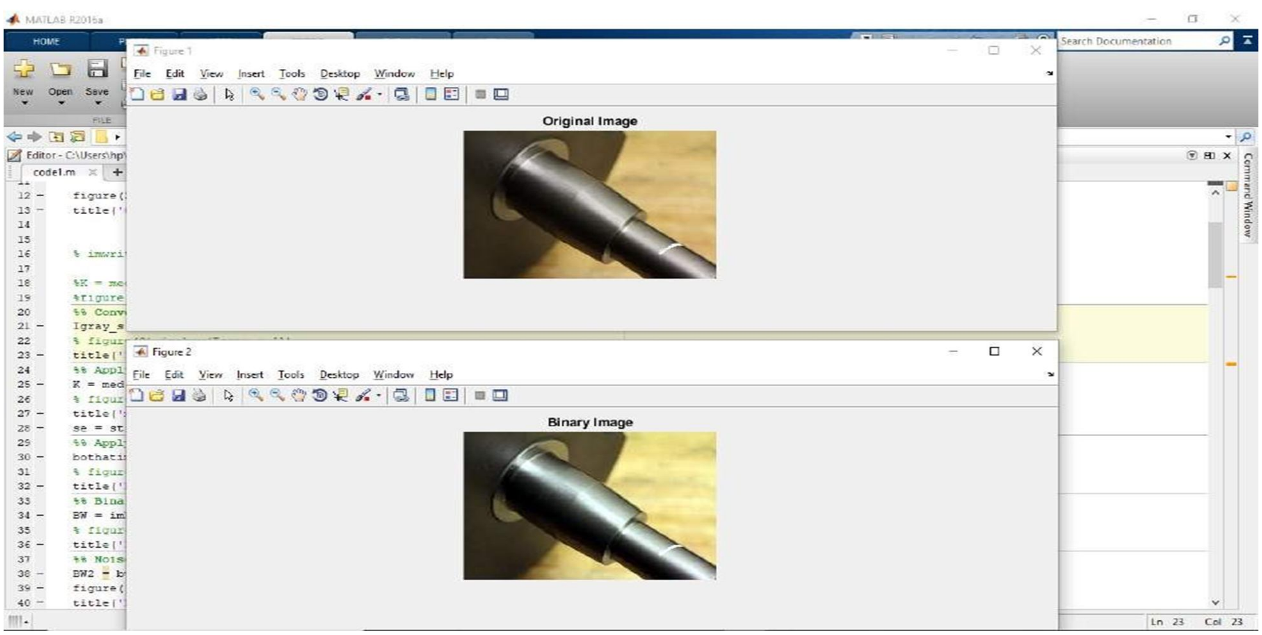

Figure 6.16: Original and Contrast Stretched Image of Shaft-2

Figure 6.16 shows the Original image and its contrast stretched image of Shaft-2. Contrast stretched algorithm is used to adjust the various features of image like brightness, gain and contrast of the original input image of shaft-2 image.

ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue IV Apr 2021- Available at www.ijraset.com

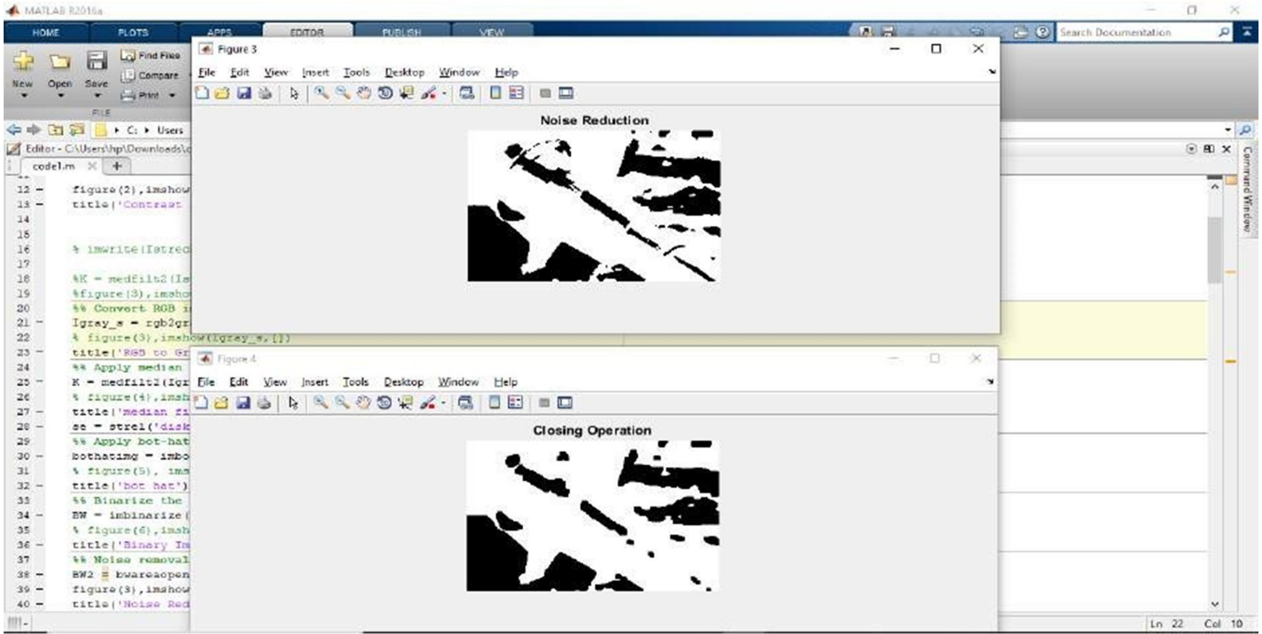

Figure 6.17: Noise Reduction and Closing Operation Image of Shaft-2

Figure 6.17 shows the noise reduction of the contrast stretched image and then closing operation is performed to find out the image without any crack detection of shaft-2 image.

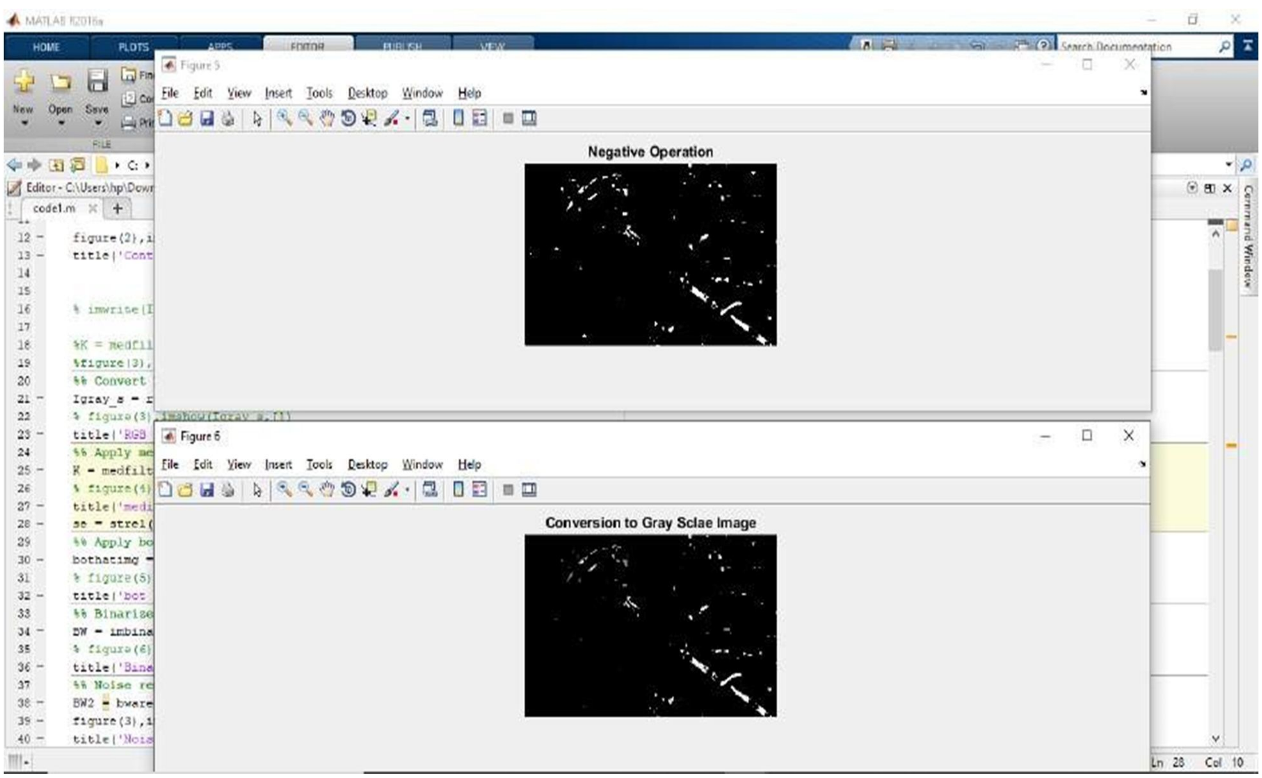

Figure 6.18: Negative Operation and Conversion to Gray Scale Image of Shaft-2

Figure 6.18 shows the negative operation performed after the closing operation on the image. In the second image binary scale image is get converted into gray scale image of shaft-2 image.

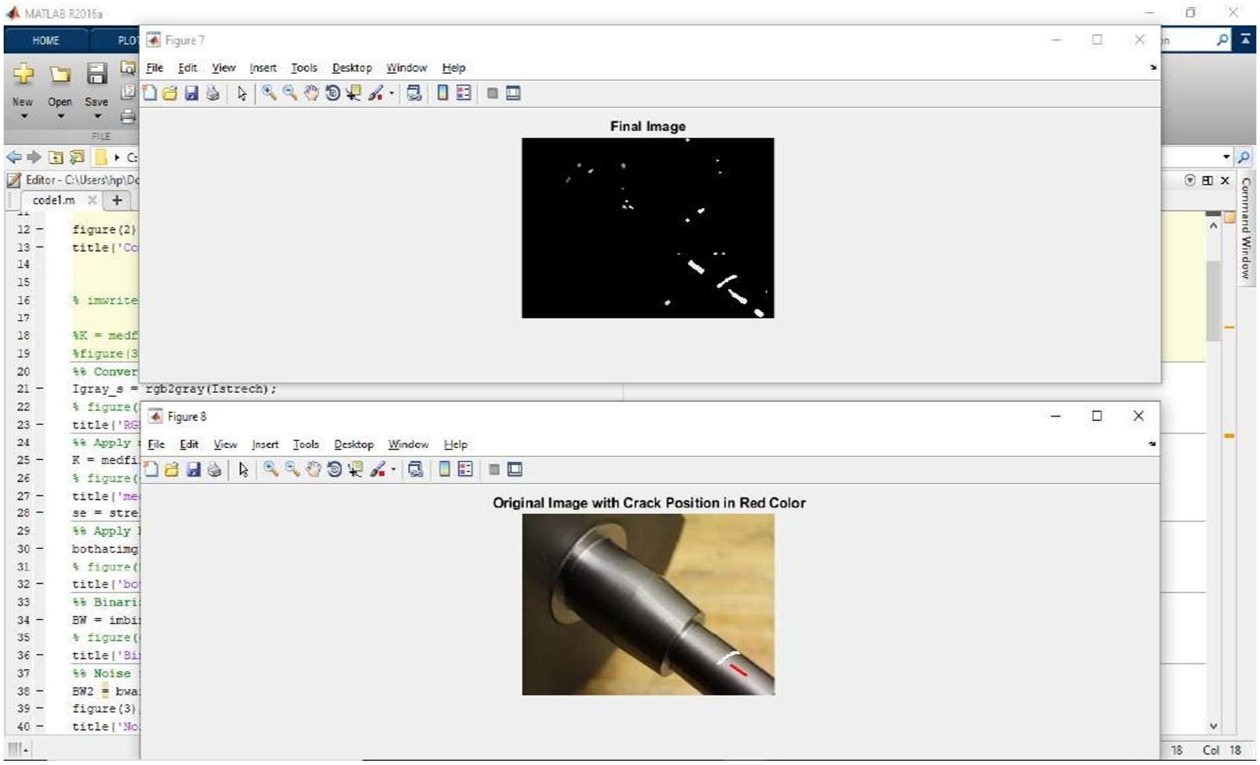

Figure 6.19: Final and Marked Cracked Images of Shaft-2

Figure 6.19 shows the final image with the cracked position in shaft-2. Then in the second sub image the original image with the cracked position is pointed by red color line is displayed on the shaft-2 image.

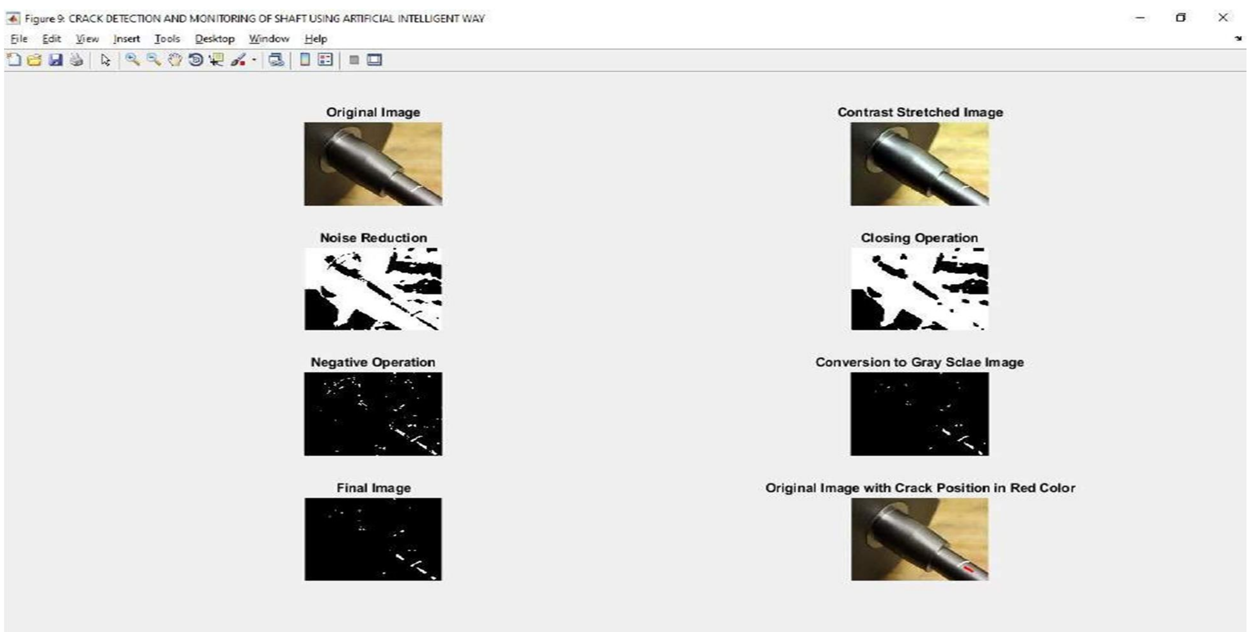

Figure 6.20: Stepwise Operations Performed to Get Cracked Position in Image of Shaft-2

Figure 6.20 showed the all sub steps in detecting the crack present in the original input image of shaft-2. The steps involved are displaying original image, contrast stretched image, noise reduction image, closing operated image, negative operated image, gray scale image, final image and in last original image with the cracked location highlighted by red color on the shaft-2 image.

Table 6.1: Various Objective Parameters for Showing Comparison of Techniques

S. No.	Part Name	Time Taken by Traditional Machine (in Seconds)	Time Taken by Image Processing Setup (in Seconds)	Accuracy (Traditional Machine)	Accuracy (Image Processing Setup)
1.	Bolt	2.8	2.2	90 %	92%
2.	Shaft	2.9	1.9	95%	95%
3.	Pipe	2.5	2.0	89%	91%
4.	Shaft-2	3.0	2.1	90%	92%
5.	Other Parts	2.8 (Avg. Time)	2.3 (Avg. Time)	92% (Avg. Accuracy)	94% (Avg. Accuracy)

B. Conclusion

This research work has proposed a digital image processing methodology for time efficient automated crack detection for various mechanical parts. The methodology works on the extraction of various cracks present in the input digital image of the mechanical part. The benefit of this technique is that crack can be easily detection in any orientation on the mechanical part. For finding the efficiency and validity of the proposed technique, various experimental investigations are performed. By verifying the various experiments, it was found that the proposed image processing methodology could replace the traditional machine for crack detection in mechanical parts. The proposed image processing method could be efficiently used for crack detection in the mechanical parts with the advantages of reduction in cost and rapid inspection with good accuracy.

C. Future Work

In the future work the methodology can be more extended to find inner cracks in the various mechanical instruments by inserting narrow camera in the inner part of the mechanical instruments. Also the speed as well as accuracy can be further increased with the help of using more fine and calibrated cameras.

VII. ACKNOWLEDGEMENT

I express my sincere gratitude to the Desh Bhagat University Mandi Gobindgarh for giving me the opportunity to work on the thesis during my final year of M.Tech. in Mechanical Engineering (MME-500) work is an important aspect in the field of engineering.

I would like to thank my supervisor **Er. Puneet Bansal**, Assistant Professor of Department of Mechanical Engineering at Desh Bhagat University Mandi Gobindgarh for his kind support and healthy criticism throughout my thesis which helped me immensely to complete my work successfully.

I also owe my sincerest gratitude towards Head of Department of Mechanical Engineering at Desh Bhagat University Mandi Gobindgarh for his valuable advice.

Last but not least, a word of thanks for the authors of all those books and papers which I have consulted during my dissertation work as for preparing this report.

REFERENCES

[1] R. Gradzki, Z. Kulesza and B. Bartoszewicz, “Method of shaft crack detection based on squared gain of vibration amplitude,” Nonlinear Dyn 98, pp. 671–690, 2019.

[2] H. K. Jung, C. W. Lee and G. Park, “Fast and non invasive surface crack detection of press panels using image processing,” ELSEVIER 6th Asia Pacific Workshop on Structural Health Monitoring, pp. 72-79, 2017.

[3] A. Mohan, S. Poobal, “Crack detection using image processing: A critical review and analysis,” Alexandria Engineering Journal, 2017.

[4] A. A. Cavalini Jr., L. Sanches, N. Bachschmid, and V. Steffen Jr., “Crack identification for rotating machines based on an online approach,” Mechanical Systems and Signal Processing,vol. 79, pp.72–85, 2016.

[5] D. L. Sampaio and R. Nicoletti, “Detection of cracks in shafts with the Approximated Entropy algorithm,” Mechanical Systems and Signal Processing, vol. 72-73, pp. 286–302, 2016.

[6] A. A. Cavalini Jr., L. Sanches, N. Bachschmid, and V. Steffen Jr.,“Crack identification for rotating machines based on an online approach,” Mechanical Systems and Signal Processing,vol. 79, pp. 72–85, 2016.

[7] D. L. Sampaio and R. Nicoletti, "Detection of cracks in shafts with the Approximated Entropy algorithm," Mechanical Systems and Signal Processing, vol. 72-73, pp. 286–302, 2016.
[8] E. Balasubramanian S. Sankarasrinivasan, K. Karthika, U. Chandrasekar and Rishi Gupta, "Health Monitoring of Civil Structures with Integrated UAV and Image Processing System," Eleventh International Multi-Conference on Information Processing, 2015.
[9] K. Shivprasad, M. K. Vishwanath and N. Kaulgud, "Morphology Based Surface Crack Detection," Journal of Advanced and Science, vol. I, 2015.
[10] C. H. Kim, S. H. Choi, W. J. Joo, G. B. Kim, "Classification of surface defect on steel strip by KNN classifier," Advances in Engineering Software, vol. 83, pp. 99-108, 2015.
[11] Y. S. Yang, C. M. Yang, C. W. Huang, "Thin crack observation in a reinforced concrete bridge pier test using image processing and analysis," Advances in Engineering Software, vol. 53, pp. 99-108, 2015.
[12] W. Zhang, Z. Zhang, D. Qi and Yun Liu, "Automatic Crack Detection and Classification method for Subway Tunnel Safety Monitoring," Sensors, 2014 .
[13] A. Patil, M. Pathak, P. K. Sharma, "Review of Numerical Solution to the Detection of Crack in Structure by using Fuzzy Logic," International Journal of Advance Research in Science And Engineering (IJARSE), vol. 3, 2014.
[14] W. Zhang, Z. Zhang, D. Qi and Y. Liu, "Automatic Crack Detection and Classification method for Subway Tunnel Safety Monitoring," Sensors 2014 .
[15] A. Kammar, V. Reddy, N. D, B. Sowmyashree, "Hough Transforms to Detect and Classify Road cracks," International Journal of Engineering Research and Technology (IJERT), vol. 3, 2014.
[16] Q. Zou, Y. Cao, Q. Li, Q. Mao, S. Wang, "CrackTree: Automatic crack detection from pavement images," Pattern Recognition Letters, Vol. 33, pp. 227-238, 2012.
[17] J. Valenca, D. Dias Da Costa and E. N. B. S. Julio, "Characterization of concrete cracking during laboratorial tests using image processing," Construction and Building Materials, vol. 28, pp. 607-615, 2012.
[18] A. Landstr Om and M. J. Thurley, "Morphology-Based Crack Detection for Steel Slabs," IEEE Journal of Selected Topics in Signal Processing, 2012.
[19] C. Gunkel, A. Stepper, A. C. Mu¨ller, C. H. Muller, "Micro crack detection with Dijkstra's shortest path algorithm," Mach. Vis. Appl. 23 (3), 2012.
[20] J. T. Sawicki, M. I. Friswell, Z. Kulesza, A. Wroblewski, and J. D. Lekki, "Detecting cracked rotors using auxiliary harmonic excitation," Journal of Sound and Vibration, vol. 330 (7), pp. 1365–1381, 2011.
[21] Y. Fujita and Y. Hamamoto, "A robust automatic crack detection method from noisy concrete surfaces," Machine Vision and Applications, vol. 22, pp. 245-254, 2011.
[22] J. T. Sawicki, M. I. Friswell, Z. Kulesza, A. Wroblewski, and J. D. Lekki, "Detecting cracked rotors using auxiliary harmonic excitation," Journal of Sound and Vibration, vol. 330 (7), pp. 1365–1381, 2011.
[23] J. T. Sawicki, D. L. Storozhev, and J. D. Lekki, "Exploration of ND E properties of AMB supported rotors for structural damage detection," Journal of Engineering for Gas Turbines and Power, vol. 133(10), pp.1–9, 2011.
[24] Z. Kulesza and J. T. Sawicki, "Auxiliary state variables for rotor crack detection," Journal of Vibration and Control, vol.17 (6), pp. 857–872, 2011.
[25] J. T. Sawicki, D. L. Storozhev, and J. D. Lekki, "Exploration of NDE properties of AMB supported rotors for structural damage detection," Journal of Engineering for Gas Turbines and Power, vol. 133 (10), pp.1–9, 2011.
[26] M. R. Karthikeyan, R. Md. Tiwari, "Detection, localization and sizing of a structural flaw in a beam based on forced response measurements: - An Experimental Investigation," Mechanism and Machine Theory, vol. 45 (4), pp. 584-590, 2010.
[27] T. Yamaguchi, S. Hashimoto, "Fast crack detection method for large-size concrete surface images using percolation-based image processing," vol. 21, pp. 797-809, 2010.
[28] A. C. Chasalevris and C. A. Papadopoulos, "A continuous model approach for cross- coupled bending vibrations of a rotor-bearing system with a transverse breathing crack," Mechanism and Machine Theory, vol. 44, pp. 1176-1191, 2009.
[29] J. W. Xiang, X. F. Chen, Z. J. He, "A new wavelet-based thin plate element using B-spline wavelet on the interval," Computational Mechanics, vol. 41 (2), pp. 243–255, 2008.
[30] J. W. Xiang, X. F. Chen, L. F. Yang, "A class of wavelet-based flat shell elements using B- spline wavelet on the interval and its applications," CMES – Computer Modeling in Engineering and Sciences, vol. 23 (1), pp. 1–12, 2008.
[31] T. R. Babu, S. Srikanth, and A. S. Sekhar, "Hilbert—Huang transform for detection and monitoring of crack in a transient rotor," Mechanical Systems and Signal Processing, vol. 22 (4), pp. 905-914, 2008.
[32] T. H. Patel and A. K. Darpe, "Influence of crack breathing model on nonlinear dynamics of a cracked rotor," Journal of Sound and Vibration, vol. 311, pp. 953-972, 2008.
[33] J. W. Xiang, X. F. Chen, Z. J. He, "The construction of 1D wavelet finite elements for structural analysis," Computational Mechanics, vol. 40 (2), pp. 325–339, 2007.
[34] A. Morassi, "Damage detection and generalized Fourier coefficients. Journal of Sound and Vibration 302, 229–259, 2007.
[35] J. K. Sinha, "Higher order spectra for crack and misalignment identification in the shaft of a rotating machine," Structural Health and Monitoring, vol.6 (4), pp. 325–334, 2007.
[36] N. Mahayotsanun, J. Cao, M. Peshkin, S. Sah, R. Gao, C.T. Wang, "Integrated sensing system for stamping monitoring control," IEEE SENSORS 2007 Conference, vol. 5, pp 1376-1379, 2007.
[37] H. Elbehiery, A. Hefnawy, M. Elewa, "Surface defects detection for ceramic tiles using image processing and morphological techniques," International Journal of Computer, Electrical, Automation, Control and Information Engineering, vol. 1(5), pp. 1488-1492, 2007.
[38] S. Caddemi and A. Morassi, "Crack detection in elastic beams by static measurements," International Journal of Solids and Structures, vol. 44, pp. 5301–5315, 2007.
[39] Matlab: www.mathworks.com

[40] Vector: www.vectorndt.in/industries/automotive/