

Fretting Fatigue Rupture Detection of Conductor Using UAV and Image Processing

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Abstract: This project presents failure analysis of an electric aluminum alloy conductors damaged and broken for fretting fatigue phenomena induced by Aeolian vibrations. Life of electric conductors is often reduced by various degradation mechanisms such as repeated bending, fluctuating tension, distortion, fatigue, wear and corrosion phenomena. However the main limiting factor of the electrical conductors is related to Aeolian vibrations in the high frequency range (between 5 to 50 Hz). Conductor oscillations may lead to fretting fatigue problems caused by wind excitation, mainly in the suspension clamp regions, spacers or other fittings. Vibration dampers are considered the most effective method to extend service life of electric conductors, as they are the means to reduce fretting damage of aluminum conductors.

Keywords: Hough transform, Diameter, Corrosion, Twist Angle, ACSR, Overhead transmission lines.

INTRODUCTION:

The most commonplace conductors which use overhead power transmission lines are Aluminum Alloy Conductors. All Aluminum Conductor (AAC), All Aluminum Alloy Conductor (AAAC), Aluminum Conductor Steel, Reinforced (ACSR), Aluminum Conductor Aluminum- Alloy Reinforced (ACAR), Bundle Conductors, etc. are best conductors use for power transmission lines. There are various kinds of sub conductors which use for Aluminum Alloy Conductors are AAAC-HS, AACSR, ABB and ACAR. AAAC and ACSR are the most common sort of conductors which use within the transmission line. The ACSR & AAAC conductors are important components in transmission line because these conductors are suspended by towers. So in this developed work, we are going to monitor parameters of these conductors like twist angle, diameter variations, corrosion, etc. by using image processing in MATLAB Tool. The developed work is divided in two sections to investigate the failure of an ACSR and AAAC overhead transmission lines. The first sections of developed work focused on overhead transmission line inspections and detection of fretting fatigue failure, corrosion, broken strand etc. using unmanned aerial vehicle (UAV) and image processing. Second section of developed work comprises an apparatus to analyze the conductors for diameter, twist angle, corrosion, fretting fatigue rupture etc. using image processing and Hough Transform. Aims of developed work are,

1. The main aim of the developed work is inspection of transmission line using UAV and design and development of apparatus for fretting fatigue rupture detection.
2. To provide fruitful information by using image processing technique for following parameters,
 1. Diameter variations
 2. Corrosion
 3. Twist angle
3. To Minimize Risky Manpower, Scheduled Maintenance, Maintenance Time and Maintenance Cost.
4. To avoid Conductor failure, Power Failures, Damages and Hazardous Situations as



Fig 1. (a) Damage at support points



Fig 1. (b) Worn-out due to broken tie wires



Fig 1. (c) Spicing and broken strands



Fig 1. (d) Fatigue breaks



Fig 1. (e) Risky power line inspection



Objectives of developed work are,

1. To inspect the different power conductors by using vision based UAV.
2. To obtain and maintain the conductor health related database.
3. Analysis of different power conductor defects by using a robust image processing algorithm.
4. Extract the major features about defects like fretting fatigue, corrosion, twist angle etc.
5. Design and development of an apparatus to inspect the conductors for above mentioned features.

BLOCK DIAGRAM:

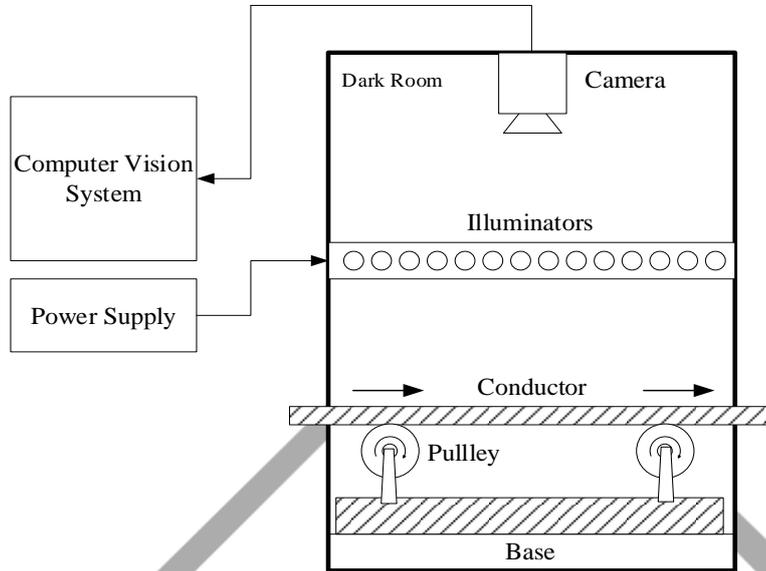


Fig 2. Block Diagram of developed system

The above block diagram consists of the darkroom, USB web camera, illuminators, computer vision system like a PC which has a simulation tool & power supply. Here the darkroom is used to capture images of ACSR conductor & illuminators are used to get proper images. A USB web camera captures images and sends them to a computer vision system like a PC for further processing & parameter calculation.

FLOW CHART:

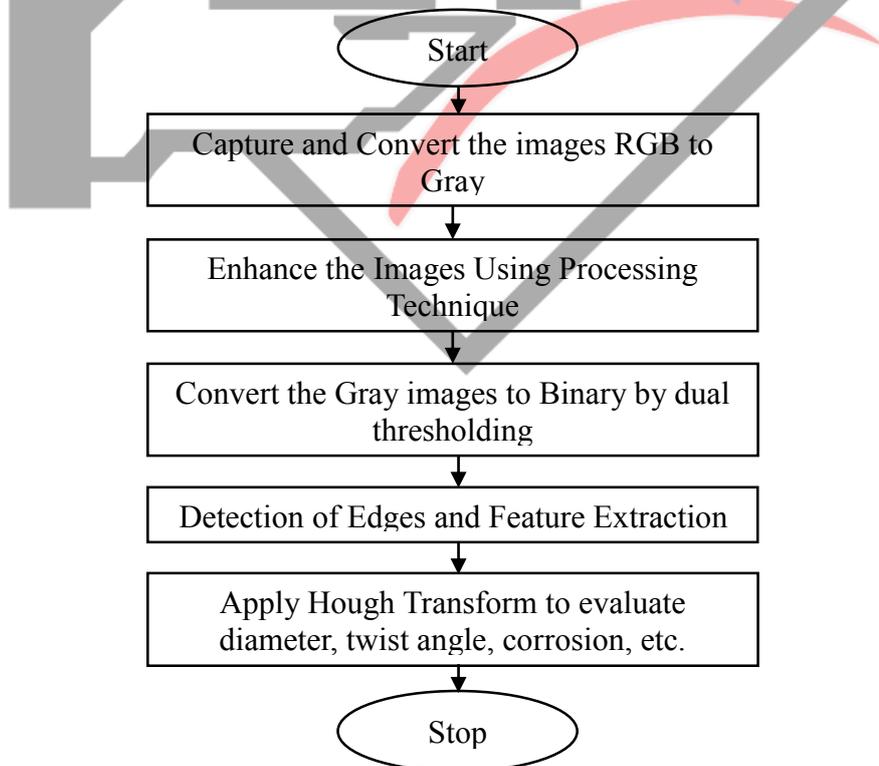


Fig 3. Flow Chart of developed system

The above flow chart shows the working flow of this developed system & the detailed information about these steps is given below in the methodology of this system.

METHODOLOGY:

Step 1: Create Graphical User Interface (GUI). The GUI is a structure of a user interface that allows users to interact with electronic devices through graphical icons. Created GUI consists of panel for preview of web cam and push-button for initialization of the system, preview & capturing, calculation & detection of parameters.

Step 2: In this step, the image is going to be captured from USB web camera and contrast stretching is done on captured image. Pre-processing operations are possible only on gray scale images, so captured image is converted from RGB to Gray Scale. Some morphological operations applied to gray scale image like spatial filtering, cleaning, filling, etc. to remove noise from image & get better results for further operations. After that gray image is converted into a binary image.

Step 3: In this step, we are going to apply linear Hough transform on a gray scale image to calculate the twist angle. The Hough transform become firstly evolved to recognize lines and has later been generalized to cover arbitrary shapes. But for calculating the twist angle, we are using Linear Hough Transform which is representation of lines in the Hough Space. Hough Space contains two dimensions of the line, i.e. rho (r) & theta (θ), where θ is the angle of line & r is the distance from the line to origin. So in this case theta is nothing but the twist angle of that detected line.

Step 4: To get results of diameter we should highlight that particular portion in capturing images. So for that we used here boundary detection of objects, which traces the exterior boundaries of objects. And also there are two options i.e. either 'holes' or 'noholes', specifying whether you want to include the boundaries of holes inside objects. For our application, we are specifying second option, which was 'noholes'.

Step 5: In the last step, we are going to detect rusted part of a transmission line using image segmentation & thresholding. Here we are computing global thresholding from captured image using Otsu's method. Otsu's technique returns one intensity threshold that separates the pixels into two categories, foreground and background. This threshold is set by minimizing intra-class intensity variance, or equivalently, by maximizing inter-class variance. After thresholding, the input image is converted into a binary image using threshold level by replacing all pixels in the input image with intensity greater than level with the value 1 (white) and replacing all other pixels with the value 0 (black). For rusted image, the black pixel represents the rusted area.

SIMULATION RESULTS:



Fig 4. Develped GUI

Above figure shows developed Graphical User Interface (GUI), which contains a panel for preview of web camera & three push-button for initialization of the system, preview & image capturing, parameter calculation & detection.

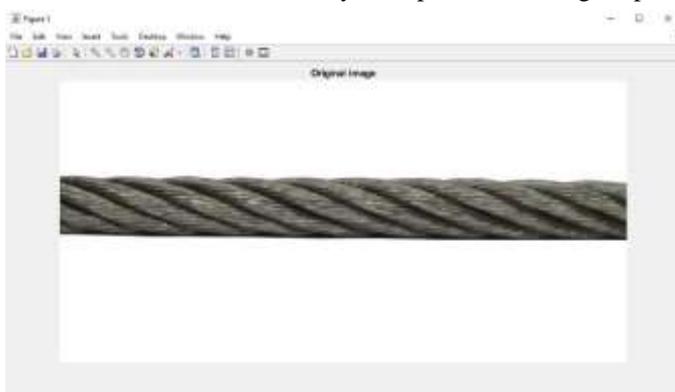


Fig 5 (a). Original Image

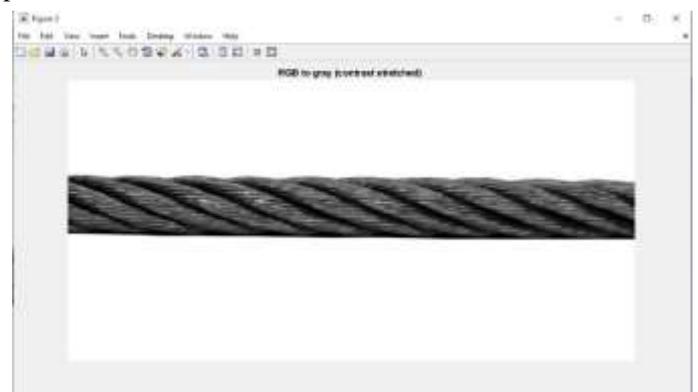


Fig 5 (b). Gray Image



Fig 5 (c). Image after processing

Figure 5 (a) shows, original image which is captured from USB web camera. In fig 5 (b), original RGB image converted into a gray scale image. Fig 5 (c) shows, image after cleaning, filling, filtering.

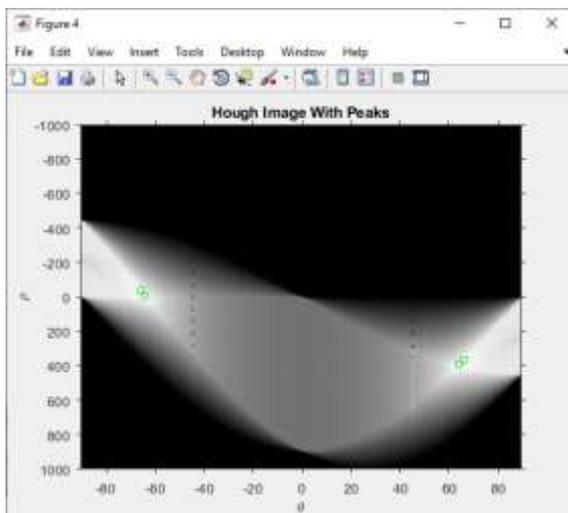


Fig 6 (a). Hough Space with Peaks

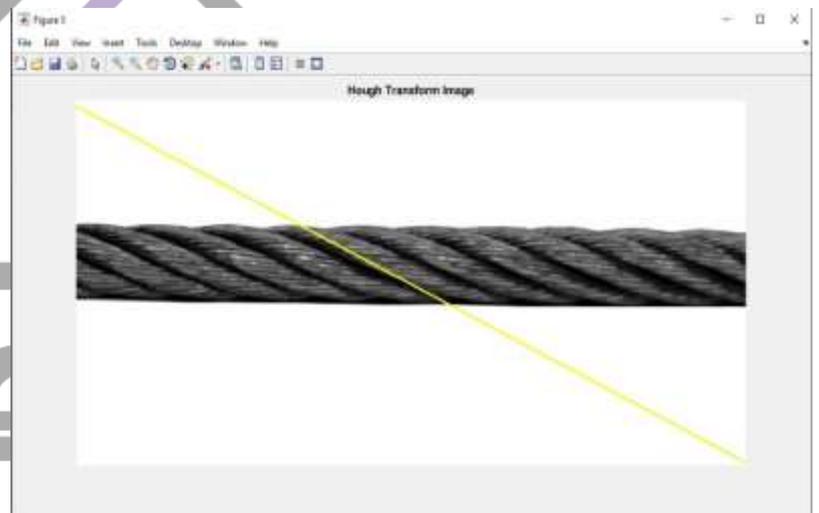


Fig 6 (b). Hough Transform Image

For each point, Hough Transform draw sine like line in Hough Space and by finding the highest value in accumulator space, lines can be extracted. Fig 6 (a) shows Hough peaks and by using these peaks line is extracted in gray image which is shown in fig 6 (b). Each coordinate has two dimensions r & θ and here θ is the twist angle of that line which is passing through that particular point. Below table shows some results of twist angle which are observed during simulation.

Table 1. Results of twist angle & diameter

Sr. No.	Twist Angle (in degrees)	Diameter (in cm)
1.	64.15	1.78
2.	64.00	1.78
3.	64.50	1.77
4.	64.10	1.79
5.	63.98	1.78
6.	63.90	1.76
7.	63.85	1.77
8.	64.00	1.79
9.	64.20	1.79
10.	64.00	1.76

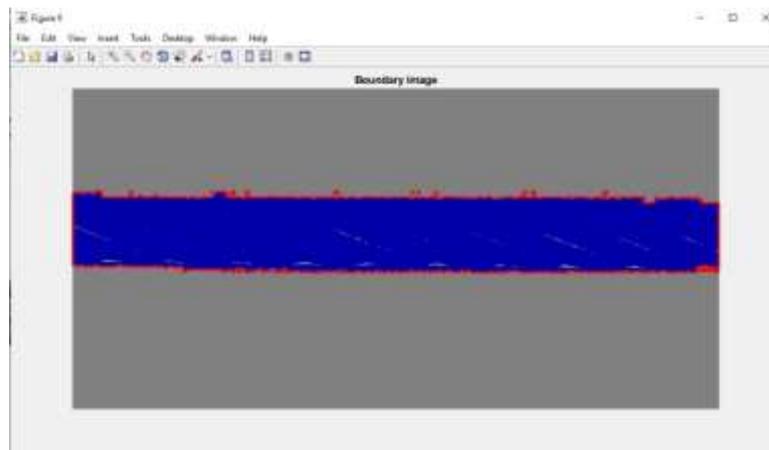


Fig 7. Boundary of an object

In above fig 7, the boundary of an object is detected to calculate diameter of that object. Some results of diameter calculation observed during the simulation are shown in table 1.

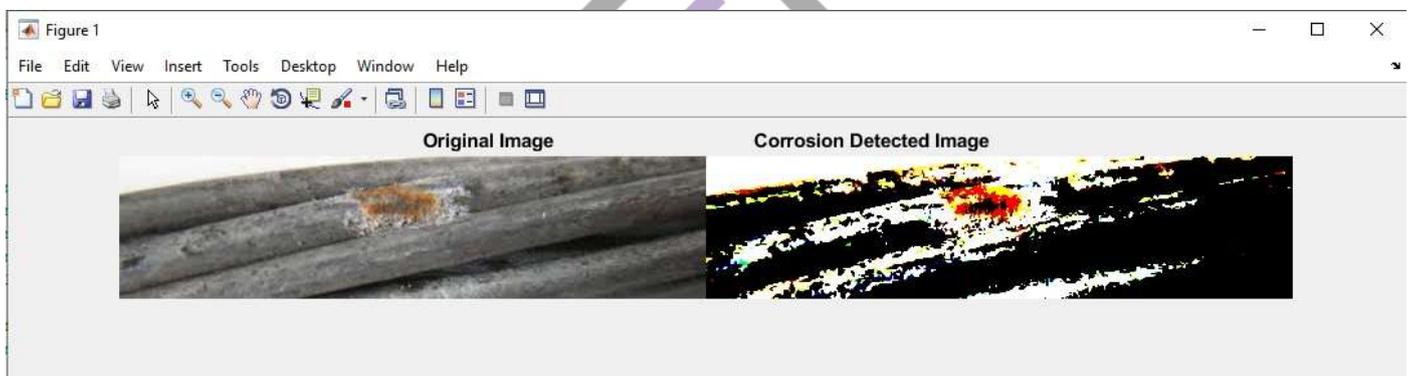


Fig 8. Corrosion Detected Image

CONCLUSION:

This paper focused on the parameters like twist angle, diameter variations, corrosion, etc. of an electrical conductor and developed the utility of image processing in MATLAB tool and GUI to monitor and detection of above noted parameters of the electric conductor in overhead transmission line. As a result, the developed framework had sufficient precision of the diameter and twist angle estimation of the conductor for an image captured by USB camera and these images were recognized well. In addition, the developed framework was competent to identify corrosion of the electrical conductor. At last, the confirmation utilizing the actual electrical conductor was conducted. In spite of the fact that a few results having an error, most results have great precision, and the parameters were recognized well by the developed framework.

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