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Fault Detection using Image Processing and Orbit Analysis

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Abstract— **Vibrations have been traditionally associated with trouble in machines. However, vibrations are merely symptoms of good or bad mechanical behavior. Today these symptoms are used to detect and solve many mechanical problems. To prevent the great loss in production due to motor failure, early detection of faults with diagnosis of its root cause is necessary. This project is an approach for fault detection in rotating machines using orbit analysis of shaft and Image processing. Several works have been focused on detecting early mechanical faults before damage appears in the machine. All these techniques such as Motor Current Signature Analysis, Vibration Monitoring, Thermal imaging, Oil particle analysis are very effective their way. In this project a new methodology for low speed rotating machines is proposed for identifying and detecting different faults in motors. Through Image Processing Based on Orbital Analysis, different faults will be studied, generating characteristically different patterns that are used for fault identification.**

Index Terms—**Orbit Analysis, Image Processing, Rotating Machines, Fault Detection**

I. INTRODUCTION

For many years (and in many plants till today), philosophy has been to simply run the plant until a machine failed, deal with it and get it back in good condition, running it once again. If machines failed, they were repaired or a spare was used. Little thought was given to equipment reliability or predicting failures. The maintenance department was a huge cost sink and that was considered the standard part of running the business. More recently, the philosophy has changed. Rotating machines have a high capital cost and hence the development of condition monitoring techniques is very important. Now organizations recognize that it is worth the investment of time and money to change the maintenance practices to be more proactive and to work to improve equipment reliability. Great cost savings have been realized because of this. Several works have been focused on detecting early mechanical and electrical faults before damage appears in the motor. All the modern methods that use accelerometer are very effective except the potential problems that may occur at low frequency vibration.

The two disadvantages are:

1) Reduced sensitivity at low frequencies especially below 300 rpm due to electrical noise.
2) Instrument integration errors on vibration spectrum.

In this project, a new methodology is proposed for identifying and detecting different faults in motors. Through image processing specially for low speed machines below 300rpm, different faults will be studied, based on orbital analysis, generating characteristically different patterns that are used for fault identification.

Basic Block Diagram

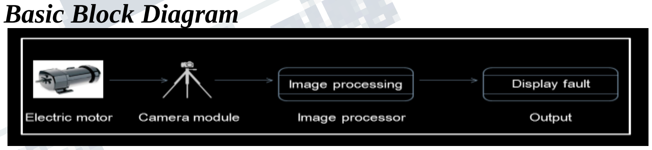

Figure (i)

From fig.(i):

1) Device under test is the rotating machine for e.g. electric motor or pump whose shaft facing is visible with a dot or point (for plotting) on it.
2) A high resolution camera module will capture a slow motion video of the rotating shaft.
3) Image processing section will process the video using matlab.
4) Image processing section includes conversion of video to frames, detecting the dot in the frame, plotting of dots from the frames, classification of plot according to the fault.
4) Output will be displayed on the screen.

Electric Motor

Electric motors impact almost every aspect of modern living. In addition to running the commonplace appliances that we use every day, electric motors are also responsible for a very large portion of industrial processes. Electric motors are used at some point in the manufacturing process of nearly every conceivable product that is produced in modern factories. Because of the nearly unlimited number of applications for electric motors, it is not hard to imagine that there are over 700 million motors of various sizes in operation across the world.

Why condition monitoring?

All operating machines vibrate. Machines vibrate due to imperfections. Different imperfections produce Vibrations of different characteristics. So there is a need to analyse the characteristic patterns that different faults represent. Most common defects in rotating machines are: Unbalance, Misalignment, Bent Shaft, Eccentricity, Mechanical looseness.

Orbit Analysis

Orbit analysis is carried out and more effective for a limited number of rotating speed or rpm. Orbits are Lissajous patterns of time domain signals that are simultaneously plotted in the XY coordinate plane of an oscilloscope or vibration analyser. Orbit plots can efficiently be used in vibration diagnosis where other techniques, such as FFT and time waveform, may not provide sufficient information specially at lower speeds of rotating machines.

In the following, some vibration problems are discussed:

1) Unbalance:

Unbalance will generally produce 1xRPM vibration with 90 phase shift between the horizontal and vertical directions. This will result in ellipse-shaped orbit.

2) Misalignment: When radial preloads due to misalignment, gravity, fluid forces and other causes increase in magnitude, the orbit will become acutely ellipsoid.

3) Mechanical looseness

When the foundation is loose, the machine vibration will increase giving any random orbit pattern.

4) No fault: The pattern will be circular.

Orbit Patterns:

Figure (ii)

Image Processing

In this section, a stream of video is converted to multiple image frames. The programming language used is matlab. Each image frame consists of the dot on the shaft. The unnecessary part except the dot is again filtered from each frame. After experimenting the above procedure, the frame before and after filter is as shown in the figure:

Figure iii (a)

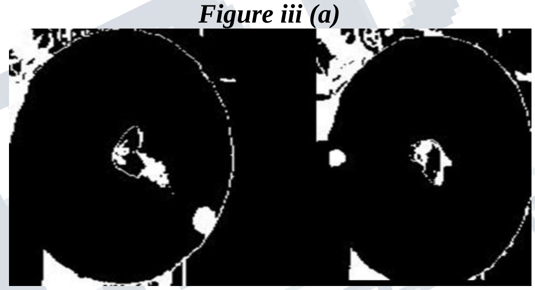

Figure iii (b)

Figure iii (a) is the frame that is converted from the stream of videos. Figure iii (b) is the frame that is filtered using matlab. After further filtering, these frames will be plotted so as to represent a characteristic pattern. This is shown in Figure iii(c). The pattern of the plot will be used for recognition of type of fault in rotating machine. From Figure (iii)c, it is seen that the plot is circular. This concludes that there is no fault in the machine.

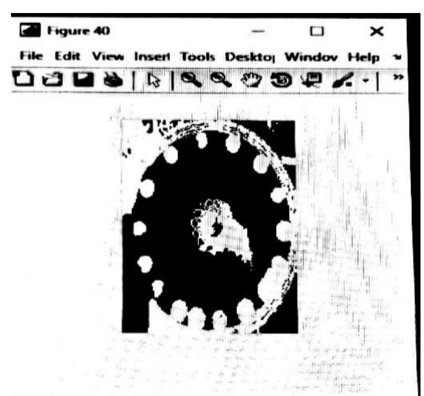

Figure (iii) c

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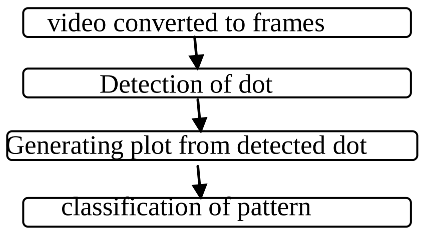
Flow chart for matlab code:



Classification methodology

K-nearest neighbour is a non-parametric lazy learning algorithm. KNN assumes that the data is in a feature space. More exactly, the data points are in a metric space. The data can be scalars or possibly even multidimensional vectors. Each of the training data consists of a set of vectors and class label associated with each vectors. We are also given a single number k. This number decides how many neighbours (where neighbours is defined based on the distance metric) influence the classification. This is usually an odd number if the number of classes is two. If k=1, then the algorithm is simply called the nearest neighbour algorithm.

Example of KNN classification:

The test sample (green circle) should be classified either to the first class of blue squares or to the second class of red triangles). If k=3(solid line circle) it is assigned to the second class because there are two triangles and only one square inside the inner circle. If k=5, (dashed line circle) it is assigned to the first class (three squares v/s two triangles inside the outer circle).

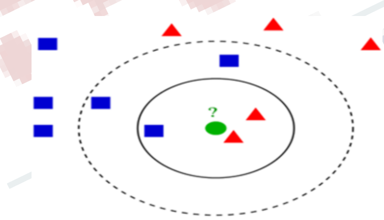


Figure (iv)

Output

After the classification of the pattern, the output will be displayed on the computer screen. Depending on the type of fault, the output can be as follows:

1) No Fault (when pattern is circular)
2) Unbalance (when pattern is an ellipse)
3) Misalignment (when pattern is an ellipsoid)
4) Loose Foundation (when pattern is random)

Advantages

1) Increases machine RELIABILITY.
2) Gives early warning of potential failure.
3) Cost effective.
4) Less manpower required.
5) New challenging point of view for condition monitoring in the field of mechatronics.
6) More profitable to the company.

CONCLUSION

Fault detection in Rotating machines is possible with the new methodology which is proposed in the project using orbit analysis and Image Processing. Use of high resolution camera will add on to the effectiveness of the output.

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