Machine Condition Monitoring by Image Vision System through Tribo Analysis of used Oil

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Abstract: The modern information science and knowledge engineering has been strongly utilized towards the development of condition based maintenance strategy. Amongst the available strategies of monitoring, wear debris analysis is one of the most important in fault diagnosis of any machinery. It has been found from the survey that almost 20% - 30% of faults can be detected from this method when used separately. In the present work, gearbox of the rolling mill has been examined by considering the wear conditions especially the proper lubrication, normal operation and the presence of contaminant particles in the lubricants. After testing ferrographically, the severity occurred and accordingly the vision system has been applied. Some of the morphological characteristics have been judged, so that the health monitoring of the equipment can be done properly for making the strategic planning.

Keywords: Machine condition monitoring, Image vision system, Wear particle analysis, Ferrography.

I. INTRODUCTION

The maintenance strategies of machines can be divided into several ways like, corrective, i.e. Run-to-failure maintenance, predictive maintenance i.e. scheduled maintenance and condition based maintenance. The Run-to-failure maintenance strategy causes minimum maintenance costs up to the first failure and it can apply to any system when the user takes a great risk. But unfortunately this principle is no longer acceptable in the large complex machines where the losses due to unexpected shut down of production occur. Many industries often recommend the scheduled maintenance strategy as it is quite a traditional process and is widely accepted in any type of organization. The scheduled maintenance strategy can lead to excessive maintenance costs caused by any unnecessarily short time between overhauls and where the machines are maintained whether overhaul is needed or not. The purpose of condition monitoring is to eliminate breakdowns and prolong the preventive actions intervals as much as possible. In any condition monitoring system generally some of the important steps are involved like,

- Real-time application
- High reliability
- At early stage, alert when fault is impending, so that maintenance can be planned when asset is not being used
- Identification of the fault(s)
- Classify faults in different categories, when a fatal fault occurs automated shut down should be a possibility
- The alerts should be easy to understand
- The system should be connected to a computer

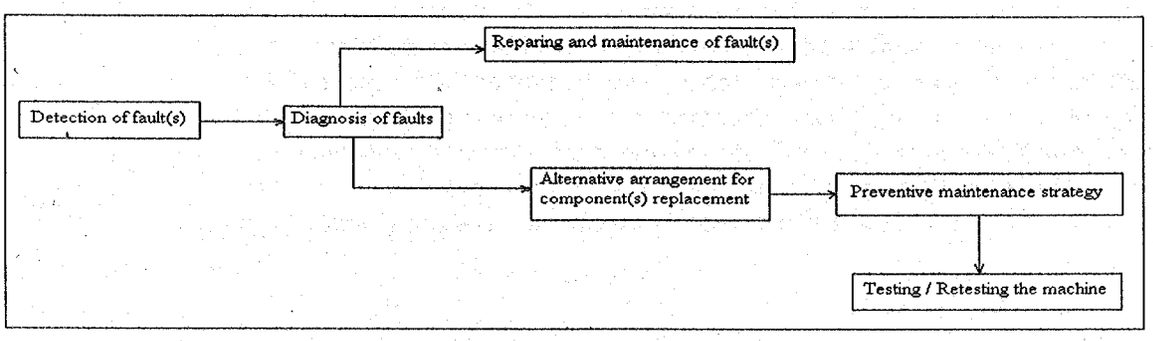

Fig.1: Condition based maintenance process

Machine condition monitoring involves the continuous analysis of operational equipment and the identification of problems before component breakage or machine failure. Three types of major techniques have been considered in condition monitoring,

- Vibration monitoring
- Lubrication / Wear / Degradation by-product monitoring
- Performance monitoring

Apart from the type of monitoring processes there are some testing methodologies involve, which can be used in industrial process. Amongst them vibration analysis is quite an important process, but wear particle analysis technique has been adopted in the present work using automated image vision systems.

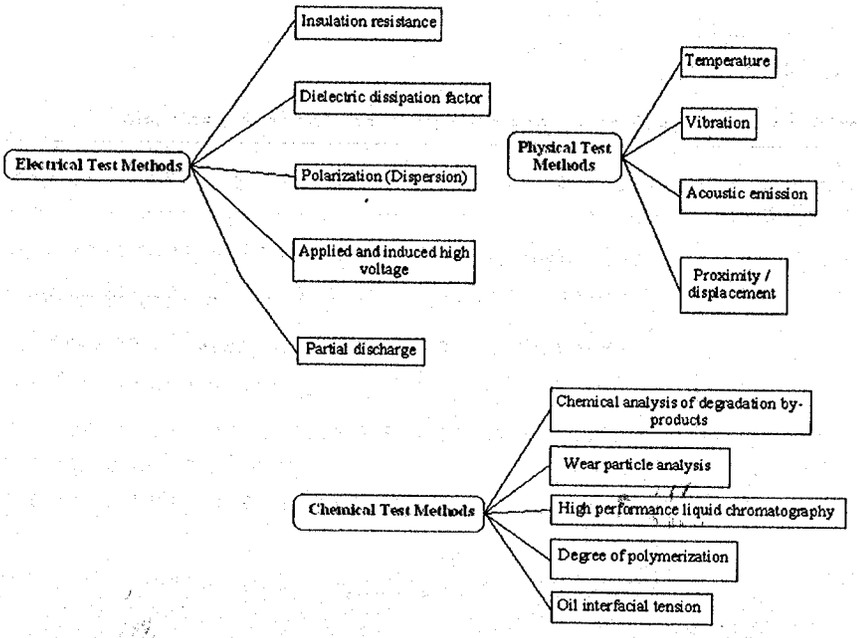

Fig.2: Various testing methodologies

1.1 Wear Debries Analysis

Wear is the primary mechanism through which the industrial plants can deteriorate easily. Therefore, by observing the amount and mechanism of wear periodically, monitoring the deterioration of plant is possible. Generally SOAP (spectrometric) analysis of used oil is done for this kind of analysis, but modern technology supports many analysis techniques like ferrography is one of them. Usually, wear debris analysis overcomes the particle size limitation and gives the additional information on the mechanism, location and extent of wear as well as the state of the lubricant and contaminant content. Fig.3 shows the steps involved in wear debris analysis,

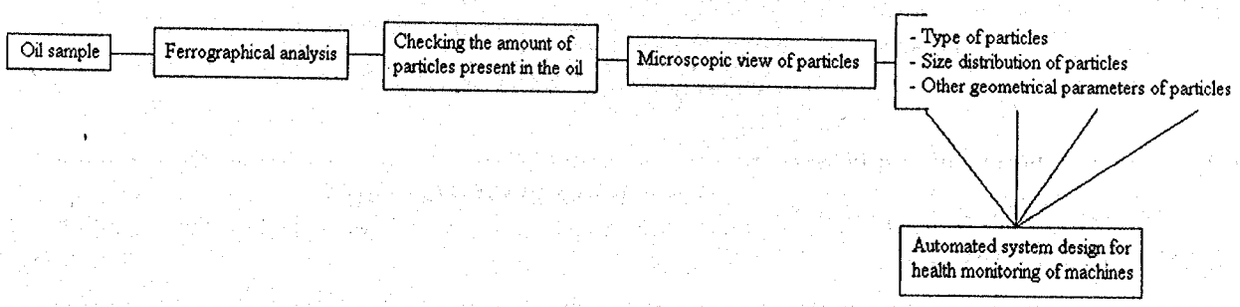

Fig.3: Automated system design for wear debris analysis

Different types of wear particles have found from several experimentations from which wear modes can be fixed up.

- Normal rubbing wear
- Severe rubbing wear
- Cutting wear
- Chunks
- Laminar wear
- Spheres
- Red oxides
- Corrosive wear
- Nonferrous metals
- Nonmetallic particles
- Friction polymers
- Fibers

1.2 Ferrographical analysis

Ferrographical techniques provide sufficiently specific particle characteristics so that the operating wear modes within the machinery can be determined. Ferrograms are prepared in this technique and the used

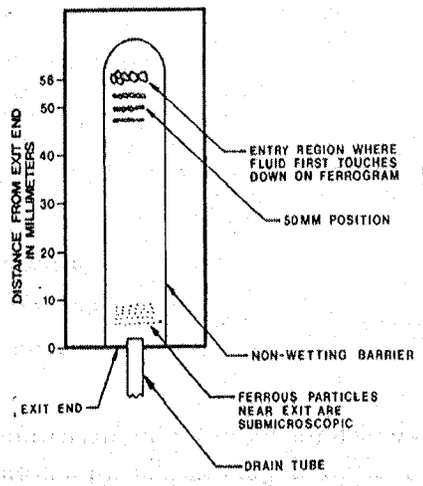

Fig.4: Particle deposition in ferrogram

oil is applied in such a way that the bigger particles can be deposited at the entry level and smaller particles are deposited in exit level. Then the ferrogram is being checked out microscopically so that the particle size and its other parameters can be checked out for further processing. The automated analysis can be done with the help of severity index nature and if it is in increasing mode then further analysis can be done. The severity index can be defined as,

$$S.I.=(L+S)\ (L-S)=L^2-S^2 \quad \text{..... (i)}$$

where, L = large particles and S = small particles

L+S = concentration of the particles

L–S = size distribution of the particles

2. IMAGE PROCESSING

An image is the optical representation of any object illuminated by a radiation source. Three basic elements are very important in the image formation process,

- Object
- Radiation source
- Image formation system

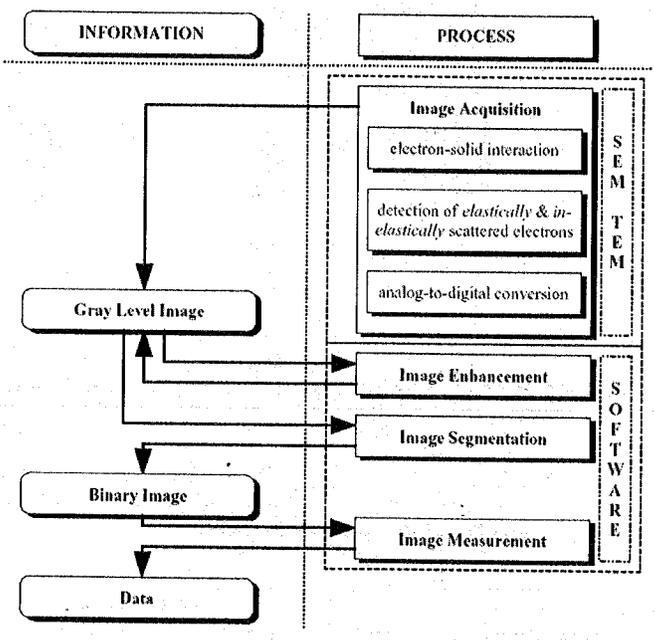

Fig.5: Image processing stages

The digitized data can be analyzed in such a way that the information can be made up and accordingly the monitoring evaluation can be done properly.

3. CASE STUDY

Ferrographical analysis of used lubricant has been made in the present work and different ferrograms have been analyzed by microscopic view of the particles. Color CCD acquisition has been utilized to detect the wear mechanism at the present work. Some of the geometrical parameters have been detected after interpreting with the computer. Various image processing techniques have used to make the proper visualization such as, spatial filtering, sharpening process, masking etc. Some of the microscopic images have been acquired from the CCD camera. High resolution PC i.e. 1280x1024 has been utilized for the present system.

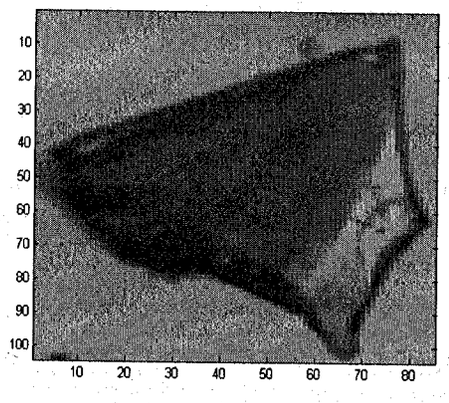

Fig.6: Rubbing wear particle at 104x85 resolution scale (Image 1)

After doing some image processing techniques it has found,

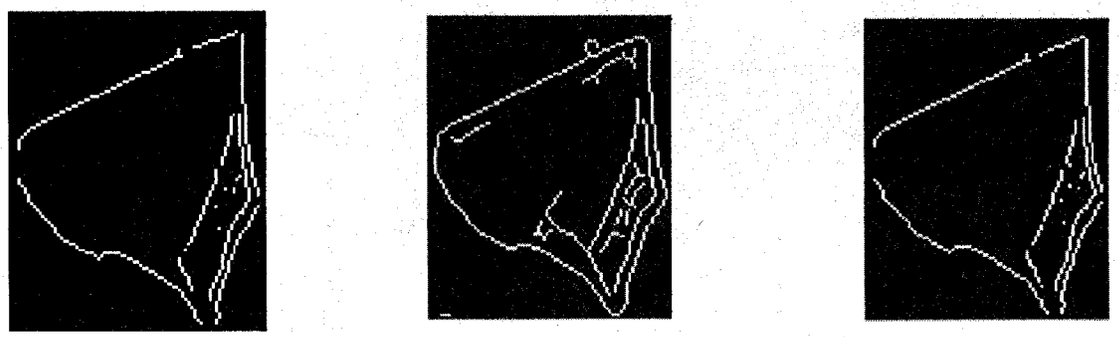

Fig.6: (a): Processed image

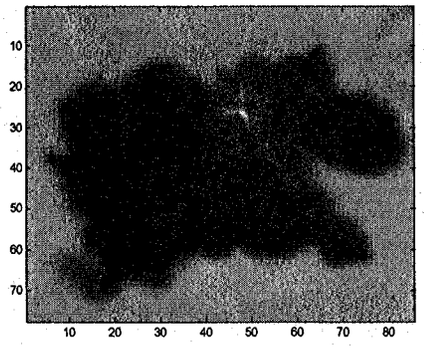

Fig.7: Laminar wear particle (Image2)

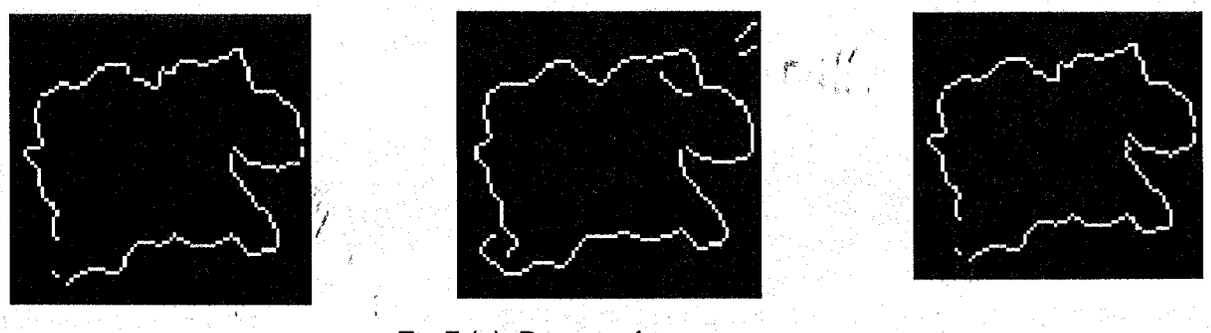

Fig.7 (a): Processed image

The numerical descriptors have been calculated from the digitized images and accordingly those parameters with images have been compared with the original image of wear particle atlas. In this paper two images have been considered for automated analysis.

3.1. Observation and Discussion

The geometrical parameters have been formulated as,

Form factor = $4\pi A / P^2$

Roundness = $4\,A / (\pi \,.\, \text{diameter}_{max}^{\,2})$

Aspect ratio = $\text{diameter}_{max} / \text{diameter}_{min}$

Compactness = $\text{sqrt.}\,(4*A / \pi) / \text{diameter}_{max}$

where A = area of the particle and P = perimeter of the particle

Table-1: Values of geometrical paramenters

Sl.No.	Area (μmm^2)	Perimeter (μmm)	Form factor	Roundness	Aspect ratio	Compactness	Remarks
Image 1	6074.8	276.91	0.995	0.836	0.858	0.914	Rubbing wear
Image 2	3965.8	162.07	1.897	0.81	1.233	0.9	Laminar wear

From Tabl-1, the type of particle has been categorized according to the wear particle atlas where the dimensions have matched and finally it has been concluded as, the types of particles are rubbing and laminar nature. In this way, different types of particle have been recognized but only two of those have been shown in this paper.

4. CONCLUSION

The case study based on the gearbox of cold rolling of steel from where the oil has been taken as a sample and a lot of image processing techniques have been applied with their morphological analysis. Some of the numerical descriptors like length, width, perimeter, area, compactness, roundness, fractal dimension, form factor, feret diameter etc. have been calculated, but some of them have been highlighted in the present paper. After getting those parameters, comparisons have been made with the original images from wear particle atlas and finally the satisfactory results have come out. The mechanisms have been detected from the case study and finally the maintenance strategy can be done with the help fuzzy inference methodology so that the proper health monitoring of the equipment can be judged properly.

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