A MECHATRONIC SYSTEM APPLIED TO WEAR PARTICLE ANALYSIS

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ABSTRACT

This paper describes the development of a mechatronic system for a predictive maintenance grounded on wear particle analysis. The reckoning of wear particles containing in lubricating industrial oils brings the image acquisition system into being. The ISO 4406:1999 standard is a guide to establish the counting and evaluation processes of particles. The system applied to the acquisition and analysis of the data consists of a digital camera, a monocular microscope and an oil filtering system. A computational program was developed with the application of Visual Microsoft C++ in a way to detain the oil sample image from the microscope slide to the computer screen. Quantitative analyses of the wear debris particles bulk are exploited applying a graphical interface that was developed to render the image processing of the sample test. The implemented system has a reachable cost thus it can be applied for schooling goals and for bolstering laboratories of minor industries and medium size companies.

Keywords: Wear particles; mechatronic system; Graphical interface; Computational program.

INTRODUCTION

Wear debris analysis is an eminently usable technique for monitoring the condition of machinery components, for instance those found in engines, transmissions and other machineries. The term '*wear*' is associated to the field of tribology, which is an area that trades the study of wear, friction and lubrication [1]. Particles contained in the lubricating oil can be separated for examination and analysis by using different methods. Visual inspection of microscopic wear particles in lubricating oil is an important stage of the wear debris analysis. Particles images are distinguished by their size, quantity, shape, edge detail, edge curvature or surface texture [2]. Particles quantity enables the extent and rate of wear to be monitored. Wear particle size distribution analysis is quantifiable by an automatic-particle-counting procedures usage or by devised image analysis [3-4]. Automatic image analysis offers the potential to collect statistical information associated to a huge number of particles and the formation of a reference database against, which particles of unknown type and origin can be typified.

There are three methods employed to particle counting: optical particle counting, pore-blockage particle counting and microscopic evaluation. The optical particle method is deemed as a sophisticated automatic method, which can be used with very clear or dusky oils alike. The foremost drawback of it is the cost. The microscopic assessment processes, which this matter considers, are implemented to conditions where exceedingly dirty oils are the pattern. Under the microscope process, a solvent-weakened ratio of specimen is used to prepare a patch, where contamination is refined onto a patch for microscope examination. The patch makers range from

the portable, manual vacuum pump-type to the more advanced bench-mount setup with an electric vacuum pump. The ISO 4406:1999 Standard grounds the preparation of the sample test [5]. The sample filtration is constituted by the oil sample, and after the purification, the membrane filter is transferred to *petri* dish being ready for a microscopic inspection. In order to become aware of the particles count, it is necessary to seize the image of the field that will be investigated. The image will be analyzed to a computer vision process that locates and recognizes objects in digital images with the use of image processing techniques.

EXPERIMENTAL SETUP

Description of the system

The developed apparatus system applied into this work consists of two modules, named patch bench-mounted setup and computer image processing system. The apparatus system shown in Figure 1 includes a filter holder, a vacuum pump, a Canon A-520 digital camera connected to a 'Quimis Q-705M1' monocular microscope and a microcomputer connected to the digital camera via USB port.

Figure 1. System apparatus.

A program denominated "Image Acquisition System Software (IASS)", which was developed to counting automatically particles of a patch test, controls the computer image processing system.

System operation

The description of system operation is summarized in the flowchart showed in Figure 2.

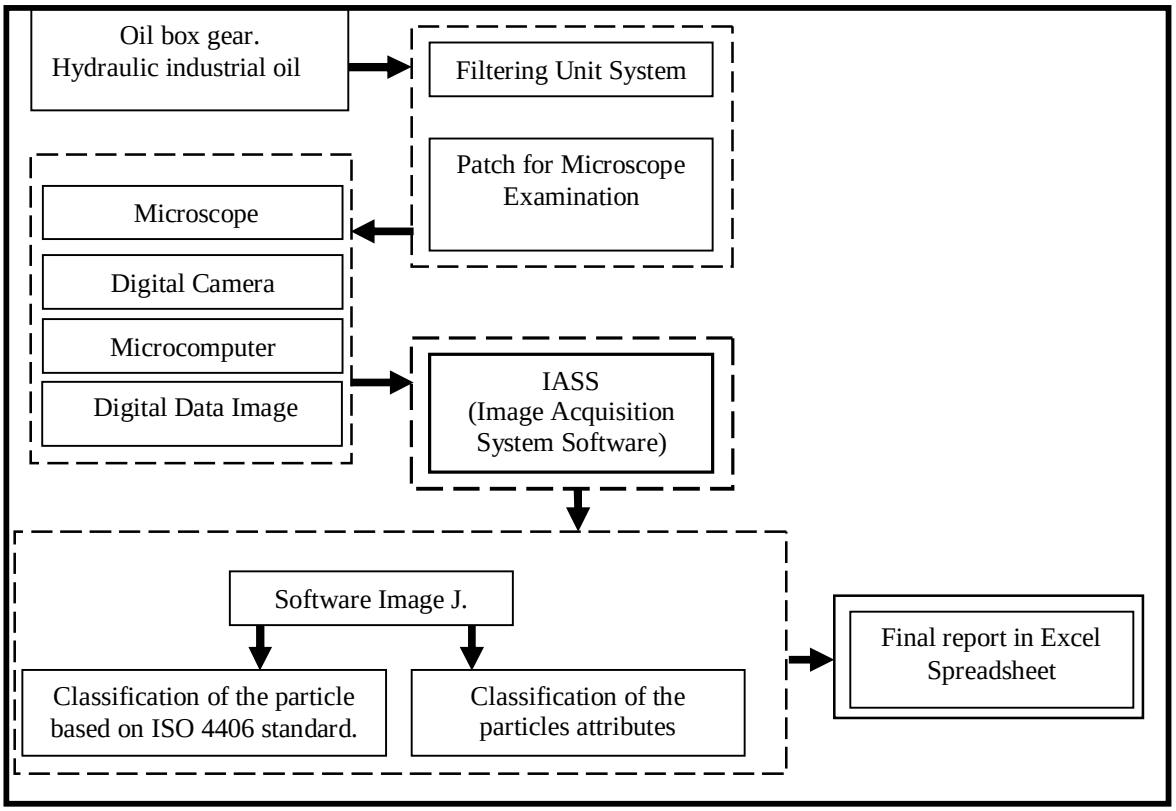

Figure 2. System operation flowchart.

Following the flowchart, the process starts with monitored equipment as an oil box gear or hydraulic industrial oil. The oil sample is obtained in 100ml in which the quantity of 50ml is input in a filtering unit system. A membrane of a 47mm of diameter and having a pore size of 1.2 μm is used to make the filtration. After the filtration, the filter patch is removed from the filtering unit and then placed a monocular microscope for examination using magnification factor of hundredfold. The patch filter brings the particles of contamination contained in the oil sample. A digital data image of patch is obtained through the digital camera and transferred to the computer and then is processed with the Image Acquisition System Software (IASS) which makes the counting particles process guidance; calling other programs used in this process as Microsoft Excel spreadsheet and Image J.

IMAGE ACQUISITION SYSTEM SOFTWARE

The IAAS works under “Microsoft Windows” environment to capture the images of the patch tests. The main window of IASS is shown in Figure 3 with a wear image been displayed. There are five top-level menu items with their pop-up menus for the users to control and access the system.

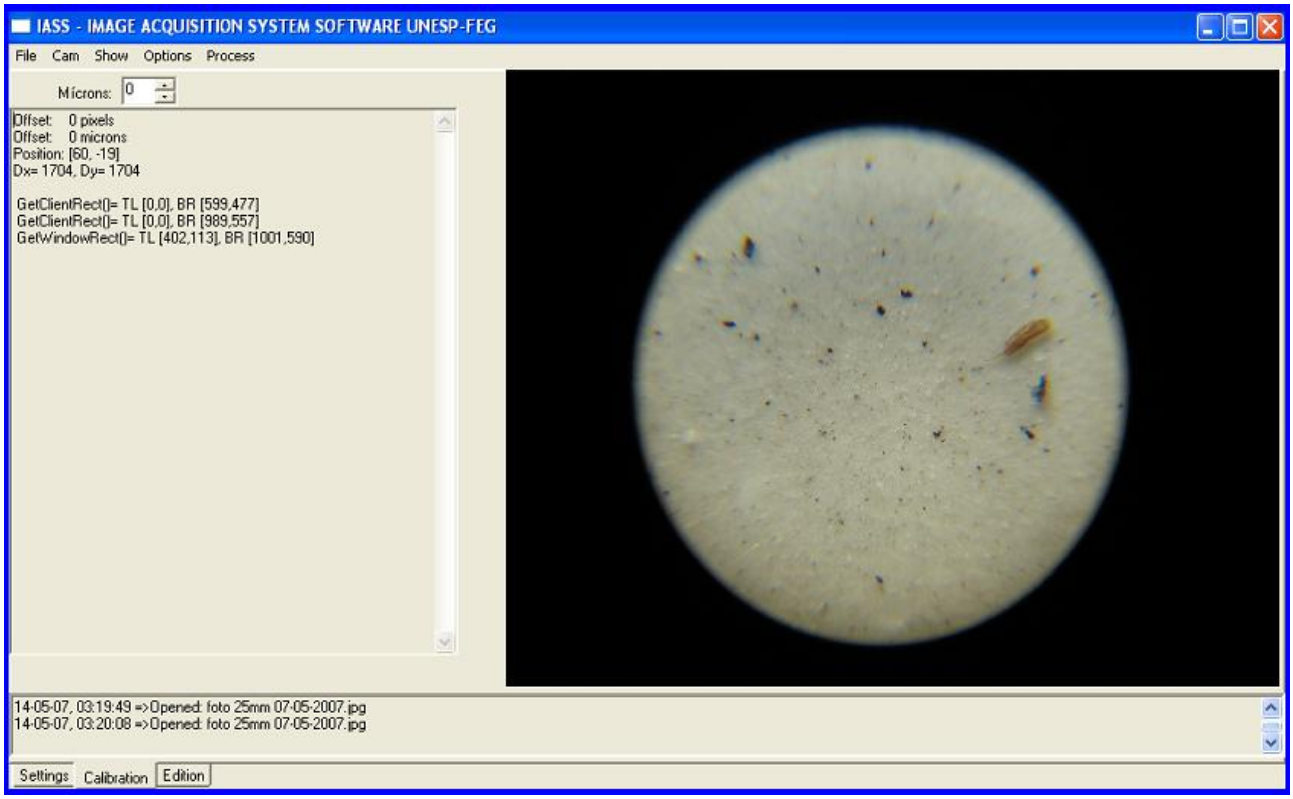

Figure 3. Digital image of the patch test.

The image capturing from the microscope is saved in joint photographic experts group format (JPEG) under the "Camera" menu item. The program has also a link to ImageJ under "Options" menu item. ImageJ [6] is a public domain image analysis program, which has been used to count the wear particles detected within specific ranges of sizes. The criterion adopted to estimate the particles on this article is based on ISO 4406:1999 standard, which is a process that evinces the category and sharpness of the wear-taking place. The results of particle counter are presented on an Excel spreadsheet under the associated pop-up menu "Start Report" from "Options" menu.

Calibration process

The first step under ImageJ environment is the calibration process of visual field of the microscope. The idea under this process is to evaluate the dimension of the wear particles. The calibration is processed using a standard stage micrometer, which is a glass slide with etched graduations divided into 0.01 mm. The calibration is performed as shown in Figure 4. A straight line is created using the line tools from ImageJ toolbar. This line is overlapped with the graduated scale. Then in the menu of ImageJ under the item "analyse" select the pop-up "set scale" in a way to determine the calibration factor between metric scale and the size of the pixel (μm/pixel).

Figure 4. Process of calibration.

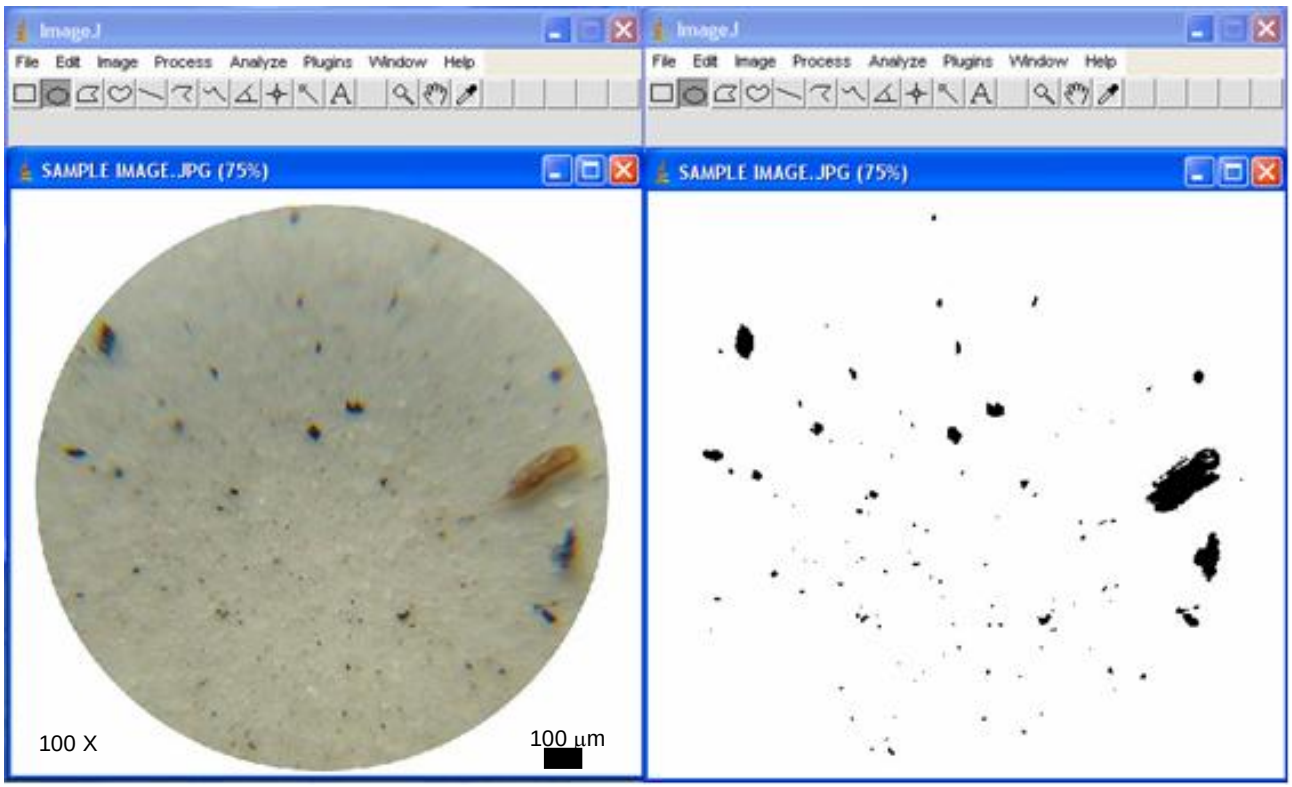

Figure 5. Thresholding of the grabbed image.

Particle size distribution

For the particle size distribution the grabbed image, has to be thresholded first. This process consists of image segmentation that divides the field of view into background and foreground intensity levels [7]. The threshold value can be selected either automatically, or manually. After the thresholding, all detected wear particles are globally classified. The globally analysis consists of particle counting, size and classification of shape features. Figure 5 shows the thresholding method of the grabbed image processed under ImageJ environment.

The system can count particles according to their size distributions following the measurements of size and distributions according to ISO 4406:1999 standard.

PARTICLES SHAPE CLASSIFICATION

After size distributions shape features are important factors applied in the recognition of wears particles [3], since they have a close relationship within wear modes and condition of machines. Shape features on this article are classified using roundness, aspect ratio and area.

Roundness is expressed as the radius of average radius of the edges or corners to the radius of curvature of the maximum inscribed sphere. The roundness factor is defined as the ratio of perimeter squared to the area contained within the outline shape [7]. This parameter is normally scaled to give a minimum value of unity for a circle, and larger values for irregular boundary shape. Another technique used to identify the shape of wear particles is aspect ratio, which is a dimensionless factor defined as the ratio of its longer dimension to its shorter dimension.

REPORT OF THE OIL SAMPLE ANALYSIS

A report of oil sample is presented in Excel Spreadsheet shows the image of the patch, the classification of oil sampled in accord with ISO 4406:1999 and it also provides the distribution of particles based on shapes features applied in this work for recognition of wear pattern.

Figure 6 shows the result of report with details of the sample test.

The classification of particles shape features is shown in Table 1. This classification provides the distribution of particles for 1 ml of oil in accord with the shape features.

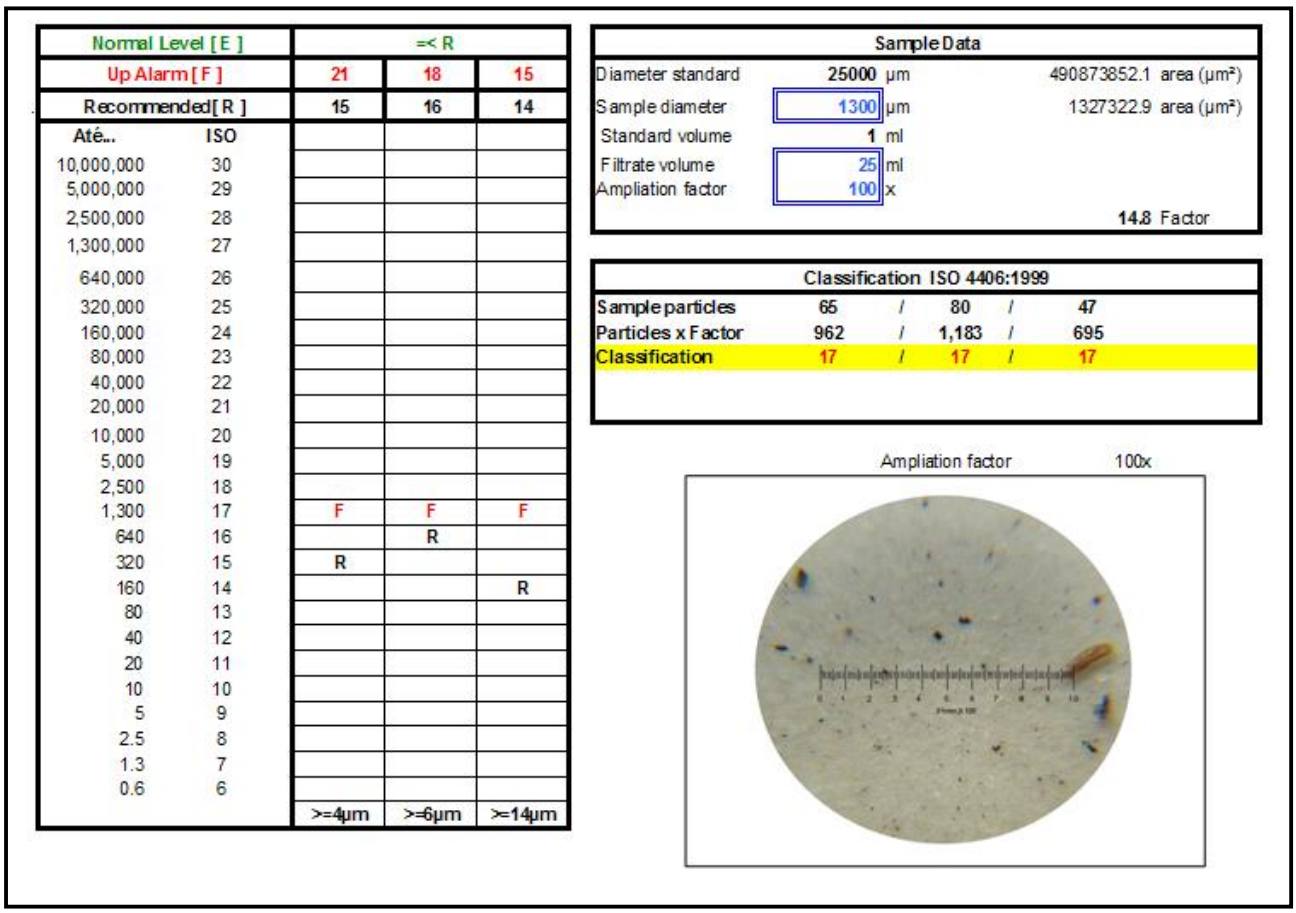

Figure 6. Result of report of oil sample.

Table 1. Classification of particles as shape features.

ISO 4406	Area µm²		Roundness		Aspect Ratio		Number particles in filter patch
	Min	Max	Min	Max	Min	Max	
>4 and <6 microns	4,58	14,87	1,00	1,75	1,04	4,00	962
>6 and <14 microns	6,86	77,78	1,00	3,00	1,06	5,49	1183
>14 microns	33,17	13125,91	1,24	4,05	1,04	6,09	695

CONCLUSIONS

Computer vision and image processing techniques are applied to extract important information from wear particles images. This article presents a low cost integrated image view system for use in wear debris analysis. This system that is based on image processing techniques has been used to evaluate particles size measurements and distributions. It is expected promising results for helping the maintenance of industry environment personnel and it structures with affordable resources an oil-analysis program laboratory into the university. Future improvements have been done to the system, like the uses of neural networks for image recognition of wear particles and improvements in the hardware system. It is also intended to build database of wear particles.

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