LINE PART OF ETCS L2 APPLICATION IN THE CZECH REPUBLIC – CURRENT STATUS

Milan Kunhart[1]

The article is concerned with the Pilot Project for homologation of ERTMS/ETCS system in the Czech Republic (PP).

The article describes an operational characteristic of the PP (ETCS application on the conventional lines, mixed traffic with equipped and unequipped trains) and a technical characteristic of the PP (level 2 application, cooperation with existing trackside system from domestic supplier, development of the specific transmission module of the national Automatic Train Protection system of the LS type).

The article describes the architecture of the ETCS L2 application and a development of the special interlocking - RBC interface IRI, its functionalities and behaviour.

The article describes some of the test procedures used on the PP for the purposes of assessment and validation of the system components and procedures. The functional tests of the system components were performed primarily. Then the integration tests between laboratory simulators and then between real equipments were carried out. Very complex tests had to be done in order to obtain a preliminary technical approval of the new interlocking software. Test strategy was crowned by performing the on-site tests of the real equipment on the PP line.

Key words: ERTMS, ETCS L2, Interlocking - RBC Interface, system architecture, test procedures for the purposes of assessment and validation

[1] doc. Ing. Milan Kunhart, PhD, Research and Development Department of the AŽD Praha s.r.o., Žirovnická 2, Praha 10. Czech Republic, E-mail: kunhart.milan@azd.cz

WEAR DEBRIS ANALYSIS IN TRANSPORT

Stanislav Machalík[1], Roman Juránek[2]

The goal of this paper is to outline the possibilities of improvement in image analysis with the help of automatic evaluation of wear particles by using modern methods of artificial intelligence.

Key words: image analysis, wear debris analysis, machine learning methods

1 Introduction

Lubricants used in mechanical parts must accomplish contradictory requirements on their function in many cases and, at the same time, they must often work in extreme conditions with longer service life. The increase of reliability and the economy of machine use are closely connected to monitoring the condition and state of technical parts of used lubricant with the purpose of diagnostics. Computer image analysis of wear particles is a useful supporting tool for detail analysis of oil samples. Presently, laboratory methods of analyzing each element under a microscope are used most frequently. Modern methods, including machine learning, provide possibilities of automation of wear debris analysis.

2 Current state of the problem

The analysis of the image obtained with a set-up consisting of a microscope and a digital camera can be used very effectively in experimental branches related to the evaluation of operational substances and construction materials used in transport. Each abrasion particle is extracted from the obtained image and it is analyzed in order to determine the prevailing wear type.

The method of analytic ferrography is currently being used at the Jan Perner Transport Faculty in the first place as one of methods used to prepare the sample in order to obtain a quality snapshot of the abrasion particles in the lubricant.

2.1 Fundamental principles of analytic ferrography

The results obtained through the method of analytic ferrography indicate the real technical state of the lubricating system and lubricated parts as well as the way of wearing out the particular abrasion pairs. Each part is evaluated using a microscope.

[1] Ing. Stanislav Machalík, University of Pardubice, Jan Perner Transport Faculty, Department of Informatic in Transport, Studentská 95, 532 10 Pardubice, Czech Republic, tel.: +420 466 036 181, E-mail: stanislav.machalik@upce.cz

[2] Ing. Juránek Roman, Brno University of Technology, Faculty of Information Technology, Department of Computer Graphics and Multimedia, Božetěchova 2, 612 66 Brno, Czech Republic, tel.: +420 541 141 285, E-mail: ijuranek@fit.vutbr.cz

In short, the procedure of obtaining and evaluating the wear particles can be summarized in several steps:

- **Preparation of sample –** Before starting the ferrographic analysis, the sample has to be homogenized in order to dispose of the sedimentation of particles from the bottom or the wall of the vessel containing the sample. The next operation is to dilute the sample. The goal is to achieve a suitable level of viscosity of the solution of oil and diluent. At the correct level of viscosity, a mark of wear particles of even density is established in the magnetic field of the ferrograph; the extent of overlapping particles is minimum and they are prepared for the analysis in an ideal state.
- **Preparation of ferrographic mark** – the ferrographic analysis starts with magnetic separation of particles from the oil sample. The oil flowing down the pad is effected on by a magnetomotive force that speeds up the vertical motion, and by the viscosity of the liquid surrounding slowing down the descent of the particle. The variable intensity of the magnetic field results in the sedimentation of particles present in oil in places determined by their size as well as magnetic characteristics. Hence, magnetic particles are sedimented (based on their size) along the whole ferrogram in typical rings (chains). These chains are established in the direction of lines of the magnetic force so they are perpendicular to the direction of flow of oil. Non-magnetic particles are sedimented randomly along the whole ferrographic mark; they are often captured in the chains of magnetic particles.
- **Analysis and evaluation of sample –**evaluation of the ferrogram obtained in the way described above allows more detailed analysis of morphology of particles, their type, surface etc. using special microscopes. Based on the results of the image analysis of captured particles, the mode of wear of the mechanic system (engine, gear box etc.) can be determined.

2.2 Adjustments and image analysis of a ferrogram

The system for performing the computer image analysis consists of a digitizing device and a computer equipped with special software used to preprocess the image. The LUCIA system (Laboratory Imaging, s.r.o. Praha) is used at the Jan Perner Transport Faculty. A microscope connected to a digital camera is used for digitizing. The image is then adjusted (overlapping of particles, removal of interference elements in the image etc.) as needed. The result is an image ready for segmentation of each particle and its evaluation.

The key step of the image analysis is so called segmentation during which the objects to be evaluated (abrasion particles) are identified in the image; the measuring can take place and the required morphometric or densitometric characteristics of objects (e.g. area, perimeter, length, roundness of objects or intensity of selected color element) can be determined only after that step.

Therefore, wear particles are currently evaluated primarily using the mathematical markers and an evaluation of the wear type is based on the fact that particular wear types are described by given shapes of abrasion particles (markers values are contained in a range that is typical for a particular wear). This means that it is possible to draw a conclusion determining the wear type that resulted in the creation of the particle, based on morphological parameters of the wear particle. More detailed description of characteristic shapes of wear particles is outside the scope of this paper and can be found in literature [1].

The disadvantage of analytical ferrography is that there are requirements of expert knowledge on the ferrograph operator (preparation of sample, adhering to the work procedure) as well as the person who is preprocessing the image. However, the critical factor is the experience of the person performing the analysis itself and the evaluation of the ferrogram image. Based on the number and the characteristic shape of abrasion particles, the prevailing wear type has to be determined correctly.

3 Automating the image analysis and the evaluation of wear type

The element determining the success of the evaluation of the type and weight of wear is the expert erudition of the person performing the image analysis of the sample in case of using the method of analytic ferrography. The goal of this paper is to introduce one of the options of automating the whole process, targeting the minimization of human fault and, above all, the independence on expert knowledge and skills of staff.

Effort is made to use machine learning for creation of an automatic classifier of wear particles. Unlike the current method of particle evaluation which takes primarily their morphological parameters into account, the newly created classifier works directly with images of each particle. The basic idea is based upon methods of machine learning. The classifier uses the capabilities of machine learning; in this case, it is performed using a database of model images of particles with a known wear type that resulted in their creation. If a particle database large enough is used, the classifier is then able to analyze newly submitted image automatically and to assign it to one of predefined classes of wear based on its similarity to training models. It should be noted that the crucial point is the creation of the database of model particles of sufficient quality.

3.1 Data collection in order to create the database

The quality of the set of input data represented by the images of each particle is one of the most important factors influencing the success rate of the classifier when evaluating the tested particles. When using the methods of machine learning, the more input data are available for training the classifier, the higher the success rate is when evaluating real particles. As obtaining the images of each particle directly from the ferrogram image manually would be very time-demanding, laser counter of particles was used to collect the data.

Laser counter of particles (LaserNet Fines, LNF)[1] is a device using laser technologies and advanced software to identify particles in lubricants. It is based on the technology combining laser rendering with a neural network in order to determine the characteristics of abrasion particles as well as other particles contaminating the lubricant.

A characteristic sample of the oil is submitted for analysis. The LNF device pumps the examined oil using a surveillance cuvette lit with a pulsed laser diode. This allows for obtaining the image documentation. The image is continuously recorded with a video camera with magnifying optics. The snapshots are then examined using a program that uses a neural network to determine the type of particles as well as their grain size distribution (Fig. 1).

Within the scope of this project, the LNF device was used to obtain the input data file containing about 8,000 particle images currently.

The disadvantage is the loss the information of color scheme of particles (the output of the LNF device is in the form of binary images only). However, this flaw is not significant because the analysis of wear type of particles is based primarily on the shape of particles. Therefore, this simplification is acceptable.

[1] The LNF device is capable of determining the type of prevailing wear by itself but its price is too high and out of financial capacity of the Jan Perner Transport Faculty. One of the goals of this project is to create a classifier working with a similar principle.

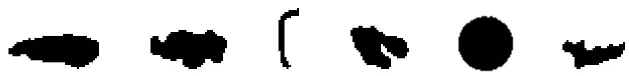

Fig. 1: Input data from the LNF device

3.2 Adjustment of input data

The size of particle images obtained from the LNF varies. The size of image is directly proportional to the size of particle. The size of image ranges from several pixels to hundreds of pixels. In order to allow the use of images for training, several conditions have to be satisfied. Firstly, the size of models has to be the same so the particle images have to be normalized. Normalizing can mean simply re-sampling all images to a uniform size; however, this adjustment does not keep the information of relative particle size if compared to each other. Some small particles could seem larger than others that are larger in reality. As the particle size is important for classification, it has to be represented when normalizing. Therefore, the result of normalizing is a set of images of uniform size, preserving the relative particle size.

In the next step, the particles are centered in the image so that their center of gravity lies exactly in the center of the image.

3.3 Training

Training is based on the AdaBoost algorithm which iterates through the selection of so called weak classifiers that classify the training models into target classes (wear types in this case) in the best way. Hundreds of weak classifiers are selected (out of several hundreds of thousands). A weak classifier is a very simple function (it is sufficient if it is just a little better than a random function). In this case, the classifiers are based on image markers (particle perimeter, roundness length, width etc.).

The evaluation of the whole process of classification is based on the weighted sum of responses from selected weak classifiers. Thanks to the extension named WaldBoost, it is possible to eliminate a high amount of calculations: it is not necessary to evaluate all weak classifiers, which allows for very quick evaluation of classifiers.

3.4 Extending the analysis to a group of particles

In practice, the evaluation of individual particles is not very important; therefore, the main goal is to classify particles from an input area as large as possible (the whole ferrogram in an ideal case). The classifier then determines the prevailing wear type.

The main task is to obtain the image of the whole ferrogram with respective magnification as the input for the classifier in this case which requires sequential scanning of the ferrogram combined with its automated shifting under the microscope. The set of snapshots that is created has then to be connected panoramically in the horizontal as well as vertical direction.

4 Conclusion

The expected output is an automatic classifier of wear particles that will be capable of evaluating the given particle and determining the wear type that resulted in the creation of the particle. This step will be further extended with the ability of analyzing a snapshot containing larger number of particles where the result will indicate the prevailing wear type.

The implementation is planned for the year 2010.

Reference literature

1. MACHALÍK, Stanislav. *Rozpoznávání objektů ve ferrografii s využitím obrazové analýzy*. PhD Thesis. Brno: Brno University of Technology. Faculty of Information Technology, 2007.