Spectro Scientific
Confidence in knowing

APPLICATION NOTE

Ferrous Density Alarm Development for Rail DMU Final Drives – Lubmat '18

J. McGrath, S. O'Rourke | T.E. Laboratories Ltd, Tullow, Co. Carlow, Ireland
D. Walsh | Spectro Scientific Inc, Boston, USA

ABSTRACT

Ferrous density meters have been widely adapted by oil analysis laboratories globally for many years now to overcome the limitation of atomic emission spectroscopy for abnormal ferrous wear [1]. Ferrous density meter technology in the market place has developed enough so that iron content (that is quantitatively measured in mg/l (ppm)) is now preferred over the older, flux qualitative PQ. Incidentally, there is very little information on alarm levels for ferrous debris in common rotating components available for OEM and end users. This presentation reviews data on a series of equipment and proposes alarm guidelines based on statistical methodology. The recent release of an ASTM standard enables laboratories to now standardize the method. This presentation discusses the recent advances supported with sample data from a variety of industries including road, rail and manufacturing.

KEYWORDS

- Ferrous density meters

Introduction

Ferrous density analysis provides a fast and powerful picture of the entire wear situation of a lubricated component. Using both ferrous density meter readings and elemental iron results provides the maintainer with more information about the type of wear occurring and the distribution of wear particle sizes. This extra information concerning total ferrous debris present is particularly helpful for both rotating and reciprocating machinery to indicate when an abnormality is occurring. For the oil analysis provider, it is a useful trigger to determine when analytical ferrography needs to be performed – a significant time and cost saving opportunity for the laboratory, and reducing turnaround time for results back to the customer. T.E laboratories undertook a study to establish statistical alarm limits with the recently released technology to incorporate into the Irish Rail condition monitoring program.

Over the past 3 months, TE have utilized the Spectro Scientific Inc, FerroCheck 2100 to test samples from our varied customer base – rail, road transport and manufacturing. We have used a statistical approach to establish a guide level for each component in ppm.

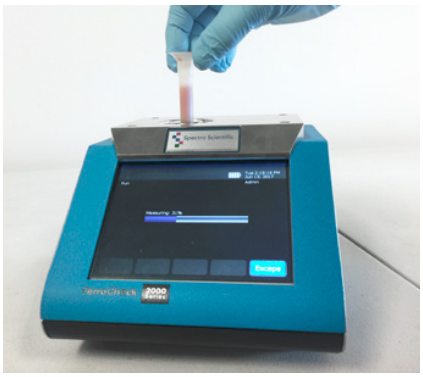


Figure 2-1: Introducing a sample to Ferrocheck 2100.

Explanation of the Test

Ferrous density meters have been in the market place since the 1970's, and all of them employ a slightly different aspect of traditional electromagnetism theory to take advantage of a change in electrical signal when a ferromagnetic metallic particle is sensed. Changes in magnetic flux, dielectric constant, and magnetic inductance or capacitance techniques have all been used in prior systems. The Spectro Scientific FerroCheck 2100 ferrous density meter is a recently released (2017) system that consists of a solenoid-style magnetometer with an inner coil diameter of sufficient size to accommodate a sample tube containing a lubricant with ferrous debris. A disposable HDPE sample tube (3 mL capacity) is filled with oil, directly from the sampling bottle (agitated prior) and placed in the device when prompted (Fig. 2-1) An exciting AC magnetic field is applied to the lubricant under test. The induced current in either a separate sensing coil, or the excitation coil itself, due to the presence of the ferrous debris is measured. From this induced current, the magnetic susceptibility of the lubricant is determined [2].

This magnetic susceptibility is then correlated to the concentration of ferrous debris in the lubricant by means of the known magnetic susceptibility of such debris. The new approach takes advantage of an innovative coil arrangement (Figure 2-2), complete with advanced electronics to provide a very sensitive monitor for particles ranging from sub ppm to % concentration in under a minute (Figure 2-3) the technology is covered under a recently released ASTM [3] standard, ASTM D 8120.

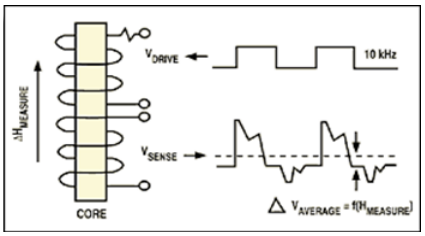


Figure 2-2: A drive coil creates a magnetic field, the sense coil measures it. When ferromagnetic material is present, it affects the sense coil, thus allowing the magnetic susceptibility to be measured.

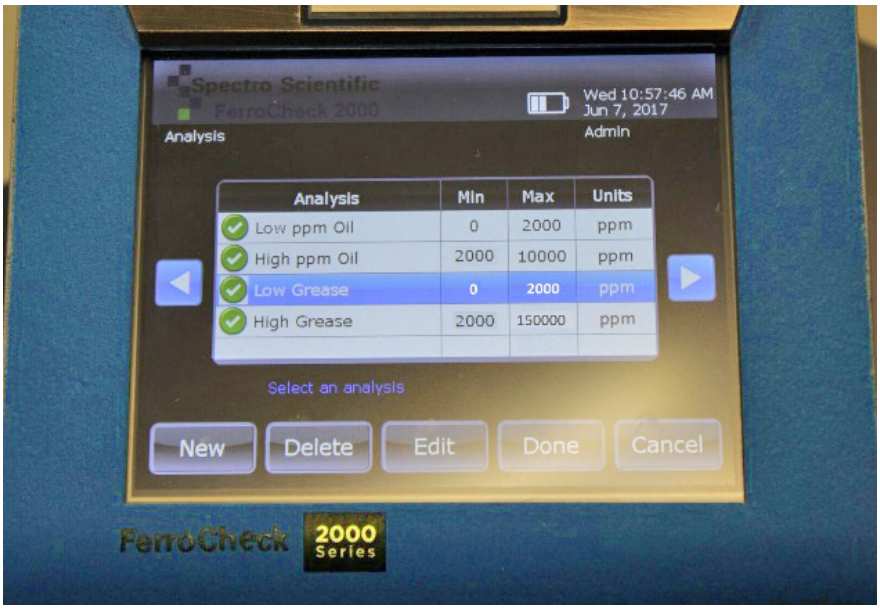


Figure 2-3: the device is calibrated with NIST traceable standard, and calibration ranges for both oil and grease permit ranges from 0 to 15% Ferrous content.

Case Study — Iarnród Éireann (Irish Rail)

Figure 3-1: DMU Class 29009 at Dublin Connolly Station, July 2016

Iarnród Éireann also known as Irish Rail in English, has been the operator of the national railway network in Ireland since 1834. It is unique in the EU with a track gauge of 1600mm. Since 2010, T.E. Laboratories Ltd has provided oil analysis services to the rail company. This case study is based upon 29000 Class DMU based in Drogheda, Co. Louth.

UNIT 29106 FINAL DRIVE PRIMARY

In late 2017 two final drives were identified with wearing issues. The first unit Final Drive 29106 had returned a bad oil sample during October, from this a second and third sample were taken to corroborate the first. The issue was a high Iron content in the oil. According to the OEM the alarm profile for Iron is 150ppm.

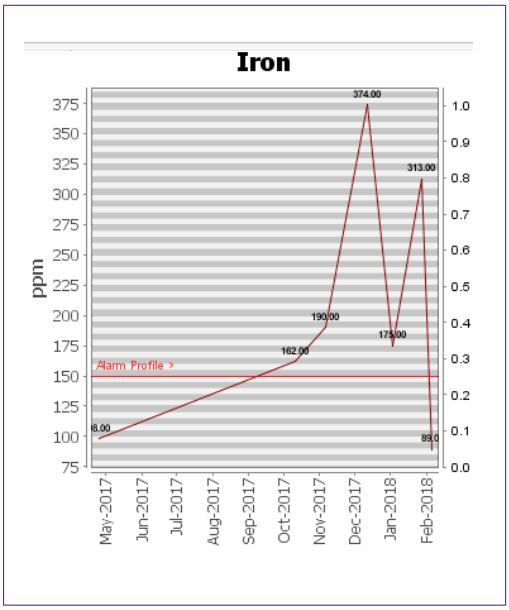


Figure 3-2: Graph of Iron levels of Final Drive 29106

Visual inspection of the oil showed it was contaminated due to the colour. All other values were satisfactory. As the issue was seen to be worsening, it was decided to stop the vehicle and have the bogie replaced.

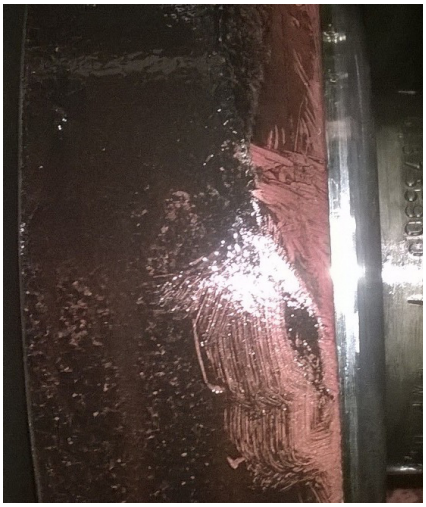


Figure 3-3: Bearing race migrated to the right.

Upon closer inspection whilst being stripped, damage was noted internally on both drives which explained the wear metal issues picked up on the oil sample analysis reports. 29106 had a worn bearing housing, at the pinion end of the input shaft. The bearing had migrated somewhat and the outer race was loose within its associated bore. This wear explained the high Iron content in the sample.

Figure 3-4: Wear mark from bearing race slip.

UNIT 29217 FINAL DRIVE SECONDARY

At the same time there was a second sample with a high result 29217 Final Drive Secondary. There was a high Iron, chromium and elevated Nickel in the oil. From these materials, it was concluded the likelihood of a steel part inside the drive was wearing. Visually the oil condition was poor as it was also very discoloured (a sign of wear metal contamination or oxidation).

Upon closer inspection whilst being stripped 29217 Final Drive Secondary had a similar issue in a different location to 29106. The bore in this case was steel and supported the input shaft, input end bearing. This wear explained the high Iron, Chromium and elevated Nickel levels in the sample. It is worth noting that a subsequent oil sample taken showed Iron and Chromium levels below alarm levels but still quite high. The engineers considered the erosion had slowed due to oil entering the area and lubricating the surfaces.

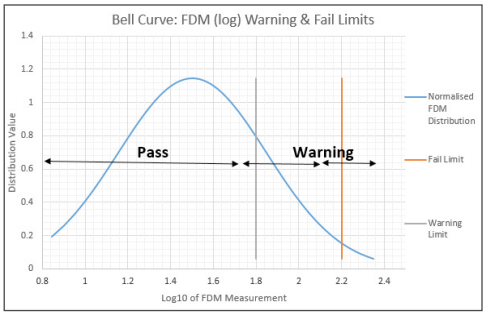


Figure 4-1: FDM Levels of Final Drive

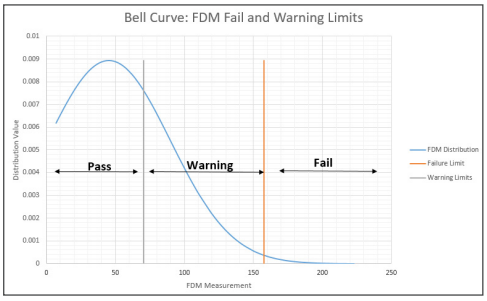


Figure 4-2: Setting Limits.

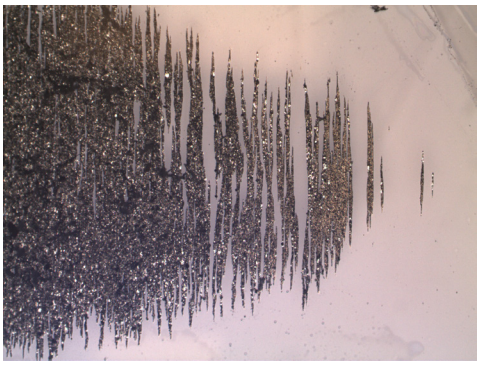


Figure 4-3: Benign Rubbing Wear (Ferrous) x 100Mag 29106 Final Drive Primary December 2017

Ferrous Density

SETTING LIMITS

Over the course of the last few months we have tested over 470 samples from primary and secondary final drives from the entire fleet. In order to develop limit levels for Ferrous Density in ppm we have plotted the following graph of ferrous density by using a spreadsheet developed in house by of diagnosticians.

The bell curve above represents the FDM data when the log to the base 10 is found. The warning and fail limits are for mean+1std.dev and mean+2std.dev.

The log scale warning and fail limits come out as 1.8 and 2.2 respectively. Converting these to ppm values gives warning limit at 71 ppm and fail limit at 158ppm. Note that actual bell curve is highly positively skewed.

REVIEW OF FINAL DRIVE FERROUS DENSITY

Using the FerroCheck 2000 we retested the available archived samples for each final drive. The levels from the ferrous debris analyzer were found to be greatly higher than the calculated limit of 158ppm.

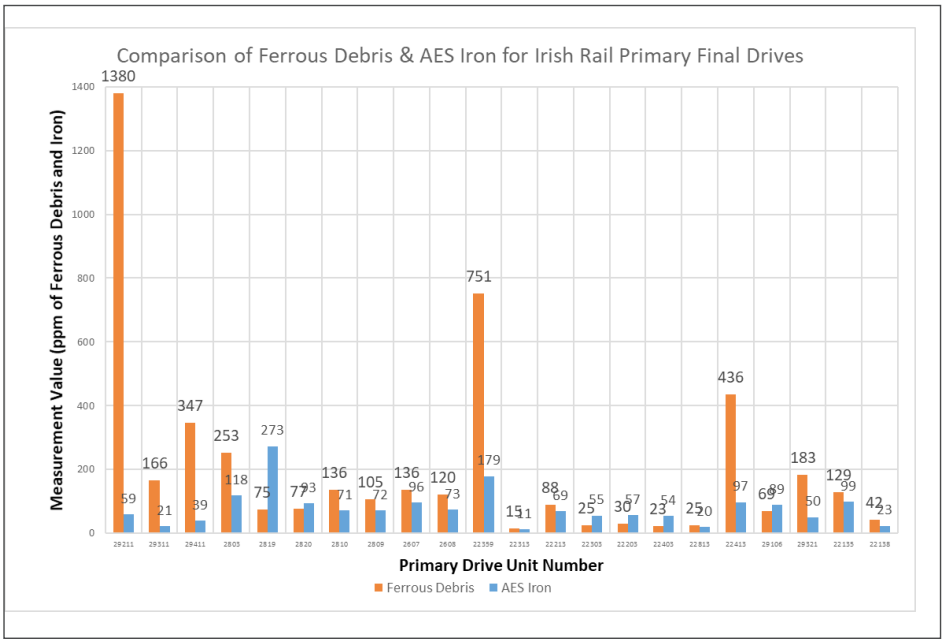
In order to support these finding we conducted Ferrography on the available samples. The samples were diluted due to the high level of particles present. All samples were quite similar with evidence of heavy rubbing particles present in each sample.

DATE	LAB ID	FDM (ppm)	IRON (ppm)
12.12.2017	R12692	969	374
03.01.2018	S304	1988	175

Table 1: Unit 29106 Final Drive

DATE	LAB ID	FDM (ppm)	IRON (ppm)
28.11.2017	R12735	1009	271
02.01.2018	S326	1616	133

Table 2: Unit 29217 Final Drive



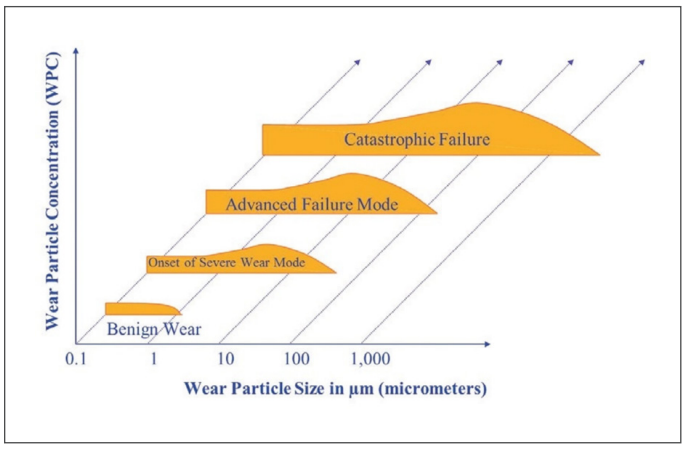


Figure 4-4: Wear particle concentration to size and severity comparison[4]

Discussion

Wear condition Monitoring studies describing sliding wear conditions (most common) describe the progression of severe wear being identified by an increase in the quantity and size of large (>10 micron major diameter) particles[4]. AES captures particles at most <10 micron – above that AES is blind. When an abnormality occurs, AES trend increase is a lagging indicator (due to comminution of wear to smaller sizes, but quantity is affected if top-ups or filter changes occur.

The ferrous density technology is useful for detecting the increase in abnormal particulate quickly, and even though FDM looks at submicron and larger debris – we are not comparing apple to apples, but trends should be in lockstep when an issue is occurring.

Re-analyzing the retained samples that flagged a problem in late 2017 with the ferrous density meter and comparing them to the statistically derived alarm limits was very informative.

1) The Ferrous density results for the problem gearboxes significantly exceeded the alarm limit sets. This would have prompted the diagnostician to perform additional wear debris analysis by ferrography in consultation with the client.
2) Follow up ferrography (not performed originally when AES iron alarmed) confirmed the severe nature of the wear present in the retain samples
3) Reviewing a history of samples. Several drive units that exceeded alarms should be prioritized for inspection at the garage above those units where AES iron is dominant
4) The ratio of total Ferrous to AES iron is similar to Large particle ratios (%PLP) metrics to determine severity of wear occurring.

REFERENCES

[1] Hunt T.M. Handbook of Wear Debris Analysis and Particle Detection in Liquids, Elsevier Press, 1993 pp 148-153
[2] Barraclough, T. "Linking Ferrous Measurements To Particle Counting for Machine Condition Monitoring" Presentation to STLE Annual Meeting 2015
[3] American Society for Testing and Materials, D2 Petroleum Standards, ASTM D8120 (17) URL : www. astm.org
[4] F.E. Lockwood and R. Dalley, Lubricant Analysis, Friction, Lubrication, and Wear Technology, Vol 18, ASM Handbook, ASM International, 1992, p 299–312

Spectro Scientific | One Executive Drive, Suite 101, Chelmsford, MA 01824-2563
978-431-1120 | www.spectrosci.com | sales@spectrosci.com | An ISO 9001:2008 company

Copyright © 2018 Spectro Scientific. All rights reserved. While every effort is made to assure the information in this document is accurate, Spectro Scientific does not accept liability for any errors or mistakes that may arise. Specifications are subject to change without notice.
AN_Ferrous Density_Rail DMU Final Drives_2018-10-25