Global Research and Development

Online oil detection and thickness measurements on steel coils.

M.Ferté (PhD Student, LCPME, ArcelorMittal Maizières Research SA)
D.Glijer (PhD, ArcelorMittal Maizières Research SA)
C.Carteret (PhD, LCPME)

Introduction

For steel industry, measuring the thickness of the oil layer on steel strip is of major importance for product quality. Indeed, oil can be used at different steps of the process as coolant and lubricant in the rolling process or as corrosion protection substance in storage and transport. In another part of the process, such as lacquering, the oil film must be maintained beneath specific tolerances. For quality reasons, the deposited layer needs to be homogeneous and for cost reasons, the thickness needs to be as thin as possible.

Oil is an organic compound which has specific signatures in infrared. The most intense vibration modes are located around 3.5 µm (i.e. 2800cm^{-1}) which correspond to C-H vibrations. It is well known by spectroscopic experts that the absorption intensity due to the vibration mode is proportional to the thickness of the analyzed layer.

To answer to this industrial need in terms of measurement, we can find on the market different sensors working in infrared spectral range and dedicated to oil thickness measurement. Some are dedicated to off-line measurements, and meanly with contact, so not easily implementable in industrial conditions. Others are dedicated to on-line measurements but unfortunately, most of these devices give a punctual measurement and need a travelling system. For quality reasons, oil thickness needs to be controlled on whole strip width (around two meters width).

Due to recent technological developments, it is possible to find measuring devices that could both measure online oil spectral signature and spatial information on steel product, for an affordable cost. By integrating spectrographs, it seems to be possible to measure, with a good sensitivity, the absorption of oil molecular vibrations.

Aims

The purpose of this paper is to give an overview of a new technique answering to industrial needs for online detection of lack oil and oil thickness measurements.

Materials and methods:

Reference samples with thin oil layers.

Reference samples have been created by laboratory and industrial deposition of oil on steel surface (with different thicknesses of oil).

In order to characterize the surface state of these samples, i.e. oil presence and layer thickness, the samples have been analyzed respectively by infrared spectrometry and spectroscopic ellipsometry.

Acquisition method

As shown on figure 1 [MOR_09] which represent a standard oil spectrum in infrared spectrometry, some of the most intense peaks are located on spectral range 3-5 µm (3300-2000 cm^{-1}).

The used camera is composed by a 2D array matrix dedicated to the spectral range 3-5 µm coupled with a spectrograph that is installed in front of the matrix (see figure 2). [ELM_10]. This device has been used to characterize several samples with oil layers The optical assembly is detailed on the figure 3.

Data processing

As shown on figure 1, infrared spectrometry results are expressed in absorbance (see equation on figure 4) . The same data processing has been used with our data.

Results

Feasibility trial:

Figure 5 shows a RGB and a hyperspectral picture (at λ=3.4µm) of steel plate with an important layer of oil on the surface. The ability of the MWIR hyperspectral camera to detect the presence (in white) or lake (in dark) of oil layer is validated.

Lack detection:

Figure 6 a) shows an hyperspectral picture (λ=3.4 µm) of an industrial sample with a lake of oil (in white on the picture). Spectra have been extracted from the raw data cube. An absorbance calculation has been practiced on three different areas. The results without and with a baseline correction are illustrated respectively on the figure 6 b) and 6 c). The ability of the MWIR hyperspectral camera to detect a lack of oil on an industrial sample is also validated.

Thickness measurement:

Based on spectroscopic knowledge, it is known that the absorption is proportional to the thickness [TOL_03].

Eleven industrial samples with different oil thicknesses characterized with off-line spectroscopic ellipsometry and have been studied with the hyperspectral camera. The figure 7 shows that, after pre-processing (dark and baseline correction), the absorbance intensity under the curve is directly proportional to the thickness.

Conclusion

This poster is focused on the study of spatial homogeneity of oil layer detection on steel surface for potential new online solution. The advantage of this new technique, compared to infrared spectrometry and usual industrial techniques is to give access to a higher acquisition speed and a spatial information.

The ability of this new device to characterize thin oil layers has been demonstrated in this document.

Furthermore, it has been also demonstrated that, thanks to a specific calibration, it could be possible to get access to oil layer thicknesses and oil lack detection over the whole strip width.

The presented results confirm the interest of the hyperspectral camera in the 3-5µm spectral range to potentially answer to industrial needs.

1

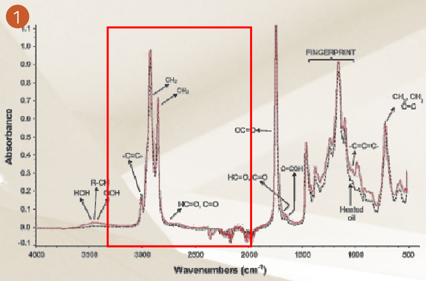

Fig. 1: Infrared spectral signatures of oil [MOR_09]

2

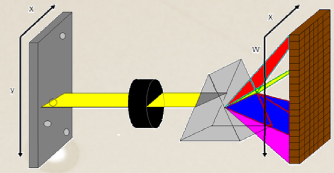

Fig. 2: Decomposition of electromagnetic flow (Spatial and spectral decomposition) in the hyperspectral camera (Matrix + spectrograph)

3

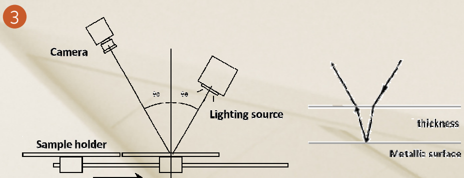

Fig. 3: Optical assembly of the characterization with the new technique

4

$$\text{Absorbance} = \log_{10}\frac{\text{Intensity from steel without oil}_{\lambda}}{\text{Intensity from sample}_{\lambda}}$$

Fig. 4: Equation of absorbance

5

Fig. 5 a) RGB picture and b) hyperspectral picture (λ=3.4µm) of steel with oil layer on the surface

6

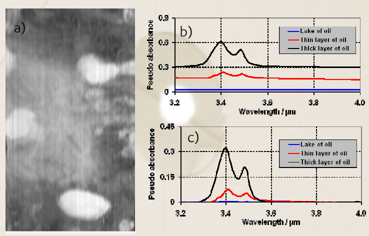

Fig. 6: a) Spectral picture (λ=3.4µm) of steel sample without and with oil layer and b) Calculation of the ratio value on sample width

7

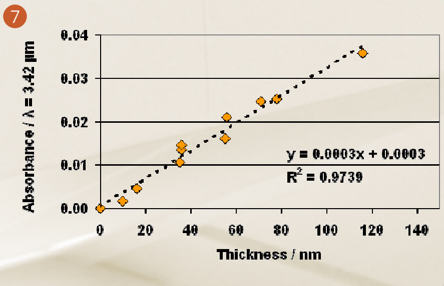

Fig 8: a) Infrared spectrum of thin layer of oil obtained by hyperspectral camera and b) correlation between absorbance and oil layer thickness

Literature cited :

-[ELM_10]: Gamal ElMarsy and co, Chapter 1-2010, Pages 3-43.

-[MOR_09]: Javier Moros and co, Food chemistry, 2009, vol. 114, pp.1529-1536.

-[TOL_03]: Valeri P. Tolstoy and co, A JOHN WILEY & SONS, INC, PUBLICATION

Acknowledgements :

I thank ArcelorMittal Maizières SA for all the tools put at my disposal (including the hyperspectral camera)

I thank LCPME laboratory for infrared spectrometer put at my disposal for the analyses.

Further information :

Please contact morgan.ferte@arcelormittal.com, cedric.carteret@univ-lorraine.fr or david.glijer@arcelormittal.com.