Research Activity Report **2013.10.31**

Research title		Sensor and Data Fusion between Electromagnetic Nondestructive Testing and Ultrasonic Testing
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Visiting institution		MATEIS (MATEriaux Ingénierie et Science), INSA de Lyon, France
Visiting period		September 2011 - July 2012
Host researcher	**Name**	Joël Courbon
	Affiliation	MATEIS (MATEriaux Ingénierie et Science), INSA de Lyon, France
	Title	Director, Professor

Summary of Collaborative Research Activities

Through the present project, IFS team and MATEIS team focus on the complementarity between electromagnetic nondestructive testing and ultrasonic testing, and investigated two topics as follows.

1) Development of novel EMAT-EC dual probe

An electromagnetic acoustic transducer (EMAT)-eddy current (EC) dual probe as shown in Fig. 1 was developed to assess wall thinning. With a view to developing compatible EMAT and EC operating modes, the probe's capability to size width and depth of wall thinning was quantitatively evaluated. Experiments carried out on austenitic stainless steel plates with various groove sizes showed that the EMAT mode of the dual probe functions best when thinning is shallow but wide, whereas the EC mode functions best when thinning is deep but narrow, as shown in Fig. 2. Mode complementarity indicates this dual probe offers greater reliability in wall thinning monitoring.

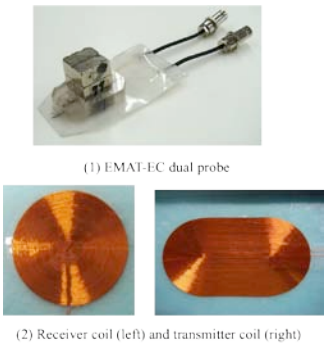

Fig. 1: EMAT-EC dual probe

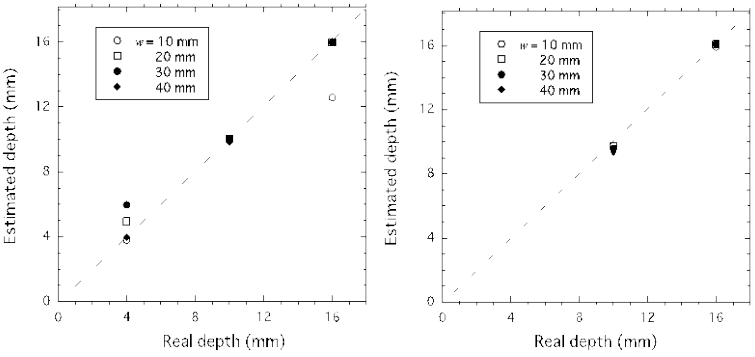

Fig. 2: Evaluation of slot depth values by EMAT mode (left) and EC mode (right) of EMAT-EC dual probe

2) Development of novel EMAT-EC dual probe

Boiler tubes in thermal power plants are used in hot corrosive environment, and thermal spraying is applied on the surface of tubes for mitigation of abrasion. Cracking, delamination, and thinning of thermal spraying can occur due to aging degradation and coating thickness must be non-destructively evaluated for the management of boiler tubes. In this project, eddy current method and acoustic

microscopy were used to evaluate the evolution of the thickness of 22-type Hastelloy coating on 304-type austenitic stainless steel as shown in Fig. 3, when submitted to long-time exposure to sulphur dioxide at 650°C. The eddy current method showed its robustness and its ability to be used in plant environment, yet suffered from the sensitivity to ferromagnetic phase transformation at the interface of the coating with the bulk metal. The acoustic microscopy demands a polished surface, which is indeed a limitation for in situ measurements, but it should have the advantage of being less sensitive to the phase transformation in the frequency range of our device. We now focus on the microstructural characterisation of the interface, by quantifying its effect on EDT response, developing of a robust numerical model for acoustic microscopy and finally by comparing the two methods. Fusion of the ECT and US data consists here in considering a linear combination of the two datasets, and Fig. 4 shows the result of fusion of these two methods (US or ECT) which is better than that of a single method.

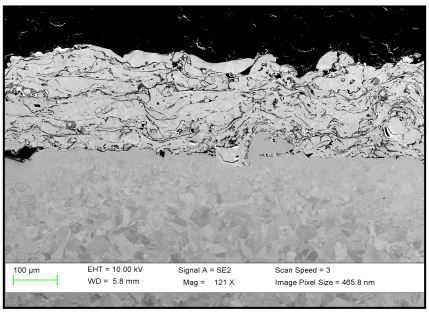

Fig. 3: SEM of the thermal sprayed 22-type Hastelloy coating on 304 steel

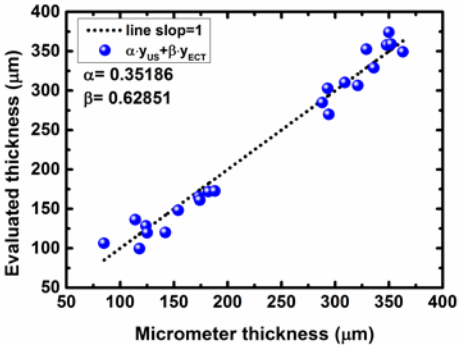

Fig. 4: Evaluated coating thickness by integrity of these two methods.

Publications

1) Journal or conference papers with full paper review (including review papers, invited papers, etc.)

[1] Tetsuya Uchimoto, Philippe Guy, Toshiyuki Takagi and Joel Courbon: Evaluation of an EMAT-EC Dual Probe in Sizing Extent of Wall Thinning, *NDT & E International*, under review.

[2] T. Uchimoto, T. Takagi, J. Courbon, T. Douillard, V. Masenelli: Thickness evaluation of thermal spraying on boiler tubes by eddy current testing, *International Journal of Applied Electromagnetics and Mechanics*, in preparation.

2) Conference papers or presentation without full paper review

[3] T. Uchimoto, Y. Takahashi, T. Takagi, X.D. Deng, T. Monnier, J. Courbon, T. Douillard, V. Masenelli: Thermal sprayed coating integrity evaluation using acoustic and electromagnetic methods, *2012 annual ELyT workshop*, Zao, February 2013.

[4] X. D. Deng, T. Monnier, T. Uchimoto, J. Courbon, T. Takagi and Y. Takahashi: Non Destructive Evaluation of thermal sprayed coating integrity by the fusion of acoustic microscopy and swept-frequency eddy current testing, *1st ICMST Conference of the Japan Society of Maintenology*, November 2012.

3) Patent, award, press release etc.

Not applicable