

PYRAMID

Piping sYstem, Risk management based on wAll thinning MonItoring and preDiction

MAIN PARTICIPANTS

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OVERVIEW (keep within this page)

Starting year: 2017

Current researchers (permanent/non-permanent): 3 person-month/year

Positioning <i>(Multiple selection allowed – total 100%)</i>	Transportation	Energy	Eng. for Health	Include partner from <input checked="" type="checkbox"/> Outside ELYT <input checked="" type="checkbox"/> Industry
				Main funding source(s) <input checked="" type="checkbox"/> Public project(s) <input type="checkbox"/> Industrial <input type="checkbox"/> Own resources
				IFS CRP/LyC project? <input type="checkbox"/> Yes <input checked="" type="checkbox"/> No
				For main projects: Agency / year / name of project (<i>up to 3, past projects in gray</i>) • ANR-JST project PRCI, 17-CE08-0046
Materials and structure design			75 %	Estimated annual budget: 325k€
Surfaces and interfaces			25 %	
Simulation and modeling				
Other:				

Highlights & Outstanding achievements <small>(3-5 bullet points)</small> <ul style="list-style-type: none"> • Mass flux and mass transfer coefficient evaluation method through a diffusion-controlled limiting current measurement under flow by using a rotating cylinder electrode has been developed. • Solid-liquid two-phase flow evaluation (CFD calculation) : three-dimensional solid-liquid two-phase flow calculations around elbow were conducted with a solid-particle simulation model. Flow drift and separation around the elbow were compared with the experiment described above, and the qualitative agreement was validated. As a result, we have found that the flow velocity profile and mass transfer • Online wall thinning EMAT evaluation have been carried out during controlled electrochemical corrosion tests. A good agreement between the ultrasonic evaluation and the profilometer measurements have been found. From these preliminary results, a new corrosion cell is under development. • Prototype point focus transducers were fabricated, and it was confirmed that incident beams were successfully focused, observing the sound field experimentally. • Development and validation of simulation tools to support the optimal design of EMAT and EMAR probes • Risk Evaluation: a probabilistic evaluation method of future damage was proposed. 	Illustration <small>(5x5 cm² max)</small>
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PROJECT DESCRIPTION

Background (10 lines max; Calibri 11)

From a recent NACE report, cost of corrosion in US is estimated to reach 2.5 trillion US\$, which is equivalent to 3.4% of Gross Domestic Product. It is estimated that an available corrosion control practices could be save 15 and 35% of this cost. Because this value can be extend to other country, it can be concluded that a project focused on corrosion monitoring is relevant for economy and environment. The inspection and maintenance of piping systems in harsh conditions has been evocated as a crucial issue in many industrial domains such as nuclear plants, chemical storage and transport. In Japan there is a great need to develop quickly NDT methods able to be deployed in very harsh environments, and especially in the objective of Fukushima Dai-ichi nuclear plant decommissioning.

Moreover the performance of the flow damage of carbon steel pipes in power generating plant has cause considerable concern. Carbon steels are the principal coolant pipe materials in nuclear and other fuel power plants. Erosion-corrosion induced wall thinning of pipe bores by the radiation, humidity, high temperature, velocity and pressure water flow has required structural evaluation of these pipes to allow integrity of these piping systems to be maintained.

A safe process for disassembling complex piping systems, requires new tools and techniques to detect and quantify wall thinning due to Flow Accelerated Corrosion (FAC). This is very important to evaluate if the piping system will resist to the multiple drainings of a polluted tank for instance. The corrosion phenomena associated to erosion are expected to be very complex, and highly influenced by the presence of particles into the liquid flow.

Key scientific question (2 lines max; Calibri 11)

Flow Accelerated Corrosion FAC, understanding and modelling.

EMAT for guided waves devices and simulations and Risk Management tools development

Research method (8 lines max; Calibri 11)

The mass flux and mass transfer coefficient evaluation method through a diffusion-controlled limiting current measurement under flow by using a rotating cylinder electrode has been developed. Permanent dialog between partners and comparison of experimental and simulated results, both for the electrochemical aspects of FAC and NDT methods aimig at feeding the risk management model to be developed.

Research students involved (gray color for previous years)

Ph.D. candidates (years, institution):

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Master/Bachelor students (years):

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Visits and stays (gray color for previous years)

COMMUNICATIONS AND VALORIZATION

Journal publications *(gray color for previous years)*

	Authors	Title	Journal	Vol.	pp. / ID	Year	DOI
1	Hiroyuki Nakamoto, Philippe Guy, Toshiyuki Takagi	Corrosion Induced Roughness Characterization by Ultrasonic Attenuation Measurement	E-Journal of Advanced Maintenance			2020	http://www.jsm.or.jp/ejam/Vol.11No.4/AA/AA167/AA167.html
2	H. Sun, R.Urayama, T. Uchimoto, T. Takagi, M. Hashimoto	Small electromagnetic acoustic transducer with an enhanced unique magnet configuration	NDT & E International	110	102205	2020	10.1016/j.ndteint.2019.102205
3	H. Sun, T. Uchimoto, T. Takagi	New Combination of Magnet and Coil of Electromagnetic Acoustic Transducer for Generating and Detecting Rayleigh Wave	IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control	67	832 - 839	2020	10.1109/TUFFC.2019.2956711
4	H. Sun, R. Urayama, T. Uchimoto, L. Udpa, T. Takagi, K. Kobayashi	Data processing method for thickness measurement using electromagnetic acoustic resonance	Electromagnetic Nondestructive Evaluation XXII, Studies in Applied Electromagnetics and Mechanics	44	1-6	2019	10.3233/SAEM190002
5	T. Takagi, H. Sun, R. Urayama, T. Uchimoto	Electromagnetic acoustic resonance method for thickness measurement of metals	Reprinted from The Reports of the Institute of Fluid Science, Tohoku University, Sendai, Japan	31	15-27	2019	

Conferences *(gray color for previous years)*

	Authors	Title	Conference	Date	City	Country	DOI (if applicable)
1	T. Takagi, P. Guy, Y. Watanabe, H. Abe, S. Ebara, T. Uchimoto, T. Aoki, M. Hashimoto, R. Urayama, H. Sun, T. Monnier, J. Antoni, B. Normand, N. Mary, R. Morita, S. Watanabe, A. Iwasaki, H. Nakamoto, C. Reboud, P. Calmon, E. Demaldent, V. Baronian, X. Artusi, S. Chatillon, A. Lhemery	Progress of PYRAMID project -Piping system, risk management based on wall thinning monitoring and prediction-	第4回福島第一廃炉国際フォーラム	2019/8/5	Iwaki	Japan	

2	P. CALMON, C. REBOUD, E. DEMALDENT	Advanced simulation tools for nondestructive assessment of corrosion affecting steel pipes	ElyT Workshop 2019	2019/3/11	Sendai	Japan	
3	P. GUY, B. NORMAND, H. NAKAMOTO, et al.	Recent advances in PYRAMID project : EMAT experimental results for corrosion characterization	ElyT Workshop 2019	2019/3/11	Sendai	Japan	
4	T. TAKAGI, P. GUY	Piping system, risk management based on wall thinning monitoring and prediction	ElyT Workshop 2019	2019/3/11	Sendai	Japan	
5	A. TEZUKA, T. TAKAGI, et al.	Development of Point Focusing Electromagnetic Acoustic Transducer Aiming at the Local Pipe Wall Thinning Measurement	14th International Conference on Flow Dynamics	2018/11/8	Sendai	Japan	
6	T. TAKAGI, et al.	International Joint Project for Risk Management of Piping Systems Based on Monitoring and Predicting Wall Thinning during Decommissioning of Fukushima Daiichi Nuclear Power Plant	14th International Conference on Flow Dynamics	2018/11/5	Sendai	Japan	
7	H. Sun, R. Urayama, T. Uchimoto, L. Udpa, T. Takagi	Thickness measurement of uneven specimen using frequency domain signal of pulse echo by electromagnetic acoustic transducer	The 4th ICMST-Tohoku 2018	2018/10/23	Sendai	Japan	
8	S. WATANABE and R. MORITA	Piping system, risk management based on wall thinning monitoring and prediction -Numerical evaluation of flow structure of liquid-solid two phase flow-	The 4th ICMST-Tohoku 2018	2018/10/23	Sendai	Japan	
9	T. TAKAGI, P. GUY, Y. WATANABE, et al.	Piping system, risk management based on wall thinning monitoring and prediction	The 4th ICMST-Tohoku 2018	2018/10/23	Sendai	Japan	

10	A. IWASAKI	Bayesian Evaluation of Damage Risk from Monitoring Data	The 4th ICMST-Tohoku 2018	2018/10/23	Sendai	Japan	
11	H. NAKAMOTO, P. GUY and T. TAKAGI	Corrosion Induced Roughness Characterization by Ultrasonic Attenuation Measurement	The 4th ICMST-Tohoku 2018	2018/10/23	Sendai	Japan	
12	Christophe REBOUD, Sylvain CHATILLON, Pierre CALMON, et al.	Advanced simulation tools for nondestructive assessment of corrosion affecting steel pipes	The 4th ICMST-Tohoku 2018	2018/10/23	Sendai	Japan	
13	Ryota NAKAGAWA, Hiroshi ABE, Yutaka WATANABE	Evaluation of Mass Transfer Coefficient for Prediction of Pipe Wall Thinning Rate in Solid-Liquid Multiphase Flow	4th International Conference on Maintenance Science and Technology (The 4th ICMST-Tohoku 2018)	2018/10/23	Sendai	Japan	
14	A. TEZUKA, T. TAKAGI, et al.	Development of thickness gauging method for pipe wall thinning inspection with Point Focusing EMAT	The 23rd International Workshop on Electromagnetic Nondestructive Evaluation	2018/9/11	Detroit, Michigan	USA	
15	H. Sun, R. Urayama, T. Uchimoto, L. Udpa, T. Takagi, K. Kobayashi	Data processing method for thickness measurement using electromagnetic acoustic resonance	The 23rd International Workshop on Electromagnetic Nondestructive Evaluation	2018/9/11	Detroit, Michigan	USA	10.3233/SAEM190002
16	T. Takagi, H. Sun, T. Uchimoto, R. Urayama	Electromagnetic acoustic resonance method and its application to pipe wall thinning measurement	Materials Service Performance in Nuclear Power Plants (MSPNP 2018)	2018/8/5			
17	T. Takagi P. Guy	Piping system, Risk management based on wall thinning Monitoring and prediction	ELyT Workshop 2018	2018/3/7	Satillieu, Ardèche	France	
18	P. Guy H. Nakamoto	Study of the surface roughness measurement by ultrasonic scattering on a carbon steel block	ELyT Workshop 2018,	2018/3/6	Satillieu, Ardèche	France	