Non-destructive non-contact crack detection and evaluation in a power plant by using automated surface wave scanner

Bogdan Piwakowski[1], Charles Ciccarone[2], Radoslaw Drelich[3], Jean-Marie Henault[4], JI LI[5], Vincent Garnier[6], Frederic Skoczylas[7]

[1]TPIA, IEMN -CentaleLille, France, [1]IEMN , Universite Lille, France, [1] LamCube, Centrale Lille, Poland, [1]Faculty of Mechatronics, Kazimierz Wielki University, France, [1]R&D-STEP, Kazimierz Wielki University, France, [1]IEMN TPIA, EDF , France, [1] CNRS, Universite LIlle, France

The paper presents the results obtained with the frame of the French research project "Non-Destructive Evaluation of Containment Nuclear Plant Structures" (ENDE), being conducted in the period between 2015-2020, which are related to the monitoring of concrete in a nuclear industry context. The project aims to develop Non-Destructive Testing techniques (NDT) that can be applied to evaluate concrete in containment enclosures [1]. The main goals of this project are the estimation of concrete properties and the detection of concrete damages and cracks. Generally, methods based on different physical approaches like acoustic-ultrasonic, electric, electromagnetic, optic, thermal, X rays, etc. can be used for the NDT of concrete [2]. The common feature of the method presented in this paper is the use of acoustic Surface Waves (SW). They propagate along the surface of the inspected material, and their depth of penetration is frequency-dependent and is close to SW wavelength. This property is useful to inspect the concrete wall at different depths [3,4]. The paper presents the results obtained using the automated Low Frequency Surface Wave Scanner (LFSW) designed for the non-destructive control of concrete using ultrasonic surface or plate waves. The LFSW's operation is similar to the operation of the High Frequency scanner described in [4,5]. The measurement consists of signal recording by means of the non-contact receiver moving along measured sample surface. The signal is radiated by a non-contact emitter and can cover the sonic and ultrasonic frequency band, ranging from 5 to 50 kHz, just assuring that SW penetrates in concrete up to depth to 50 cm (inspected wall thickness). Its non-contact operation does not require any physical contact with the tested object (i.e., air is used as a coupling medium) and it is of particular interest for fast scanning of great surfaces, where coupling (physical contact) between the ultrasonic transducers and tested materials should be avoided. Because of the very low transmission coefficient between air and concrete, in order to improve the signal /noise ratio, the chirp technique is used [4]. The scanner is, portable and can be used in a laboratory and as well as in site. The acquired multi-channel spatio-temporal signal is processed in order to obtain the ultrasonic group velocity, the velocity dispersion characteristics and the ultrasonic attenuation versus frequency. The in situ experiments aiming in validation of the developed technique were carried out in the VeRCoRs containment mock-up which constitutes the containment building of a nuclear power plant in scale 1/3 [1]. The measurements were performed at the zone having two known cracks in two stages: 1. During the leakage test carried out in one week in March 2019. During this test the internal pressure increases up to 4 bars and next the pressure decreases (as a leakage effect); internal temperature is kept constant. 2. During 1 month, with constant atmospheric internal pressure, but the plant was subjected to temperature changes caused by internal heating and by natural variations of external temperatures. The results obtained in (1) concerning the crack evaluation well correlate ($R2=0.8-0.95$) with the crack opening measured by means of fiber optics (FO)[6] which is considered a very accurate method for estimation of cracks openings [6]. This proves the potential utility of the LFSW in monitoring the concrete cracks and suggests that the LFSW could alternatively replace FO technique in in monitoring of structures not equipped with fiber optics. The LFSW displays the ability to detect very small crack openings of few micrometers. This permits to use this approach in nuclear industry and as well in civil application were researched for openings are even much greater (order of 100 micrometers). The results obtained in (2) show that the variations of the internal and external temperature induce the modifications of cracks openings, and these modifications are of the same order as those obtained during the leakage tests. Independently the obtained values od SW velocity, its dispersion and attenuation show that the LFSW permits to follow mechanical parameters of concrete. The presented work aimed in the power plants NDT, but the LFSW is also well adapted to the diagnostic of concrete elements, bridges and buildings. Keywords: Automated NDT, concrete, surface waves, air-coupled ultrasonics, crack detection and evaluation, power plant, civil engineering, guided waves, NDT for bridges and buildings References [1] V. Garnier, B. Piwakowski, J.M. Henault, J. Verdier, J.P. Balayssac, N.

Ranaivamonana, J.F. Chaix, S. Rakotonarivo, G. Villain, O. Abraham, X. Derobert, C. Payan, Sbartai, J. Saliba, E. Larose, H. Hafid, R. Drelich, Ch. Ciccarone "Non Destructive Evaluation of the durability and damages of concrete in nuclear power plants". 12th European Conference on Non-Destructive Testing (12th ECNDT) Goteborg Sweden, June 2018. [2] J.P. Balayssac, V Garnier « Évaluation non destructive des ouvrages en génie civil »ISTE Editions 2018. [3] B.Piwakowski, Q.Liu, J.-P. Balayssac, G. Villain, V. Garnier, M. Kaczmarek, R. Drelich" Identification of inhomogeneous concrete cover by non-contact ultrasonic method" 7th European Workshop on Structural Health Monitoring (EWSHM) and Second European Conference of The Prognostics and Health Management Society; Nantes France July 8-10 2014. [4] M.Kaczmarek, B.Piwakowski, R.Drelich. "Noncontact Ultrasonic Nondestructive Techniques: State of the Art and Their Use in Civil Engineering". J. Infrastruct. Syst. 2016. 23(1): B4016003. [5] O. Abraham, B. Piwakowski, G. Villain, O. Durand "Non-contact, automated surface wave measurements for the mechanical characterization of concrete" in Construction and Building Materials, Volume 37, December 2012, pages 904-915. [6] J.M. Henault, P.Laviron, S.Desforges, D.Vautrin, A.Courtois,B. Martin, A. Legrix. « How to characterize the airtightness of containment structure; Overview of monitoring techniques tested on VeRCoRs Mock Up" TINCE 2018 – Technological Innovations in Nuclear Civil Engineering France, Paris-Saclay – 2018, August 29.