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AUTOREGRESSIVE MODEL-BASED CHANGES DETECTION IN CONCRETE STRUCTURES USING ULTASONIC SENSORS

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Abstract

Most of bridge decks are made generally of reinforced concrete. When bridge is open to traffic, then it is safe to drive on it or under it. However, when bridges no longer have the capacity to meet the current traffic loading and material degradation due to environmental conditions, it is necessary to inspect and monitor bridge deformation. Since bridges deck made of reinforced concrete, material degradation is an issue with concrete structures. Loads, such as wind and traffic, could result in progressive and continuous micro cracks, which leads to the increased permanent strains and decreased stiffness of the structure. The way to determine the health of the bridge is almost like giving medical person an Electrocardiogram (EKG) to determine the health of their heart. A variety of sensors are placed strategically throughout a structure coupled with various power systems, databases and computer programs, and then structures' "heartbeat/signal" is developed. Analysis of this "heartbeat" will give the current situation of the bridge. Before any intervention is taking, it is important to settle down bridge health monitoring with NDT techniques for safety investigation. The most used set of NDT techniques for reinforced concrete inspection are acoustic and ultrasonic pulse velocity systems (active or passive sensing). In this paper we will focus on ultrasonic system.

Ultrasonic pulse velocity (UPV) system is based on sending and receiving ultrasound pulse waves inside a structure. The main benefits of UPV is its sensitivity. It can detect very small changes in the structure. UPV method consists of high frequency sound waves which is normally above 20 kHz frequency introduced into the material. We need at least two transducers to do the UPV test, one transmitter and one receiver. There are three basic ways in which the transducers can be placed: direct, semi-direct and indirect. A signal pulse generator and amplifier is used to produce an amplified electric wave, then it is converted to mechanical vibrations by a piezo-electric crystal transducer and transmitted through the structure. Then reflected wave is received by the receiver and converted back to an electric wave which called as an echo [1,2]. We can extract information about changes in a medium by monitoring the velocity changes from receiving wave propagation. For general ultrasonic experiments, the common sensors used by the operator are simple ultrasonic transmitter and receiver. But for our experiment we will use a new ultrasonic transducer "SO807" which was designed by acoustic control systems in Moscow in cooperation with and exclusively for BAM [3]. The main part of this sensor (SO807) is a hollow piezo ceramic cylinder. The primary benefit of this sensor is it can use as a transmitter or receiver and vice versa. The main benefit of this sensor is it can be installed easily during the construction. So that we can monitor inside the concrete [3]. In this paper we will use ultrasonic signal where velocity will 10% faster than the transmitted signal.

Bridge health monitoring refers to the observation of a bridge deck over time and obtaining material

responses using an array of sensors, from this response extraction of damage-sensitive features, and statistical analysis to detect changes that may indicate change in the bridge structure. A common approach for extracting the damage feature from sensor data is to use time series models. When a considered time series model approximates the response of a material and model coefficients or residual error are obtained, any deviations in these coefficients or residual error can be inferred as an indication of a change in the structure, which can be further considered as a damage signature. This study is part of the INFRASTAR project, dealing with advanced monitoring and non-destructive testing (NDT) techniques for pressure, temperature and strain measurements and fatigue damage assessment. The project aim is to get benefit from novel sensors and improved data processing methods to "smart" the structures. In this study, we focus on extraction of small changes based on time-series analysis of measured signals using ultrasonic sensors, with special attention to AR models as a tool for model-based diagnosis. These linear time series models have been used in such a damage detection process that include applications to a wide range of structures and associated damage scenarios including cracking in concrete columns [4,5], loose connections in a bolted metallic frame structure [6], or damage to insulation on wiring [7]. However, the linear nature of such modelling approach limits the scope of application and the ability to accurately assess the condition of systems that exhibit nonlinearity in their undamaged state. In this paper, we demonstrate how AR model may be used for ultrasonic sensor data to create a linear/nonlinear time-series model that provides structural changes or damage features. The AR model may be used as a changes/damage feature extractor. This AR model approach consists of using the parameters estimated from the baseline condition and calculate the response of data obtained from the structure. We will use least square approximation to parameters from baseline condition to predict the response. The residual error is the difference between the measured and predicted signal. Our approach is based on the assumption that changes in material will introduce either linear deviation from the baseline condition or nonlinear effects in the signal and, therefore, the linear model developed with the baseline data will no longer accurately predict the response of the degradation system. As an outcome, the residual errors associated with the changes in material will increase. The estimation of the AR order can be achieved by minimizing the RMSE value. For the purpose of finding the optimum AR model for our system, the RMSE is plotted in Fig. 2 as a function of the model order. Fig. 1 shows the ultrasonic reference signal and 10% faster signal caused by changes in material. From Fig. 1(b) we can see that residual errors of 10% faster signal (2nd) has increased than reference signal (on undamaged situation). In conclusion, AR residual appears to be potential damage-sensitive features.

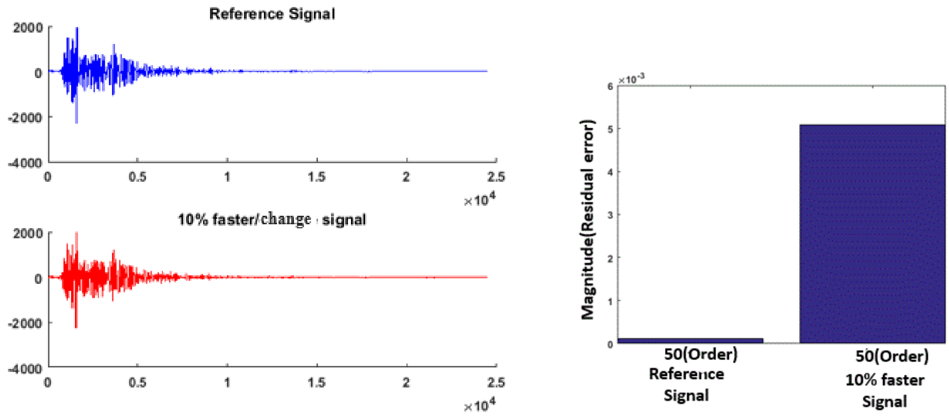

Fig.1. (a) Simulated signal from ultrasonic sensors, (b) Residual error for the reference signal and 10% faster signal (signal for a damage structure)

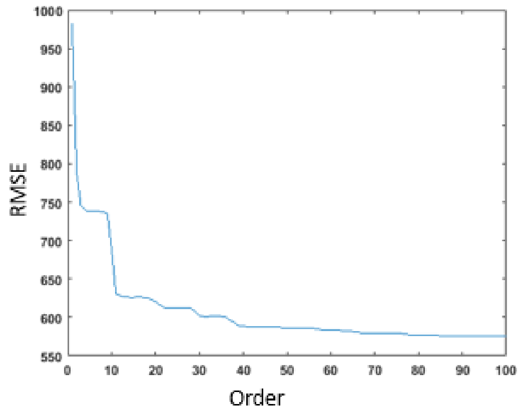

Fig. 2. RMSE for optimum AR model

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