Measurement 89 (2016) 197–203

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Contact and non-contact approaches in load monitoring applications using surface response to excitation method

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ARTICLE INFO

Article history:
Received 3 February 2016
Received in revised form 30 March 2016
Accepted 6 April 2016
Available online 8 April 2016

Keywords:
SHM – structural health monitoring
Surface response to excitation method
Load monitoring
Piezoelectric
Laser Doppler
Vibrometer
Digital signal processor

ABSTRACT

Surface response to excitation (SuRE) method is a low-cost alternative to electromechanical impedance based structural health monitoring (SHM) technique. The SuRE method uses one piezoelectric transducer to excite the surface of a structure with a sweep sine wave. Piezoelectric sensors or scanning laser vibrometer can be used to monitor the dynamic response of structure.

In this study, the performance of the SuRE method was evaluated with the conventional piezoelectric elements and scanning laser vibrometer used as contact and non-contact sensors, respectively, for monitoring the presence of loads on the surface. In order to determine the accuracy and reliability of both monitoring approaches in detecting changes in level of applied load, three different experimental setups were studied. Response of a system in the presence of a single load applying and multiple loads applying and its performance in detecting tightness in a nut and bolt system were investigated. The spectrum of the dynamic response is collected at the optimal operating condition. Any significant change of the spectral characteristics may indicate defects, improper loading or loose fasteners. The performance of the SuRE method using contact and non-contact sensors indicated that both variations of the method could be successfully used in load monitoring applications.

1. Introduction

In the last few decades, active SHM techniques especially guided waves based methods such as wave transition methods [1–3] and Impedance based methods [4,5] has received a lot of interest. Timely detection of defects using SHM methods plays a pivotal role in maintaining required level of integrity and safety in different industries. It is well established that dynamic characteristics of a structure is sensitive to certain changes in the structure. Over the last few years, many studies have been performed to improve understanding on interaction between defects and changes in dynamic response of structures. A significant amounts of the research in this field primarily focused on damage detection and localization in plate structures [6–14].

In the Electromechanical Impedance (EMI) method, health of the structure can be investigated by measuring the mechanical impedance of the structure using piezoelectric transducers [13]. However, impedance analyzers are extremely costly and it has been tried to be replaced by cheaper alternatives such as cheaper electronic circuits [14–18]. Other variations of this method such as SuRE method has been recently introduced which removes the need for an impedance analyzer [19–22].

It has been shown that the dynamic response of a structure is not only sensitive to defects but it is also sensitive to loading [8,11,23]. Annamdas et al. used electromechanical impedance method for monitoring of load on carbon steel gear specimen [24]. The US Army Construction Engineering Research Laboratory also reported the use of the electromechanical impedance method in load monitoring applications for unreinforced masonry wall specimens and masonry wall reinforced with composite overlays [25]. Electromechanical impedance approaches have been also utilized in monitoring of bolt-joints structures and investigating of loose bolts [26,27]. However, interaction between loads and dynamic response of structures, which normally is recorded by bonded piezoelectric transducers, is not well understood yet. In this experiment, the performance of the SuRE method as a low cost

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http://dx.doi.org/10.1016/j.measurement.2016.04.013
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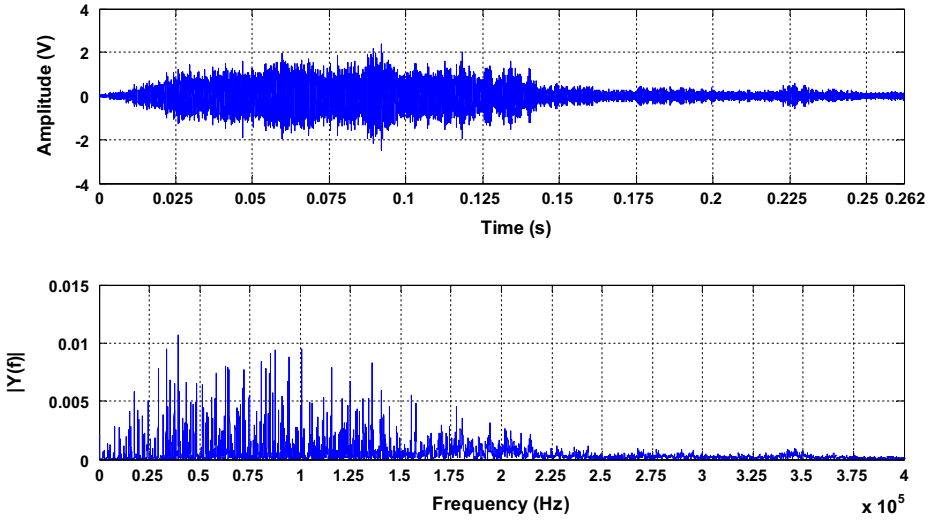

Fig. 1. FFT response of plate for 1–400 kHz.

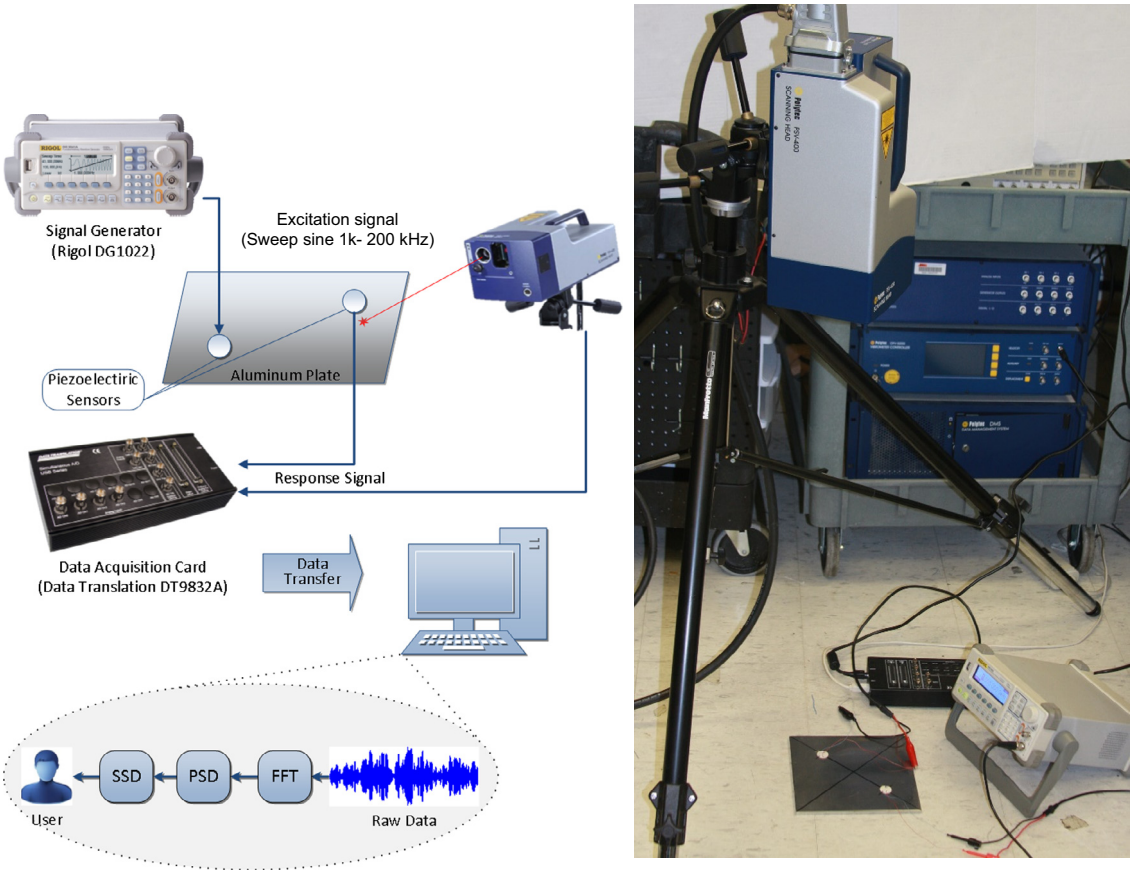

Fig. 2. Experiment setup.

alternative for EMI based methods in some load monitoring applications was studied. The conventional piezoelectric elements and scanning laser vibrometer were used in the course of the experiments. Successful performance of the SuRE method in load monitoring applications in three different scenarios, including the response of the system in the presence of a single load and multiple loads and its performance in detecting tightness in a nut and bolt system in aluminum plate, was shown.

2. Method

In this study, a modified surface response to excitation (SuRE) method has been implemented for monitoring and identifying different levels of load on structure. Typically, in the SuRE method, the surface of a structure is excited by a sweep sine wave over a certain frequency range using a piezoelectric transducer and also another piezoelectric transducer is used on the other side of