COMSOL Multiphysics® Software for Simulation of Surface Response to Excitation Method for Manufacturing Process Performance Monitoring

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Abstract

In this study, COMSOL Multiphysics® software was used to simulate the surface response to excitation method (SuRE). SuRE is a structural health monitoring method that is developed for detection of various types of structural damages. This method also has been used to monitor manufacturing operations. SuRE is a frequency-domain technique similar to electromechanical impedance method where the frequency spectrum of the structure is monitored through a certain range of frequencies (20kHz-400kHz). A function generator excites a sweep sine wave using a piezoelectric actuator on the surface of the structure. Another piezoelectric element or laser scanning vibrometer measures the oscillations in a secondary point. The spectrum of measured data is created using Fast Fourier Transform (FFT). The main concept of the method is based on the change of spectrum of measurement points due to the change in the condition of structure. Sum of squared differences (SSD) was used to compare the spectrums.

In this study, COMSOL was used to investigate the effect of parameters of the experiment and to see if simulations confirm the observations of previous experimental studies. The model was created by appropriately dimensioning a thin aluminum plate with a cylindrical piezoelectric device bonded to the middle. Using the Piezoelectric Device physics interface in COMSOL we were able to define the experimentation parameters such as boundary conditions and material properties. The Piezoelectric Device physics interface also allowed us to define the terminal as well as a ground location, in which we applied a voltage load in order to excite the surface waves on the beam via piezo device. Various manufacturing operations on the beam including drilling, cutting and milling were studied. Point probes defined on a grid of scan point, which measured the acceleration and created frequency spectrum. The contour map diagram of SSD values revealed the maximum changes after each manufacturing operation occurred in the vicinity of that operation. The change in SSD values even in measurement points far from the operation successfully indicated that an operation was performed. Also the shape of the operation could be estimated with the contour maps confirming similar experimentation observations.

Reference

1- Nienwenhui, J. H., et al. "Generation and detection of guided waves using PZT wafer transducers." Ultrasonics, Ferroelectrics and Frequency Control, IEEE Transactions on 52.11 (2005): 2103-2111.

2- Hadi Fekrmandi, Javier Rojas, Jason Campbell, Ibrahim Nur Tansel, Bulent Kaya, Sezai Taskin, “Inspection of the Integrity of a Multi-Bolt Robotic Arm Using a Scanning Laser Vibrometer and Implementing the Surface Response to Excitation Method (SuRE)” International Journal of Prognostics and Health Management, Vol. 5 No. 1, 2014, pages 1-10.

Figures used in the abstract

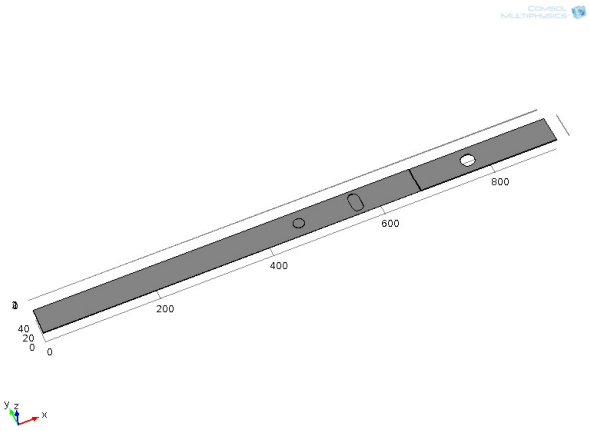

Figure 1: Beam, piezoelectric element and manufacturing operations.

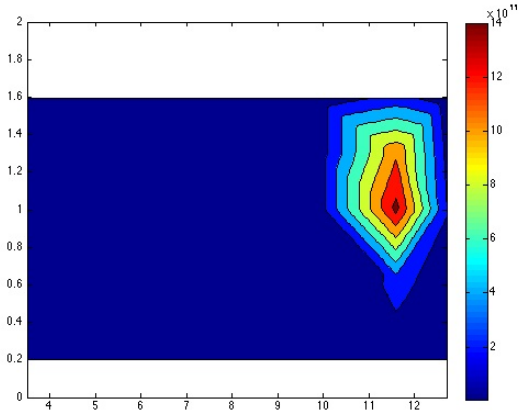

Figure 2: Color map of SSD, Drilling.

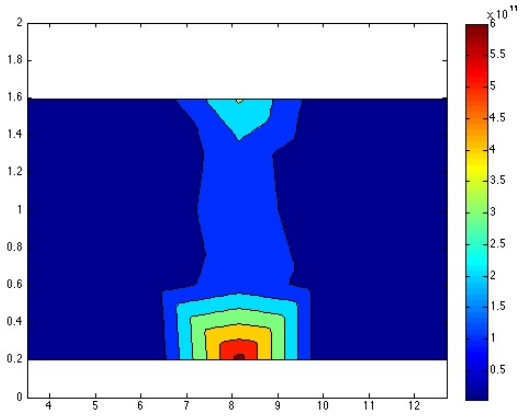

Figure 3: Color map of SSD, Cutting.

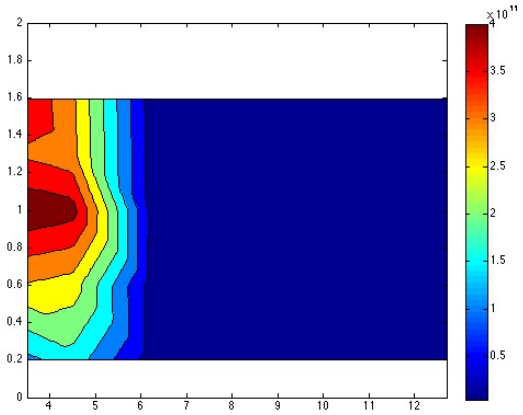

Figure 4: Color map of SSD, Milling.