Proceedings of Meetings on Acoustics

Volume 19, 2013 http://acousticalsociety.org/

ICA 2013 Montreal
Montreal, Canada
2 - 7 June 2013

Engineering Acoustics
Session 4aEAa: Non-Contact Ultrasonic Methods

4aEAa2. Improving the focal quality of the time reversal acoustic noncontact source using a deconvolution operation

Brian E. Anderson*, T. J. Ulrich and Pierre-Yves Le Bas

***Corresponding author's address: Geophysics Group (EES-17), Los Alamos National Laboratory, MS D446, Los Alamos, New Mexico 87545, bea@lanl.gov**

The time reversal acoustic noncontact source (TRANS) utilizes time reversal (TR) from several transducers arranged in a cavity to focus energy onto a solid surface to allow inspection of that surface. The advantage of TRANS is that multiple transducers may be used to increase the amplitude of the focused energy onto the surface and potentially allow interrogation of nonlinear surficial features such as cracks and delaminations. TR is known to be a matched signal process and therefore is limited in the temporal fidelity and spatial compression of the focused energy. Fortunately, using a deconvolution operation in conjunction with TR (or inverse filter similar to Tanter et al. [JASA, 108, 223-234 (2000)]) can greatly improve the quality of the spatial focusing as well as increasing the temporal fidelity. Visualizations of the impact of the deconvolution operation will be presented to provide insight into the increased quality of the spatial focusing along with results from using the deconvolution operation in conjunction with TRANS. [This work was supported by Institutional Support (LDRD) at the Los Alamos National Laboratory]

Published by the Acoustical Society of America through the American Institute of Physics

Received 16 Jan 2013; published 2 Jun 2013

INTRODUCTION

Time reversal (TR) is a signal processing technique used to locate a source or to intentionally focus sound energy at a specific location in space.[1-2] Here we show that TR may be used to focus sound onto a solid surface in order to create a method of exciting the surface in a noncontact manner. This paper will review the principles behind the Time Reversal Acoustic Noncontact Source (TRANS)[3-5] and then present some new experimental results that show a greatly improved spatial focusing of energy and an improved temporal fidelity of the focus when a deconvolution operation is incorporated with the TRANS.

Noncontact sources are often used for nondestructive evaluation of a sample under test. In order to provide a local inspection of a sample (rather than a global evaluation), one typically must use ultrasonic frequencies (>20 kHz) in order to produce a sufficiently small spot size on the sample. One of the key limitations is the efficiency of ultrasonic sound in coupling to vibration of a solid surface. Other noncontact sources traditionally utilize geometrical focusing to focus sound, generated by a curved surface, to a specific location in space. These sources are typically narrowband in their frequency response and have a fixed standoff distance for optimal performance.

A TRANS employs piezoelectric transducers mounted onto the inside of a reverberant cavity. To calibrate the TRANS one by one each transducer emits the desired signal to be focused onto the sample surface. The reverberant cavity is designed to create multiple impacts of scattered sound energy at the sample surface. A laser vibrometer is then used to record the vibration response of the sample surface. The vibrometer signal is then reversed in time and stored for each transducer's broadcast. After all transducer calibration reversed signals have been recorded, they are then emitted simultaneously from each transducer resulting in coherent focusing of sound energy at the position where the laser vibrometer recorded the surface vibration.

As is well known in TR research, the TR process is a matched signal processing, meaning that the original source signal cannot be perfectly reproduced. The matched signal nature of the TR process results in side lobes in the temporal focal signal (repeats of the source signal at times other than the focal time), and fringe patterns in the spatial focusing. Side lobes and spatial fringes are specifically due to the use of narrowband transducers and the frequency response of the system in which the focusing occurs. In order to improve the TR focusing quality, a deconvolution process has been proposed to remove these effects.[6-7]

The purpose of this study is to determine the potential performance improvements when the deconvolution process is incorporated with the TRANS.

EXPERIMENTAL SETUP

In order to image the focal wave field produced by the TRANS with and without the use of the deconvolution operation we train the TRANS to focus on a thin plate. A thin plate ensures that the vibrations will be the same on each side of the plate, which then allows us to use a scanning laser vibrometer to image the spatial distribution of the focusing wave field from the back side of the plate, whereas we cannot scan the front side due to the presence of the TRANS cavity obstructing the view of a laser. Figure 1 displays photographs of the experimental setup from the back side of the plate (a) and the front side of the plate (b). A single point Polytec laser vibrometer is mounted to a Cartesian scanning stage system to allow scanning as the experiment is repeated for each scan point. The edge of the TRANS Cavity is placed 3 mm from the plate surface.

Eight piezoelectric transducers are bonded onto the cavity on its inner surfaces. The procedure outlined in the introduction is carried out to train the TRANS to focus TR from each of the eight channels onto the plate simultaneously. The laser vibrometer shining on the back side of the plate is used for the training procedure since the vibration on each side of the plate should be identical. The plate is a 0.45 mm thick aluminum plate. The source signal is centered at 75 kHz and has a 50 kHz bandwidth. The specific deconvolution operation used in this study corresponds to that outlined in Ref. 7.

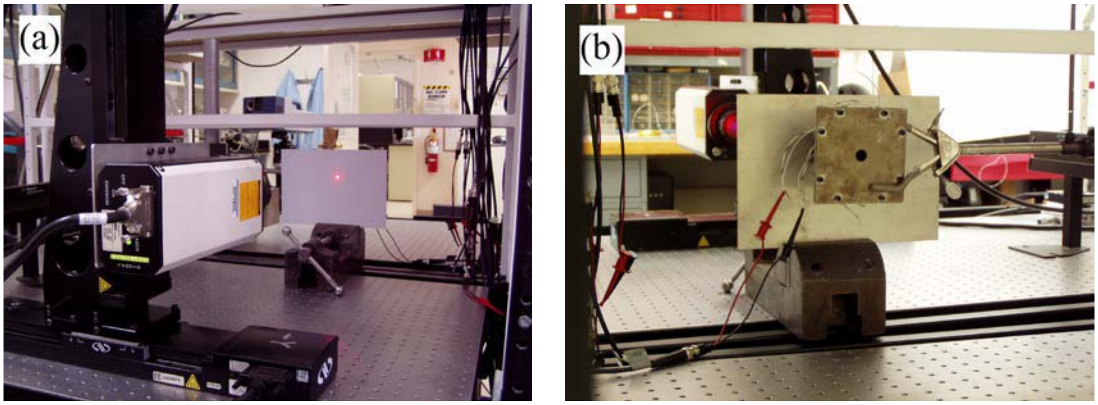

FIGURE 1. (a) Photograph of the experimental setup with a back side view of the plate. (b) Photograph of the experimental setup with a front side view of the plate and the TRANS cavity.

RESULTS

Figure 2 displays the results of the focusing produced on the aluminum plate with TR and then with TR and a deconvolution operation. One can note the reduction in absolute focal amplitude when the deconvolution operation is used. However, the spatial map from the deconvolution operation has lower side lobe energy distributed at locations other than at the focal location and the temporal focus of energy is tighter.

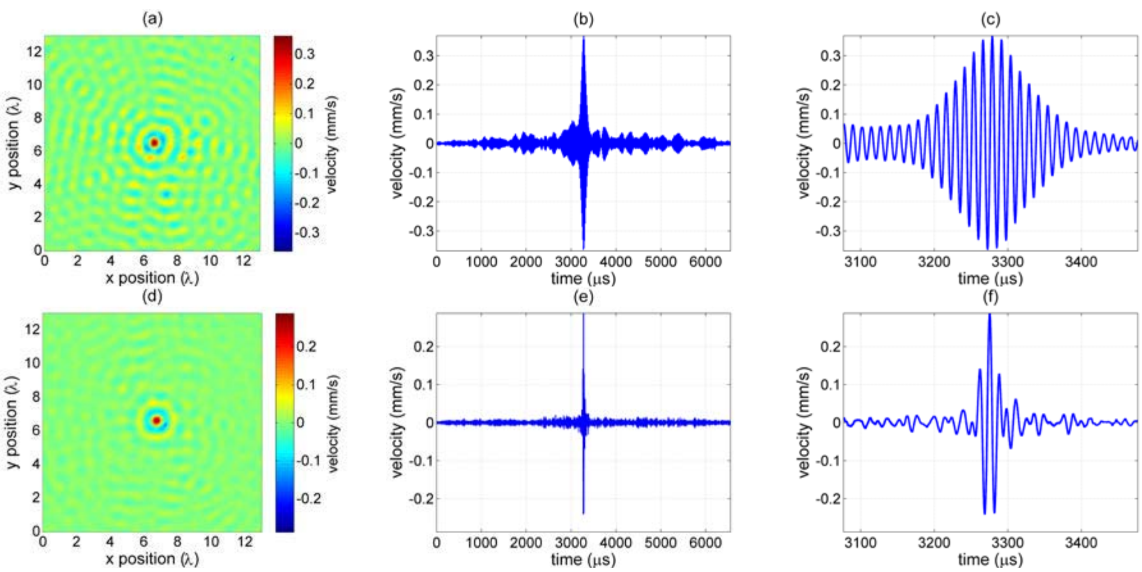

FIGURE 2. Subplots (a)-(c) pertain to the focusing wave field produced by the classical TR procedure. Subplots (d)-(f) pertain to the focusing wave field produced by the deconvolution TR procedure. (a) and (d) are respective spatial maps at the focal time. (b) and (e) are respective temporal signals at the focal position. (a) and (d) are respective temporal signals at the focal position, zoomed in on the focus.

CONCLUSIONS

The use of the deconvolution operation with TR provides a sharper focus of energy in both time and space relative to the focusing produced by the classical TR procedure for the TRANS. The trade off for improved spatial and temporal compression is that deconvolution operation does reduce the total focal energy.

ACKNOWLEDGMENTS

This research was funded by institutional support (LDRD) at the Los Alamos National Laboratory.

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