Fast total focusing method for ultrasonic imaging

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***Abstract*—This work deals with advanced and fast imaging techniques using phased array probes for non destructive evaluation or medical imaging. These methods employ a large amount of summations in order to focus at each pixel of the reconstruction image, which often represent a prohibitive computational cost. We present two acceleration methods, *i.e.* GPU computation and a migration approach. The GPU computing uses massively parallel computations. The migration approach works in the wavenumber domain and permits a significant improvement in terms of image quality. In this paper, we demonstrate the benefits of these techniques with experimental data captured from an aluminum block containing artificial flaws.**

I. Introduction

Fast imaging methods are necessary in non destructive evaluation or medical imaging for real-time imagery. In particular, post-processing methods such as the total focusing method (TFM) has shown good results in terms of image quality [1] but have a prohibitive computation time. In this paper, we present several techniques in order to accelerate the imaging process. First we propose implementations of the total focusing method using graphics processing unit (GPU) [2]. We also show that a full insonification enables to speed-up the process by reducing the number of acquisitions [3]. Then, a different approach called migration having interesting performances is presented [4]. The principle is to transpose the imaging problem in the wavenumber domain [5], [6], [7].

This paper is dedicated to experimental results. The theoretical background of the employed methods is not explained here but references to relevant papers will be indicated. Moreover, previous communications have exposed the details of the methods [10], [11].

II. Focusing methods using GPU computation

The inspected object is an aluminum block containing 1mm side drilled holes (SDH) as represented in Fig. 1-b. The phased array probe has 64 elements and the center frequency is 5MHz, that is a standard in non destructive evaluation. We use the OEMPA instrument from AOS NDT[1] in order to acquire the data with high rate (150MB/s).

In this section, the methods have been implemented on graphics processing units in order to speed-up the computations. The parallel computing is effected for each pixel of the

[1]Advanced OEM Solutions: `http://aos-ndt.com`

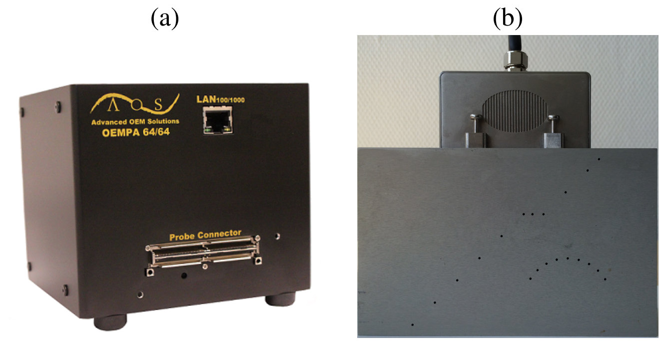

Fig. 1. (a) Phased array instrument from AOS NDT [8], (b) Aluminum block with 1mm diameter side drilled holes.

image to reconstruct [2]. We first present the total focusing method [1], [9]. This approach uses all transmitter-receiver pair signals from an array of transducers and is equivalent to focus at each point of the reconstruction zone. The imagery of the aluminum block is presented in Fig. 2-a.

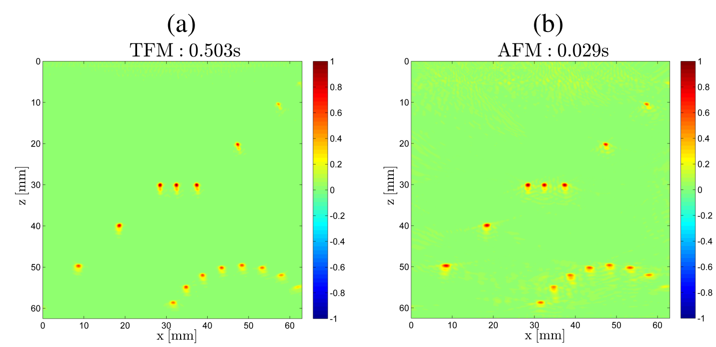

Fig. 2. Imagery of the aluminum block containing SBH obtained by (a) TFM and (b) AFM. Each image has 5M pixels.

We also present a faster acquisition technique which consists in using a full insonification of the material under test [3]. The reconstruction is almost identical to TFM and is based on focusing at each reconstruction point. This method refers to AFM for advanced focusing method. The result is represented in Fig. 2-b. TFM needs more data than AFM and is hence more computationally demanding. On the other hand, the signal to noise ratio (SNR) is generally greater for TFM due to averaging. Nevertheless, AFM has a good SNR since the

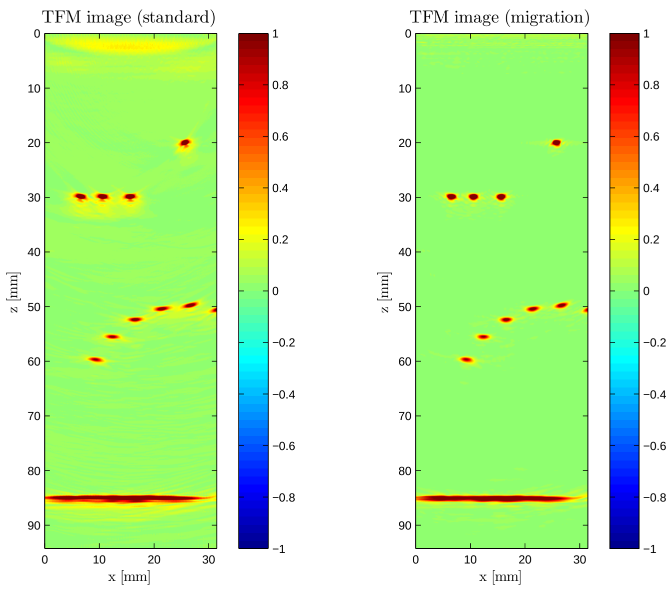

Fig. 3. Imagery by standard approach and migration approach.

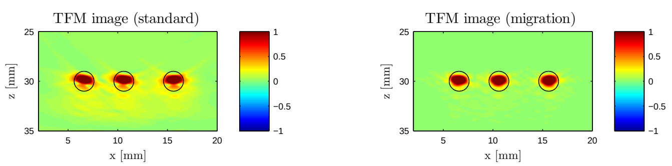

Fig. 4. Imagery by standard approach and migration approach (zoom on the three close SDH).

full insonification is more optimal and powerful compared to single element radiation in TFM.

The GPU computations speeds-up the computing time by a factor of a few thousands which enables real-time imaging. For instance, TFM and AFM can produce about 6Hz and 60Hz, respectively.

III. The migration approach

The migration approach comes from the geophysics community [4]. The principle is to do a mapping of the data in the wavenumber domain. It has been formalized for several inspection configurations including TFM and AFM [5], [6], [7]. The principle has been more detailed in previous communications [10], [11]. The imaging results of the aluminum block are presented in Fig. 3. The migration approach shows a lower SNR than the standard approach. Moreover, it produces less diffraction artifacts, as it can be seen on a zoom around the three close side drilled holes in Fig. 4. In terms of CPU time, the migration is more effective than the standard approach since we manipulate constant size images in order to respect the Nyquist-Shannon sampling theorem. Larger images are obtained by interpolation. CPU times are presented in table I for both approaches. The almost constant CPU time for the migration approach is remarkable compared to standard TFM,

TABLE I
CPU time (s) for standard TFM and migration TFM

Image size	standard TFM	migration TFM
0.19M	91.3	12.3
0.38M	177.8	12.2
0.77M	353.3	12.6
1.54M	719.1	14.0

where CPU time linearly increases as a function of image size.

IV. Conclusion

This paper has presented fast imaging techniques for non destructive evaluation or medical imagery. The GPU implementations are very efficient for standard approaches such as the total focusing method. It permits a near real-time imaging of the pieces under test. We have also presented a migration approach that gives better images in terms of quality and CPU time. Depending on needs and possibilities, the variety of such methods can be employed for real-time imagery.

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