

Signal Processing Techniques for Nondestructive Evaluation Using Laser Ultrasonics

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Abstract - Laser ultrasonics is a form of ultrasonic evaluation in which a pulsed laser generates an ultrasonic wave in a sample which interrogates a specific feature. When this wave returns to the surface a separate laser interferometer detects the small resulting displacement. This technique is strictly noncontact and is thus suitable for in-process inspection of parts at high temperature or moving at high speed. In many applications the acquired temporal signals have features which differ from those acquired using conventional transducers. In this paper we will describe these features and discuss techniques which have been used to process these signals.

Key words - Laser ultrasonics, adhesive inspection, crack measurement

1. LASER ULTRASONIC INSPECTION

Laser ultrasonics [1] is a valuable technique for performing noncontact inspection on parts that are small, moving and/or at elevated temperature. As shown in Fig. 1, laser ultrasonics is a modification of conventional transducer-based contact ultrasonic inspection. Instead of transducers, a pulsed laser is used to generate the ultrasonic waves and a laser ultrasonic receiver is used for detection of the ultrasonic waves as they return to the surface. The receiver performs a linear conversion of the measured optical phase modulation to intensity modulation at its output. While the methods for generation and detection of ultrasonic waves are quite different from those using transducers, these waves interact with surfaces and defects in a similar manner. One unique feature of laser-generated ultrasound is that the full complement of ultrasonic waves (longitudinal, shear, surface and plate) are simultaneously produced, with each having its own pattern of directionality. The key to harnessing these waves effectively is the proper location of the points of generation and detection.

The laser generation process falls into two regimes: ablative and thermoelastic. At higher generation pulse energies, ablation is produced at the surface through formation of a plasma and the ejection of a small amount of material. The surface recoil from this material removal process produces waves with high amplitude. However, the associated surface damage may not be acceptable in some organic materials, such as composites.

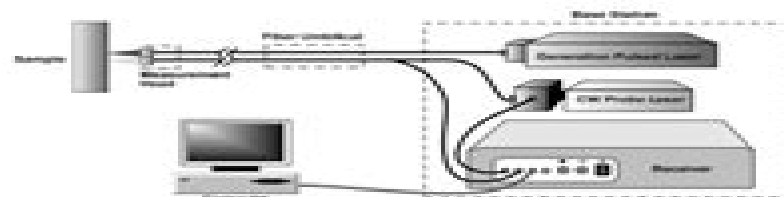


Fig. 1. Laser ultrasonic inspection system.

At lower generation pulse energies (thermoelastic regime), elastic waves are generated as a result of rapid heating and thermal expansion. No damage of any kind is produced. In metals the heat is deposited in a very thin layer near the surface. The free surface takes up a large fraction of the thermal expansion and thus the amplitude of the generated ultrasonic waves is lower than for ablation.

When using a short laser pulse for generation, the resulting ultrasonic waves have very high bandwidth. A number of factors in the test sample (such as attenuation and/or grain scattering) can reduce the bandwidth of the travelling ultrasonic waves, but it is still high in comparison with typical transducer-generated waves. This high bandwidth enables good depth resolution for accurate location of small, subsurface features. It also allows detection of features that are very close to the surface where generation occurs.

In summary, laser ultrasonics has several advantages over other NDT techniques:

- It is noncontact, with only laser beams reaching the part.
- The small beam footprint on part provides high spatial resolution and allows access to small spaces and curved surfaces.
- Fast scanning is possible by mechanical means or by scanning the beams with rotating mirrors.
- Compressional, shear, plate and surface waves are readily produced.
- High bandwidth (extending to 100 MHz) provides high temporal and depth resolution.

A photo of a commercial IOS receiver is shown in Fig. 2. IOS receivers are "adaptive" in that they have the ability to compensate for rough surfaces that may be moving and/or at high temperature [2].

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Volodymyr P. Kojemiako, Sergey Kostyukevych, 2001 Computer Vision and Image Processing Deep Gupta, Kishor Bhurchandi, Subrahmanyam Murala, Balasubramanian Raman, Sanjeev Kumar, 2023-05-06 This two volume set CCIS 1776 1777 constitutes the refereed proceedings of the 7th International Conference on Computer Vision and Image Processing CVIP 2022 held in Nagpur India November 4 6 2022 The 110 full papers and 11 short papers were carefully reviewed and selected from 307 submissions Out of 121 papers 109 papers are included in this book The topical scope of the two volume set focuses on Medical Image Analysis Image Video Processing for Autonomous Vehicles Activity Detection Recognition Human Computer Interaction Segmentation and Shape Representation Motion and Tracking Image Video Scene Understanding Image Video Retrieval Remote Sensing Hyperspectral Image Processing Face Iris Emotion Sign Language and Gesture Recognition etc

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