Insights

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High Speed Nondestructive Inspection by using Laser Induced High Frequency Ultrasound

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There are several ways to generate ultrasonic waves. Among them, the most common and widely used method is using a piezoelectric disk material that converts electric signals into stress waves. Typically, piezoelectric sensor based probes require ultrasonic coupling agent in a form of liquid or gel. Most of the nondestructive inspection (NDI) methods involving contact probes are slow in nature and difficult to automate for inspection processes.

It is often better to avoid acoustic coupling agents if inspection speed is an important factor, as well as accuracy and repeatability. As a non-contact ultrasonic inspection technique, a laser induced ultrasonic wave generation method is proposed for inspecting E-car battery tab weld joints in a production line.

When describing laser induced ultrasound, two extreme limits of laser beam energy density are generally considered: thermo-elastic and ablative mechanisms. The thermo-elastic source is a rapid, thermally induced expansion of the skin depth of the sample illuminated by the laser at a low incident power density. With the ablative source, on the other hand, a thin surface layer of the material and/or air at the surface of the material is illuminated by a higher power density laser beam, and ablation of the surface or plasma formation of the air above the surface occurs. The thermo-elastic regime is generally the most desirable, as any potential damage to an irradiated surface is minimized. The generation and detection lasers can be tightly focused on the sample surface allowing for high lateral resolution opening up the possibility of using laser ultrasonics to characterize conditions of materials down to a submicron scale.

At present, the majority of laser based ultrasonic work has been performed in one of two frequency regimes. In the first regime, high speed Q-switched laser sources, with pulse lengths in the ~ 7-100ns range, are used for ultrasound generation. These sources allow for the generation of acoustic waves in the kHz to 10's of MHz frequency range. This bandwidth is suitable for a wide variety of NDE applications where the spatial resolution requirements are in the range of 0.01 - 1.0 mm. In the second regime, ultrafast (femto- to pico-second) laser pulses generated from mode-locked laser sources can generate ultrasonic waves with bandwidths in the 100's of GHz regime. This frequency regime is of use in the semiconductor test and measurement sector for thin film analysis.

For E-car battery electrode tab weld inspection applications, it is believed that a high speed Q-switched laser is sufficient to generate ultrasonic waves between 20 to 40 MHz. In terms of spatial resolution, this frequency range would easily allow for detection of a defect size down to 50 microns. By incorporating 2D optical scanning technology using a gimbal-less two-axis (tip-tilt) micromirror, the laser beam can be steered angles of up to 32 deg. at high speeds in both axes. In this way, a pulsed laser beam can be scanned over a weld joint area at a speed of several millimeters per millisecond. A weld spot of 1 mm in diameter, for example, can be scanned several hundreds of times in a second to ensure the inspection results are accurate and dependable. A battery production line capacity is estimated to be approximately 2 million cells per year utilizing three shifts per day. This means that it makes almost 7 welds per minute, which is equivalent to 1 weld every 10 seconds. With the proposed laser induced ultrasonic inspection technique, it is possible to increase the battery cell production rate up to 10 million cells per year, a 500% improvement, (1 weld every 2 seconds) for a single manufacturing line.

The faster inspection processing speed enables:

- More battery cells to be inspected per shift
- Lower cost per battery
- Greater accuracy in each measurement
- Greater confidence in the end product
- Inspection is no longer a bottleneck operation

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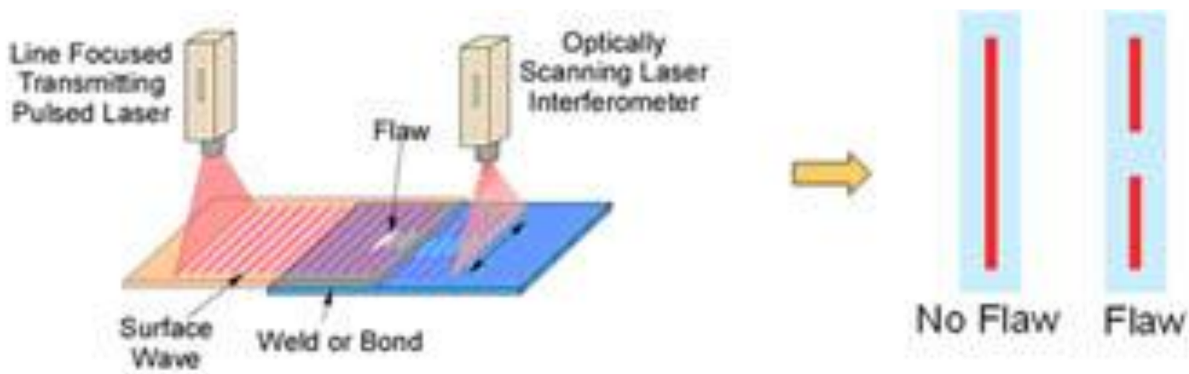

Non-contact Laser Based Ultrasonic Surface Wave Generation Technique to Inspect Defects at a Joint