Laser Bond Inspection

Non-Destructive Evaluation for Adhesively Bonded Structures

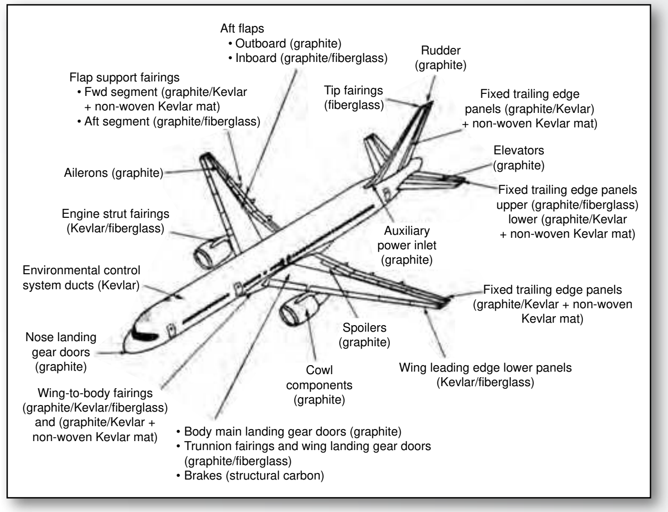
Adding Efficiency and Precision for Your Applications

LSP Technologies

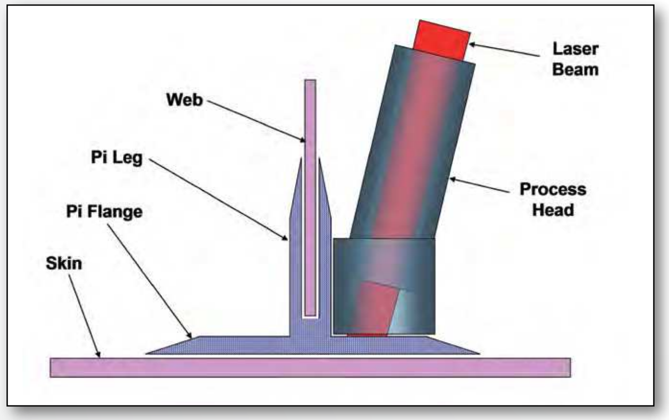
Benefits

As composites become more prevalent in the aerospace and wind energy industries, these materials present new technical challenges that must be addressed: Enter Laser Bond Inspection. Laser Bond Inspection (LBI) validates that adhesively bonded materials are properly bonded, and detects weak and kissing bonds. LBI is a nondestructive evaluation method that gauges a bond's response to laser-generated stress waves to determine bondline strength and structural integrity.

Laser Bond Inspection is performed using a mobile laser system, enabling bondline inspections in production and depot environments or in the field. LBI replaces the use of test samples, saving time and money by improving the efficiency of bond strength validation. LBI can be used to inspect complicated primary structural joints like Pi Joints.



LBI tests bond strength for aerospace composites



Inspection head on Pi Joint

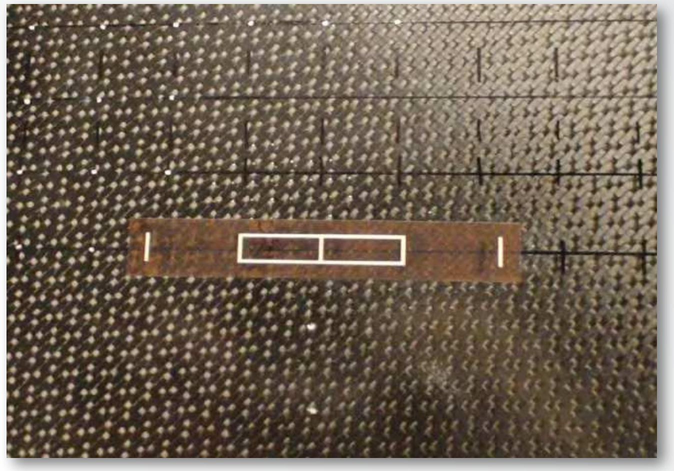
Wind turbine blades

Applications

- **Aerospace**
  - o Composite structures
  - o Scarf repairs
  - o Boron patch repairs
- **Power Generation**
  - o Wind turbine blades
- **Coating Adhesion**
  - o Heat resistant coatings
- **Adhesively Bonded Materials**
  - o Metal-to-metal
  - o Metal-to-composites
  - o Composites-to-composites

How LBI Works

1. **Determine bond line fluence levels**
   Testing and modelling establish two laser fluence levels: a threshold fluence that disassociates a "good" adhesive bond, and a test fluence that is below the threshold fluence and reveals if the bond line meets the requirements. Each fluence creates a stress wave with a specific peak stress.



Inspection tape with copper trace for EMAT

2. **Inspection spot preparation**
   The real-time bond strength test starts with the application of the inspection tape to the surface of the inspection location. The inspection tape translates the vibrations from the laser-induced stress waves to the EMAT sensor.
3. **Surface protection**
   The inspection tape is covered with a black (opaque) tape that absorbs the laser energy and generates the stress wave, as well as protects the material from the laser beam.
4. **Position inspection head**
   The inspection head is aligned with the lines of the inspection tape. It is now ready to begin the three-laser-pulse inspection method.
5. **Base line inspection laser pulse**
   The bond line testing begins with a low-energy laser pulse that generates an EMAT signal characterizing the bondline response to the laser-generated stress wave.
6. **Bond line interrogation laser pulse**
   A second laser pulse at the test fluence is applied to stress the bond such that a good bond will not be affected but a substandard bond will fail.
7. **Base line comparison laser pulse**
   The bond line testing finishes with another low-energy laser pulse, equal to the first base line pulse, that re-characterizes the response of the bond line to the laser-generated stress wave.
8. **Data analysis results**
   The EMAT signal traces from the inspection and comparison laser pulses are analyzed by a computer algorithm. If the two traces are identical, the bond is sufficiently strong. If the traces are different, the bond is substandard. Results are displayed on the LBI inspection head with a green light indicating an acceptable bond and a red light indicating a substandard bond. All EMAT signal traces are stored for additional evaluation.

Features

- ✓ Eye safe process
- ✓ Controlled laser environment to protect and optimize laser performance
- ✓ Cart mounted construction for jobsite movement
- ✓ Cart provides maneuverability on flat jobsite floors
- ✓ Articulating arm laser beam delivery with a 5.7 to 10 ft. reach
- ✓ Amplifier lamps are replaceable without need of realignment

Flat surface inspection head

Inspection Heads

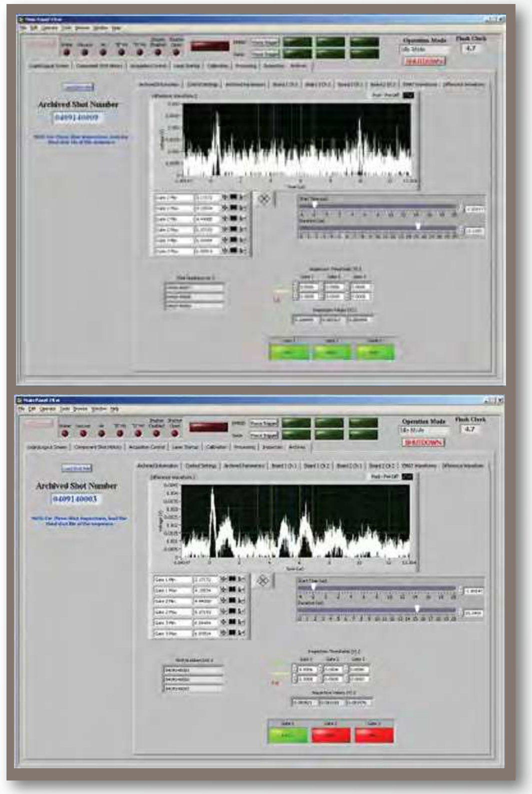
- ✓ Easy operator controls
- ✓ EMAT sensor
- ✓ Vacuum suction to stabilize inspection head on part surface
- ✓ Water evacuation ports to maintain surface
- ✓ Safety features to protect the operator during inspections

Green lights on the inspection head denote a good bond is present

Red lights on the inspection head denote a bad bond is present

Key Benefits

- ✓ Detects weak bonds
- ✓ Detects kissing bonds
- ✓ Nondestructive to strong bonds
- ✓ Detects bond quality variations from:
  - o Surface preparation
  - o Adhesive mixing, and
  - o Contaminations
- ✓ Measures bond strength



Test result screen display

Laser Class 4 in accordance with IEC 60825-1, EN 60825-1 and FDA 21CFR CH.1, 1040

The Technology

LBI Technology provides a measurable and effective NDI method to repeatedly validate the safety and integrity of adhesive bonds.

Conventional nondestructive inspection techniques, such as ultrasonic probing, do not detect relative bond strengths because the nature of the materials will not change under ultrasound transmission and reflection characteristics. Kissing bonds in particular are defects where the surfaces are in intimate contact but have no mechanical strength. Conventional NDI methods are incapable of detecting or identifying kissing bonds.

The LBI system consists of a pulse laser coupled to an inspection head by an articulated arm. The inspection head contains an EMAT sensor that allows real-time detection of substandard bonds by obtaining a stress wave signature at the front surface of the material. When a bond is not acceptable, the LBI system will identify a defective condition.

Figure 1 shows stress distribution through a part, the part thickness being the "Y" axis. The color contour plots stress, with the compressive stresses between green and red and the tension stresses between green and blue. Green indicates very low stress. The figure shows a cross section of a specimen with (1) the laser deposition on the front face, (2) a compression wave propagating toward the rear face, and (3) reflection of the compressive wave at the back surfaces as a tension wave (in blue).

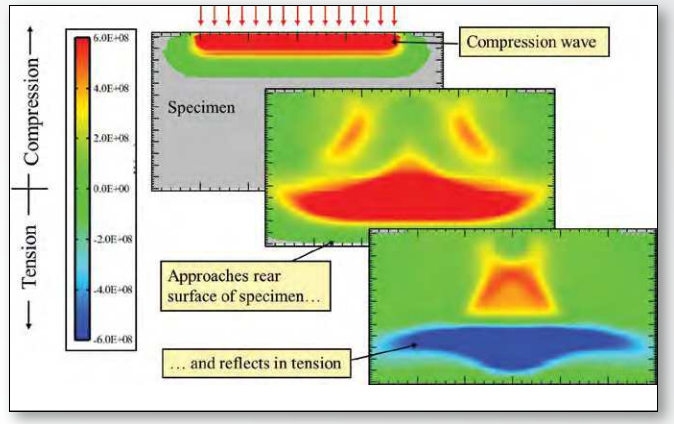


Figure 1. **Modeling of stress waves moving through a part**

Figure 2 illustrates the application of the LBI process. The lower diagram shows a one-dimensional approximation for laser based stress wave generation and stress pulse propagation in a solid slab. Graph T1 shows the pressure pulse produced at the surface of the composite. Graph T3 shows the pulse after propagating to the rear surface. Graph T6 shows the tensile wave after just completing reflection from the back surface and then starting the propagation toward the front surface.

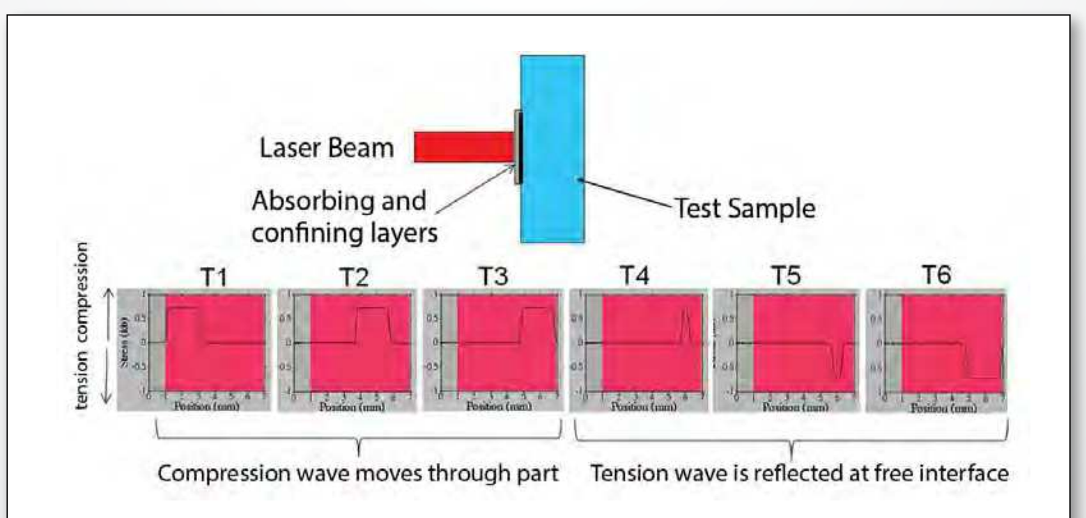


Figure 2. **One-dimensional representation of the stress pulse propagation**

The LSPT Advantage

LSP Technologies, Inc. (LSPT) is the world's premier provider of material enhancement and inspection high energy lasers. LSPT's laser technology team of engineers and physicists designed and built the world's first commercial laser peening laser system in the 1980s. In the mid-1990s, we helped GE Aviation establish their in-house laser peening capability and designed and built our own laser peening metal surface improvement systems.

In 2001, we developed laser peening applications for Rolls Royce's Trent 800 1st stage fan blades and BR710 discs. Meanwhile, we began working with Boeing on our patented Laser Bond Inspection technology for aerospace adhesively bonded composite structures. By 2003, we began laser peening production on an engine component for Pratt & Whitney's F119 engine on the F-22 Raptor. In 2007, we built a prototype mobile LBI system and have demonstrated technology advancements with it since then, including the inspection of hidden surfaces and Pi Joint applications. In December 2012, we delivered the first commercial Laser Bond Inspection system for use in the aerospace industry to the Boeing Company in Seattle, Washington.

We continue to provide production Laser Peening for an array of companies and industries, including major OEMs for power generation and aerospace. We're also making improvements in laser system technology. We have introduced our Procudo® Laser Peening System to create the highest power Laser Peening system in the world. We continue to develop advancements in Laser Bond Inspection by decreasing the inspection head size and the ability to inspect complex structural elements like Pi joints.

LSP Technologies Inc. operates an AS9100:2016 and ISO9001:2015 registered Quality Management System for Laser Processing Services and Equipment Manufacture at its facility in Dublin, Ohio.

Key Milestones

- **2002: Patented LBI process**
- **2004: Demonstrated process on flat panels**
- **2006: Built prototype with SBIR Phase I contracts**
- **2010: Demonstrated process on Pi joints**
- **2012: FIrst system delivered to Boeing**
- **2014: Designed inspection head for confined spaces using SBIR Phase II contracts**

"I'm Jeff Dulaney, Founder, President and CEO of LSP Technologies, Inc. I commit to you that we will deliver our equipment and services to you at a cost that is affordable, on time, and with all of the quality requirements established for your products."

~ Jeff Dulaney

Avantages

Au fur et à mesure que les composites deviennent de plus en plus prévalents dans l'industrie aérospatiale et de l'énergie éolienne, ces matériaux présentent de nombreux défis techniques sur lesquels il faut se pencher: Entrez dans le monde de l'inspection au laser de l'adhésion (Laser Bond Inspection, LBI). L'inspection au laser de l'adhésion (LBI) valide que les matériaux liés par adhésion sont correctement liés ensemble, à l'aide d'une réponse à l'adhésion aux ondes de contrainte générées par rayon laser afin de détecter les adhésions structurellement insuffisantes. LBI est un processus d'évaluation non destructif qui détecte les adhésions faibles ou les surfaces mal préparées.

LBI effectue des inspections sur les structures liées par adhésion dans les environnements de production et les dépôts, ainsi que sur le terrain. LBI réduit le réusinage et remplace l'utilisation des échantillons de test, ce qui vous économise du temps et de l'argent. Grâce à sa nouvelle tête d'inspection, LBI est en mesure d'inspecter des joints structuraux primaires complexes tels que les Joints PI.

Vorteile

Durch das immer häufigere Einsetzen von Verbundwerkstoffen in der Luftfahrt- und Windenergieindustrie ergeben sich durch diese Materialien viele technische Herausforderungen, die es zu bewältigen gilt. Wir stellen vor: Laser-Bond-Inspektion (Laser Bond Inspection, LBI). Laser-Bond-Inspektion (LBI) bestätigt, dass geklebte Materialien richtig miteinander verbunden sind, wobei die Reaktion der Verbindung auf durch Laser erzeugte Spannungswellen verwendet wird, um strukturell unzureichende Verklebungen ausfindig zu machen. LBI ist ein zerstörungsfreies Überprüfungsverfahren, das schwache Klebeverbindungen und Adhäsionsstörungen (sog. Kissing Bonds) erkennt.

LBI führt Inspektionen von Klebeverbindungen in der Produktion und im Lager sowie vor Ort durch. LBI reduziert Nacharbeit und ersetzt den Einsatz von Probestücken, wodurch Sie Zeit und Geld sparen. Mit dem befindlichen neuen Prüfkopf ist es LBI möglich, komplizierte primäre strukturelle Verbindungen wie Pi-Verbindungen.

利点

航空宇宙および風力エネルギー産業において複合素材が普及すればするほど、同素材は対処しなければならない多くの技術的問題をもたらします。そこでレーザー接合検査(Laser Bond Inspection, LBI)が用いられます。レーザー接合検査（LBI）は、レーザー誘起応力波に対する接着剤の反応を用いて構造的に不十分な接合を検出することで、接着された素材同士が適切に接合されていることを確認します。LBIは微細な接合不良（キッシングボンド）を検出する非破壊評価プロセスです。

LBIは製造および倉庫環境、さらには現場で、接合構造に対する検査を実施します。LBIはやり直しを減らし、テストサンプルの使用に取り代わり、時間と費用を節約します。開発中の新たな検査ヘッドにより、LBIはPiジョイント、ダンパー、振動絶縁アセンブリ、および流体シールなどの複雑な主要構造接合部を検査することができます。

LSP Technologies

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