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Mobile Laser Peening: Extending the Service Life of the F-22

METAL IMPROVEMENT COMPANY (MIC), a business unit of Curtiss-Wright Surface Technologies, has developed a mobile laser peening service that is capable of peening large work pieces, such as aircraft, on location at a customer facility. One application of this technology has been the laser peening of the F-22. Since beginning the work in April of 2011, an MIC mobile laser peening system has been used to process the lower wing attachment lugs of 16 in-service fighter jets at the Lockheed Skunkworks in Palmdale, California under a contract with Boeing IDS. In 2014, this work will be moved to Hill Air Force Base in Ogden, Utah.

Technology Overview

MIC is presently conducting commercial laser peening operations at five processing plants: in the U.S. (Livermore and Palmdale, California, and Frederickson, Washington); the U.K. (Earby in Lancashire); and Singapore (Seletar Aerospace Park). The MIC technology has been developed to laser peen components that range in size from small parts, just a few inches in diameter, to large wing skins over one hundred feet long. The laser peening approach relies on flashlamp-pumped glass laser systems that can place high-quality square or rectangular spots onto the treatment surface at a pulse-repetition-frequency of up to 5Hz in continuous operation. High-pulse energies enable the use of spot sizes between 3 and 10 mm, providing up to 10X deeper levels of residual stress than competitive laser peening processes that rely on small spot, low-energy laser systems.

Several methods are used to scan the spots across the surface of the part in precise and repeatable patterns during processing. Smaller parts are manipulated with robotic arms through a fixed laser beam. For larger parts that are not easily moved during processing, the high-power beam can be scanned across a treatment surface while the part is stationary. Complex work pieces often benefit from a hybrid approach where the position of both the part and the beam are actively scanned during processing. Delivery of the water tamping layer is accomplished with a separate robotic arm, through a fixed nozzle attached to the beam scanning tool, or with

Figure 1. This MIC transportable laser system is en route to Palmdale, California for F-22 laser peening. MIC has a fleet of five mobile peening systems that can service marine, offshore oil and gas, petrochemical and aerospace repair and overhaul applications.

computer-activated fixed nozzles attached to the work piece. These approaches have been adapted and are in ongoing commercial production for components such as aircraft engine blades, gas and steam turbine blades, large bladed rotors, and commercial aircraft wing skins.

Challenges of Mobility

The laser peening of a large stationary work piece, such as an F-22 at a customer site, creates a number of significant technology challenges. The first is the need for a mobile, self-contained laser source. The MIC transportable laser system (Figure 1 on page 14) is housed in a trailer which can be located at a customer facility and requires a single 480 VAC power feed and a one gallon/minute tap water source delivered to a conventional garden hose fitting. The system can be parked, self-leveled, and activated in less than one day.

Another challenge is the need for a portable beam transport system between the laser and the work piece and a method of accurately scanning the beam in precise patterns across the component, often following complex surface shapes. Because the laser energy, coherence, and peak power are too great for propagation down a fiber, an automated mirror-to-mirror beam relay and delivery system is used. The MIC mobile beam delivery tool, called the dual-gimbal stinger (DGS), allows a laser spot pattern consisting of hundreds or up to many thousands of spots to be applied from a single robot position (Figure 2). High-speed adjustable optical components are used to direct the beam to each treatment spot rather than robotic motion.

Pattern Registration and Beam Delivery

For smaller work pieces such as turbine blades and rotors, fixed tooling can be used to ensure a precise, repeatable location and orientation between the laser peening system and the part. However, when laser peening a large aircraft such as the F-22, the process cannot rely on each plane being delivered to exactly the same location in the processing cell. For this reason, the DGS uses built-in optical metrology combined with a known surface model of the work piece to register the laser pattern quickly and accurately for each pattern of spots. This eliminates the need for placing the work piece in a known location and orientation with respect to the laser tool and is particularly valuable when laser peening large items such as aircraft.

High speed gimbals under closed-loop control are used to maintain accurate alignment between the mobile laser system and the beam delivery tool, eliminating any beam drift associated with the mechanical stability of the system. A self-contained mobile pallet allows the laser delivery robot to be quickly and easily positioned at locations on either side of an F-22 using an air bearing support system.

Related Applications

In the case of the F-22, the laser trailer is located just outside of the laser safety tent that houses the jet during laser peening operations (Figure 3). In other applications also currently in process, the trailer is located as far as 150 feet from the laser peening work area and the beam is supplied through a series of beam tubes and mirrors. This distance could be increased to well over 500 feet for surface treatment in challenging environments, such as inside of the containment building for a nuclear reactor. MIC has used variants of the mobile laser approach to set up shop-in-shop laser peening operations for original equipment manufacturers. Boeing and Rolls-Royce-Singapore have already realized the benefits from this arrangement, receiving significant savings in non-value-added turn time and cost reduction by eliminating the need for the shipment of parts in and out of the facility.

Figure 2. Mobile beam delivery system. The dual-gimbal stinger (DGS) is held by a robot arm. The entire assembly can be freely moved around the processing cell on air bearings. High speed gimbals maintain the optical path between the laser system and the DGS.

Figure 3. Laser safety tent used for the peening of F-22 fighter jets. The transportable laser system can be seen just to the left of the tent and the mobile beam delivery system is visible inside.