LASER SHEAROGRAPHY
A STRAIN IMAGING VIDEO CAMERA
FOR COMPREHENSIVE NONDESTRUCTIVE INSPECTION

John Tyson, II
1055 W. Germantown Pike
Norristown, PA 19403

INTRODUCTION

Laser shearography, a form of electronic holography, provides more than 350,000 adjacent real time strain gages on the surface of the component or structure being imaged. This is performed without contact or surface preparation. This powerful tool has been successfully applied to a broad range of nondestructive testing applications, providing a rapid and precise wide area inspection. This technique provides unique capabilities and cost efficiencies over more typical inspection techniques such as x-ray and ultrasonics.

With video inspection using laser shearography, inspections can be easily performed manually, or can be computer automated for real time on-line inspections. The video results are intuitive, making the training of the inspector relatively easy. The shearography training requirements are now being defined in the latest ASNT (American Society of Nondestructive Testing) SNT TC-1A (1996), NDT Inspector Training Requirements.

Successful applications include pharmaceutical to aerospace, tires to orthopedic implants, from field inspections of the NASA Space Shuttle to production line inspection of hundreds of thousands of medical parts per year. As an example of cost effectiveness, the inspection of Concorde elevons using shearography has reduced the inspection time from more than 250 hours per aircraft to less than 30 hours, with a typical increase in defect sensitivity of more than 100%. As an example of throughput, a maker of orthopedic implants reported that in 1994, with three production shearography inspection systems, 175,000 pieces were inspected. They have since taken delivery of a fourth production inspection system, in early 1995.

The inspection of complex structures or parts with complex geometries such as the F-15/F-16 fighter plane engine housing constructed of titanium honeycomb and titanium skins is simple for the non-contact nature of the shearography inspection, see Figure 2.

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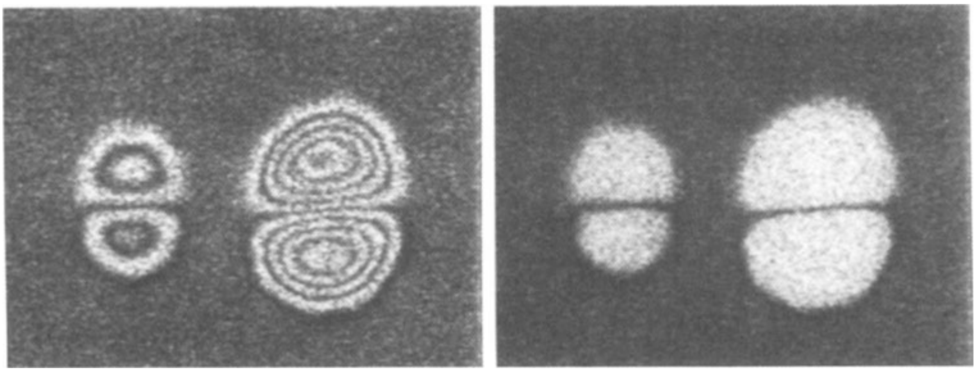

Figure 1. Typical shearography results show the exact size shape and location of the defect, either with fringes (left), which show a quantitative measure of strain, or without fringes (right) showing an easily detectable indication.

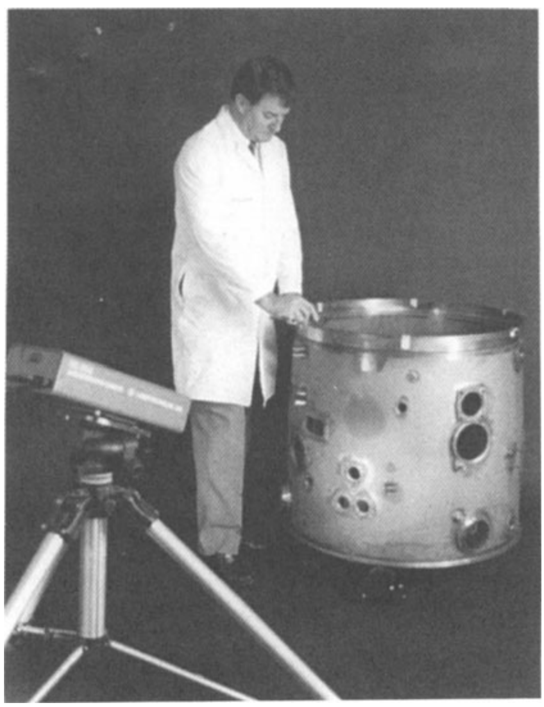

Figure 2. F100 Fan Duct, 32 inches in diameter, 28 inches high and approximately 0.3 inches thick. Titanium skins over titanium honeycomb. Tested using LTI-4000 series Shearography system with vibration excitation between 4 and 10kHz.

COMPOSITES INSPECTION

Shearography is a powerful tool for the inspection of composites, because it measures the local strength of the structure, and is not influenced by variations in construction or the nonhomogeneous nature of composites. As an example, a common aerospace composite structure has a Nomex honeycomb core with graphite skins and may possess one or more septums (inner skins). This type of structure may also possess varying amounts of adhesive and foaming adhesive filler.

With this type of construction, shearography can use pressure reduction stressing to lift the skin from the core where there are skin to core unbonds, crushed core or delaminations. Shearography is sensitive to unbonds that are less than the honeycomb cell size if the skin is not too thick, or can reliably detect a ½" dia. defect under 0.100" skins and a 1" dia. defect under 0.200" skins.

Shearography can be used in a number of configurations depending on its use in production or field inspection. Typically in production, a shearography composites inspection station consists of a pressure reduction chamber in which parts can be placed in a fixture. A zoom shearography camera is used to image large areas up to ten square feet. This type of system can locate defects as small as ¼ inch. This type of system is standard for aerospace applications such as the B-2 control surfaces, where a 36 foot chamber can inspect 30 foot parts; with each image covering 10 square feet in 8 seconds.

Shearography with pressure reduction is also used for deeper defects, such as septum unbonds and far side defects.

An example using the common aerospace structural material described above, a manufacturer for commercial aircraft can locate a 1¼" septum unbond through 3" of core with 0.050" top skins. An additional advantage for production inspections is that the shearography video results provide a documentable image set of the structure, which can be printed out or archived onto optical disk (standard) for 100% documentation and traceability of production quality or shop and field applications, portable shearography equipment is used to rapidly inspect aerospace composite structures, with nearly the same sensitivity as the production inspection equipment. In-service defects such as impact damage, crushed core and disbonding are detected with inspections covering up to 50 square feet per hour.

This technique is used for applications such as the field inspection of the fuselage, composite panels, and metallic and composite control surfaces. These single sided inspections are routinely performed on the aircraft, typically saving extensive disassembly time. Advanced composite engine housings made by Martin Marietta are inspected in production using through transmission ultrasonics, while field inspections are performed with shearography and vibration excitation, with the engines mounted on the aircraft. For this application shearography has a sensitivity of 1" diameter

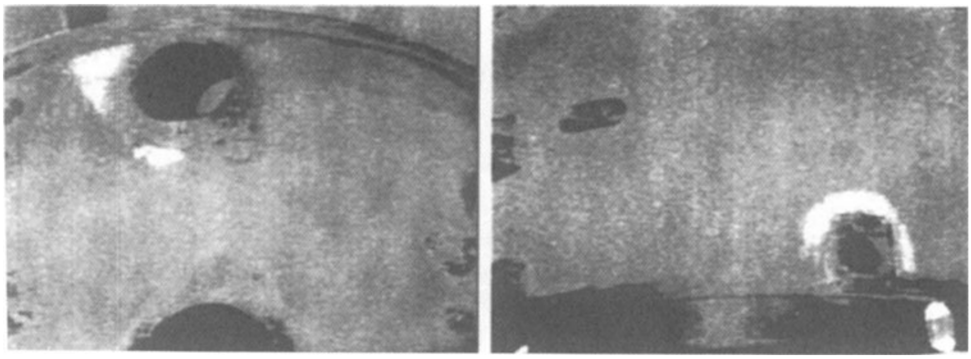

Figure 3. Shearography images of defect indications surrounding through wall fittings. Both are near side disbonds between outer skin and honeycomb core.

disbonds between the highly contoured graphite skins (0.200" in critical areas) and the aluminum honeycomb. This structure, like many real world applications, has many fittings and other attached structure, which makes most NDT difficult. Shearography, on the other hand, can inspect all around these problem areas, as it can inspect all material that it can see, without actual contact to the area.

Another example of a difficult application that shearography performs easily is the inspection of composite rudders of many commercial aircraft. These structures are constructed of two honeycomb panels with internal ribs, with 3-5 ply graphite skins (0.024" to 0.040") and ½" to 1" Nomex core. Water ingress with freezing can cause disbonding of either the outer or inner skins.

Shearography with vacuum stressing detects disbonds at either location, allowing complete rudder inspections in less than a hour. Airbus has also reported the ability of shearography to detect water in as little as a single honeycomb cell using thermal stressing.

Composites inspection with shearography provides a rapid and reliable evaluation of many types of structure. Concerning reliability, a P.O.D. (probability of detection) analysis is the best method to compare different technologies.

In a Rockwell P.O.D. study comparing the real performance of shearography to ultrasonics on a space-based aluminum honeycomb structure, shearography demonstrated a 50% increase in sensitivity at a 90% reliability and 95% repeatability as compared to through transmission ultrasonics.

CONCLUSION

Shearography has been found to be highly effective for the inspection of a broad variety of materials and structures from leak testing microelectronic and pharmaceutical packaging to the nondestructive testing of tires, piping, complex composite structures and composite repairs.

As a real time imaging technique, it can inspect large areas rapidly, providing truly cost effective NDE.

Since it is directly measuring the weaknesses in the material, it can be reliably applied to a broad variety of applications, particularly nonhomogeneous structures such as composites, primarily due to the difficulties associated with inspecting these nonhomogeneous structures with transmission type NDT methods.

Since it is a video based system, it is easily implemented and provides both manual and automated capabilities, taking NDT and process control into the next century.

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