Shearography as an Industrial Application Including 3D Result Mapping

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Abstract. Shearography is a highly accurate optical NDT technology for the detection of cracks, delaminations and disbondings in composite structures. The object under inspection is stressed by a minor load far below the load in real conditions.
Steinbichler Optotechnik develops and manufactures optical systems, e.g., for 3D coordinate measurement and NDT for more than 20 years. The combination of shearography and 3D result representation offers unambiguous test documentation even for huge test objects like aircrafts.
This paper illustrates the applications of shearography for production and in-field service in the aviation industry. Several system types are available to satisfy the demands of a wide application range with all systems having the same technical basis. Featuring 3D result representation and automatic test documentation, the ISIS NDT systems by Steinbichler Optotechnik are optimized for a fast and cost-effective inspection. For in-field service, a fully automatic localization of each single measurement is provided with the use of a tracking system.
Thus, a fast, easy-to-use and reliable tool for the detection of delaminations and even “kissing disbonds” in monolithic and sandwich structures of aircrafts is available, incorporating automatic test documentation.

Introduction

The detection of internal flaws such as cracks, disbonds and voids in composites is a major production and safety issue for the newest aircraft generations. Most NDT methods currently used in aerospace applications (UT, tap testing) have limitations in testing sandwich structures and can hardly detect “kissing disbonds” without gaps between the separated plies. Tap testing for huge areas is time consuming and offers no test documentation. In general, the field of view of the test equipment is much smaller than an aircraft. Therefore, many single measurements have to be performed. Fault-prone and manual documentation is necessary for fault localization, causing a lot of additional paper work.

The Steinbichler ISIS shearography systems are designed for the quick and unambiguous determination of flaws, also in honeycomb and foamed sandwich structures. Each measurement is fully automatically documented together with date/time information, as well as 3D coordinates of the field of view and other relevant information defined by the customer. A detailed test report including an overview of the single measurements is generated automatically.

1. Measurement Principle of Shearography

Internal flaws weaken composite structures and cause fault-typical deformations under stress up to break-down below load limit. Even a minor load can already cause a fault-typical deformation below one micron on the object´s surface. Shearography as a laser-based interferometric technique is accurate enough to detect such small deformations of the object's surface. Repeatable loading causes repeatable deformations and result images.

1.1 Setup

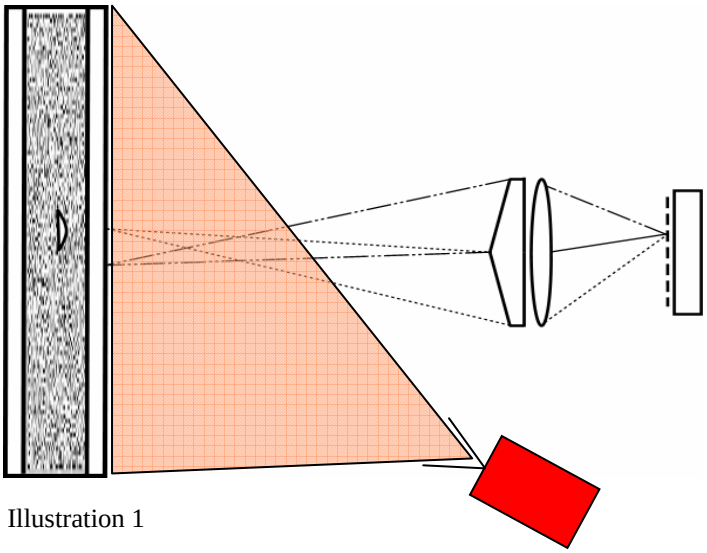

Illustration 1

Illustration 1 shows a sandwich panel on the left with an internal void, illuminated by a diode laser on the right bottom corner and observed using a shearing optics in front of a CCD camera chip.

This shearing optics project the object image onto the camera chip twice; each object point is thus represented twice on the CCD chip. On each CCD pixel there is a light interference of 2 object points.

1.2 Load and Deformation

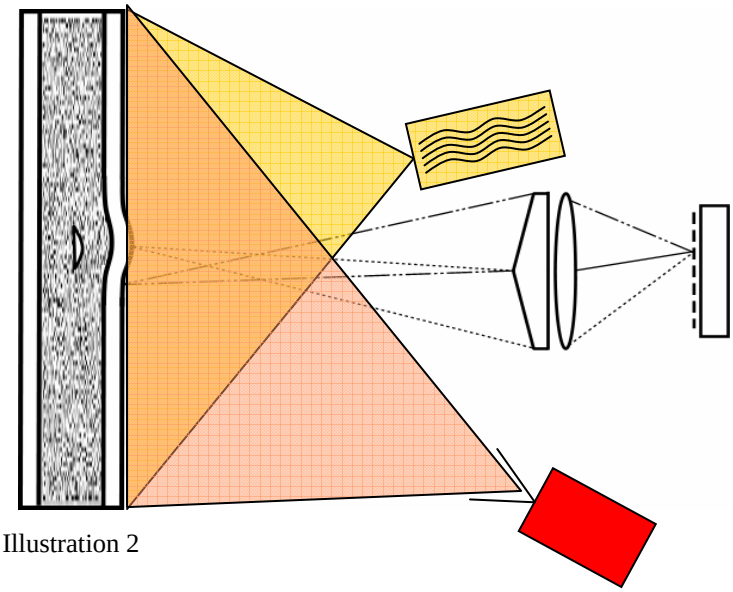

Illustration 2

Illustration 2 shows the sandwich panel of illustration 1, still illuminated by a diode laser on the right bottom corner and observed using shearing optics in front of a CCD camera chip.

Now, the object is loaded by e.g. a heating source. The temperature on the object's surface changes by some Kelvin. This causes a fault-typical deformation on the surface at the internal void.

1.3 Result image

When object points are deformed under load, their light interference on the CCD target changes. By subtracting an image showing the unloaded object state with an image taken in the loaded state, the deformation of an image point can be determined.

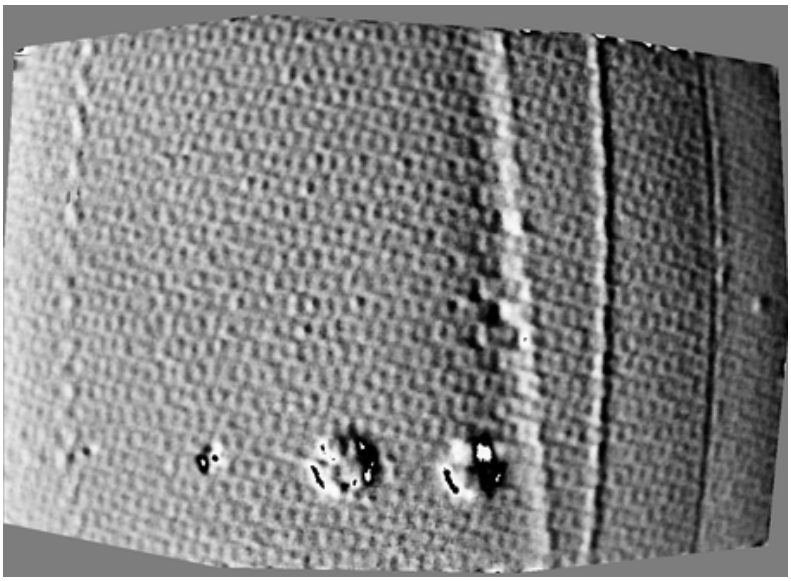

Illustration 3

Illustration 3 shows a ROHACELL® NDT test panel.
(sandwich panel 51 WF 2 x 50 mm, glued with FM300 with 0.5 mm CFK ply with artificial faults**:** release film, dents, cracks, foam glue, drillings)

2. Typical Result Images

2.1 Defects

Shearography result images can easily be interpreted. Fault-free areas are displayed as grey areas with nearly no structure. Faulty areas show double fringe systems with high contrast.

These images with double fringe systems can be used as result images or can be further processed using standard image processing algorithms, in order to highlight faulty areas even more.

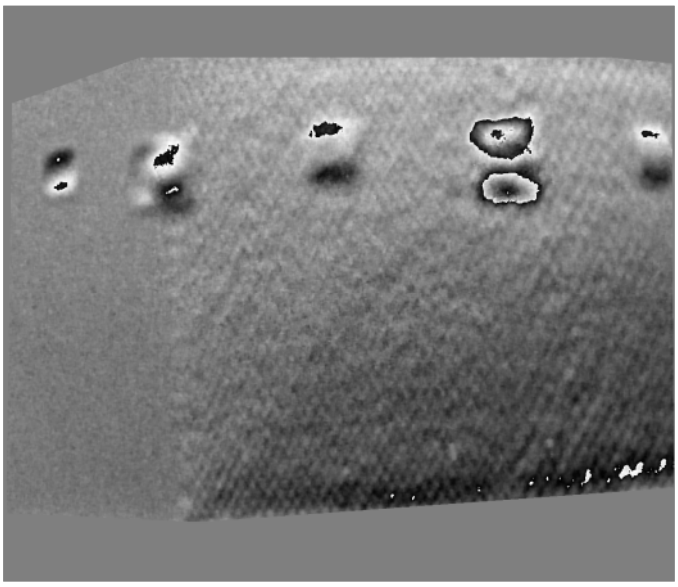

Illustration 4

Illustration 4 shows a honeycomb sandwich panel with a monolithic section on the left side. The separations in the upper area can be clearly identified.

2.2 Internal Structure

As already shown in illustration 4, the monolithic and the honeycomb areas can be easily identified. So shearography also gives information about the internal structure of the inspected part.

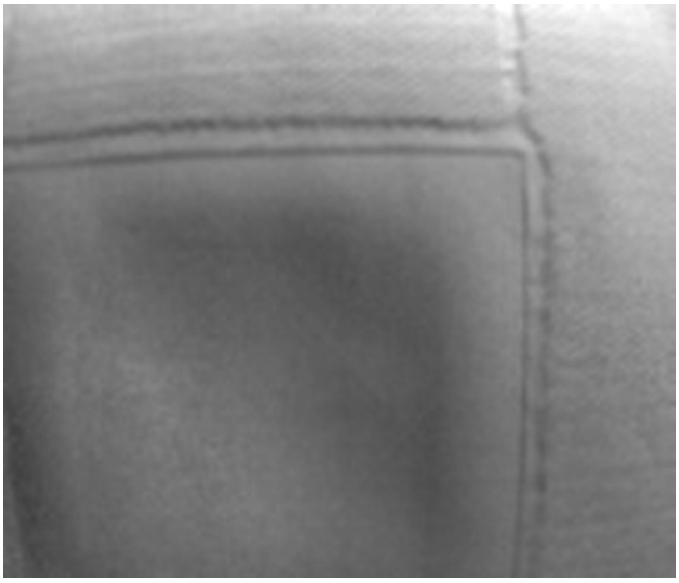

Illustration 5

Illustration 5 shows a honeycomb sandwich panel with internal stringers to reinforce the structure.

3. Products of Steinbichler Optotechnik

3.1 NDT Systems

Steinbichler Optotechnik offers shearography technique in several products for non-destructive testing. ISIS *basic* is designed for R&D purposes: a shearography measuring head including camera and diode laser illumination, fixed on a tripod.

ISIS *mobile* is mainly designed for in-field service of aircraft which also incorporates means and controller for heat and / or vacuum loading. It sucks on the surface of the test object and fulfills laser class 1 criteria.

ISIS*robot* and ISIS 1200 are fully automatic stationary systems for production purposes including measuring head positioning and control of heat and vacuum loading.

Illustration 6: ISISmobile 3000 system at Airbus, Germany
Illustration 7: ISISrobot – measuring head adapted to an industry robot

3.2 3D Coordinate Measurement Systems

To obtain the 3D contour of objects for applications in design, quality control and rapid prototyping, Steinbichler Optotechnik also develops and manufactures a variety of highly accurate coordinate measurement systems such as T-SCAN and COMET.

Illustration 8: handheld laserscanner T-SCAN,
whitelight fringe projection system COMET IV

3.3 NDT and 3D Display Capabilities

The ISIS systems also feature a combination of shearography NDT inspection with 3D object data - shown in the screenshot below with a display of the actual measuring head position and single superimposed result images on an Airbus 320 spoiler.

Thus, a clear and unambiguous identification of each single measurement is possible for the inspection process and test documentation as well.

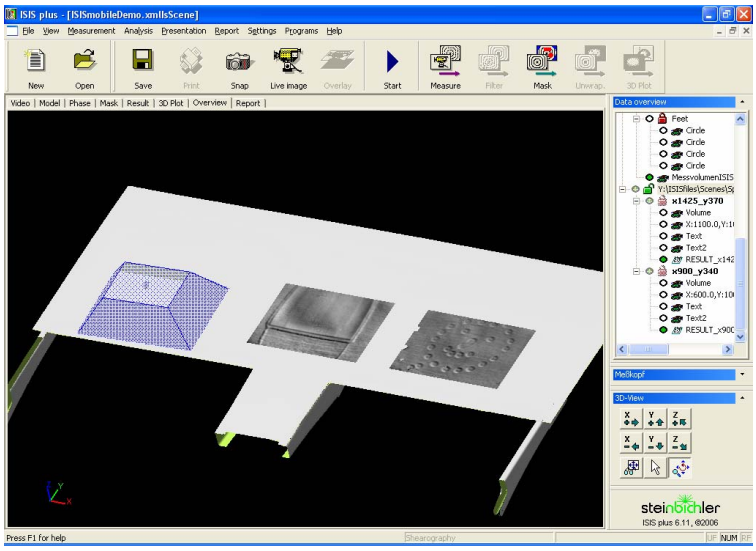

Illustration 9: test program generation and documentation

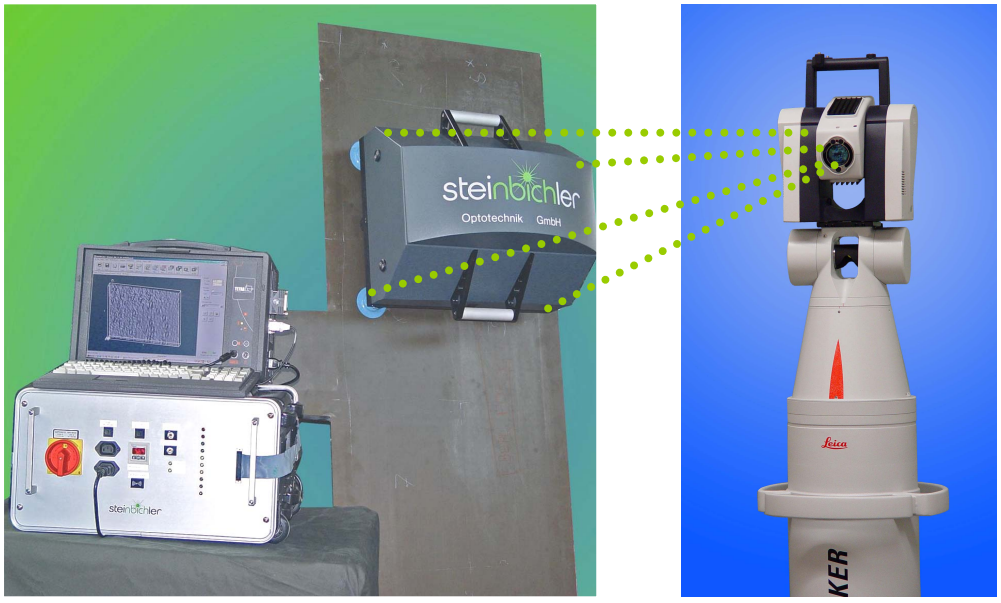

Illustration 10: combination of mobile shearography system with laser tracker

By combining the mobile ISIS shearography unit with a laser tracker, the exact position of the manually positioned measuring head can be determined. This is especially important for the inspection of large-scaled test parts (e.g., in aerospace or shipbuilding) where a fast and easy localization of already measured areas and detected faults is vital for a time-saving test procedure. It also allows a full automatic test documentation. This leads to a both cost-effective and highly accurate quality inspection process ensuring a high product safety level.

4. Conclusion

Shearography is an innovative technique offering decisive advantages for the non-destructive testing of high-performance materials. The ISIS systems developed by Steinbichler Optotechnik represent powerful and easy-to-use solutions for application in industrial environment and are available as mobile and stationary units, e.g., for production or maintenance. With shearography, a timely detection of material defects which contribute to the weakening of components, is possible before a major failure of the part occurs. Necessary corrective action can thus be taken early on, increasing process efficiency and saving costs. The measurement results are displayed clearly for unambiguous judgement and can be stored for a safe and easy documentation.