Detection Capabilities of State-of-the-Art Shearography Systems

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Abstract

Shearography has been validated as fast and reliable inspection technique for aerospace components. Following several years phase of evaluation of the technique, meanwhile, shearography has entered the industrial production inspection.

Modern hi-tech products today widely are made of composite materials, which are specifically designed for the purpose of their application. Other than a precise knowledge of the characteristics of these materials, which often are anisotropic, quality control is of the essence. As said components, e.g. in aerospace, aircraft, or also boat industry are safety relevant, and also of great economic value, rapid defect recognition has to be carried out in production as well as in maintenance.

Shearography is a full field inspection technique, which is specifically suited to do fast defect detection. It is widely accepted as a reliable and fast inspection method especially designed for modern composite material.

Latest generation of Shearography technique and software are presented and the potential is outlined.

Different challenges are presented in production control and in maintenance.

In case of complex components, robotic manipulation of the shearography camera has proven to be the optimal solution. An industry 6-axis robot gives utmost flexibility to position the camera in any angle and distance. Automatic defect marking systems have also been introduced to indicate the exact position of the defect directly on the inspected component.

In this presentation emphasis is put on its potential and position in aircraft and boat industry.

Keywords: shearoghrapy, non-destructive testing, composite material

Introduction

Shearography is a very fast NDT/NDI technique and can do inspection of composite components in very short time. This is why, it can be used for screeniung purposes, in order to sort out all sound parts of components. In the folllowing steps further inspections, as well as other techniques may be used to investigate the defects. However now several production lines for aerospace components have been equipped with automatic shearography inspection systems.

Shearography, although very similar to ESPI, is typically used for nondestructive testing rather than for material analysis and strain measurement. The shearography method is less susceptible to environmental noise and typically requires less of a technical understanding in order to operate the equipment. It is typically used qualitatively, because additional information and processing is required to determine the absolute value of the deformation.

The consequent development to realize small and well working sensors facilitate nowadays an easy made application in complex systems. In this way it becomes possible to achieve an economic integration in automatic production inspection systems.

Automatic Shaeraography Inspection Systems

Automatic shearography inspection system for helicopter rotor blades

Helicopter rotor blades as highly sophisticated products are composed from different materials and components. They are safety relevant components and, therefore, 100 % quality control has to be assured.

Each rotor blade is manufactured as composite, with foam or honeycomb materials as core of the blade, covered on the outside with one or more layers of fiber reinforced plastics. As reinforcement carbon fibers, kevlar fibers or glass fibers are used. In special, highly loaded areas, as, e.g. at the front edge of the blade, metallic layers serve as additional reinforcement.

Consequently, the production of these rotor blades follows a rather complicated and complex procedure. Therefore a 100 % inspection of the blades is required after production. After repairing of defective rotor blades, an inspection of the repaired area is also required.

The rotorblades are mounted in a 10 m long vacuum chamber, fig. 1 and loaded with a relative pressure difference of up to 50 mbar .At this load, debondings and structural defects show up as tiny deformations of the surface of the rotor blades with amplitudes in the range of few micrometers. Two miniaturized shearing cameras, fig. 2 are positioned on a separate guiding system on each side of the rotor blade and observe both sides of the rotor blade. This allows the simultaneous inspection of both sides of the rotor blade during one loading cycle.

Fig.1: Helicopter rotorblade inspection system

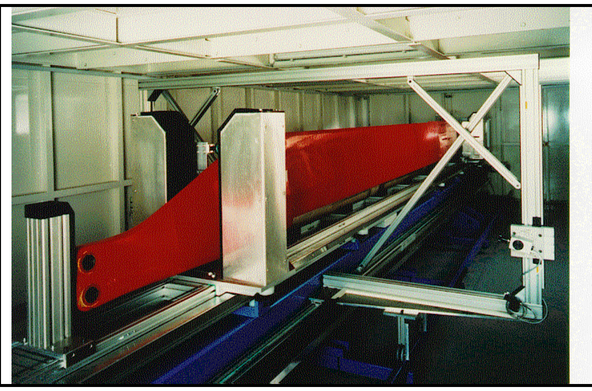

Fig.2: View inside the vacuum chamber with rotorblade in testing position

The inspection areas are illuminated by a 5 Watt Nd:YAG laser, coupled into two fiber coupling systems. The laser beam expanders are positioned together with the shearography cameras on the guide and provide a homogeneous illumination on the whole measurement field. This allows an inspection of areas up to of 600 x 800 mm² on each side of the rotor blade. After each loading and measurement cycle, the shearography cameras are moved on the linear guide to the next measuring area. Up to 15 measurement steps are required for complete inspection of the largest rotorblades.

The inspection results are fully automatically analyzed, by comparing the measured data with a set of earlier taught master data. This allows to distinguish between structural information and defects. The automatic defect localization is carried out during the test cycle and indicates the defect position on the screen. Sizes and positions of the defects are printed in a test report, which is automatically prepared after every test cycle.

Automatic shearography inspection system for thermal protection parts

In the aerospace industries lightweight sandwich constructions are very common. As example, the thermal protection parts of the European ARIANE 5 launcher are made of carbon reinforced composite materials using honeycomb structure cores and monolithic structures in one part. These thermal protection parts show quite complex shapes, as cylindrical or conical and contain flanges and edges. In an extensive validation process shearography has been chosen as technique for 100 % inspection of all components for its performance and inspection speed. Two different stressing methods are used for the shearography inspection of these components. The honeycomb composite parts are inspected with thermal load, because their structure is, comparing to the monolithic areas, porous and not completely sealed. The sealed monolithic carbon structures are stressed by vacuum. Due to the great variations of shapes of the components the shearography camera is positioned by a very flexible 6-axis industry robot, fig.3.

Fig.3: 6-axis industry robot in automatic inspection system of thermal protection parts.

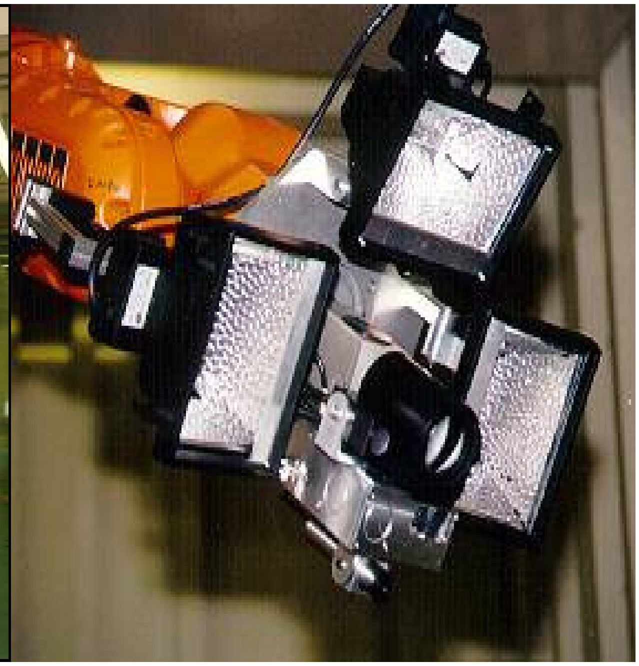

Fig.4: Sensor, illumination optic, thermal loading defect marking system on the tip of the robot.

The robot is mounted on a vibration isolated base plate in the center of a 20 m³ vacuum chamber. Additionally, the robot head carries 3 halogen heaters for thermal loading of the components, fig.4.

The robot's repositioning accuracy of less than 0.1 mm enables reproducible measurements of any complex part. The automatic defect recognition function of the system compares the results of "good" parts with the actual measurement results. Besides delaminations and debondings, the automatic defect detection function also shows missing or badly positioned honeycomb fillers.

The operator is supported with the localization of the detected defects by a defect marking system, mounted near to the shearography sensor on the robot head, fig.4. Using the measurement information, fig. 5, the software directs a laser beam onto the position of the defect at the surface of the test part. This makes it easy for the operator to manually mark the position of the defect on the part.

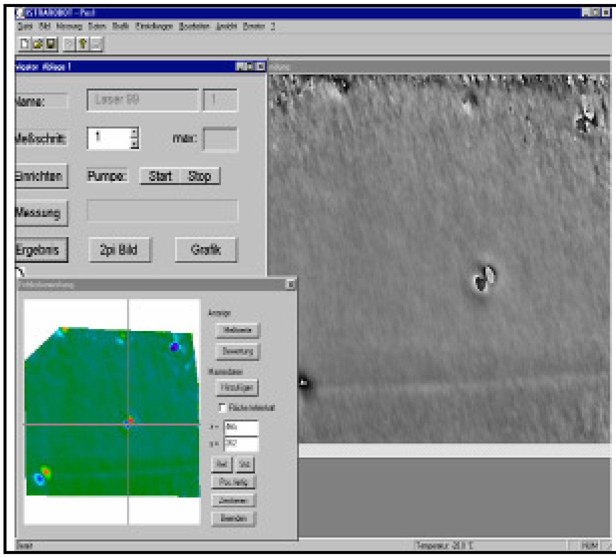

Fig.5: Software interface with defect and marking menue.

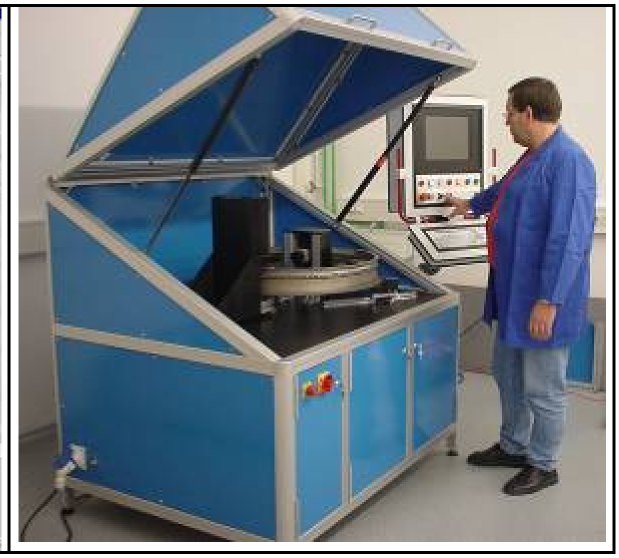

Fig.6: Automatic shearography system for abradable seals inspection.

Inspection of abradable seals

In order to optimize efficiency of jet engines, the gap between the rotating blades and the casing should be as small as possible. Therefore, designers introduce a socalled abradable seal between the blade and the casing. This seal is made from felt metal and has to be renewed after certain operation intervals.

The replacement seal is soldered manually to the casing. The manufacturer demands a 100% inspection of each replaced seal to avoid any damage caused by bad bonding between casing and seal. Fig. 6 shows a laser shearography inspection system for abradable seals. The jet engine section to be inspected is positioned inside the system. A shearography camera looks on a 30° section of the circumference while the section is excited by a electrodynamic shaker with white noise. The white noise excitation causes the unbonded areas of the seal to vibrate and produce an amplitude indication in the shearography system. The complete inspection time for one 300 segment is less than 30 seconds !

Fig. 7: Portable shearography system for field inspection of composite materials

Fig. 7: Portable shearography system in situ on a boat structure

Portable Inspection Systems

In many cases, as, e.g. maintenance or assembly of aeroplanes, it is not possible, to transport the part to be inspected into a stationary test system. For such purposes, a portable shearography inspection system has successfully been developed and used in industry. In Fig. 6 such a system is presented. It consists of a portable vacuum hood, which sucks directly to the surface to be inspected. Inside the hood, a shearography camera records all deformation of the component's surface, when a vacuum is pulled. Debondings or other defects will show up in typical deformation patterns, fig. 7. The operator can view the inspection result with ahead up display and therefore is flexible to operate on scaffolds or inside openings. Typical inspection time is less than 30 seconds per image. One image covers approx. 220 x 180 mm².

Conclusion

Recent improvements of shearography sensors, as well as in software and the development of adapted evaluation techniques enabled the successful integration of automatic shearography inspection systems into the production lines of aerospace industries and into different specific applications. In comparison to conventional inspection techniques, shearography offers the advantages of non-contact, full field inspection and an overall significantly increased inspection speed.

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