IMPROVEMENT OF THE APPLICABILITY OF SHEAROGRAPHY UNDER AIRCRAFT PRODUCTION AND MAINTENANCE CONDITIONS

H. Manzke[1], M. Kalms[2], E. Rau[1], E. Grauvogl[1]
[1]EADS Deutschland GmbH, Manching, Germany; [2]Bremer Institut für angewandte Strahlentechnik, Bremen, Germany

Abstract: Defects like delamination and debonding produce a small but significant stiffness change at the surface of the test object. This effect can be used by the shearography-testing-method for the full range of aeronautic inspection demands.
One attempt to deal with bad optical surface conditions is to improve the laser light distribution by two compact laser sources.
Successful loading the test object to achieve reliable inspection results needs further attention. Especially thermal loading – the easiest way especially in case of aircraft maintenance inspection: improvements are necessary to develop a portable system to introduce heat in a controlled, but fast way to the test object.
Making shearography testing highly mobile is a further necessary attempt to rise the acceptance level in the maintenance world: A portable shearography set for heat loading is still innovative.
Traditional CCD cameras have a limit in dynamic range. This is a problem with the Gaussian shaped illumination from the laser. Using a CMOS camera with possibilities to program the dynamic range for each pixel independent of each other is a totally new concept which will increase the usefulness dramatically since it will result in easier illumination. First attemps with common CMOS-sensors have shown that the loss of quality due to the lower dynamic range against the CCD-sensor is significant when preventing overmudulation.
The presentation will describe the developments within the EC-funded project INCA with the following examples:
The development of a mobile shearography-system for aircraft in-service inspection. Integration of a CMOS-sensor. Results of examinations on real aircraft structures.

Introduction: Shearography has a high potential as a rapid inspection method for large areas. Actual application are nevertheless few. In the scope of the European project INCA applicability was focused by looking at complete aircraft components inspection and included feasibility aspects for production inspection.
A systematic approach to loading the inspected component would also increase applicability of shearography. Another problem is due to one of the major disadvantage of shearography: it has difficulties when applied to polished, perfectly painted or metallic surfaces, due to the direct reflex of the illuminating laser, the high dynamic of the light distribution, etc. A similar problem is rising when testing black surfaces like unpainted carbon fibre components. For maintenance application it is also necessary to work under daylight conditions. There are several options to achieve this goal so that restriction for using shearography as a successful and universal maintenance test method will be drastically reduced.

Results: The development of the shearography demonstrator in the scope of the EC funded INCA project was finished recently. The demonstrator (Fig. 1+2) consist of three main components:Mobile rack, PC, and the cabinet.
The mobile rack includes all necessary electronic devices for energy supply of the laser, which are located in the cabinet. An other component placed in the mobile rack is the vacuum control unit. It provides two independent circuits with vacuum power. Each vacuum-circuit ends in three suction pipes at the cabinet. The power of the vacuum pump is designed to hold a stable connection between the cabinet and the testing object with only three suction pipes (one circuit). Every circuit is monitored by pressure indicators (fig. 1 upper left side of the front panel) and in the case of a drop in pressure it will be indicated by an optical and acoustical signal. In spite of these securities it is recommended to use an additional security (e.g. belt) but it's not inevitable necessary.
For loading components it was chosen an infrared heating system in a short wave range (0,8 – 4μm). There are three infrared heating bars (2x 900W and 1x1800W) which are located on lateral and upper side of the cabinet (fig. 2). For driving the heat it was installed a 2 channel stipples control unit on the upper right side of the front panel. The maximum output of loading power is up to 3600W.
A stand alone PC includes the fringe-analysis-software for image processing. The PC is connected with the CCD-camera and record resulting images in nearly real time. The software provides some filter and demodulation features for building up reportable images.

The cabinet in fig.2 also includes the laser illumination. Two 2W diode-lasers provide a sufficient illumination for a testing area about 200x300 mm. Each laser has its own active cooling fan to get heating problem under control. Tests have shown that the shearography system is able to work over several hours continuously.
The whole equipment (Laser, vacuum pump, heater) can be driven by 2x230V AC-power. This is a big advantage to operate the system in full-field maintenance conditions.

Fig. 1: Mobile rack with PC

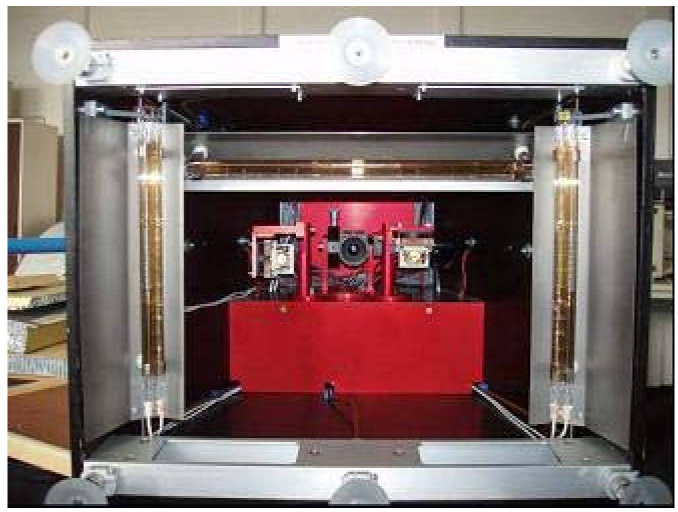


Fig. 2: Shearography cabinet

The first tests on real aircraft structures were performed on a fuselage of Breguet Atlantic 1150, a reconnaissance marine aircraft of the German forces. During a routinely US-inspection for debondings in aluminiumhoneycomb structure, the new shearography inspection system was evaluate under maintenance conditions very successfully:
The equipment is able to operate on a narrow working place (see fig. 3).
Due to the stable connection of the cabinet and testing part relative movement could be prevented. The test results of these measurements are not influenced by any movement disturbances.
Defect is clearly detected and confirmed by ultrasound testing. The image processing-software provides different features to process the resulting pictures (fig. 4)

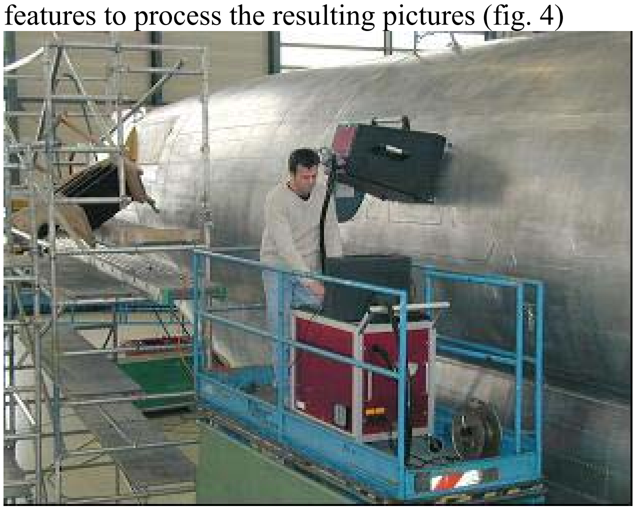


Fig.3: First performed tests on a aircraft fuselage with aluminium honeycomb structure

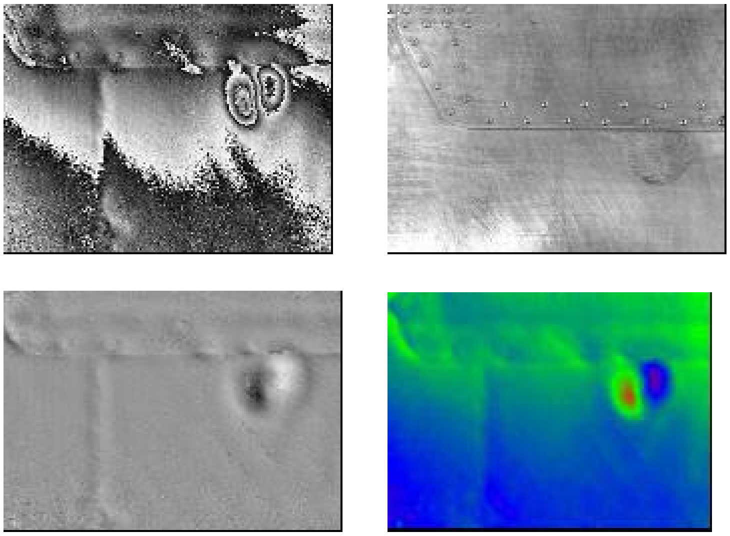


Fig.4: Results of performed tests on a fuselage of Breguet Atlantic aircraft (Camera view, Phase-Image, demodulated and filtered picture, coloured picture).

The next examinations on aircraft structures were performed on a fuselage cut out of monolithic-CFRP-structure (fig. 5). Previous US-inspection (fig. 6 a) detected a delamination in the CFRP-structure. The shearography measurement confirmed the defect. Figure 6b to 6d shows separate steps to create resulting images provided by the fringe-analysis-software. Figure 6b is the phase-image. This is the display provided during the measurement. Figure 6c and 6d are processed images (demodulated/filtered and coloured). For reporting purposes these pictures can be converted into a BMP-file.

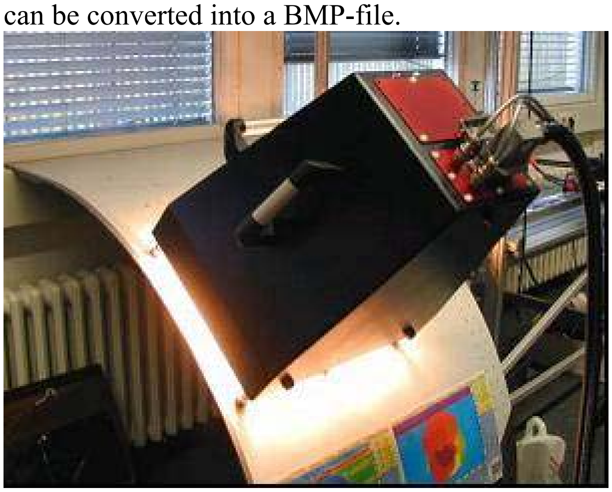
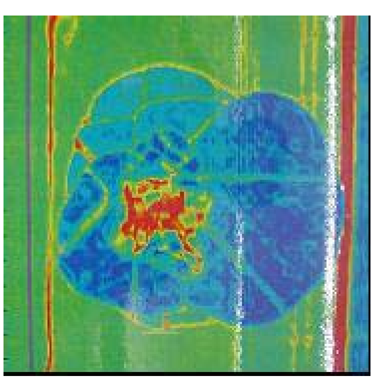
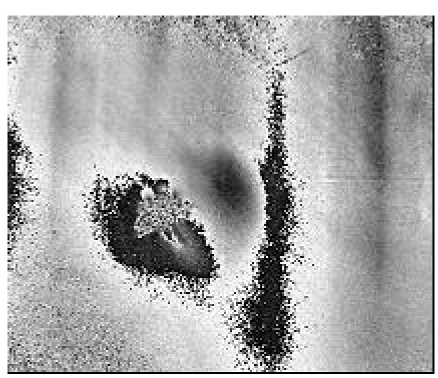


Fig. 5: Performed test on fuselage part of monolithic-CFRP-structure

a. 

b. 

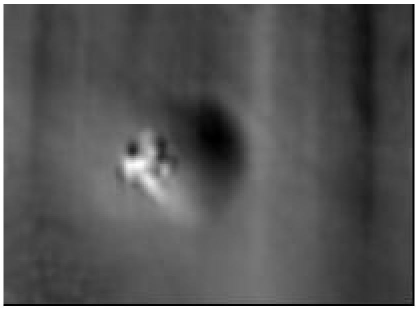
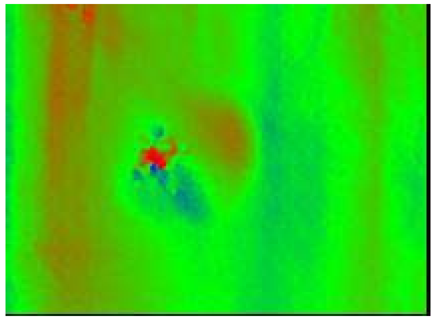
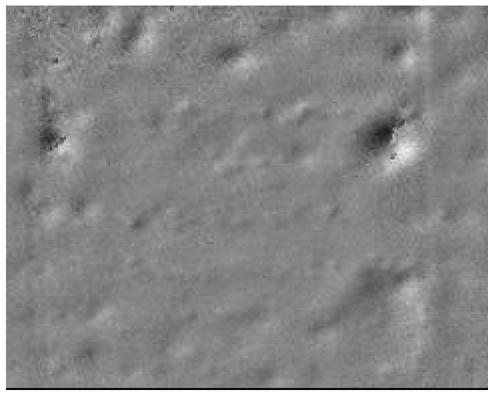
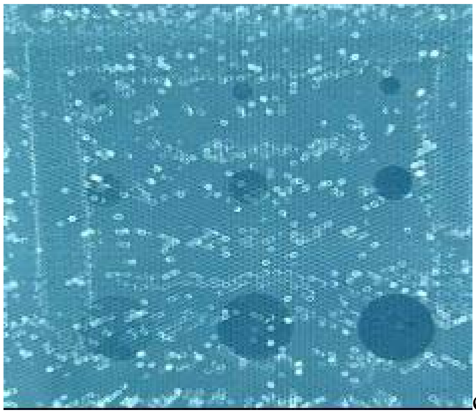
c.  d. 

Fig. 6: Results of performed test on fuselage out of CFRP monolithic structure

Next tests were carried out on test samples of CFRP-H/C-structure (fig. 7a). In this test samples debondings of the H/C core are simulated by holes of various depths. It is shown that the holes which are penetrating the complete honeycomb core pointed out very clearly (fig. 7b). The other holes are difficult to recognize. Additionally many defect indications distribute on the entire testing area are shown. After a X-ray examination (fig. 7c) it was determined that there is an accumulation of resin within the H/C cores.

a.


b.



c.

Fig. 7: Performed test on a CFRP-Honeycomb-Composite-Structure

The problem of over modulation of CCD-sensors at shiny and strong reflecting surfaces can be prevented with CMOS-sensor-technique. Therefore the shearography demonstrator system was equipped with the latest CMOS-sensor (fig.8). Its resolution is about 1280x1024 active pixels and the dynamic range amounts 66dB (Signal/noise ratio).

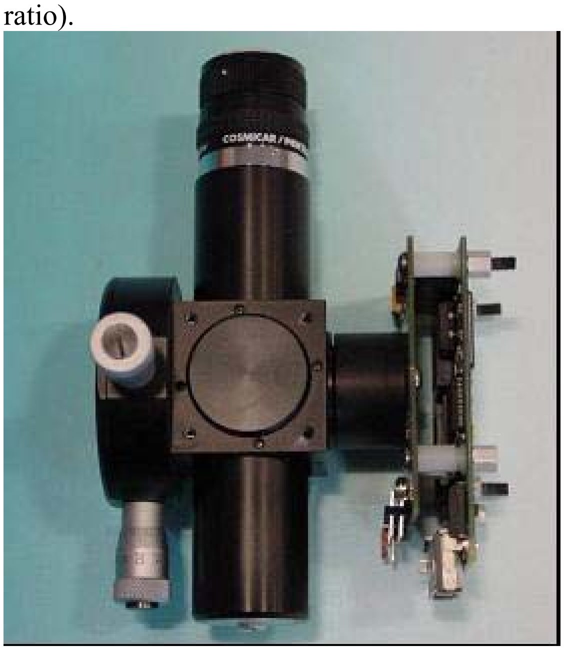
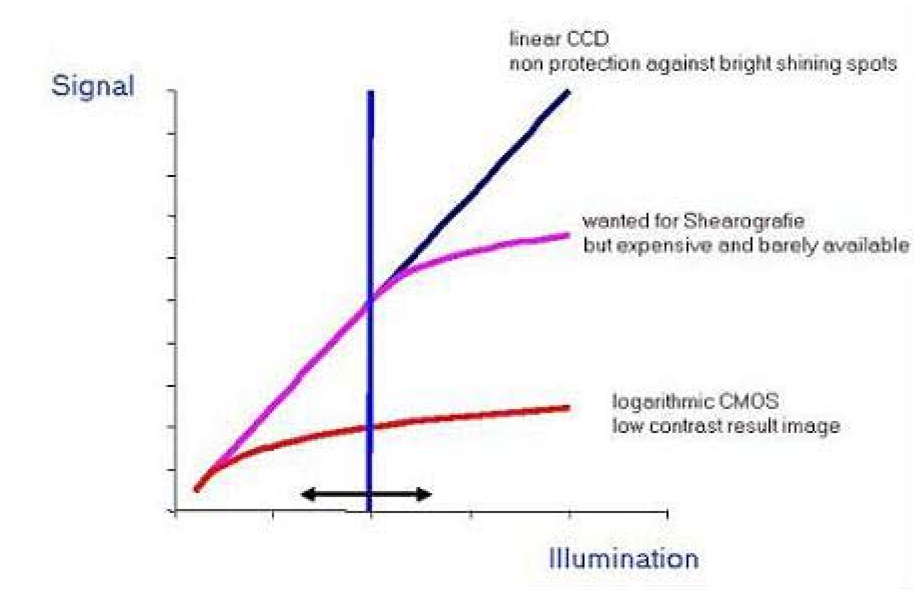


Fig. 8: CMOS-camera with shear element

A CMOS-sensor has the advantage, that is nominal line (ratioto light density to voltage output) is logarithmic (CCD is linear). Due to the nominal lines the CMOS-sensor is able to process more intensity variations than a CCD-chip (over six decades). However the dynamic in grey scale and hence the contrast of an image of a CMOS-sensor is worse than a CCD-sensor, because the CMOS-sensor has to depict a much bigger range of intensity on the provided range of value.



In the scope of a comparison study between both sensor types (CCD against CMOS) the reduction of the over modulation shown in fig 10+11 is not significant as it was expected. Further settings of the CMOS-sensor for more reduction of the overmodulation effect follows a decrease of the image quality.

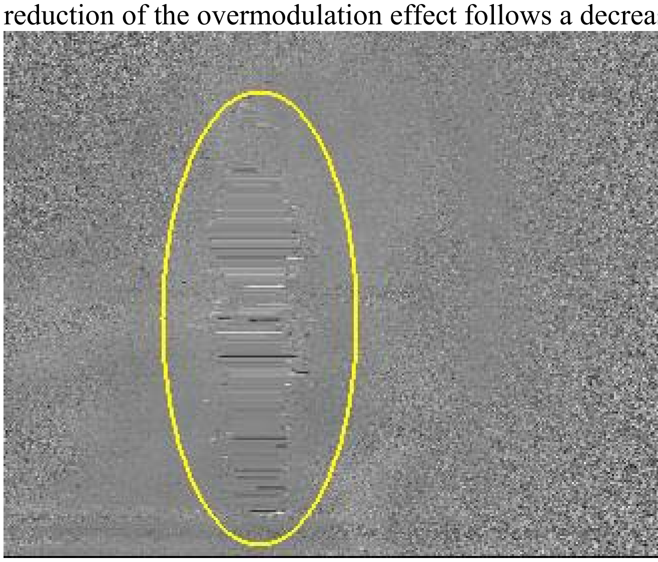


Fig. 10: Over modulated image with CCD-technique

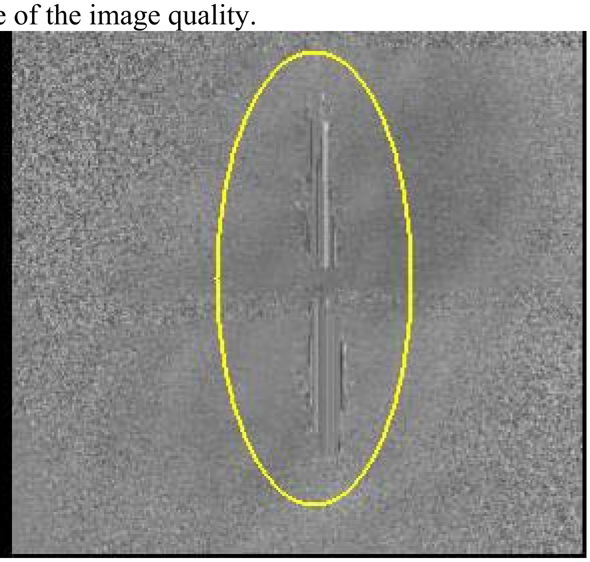


Fig. 11: Over modulated image with CMOS-technique

Conclusions: The development of a front end shearography demonstrator for aircraft maintenance resulted in a reliable tool for fast inspections for full size aircraft components (e.g. wing, fuselage, fin, etc.). Its user friendly analysis software, the low weight and small size cabinet makes the demonstrator to a practicable tool for flaw detection.

Due to the adjustable suction pipes for connecting the cabinet to the testing area it is feasible to test curved structures in each position.

The operation of a CMOS-sensor in the shearography demonstrator system wasn't successfully yet, due to its nominal line of the applied CMOS-sensor. Future CMOS-sensors may improved over modulated images.

The implementation of compact heat sources for thermal loading and two active cooled diode lasers into the test cabinet was a great step forward in a portable test equipment.

As the test system can cope with non-coorperative aircraft surfaces (e.g. metallic blanc) no additional surface treatment and cleaning after the test is necessary. This fullfills the call for reduction of aircraft downtime and maintenance costs.

References: [1] INCA Proposal Part B Contract Nr. G4RD-CT-2001-00507 - Improved NDE Concepts for Innovative Aircraft Structures and Efficient Operational Maintenance, 2000
[2] Michael Kalms, Wolfgang Osten – Mobile shearography system for inspection of aircraft and automotive components, Optical Engeneering, Vol 42 No. 5, May 2003