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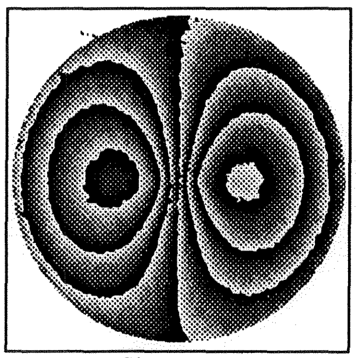
Shearography - a Practical Optical Testing and Measuring Method

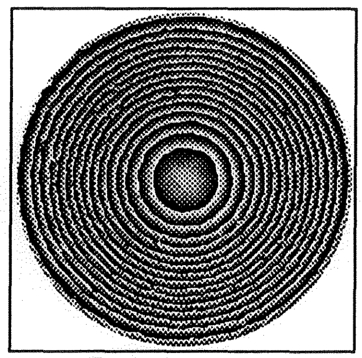
Shearography is a laser optical method which is suited for either nondestructive testing or for strain analysis. Contrary to holography which measures surfach displacements, shearography measures derivatives of surface displacements. Since strains are functions of displacement derivatives, shearography allows strains to be determined without numerical differentiating displacement data. Defects in object normally create strain concentrations; it is easier using shearography to correlate defects with strain anomalies rather than displacement anomalies applying holography. Furthermore, rigid body motions do not produce strain, thus shearography is insensitive against such motions and does not need adopting any particular device for vibration isolation. It is an industrial tool suited very well for the following ares:

1. strain measurement and strain analysis
2. nondestructive testing and quality assurance system
3. optimization of machine parts and structures of any material

Comparison between Shearogram and Hologram

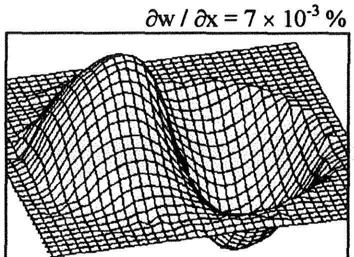


TV-Shearogram



TV-Hologram

$\partial w / \partial x = 7 \times 10^{-3}$ %



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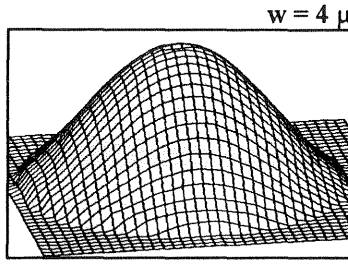
$\partial w / \partial x = -7 \times 10^{-3}$ %

3D-dimensional plot of the phase distribution depicting deflection derivative $\partial w / \partial x$ of the plate

w = 4 µm



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3D-dimensional plot of the phase distribution depicting deflection w of the plate

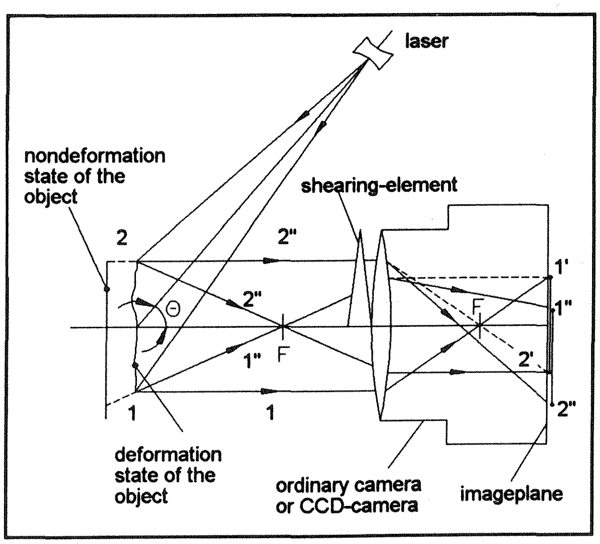
Object: A clamped circular aluminium plate of 150 mm diam and 3 mm thickness
Stressing: Central loading by the force F = 4 N

Principle of Shearography

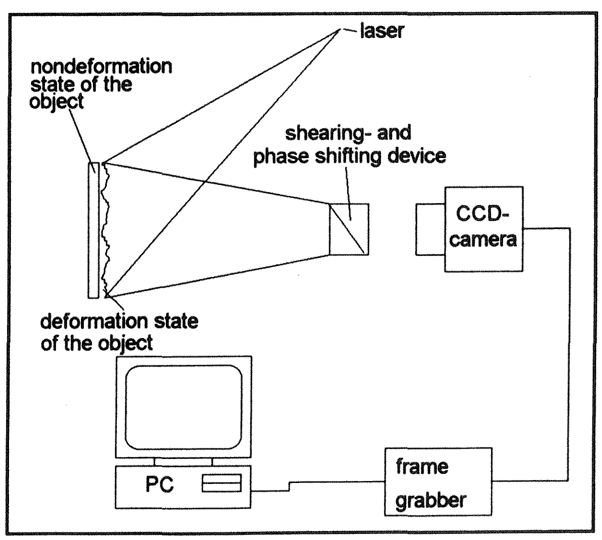
Shearography, also called speckle pattern shearing interferometry (SPSI), is an interferometric method which permits full-field observation of surface displacement derivatives. The optical principle of shearography is shown below on the left side. The object to be studied is illuminated by an expanded laser beam. The light reflected from the surface of the object is focused on the image plane of an image shearing camera or a CCD-camera. In this camera a shearing device is implemented in front of its lens. While various devices and methods may be used to accomplish the shearing effect, only a thin glass wedge is herein described. Because of the thin glass wedge a pair of laterally sheared images of the object are generated. The two laterally sheared images interfere with each other producing a random interference pattern commonly known as a speckle pattern. By comparing the speckle patterns before and after deformation, a fringe pattern, i.e. shearogram, depicting derivatives of the surface displacement is produced.

In order to observe the shearogram, the conventional technique of shearography requires photographic recording, the wet processing and the reconstruction of the interferogram, thus it is obviously inconvenient, time consuming and expensive to be implemented in an industrial environment.

Digital shearography, also called TV-shearography, is a further technical development of shearography. The experimental setup of digital shearography is shown below on the right side. It is the technique using laser speckle as the carrier of the displacement information, recording the speckle interference fields created by two states of deformation using a CCD-camera, comparing and processing the information by digital methods and displaying the shearogram on a monitor screen. There is no difference between digital and conventional shearography in optical theory, but technically digital shearography is a computerized process which eliminates photographic recording, wet processing and reconstruction. This leeds to a rapidly increased testing speed and enables it to observe the shearogram in ***real time***. By means of the phase shift technique digital shearography realizes the shearogram automatically and numerically to be evaluated, and thus the strain measurement with digital shearography becomes more convenient and more practical.



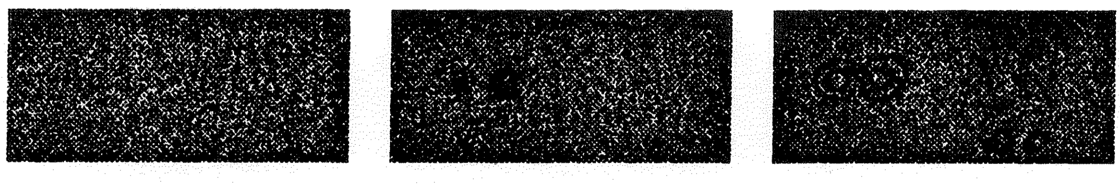
Optical principle of shearography



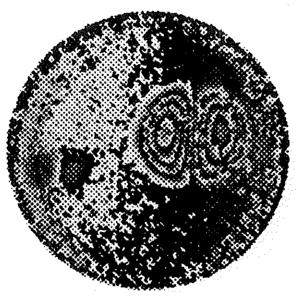
Experimental setup of digital shearography

Applications of Shearography

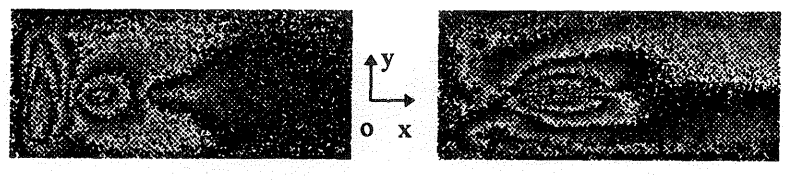
Nondestructive testing



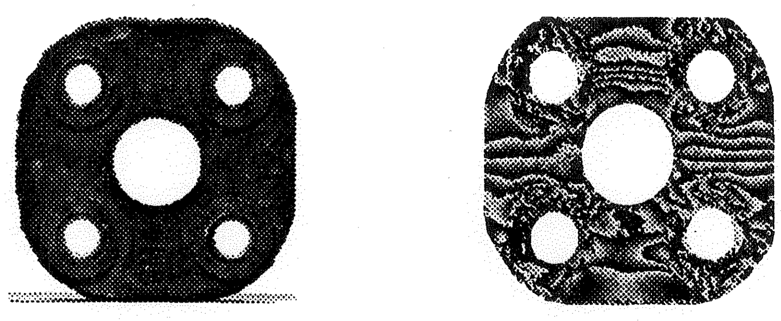
Real time-shearograms of a glass-fibre reinforced plastic tube (GRP) with two disbonds stressed by different internal pressure: 0,5 bar, 1,5 bar and 6 bar (from left to right)



Shearogram for a rubber glued aluminium plate showing two flaws

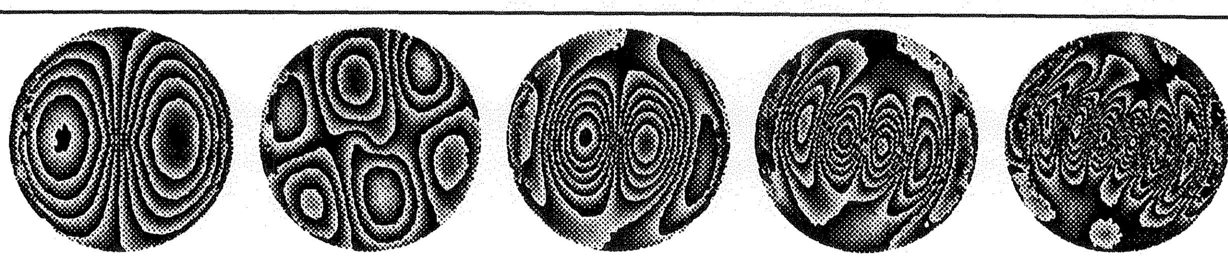


Shearogram for a GRP tube with a micro crack stressed by 0,4 bar internal pressure, left in x-shearing direction, right in y-shearing direction



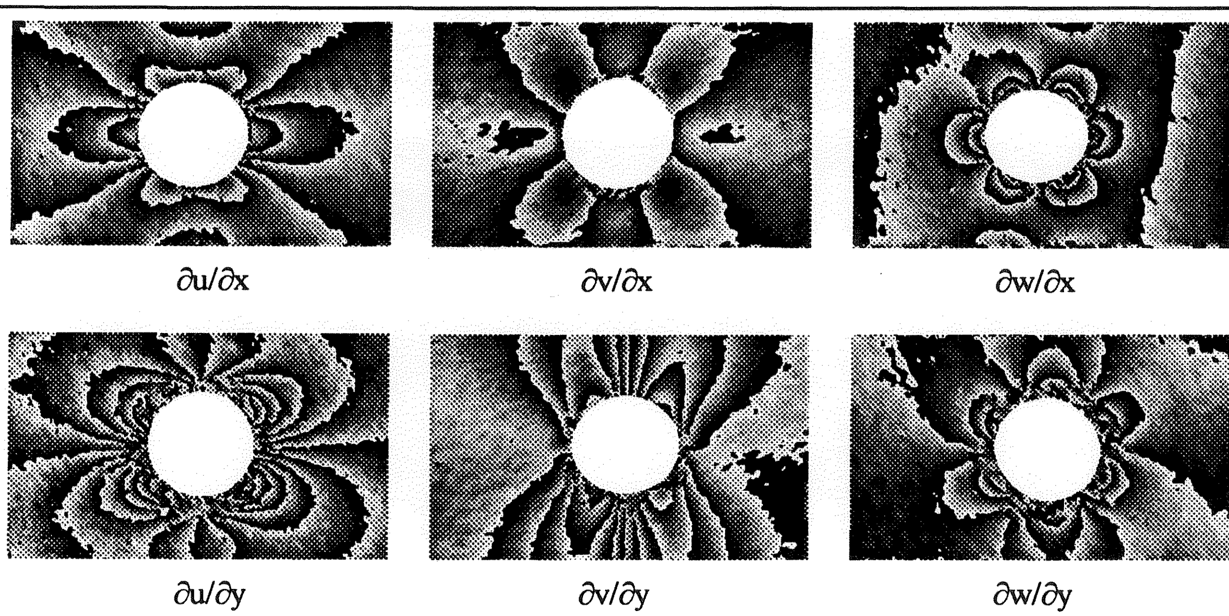
Left: Fiber reinforced steering shock absorber, right: the shearogram shows the unequal interference fringes due to an unequal covered textile fiber

Dynamic investigation



Out-of-plane shearograms of a thin circular plate clamped all around using harmonic exciting showing the frequencies of 1270 Hz, 4300 Hz, 4860 Hz, 10900 Hz and 18960 Hz (from left to right)

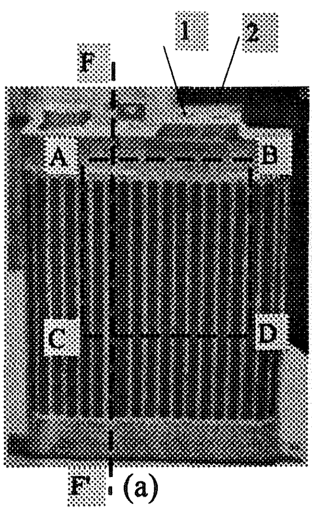
Strain measurement

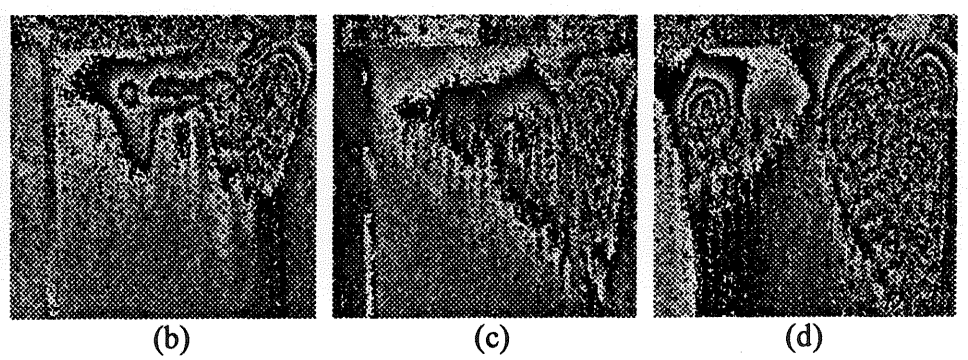


Strain components of a tension bar with a hole loaded by the force F = 300 N

Optimization of machine parts and structures

Left in the cross section F- F' of the fig, (a) shows an air cooler and right a fluid cooler, which are connected by screws or by welding.





(a) View of the tested heat exchanger, the marking (A-D) is the testing field, 1 = entrance and 2 = exit; (b) shearogram for the heat exchanger with a baffle plate under the entrance, connection between air and fluid cooler by screws; (c) same situation like (b) but without the baffle plate; (d) shearogram without the baffle plate, connection between air and fluid cooler by welding

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