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FOCUS ON IMAGING

In Application

High-Speed Stereo-DIC Measurement at Micro Scale

Introduction

Digital Image Correlation (DIC) is an established technique for optical, non-contact, full-field deformation, vibration and strain measurement. The majority of applications relate to „standard" objects, in the range of a few cm to metres and a temporal resolution of a few 10 Hz.

Increasingly, there are requirements that go beyond this range. For example, much smaller measuring fields, in the mm range and below, have to be realized. Or even very fast processes with a few 10 kHz must be detected. There are solutions for some of these requirements, but the combination of highly dynamic processes in the mm range, for example, remains a challenge.

Here we describe a system in which high-speed cameras are coupled with a stereo-microscope, enabling deformation measurements in the mm range at 150 kHz.

Principle

For high magnifications (in the range of 1x to 10x), the use of stereo-microscopes has proven to be advantageous. Stereo-microscopes combine a modular concept with a robust design. They generally have a zoom lens so that different magnifications can be realized easily and continuously. The working distance between the microscope lens and the object is usually several cm and therefore allows an easy access to the measurement area. They have camera adapters for stereo-DIC and offer a wide range of illumination options. Last but not least, they can be controlled by software, which increases convenience and allows all important parameters of a measurement to be saved automatically with the measurement data.

For the measurement of very fast processes, such as fracture mechanics, impact, explosion tests or vibration measurements, frame rates of more than 1 kHz up to several 100 kHz are required. There is a range of high-speed cameras available for these applications, typically with a resolution of 1 - 4 MPx and frame rates of up to 75 kHz. They have very good image quality, have an internal memory for buffering image series consisting of several thousand images and can be operated at higher frame rates with reduced image size. Synchronized image recording with stereo-DIC and triggering with the experiment is ensured by the Programmable Timing Unit (PTU).

In addition to the imaging system and the camera, the lighting plays a decisive role, especially for high-speed imaging. The maximum exposure time is determined by the frame rate. With fast deformations, this often leads to motion blur, so that the strength of the illumination must allow a significantly shorter exposure time. If the shortest exposure time that the camera can realize is not sufficiently short, the illumination must be carried out with pulses that are much shorter, and able to avoid motion blur. Exposure times of a few ns are possible with the use of pulsed lasers.

Experimental setup

The approaches described above were used together in one system. A stereo-microscope (Zeiss Discovery V12) with a zoom lens suitable for the magnification range (0.64x - 8.0x) and sufficient working distance serves as the basis. The optical axis is aligned horizontally so that it can be easily used for measurements on a tensile testing machine. The high-speed cameras are connected to the microscope using eyepiece adapters.

Two Phantom T3610 cameras are used, which achieve a maximum frame rate of 38 kHz at full resolution (1280 x 800 px) and a frame rate of 150 kHz at reduced resolution in binning mode (640 x 384 px). A high-speed pulse laser is used for the illumination. With this, sequences of 14 ns pulses with 450 µJ energy can be achieved at 150 kHz (see Fig.1).

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High-Speed Stereo-DIC Measurement at Micro Scale

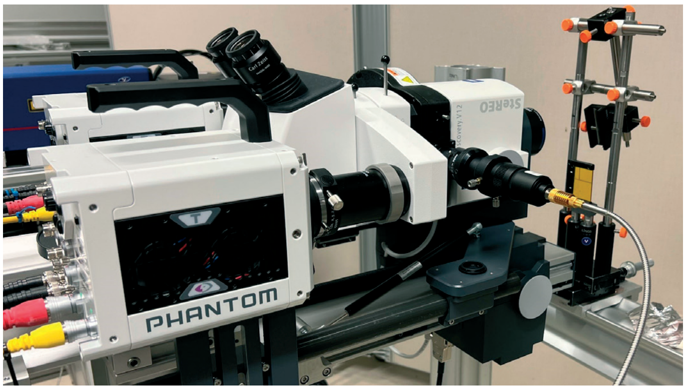

***Figure 1**: High-speed cameras attached to stereo-microscope*

The entire system is mounted on two traverses so that it can be easily moved to the measurement object using the DaVis software. To ensure optimum illumination of the measuring field during different magnifications, the laser is reflected into the microscope using a fibre and projected onto the object through the zoom lens (coaxial illumination). The use of photogenic pattering means that there are no disturbing reflections, as is usually the case with coaxial illumination. An image, showing the quality of the speckle pattern in the camera images, is displayed in Fig, 2.

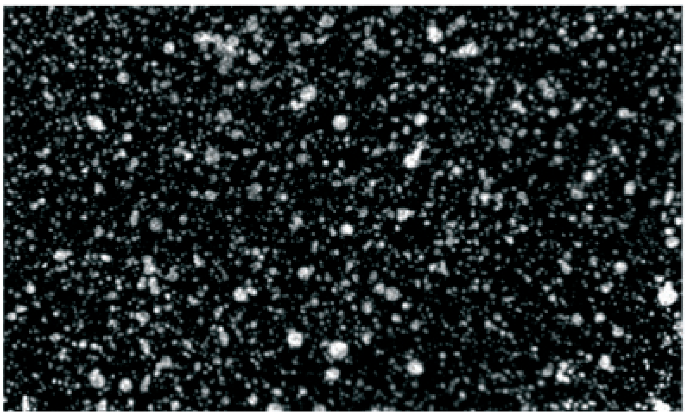

***Figure 2**: Image of the field of view with photogenic patterning*

In order to ensure sufficiently good modelling of the stereo-microscope image for the DIC evaluation, the polynomial approach was used for calibration instead of the pinhole model. By automatically moving the microscope in the direction of observation, the images of the calibration target required for this can be easily recorded.

Results

The example below with crack propagation in an aluminium foil was performed at 30 kHz frame rate and evaluated using 25 pixel subset and 5 pixel step size. Fig. 3 shows the horizontal displacement at 4 time steps (upper left: @0.4 ms, scaled ±10 µm; upper right: @2.0 ms, scaled ±50 µm; lower left: @3.5 ms, ±100 µm; lower right: @5.0 ms, scaled ±200 µm).

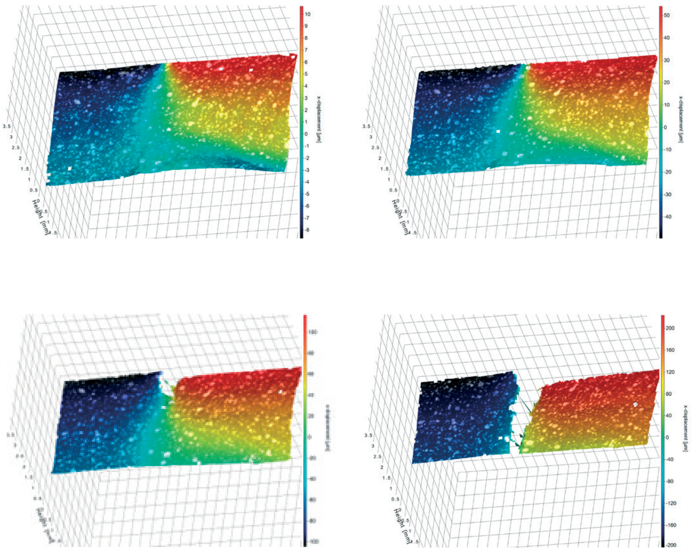

***Figure 3**: Development of horizontal displacement of crack propagation in aluminium foil in µm. (scaled individually)*

Conclusion

The integrated system of high-speed cameras and stereo-microscope, together with high-speed lasers and photogenic patterning, allows accurate and robust measurements. This approach showed the capability to acquire full field data at 150 kHz on millimetre scale fields of view with incredible spatial resolution.

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