Laser Speckle Extensometer ME53
INTRODUCTION

When establishing the mechanical properties of today's diverse range of materials and components it is necessary to use accurate testing machines and instrumentation that do not influence the results.

Stress and strain are the two main parameters from which most mechanical properties are calculated during uniaxial testing. Stress is normally obtained by fixing a test specimen in grips or adapters and loading via a calibrated load cell. Care must be taken to ensure that neither the fixation method, nor alignment, nor specimen shape influence the results obtained.

For rigid materials, strain can be measured using conventional 'clip-on' mechanical extensometers or by bonding foil gauges to the specimen. These devices however are not usually suitable when testing delicate specimens such as fibres, films, foils, foams or soft plastics as their weight and method of attachment can influence both the results obtained and the point of rupture.

In many instances it is necessary to establish the material properties over large strain ranges up to the point of rupture and most mechanical devices have a limited travel and require removal from the specimen prior to fracture. If a specimen is to be tested at elevated temperature within a confined chamber, then this can restrict the use of many mechanical units.

Various non-contacting extension measuring systems e.g. mechanically driven followers and laser extensometers have been available over latter years, but these systems do not have the necessary resolution to accurately determine the material properties at low strain levels. Also as the devices operate on a single measuring line between targets a second unit would be required if the transverse strain had to be simultaneously measured.

In order to overcome these limitations, the ME-53 Laser Speckle Extensometer was developed by the Austrian company Messphysik GmbH, on the basis that “If it can be seen, then it can be measured”. It's an easy to use class 1 measurement system, having the capability to measure very small strains and high strains, completely contact-free.

This enables the usage in a wide range of applications, including applications using elevated temperatures.
MEASUREMENT PRINCIPLE

When an optically rough surface is hit by a coherent laser beam, the light will be dispersed in many different directions. Where these rays travel through the original beam the light will be spatially 'eliminated', resulting in a granular looking, so called Speckle Pattern.

The surface of the specimen and therefore the Speckle Pattern change comparatively slowly during loading. Due to this fact the Video Processor is able to find an initially stored reference-pattern in consecutive images and measure the distance this pattern has moved in the meantime.

Applying this procedure iteratively from image to image in real-time, (true) strain within the distance of the two cameras can be measured. With each cycle a new reference-pattern will be taken from the image, but always at the same coordinates.

\[ \varepsilon = \frac{\sum d_{\text{Slave}} - \sum d_{\text{Master}}}{l_0} \]

with \( \sum d_{\text{Master}} \) ....Sum of displacements on Master Camera

\( \sum d_{\text{Slave}} \) .......Sum of displacements on Slave Camera

\( l_0 \) ............Distance of initial reference patterns
EVALUATION ALGORITHM

The fundamental task of the Laser Speckle Extensometer’s software is to recognize a complex pattern (i.e. region of the video image) in consecutive images. To accomplish these highly intensive calculations state-of-the-art computers are used for Video Processors on one hand and carefully programmed algorithms employed on the other hand. First the analogue video images have to be transformed into digital images by means of a so called Frame Grabber. Built into the Video Processor this special hardware translates the video signal into a two-dimensional matrix with 756x576 elements (pixels) with 256 grey shades each at a rate of 25 frames per second. But it is neither necessary nor possible to analyse the entire video image in real-time a region of variable position and size is sufficient enough.

These regions also function as virtual markers, between which strain is measured as explained earlier. This involves the calculation of the displacements of these markers from frame to frame.

The regions of the entire pattern can also be understood as sub-matrices or two-dimensional, discrete functions \( f(x, y) \). Let \( f(x, y) \) be the function of a reference pattern and \( g(x, y) = f(x+\alpha, y+\beta) \) the mathematical representation of the shifted pattern, then the so-called Correlation Function \( f(x, y) \cdot g(x, y) \) yields the distance the pattern has travelled.

Solving the necessary equations requires sophisticated two-dimensional discrete Fast Fourier Transformations (FFTs) and interpolation techniques to eventually obtain highly accurate and reproducible results.

Two-dimensional correlation function applied to sequential speckle patterns
SYSTEM COMPONENTS

The Laser Speckle Extensometer comprises a PC-based Video Processor, which continually measures the displacement of two speckle patterns, recorded by two video cameras in a master-slave-configuration. These two displacements are converted into a strain signal, which is sent to a control and evaluation system (not part of the extensometer) for data handling and control of the testing machine.
HARDWARE

PARALLEL SENSOR HEAD

This sensor head comprises two full image cameras for uni- or bi-axial strain measurement with the Laser Speckle Extensometer ME53 series (in both tension and compression mode).

The arbitrary adjustment of the cameras along the vertical axis allows a wide range of different initial gauge lengths. The servo drive is designed to make the system easy to handle by software. It can also be used to set gauge lengths automatically in a process controlled loop.

TECHNICAL SPECIFICATIONS

- ISO 9513 Class 1 strain measurement system
- Working distance g: 180 - 630 mm
- Optical magnification: 0.5 (g=630 mm)
  2.4 (g=180 mm)
- Gauge length range: 1.5 - 230 mm
- Mass of sensor head: 4.6 kg
- Laser light source: Class 2, 0.9 mW, 635 nm (red laser light)
- Software remote control of camera settings and gauge length
SOFTWARE

Core part of the Laser Speckle Extensometer is its software. This 32-bit programme, requiring Windows™ XP/VISTA, has been developed to provide a simple and easy to handle user interface without restricting functionality. Most frequently used functions can be accessed with “a touch of a button”.

Both the master and the slave cameras’ video images are displayed in separate windows.

A big advantage of utilizing area scan sensors instead of line cameras is, that you can actually see, where the virtual markers are placed. You can either have their “best” position recognized automatically or you can move them around yourself.
SYSTEM INTEGRATION

In many cases the Laser Speckle Extensometer will be integral part of an entirely new Messphysik Materials Testing system. But the capability to integrate it into virtually any existing third party system, enables you to work with this exciting new technology without having to purchase a new loading frame or controller.

DIGITAL LINK

The Video Processor is linked to the controlling computer via a digital interface (RS232, LAN). When not using one of Messphysik's Application Programmes, you must have access to your programme's source code and the ability to integrate a so-called Dynamic Link Library (DLL).

DIGITAL-TO-ANALOGUE CONVERSION

The digital extension or strain signal obtained by the Laser Speckle Extensometer is converted into an analogue signal by means of an optional digital-to-analogue converter. These voltages can be fed into the controller of your testing machine and/or sent to a chart recorder.
SYSTEM INTEGRATION

ANALOGUE-TO-DIGITAL CONVERSION

Analogue signals for load, stroke or other readings can be fed into an optional analogue-to-digital converter built into the Video Processor. There these voltages are translated into figures, which are stored into files in perfect correlation with the strain measured by the Laser Speckle Extensometer. These ASCII files can be post-processed by either one of Messphysik’s Application Programmes or a multitude of third party programmes (e.g. Microsoft® Excel™).
SYSTEM VARIANTS & OPTIONS

TRANSVERSE STRAIN

One of the biggest advantages of utilizing full image cameras instead of line cameras is their two-dimensionality and therefore the possibility to measure strain in two dimensions. Although it would also be possible for line camera systems to measure axial and transverse strain simultaneously, but this would require a total of 4 cameras. The Laser Speckle Extensometer on the other hand can achieve the same with two or even one camera only. Two additional patterns are introduced into the system to measure transverse strain.

SINGLE CAMERA CONFIGURATION

Most applications will require a two camera setup: In order to achieve initial gauge lengths of more than 25mm it is necessary to use two cameras either mounted in a fixed distance equalling the initial gauge length or on a Parallel Sensor Head enabling variable gauge lengths. Each camera provides its own single speckle pattern based on whose displacement strain is calculated during testing. However, where initial gauge lengths smaller than 25mm are required a single camera solution can also be employed: The two necessary speckle patterns are recorded by only one camera with a suitable field of view. This does not only provide cost savings but also facilitates the handling of the Laser Speckle Extensometer in cases of small to very small gauge lengths: It is not longer necessary to adjust the distance or the angle between the two cameras, only one camera has to be calibrated etc.

Testing at small to very small gauge lengths can be carried out by means of a single camera configuration. In the application shown above, the initial gauge length was 1mm only.
SYSTEM VARIANTS & OPTIONS

DIAMETRIC STRAIN MEASUREMENT

A versatile optional feature of the Laser Speckle Extensometer is the ability to simultaneously process signals from two sensor heads.

The second sensor head can be mounted opposite the first one to eliminate any effects caused by bending stresses e.g. when testing bent specimens. It is possible to measure with two different or offset gauge lengths.

BIAXIAL MEASUREMENT

SPECIFICATIONS

Axial strain measurement under coherent light by means of Laser Speckle Extensometer
Simultaneous transverse strain measurement under incoherent light with Videoextensometer
Videoextensometer scans profile of specimen to determine R-Value and/or necking and reduction of area before break

SYSTEM REQUIREMENTS

Laser Speckle Extensometer D/DT
Multiple Video Sensor Option
Second Dimension including light screen

2x Dielectric Filters
(for Laser Speckle Extensometer Cameras)

1x Laser Cut Out Filter
(for Videoextensometer Camera)
APPLICATIONS

Because of the non-contacting nature of the Laser Speckle Extensometer and due to the fact that it makes markings unnecessary, this new type of extensometer allows direct strain measurement on materials or in environments never possible before.

Measuring E-Moduli of delicate materials such as thin films or metal foils do no longer pose problems nor will elevated or high temperatures - the Laser Speckle Extensometer is the ultimate solution.

HF-GENERATOR INDUCED HIGH TEMPERATURE

Measuring strain of metals at high temperatures is one of the most demanding tasks in materials testing. Contacting extensometers can notch the softened specimen. The actual gauge has to be placed outside the furnace with silica rods reaching through port holes levers that can bias the results dramatically. Markers for non-contacting devices can not be attached because they would burn off.

Another problem can be the long preparation times for each test with heating as the most time consuming part.

As successful solution for both problems Messphysik developed a system incorporating a High Frequency Generator instead of a standard furnace and the Laser Speckle Extensometer to measure strain within the heated zone.

Due to its unique design of arbitrary but fixed gauge lengths (i.e. the distance between the virtual markers does not change), the Laser Speckle Extensometer can “look” through the helices of the induction coil.
APPLICATIONS

FULLY AUTOMATED TESTING SYSTEMS

Due to its simple design with the lack of any moving parts and its high degree of system integration the Laser Speckle Extensometer is predestined for fully automated, high throughput testing systems.
ACCESSORIES

Vertical Positioning Unit

The Vertical Positioning Unit was designed to set up the height of the Sensor Head easily, but also to prevent from having breaks outside the measuring length of the extensometer.

Due to most machines do not tear the specimen in two directions but only in one, the vertical positioning unit ensures that the extensometer is always located in the middle of the specimen.

The vertical positioning unit comprises:

A precision slide to carry the Sensor Head, allowing vertical movement but no radial freedom.

The slide is linked via a drive pulley to the moving and to the fixed crosshead. This ensures that the sensor head travels exactly half of the stroke of the moving cross head.

Consequently the sensor head will measure strain symmetrically within the parallel length of the specimen throughout the entire test.

Recommendations:

This optional unit is recommended for testing of mild steel and ther ductile metals with a tendency to necking.

It is absolute necessary for testing of polymers with a breaking extension >50 % (e. g. Rubber).

This unit is also applicable to the Videoextensometer ME 46 and ME46-NG.
SPECIFICATIONS

- Class 1 measurement device (ISO 9513)
- Initial Gauge Length: 0mm → ∞
- Measuring Range: ∞
- Temperature Range of Test Specimen: up to 1600°C (requires observation ports in furnace and optional band width filter)
- Laser Diodes: 635nm / 0.9 mW, Class 2
ADVANTAGES

- Contact free
- No specimen preparation or markers needed
- No moving parts, maintenance free
- Two-dimensionality
- Arbitrary initial gauge lengths, indefinite measuring range
- Testing temperatures up to 1500°C
- High degree of automation and system integration
- Measuring E-Moduli and breaking strains with a single system
- User friendly software