Choosing the Right Extensometer for Every Materials Testing Application

Extensometry involves the measurement and analysis of changes in linear dimensions during tensile testing. An extensometer measures test specimen elongation, characterizing strain. These instruments are divided into two main categories: contact and noncontact extensometry. The range of applications where extensometers are used is diverse and the technical requirements for these devices are multifaceted. As a result, there is no single device which satisfies all needs.

In recent years, significant development occurred in the area of noncontact extensometers, including those based on laser and video technology. Choosing the right extensometer for a specific application requires an understanding of the material being tested as well as the strengths and weaknesses of both contact and noncontact instruments.

This article can help users determine the most suitable device for their testing requirements; whether their need can be met using a traditional clip-on extensometer, or whether it requires the very latest in laser interferometry.

Role of test specimen properties in extensometer selection

The requirements for an extensometer are determined primarily by the characteristics of the material to be tested. This includes the material’s shape and dimensions, test requirements, and the test standards that must be followed. These conditions define the gage length, accuracy, test sequence, and environmental conditions (Fig. 1).

The proper choice of extensometer cannot be based on material characteristics such as specimen dimensions, stiffness, strength, and plasticity alone. It is also necessary to decide whether an extensometer can be connected directly to the specimen without influencing the load measurement or mechanically damaging the specimen itself. Very thin specimens such as foils can be sensitive to clamping forces, while very small wire specimens, for example, do not provide enough visible area for reliable noncontact measurements.

A high stiffness in the initial extension range, followed by high plasticity traditionally requires more than one extensometer. The first measures small strains (typically up to 5 mm) very accurately in the elastic range, and the second measures very high extensions (typically ≥500 mm). Materials with very smooth surfaces, or those made of transparent materials are not suitable for noncontact measurements without first fixing measuring marks onto the surface of the specimen.

One very important consideration is the behavior exhibited when the specimen fails. Metals and hard plastics will slip through the knife edges of a contact extensometer without damaging them, and rotatable knife edges should be used to further reduce the risk of damage if the surface of the specimen is particularly rough. High extension or flexible specimens can damage or destroy the knife edges and even the extensometer itself due to whiplash, splintering, or delamination of specimens. For these applications, noncontact measurement is a must. Criteria for accurate measurements are discussed below.

Fig. 1 — Selection process for extensometers.
Measurement travel range and gage length

With contact extensometers, the measurement travel is normally an engineered, fixed value, which is dependent on the range of the measurement transducer and, with fulcrum hinged-sensor arms, the leverage ratio. The initial gage length is set manually with fixed steps or automatically over a defined range.

Noncontact extensometers that use a video camera or laser interferometry system must have the field of view larger than the required range plus the initial gage length. Because the specimen portions that are outside the gage length (and the machine components themselves) deform in the direction of loading, the position of the measuring marks on the specimen changes during the test.

For extension and/or gage lengths that are expected to be outside of the field of view, the objective lens must be changed, or the distance between the specimen and the video camera must be increased. All these actions decrease the accuracy of the measurement, and in addition, every changed measurement configuration must be adjusted and calibrated.

Measurement accuracy

“Accuracy” is a qualitative term. To qualify the integrity of a measured signal, standards use quantitative terms such as resolution, deviation, and uncertainty, and these terms are given definitive values. Requirements for the accuracy of extension measurements are normally given in application-specific test requirements and international standards.

Many test standards, for example, tensile tests on metals and plastics refer to standards for calibration of extension measurement systems and the required accuracy classes contained therein (Fig. 2).

Ergonomics and economy

Devices that are easy to set up and sequences that can be automated reduce personnel time and effort, and, at the same time, improve the quality of the test results because subjective influences are minimized. Higher initial acquisition costs can be quickly amortized, especially when the extensometer can be used for a wide range of applications. Many applications can be handled using either a video or laser extensometer. The higher initial cost of the laser extensometer, which requires no specimen marking or attachments, can often be justified by the savings in personnel time and cost and the reduction in human error.

Contact-type measurement extensometers

Clip-on extensometers are, as the name implies, mounted directly onto the specimen. The mechanical parts that transfer extension, via knife edges, from the specimen to the internal transducer are short and stiff. There is practically no relative movement between the specimen and the extensometer, resulting in a high level of measurement accuracy.

The range of a clip-on extensometer is limited to a few millimeters, and it applies a load directly to the specimen. Extensometers with counter-balance weight and double-sided measuring systems are used to compensate for superimposed bending stresses. The application and removal is normally manual. However, to minimize setting errors, some clip-on extensometers are equipped with motorized application and removal systems (Figs. 3 and 4).

Sensor arm extensometers offer the advantages of automatic operation and a large measurement range with high measurement accuracy. Precision designs with a very smooth and balanced mechanical operation apply minimum loading to the specimen (as little as the measurement marks used for noncontact extensometers). Because the sensor arms are in contact with both sides of the specimen, superimposed bending strains are largely compensated. Clip-on and sensor arm extensometers are in direct mechanical contact with the specimen via knife edges that are perpendicular to the gage length. The extremely small contact force from the knife edges can cause a microscopic indentation into the specimen surface, which enables precision in positioning at the contact point.

Because of the direct contact with the specimen, sensor arm extensometers can be damaged or even destroyed.
at the failure point of high elasticity/high extension specimens. An example from the automotive industry is the testing of safety belts. At the point of failure, the material will exhibit backlash or whiplash characteristics that could damage the testing equipment.

**Noncontact video extensometers**

A primary advantage of noncontact video extensometers is that they may be used up to the material breaking point without damage, even when testing specimens that exhibit whiplash. Another advantage is the capability to more accurately determine strain and use strain as a control loop mechanism for test samples undergoing large deformations. An example of this may be found in characterization of biomaterials and medical-grade polymers, where video extensometry supports measurement of large strains. Additional applications include testing of medical components in solution, where attachment of a traditional extensometer would not be practical (Fig. 5).

Noncontact video extensometers require measurement marks to be attached to the specimen, which are optically distinct from the surrounding area of the specimen. The measurement marks are clipped, tacked, or glued onto the specimen, or the specimen is marked with a colored pen. The application of the measurement marks adds a step to the test cycle, potentially reducing throughput, increasing the cost of testing, and introducing inaccuracies through human error (Fig. 4).

The position of the measurement marks on the specimen is evaluated by software algorithms, which determine a certain area around an optical center point. This becomes the gage length, and as a load is applied to the specimen, the
movement of the marks is converted to extension values. Special lighting for surface or background illumination of the specimen optimizes the contrast to the measurement mark. During deformation, the ambient lighting changes on the measurement marks as well as on the specimen, and surrounding influences (such as reflections) can influence the optical center point. This is often the cause of scatter in the test results.

**Noncontact laser extensometers (laser interferometry)**

The latest in extensometer technology uses a noncontacting device that does not require measurement marks. The laser extensometer uses the unique structure of a specimen’s surface as a “fingerprint” to generate a virtual measurement mark. Laser light directed on these measurement positions is reflected in various directions corresponding to the surface structure and creates a specific pattern of speckles. Selected measurement points are constantly fol-

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allowed and converted to direct extension values. The change in the surface structure, which is the basis of the speckle pattern, is continuously evaluated during specimen deformation (Fig. 6).

This laser interferometer-based method of noncontact extensometry allows test labs to characterize materials, components, and even subassemblies making it well-suited for quality control and R&D applications. Additionally, this novel approach to extensometry supports tests on microspecimens with small gage lengths that require exceptional accuracy in strain measurement (Fig. 7). Such tests would not be possible using traditional extensometry. Speeding up throughput and delivering the utmost accuracy in strain measurement, laser interferometer noncontact extensometers offer significant value for high volume test labs.

**Summary**

Contact-type extensometers measure extension accurately and are cost effective. However, clip-on extensometers require more manual intervention and, without care, can introduce scatter in the test results. Sensor arm extensometers offer extremely high accuracy, excellent repeatability, and ease of use due to fully automatic operation, which includes the setting of variable gage lengths.

Noncontact extensometers are required when the specimen is sensitive to notching from knife edges, or when the extensometer may be damaged when the test specimen fails. In addition, noncontact extensometers can be relatively expensive to purchase and time consuming to set up and calibrate compared to contact type extensometers.

There is no such device as a universal extensometer. The large range of applications demands various devices having different functions and characteristics, and the extensometer must be selected for each specific application.

**References**


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