Clip-on extensometers directly measure the elongation of a specimen during load application.
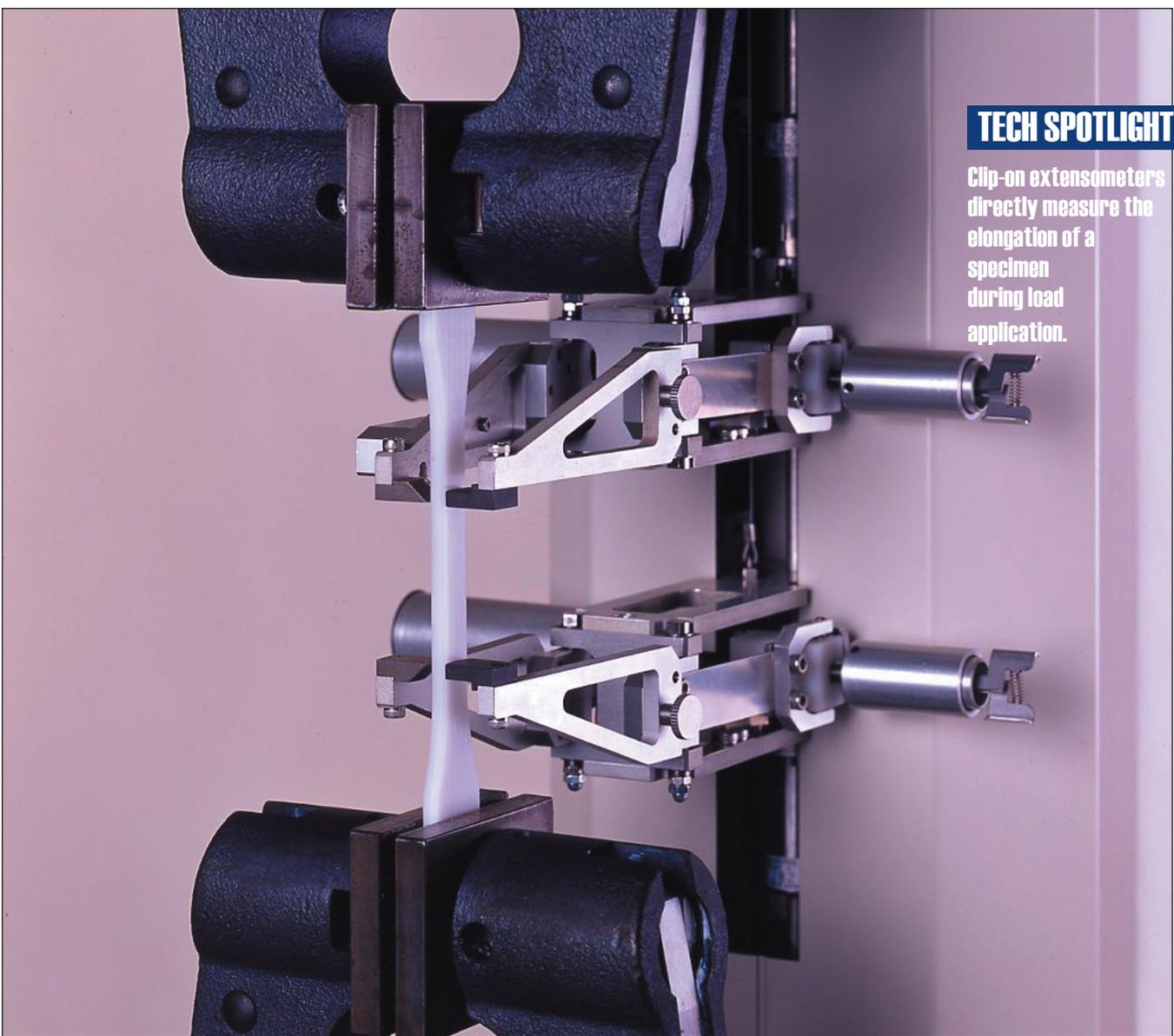

Fig. 1 — Clip-on extensometers can be attached to a test specimen to measure elongation or strain as the load is applied.

Automatic extensometers

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An extensometer is an instrument for measuring changes in length that are caused by application or removal of a force. The elongation of a specimen during load application can be measured directly with various types of devices, such as clip-on extensometers, which are discussed in this article.

Clip-on extensometers can be attached to a test specimen to measure elongation or strain as the load is applied, as shown in Fig. 1. This is particularly important for metals and similar materials that exhibit high stiffness. Typical extensometers have

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fixed gage lengths such as 25 or 50 mm (1 or 2 in.). They are also classified by maximum percent elongation, so that a typical 25 mm (1 in.) gage length unit would have different models for 10, 50, or 100% maximum strain.

The two basic types of automatic clip-on extensometers are linear variable differential transformer (LVDT) devices and strain-gage devices, as well as combinations of the two. LVDT extensometers are based on an LVDT with a core, which moves as the specimen deforms and produces an electrical signal proportional to the amount of core movement. LVDT extensometers are small, light in weight, and easy to use. Knife edges provide an exact point of contact and are mechanically set to the exact gage length. The extensometers discussed in this article are a com-

bination of strain gage and LVDT extensometers.

These extensometers must operate accurately in any condition without disturbing the sample, a basic challenge that involves certain factors. The first difficulty is fixing the extensometer on the sample without modifying specimen shape or surface. With a rigid sample, such as a steel or hard plastic, this task is relatively easy. However, when the sample is soft (plastic, rubber, soft metal), the task becomes more challenging because the weight and the clamping of the extensometer become a factor. Second, the integrity of the extensometer must be maintained in all circumstances, through break if possible. Third, the extensometer must accommodate a large extension range without losing accuracy and precision, even through the break point. *Continued*

Table 1 — Extensometer classifications

Organization	Classification	Relative error	Fixed error
ASTM E-83	Class B1	0.5 %	± 5.0 μm
JIS B7741	Class 0.5	0.5 %	± 1.5 μm
ISO 9513	Class 0.5	0.5 %	± 1.5 μm

Extensometer classification

Extensometers are classified in a variety of ways to rate performance, as shown in Table 1. These classifications are established by organizations such as ASTM, JIS, and ISO. The rates or classifications differ from one organization to another. As an example, the ASTM Class B1 listed in the table means the relative error has to be less than 0.5% with a fixed error no greater than 5.0 microns. For small displacements, the fixed error is a determining factor.

To show what these classifications mean, we extracted several examples from ASTM, JIS, and ISO. (Original documents are available on the Web sites of those organizations.)

A 100 μm displacement could not be determined with a JIS B7741 class 0.5 extensometer with a precision better than ±1.5 μm, which is a 1.5% relative error, as shown in Fig. 2.

Some challenging requirements

For plastic applications, the determination of the elastic modulus (Young's modulus) represents a challenge because the elastic region on the curve is very short (Fig. 3). Standards ISO 9513, ISO 527-1, 527-2, and 527-3 illustrate how to determine the modulus of elasticity, which is defined as:

$$E_t = (\sigma_2 - \sigma_1)/(\varepsilon_2 - \varepsilon_1)$$

E_t = Young's modulus of elasticity in MPa
σ_1 = Stress, in MPa, measured at strain value $\varepsilon_1 = 0.0005$
σ_2 = Stress, in MPa, measured at strain value $\varepsilon_2 = 0.0025$

In other words, for a sample with a 50 mm gage length, the extensometer should be able to measure the stress at 25 μm and 125 μm elongations. Most of the extensometers of class B1 and B2 are able to read those displacements; however, the fixed error of strain is relatively large. A class B1 extensometer should have a fixed error of strain less than 0.0001 mm/mm, and for a class B2 it should be less than 0.0002 mm/mm.

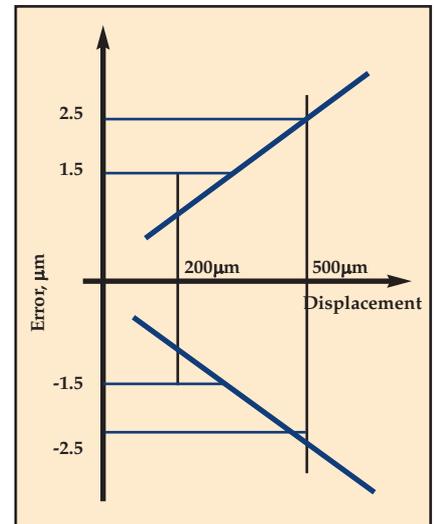Expressed in displacement for a 50 mm gage length, the maximum fixed error for B1 extensometers is 5 μm,

Fig. 2 — A 100 μm displacement could not be determined with a JIS B7741 class 0.5 extensometer with a precision better than ±1.5 μm, which is a 1.5% relative error.

and 10 μm for B2. Although the maximum relative error of these extensometers is 0.5%, it is difficult to expect very good precision on the measurement of Young's modulus (in compliance with the standard ISO 527) with a regular class B1 or B2 extensometer (ASTM E-83). As indicated in ISO 527-1, it is imperative to use an extensometer with a maximum fixed error of 1.5 μm and a maximum relative error of 0.5%.
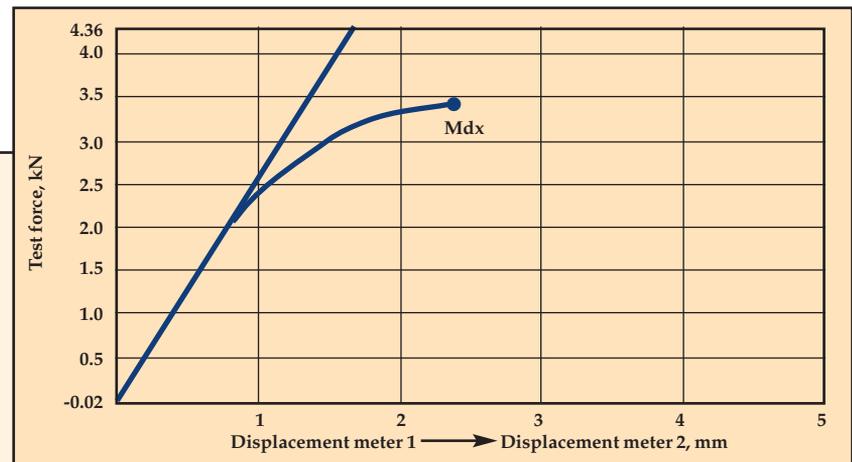
The automatic settings, such as

Elongation of a plastic specimen

The Shimadzu SIE-560S extensometer, AG-100kNI testing machine (floor model), and 100 kN non-shift wedge type grips were used for the test. Testing speed was 1 mm/min. As shown in Table 2,

• Displacement Meter 1 was set as the strain gage sensor (4 mm full scale) and

• Displacement Meter 2 was set as the magnetic induction linear sensor (25 mm full scale).

The extensometer is capable of measuring to the break point, even for specimens with large elongations, such as the one shown in this graph. This instrument is designed to provide measurement of elongation with a precision of 0.5% maximum of the indicated value or ±1 μm fixed error in compliance with the ISO 527 standard. It has a gage length of 50 mm for optimal precision, and also has an optional variable gage length from 10 to 40 mm. It also allows very large displacement, up to 560 mm.

Table 2 — Plastic specimen with flat plate shape

Measurement	Thickness	Width	Distance between grips
Units	mm	mm	mm
Meters 1 - 2	4.2000	10.2000	100.0000
Test	Std. elasticity mod.	Max.test force	Max. displacement
Parameter	0.05, 0.25 %		
Units	N/mm^2	kN	mm
Meters 1 - 2	2988.00	3.46875	2.36538

centering, mounting and dismounting, detection of gage marks, and the combination of digital strain processing with a high accuracy magnetic-induction linear sensor and ultra-accurate strain gage sensors, provide the features to achieve the specifications in most standards.

In addition to the challenges described previously, we need to take into consideration that one source of error with this type of measurement is operator error. This error is very difficult to quantify and could vary greatly from one operator to another. One of the difficulties that the operator causes is clamping the sample on the machine without applying any stress on the sample, or at least a stress lower than the stress resulting from a 0.05% strain.

To reduce the operator error, it is recommended to simplify the loading process by using pneumatic grips. Another option is a system such as the AG-IS Autograph Universal Tester, which provides a sample protection function. This function maintains the load at zero during sample clamping. ⬢
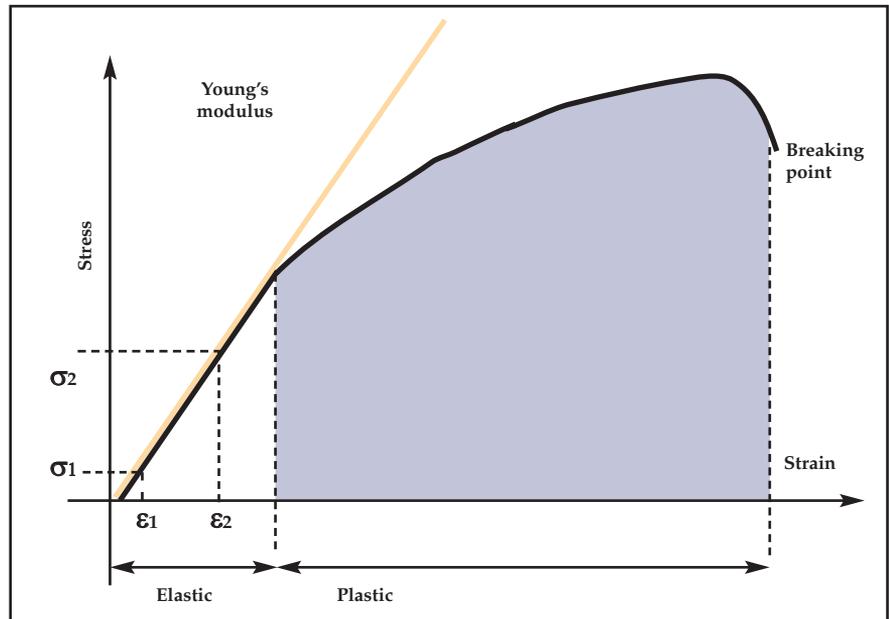

Fig. 3 — For plastic specimens, the determination of the elastic modulus (Young's modulus) represents a challenge because the elastic region on the curve is very short.

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