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Tech Notes

Extensometer Strain Control Basics

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What is strain control?

The crosshead position of a test frame is usually *controlled* using one of three common modes of control: *displacement (crosshead) control, force (stress) control* and *strain control*.

It is common practice to use different control modes during different portions of a tensile test.

The *control mode* of a test refers to the input used by the test frame's controller for control feedback and is a user-selected test parameter. When a test is operating in *force control*, the crosshead will move to maintain the prescribed *force*; in *strain control*, the crosshead will move to maintain the prescribed *strain*.

The control mode is different than the *end point* or *target value*. For example, a test might be defined as 1.0 mm/minute up to 0.2%ε: this would be a *displacement-controlled* test segment.

Which extensometers are suitable for strain control?

Most extensometers may be used for strain control applications. Extensometer design factors which are likely to make it very difficult to use an extensometer for strain control include:

- Mechanical hysteresis (extensometers using LVDTs or sliding joints, many tower extensometers)
- Stepping / cyclic characteristics (potentiometer-based extensometers, DIC systems)
- Loose parts or other extensometer damage

Other factors may make it more difficult to use *any* extensometer in a *particular strain control application*:

- Digitization problems (low-resolution DAQ, poor calibration practice, poor test design)
- Test measuring range too small relative to instrumentation (poor signal-to-noise ratio)
- Environmental vibration insults, and/or extensometer dynamics
- High test speed requirements
- Yield outside the gauge length / discontinuous yielding / strain banding
- Excessive hysteresis or filter phase lag
- Slipping of extensometer on the specimen or specimen in the grips
- Insufficient preload, load train / specimen misalignment, load train slop
- Bad control system design (some test frame control software)
- Excessive signal noise relative to the control settings

These factors often combine to affect the strain control performance of a *system*. It is a common mistake for users experiencing difficulty with strain control to conclude that a specific extensometer "does not work for strain control." *Most of the time, the application has not been suitably configured and tuned to achieve optimal strain control performance.*

Good strain control performance is a **system** *property, not just an extensometer property. Optimal control parameters differ between applications.*
Some applications are simply unsuitable for strain-controlled testing.

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Diagnosing strain control problems

Strain control problems are often indicated by sinusoidal test results, loops, or by runaway "loss of control". See this tech note on Test Curve Nonlinearity

> *The first step in troubleshooting* any *strain control problem is to repeat the test in displacement or force control.*

If the problem is resolved under displacement or force control, control loop optimization often provides a solution. Some applications, such as discontinuous yielding materials, should not be run in strain control.

Runaway "control loss" problems are often misdiagnosed. For example, a user might report that "the extensometer slipped, causing loss of control." Often it is poor control loop tuning that causes slip in the first place. That said, potential control loss should be considered.

> *Loss of control can result in injury or damage to equipment. Always use suitable limits on force, crosshead speed and displacement when running in strain control. Always assume that the specimen might break unexpectedly, or that the extensometer might slip.*

Optimizing strain control applications

Control loop tuning

When strain-controlled results are much noisier than displacement-controlled results, exhibiting large oscillations, the control loop tuning may be poor. *A recommended starting point for troubleshooting a standard PID control is to set I=D=0, and reduce P by 100x or more.* Increase P to make the system more responsive, but not so much that oscillation sets in.

> *PID tuning is a* **systems** *problem. PID values yielding good control with one extensometer, specimen, and test might not be good for a different extensometer, specimen, and/or test.*

Changing control modes

Many applications call for a change in control mode between test segments (*e.g ISO 6892-1)*. Materials which exhibit discontinuous yielding or may yield outside the gauge length should be tested using displacement control after yield.

Using cascaded control methods for cyclic testing

Some applications call for a specified strain rate or strain end points, but achieving that rate under strain control may be difficult. One way to approach this is to use cascaded (dual loop) control design. In this scheme, a displacement (or force) control mode is used (inner loop). The outer loop monitors the resulting strain, and periodically updates the specified displacement (or force) rate. This method avoids PID feedback and tuning problems; it is particularly useful in cyclic applications, where the displacement rate and endpoints can be adjusted once per cycle (*e.g., ref ASTM E606 8.3.1)*. ISO 6892-1 method A2 uses a similar method.

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Using low-pass filters

When using signal filters in strain control applications, phase lag will affect the control response; it can be beneficial in some applications to place the filter *downstream* from the control input and to ensure that all data channels have similar phase.

Vibration & control feedback loops

A common source of strain control problems is mechanical vibration. A strain control loop will interact with any vibration sensitivity of the test system (including specimen, frame, extensometer, and mounts) and can cause feedback which amplifies any existing vibrations, just like familiar audio feedback loops. These cases may be resolved by:

- Mitigate ambient vibration sources (hydraulics, nearby heavy equipment, people)
- Reduce sensitivity to vibration sources (stiff mounting, vibration isolation pads, etc.)
- Tune the control loop to mitigate feedback response to vibration (typically, reduce P)

> *Even a vibration sensitive system subjected to vibration insult can be run in strain control without inducing feedback with a sufficiently conservative control loop.*

Keep in mind that basic loop tuning problems are often misdiagnosed as vibration problems, since both are typically sinusoidal in nature; a displacement-controlled baseline is helpful for diagnosis.

Be cautious when trying to assess a vibration problem by poking at the extensometer or its cables. This is a severe mechanical insult which *will* create a response; it is not a good indicator that something is wrong with the extensometer.

Best practices for test design

Some systems offer a wider margin for strain control than others. To make life easier, in general it is a good practice to select a larger gauge length; this generally yields better mechanical stability and dynamics and all noise sources are reduced in significance. Smaller measuring range extensometers often yield better dynamics as well.

Some extensometer models offer better dynamics than others, making strain control easier. For example, a 7650A will outperform a comparable 3448 for a high temperature strain control test. When in doubt, enquire with Epsilon's engineering team for product recommendations.

Test speed / frequency can be an issue as well. Slower tests allow for more conservative control parameters to be used, which can improve the strain control response.

Control systems design

Unfortunately, some control systems simply aren't as good as others and cannot be tuned easily. In such cases loop tuning options may be limited.