Operation of the Instron Model 3382 Universal Testing Machine

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1 Introduction

The mechanical properties of metallic materials stem from their elemental composition, the manufacturing processes employed in forming them, and post-production exposure to load and environment. Mechanical property measurement can aid in the determination of a material's alloy class, heat treatment, degradation (during service or post-service exposure) and conformance to material specifications.

The Instron Model 3382 Universal Testing Machine can impose tensile, compressive, shear, or bending stresses depending on the test fixture configuration and specimen geometry used. These types of mechanical tests can be performed under various atmospheric and temperature conditions.

2 Scope

This document applies to case working personnel using the associated instrument in support of metallurgy examinations.

This document outlines the basic processes for performing uniaxial load (tension, compression, bending, or shear) tests using the Instron Universal Testing Machine. Published ASTM standards provide guidelines for a variety of test configurations.

3 Principle

The mechanical test system is designed to apply, read, and record a calibrated load along a central load axis. The type of stress imparted to a specimen depends upon the configuration of components (load cell, test fixtures, and specimen) along this load axis, called the load train. The repeatability and usefulness of the data generated will be affected by the alignment of the specimen into this load train, so selecting effective specimen fixturing is critical. An electrically powered screw mechanism drives the crosshead during testing. Test speeds are controlled to isolate the effect of strain rate, which can be substantial for some materials. Deformation of the test specimen during and/or after the test can be monitored and recorded.

A. Tension: The load train is configured to apply a tensile force, usually directly pulling on the ends of a test specimen with a reduced cross-sectional area referred to as a gauge section. Force-extension data is monitored using an extensometer, allowing generation of a stress-strain curve and determination of the modulus of elasticity (E), Poisson's ratio (ν), yield strength (YS), tensile strength (TS), elongation, reduction in area (RA) and the strain hardening characteristics.[1] See ASTM E8/8M for guidance selecting test specimen grips.

B. Compression: The load train is configured to apply a compressive force, usually by directly pushing on the ends of a right circular cylindrical test specimen with a

[1] In situations where breaking stress (or load) is the only desired output, the crosshead displacement can be substituted for the strain signal.

length-to-diameter (l/d) ratio of less than 2.0. Force-extension data is monitored using an extensometer, allowing generation of a stress-strain curve and determination of the bulk elastic modulus, yield strength, and strain hardening characteristics.[1]

C. Bending: The load train is configured to apply a bending force, usually to a flat, rectangular test specimen or beam. Bend ductility tests determine the smallest radius around which a specimen can be bent without cracks being observed on the tensile surface. Bending strength tests determine the modulus of elasticity in bending and the bending strength. For both of these types of testing, a wide variety of test fixtures are available. See ASTM E290 for guidance selecting test specimen fixtures.

D. Shear: The load train is configured to apply a shear force to a test specimen. For example, tests are often performed on fasteners, oriented to the load as they would be in service, to measure their shear strength. Translational shear tests are performed on sheet materials to characterize shear anisotropy. Torsional (rotational) shear tests are not covered by this procedure. For all types of shear tests, a wide variety of test fixtures are available. See appropriate standards for guidance selecting test specimen fixtures, such as ASTM B769 for aluminum.

E. A variety of other mechanical properties, such as stress relaxation and spring constant, can also be determined using the universal testing machine. Guidelines for performing such tests are available from standards-producing organizations like ASTM International. Additional standards are also available for specific inspections sequences, such as ASTM E190 for bend testing of weld ductility. See Annual Book of ASTM Standards, Vol. 3.01 for a collection of potentially useful standards.

4 SPECIMENS

Destructive testing must be approved by the contributor prior to performing any of the tests in this procedure on evidence. Known materials are often tested to interpret the possible load-bearing capacity of evidentiary components.

Specimens must be mounted into the test frame such that the appropriate stress mode is conveyed to the desired portion of the specimen. Entire components may be tested if the load train configuration can accommodate the component alignment. ASTM vol. 3.01 provides test specimen size and shape specifications for many mechanical tests that can be performed in the universal testing machine. (See 13 References.)

The orientation and location of specimens taken from parent materials must be recorded, particularly for anisotropic materials. Proper orientation of the stresses with respect to the principal axes of microstructural orientation is an important test consideration

5 EQUIPMENT

- Instron Model 3382 Universal Testing Machine
- Computer for instrument control, data acquisition, and analysis

- Calibrated load cell
- Calibrated extensometer (optional)
- Test fixtures (grips, platens, etc.) appropriate for the test specimen(s)
- Standard weights with calibration certificates from supplier: 1, 2, 5, 10, 20, and 50 lbs and 2, 5, 10, and 20 kg.
- Calibrated dimensional measuring device(s) such as a micrometer, caliper, traveling microscope, etc.

6 STANDARDS AND CONTROLS

Adequate instrument performance is verified every time the instrument is powered up for use or the load cell scale is changed. The individual load cell to be used will be verified using supplier-certified standard weights, and the extensometer or crosshead displacement will be verified using a calibrated linear measurement device such as a micrometer, caliper, or traveling microscope according to the procedures outlined in section 7.1 Verify Instrument Performance.

7 PROCEDURE

7.1 Verify Instrument Performance

7.1.1 Load Cell Performance Check

The output of the specific load cell to be used must be verified on the day of the test.

A. Select, install, and connect the appropriate load cell for the type of test and material being tested. The maximum capacity of the cell must exceed the breaking strength of the test specimen.

B. Attach a fixture to accommodate hanging weights.

C. Apply power to both the load frame and computer. Allow the system to warm up for 15 minutes to stabilize the load cell before verifying it.

D. Zero the load channel in the control software.

E. Hang standard weights from the fixture using at least 1% of the load cell capacity. When applying the weights, never exceed the maximum capacity of the load cell.

F. Assure that the value displayed by the load channel matches the applied load within the measurement uncertainty on the most recent calibration certificate of the load cell in the ’As Left’ condition for a similar % of total Range of applied load. If it does not, the load cell and output channel must be serviced and recalibrated by a service provider that meets the FBI Laboratory requirements.

G. Record the load cell identifier and the results of the performance check in the instrument log. Retain the data in the examiner’s case notes.

7.1.2 *Strain Extensometer Performance Check (optional)*

If an extensometer will be used to report strain, or to measure strain that will be included in the calculation of a reported property, the device output must be verified on the day of the test.

A. Select and connect the appropriate extensometer for the specimen geometry and expected elongation range to be tested. Select the corresponding scale in the control software.

B. Mount the extensometer on the verification device (e.g., calibrated micrometer) in the same manner as it is normally attached to the test specimen.

C. Position the extensometer at approximately the neutral position (not compressed or extended) and zero the strain channel in the control software.

D. Dial the full range of the extensometer extension on the micrometer. Adjust the scale factor in the software to assure the electronic output on the strain channel matches this extension.

E. Verify the extensometer's linearity by returning it to zero in increments. Use at least ten increments which span the entire extensometer range. Record the micrometer spacing versus extensometer output.

F. Repeat for compression if the extensometer is so rated.

G. Assure that the value displayed by the strain channel matches the measurement device reading within the measurement uncertainty on the most recent calibration certificate of the extensometer in the 'As Left' condition for each similar % of total Range of extension. If it does not, the extensometer and output channel must be serviced and recalibrated by a service provider that meets the FBI Laboratory requirements.

H. Record the extensometer identifier and the performance check results in the instrument log. Retain the data in the case notes.

7.1.3 *Crosshead Displacement Performance Check (optional)*

If crosshead displacement will be used to report extension or will be included in the calculation of a reported property, the device output must be verified on the day of the test.

A. Mount a traveling microscope onto the load frame base and mark a point on the crosshead for observation.

B. Zero the displacement channel in the control software.

C. Move the crosshead to the extreme range expected to be encountered during the test and measure the interval with the traveling microscope. Record the distance traveled by the microscope versus the displacement transducer output.

D. Return the displacement to zero in (at least) ten increments over the total range, focusing on the marked observation point with the traveling microscope. Record the position of the microscope versus the displacement transducer output at each increment.

E. Assure that the value displayed by the displacement channel matches each interval measured by the traveling microscope within the maximum % error reported on the most recent displacement calibration certificate. If it does not, the displacement and output channel must be serviced and recalibrated by a service provider that meets the FBI Laboratory requirements.

F. Record the performance check results in the instrument log. Retain the data and in the case notes.

7.2 Specimen Preparation

A. Whole components to be tested should be cleaned of loose debris using materials that do not penetrate the specimen material. Wiping the exterior with a lint-free wipe or brushing with a soft bristle brush is typically sufficient.

B. Standard sized specimens that are machined from a larger component or from bulk material must be prepared by a vendor that meets FBI Laboratory requirements. See standard specimen sizes referenced in ASTM E8/8M and E9 (13 References) for size, geometry, and finish requirements.

C. Other material-specific standards contain guidance for preparing test specimens, such as ASTM A370 for steel. See Annual Book of ASTM Standards, Vol. 3.01 for a collection of potentially useful standards.

7.3 Specimen Testing

The guidelines below apply for methods that have been pre-programmed in the instrument software to perform an appropriate test sequence, calculate desired values, and output data in a specific format. Newly created methods must be validated in accordance with FBI Laboratory requirements.

A. Select and install the appropriate components and fixtures for the type of test and the material being tested, and assure the measuring components are verified, as in 7.1 Verify Instrument Performance. Load cells and extensometers are to be used only within their rated capacities. Capacities are listed on certification sheets stored near the instrument.

B. Adjust the crosshead position to achieve appropriate fixture separation for the test being performed.

C. Adjust the mechanical crosshead stops on the crosshead rails to the positions required by the test.

D. In the control/data acquisition software:

   1. Load the appropriate test method.

   2. Set the appropriate display units.

   3. Set the appropriate upper and lower limit stops for crosshead motion.

   4. A method may also contain programmed test pauses or end points.

E. Measure the required dimensions of the specimen and enter them into the appropriate software data fields.

F. Mount the specimen in the test fixtures.

G. (Optional) Attach and align the extensometer on the specimen.

H. Zero the transducers using the control software.

I. Start the method sequence. The instrument software will prompt the user for information, perform the test, and display the test progress.

   1. If using an extensometer, pause the test and remove the extensometer before displacement threatens to surpass its rated extension or compression range.

   2. Stop the test when the specimen fractures or when the desired data has been acquired.

   3. Such pauses and end points can be programmed into the method.

J. Observe the progression of the test. Problems such as the specimen slipping in the test fixtures, will generally be reflected in the stress-strain curves generated during data collection. Investigate the factors responsible for unexpected curve non-linearities or erratic curves.

   1. If the specimen slipped in the fixtures and the load did not exceed yield, the specimen fixtures may be able to be retightened and the test continued.

   2. Other situations may invalidate the test, requiring specimen replacement

K. Remove the specimen from the fixtures; return the crosshead to the starting position and repeat the test for the desired number of specimens.

L. Save the test data. Print a report of the data and test results and retain the report in the case notes.

8 CALCULATIONS

8.1 Quantitative Analysis

A. A variety of mechanical properties (such as E, YS, TS, and elongation) can be automatically calculated by the instrument software from the load and extensometer/displacement data. These readings, and their associated measurement uncertainties, may be used to report a range or series of measurements.

B. To report averaged measurements, collect at least five values. Calculate and report the mean and expanded measurement uncertainty. The mean value of a property, such as tensile strength, is calculated as: $\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$, where $\sum_{i=1}^{n} x_i$ is the sum of the measurements, n is the number of measurements, and $\bar{x}$ is the mean tensile strength of the test specimens.

C. Estimate measurement uncertainty as detailed in CHEM-100. Include the repeatability component of the test specimens.

D. For the evaluation of component design strength, mechanics-based design equations can often be used to predict the approximate behavior of materials under complex stresses from the measurements of mechanical behavior under uniaxial tension or compression. See Roarke's Formulas for Stress and Strain (section 13 References.)

8.2 Comparative Analysis

Where quantitative data from two specimens are being compared, a pooled, two-tailed Student's t-test statistic of the sample means will be used for the comparison, as detailed in METAL-210 (Calculations section.) Typically, five to ten measurements per sample are used for performing comparisons. When multiple mechanical properties are being evaluated to compare two items, the critical t values for the Student's t-test are typically chosen so that an overall (Bonferroni corrected) value of $\alpha = 0.05$ can be achieved for the combined analysis.

9 MEASUREMENT UNCERTAINTY

Quantitative data from this procedure are sometimes used for comparative purposes. Expanded measurement uncertainty should not be used for these inter-comparisons because it increases the probability two samples will appear to be analytically indistinguishable and therefore increases the likelihood of type II errors (false inclusion). Instead, the variances associated with the samples and with data acquisition are accommodated by the statistical comparison.

When quantitative data are compared to a particular specification or when quantitative measurements are reported, the estimated measurement uncertainty will be calculated in accordance with CHEM-100.

Measurement uncertainty is expected to be significantly influenced by composition, heat treatment, part geometry, and other factors. Since these factors are specimen dependent, the measurement uncertainty will be calculated on a case-by-case basis.

10 Acceptance Criteria

10.1 Calibration

The instrument components (load cells, strain gages, crosshead displacement, speed, and computer output) are calibrated annually by a service provider that meets the FBI Laboratory requirements.

10.2 Performance Check

The user will verify the performance of the load cell and, if needed, strain or displacement measuring device each day that the configuration is used to perform tests. See 7.1 Verify Instrument Performance.

A. Verification of a load cell is acceptable when the load values determined by the instrument on a given standard weight fall within the range of measurement uncertainty reported on the most recent load cell calibration certificate.

B. Verification of strain or displacement is acceptable when the displacement determined by the instrument for a given distance on a certified measuring device falls within the certified measurement uncertainty or % error of the measuring device, found on its most recent calibration certificate.

10.3 Quantitative Analysis Conclusions

Variability in mechanical property measurements among parts may be metallurgically significant (e.g., resulting from grain size differences, heat affected zones, or cold worked regions.) If this is observed, the results should not be averaged but should be reported individually for the specimens tested.

10.4 Comparative Analysis Conclusions

When evaluating whether the means of a mechanical property determined on different sets of specimens are statistically distinguishable, a Student's t-test of the means will be employed, as detailed in METAL-210.

11 Limitations

A. Application of this procedure is limited by the material availability, component geometry, and numerous other factors specific to the situation under consideration.

B. The conclusions derived from this procedure are based on careful interpretation of all of the data gathered during testing. The applicability of the test results depends on the uniformity of the material response during testing, the material homogeneity, and how well the test specimens represent the component, among other factors.

12 Safety

A. Wear safety glasses when operating the universal testing machine.

B. Wear personal protective gear and use engineering controls that are appropriate for the task being performed when preparing specimens.

C. High loads on test pieces with large cross-sections may generate projectiles when they fracture. If such loading conditions are anticipated, install a shield between the test piece and the operator.

D. Ties and other loose clothing should not be worn when operating this instrument, and long hair should be tied back. If entanglement occurs, a red "EMERGENCY STOP" button can be used to interrupt the instrument power and halt the screw drive motion.

E. When testing at elevated temperatures, wear appropriate heat resistant protective gloves and clothing.

13 References

- CHEM-100, Quality Assurance and Operations Manual, FBI Laboratory, Chemistry Unit, latest revision
- METAL-210, Examinations for Association or Origin, Chemistry Unit, latest revision
- Annual Book of ASTM Standards, Volume 03.01 Metals – Mechanical Testing; Elevated and Low Temperature Tests; Metallography, ASTM International, West Conshohocken, PA, latest revision
- Young, W. C. and Budynas, R. G., Roarke's Formulas for Stress and Strain, 7th ed., McGraw-Hill Publishers 2002
- ASTM E8/E8M, Standard Test Methods for Tension Testing of Metallic Materials, ASTM International, West Conshohocken, PA, latest revision

- ASTM E9, Standard Test Methods of Compression Testing of Metallic Materials at Room Temperature, ASTM International, West Conshohocken, PA, latest revision
- ASTM A370, Standard Test Methods and Definitions for Mechanical Testing of Steel Products, ASTM International, West Conshohocken, PA, latest revision
- ASTM B769, Standard Test Method for Shear Testing of Aluminum Alloys, ASTM International, West Conshohocken, PA, latest revision
- ASTM E290, Standard Test Methods for Bend Testing of Material for Ductility, ASTM International, West Conshohocken, PA, latest revision
- ASTM E190, Standard Test Method for Guided Bend Test for Ductility of Welds, ASTM International, West Conshohocken, PA, latest revision

14 Revision History

Revision	Issued	Changes
04	09/30/2022	Revised to comply with new formatting requirements. Distributed information from previous Instrumental Conditions and Decision Criteria sections into Acceptance Criteria, Limitations, and Procedure sections. Removed informational references. Removed environmental testing option.