Do I retrofit or replace my Universal Testing Machine?

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When testing metals, the primary function of a testing machine is to generate a stress-strain curve. (Figure 1) Once the diagram is complete, you can use a pencil and straight edge or a computer algorithm to calculate yield strength, Young's modulus, tensile strength and total elongation.

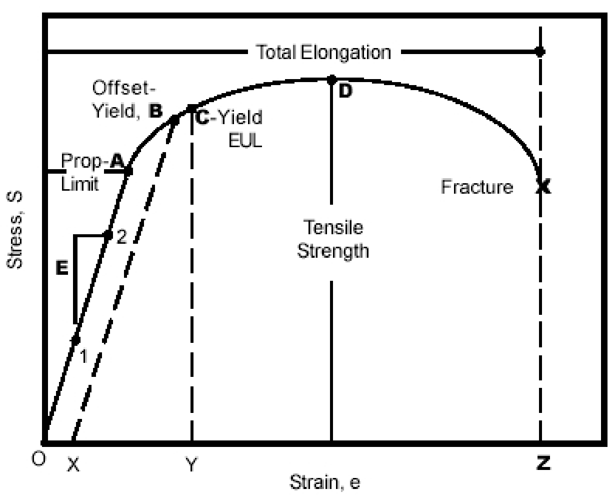

Figure 1: Engineering Stress-Strain Diagram depicting important mechanical properties for metals.

Testing machines are either electromechanical or hydraulic. (Figure 2) The principal difference is the method by which the load is applied. Electromechanical machines are based on a variable speed electric motor; a gear reduction system; and one, two or four screws that move the crosshead up or down. The crosshead motion loads the specimen in tension or compression. Hydraulic testing machines are based on either a single- or dual-acting piston that moves the crosshead up or down. However, most static hydraulic testing machines have a single acting piston or ram. In a manually operated machine, the operator adjusts the orifice of a pressure compensated needle valve to control the rate of loading. In a closed-loop hydraulic servo system, the needle valve is replaced by an electrically operated servovalve for precise control.

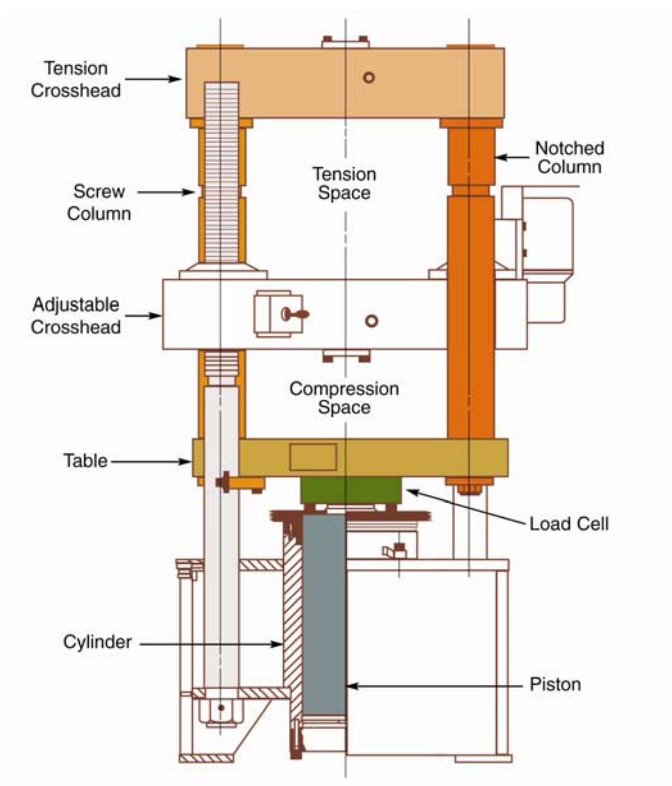

Figure 2: Anatomy of a universal hydraulic testing machine.

Hydraulic machines capable of generating 60,000, 120,000, 300,000 or 400,000 pounds of force are the most commonly used machines for testing metals. Many of these hydraulic machines were manufactured in the 1940' and are still in use today; as are machines manufactured more recently. Most of these machines were conservatively designed structurally and will never wear out mechanically. However, the load and strain measuring systems become unreliable or cannot meet today's more stringent testing requirements and have to be replaced.

So what to do when the old system breaks or your customer requires a test that cannot be performed with your existing machine? Do you replace the machine with a new one or do you upgrade/retrofit the existing machine?

When considering the purchase of a new or upgrade of an existing hydraulic testing machine of 60,000 lb capacity or higher it is almost always less expensive to upgrade the existing machine. New 60,000 lb and 400,000 lb hydraulic testing machines cost between $50,000-55,000 and $150,000-200,000, respectively. In general, retrofits cost between $500, for the integration of a simple digital indicator, to $35,000 for a new servo-hydraulic power unit with a Windows-based materials testing system. As a rule, the dollar savings increase as the capacity of the machine increases. So, a retrofit would save well over $100,000 on a large machine and tens of thousands of dollars on a smaller machine.

In addition to the direct machine costs, there are other considerations that come into play. You have to consider your investment in grips, fixtures and test jigs for your existing machine(s) – the larger the investment, the greater the replacement expense. Another common situation is that all of a company's machines are identical and it is best from a fixturing, training and maintenance standpoint to keep it that way. In some cases, either because of contractual terms or regulations, new machines would require recertification. Finally, there is the very pressing situation when your existing machine has failed and you need a quick repair and the lead time for a new machine is too long. Retrofits can be installed at the customer's site in one to three days.

A number of upgrade packages are available for retrofitting hydraulic testing machines. Most of the packages when installed and calibrated will extend the certified force measuring range of the machine with a single load range. A description of each upgrade package type follows:

+ The simplest package keeps the existing manual control valves and replaces the dial gage with a new single-channel digital indicator to display load and report ultimate tensile strength. (Figure 3) Some of the more sophisticated single channel indicators are also capable of calculating yield by the halt of the pointer method and downloading results and load vs. time data to a computer for reporting and plotting.

Figure 3: Single-channel digital indicator for simple retrofits of manually operated machines.

+ The next step up when keeping the existing manual control valves is to incorporate a two- or three-channel digital indicator that is capable of measuring force, displacement and strain. A testing machine equipped with a two- or three-channel indicator is capable of generating a stress-strain curve and calculating offset yield, Young's modulus, ultimate tensile strength and percent elongation according to ASTM E8. (Figure 4) Results and stress-strain curves can be printed directly to a printer or downloaded to a remote computer for further review and analysis. New or existing extensometers can be connected to the indicator for measuring strain.

Figure 4: Multi-channel digital indicator capable of calculating the common mechanical properties of metals.

+ Installing a Microsoft Windows-based materials testing system (Figure 5) is the most sophisticated upgrade package for a manually controlled hydraulic testing machine. It provides all of the capability of the three-channel digital indicator but adds calculations for plastic strain ratio (ASTM E517), K and n values (ASTM E646) plus many more.

The next level of retrofits convert manually operated machines to automatic closed-loop servo hydraulic testing systems that are microprocessor controlled. This is accomplished in one of two ways.

+ The least expensive servo retrofit is to keep the existing hydraulics, bypass the existing manual control valves and install a new servovalve manifold. Either a multi-channel digital indicator or a Windows based materials testing system can be used to control the machine. The standalone digital indicator is more suitable for running similar tests repeatably, whereas the Windows-based system provides more control capability for performing a variety of tests.

+ The more expensive servo retrofit is to replace the existing hydraulic console with a new servo hydraulic power unit. Again, either the multi-channel digital indicator or Windows-based system can be used to perform the tests.

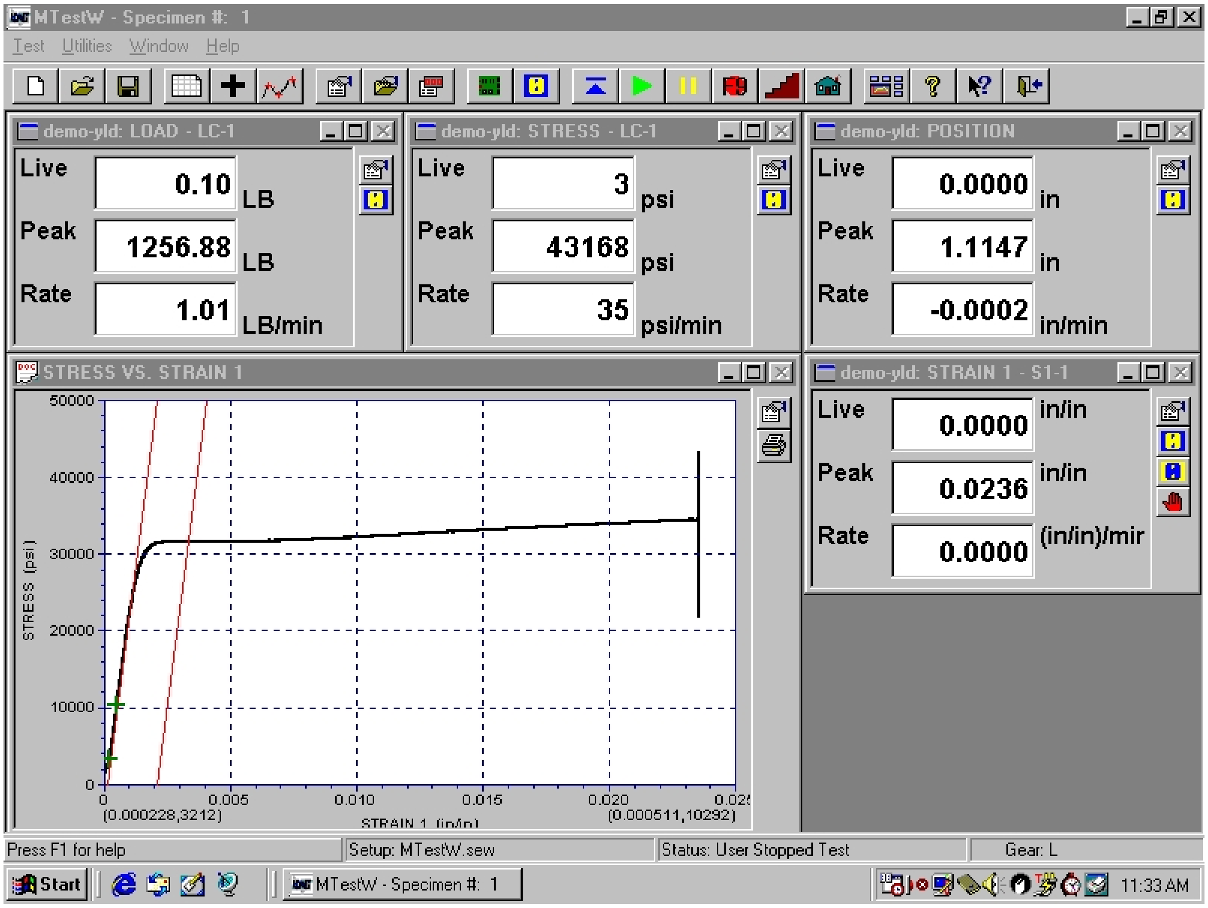

Figure 5: Sophisticated Windows-based materials testing system capable of calculating both common and more difficult to measure mechanical properties of metals.

Regardless of whether you retrofit or replace, it is important that you keep your testing capabilities current. (Figures 6 & 7) Up-to-date equipment will reduce test times; eliminate data entry errors, and speed materials and product development. Employing testing systems that automatically perform the tests according to specification automatically calculate results and seamlessly communicate with computers and programs running on your corporate network are paramount to operating a successful testing laboratory.

Figure 6: Retrofit of 400,000 lb capacity hydraulic testing machine with Windows-based system and existing manual controls.

Figure 7: Retrofit of 60,000 lb capacity testing machine with Windows-based system and new servo hydraulic power unit.

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Test Methods and Specifications

The following is a partial list of ASTM test methods and practices for metals testing. Copies may be obtained from ASTM, the American Society for Testing and Materials. ASTM standards are available from the ASTM Web site (www.astm.org) or through Customer Service (610/832-9585; fax: 610/832-9555e-mail: service@astm.org). 100 Barr Harbor Drive, West Conshohocken, PA19428-2959.

Test Method E8-00b Standard Test Methods for Tension Testing of Metallic Materials

Test Method E8M-00b Standard Test Methods for Tension Testing of Metallic Materials [Metric]

Test Method E111-97 Standard Test Method for Young's Modulus, Tangent Modulus, and Chord Modulus

Specification A356/A356M-98e1 Standard Specification for Steel Castings, Carbon, Low Alloy, and Stainless Steel, Heavy-Walled for Steam Turbines

Practice E1012-99 Standard Practice for Verification of Specimen Alignment Under Tensile Loading

Test Method A370-97a Standard Test Methods and Definitions for Mechanical Testing of Steel Products

Test Method E345-93(1998) Standard Test Methods of Tension Testing of Metallic Foil

Practice E4-01(2001) Force Verification of Testing Machines

Practice E29-93a (1999) Standard Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

Practice E83-00 Standard Practice for Verification and Classification of Extensometer

Test Method E21-92(1998) Standard Test Methods for Elevated Temperature Tension Tests of Metallic Materials

Practice B598-98 Standard Practice for Determining Offset Yield Strength in Tension for Copper Alloys

Test Method E646-00 Standard Test Method for Tensile Strain-Hardening Exponents (n-Values) of Metallic Sheet Materials

Test Method E517-00 Standard Test Method for Plastic Strain Ratio r for Sheet Metal

Test Method F606-00 Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets

Test Method F606M-98 Standard Test Methods for Determining the Mechanical Properties of Externally and Internally Threaded Fasteners, Washers, and Rivets [Metric]

Materials properties definitions

Many of these definitions are taken from ASTM E6 Standard Terminology Relating to Methods of Mechanical Testing, ASTM

Ductility - the ability of a material to deform plastically before fracture.

Elastic Limit - the greatest stress which a material is capable of sustaining without any permanent strain remaining upon complete release of stress.

Elongation at Break or **Total Elongation** - the amount of plastic or permanent deformation determined after fracture by realigning and fitting together the broken ends of the specimen.

Elongation at Fracture or **Maximum Elongation -** the elongation at the time of fracture, including both plastic and elastic deformation of the tensile specimen. Usually determined by keeping an extensometer on the specimen thru break.

Engineering Strain - a dimensionless value that is the change in length per unit length of the original linear dimension along the loading axis of the specimen. Frequently expressed in inches per inch or percent.

Engineering Stress - the normal stress, expressed in units of applied force per unit of original cross-sectional area.

Extensometer - a device for measuring strain.

Gage Length - the original length of that portion of the specimen over which strain or change in length is determined.

Hardness - the resistance of a material to deformation, particularly permanent deformation, indentation, or scratching.

Hooke's Law (Hookean behavior) - within certain force limits, the stress in a material is proportional to the strain which produced it.

Mechanical Properties - those properties of a material that are associated with the elastic and plastic reaction when force is applied.

Offset Yield Strength - the engineering stress at which, by convention, it is considered that plastic elongation of the specimen has commenced. Offset Yield Strength is determined by constructing a line parallel to the linear elastic region of the stress-strain curve and shifting it in the strain direction an amount specified as a percentage of gage length.

Plastic Strain Ratio - the ratio of the true strain in the width direction to the true strain in the thickness direction of a sheet material loaded beyond yield**.**

Proportional Limit - the greatest stress which a material is capable of sustaining without deviation from a linear relationship of stress to strain.

Reduction of Area - the difference between the original cross-sectional area of a tension test specimen and the area of its smallest cross-section. The reduction of area is expressed as a percentage of the original cross-sectional area.

Strain Hardening Exponent, n - a measure of the increase in hardness and strength caused by plastic deformation of a tensile specimen. A power curve is used to approximate the shape of the stress-strain curve between yield and ultimate stress. "n" is the calculated exponent of the power curve.

Ultimate Tensile Strength or **Tensile Strength -** the maximum tensile stress that a material is capable of sustaining. Tensile Strength is the maximum load during a tension test carried to rupture divided by the original cross-sectional area of the specimen.

Yield by Extension Under Load (EUL) - the engineering stress at which, by convention, it is considered that plastic elongation of the specimen has commenced. EUL is determined by constructing a line perpendicular to the strain axis of a stress-strain curve at a strain value that is specified as a percentage of gage length.

Yield Strength - the engineering stress at which, by convention, it is considered that plastic elongation of the material has commenced.

Young's Modulus of Elasticity - the ratio of stress to corresponding strain below the proportional limit.