WHITE PAPER

Material Testing, Instrumentation, and Data Acquisition in Academic Institutions

Knowledge of materials has shaped the development of human civilizations since the dawn of time. Materials are so crucial that historians have defined entire periods of time by the predominant material of those eras, such as the Stone Age, Bronze Age, Iron Age, etc. In fact, the period spanning the late 20th century to the early 21st century is considered by some to be the Silicon Age (from a chemistry perspective) or the Information Age (from a sociological point of view).

Materials science was originally regarded as a sub-field of chemistry, physics, and engineering. Over time, however, this subject began to be increasingly recognized as a specific and distinct field of science and engineering. Today, materials science is known as an interdisciplinary field that involves developing, inventing, and researching materials. Commencing in the 1940s, technical universities worldwide started to create dedicated schools for its study.

As far back as the early 1800s, European universities collaborated with industrial companies on everything from fundamental research to marketable products. Similarly, relationships between universities and industry in the United States evolved alongside the Industrial Revolution. More recently, commencing in the early 1970s, the US government started to aggressively encourage the relationship between academia and industry via funding programs like the Industry-University Cooperative Research Projects Program (I/UCRPP) and the Industry-University Research Centers Program (I/URCP).

Today, materials science is a significant domain of collaboration between academia and industry, with benefits accruing to both sides. Companies may gift equipment, fund buildings, or sponsor entire university departments. In return, those companies may guide research directions and gain access to research results while also having access to a potential source of highly-trained employees.

Material Testing

Materials come in many forms, including relatively simple materials formed from a substance or mixture of substances that constitute an object and composite materials formed from two or more constituent materials. In this latter case, the constituent materials, which typically have notably dissimilar chemical or physical properties, are merged to create a new material with properties unlike its elements. It's also becoming increasingly common to see 3D-printed materials (e.g., NASA Alloy GRX-810).

The term "composite structure" refers to something formed from multiple materials. Testing such a structure takes place on several levels (Figure 1). Level 1 involves coupon testing (i.e., material testing), where the term "coupon" refers to a relatively small sample of the material to be tested. Coupons may also be referred to as "dog bones" due to the iconic dog-bone biscuit shape of the test samples, whose geometry reduces the influence of stress concentrations induced by tester gripping mechanisms.

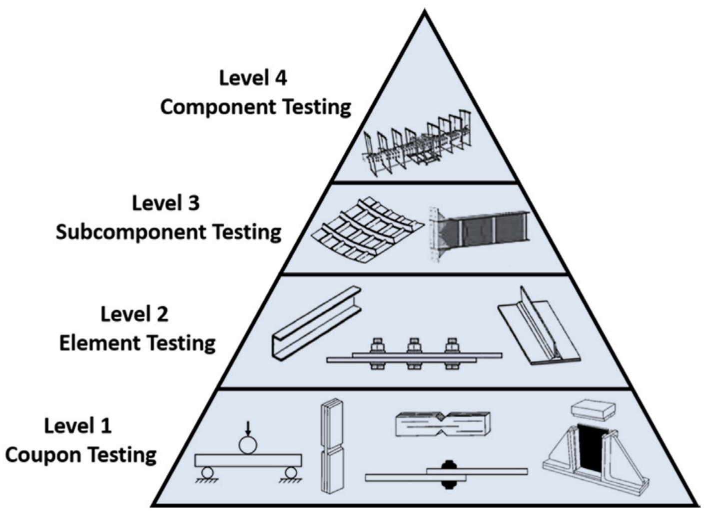


Figure 1. *Building block approach for composite structures (Source: Dan Adams)*

Level 2 (Element Testing) includes things like bonded or bolted joints. Level 3 (Subcomponent Testing) typically involves an assembly representing a portion of the final composite structure, such as an aircraft's wing. Level 4 (Component Testing) may describe the entire structure, such as a complete aircraft.

Most of the Level 1 testing—perhaps accompanied by some amount of Level 2 testing—will primarily be performed by universities and research institutes. In contrast, the majority of Level 2 testing and all Level 3 and Level 4 testing will typically be performed by companies in the associated industry.

Similarly, material testers come in many shapes and sizes, including desktop and free-standing machines employing hydraulic and/or electromechanical (e.g., screw jack) mechanisms. Common material tests include tension, compression, shearing, torsion, bending, buckling… and many more (Figure 2).

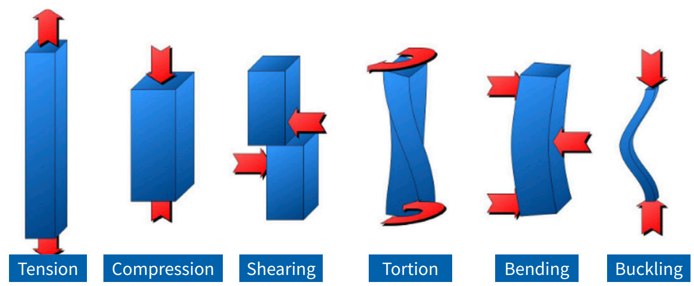


Figure 2. *Some common material tests (Source: TECS)*

In addition to one-off tests—which are often performed to destruction—it's also common to perform fatigue testing, which involves repeated loading (tension, compression, torsion, etc.) to determine the total number of cycles until the material fails.

Augmenting the ability to perform physical deformations, many load frames and other test machines can enclose the material to be tested in a small thermal chamber. This is necessary because materials behave differently at different temperatures—more flexible at higher temperatures and more brittle at lower temperatures.

The ability to control the temperature of the test facilitates the study of phenomena like creep. For example, consider applying a load that would typically be within the elastic range of a material, which means that when the load is removed, the material returns to its original shape. Now consider applying the same load for an extended period when the material is at, say, 50% of its melting temperature. In this latter case, the material may end up permanently deformed.

Instrumentation Options (What to Look For)

The machines used in universities for material testing are typically relatively small benchtops or floor-standing devices. These machines can detect and record the amount of tension, compression, torsion, etc., that they apply, but they can't report what's happening at different points along and around the coupon. This is where sensors like strain gauges (accompanied by thermocouples) come in.

In general, universities are on a tight budget. They are looking for cost-effective, high-accuracy test instrumentation products that are easy to install and use.

Another consideration is that many cheaper instruments support only one type of sensor, requiring more instruments to be purchased as additional sensors are brought into play. This means it can be significantly more cost-effective over time to purchase instruments that can work with multiple sensor types (strain gauges, crack gauges, load cells, pressure transducers, force transducers, torque transducers, etc.).

Many materials science departments start with stand-alone test instruments sitting on a desk or workbench. As the test environment increases in sophistication, with additional instrumentation, power supplies, and servers added to the setup, mounting everything in a rack may become necessary. Thus, purchasing test instruments that can be used both standalone on a desk and mounted in a rack is a good idea.

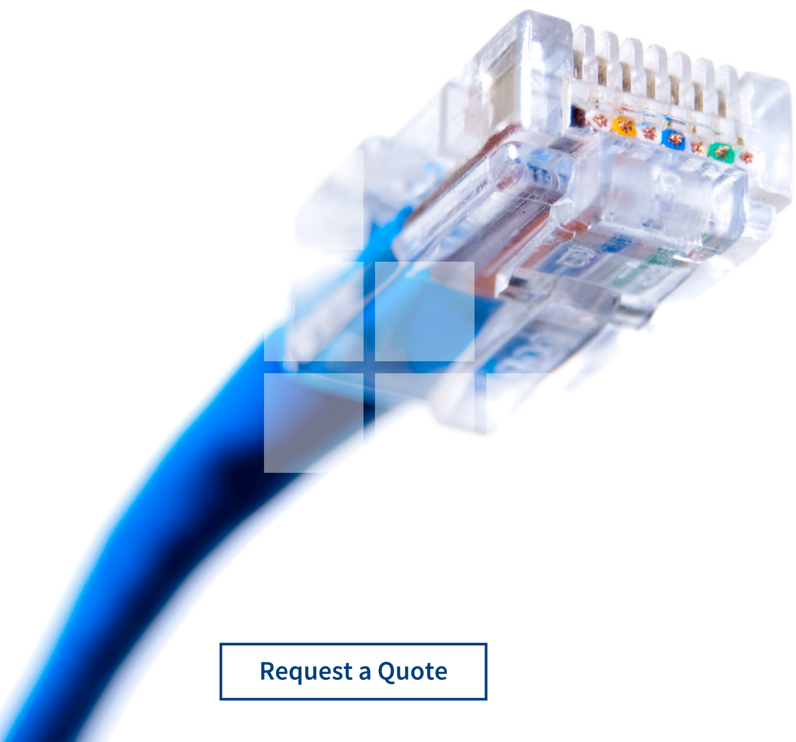
One final piece of advice is to avoid instruments that require special, proprietary (expensive) connectors. Instead, opt for instrumentation that employs common, low-cost, easy-to-use solutions like RJ45 connectors.

Data Acquisition Capabilities (What to Look For)

Many test instruments require special data acquisition software to make them function. While this does provide a turn-key solution, it may prove to be an expensive option, especially for software requiring an annual license fee.

Other options are available. LAN eXtensions for Instrumentation (LXI) is a standard developed by the LXI Consortium,[1] which maintains the LXI specification and promotes the LXI Standard. This standard defines the communication protocols for instrumentation and data acquisition systems using Ethernet.

The LXI standard also embraces the concept of Interchangeable Virtual Instrument (IVI) drivers as defined by the IVI Foundation.[2] IVI drivers define an I/O abstraction layer that provides an interface-independent communication channel for test and measurement instruments. Furthermore, IVI drivers encapsulate Standard Commands for Programmable Instruments (SCPI) commands, which are ASCII-based commands for reading and writing instrument settings and measurement data. The IVI standard allows an abstract way to program remote-control applications using various programming languages.



Some test instruments are accompanied by a free web-based utility that allows the instruments to be monitored and controlled over Ethernet. Others are accompanied by software drivers enabling users to create their own data acquisition applications. And some allow users to create driverless applications in programming languages like Python, C/C++, and Java.

In the case of data logging, some test instruments allow the test data to be stored in internal memory, others will enable it to be stored on a plug-in USB Flash Drive (a.k.a. a memory stick), and some allow the data to be streamed to a server over Ethernet. It's recommended to purchase test instrumentation that supports all three of these options because each may be advantageous in different situations.

It's also a good idea to ensure that any test instruments store and manipulate data in a standard CSV (comma-separated value) format that can be accessed by any application, as opposed to some weird and wonderful proprietary design that will end up having to be translated somewhere down the line.

If you wish to write your own software, look for instruments backed by free-of-charge IVI-compatible drivers and/or driverless solutions, along with documentation on creating your own applications. If using drivers, ensure these are (a) free and (b) available for both the Linux and Windows operating systems. Last, but certainly not least, whether creating driver-based or driverless applications, make sure your test instrumentation solution supports popular programming languages like Python, C/C++, and Java.

VTI's Instrumentation and Data Acquisition Solutions

VTI Instruments provides a wide range of products and systems to monitor and record the data that characterizes the physical integrity and performance of everything from materials to large structures like engines, aircraft, and wind turbines.

In the case of materials testing, two particularly relevant instruments are the EX1401 16-channel isolated thermocouple and voltage measurement instrument and the EX1403A 16-channel precision bridge and strain gauge instrument.

The EX1401 delivers accurate and highly repeatable thermocouple (±0.2°C) and voltage measurements by implementing fully integrated signal conditioning, providing 24-bit analog-to-digital converters (ADCs), and offering independent Cold Junction Compensation (CJC) on a per-channel basis.

Meanwhile, the EX1403A sets a new standard for strain and bridge measurements, delivering the highest performance measurements possible while controlling overall test hardware costs. With its ability to provide constant voltage and constant current excitation, the EX1403A can measure all standard strain gauge configurations (1/4, 1/2, Full) and any standard bridge measurement (pressure, force, displacement). Furthermore, by taking advantage of the constant current excitation, Resistor Temperature Detectors (RTDs) can also be connected to the EX1403A for high accuracy temperature measurements.

Both instruments are equipped with rubber protection sleeves, thereby allowing them to be used standalone on desks or work benches (Figure 3a). These sleeves can be removed to mount the instruments in racks (Figure 3b).

In addition to supporting Power over Ethernet, the EX1401 and EX1403A are fully LXI-compliant, including support for IVI drivers. Material testers can control both instruments (e.g., to start and stop capturing data) via a standard digital interface. And both instruments allow test data to be stored internally, on a plug-in memory stick, or streamed to a server over Ethernet.

Complete remote control of the EX1401 and EX1403A instruments is supported by their firmware, allowing them to be used "out-of-the-box" with a free web-based Software Front Panel (SPF). In the same way an Ethernet-connected printer can be queried to determine its ink-level status, the EX1401 and EX1403A can be set up and monitored using a web browser.

Associated data acquisition software, such as general-purpose, modal, and high-speed data acquisition packages are available. However, free IVI drivers are available for Linux and Windows, along with documentation allowing users to create their own applications. These drivers can be accessed from within MATLAB from MathWorks, and free drivers are also available for use with LabVIEW from National Instruments.

Of particular interest for university settings, both the EX1401 and EX1403A support a driverless interface, thereby allowing custom test data acquisition software to be created in any programming language (Python, C, C++, C#, Java, …) and run under any operating system.

Figure 3. Both the EX1401 and EX1403A can be used as standalone devices or in rack-mounted installations.

Conclusion

Materials science has become a significant collaboration domain between academia and industry, with benefits accruing to both sides. Today, every major engineering university in the world has a materials science department. The exponential growth in the discovery of new materials coupled with the rising demand for specialist materials means universities are dramatically expanding their materials science courses and capabilities.

VTI Instruments has built an enviable reputation in test and instrumentation circles over several decades. VTI's instrumentation and data acquisition solutions are used around the globe to characterize the physical integrity and performance of everything from materials to large structures like engines, aircraft, and wind turbines.

VTI's EX1403A 16-channel precision bridge and strain gauge (also voltage and RTD) instrument and its EX1401 16-channel isolated thermocouple and voltage measurement instrument are particularly interesting to university materials science departments.

In addition to being cost-effective, highly accurate, and offering support for multiple sensor types, these test instrumentation products are easy to install and use. They can be used out-of-the-box with an accessible, free web-based interface. Off-the-shelf data acquisition software is available, but users can also employ free drivers and documentation to create their applications. Users can also create driverless applications using their chosen programming languages and operating systems.

References

1 https://www.lxistandard.org/

2 https://www.ivifoundation.org/

Request a Quote

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