Technology Focus: Test & Measurement

Simulation Testing of Embedded Flight Software

NASA's Jet Propulsion Laboratory, Pasadena, California

Virtual Real Time (VRT) is a computer program for testing embedded flight software by computational simulation in a workstation, in contradistinction to testing it in its target central processing unit (CPU). The disadvantages of testing in the target CPU include the need for an expensive test bed, the necessity for testers and programmers to take turns using the test bed, and the lack of software tools for debugging in a real-time environment. By virtue of its architecture, most of the flight software of the type in question is amenable to development and testing on workstations, for which there is an abundance of commercially available debugging and analysis software tools. Unfortunately, the timing of a workstation differs from that of a target CPU in a test bed. VRT, in conjunction with closed-loop simulation software, provides a capability for executing embedded flight software on a workstation in a close-to-real-time environment. A scale factor is used to convert between execution time in VRT on a workstation and execution on a target CPU. VRT includes high-resolution operating-system timers that enable the synchronization of flight software with simulation software and ground software, all running on different workstations.

This program was written by Mohammad Shahabuddin and William Reinholtz of Caltech for **NASA's Jet Propulsion Laboratory**.

Further information is contained in a TSP *(see page 1).*

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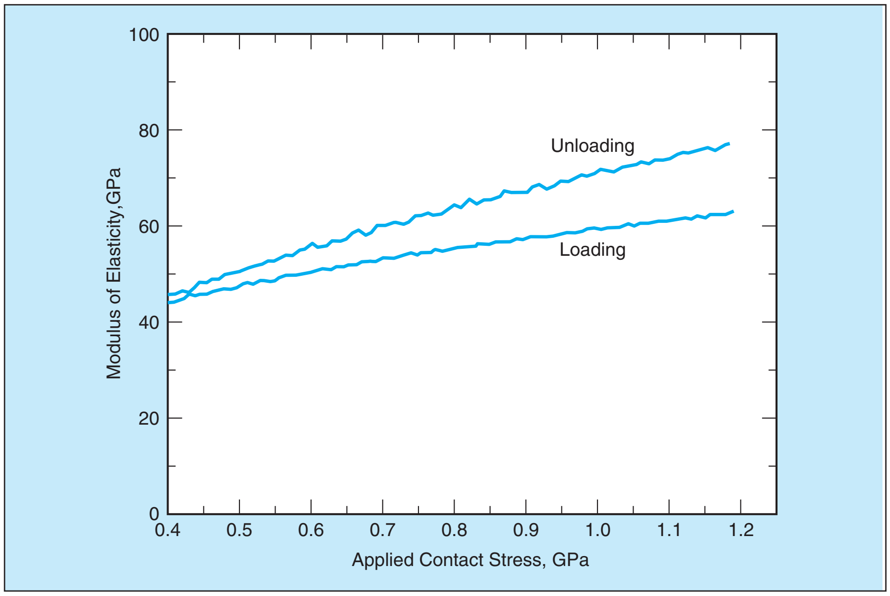
Improved Indentation Test for Measuring Nonlinear Elasticity

This technique is especially useful for characterizing thermal-barrier coating materials.

John H. Glenn Research Center, Cleveland, Ohio

A cylindrical-punch indentation technique has been developed as a means of measuring the nonlinear elastic responses of materials — more specifically, for measuring the moduli of elasticity of materials in cases in which these moduli vary with applied loads. This technique offers no advantage for characterizing materials that exhibit purely linear elastic responses (constant moduli of elasticity, independent of applied loads). However, the technique offers a significant advantage for characterizing such important materials as plasma-sprayed thermal-barrier coatings, which, in cyclic loading, exhibit nonlinear elasticity with hysteresis related to compaction and sliding within their microstructures.

A specimen to be tested by the cylindrical-punch indentation technique is prepared by standard metallographic procedures. The specimen is mounted on a load-versus-displacement-measuring apparatus, which could be any of a variety of indentation-type hardness testers or other conventional mechanical testing instruments. In the indentation test, the flat end of a round cylindrical punch is pushed into the polished, flat surface of the specimen. To minimize impression creep (a time-dependent plastic deformation that could contribute a large error to the modulus data), the specimen is preconditioned by pre-indenting it at a load greater than the load to be applied during the subse-



These **Plots of Modulus of Elasticity** as a function of applied stress were calculated from displacement-vs.-load data for a 127-μm-diameter flat-bottom cylindrical tungsten carbide punch against a thermal-barrier coating of plasma-sprayed ZrO_2 containing 8 weight percent of Y_2O_3 during the third load-ing/unloading cycle of an indentation.

quent test. Thereafter, the applied load is varied according to the specification for the test and the punch displacement is measured as a function of the applied load. The modulus of elasticity (for example, see figure) and, if desired, other aspects of the elastic response of the specimen material are computed from the displacement-versus-load data with corrections, if necessary, for the elastic response of the punch and the rest of the testing apparatus.

The flat-bottom cylindrical punch used in this technique offers important advantages over the pointed indenters used in traditional hardness testing: A pointed indenter is well suited to measuring hardness but is ill suited to measuring the modulus of elasticity of a specimen because the contact area is unknown and varies during the test, so that there is no simple relationship between applied load and applied stress. In addition, a pointed indenter causes significant plastic deformation (even at nearly zero applied load), which cannot easily be distinguished from elastic deformation. In contrast, while the flat-bottom cylindrical punch is useless for hardness testing, it is well suited for measuring the modulus of elasticity because its contact area is constant and, consequently, the applied stress is simply proportional to the applied load. Hence, the modulus of elasticity can be determined at every point on the load-versus-displacement curve. Also, if the applied load is limited to below the value corresponding to the contact stress at the onset of plastic deformation, the deformation can be relied upon to be elastic over a complete loading/unloading cycle, making it unnecessary to subtract the effects of plastic deformation.

This work was done by Jeffrey I. Eldridge of **Glenn Research Center**. *Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland Ohio 44135. Refer to LEW-17412.

Ultraviolet-Absorption Spectroscopic Biofilm Monitor

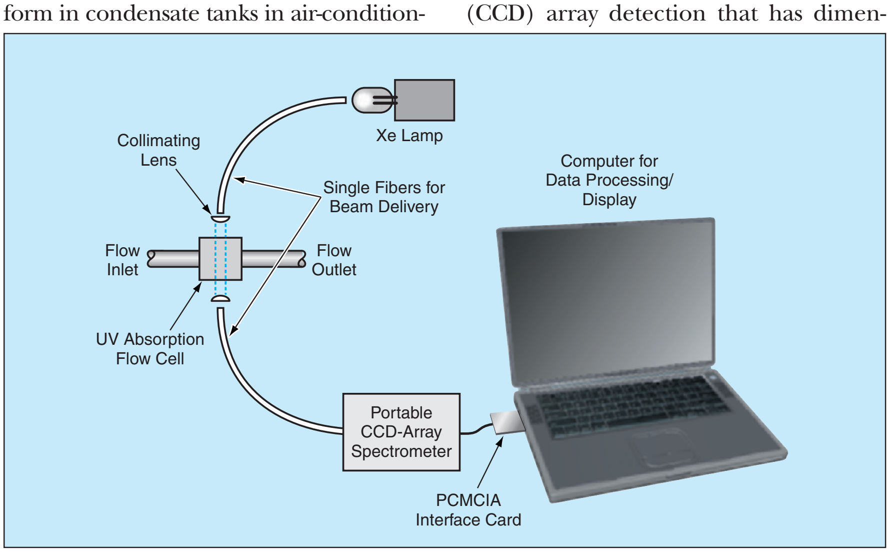
Continuous monitoring could provide early warnings of potentially harmful buildups of bacteria.

Lyndon B. Johnson Space Center, Houston, Texas

An ultraviolet-absorption spectrometer system has been developed as a prototype instrument to be used in continuous, real-time monitoring to detect the growth of biofilms. Such monitoring is desirable because biofilms are often harmful. For example, biofilms in potable-water and hydroponic systems act as both sources of pathogenic bacteria that resist biocides and as a mechanism for deterioration (including corrosion) of pipes.

Biofilms formed from several types of hazardous bacteria can thrive in both plant-growth solutions and low-nutrient media like distilled water. Biofilms can also form in condensate tanks in air-conditioning systems and in industrial heat exchangers. At present, bacteria in potable-water and plant-growth systems aboard the space shuttle (and previously on the *Mir* space station) are monitored by culture-plate counting, which entails an incubation period of 24 to 48 hours for each sample. At present, there are no commercially available instruments for continuous monitoring of biofilms in terrestrial or spaceborne settings.

The prototype biofilm monitor includes a commercial fiber-optic-coupled ultraviolet/visible (UV/VIS) spectrometer module with charge-coupled-device (CCD) array detection that has dimensions of 6 by 6 by 2 in. (about 15 by 15 by 5 cm) and that communicates with a notebook computer via a Personal Computer Memory Card International Association (PCMCIA) interface card. The instrument includes two 4-ft (1.2-m)-long optical fibers — one for coupling light from a xenon source to a flow-cell/fiber sensor assembly, the other for coupling light from the flow-cell/fiber sensor assembly to the spectrometer module. In the flow-cell/fiber sensor assembly, the ends of the fibers are coupled into the quartz windows of the cell with small collimating lenses. The inner surfaces of the windows are in contact with the flowing water to be monitored.



The **UV Absorption Spectroscopic Biofilm Monitor System** is based on a miniature UV/VIS spectrometer with a fiber-optic input and a CCD-array detector. This instrument measures UV absorption spectra of biofilms that form on the inner surfaces of quartz windows of a flow cell.

In tests of the prototype biofilm monitor, biofilms were found to produce characteristic absorption spectral bands at wavelengths from 230 to 400 nm. The absorption bands obtained from biofilms grown from a single strain of *Pseudomonas aeruginosa* were found to differ from the absorption bands obtained from biofilms grown from a mixed bacterial population from untreated urban river water; thus, it appears possible to use instruments of this type not only to detect biofilms but also to distinguish among species of bacteria in biofilms.

This work was done by Ronald H. Micheels of Polestar Technologies, Inc., for **Johnson Space Center**. *Further information is contained in a TSP (see page 1).*
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