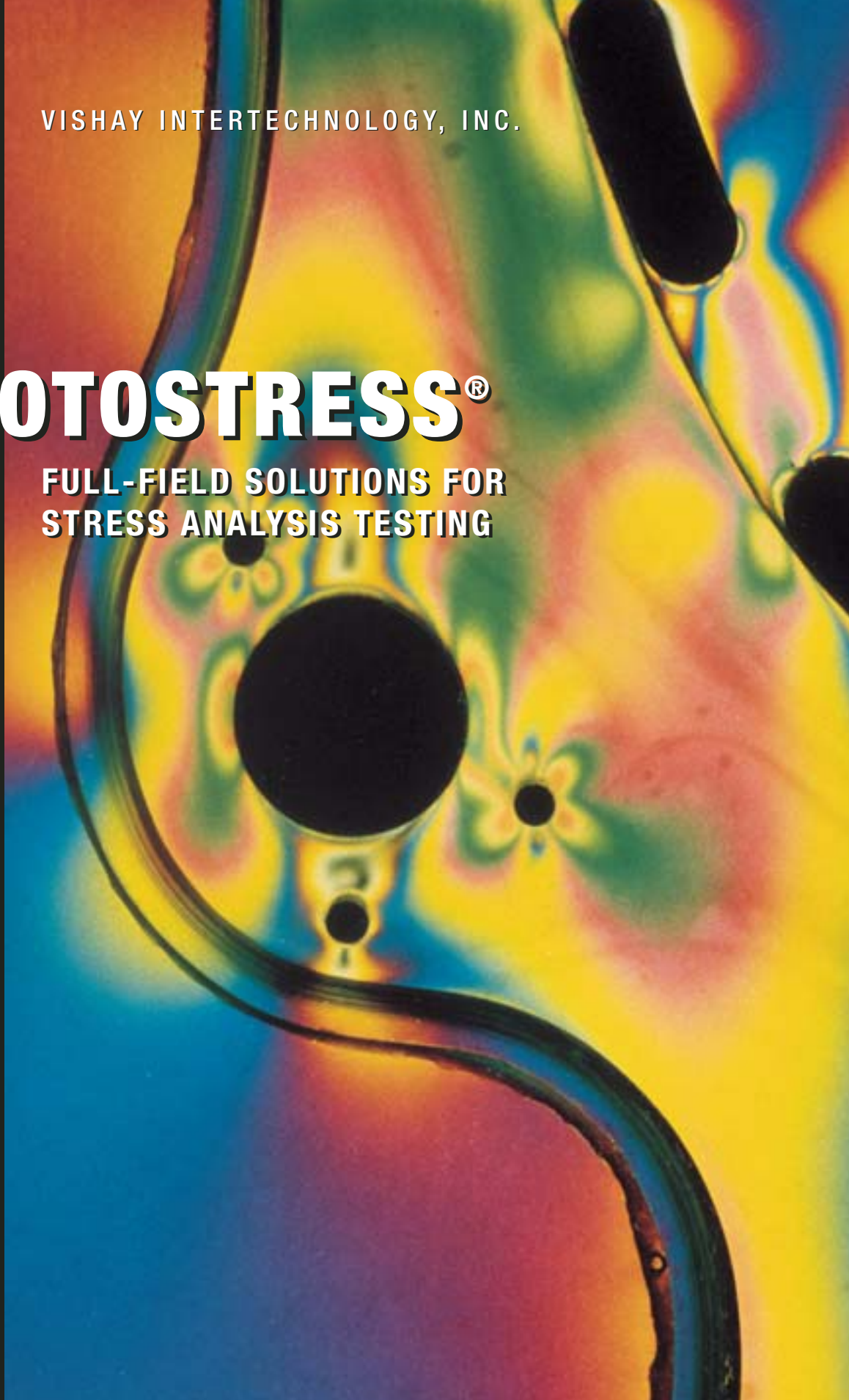
VISHAY INTERTECHNOLOGY, INC.

PHOTOSTRESS®

FULL-FIELD SOLUTIONS FOR STRESS ANALYSIS TESTING



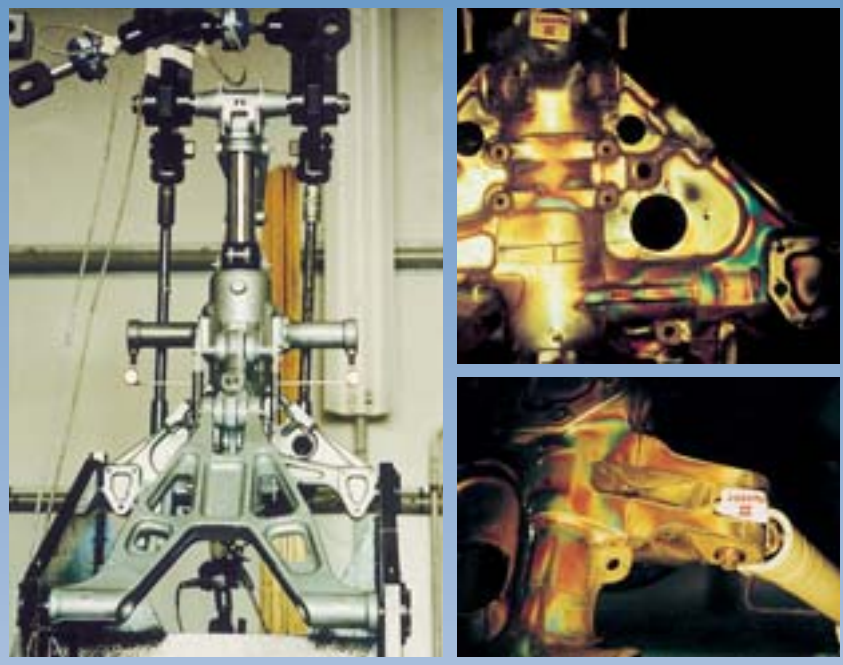
INTERTECHNOLOGY
1 Scarsdale Road
Don Mills, ON M3B 2R2
Tel: 416-445-5500 Fax: 416-445-1170 TOLL FREE: 1-800-465-1600
E-Mail: sales@intertechnology.com Website: www.intertechnology.com

What is PhotoStress?

PhotoStress® is a popular and widely used technique for measuring surface strains to determine the stresses on a part or structure during static or dynamic testing.

With the PhotoStress method, a special strain-sensitive plastic coating is first bonded to the test part. Then, as test loads are applied, the coating is illuminated with polarized light from a reflection polariscope. When viewed through the polariscope, the coating displays the surface strains on the part as a colorful informative pattern which immediately reveals the full-field strain (or stress) distribution over the entire coated area.

Using an optical transducer (electronic compensator) attached to the polariscope in combination with computer software, quantitative stress analysis is quickly and easily performed at any point on the test part. Also, with the use of digital video-imaging technology, the PhotoStress patterns revealed during a test, along with the calculated results obtained, can be viewed simultaneously by others by transmission over computer networks.



(Left) Aircraft landing gear coated for PhotoStress testing.
(Right) PhotoStress patterns showing strain distribution over different areas of gear during a load cycle.

What It Does

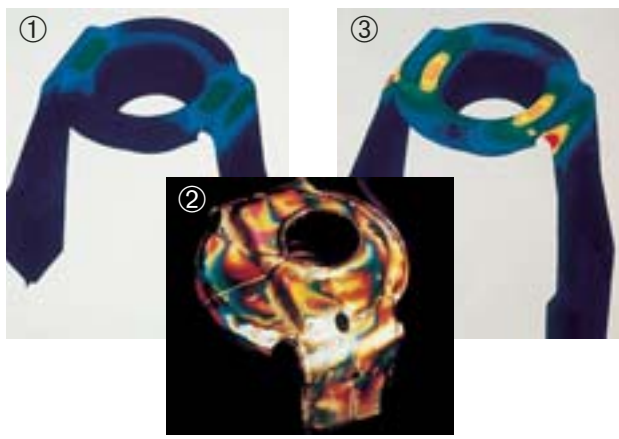
PhotoStress testing provides an accurate and economical means for stress analysis of any part or structure, regardless of the part's complexity or material composition. With PhotoStress you can . . .

- Instantly identify critical areas, highlighting overstressed and understressed regions.
- Measure principal stress directions and principal stress magnitudes.
- Accurately measure peak stresses and determine stress concentrations around holes, notches, fillets, and other potential failure sites.
- Optimize the stress distribution for minimum weight and maximum reliability.
- Test repeatedly under varying load conditions, without recoating the part.
- Make stress measurements in the laboratory or in the field — unaffected by humidity or time.
- Detect yielding, and measure assembly and residual stresses.

PhotoStress and Finite-Element Analysis

With today's sophisticated computer software programs, FEA is now widely used to help solve complex stress problems. But the design process for maximizing structural integrity and putting the product into service almost always requires qualification testing to verify the computed results. PhotoStress testing is an excellent tool to verify the accuracy of numerical results, and also serves as a guide for refining the FEA model. An example is shown here on an automotive suspension member:

1. Initial FEA model analysis
2. PhotoStress testing on actual prototype part
3. Corrected FEA model based on PhotoStress testing



The PhotoStress Plus System

PhotoStress Plus is a complete system for conducting photoelastic coating analysis. It incorporates the following features:

- A new Model LF/Z-2 Reflection Polariscope, which is simple to use and does not require any previous knowledge of photoelasticity.
- A digital video camera which is an integral part of the polariscope, allowing the PhotoStress patterns to be viewed on a computer or TV monitor, and recorded as still or moving images.
- A new electronic compensator combined with special software, which provides for quick measurement and calculation of the principal strains and stresses.
- A laser light that is built into the polariscope and permits viewing of the principal stress directions directly on the coated part or structure.
- A complete coating application kit for preparing parts and structures for PhotoStress testing.

The Measurement Process – 3 Simple Steps

1. Identify point(s) of interest from the full-field display of stress distribution.
2. To determine direction of principal stresses, a dial is turned on the polariscope until a black line covers the measurement point. Directions are then read on the dial and are also indicated on the structure by a laser light.
3. To measure stress magnitude, a knob is turned on a compensator attached to the polariscope, until color is eliminated at the point of measurement. A signal is then sent from the compensator to a computer which calculates the stress using PSCalc™ software.

Measurement of stress direction.

Measurement of stress magnitude*

*Directly measure $\sigma_1 - \sigma_2$ at any point, and σ_1 or σ_2 and sign at all free boundaries. Measure σ_1 and σ_2 and signs at any point using the Slitting Method.

PhotoStress Plus System Components

- Model LF/Z-2 Basic Polariscope
- Model 832 Electronic Compensator
- Laser Direction Finder
- Digital Video Camera
- PSCalc™ software
- Data acquisition card and software
- Calibration hardware
- Video imaging interface and software
- All cabling and computer interface hardware and software
- PhotoStress-coated startup demonstration sample
- Tripod
- Handgrip for portable operation
- Technical/operating manuals and application notes
- PhotoStress Coating Application Kit, includes:
  - ✓ Temperature-controlled casting plate
  - ✓ Teflon® carrier sheets
  - ✓ Silicone rubber snap-together molding frame
  - ✓ Mixing thermometer
  - ✓ All other supplies necessary for producing and bonding contourable photoelastic sheets to test-part surfaces

®Teflon is a registered trademark of DuPont.

TRIPOD MOUNTED

LF/Z-2 REFLECTION POLARISCOPE

HAND-HELD PORTABLE OPERATION

COATING APPLICATION KIT

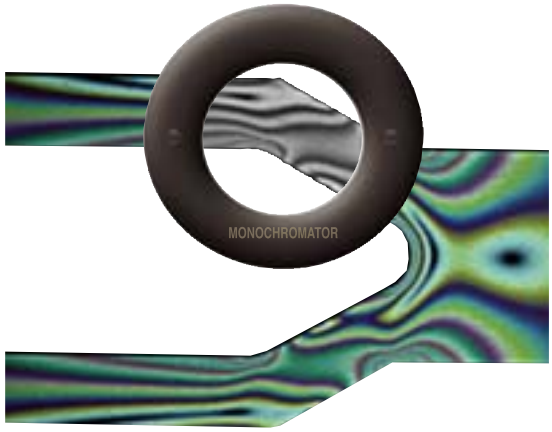
Accessories

Model 236A Stroboscopic Light

For stress analysis under dynamic conditions, the standard light source is removed from the polariscope and replaced with a strobe lamp. The lamp easily attaches to the Model LF/Z-2 Reflection Polariscope without affecting its portability. The primary feature of the Model 236A is its exceptional light intensity which is required for observing small areas at a distance, and for working in brightly lighted test areas. The complete Model 236A unit consists of lamp, power supply, and connecting cables.

Model 036 Monochromator

The monochromator is a high-quality interferential optical filter that produces a monochromatic light image of the colorful PhotoStress patterns when placed in the field of view. There are two principal applications of monochromatic light in PhotoStress testing: (1) observation of the stress bands in areas of high-stress gradient (in white light, the colorful pattern becomes paler at extreme high-stress levels), and (2) black and white photography of PhotoStress patterns. The monochromator can be hand-held, or mounted in a special housing for attachment to the video camera lens.



Slitting Tool Kit

In order to obtain principal stress values at locations removed from free boundaries, an additional measurement is necessary, which is obtained at a slit made in the PhotoStress coating (creation of an artificial boundary). The Slitting Tool Kit consists of a variable-speed motor connected to a flexible shaft with a cutting disc. With this device, it only takes a few seconds to make the slit. Also provided is a freezing spray to keep the surface of the PhotoStress coating from being overheated during the slitting process.

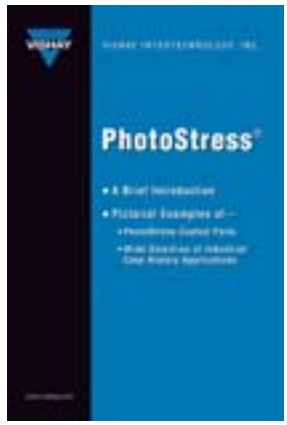
PhotoStress Coating Materials

The selection of PhotoStress coatings and their proper application to the test part is most essential to the success of PhotoStress analysis. A wide range of coating material is available in both flat-sheet and liquid form for application to metals, concrete, plastics, rubber, and most other materials. The coatings are carefully controlled formulations of resins blended to provide known and repeatable photoelastic properties, and are supplied with detailed application and handling instructions.

Applications

PhotoStress has an established history of successful application in virtually every field of manufacture and construction where stress analysis is employed. Areas of application include: automotive — farm machinery — aircraft and aerospace — pressure vessels — engines — appliances — office equipment — building construction — biomechanical — composite materials — and many others.

Shown on these pages are a few applications where PhotoStress testing was used. Other examples of PhotoStress coated parts and case history applications are vividly illustrated in a 46-page booklet, which is available on request.



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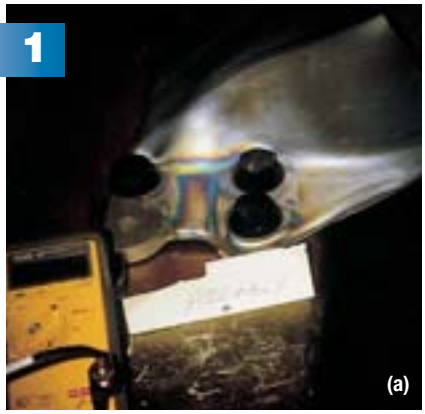

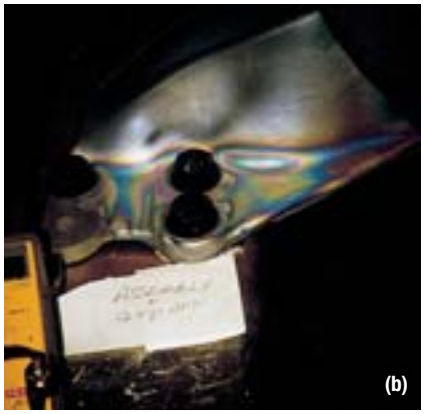

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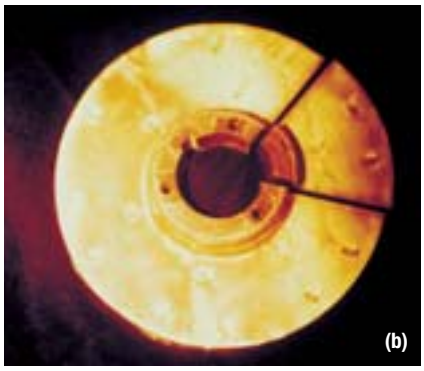

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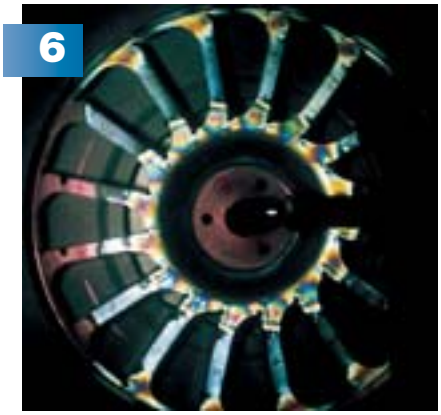

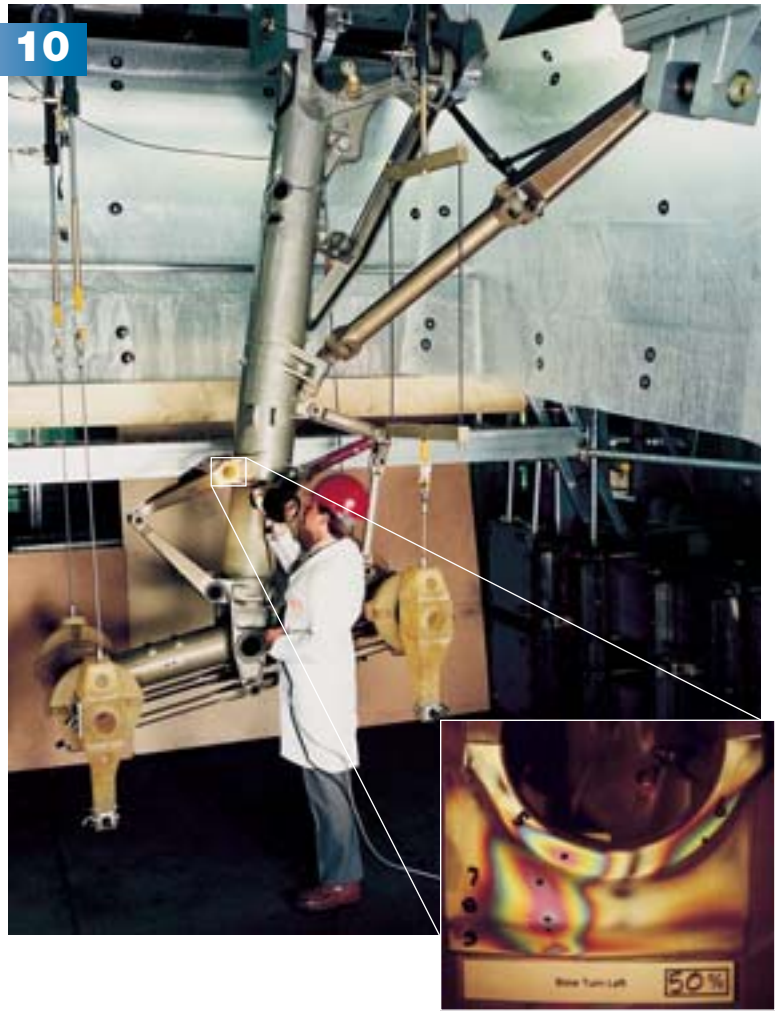

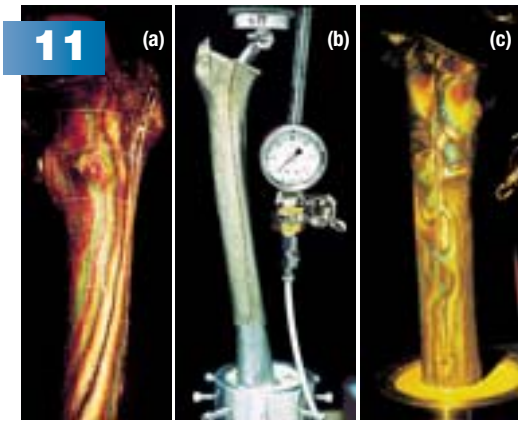

Key to Applications

1. Assembly stress analysis of spring hanger bracket on truck. (a) Stress resulting from bolt tightening only. (b) PhotoStress pattern from combined bolting and externally applied test forces.
2. Testing of a composite material structural panel.
3. Residual stress test on metal fan hub. (a) Hub was coated with PhotoStress plastic, then cut through to relieve the locked-in residual stresses. (b) Test was repeated on hub that was annealed after manufacture. After cutting, PhotoStress showed the absence of any residual stresses.
4. Stress analysis of welded area on base of street lamp post. PhotoStress coatings can be applied directly over welded joints.
5. PhotoStress validation of FEA analysis on automotive steering knuckle.
6. PhotoStress analysis of household dryer fan. There are many applications where PhotoStress can be used to analyze stresses due to dynamic events.
7. PhotoStress yield pattern originating from notch in metal test sample.
8. Testing of automobile tires. PhotoStress can be used on elastomeric materials up to 100% elongation.
9. PhotoStress testing on military aircraft panel.
10. PhotoStress analysis on a “scale model” of an aircraft landing gear.
11. PhotoStress analysis of the proximal femur to evaluate stress transfer for total hip replacement. (a) Stress pattern on femur before implant. (b) PhotoStress-coated femur with implant inserted. (c) Stress pattern after loading through implant. In other biomedial applications, PhotoStress has been used on the skull, pelvis, knee, and dental implants and bridges.