Issue 43

In This Issue

Ouch, That's Gonna Leave a Bruise

Composite materials that copy the body's ability to bruise and self-heal when damaged should simplify and reduce the costs of examining and evaluating structures.

The demand for composite materials is increasing worldwide. Their light weight, combined with exceptional strength, make them ideal for use as wind turbine blades, major aircraft components such as wings, and so on. However, they have low fracture toughness and a low resistance to crack propagation. In other words, they don't tolerate impact damage well.


Photo courtesy of NASA Dryden Flight Research Center Photo Collection

All structures in service deteriorate over time. Designers build in overcapacity to cater for the stresses from normal operation when designing structures and components. However, impacts from clumsy handling, bird-strikes, and so on, can cause damage that may be severe but almost impossible to detect without expensive testing methods and equipment. Many researchers are looking to nature, more specifically to the ability of living systems to bruise and to heal after injury.

In nature, bruising occurs when tiny blood vessels near the surface are ruptured by an impact. Blood leaks from the damaged vessels into the surrounding tissues and the subsequent discoloration is visible through the skin.

Bruising in composite materials is achieved in a similar fashion. Microcapsules containing dye chemicals are incorporated into a surface coating, typically a gel coat. An impact ruptures the capsules and releases the chemicals. In the simpler types, the ruptured capsules just spill their colored contents, while other types use a chemical reaction to create the bruised effect. Where cosmetics are important, such as the surface of an aircraft, the bruise may be actually colorless, but will fluoresce under ultraviolet light to indicate areas where deeper inspection may be required.

Healing in nature similarly involves bleeding at the wound site, and continues with clotting and scabbing of the blood in the wound. To reproduce this process in composite materials, researchers are experimenting with incorporating hollow glass tubes and microcapsules into the material itself during manufacture. Some of the tubes or capsules contain a resin, and others contain a catalyst or hardening agent. The theory is that an impact that causes cracks in the material will cause the tubes to rupture, releasing their contents into the crack. The resin and catalyst mix and harden into an epoxy plug, thereby healing the damage. Further, the chemical action can be made to cause a color change or to fluoresce, "bruising" the material.

As with any new technology, there are problems to solve. Incorporating glass tubes or microcapsules into a composite material is bound to cause some reduction in the structural integrity of the material. There must be a sufficient number of hollow tubes or capsules within the material to create the healing effect, but not so many that it destroys the integrity of the original material. Other factors include the sort of damage that is anticipated. If you have the glass fibers nearer the surface, they are more likely to be damaged in an impact, but it may be that it is the deeper damage that is structurally more compromising. The arrangement of the tubes or microcapsules is therefore very dependent on the type of risks that are likely to occur in service.

This research and development exemplifies a growing interest in the wider field of biomimicry for engineering materials and structures. The challenge is to understand the functional characteristics of natural systems in order to produce systems that work with engineering structures, feasibly and economically.

Perpendicularity in Rockwell Testing

It is a fundamental requirement in Rockwell testing that the surface to be indented must be perpendicular to the direction of travel of the indenter and that the test piece does not move or slip during the test cycle. A study showed that the effect on the HRC scale indicated a tilt angle of one degree between the specimen surface and the axis of the indenter could result in a 5% error in hardness. The perpendicularity of the indenter to the specimen is influenced by many factors including how parallel are the opposing surfaces of the material, and the dimensions and angles of the supporting anvil and the mechanical components in the tester.

The indenter and indenter holder play a crucial role in perpendicularity. If specimen movement is transferred to the indenter and the measurement system, an error is introduced into the test. With the depth measurement for one regular Rockwell point being just 0.002 mm or 0.000080 in., it is clear that such exact measurement requires a very precise measuring system and, just as important, a highly controlled process.

Q. How can I minimize variability when testing stiff materials such as composites?

A. Achieving consistent, repeatable results requires consistent, repeatable testing conditions. The major sources of variability when testing stiff materials such as composites are gripping and alignment.

Proper gripping of stiff materials or coupons is best done with a powered grip. Powered grips are most often driven by hydraulics or pneumatics, and offer the most repeatable conditions since the operator is not directly involved. Manual grips are subject to variability due to different operators applying different forces when tightening the grip onto the specimen. Furthermore, it is best that these powered grips are rigidly mounted and preloaded. Flexible couplings or loose joints can easily cause bending strains outside of NADCAP or ASTM bounds, and introduce a significant amount of scatter in results.

Finally, the location of the specimen in the grips also plays a significant role in producing repeatable results. Round specimens are less of an issue, since the "Vee" in the grip face positively locates and centers the specimen. Flat specimens, however, require specimen alignment stops to ensure that they are located in exactly the same place for every test. You should reset these alignment devices with every change in specimen geometry.

Rigid load strings, powered grips, and specimen location alignment devices are all technologies which, when combined with careful testing technique, can go a long way to maximizing measured mechanical properties, and minimizing variability.

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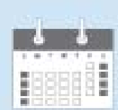

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