AN INTEGRATED SOFTWARE/HARDWARE APPROACH TO EXPERIMENTAL STRESS ANALYSIS

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Probably most "seasoned" engineers associated with design, testing, or failure analysis of mechanical components or structures can recount instances where a design or measurement problem could not be solved, at least in a cost-effective way, due to lack of access to a computer or computerized test instrumentation.

For example, new product designs that should have been subjected to a rigorous testing program may instead have been designed with excessive safety factors, increasing material costs and weight with no real guarantee of increased reliability. Or, if an existing design failed, the time required for failure analysis to determine the root cause of the failure might have been prohibitive, and the new component simply made "larger and stronger" increasing cost and weight with no guarantee of increased performance or service life.

Experimental Stress Analysis is often called the quality control of design. The most widely used method of experimental stress analysis involves the use of electrical resistance strain gages adhesively bonded or spot welded at discrete points on the test part surface. The measured strain values are used to determine the magnitudes and directions of principal stresses on the surface when the test part is subjected to various test loads. Analysis of a large or complex part or structure may necessitate measurement at numerous test points, under a large number of actual or simulated in-service loading conditions, resulting in enormous amounts of data being acquired.

In smaller organizations without access to a computer, the time required for data acquisition and analysis may simply be prohibitive. In larger organizations, where a computer is available, data may be manually collected and presented to the computer department for data reduction using software written by the test engineer. But this may mean lengthy time delays between the acquisition of data and analysis of test results. Further, the test engineer might have no indication of faults in the test instrumentation system that might produce useless data, or worse, the applied test loads might produce dangerously high stresses in the test part that would not be realized until subsequent data reduction. In either case, costly re-testing may be required.
A partial solution then, for both large and small organizations, is to have a low-cost personal computer available for data reduction at the test site. But even this approach is significantly limited because the measurement instrumentation generally is not directly compatible with the available (computer) hardware, and test data must first be acquired by the test instrumentation and then entered, by hand, into the computer for reduction and analysis. Furthermore, appropriate software for data analysis and presentation is not generally commercially available, and must be specially designed by the test engineer.

While some test engineers have become, or have access to, expert computer programmers, accurate strain gage data reduction requires an extensive understanding of the behavior of the strain gage and all possible error sources that must be accounted for to produce accurate test data. And in addition, these connection factors must be applied at precisely the appropriate point in the data reduction process.

For example, measured strain data may contain significant errors due to thermally induced "apparent strain," and a change in strain gage sensitivity, or gage factor, resulting from a change in temperature of the test part. Apparent strain will be a constant value at a given temperature regardless of the magnitude of any load-induced stress or strain in the test part. And therefore, if not accounted for, the percentage of error introduced into the measurement varies inversely with the magnitude of the test load. The change in gage factor of the strain gage will be manifested as a change in calibration with a change in temperature of the test part, referred to as temperature coefficient of gage factor. The error magnitude will be a fixed percentage of the measured strain value at a given test temperature, but will vary in direct proportion to test temperature.

These temperature-induced errors are repeatable and predictable (See Figure 1), and must be accounted for to obtain accurate stress and strain data when a change in temperature will occur during the test sequence.

Another common error source is the transverse sensitivity of the strain gage grid. The strain gage is designed for maximum sensitivity to surface strain in the test part parallel to the primary sensing axis of the strain gage grid, and minimum sensitivity to strains transverse to the primary sensing axis. While this transverse sensitivity is generally a small percentage of the strain gage gage factor, it can introduce significant errors in strain measurements obtained in a biaxial stress field where the transverse strain may be several times greater than that along the gage primary sensing axis. (See Figure 2).

The strain gage is most commonly connected as a single, variable-resistance arm of a Wheatstone bridge circuit. This "quarter-bridge" configuration is a non-