NASA TECH BRIEF
Flight Research Center

High-Temperature Capacitive Strain Measurement System

The problem:

Bonded-resistance strain gages provide very efficient means of measuring stress-induced strain and canceling thermal expansion strain at temperatures up to about 650° F (343° C). The means for measuring stress-induced strain at temperatures above 650° F are very limited.

The solution:

A capacitive strain gage and signal conditioning system that measures stress-induced strain and cancels thermal expansion strain at temperatures to 1,500° F (815° C) has been designed.

How it's done:

The system consists of a capacitive strain gage (Figure 1) that mounts directly on the specimen surface and converts the stress-induced dimension changes into: (a) changes in capacitance; (b) conditioning electronics (Figure 2) which provide a carrier voltage to the capacitive gage and demodulate the signal from the gage, producing an analog voltage proportional to strain; and (c) a three-conductor lead wire assembly connecting the gage and the conditioning electronics. The gage consists of a link about 1 in. (2.54 cm) long, which spans that portion of the specimen over which stress-induced strain is to be measured, and a capacitance-based linear differential displacement sensor. The link is rigidly attached to the specimen at one end and is left relatively free (in the strain-sensing direction) at its other end. This link serves to sum the accumulated specimen strain beneath it and to transfer the relative motion to the displacement sensor located at its free end.

When the link is fabricated from the same material as the test structure, the thermal expansion strain in the structure is canceled by the thermal expansion strain in the link, so that only stress-induced strain is transferred to the differential capacitive displacement sensor. Errors resulting from specimen bending are nullified by flexures that cause the gage to measure the chord strain between its points of attachment to the test specimen, even though the link and the displacement sensor are located above the specimen surface.

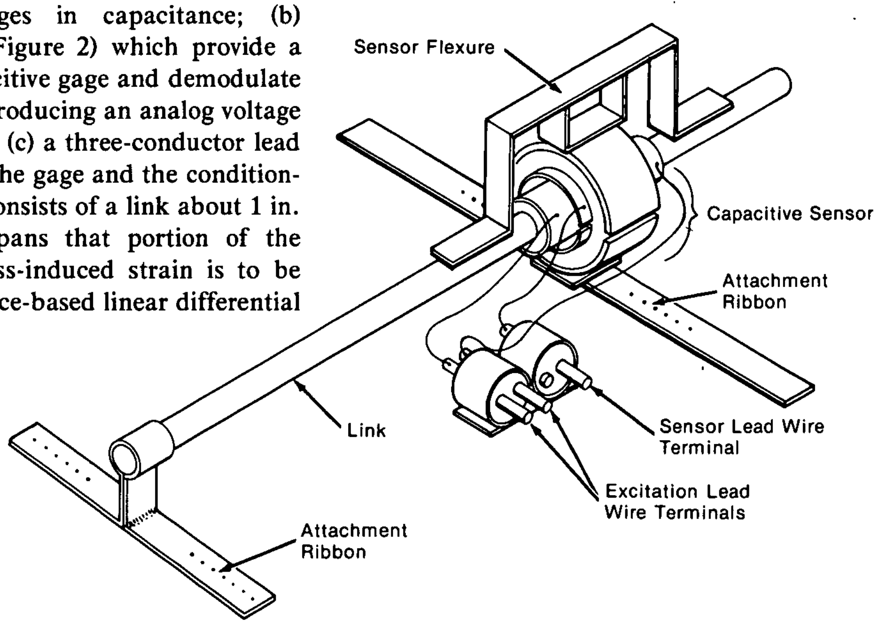

Figure 1. Capacitive Strain Gage Assembly

(continued overleaf)

Figure 2. Signal Conditioning System

The gage operates at temperatures to 1,500° F and does not significantly restrain or reinforce the specimen. The system has a resolution of better than 1 $\mu\varepsilon$, a range of over ±20,000 $\mu\varepsilon$, and excellent linearity and temperature stability. It measures static as well as dynamic strain and changes sensitivity less than 5 percent between 70° and 1,500° F (21° and 815° C). System performance is not critically dependent on the length of the cable between the gage and the conditioning electronics.

Notes:

1. The high-temperature capacitive strain gage was originally conceived and developed by The Boeing Aerospace Company under NASA Flight Research Center contract NAS4-1403. Further evaluation and improvement of the system were accomplished by Boeing under NASA contracts NAS4-1684 and NAS4-1812. Still further improvements have been and are being made at Boeing.
2. Boeing has licensed its rights to the capacitive gage system to HITEC Corporation which is now manufacturing and commercially marketing the system. Information about the system can be obtained from:

   HITEC Corp.
   Snake Road
   Westford, Massachusetts 01886
   Phone: (617) 692-4793

Patent status:

Title to the inventions of the portions of the system developed under NASA contracts has been waived under the provisions of the National Aeronautics and Space Act [42 U.S.C. 2457(f)], to The Boeing Company, Seattle, Washington 98124.

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