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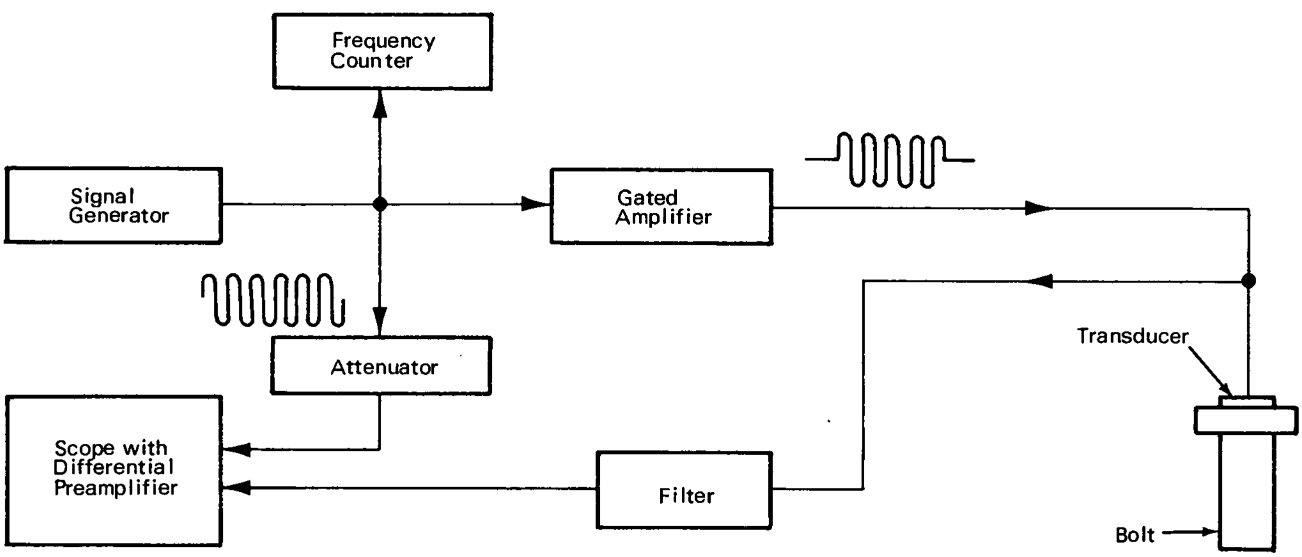
NASA TECH BRIEF

Marshall Space Flight Center

Instrument Accurately Measures Stress Loads in Threaded Bolts

An interferometric instrument, employing a frequency-nulling circuit and an ultrasonic (piezoelectric) transducer, accurately measures axial tensile stresses in threaded bolts during the tightening process. The response of the measuring instrument is linearly related to the axial tensile stresses, and, under idealized conditions, measurement errors are within approximately ±1%. The ultimate accuracy of the instrument depends on a number of variables, such as bolt material, dimensions, and geometry, and uniformity of stresses and temperature. The errors increase as the conditions depart from the ideal; but stresses on samples of as-received bolts have been measured with errors of less than ±5% (as compared with torque-wrench measurements which often exhibit errors of ±25%). The more accurate results were achieved with the frequency nulling instrumentation, using tools consistent with normal bolt-tightening procedures. Best results are obtained with the ultrasonic transducer contact-coupled to the bolt head; this coupling is facilitated by having a small flat area near the center of the bolt head.



Operation of the instrument (see fig.) is based on the fact that mechanical stresses produce small changes in the propagation velocity of ultrasonic waves traveling through metals. The piezoelectric transducer is coupled to the bolt head and driven by an rf pulse from the gated amplifier. A variable-frequency cw signal from the signal generator is fed to the frequency counter and the gated amplifier. The electrical signals generated at the transducer by the stress-induced ultrasonic echoes from the opposite end of the bolt are then fed through the filter to one input of the differential preamplifier

(continued overleaf)

coupled to the oscilloscope. The filter reduces saturation in the preamplifier by blocking the passage of the large rf driving pulse and permitting the weaker echo signals to pass. Part of the cw signal from the signal generator serves as the other input to the differential preamplifier, which ultimately mixes this signal with the echo signals from the bolt. Data are obtained by varying the frequency and amplitude of the first echo signal until almost complete destructive interference (or a null condition) between the cw and echo signal is observed on the oscilloscope. The frequency indicated by the counter is then recorded.

Clean echo signals can be reproducibly nulled with frequency variations of less than 100 Hz. With a typical cw frequency of 10 MHz, a given null frequency can be determined with an error of about 1 part in 10^5. The bolt stress is calculated from an equation which expresses the stress as a function of the bolt geometry, dimensions, and material constants, and the observed null frequency.

Notes:

1. This ultrasonic-interferometric method may be adapted for the analysis of plastic yielding and bending in threaded bolts.
2. The following documentation may be obtained from:

   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)

   Reference:
   NASA CR-102929 (N71-12965), Fastener Load Analysis Method

Patent status:

No patent action is contemplated by NASA.

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