Uncertainty Analysis of Kolsky Bar Strain Gage Output

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An apparatus has been built at the National Institute of Standards and Technology (NIST) to measure the dynamic stress-strain relationships for metals at elevated temperatures. The NIST Pulse Heated Kolsky Bar apparatus has the capability to resistively heat samples to over 1000 C with heating rates of over 10 000 C/s in addition to performing the traditional Kolsky bar impact testing. The traditional Kolsky bar (or Split Hopkinson Pressure Bar) consists of two long hardened steel bars aligned end-to-end with the sample sandwiched in between the bars. A test is carried out by striking the end of the incident bar with a projectile fired from an air gun that sends an elastic wave down the bar, which then rapidly deforms the sample. As the sample is deformed a transmitted wave is started down the second bar. Standard variable resistance metal foil strain gages are mounted in the center of each of the long bars that measure the amplitude of the strain wave as a function of time. The outputs of the strain gages are recorded on a standard digital oscilloscope data acquisition system. Using the strain gage signal recordings a high-strain rate stress-strain curve for the sample material can then be calculated using a well established method. Our Kolsky bar apparatus can test samples at strain rates from about 500 /s to 10 000 /s (normal compression machines in materials test labs operate in the range of 0.01 /s and under special conditions can go as high as 100 /s.) By measuring the temperature of the sample during the deformation (the deformation takes approximately 150 microseconds) the stress-strain curve can be reported for various temperatures.

The strain gage measuring system is calibrated by a standard method of shorting a large precision resistor across the gage and recording the output. The uncertainty of the simulated strain in this parallel resistor calibration method depends on the uncertainty of the value of the parallel resistor, the gage resistance, and the manufacturer's gage factor. There is an additional contribution to the uncertainty of the measurement results because of the dynamic effects on the gage factor. To understand the accuracy of the strain gage output the different uncertainties need to be combined in an uncertainty analysis. The uncertainty analysis of the strain gage calibration method presented in this paper uses an approach based on NIST Technical Note 1297. Future papers will address the uncertainty of the temperature measuring methods and some of the effects of the assumptions used in the Kolsky bar simple theory for relating strain in the elastic bars to the stress and strain in the sample.