TS-SSC 90-083
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Analysis of Fermilab Calibrated Collar Gages

In TS-SSC 90-069 the calibration of two sets of beam strain gages were analyzed. The gages in the first set were both assembled and calibrated at Brookhaven National Laboratory (BNL) and the second set was assembled at Fermilib but calibrated at BNL. In this note a similar analysis for a set of 16 gages assembled and calibrated at Fermilab is discussed. These gages have been installed in magnet DC0303. They were calibrated both warm and cold using a Fermilab fabricated 10 stack of length 4.125" (a "long" 10 stack).

The qualitative behavior of the 16 gages in this sample is similar to that of the gages calibrated at BNL. The stress versus strain calibration curves are shown in figure 1. The standard deviation of the stress distribution at 1500 μstrain for the warm calibrations is 1465 psi. This compares with 1300 psi for the BNL calibrated gages. The best linear approximations to these calibration curves over the range [200μstrain,2500μstrain] are:

$$\text{Stress} = (-2160 + 7.8 \times \mu e) \ \text{lbs/in}^2 \quad (300°K)$$

and

$$\text{Stress} = (-2680 + 10.3 \times \mu e) \ \text{lbs/in}^2 \quad (4.2°K).$$

This is to be compared with:

$$\text{Stress} = (-1400 + 8.6 \times \mu e) \ \text{lbs/in}^2 \quad (300°K)$$

and

$$\text{Stress} = (-2000 + 11.3 \times \mu e) \ \text{lbs/in}^2 \quad (4.2°K)$$

for the BNL calibrated gages. The shallower slopes for the Fermilab gages is to be expected from the apparently lower modulus 10 stacks used. A quantitative determination of the difference in modulus of the Fermilab and BNL 10 stacks is being planned by Dick Simms. A comparison of the modulus of the Fermilab 10 stack and the Fermilab coils will also be made.

There are two ways in which the consistency between calibrations might be improved from that displayed by these gages.

The first is to use the measurement of the pressure sensor at the moment the gage indicates a positive pressure is being applied to the block as an offset to all subsequent pressure measurements. The calibration data for these gages was not corrected for this effect, with the consequence that the initial zero strain reading of the gage fluctuated over several hundred psi and hence the errors in the determination of the strain to stress coefficients could be sizeable. Of course one must determine that offsets measured initially remain constant over the range of calibration before this correction is applied. Mark Davidson is currently working on this. A second possible way to improve the consistency from gage to gage is to fit the data beginning at 1000 psi, effectively making this the lower limit of the gages range. This would eliminate trying to fit data during the period when the "fluff" in the 10 stack is being compressed out, which may vary widely from stack to stack. Measurements of coil stress which are below 1000 psi are currently suspect for this reason.

There are two additional suggestions which might be applied to calibrations. The first is to require that the calibration curve for a gage pass an acceptance criterion. Gages of questionable quality as well as software errors could be tagged in this way. The criteria might be as simple as requiring that each calibration curve lie in a range bordered by the lines specified by:

$$\textbf{Stress} = (\approx -1000 + 7.8 \times \mu\varepsilon)\ \textbf{lbs/in}^2$$

and

$$\textbf{Stress} = (\approx -3000 + 7.8 \times \mu\varepsilon)\ \textbf{lbs/in}^2$$

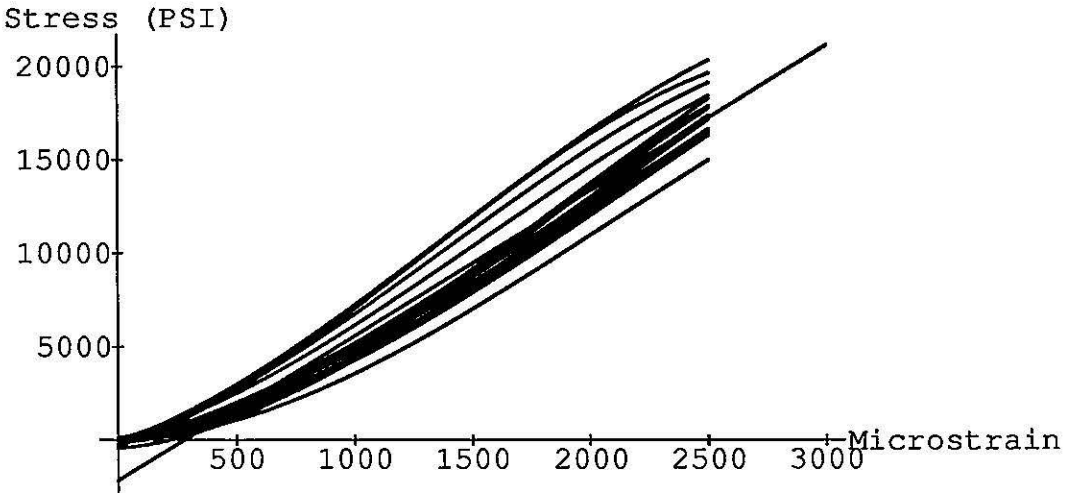
at 300°K and:

$$\textbf{Stress} = (\approx -2000 + 10.3 \times \mu\varepsilon)\ \textbf{lbs/in}^2$$

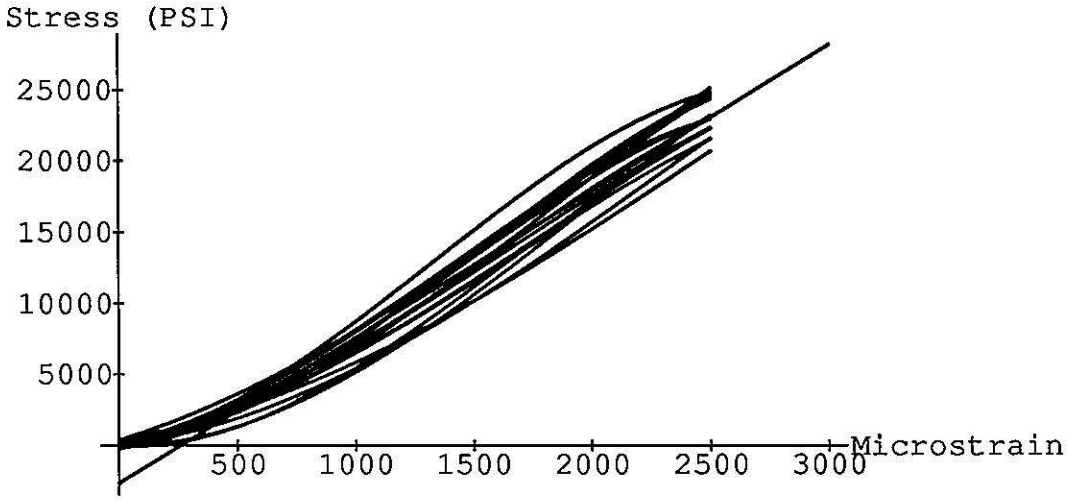
and

$$\textbf{Stress} = (\approx -4000 + 10.3 \times \mu\varepsilon)\ \textbf{lbs/in}^2$$

at 4.2°K. The constant terms in the above expressions would have to be tuned once we determine how consistently gages will be calibrated in the future. The second suggestion is to include the goodness of fit parameter (chi squared) along with the fit coefficients. This would give the user of the gage further information as to how good the calibration is.



FNL gages calibrated at FNL at about 300°K. The line shown is the best linear fit to these curves over the range of 200 to 2500 microstrain. It has the form -2162+7.76x.



FNL gages calibrated at FNL at about 4.2°K. The line shown is the best linear fit to these curves over the range of 200 to 2500 microstrain. It has the form -2681+10.3x.

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