MECH 493 project:

Residual Stress Identification of Double Yield Points in Mild Steel

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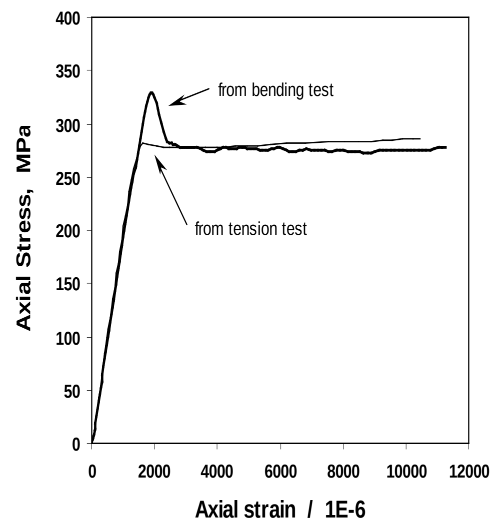
Background and Research Goal

Mild steel is unusual in that it can have a double yield point. During a tensile test, the stress rises linearly according to Hooke's Law until an "upper yield point" is reached. The stress then rapidly falls 5-10% to a "lower yield point", from which ductile yielding at approximately constant stress continues. The effect is not easy to observe and can easily be missed if the testing machine is not sufficiently stiff. The effect can be more consistently observed during bending testing, where the through-height linear strain distribution that occurs during loading causes the double yield point behaviour to be reproduced within the beam cross-section. On unloading, remnants of these stresses become imprinted in the form of residual stresses.



The Slitting Method is an effective modern method for evaluating residual stresses. It involves measuring the deformations that occur during the progressive cutting of a slit through the material thickness. The residual stresses can then be evaluated from the deformation measurements. The research interest here has three main aspects:

1. confirmation that the double yield point phenomenon leaves its imprint within the loaded beam cross-section
2. demonstration of the capability of the slitting method to observe the double yield point phenomenon. This case is interesting because the effect is very localized, so the ability to observe it would give a good demonstration of the ability of the Slitting Method to resolve fine spatial details.
3. the measurements for the Slitting Method are typically done using strain gauges, and this approach will initially be used here. Subsequently, a new measurement approach is planned using Electronic Speckle Pattern Interferometry (ESPI). This is a full-field optical method and can give a much richer and potentially more informative data set. This use of ESPI is novel and would represent a substantial advance in the application of the Slitting Method.

The use of ESPI with the slitting method is the long term goal (3) of this project. Reaching that point will be very challenging and may not be achieveable within one year. This will very much depend on the number of people working. The project would be suitable for 1-2 hands-on students, possibly 3 depending on personal dynamics.

Anticipated Work

1. Strain gauge a bending specimen, load it into the plastic region while measuring surface strains. Use an inverse calculation to infer the uniaxial stress-strain curve (hopefully demonstrating the double yield point).
2. Build an apparatus for doing slitting (using a three-axis motorized stage and motorized cutter). Write custom control software, likely in Matlab.
3. Use apparatus to do a Slitting Method measurement using strain gauges. Using an inverse calculation to infer the residual stress cross-section (again hopefully demonstrating the double yield point).
4. If making really good progress, build an ESPI system for in-plane measurements on the Slitting Method specimen.
5. Use the apparatus to do a Slitting Method measurement using ESPI measurements. Do an inverse calculation to infer the residual stress cross-section (once again hopefully demonstrating the double yield point).
6. If all goes well, write a rather nice research paper.

Facilities and team:

The student(s) will work in a lab with professor and senior PhD student in a lab full of optics equipment and mechanical tools. The computational parts of the project will be very challenging and help will be available for this part. Guidance will be available for all other parts as well, although it is hoped that student(s) will display substantial initiative and will work largely independently.