Anomalous plasticity in the torsion of thin metallic wires

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Many experiments have found that the plastic behavior of metals at the micron and sub-micron scales is obviously different from the classical plasticity. Torsion of micro-dimensioned metallic wires has been viewed as one of the most fundamental approaches for characterizing the mechanical behavior of small volumes. In this talk, the anomalous plasticity of micron-scale metallic wires will be systematically discussed experimentally and theoretically. Firstly, in order to characterize the torsional behavior of microwires, an automated torsion tester has been established based on the principle of torsion balance. The torsion tester permits the measurement of torque to nN·m, as a function of surface shear strain to a sensitivity of sub-microstrain. An electro-mechanical wire tensile tester has also been designed as a complementary test to torsion experiment. Then, we performed (monotonic and/or cyclic) torsion and tension tests on polycrystalline copper and gold wires. It is found that (i) a size effect appears in both the initial yielding and the plastic flow of torsional response; (ii) a reverse plasticity (anomalous Bauschinger effect) occurs upon unloading in cyclic torsion response; (iii) the Hall-Petch effect and the strain gradient effect are synergistic, and the interaction between two effects strongly depends upon the grain size; (iv) a significant strain gradient effect is confirmed in torsion of coper wires with different diameters but the same grain size. Finally, four phenomenological theories of strain gradient plasticity, due to Fleck and Hutchinson, to Chen and Wang, to Aifantis and co-workers, and to Nix and Gao are assessed within the context of wire torsion and tension data, and the corresponding rigid-plastic solutions are derived. Distinctions between the theories are highlighted through comparison with experiment, emphasizing the difference in predicted trends in the size dependence of initial yielding and of hardening rate.

Short bio: Dr. Dabiao Liu is an associate Professor of Department of Mechanics, Huazhong University of Science and Technology (HUST), China. Dr. Liu received his Ph.D. from HUST in 2014. He then worked as a Lecturer, then associate Professor, of solid mechanics at HUST until now. During 08/2016 to 01/2018, he was a Marie Skłodowska-Curie Research Fellow at School of Physics and Astronomy, Queen Mary University of London (QMUL). Currently his research interests focus on small-scale plasticity, mechanical behavior of fibers/silks/yarns, and experimental mechanics. As a leading author or corresponding author, he has published more than 20 peer-reviewed papers on these topics. Many of these works appeared in journals with good impacts, e.g. Science Advances, Phys. Rev. Lett. , Int. J. Plasticity, Acta Mater., APL, etc. His recent work on spider silk has aroused remarkable media interest, with interviews on the BBC World Service, and pieces in the Science, Nature, Daily Mail, Materials Today, Physics word, Physics Today, Science Daily, etc.