
Measuring plastic anisotropy and toughness at small scale

Veronique Aubin^{*1}, Vivien Lefranc¹, Abir Boujnah^{1,2}, Enzo Ceron Arana^{1,2}, Louis Cornet¹, Eva Héripré³, Camille Gandiolle¹, Jan Neggers¹, and Denis Solas⁴

¹Laboratoire de Mécanique Paris-Saclay – Université Paris-Saclay, CentraleSupélec, ENS Paris-Saclay, CNRS, LMPS - Laboratoire de Mécanique Paris-Saclay, 3 rue Joliot-Curie, Gif-sur-Yvette, 91190, France – France

²Manufacture Française des Pneumatiques Michelin – Manufacture Française des Pneumatiques Michelin – France

³Laboratoire Procédés et Ingénierie en Mécanique et Matériaux – École Nationale Supérieure d'Arts et Métiers (ENSAM) – France

⁴Université Paris-Saclay, CNRS – Institut de chimie moléculaire et des matériaux d'Orsay – France

Abstract

Some materials are available in very small volumes, yet their mechanical properties have a strong influence on those of the structure. This is the case, for example, with steel drawn wires. These wires are obtained by wire drawing after severe plastic deformation and typically have a diameter of 200 microns. This is also the case for the tribologically transformed layer, known as TTS, which is formed under cyclic fretting loading and measures around 100 microns in thickness.

Accessing the mechanical properties of these materials by conventional means is difficult. It is therefore necessary to set up micromechanical tests to gain access to their local properties.

During wire drawing, anisotropy in microstructure and mechanical behaviour develops in the steel wire. There is a lack of experimental data supporting this assumption since the classical methods used to characterize anisotropic yield behaviour is challenging on specimens with such small dimensions. Plastic anisotropy was characterized in these small-diameter wires in two complementary ways. Firstly, Knoop microhardness tests were carried out in both longitudinal and transverse directions assuming transverse anisotropy. Secondly, compression tests on FIB-machined micropillars were carried out using an in situ nanoindenter in the SEM. Both types of tests showed good agreement in terms of yield stress anisotropy. The yield anisotropy was then translated into Hill's yield criterion formulation. Results show a clear evolution of the shape of the yield surface and increasing plastic anisotropy as a function of wire-drawing strain.

In the fretting fatigue contact zone, a very hard, transformed layer appeared. Questions arise as to its role in contact, requiring characterization of its properties, both hardness and toughness. To this end, a bending test on a FIB-machined chevron-notched microbeam was carried out in situ in the SEM-FIB using a home-made testing machine. Crack size was determined by comparing DIC and FEM calculations, and toughness was measured during crack propagation. The results show that TTS is particularly brittle.

*Speaker