Residual stress measurement in microscopic steel wires by FIB hole drilling

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Abstract

Michelin produces the metallic reinforcements that are integrated in their tyres, guaranteeing exceptional resistance, durability and performance. The reinforcements consist of wires obtained by wire drawing, which leads to a complex microstructure and remarkable mechanical properties. The residual stress generated by the process impacts the mechanical behaviour and the reliability of the wires. It is therefore necessary to be able to measure the residual stress, which is challenging due to the very small diameter of the wires (about 200 μm). To characterize residual stress, the incremental hole drilling method is used, with a small hole (diameter 10 μm) machined with FIB (Focused Ion Beam) at the surface of the wire. A specialized digital image correlation (DIC) analysis is developed to measure the displacement due to stress relaxation from the SEM images at multiple hole drilling depths. Consecutively, an FE calculation is performed at each machining stage to link the surface displacement field to the relaxed internal stresses. The main measurement challenge is due to the low measurement signal (small strains) in contrast with a series of measurement artifacts: e.g., tilt of the specimen, SEM scanning errors, and positioning of the hole centre. Dedicated kinematic modes are included in the specialized DIC method to carefully handle each of these artifacts when measuring the displacement field. This method makes it possible to obtain several components of the residual stress tensor at multiple depths, which was not possible with the wire dissolution method (Boujnah 2023).

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