Very High Resolution Micromechanical Measurements on Thin Wires in Torsion

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Abstract. Experiments on the stress-strain behaviour of thin metal wires under torsion have developed since the seminal paper of Fleck et al [1]. Many laboratories have extended the methods to specimens a few centimetres long and with much more delicate torque balances, and have been able to record the elastic as well as the plastic response. We have concentrated on load-unload methods, which avoid the need for torque measurement, and using specimens up to one metre long we have reported data to microstrain (plastic strain ~ 10^{-6} to observe the first departures from elastic behaviour [2]. Now we have demonstrated an experiment using a specimen 50m long, giving access to the nanostrain regime. Preliminary results are reported here, and the potential of these experiments is discussed

Introduction

In the laboratory, it is scarcely convenient to hang a torsion pendulum longer than two or three metres at most. Even if stairwells provide more height, they are usually draughty and with too much traffic for delicate experiments. Yet the sensitivity to small plastic strain is proportional to the length. Fortunately, in the years after the Great Fire of London of 1666, Robert Hooke and Christopher Wren built a scientific instrument (in the guise of a memorial to the fire) that is ideally suited to such experiments with much longer lengths, The Monument (Fig.1).

Fig.1: The Monument, London. This structure consists of a simple stone tube of height about 70m, with no windows and a basement laboratory. There is a clear aperture from the basement, up the centre of the internal spiral staircase, to the top.

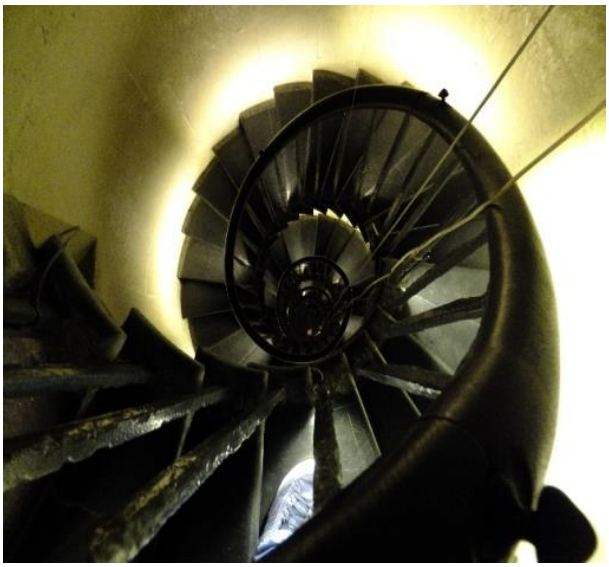

Fig.2: A view down the tower, showing the spiral staircase. The cables are to bring power and RS232 bus to the stepper motor at the top of the tower.

We have therefore developed equipment for performing load-unload torsion experiments on thin wires of length up to 50m to give plastic strain resolution down to nanostrain. A successful preliminary experiment on a 150μm diameter copper will be reported here.

Wire-handling

Particularly since The Monument is available for scientific experiments only by night and has to be available for opening to tourists in the morning, equipment had to be designed to enable the test specimen to be installed quickly and reliably. We settled on starting with the installation of a pair of guidelines (fishing line). Then a stepper motor at the top of the tower could lower a traveller running on the guidelines; the test specimen could be attached to the traveller. A synchronised stepper motor at the bottom could then unreel the test specimen from a spool as the motor at the top drew the traveller up the tower again.

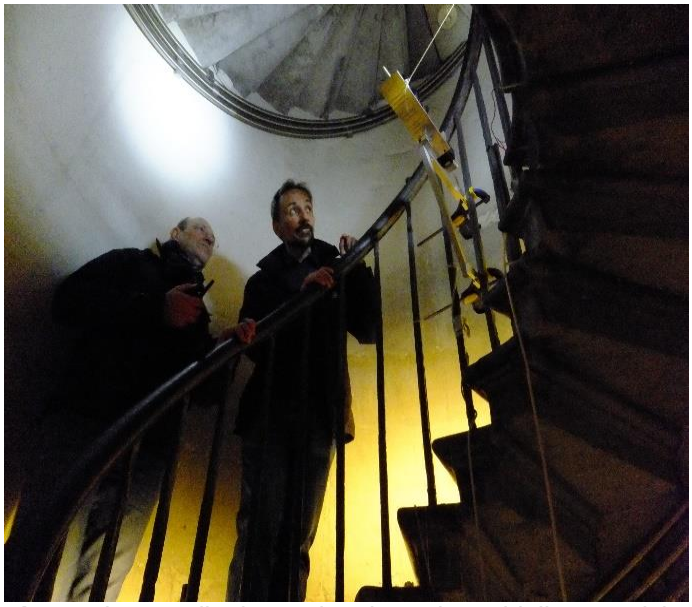

Fig.3: The traveller is running down the guidelines to pick up the test specimen.

Fig.4: The basement laboratory with the turntable for the load-unload experiment.

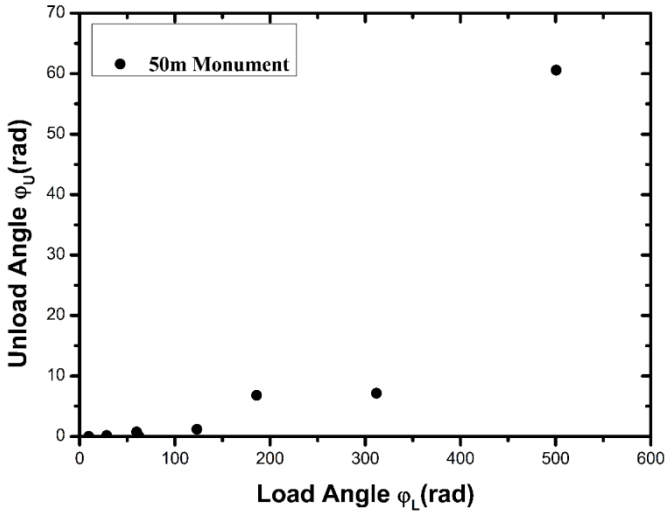

Fig.5: Preliminary data for the 150μm copper wire, gauge length 50m.

Conclusion

The preliminary experiment showed that the experiment is feasible. It also showed that various improvements are needed to enhance the speed and efficiency of data-collection in the next experiments.

References

[1] N.A. Fleck, G.M. Muller, M.F. Ashby, and J.W. Hutchinson, Acta Met. Mat., Vol. 42 (1994) p 475-487.
[2] D. Dong, D.J. Dunstan and A.J. Bushby, Philos. Mag., Vol. 95 (2015), p 1739-1750.