183 Micromechanical Tester for Micro-scale characterization

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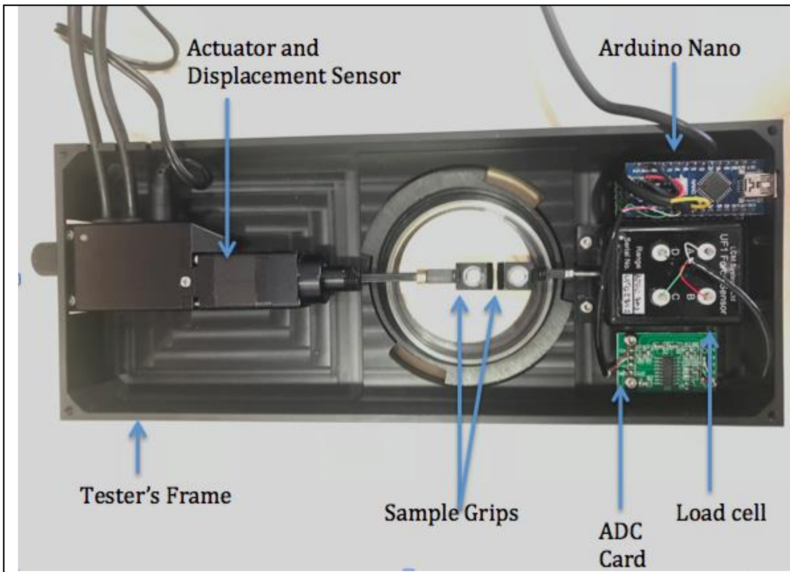
Abstract. Mechanical testing is important to ensure that the material used complies with the standard, for quality assurance, performance and fulfills the functional requirement of the final product. Mechanical testing can be conducted at different levels; at macro, micro and Nano scale. It is known that properties of nano and micro samples can be vastly different from the bulk material [1]. Therefore the purpose of the study was to prototype an affordable micro mechanical tester (with added feature of testing materials in hydration). There after an investigation was carried out to examine the quality of the tester's results and determine how effective it is using the micro scale tester for microstructures compared to conventional macro scale tester.

Introduction

In micromechanical characterization research, testers could be made in house by researchers or purchased from commercial companies. Most "in-house" put together testers by researchers were acquired at low cost and the main aim was to quickly characterize their materials. These low cost testers usually lack of verification, calibration and conformance to test standards. For most nano and micro scale testing, key challenges include loading of samples (which affects alignment of samples), fabrication and handling of fine samples (ensuring good gripping and avoiding slippages). Affects of misalignment can cause pre-stresses leading to premature breakage of micro samples. Consequently creates large deviation in results leading to inaccuracies of datasets collected from micro scale tests [2][3]. The size effects of material properties responses to different temperature are receiving considerable amount of attention in materials characterization [4]. Part of the study was to prototype, examined and evaluate the data collected from L-Shaped grips that gives the ability to grip samples in a petri dish, which conducts sample heating through water medium.



(a)

(b)

Fig 1: Images of (a) Internal setup of the micromechanical tester (b) Example of 2 different types of grips L-shaped grips (top) and straight grips (bottom).

The prototyped tester (see figure 1a) from the project encompasses a close loop control system using microcontroller Ardunio. With a footprint of Length 240mm x Width 96mm x Height 34mm, the prototyped tester is able to sit within most microscope stages to conduct in-situ characterization tests. The micromechanical tester houses a 25mm travelling actuator, a low force load cell of capacity 1KG, and interchangeable grips. The housing frame was constructed from affordable lightweight Homo polymer that is highly resistance to chemical compounds. Total weight of the micromechanical tester and its components weigh less than 1kg (not including the heating system). The cost of consolidating the tester together was approximately $5,000 (<£3000). The load, displacement sensor, travel speed, alignment of the grips, and fastening force of the screw grips for samples were verified, calibrated and checked when they were put together as a system. Finally integrity of data was also verified to ensure that the system was able to produce high repeatability of accurate and precise data. The system's price to quality ratio aims to make material characterization affordable to more research avenues.

Methods

5 pieces of Copper wires of diameters 0.1mm and 0.3mm each were used in the mechanical evaluation test. The wires were 5 cm in length. The ends of the wires of 1cm were taped up (providing an extra buffer for the bigger grips) and tested under the different testers. The Shimadzu model AGS-X and the prototyped micromechanical tester with 2 different types of grips (Straight and L-shaped grips) were used to carry out the mechanical characterization of wires tests. Wires specimens were pulled in a tension direction; at a speed of 0.02mm/sec displacement as specified by ASTM test standard D1708-06a for all tests.

Results and discussion

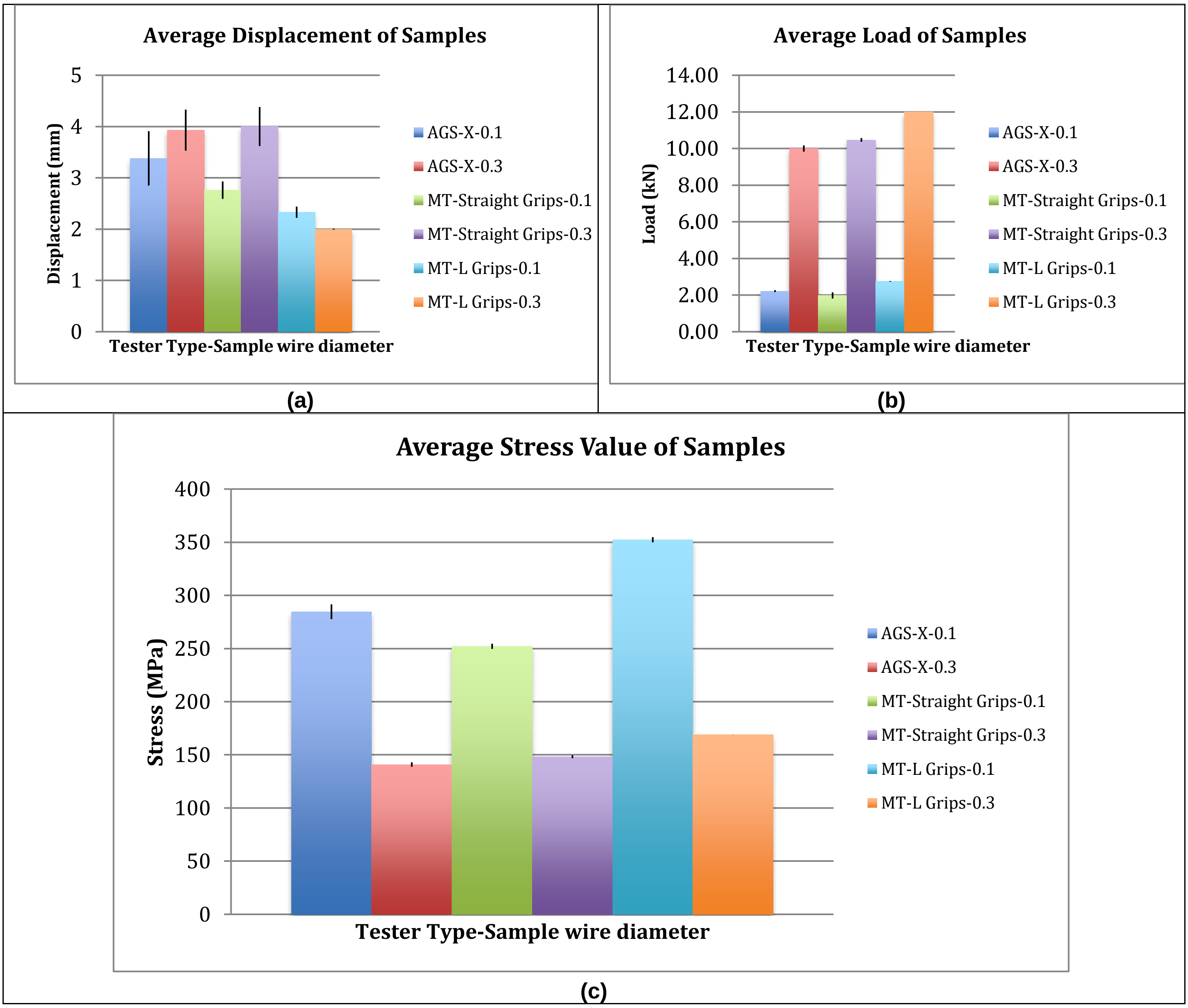


Figure 2: Graphical results on copper wire tensile tests from Shimadzu model AGS-X tester and prototyped micromechanical tester denoted by MT with different straight and L-shaped grips. (a) Shows the average displacement (b) average load at which the wire fractures and (c) average maximum stress value measured for 0.1mm and 0.3 mm specimen on the different testers and different grips.

From the above graphical data, results collected from the Shimadzu AGS-X tester and the micromechanical tester MT-Straight Grips on displacement, load and stress were comparable. The average readings for materials tested on the straight trips from both micro and macro systems did not deviate more than 10% from each other. Above results however showed that average result from displacement of the sample tests taken from AGS-X-0.1 faired poorly amongst the different testers. The standard deviation of the results was the highest for 0.1mm samples tested on AGS-X tester, followed by 0.3mm diameter samples on the same tester. Reason for this large error in data result would probably be attributed to slippage of the small samples between the large wedge grips of the system. Good gripping of samples should prevent slippage without inducing stress concentration on the samples [5]. However on the large macro system the grips were too large to hold the micro size specimen adequately this was the main reason why buffer tapes were also applied to the sample tests. Load results were slightly improved on the tests where maximum load of fracture for the materials were about 5% different between the different system. Overall the straight grips from the micro tester reported coherent values with the AGS-X tester. This method of verification of load between the testers gives a good bench mark on the calibration and accuracy of the systems as using known material properties to test they are usually very compliant [6]. L-Shaped grips on the load profile reported slightly higher values. This could probably be contributed to the added weight of the L-Shaped grips, the effects of alignment of samples, coupled with compensating bending affects between the long arms of L-shaped grips. Finally looking at the average stress values of the samples in figure 2c comparatively the standard error for the results were lower to the other 2 data sets of displacement and load samples. Macro scale tests on 0.1mm sample still do report higher standard deviation and resultant error for the data collected on the smaller samples. This result was improved for larger 0.3mm diameter specimen. From this exercise it justifies using micro testing system to carry out tests on micro size materials [7]. Data results gathered from the micro tester for both grips on the whole had significantly better results; this can be attributed to better gripping, better alignment and handling of the sample, which were adapted specifically with the small-scale systems. The repeatability and accuracy of the results were consequently influenced by gripping strength (measured by a torque gauge) and stress distribution of the tested specimen [8]. In summary L-shaped grips on the micro tester performed well in repeatability of results. However its results were slightly higher than the other 2 data sets from the straight grips of macro and micro systems. Further investigation would be needed to look at this aspect to refine the system to include hydration tests compliance.

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