Methodology of Precise Measurements of Mechanical Properties during High Resolution Tomography

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Summary: The aim of this paper is to analyze the reliability of the choice of PMMA as load transfer tube for tensile in-situ device. We propose to compare the displacement value imposed by computer of a X-ray laboratory tomography and the real displacement directly measured on quartz sand deposited on the tensile sample.

1. INTRODUCTION

High-resolution computed tomography is a modern measuring technique often used in materials science. The CT is used to study various materials, from metals, ceramics, composites to biological materials. Many papers are devoted to mechanical properties or destruction mechanisms. During many studies the material is subjected to tensile, compressive or bend tests on testing machines dedicated to tomography. Usually, the measuring area inside laboratory tomographs is very limited, so the testing machines must be small in size. The specimen makes a full revolution around its axis during the test, and the machines need to be transparent to radiation coming from various directions. As a result of small sizes and absence of classical frame, these machines have low stiffness and consequently do not give precise results for hard materials or small strains. The aim of this paper is to analyze the reliability of the choice of PMMA as load transfer tube for tensile *in-situ* device. We propose to compare the displacement value imposed by computer of a X-ray laboratory tomography and the real displacement directly measured on quartz sand deposited on the tensile sample.

2. EXPERIMENTAL METHOD

The micro tomography measurements were performed using "nanotom 180N" device produced by GE Sensing & Inspection Technologies phoenix|X-ray Gmbh. The specimens were scanned at 60 kV of source voltage and 400 μA, with a rotation of the specimen of 360 degrees in 1300 steps. The exposure time was 500 ms and a frame averaging of 4 and image skip of 1 was applied, resulting in a scanning time of 45 minutes. The reconstructed images had a voxel size of 5,0 μm^3. The polymer composites based on homopolymer PP PPH 11012 and the powder of tire rubber manufactured by Laboratory of Mechanics, Biomechanics, Polymers and Structures (LaBPS), Ecole Nationale d'Ingénieurs de Metz [1] . The quartz sand markers were placed on polymer composites specimen in order to determine the strain in a precise manner. The specimen with markers and its 3D representation is shown in Figures 1a, b. The plan of experiment involved a series of micro-tomographic measurements for successive specimen strain values. The hold time after application of a set strain was 35 minutes (without releasing the strain) to allow the internal deformation processes to come to an end. The sequence was repeated multiple times for increasing longitudinal strains. The strain speed was 0.2mm/minute which is equivalent to 100 s^{-1}. A 3D Object Counter plugin from BoneJ [2] was used for the analysis of markers' positions and displacement. This analysis used the centre of gravity of each detected grain. Figure 1c and 1d shows the markers' displacement vectors for the specimen with the 0,155 deformation.

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3. RESULTS

It was proved that despite low stiffnes of the machine it is possible to perform accurate mechanical measurements for small strains. The proposed markers method was tested and used in the measurement of mechanical properties of composite materials. Markers in the form of quartz grains were placed on the tensile specimen. Then the strength test was performed which involved tensioning and simultaneous tomographic measurement. The results was a series of tomographic data for various degrees of strain. The data were used to determine the position of markers which was performed using the ImageJ software with the BoneJ plugin. Knowing the position of markers, it was possible to determine accurately the average longitudinal strain of the specimen. In addition to longitudinal strain, it is also possible to determine the transverse strains. The analysis of grains' positions on opposite specimen walls and the grains' displacement in transversal direction allowed determining the transverse strain and consequently the Poisson ratio of the tested material. Correct choice of size and number of markers allows also testing the strain heterogeneity, e.g. during the neck formation

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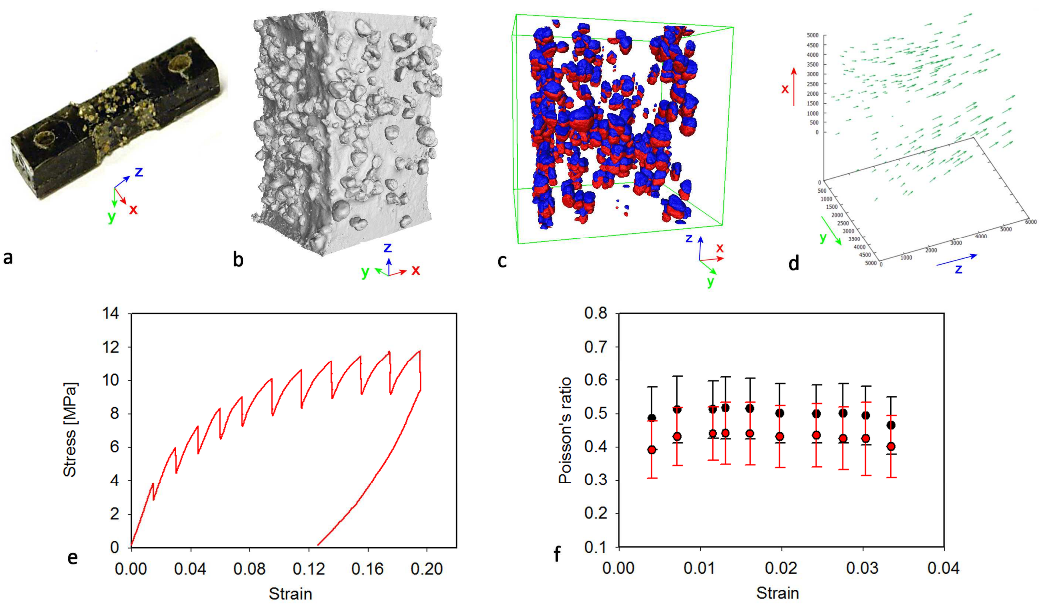

Figure 1: *Specimen with markers on its surface (a), 3D representation after tomographic measurement (b),Grains in initial (blue) and final (red) positions and markers' displacement vectors between the initial (unstrained) state and the state with strain = 0.155 (c-d), Stress-strain curve estimated base on marker displacement (e), Relationship between Poisson ratio and longitudinal strain (f)*