True-Triaxial-cell set up to estimate the stress induced anisotropy: Uniformity study

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SUMMARY

The stress anisotropy in Polymethyl Methacrylate (PMMA) subjected to triaxial stress has been investigated using True Triaxial Cell .True Triaxial Cell with 4 sealed S wave transducers inside each actuators facilitates the wave velocities measurement in different set of stresses. 108 positions of measurements have been selected and comprehensive test sequences has been allocated. The experiment analysis results confirm that the wave velocities increasing by increasing the stress in all sequences on different rates. Moreover, this experiment shows the designed True Triaxial Cell operates symmetrically and the results in both sets of transducers show a good correlation to one another which confirms the uniformity of applied stresses.
Key words: Stress anisotropy, S wave velocity, True-Triaxial Cell.

INTRODUCTION

The understanding of the stress pattern and associated anisotropy is particularly insufficient because of the availability of a limited number of measurements resulting from the time-consuming nature of laboratory testing (Kuila, U et al., 2010) and the lack of specialized accurate equipment and the complexity of ultrasonic S wave behaviour subjected to anisotropic stress.
This study investigates the ultrasonic response of cubic Polymethyl Methacrylate (PMMA) sample subjected to both isotropic stress and an anisotropic stress in a True Triaxial Cell. PMMA is macromolecular material with unique characterizations such as shape memory, transparency, high mechanical strength, isotropic behaviour and so forth. At room temperature, the strain of material is small and it can be considered as elastic material (T. Ohki et al. 2004).
The intention of this study is to investigate the impact of magnitude and anisotropy of stresses on sample velocity in 108 different sequences of pressure application.
The processes involved in different pressures interactions are non-linear in the sense that even small changes in one direction can have influences on the rate of S wave velocity. There is lack of understanding of such interactions despite the positive impact improving such understanding would have on transforming the way we utilise our resources.

EXPERIMENTAL PROCEDURE

The apparatus used to measure ultrasonic velocities under stress consisted of a cubic sample of PMMA mounted in a load frame, held in place by four actuators capable of applying stresses up to 70MPa (Figure 1a). Four S wave transducer were sealed inside each actuator and actuators were housed in steel supports, adjustable in both azimuth and elevation to allow for precise alignment. Each vertical face of the sample was connected to an actuator via a platen fabricated from 3 mm thick PEEK material to ensure uniform load distribution over the face. An Olympus 5077PR pulser/receiver was used to drive Panametrics V153 1MHz S wave transducers inside each actuator. The orientation of 2 sets of transducers was such that its polarization direction was at 90_ to the x and y axes (Figure 1b). The PMMA 50mm3 cubic sample was prepared and polished on all faces and mounted in True triaxial load cell (Figure 1c). Initial tests were carried out on the transducers sealed inside the actuators with coupling gel to provide efficient transmission of the shear wave outside the load frame to measure the dead time between 2 faces of actuators and transducers barrier (Figure 1d).

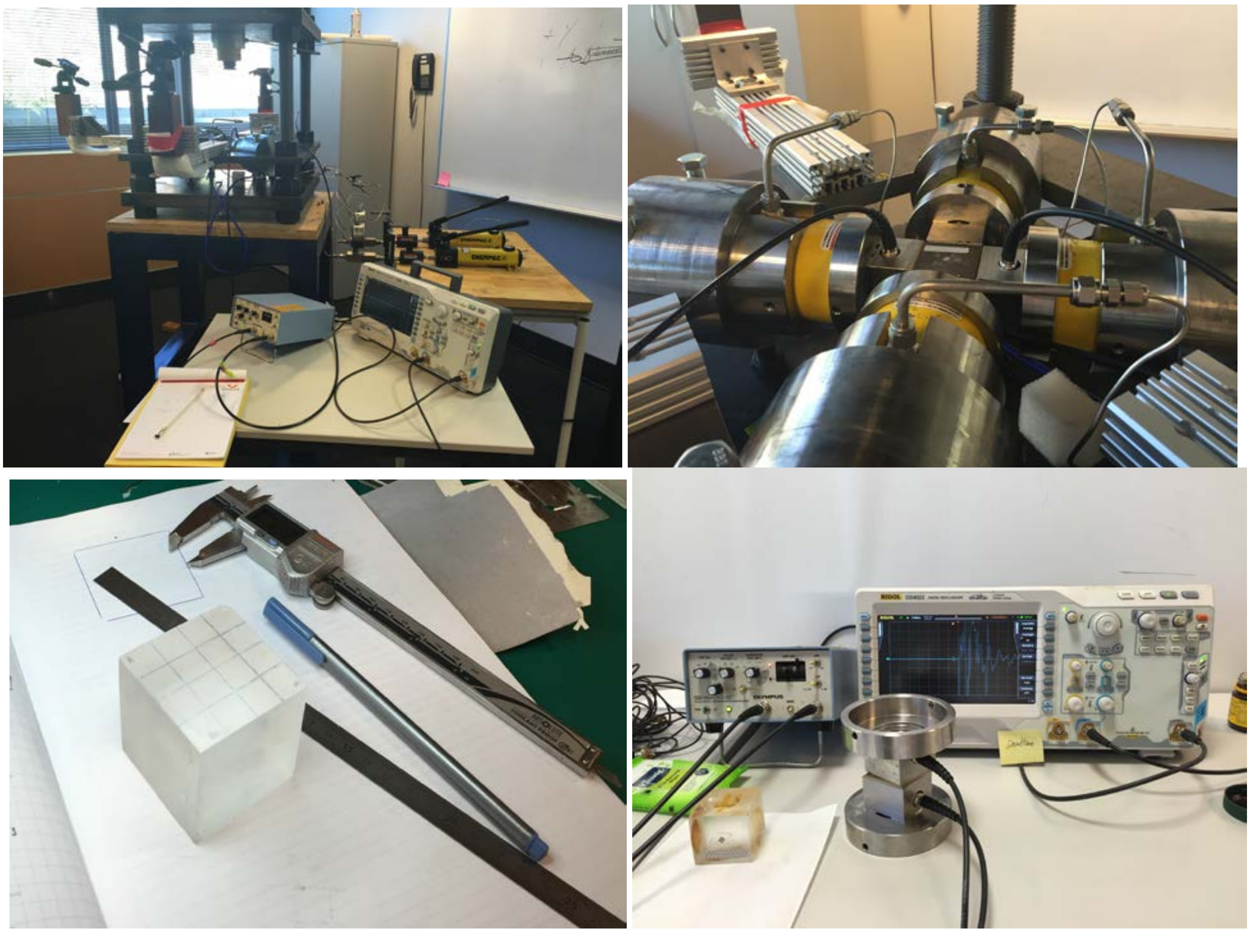

Figure 1: (a: top left) Setup of the experiment, (b: top right) 4 S wave transducers sealed on each actuators, (c: bottom left) PMMA sample polished and prepared to mount in the frame, and (d: bottom right) actuators dead time measurement

METHOD AND RESULTS

For the PMMA sample 108 measurement positions were defined on the combination of different stresses with regards to direction. 54 waveforms were recorded for each set of transducers. The waveform was first corrected for dead0time and the baseline shifted in order to correct for any DC offset in the signal. The amplitudes of the measured waveforms and the velocities were then calculated and plotted on diagrams.

Before mounting the sample on the load frame, the sample was tested with two S wave transducers on the opposite faces with coupling gel. The S and P waves measured at room conditions outside the cell are 1380 m/s and 2693 m/s respectively. P wave arises from mode conversion at the interface between the sample and the transducer (Carson and Lebedev 2014). The S wave transducers was then sealed and attached inside each actuators. The first set of transducers which placed on the direction of X axis inside the actuators of load frame called A-A transducers and the other set on Y axis called B-B. The X axis of pressure assumed as σ1 and the Y axis as σ2 (Figure 2). The sequences of each sets consist of 0 to 16 MPa pressure in 54 different combinations of σ1=σ2, and σ3=0 and the other set of σ1≠σ2, and σ3=0 stresses. Same design had been conducted for the B-B transducer and the P and S wave velocities had been measured, modified and plotted for all test sequences (Figures 3 to 12).

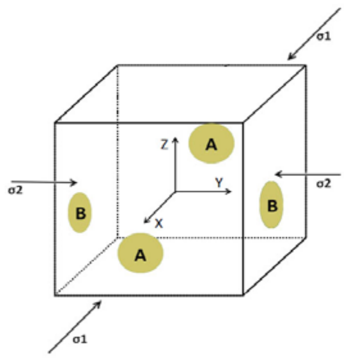

Figure2: Schematic showing the relevant geometry of the experiment and the orientation of transducers set up with regards to pressure direction.

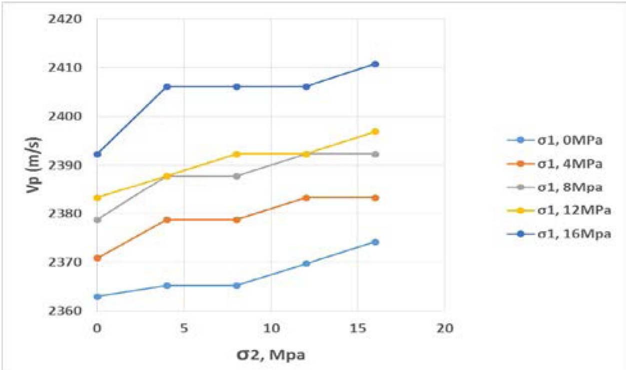

Figure 3: Vp on set A-A with the constant σ1 and increasing σ2

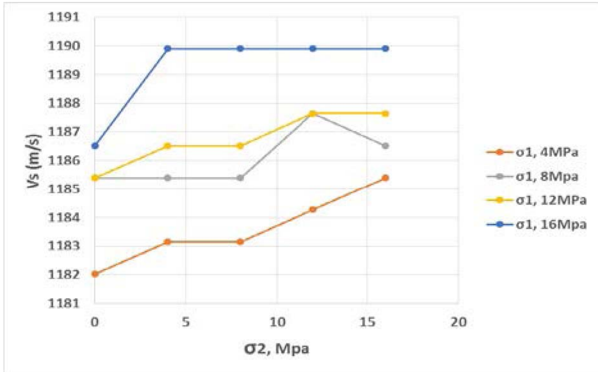

Figure 4: Vs on set A-A with the constant σ1 and increasing σ2

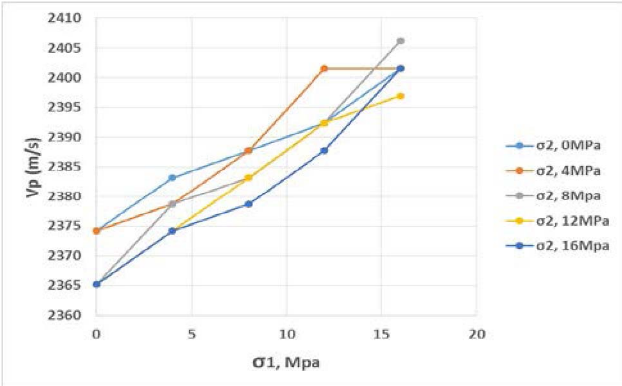

Figure 5: Vp on set A-A with the constant σ2 and increasing σ1

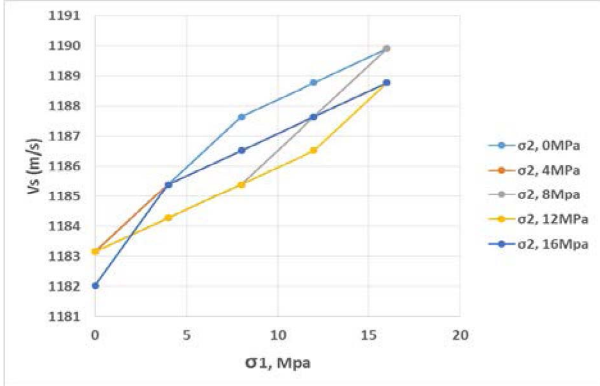

Figure 6: Vs on set A-A with the constant σ2 and increasing σ1

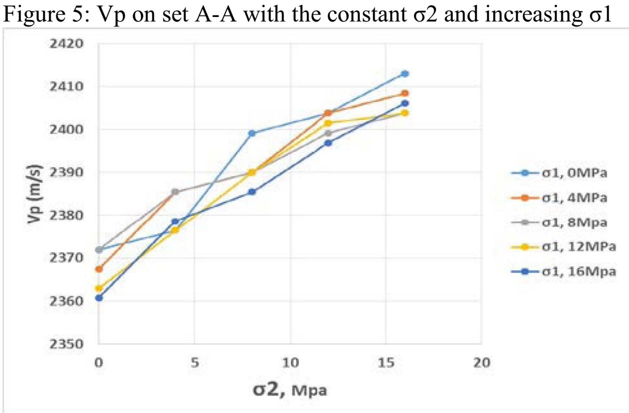

Figure 7: Vp on set B-B with the constant σ1 and increasing σ2

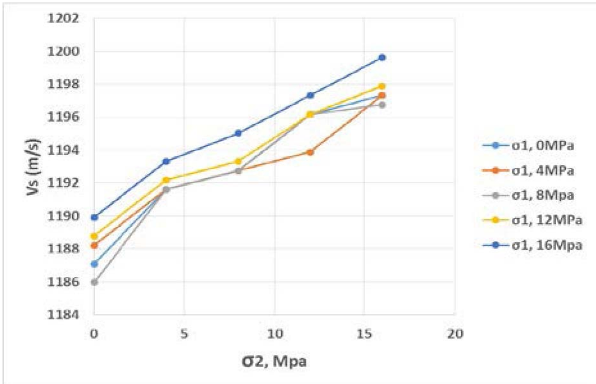

Figure 8: Vs on set B-B with the constant σ1 and increasing σ2

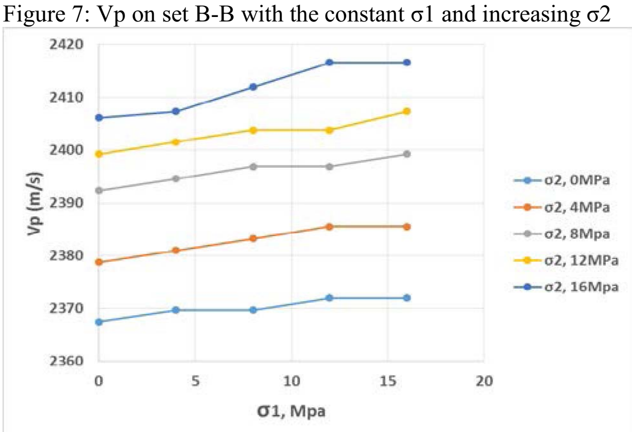

Figure 9: Vp on set B-B with the constant σ2 and increasing σ1

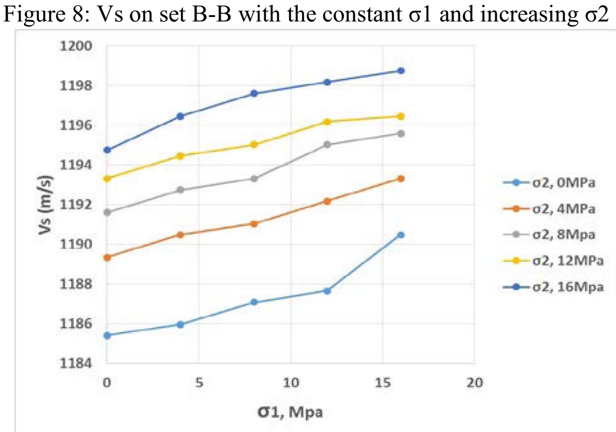

Figure 10: Vs on set B-B with the constant σ2 and increasing σ1

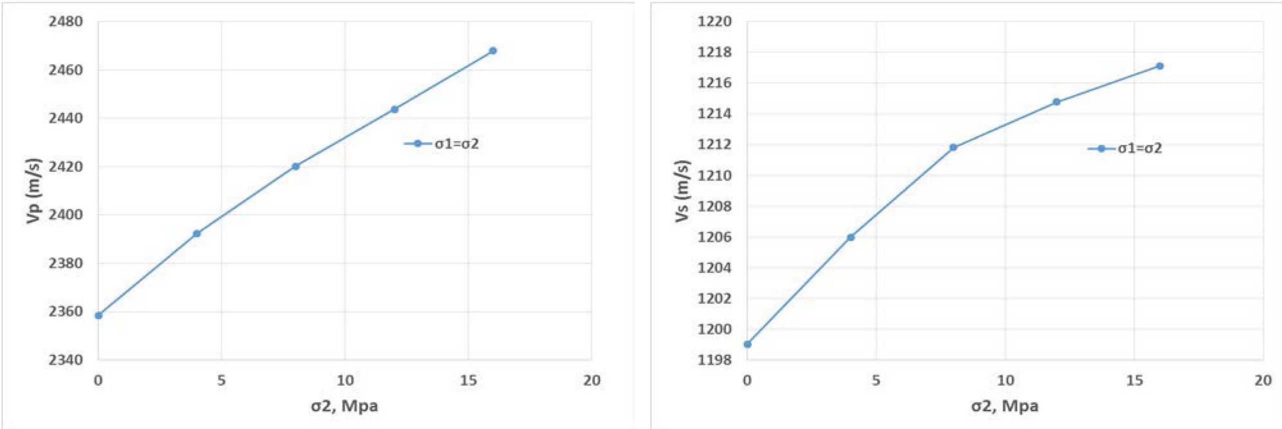

Figure 11: Vp and Vs on set A-A with increasing same stress in both axis

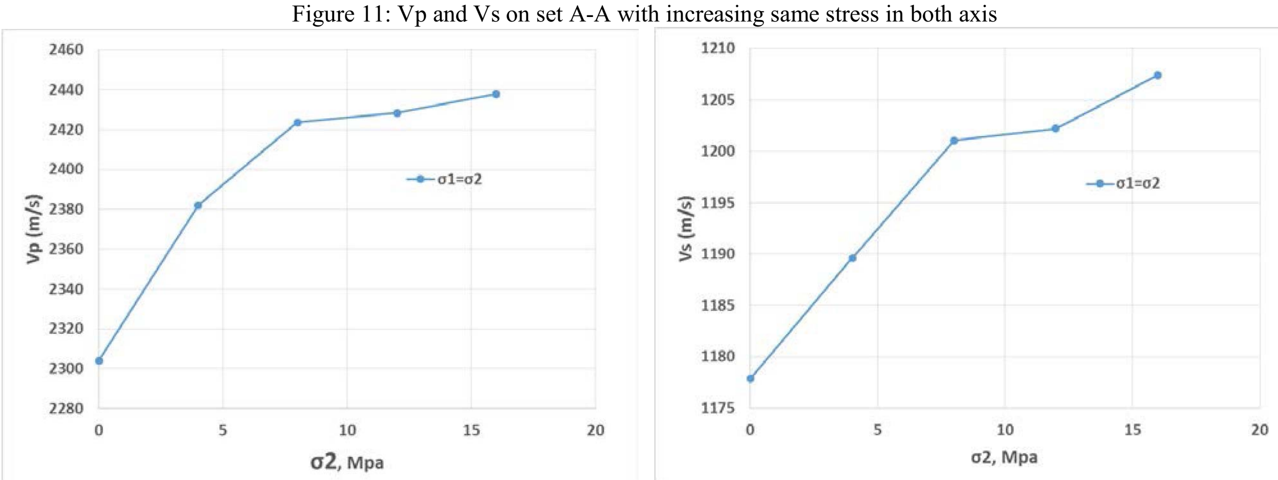

Figure 12: Vp and Vs on set B-B with increasing same stress in both axis

CONCLUSIONS

Ultrasonic measurements of P- and S-wave velocities at both atmospheric, isotropic and anisotropic elevated pressures, using 1.0 MHz P- and S-wave transducers were conducted. A hundred and eight measures of PMMA are arranged in two categories, depending upon the orientation of S wave transducer and the pressure in the axis. The induced anisotropies follow similar trends in both categories of data. The ultrasonic measurements suggest that most of the measured velocities show positive correlation with the increasing pressure in both axis. The results indicates that the designed True Triaxial Cell operates symmetrical and the extracted data in both sets of transducers show a good correlation to one another which confirms the uniformity of applied stresses by the designed set.

REFERENCES

Kuila, U., Dewhurst, D.N. , Siggins, A.F. ,and Raven, M.D.,2010, Stress anisotropy and velocity anisotropy in low porosity shale, Tectonophysics, Vol.503(1), pp.34-44

T. Ohki, Q. Q. Ni, N. Ohsako. 2004, Mechanical and shape behavior of composites with shape memory polymer.Journal. Composites. 2004(35): 1065-107

Carson M., Lebedev M., 2014, Ultrasonic measurements of S waves using laser interferometry, SEG Denver 2014 Annual Meeting, Curtin university