geoconvention
Calgary • Canada • May 15-19 2017

# Effect of Beam Skew on Pressurized Pulse Transmission Velocity Measurements in Tilted Transversely Isotropic Media

*Wei Li[1,2], Xiwei Chen[2], Changchun Zou[1], Douglas R. Schmitt[2]*

*1. School of Geophysics and Information Technology, China University of Geosciences (Beijing)*

*2. Department of Physics, Institute for Geophysical Research, University of Alberta*

## Summary

In tilted transversely isotropic media, the ultrasonic beam excited by a transmitter skews. This fact affects the pulse transmission velocity measurements. Considering the effect of pressure on anisotropy, the effect of beam skew becomes further complicated. To experimentally study the effect of beam skew, we placed two receivers: one in the beam propagation direction and the other in the straight forward direction. Then the velocities were measured under confining pressure up to 200.0 MPa. From the comparison of the results obtained from the two receivers, the beam skew affects the measurement when the confining pressure is low; the effect is negligible when the confining pressure is high.

## Introduction

Due to the phase velocity differs from the group velocity in anisotropic media, the ultrasonic beam skews in tilted transversely isotropic media. This phenomenon affects the accuracy of the phase velocity measured by ultrasonic pulse transmission method (Dellinger and Vernik, 1994). This issue is further complicated considering the effect of pressure because the anisotropy of rocks becomes weaker as the confining pressure becomes higher and thus the beam skews less (Chan and Schmitt, 2015). To physically study the effect of beam skew on pressurized pulse transmission velocity measurement, we pasted two receivers on a cubic transversely isotropic rock with the foliation 45$^o$ to its surfaces: one receiver pasted in the beam propagation direction under room pressure (noted as the shifted receiver) and the other receiver pasted in the straight forward direction of transmitter (noted as the straight forward receiver). The velocity is measured under the pressure ranging from 0.1 to 200.0 MPa. We observed that when pressure is low, the beam skews obviously and the shifted receiver offers a relatively precise result; when the pressure is high, the beam propagates nearly straightforward and a relatively precise result will be obtained from the straight forward receiver. The relative error of the P-wave velocity is about 3.5 % under room pressure. After about 40.0 MPa, the relative error is less than 1.0 %, thus the beam skew effect is negligible.

## Method

The sample was cut to make its foliation 45$^o$ to the two surfaces of the sample. The velocity was measured with pulse transmission method. The measured velocity will become faster as the receiver becomes closer to the position that the beam will arrive at the surface. The beam propagation direction can be estimated by moving the transducer along the surface to find the strongest and fastest signal. First, the receiver was placed in the straight forward position with the ultrasonic gel. Then the receiver was moved every 0.5 cm to find the beam propagation direction as shown in Fig. 1. Finally, the shifted receiver and the straight forward receiver were pasted on the sample for pressurized P-wave velocity measurements.

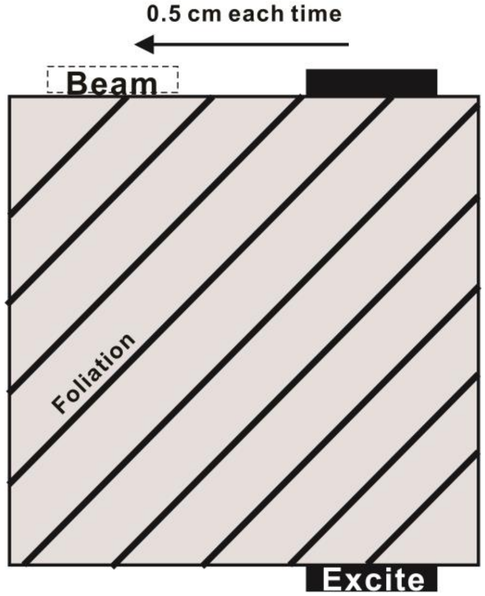



Fig. 1 Schematic of the pulse transmission measurement.

## Examples

The measurement is carried out on a mylonite that has obvious foliation from the Alpine fault in New Zealand. The mylonite is assumed to be transversely isotropic based on the observation of thin sections. As shown in Fig.2, thin layers can be observed from the thin sections that are perpendicular to the foliation; no obvious foliation or lineation can be observed from the thin sections that are parallel to the foliation.


Fig. 2 Thin section images in the direction parallel or vertical to the foliation.

The room pressure measurements help figure out the position that the ultrasonic beam arrived on the surface. The vertical distance between the transmitter and the receiver is 6.21 cm. In Fig. 3, receiver No. 1 is in the straight forward position. From receiver No. 2 to No. 6, the horizontal distance between the receiver and the transmitter increased 0.5 cm each time. It can be seen that the receiver No. 6 received the strongest and fastest signal. The phase velocity measured from receiver No.6 is about 3.8% faster than that measured from receiver No. 1.

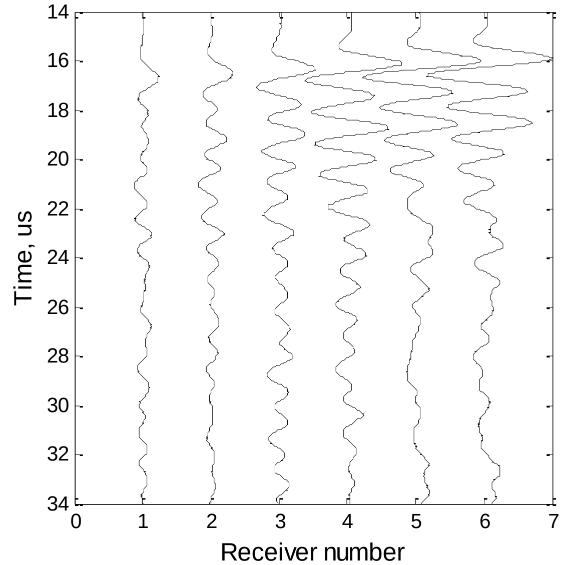



Fig. 3 Signals obtained from the pulse transmission measurement of a mynolite under room pressure. Receiver No. 1 is in the straight forward direction. The horizontal interval of the positions is 0.5cm.

Considering the anisotropy of rocks becomes smaller under high confining pressure and the difference between the signals measured from receiver No.5 and No.6 are small, we assumed the receiver No. 5 to be the beam propagation direction. In the pressurized velocity measurements, the shifted receiver is pasted as receiver No. 5 (the beam propagation direction) and the straight forward receiver is pasted as receiver No. 1 (the straight forward position). The velocities were measured with pressure went from 0.1 MPa to 200.0 MPa and then down to 0.1 MPa as shown in Fig.3. The velocities measured from both receivers were affected a lot by pressure.

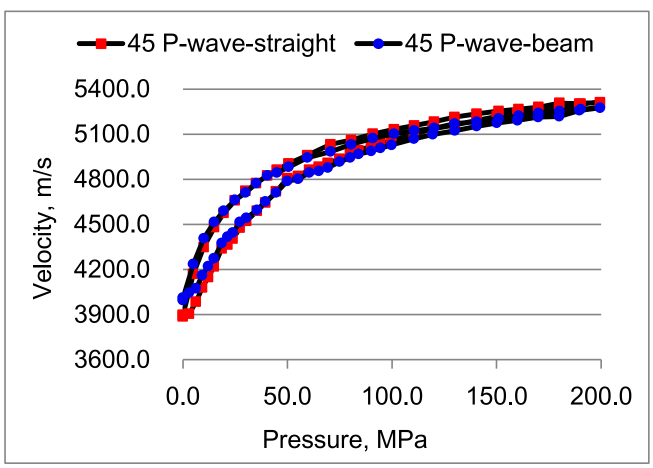
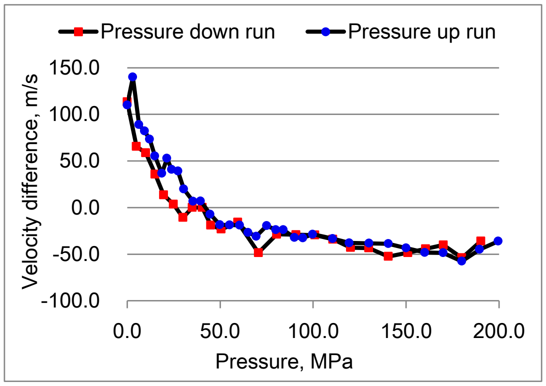
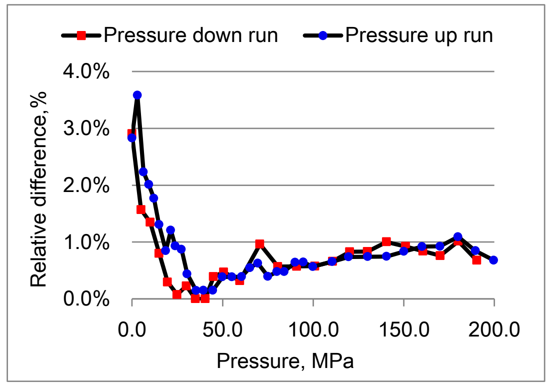



Fig. 4 Velocities measured from the receivers in the straight forward position (No. 1) and the propagation direction position (No. 5).

To analyze the effect of beam skew on pressurized velocity measurements, the difference and the relative difference between the velocities measured from the two receivers were shown in Fig. 4. When the pressure was low, the anisotropy of the mylonite was relatively strong and the beam skew was obvious. The measured velocity from the shifted receiver was about 3.6 % faster than that from the straight forward receiver indicated that the ultrasonic beam arrived closer to the shifted receiver. As the pressure went up to about 40.0 MPa, the difference of the velocities became small indicated that the ultrasonic beam arrived in the middle of the two receivers. The velocities measured from both of the positions were smaller than the theoretical value. When the pressure continued going up, the velocity measured from the straight forward receiver was faster than that measured from the shifted receiver indicated that the anisotropy of the mylonite was relatively small and the ultrasonic beam was closer to the straight forward receiver.




(a)




(b)

Fig. 5 Difference of velocities measured from the two receivers in the straight forward direction (No. 1) and the beam propagation direction (No. 5).

## Conclusions

Through the pressurized velocity measurement of a tilted transversely isotropic rock, three conclusions can be obtained:

1) In the room pressure, the beam skews obviously in the tilted transversely isotropic media and this phenomenon affects the velocity measurement. In the mylonite we studied, the P-wave beam skewed about $21.9^{o}$ and the phase velocity measured in the straight forward position was about 3.6 % less than the that measured in the beam arrival position.

2) As the pressure goes up, the anisotropy of the rocks becomes weaker and the beam skews less obvious. In our case, when the confining pressure was higher than 40.0 MPa, the straight forward receiver offers a relatively accurate result. The effect of beam skew is negligible.

3) The method we proposed might be a practical and effective way to reduce the error in pressurized phase velocity measurement through pulse transmission method.

## Acknowledgements


Wei Li and Changchun Zou's visit to the Experimental Geophysics Group at the University of Alberta was supported by China Scholarship Council (CSC).


#### References


Chan, J., and Schmitt, D.R., 2015. Elastic anisotropy of a metamorphic rock sample of the Canadian Shield in Northeastern Alberta. Rock Mechanics and Rock Engineering, 48(4), pp.1369-1385.

Dellinger, J. and Vernik, L., 1994. Do traveltimes in pulse-transmission experiments yield anisotropic group or phase velocities?. *Geophysics*, *59*(11), pp.1774-1779