Strain and deformation measurements in rock massive using borehole geophysics

Stoyko Hristov, Valentina Ilieva, Lyubomira Trendafilova
University of Mining and Geology „St. Ivan Rilski”, Sofia, Bulgaria

Borehole geophysical surveys are carried out to determine the distribution of a certain parameter in depth. Combining different measurements of different parameters and their correlations, it is possible to make conclusions about the geology, borehole technical condition and etc. In this paper the authors are showing the applications of the Acoustic Borehole televiewer – BHTV. The BHTV probe uses fixed acoustic transducer and a rotating acoustic mirror to scan the borehole walls with a focused ultrasound beam. The amplitude and travel time of the reflected acoustic signal are recorded simultaneously as separate image logs. The method is used for structural interpretation with dip and dip direction, fracture frequency, lithology, casing inspections and etc. The BHTV probe can be used in fluid filled holes ONLY. The BHTV results in generating an unrolled 360 degree false colour image of the borehole wall. The images are orientated to magnetic north in vertical boreholes or high side in the inclined holes using the integrated orientation module.

As it was pointed out before, the instrument produces two separate logs – amplitude and travel time. The travel time is the time that takes the signal to reach and reflect off the walls of the borehole. After making some calculations and determining the ACOUSTIC VELOCITY of the fluid in the borehole, we can determine the distance S between the tool long axis and the rock wall. The distance is calculated via:

S=Acoustic velocity x Travel time

The end result is a table with lengths every 2^{o} of circular cross section. This helps us to create a 3D module (Fig. 1.).

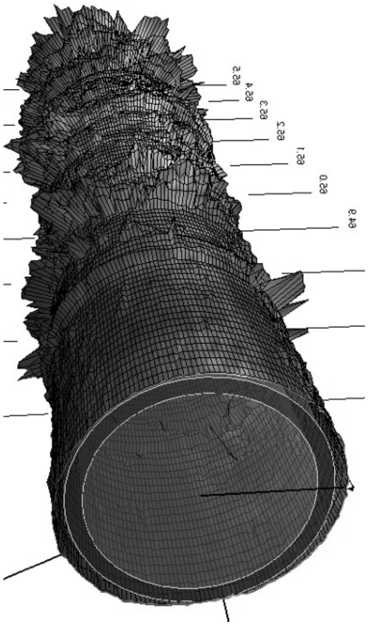


Fig.1.: 3D borehole model using time travel data.

From the model we are able to create an orientated cross section for every centimetre in depth.

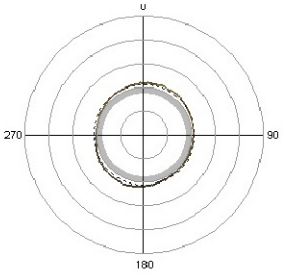
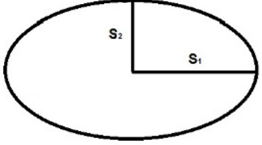


Fig. 2.. An example of a cross section created using the 3D borehole model

On the cross section we can clearly see the strain ellipse (Fig. 2.). The strain ellipse is a way to represent strain in 2D. It is the product of a finite strain applied to a circle of unit radius. The drilling rods have perfect circular cross section, which leads us to believe that the ellipse is the result of deformation after removing the rods. It is an ellipse whose radius is proportional to the stretch S in any direction. We use the length of the short and long axis $S_1$and S_2.



The ratio Rs = S_1/ S_2 is called the strain ratio and is a measure of the overall intensity of distortion.

The multiplication S_1 x S_2 is a measure of the area of the strain ellipse. It is used to measure the dilation according to the following formula:

$$1 + \Delta = S_1 \times S_2.$$

Dilation Δ is positive if the area increases, negative if it decreases.

Because the instrument has an inbuilt orientation module, which uses magnetic inclination and azimuth measurements, we can orient the ellipse in space and also in depth and so orient the direction of the stress.

If we measure the stress distribution over time in a borehole / boreholes located near an open pit mine, for example, we can see how much has the stress changed in size and direction, due to the removal of great amounts of material. Doing so, we can calculate the rotational component of deformation using the orientation of the strain axis before φ and after some time φ'. The difference

$$\omega = \varphi' - \varphi$$

is a measure of how much overall rotation has occurred during the excavation in the mine.

This technique can be implemented in underground mine activities to trace the rock massive stress changes in depth as the tunnelling work progress, helping to prevent accidents. It can be used to monitor the effect of “heavy” buildings on the substrata.

It can be used to create three dimensional models of the stress strength, direction and change in time and in depth. Such models can be used to monitor open and underground mines, seismically active faults and different zones of interest.