Recommended Methodology for DST Arrival Time Estimation

When analyzing seismic data the determination of the first arrival time is not only essential, but also often one of the more difficult elements of the analysis. Consequently this determination is somewhat subjective and the objective of this technical note is to describe a methodology that minimizes the human subjectivity when determining arrival times.

In Downhole Seismic Testing (DST) source wave distortion is predominantly due to critical angle refraction, reflections, near-field waves, and "dirty sources" (e.g., poor hammer impact, rod noise, and plate slippage). By carefully managing the data acquisition process "dirty sources" can be avoided, as can near-field waves (by maintaining an adequate seismic source radial offset). This then allows for the identification of one or more source wave features (a trending peak or trough) from a deeper trace to near surface traces. Since it easy to identify the timing of the extreme value of such a feature, the difference in arrival time at different depths can be determined accurately.

It should be noted that, as outlined in Technical Note 27, there is insignificant signal distortion due to dispersion for seismic traces recorded over typical depth intervals (i.e., 1 m to 5m) and typical Q values.

The process then starts by identifying a consistent trending source wave feature (either a trough, a peak or a combination) at a greater depth in the traces that have been selected for analysis (either the full waveform or a dominant axis response). In Figure 1 the first trough and peak are identified (and circled in green) for the trace recorded at 24 m.

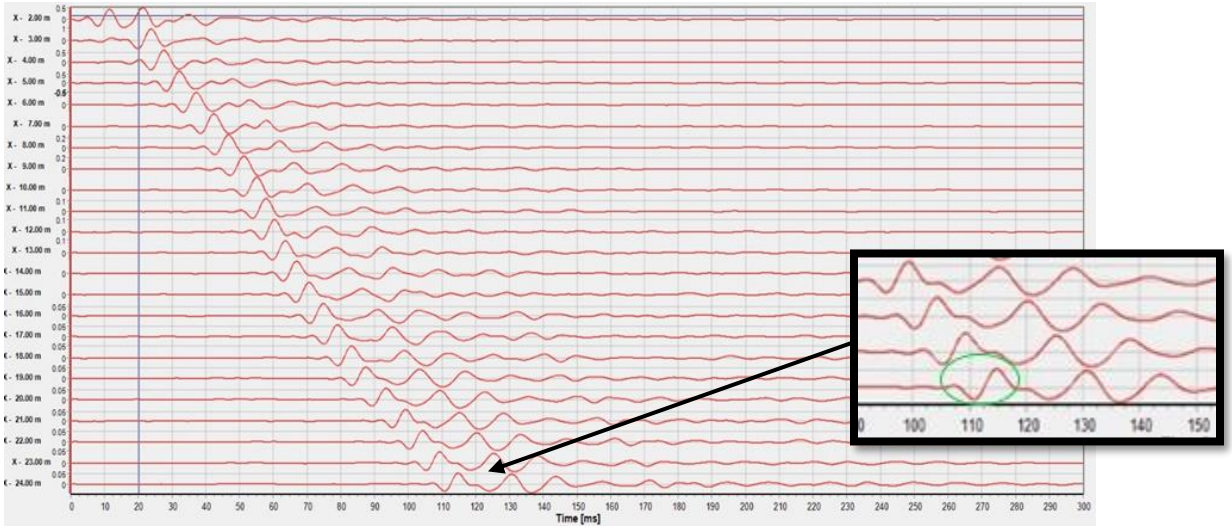

Fig. 1: Identification of trending source wave feature

This feature is then isolated throughout the profile as shown in Figure 2. It should be noted that SC3-RAV™ has an automated utility to perform this isolation.

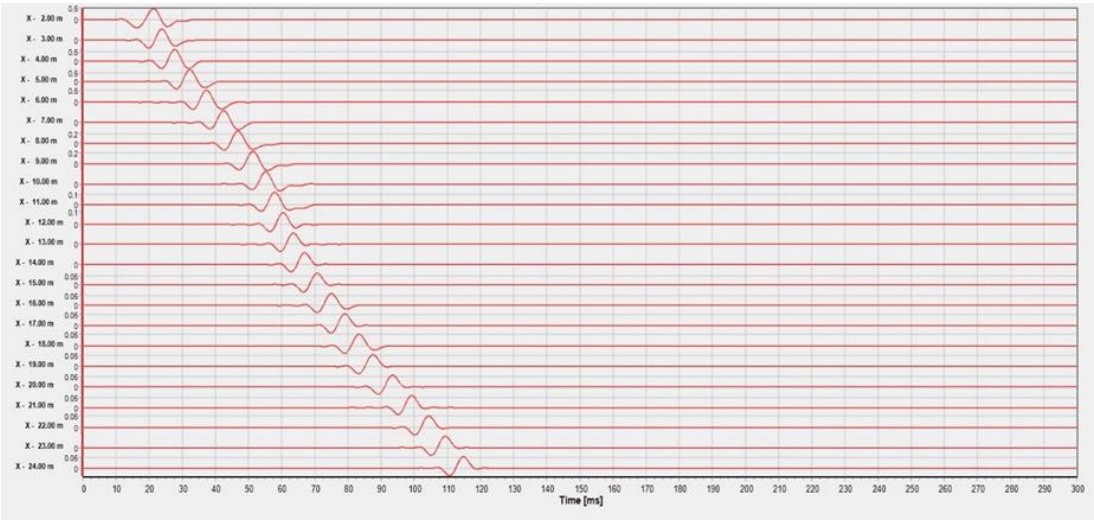

Fig. 2: Trending source wave feature isolated throughout the profile

Next batch cross-correlation is applied to the isolated seismic source wave signatures so that relative arrival times are obtained for each depth increment. In order to convert these relative arrival times to actual times, the first arrival has to be determined at one particular depth, which will then serve as the reference point. Thus the user has to identify a seismic trace as near to the surface as possible where a clear first break is present. This is the only step in the process where a subjective element is introduced in the analysis and it best done using minimally filtered traces (applying a low pass filter ranging from 400 to 600 Hz). In Figure 3 a trace is shown for a depth of 4 m and the first arrival time is estimated to be 22.5 ms. This example also shows why a larger seismic source radial offset is important: this increases the travel time and therefore if the first arrival time was estimated to be 22 ms, the change in the resulting interval velocity is minimal (given the 2 % difference is first arrival time).

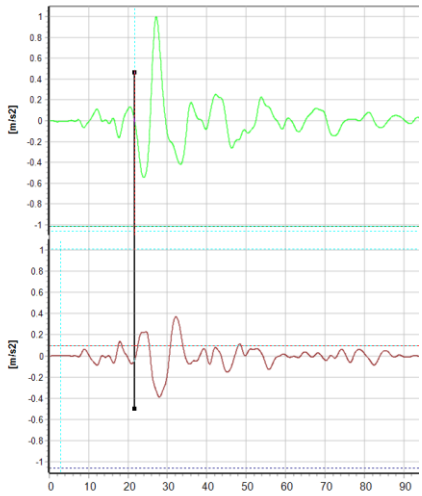

Fig. 3: Determination of the reference first arrival time

Using the arrival time of 22.5 ms at 4 m as the reference point, the true arrival times based upon the cross-correlation relative arrival times are then determined as illustrated in Table 1. Using the FMDSM technique these arrival times are then used to determine the interval velocities as shown in Table 2 are obtained

Table 1. Estimated Arrival Times

Depth [m]	Arrival Time [ms]
2	15.8462
3	18.635
4	22.5
5	27.121
6	32.1109
7	37.2802
8	41.6327
9	46.1147
10	49.9095
11	52.6983
12	55.2282
13	58.3855
14	61.752
15	65.5069
16	69.7399
17	73.8634
18	78.0665
19	82.3095
20	88.2357
21	94.0623
22	99.1918
23	104.1917
24	109.6598

Table 2. Estimated Interval Velocities

Depth interval [m]	Interval Velocity [m/s]
0.0-2.0	192.3
2.0-3.0	224
3.0-4.0	211.3
4.0-5.0	194.3
5.0-6.0	186.8
6.0-7.0	183.8
7.0-8.0	217.9
8.0-9.0	214.2
9.0-10.0	252.5
10.0-11.0	338.4
11.0-12.0	374.4
12.0-13.0	307.2
13.0-14.0	290.7
14.0-15.0	262.2
15.0-16.0	233.6
16.0-17.0	240.3
17.0-18.0	235.9
18.0-19.0	233.9
19.0-20.0	167.7
20.0-21.0	171.1
21.0-22.0	194.4
22.0-23.0	199.3
23.0-24.0	182.2

Erick Baziw
Gerald Verbeek