SPINNER DATA ANALYSIS TO ESTIMATE WELLBORE SIZE AND FLUID VELOCITY

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SUMMARY – The interpretation of velocity profiles from measured spinner data is complicated by the effects of the variation in wellbore diameter and without a calliper log is usually impossible to separate the effect of variation in wellbore diameter on interpreted velocity. By using interpreted velocity profiles from at least two different injection rates it is possible to separate the effects of wellbore size variation and fluid inflow or outflow. A unique identification of permeable zones in the well results together with identification of wellbore diameter. The method is illustrated with measurements from a recent New Zealand well.

1. INTRODUCTION

With the recent drilling practices of drilling with water or aerated fluid, wellbores are commonly quite irregular in size, due to erosion of the hole by the high velocity of the return fluid during drilling.

Figure 1 below shows a common problem in the interpretation of spinner profiles in wells now drilled in New Zealand. The velocity profile, computed using the method of Grant & Bixley (1995), has been computed from the frequency profile measured in several up and down runs over the complete openhole section. The well was recently drilled in a high-temperature New Zealand field, the openhole section is lined with a perforated liner, with all joints perforated. The well is deviated so the liner will lie to the lower side, encouraging annular flow.

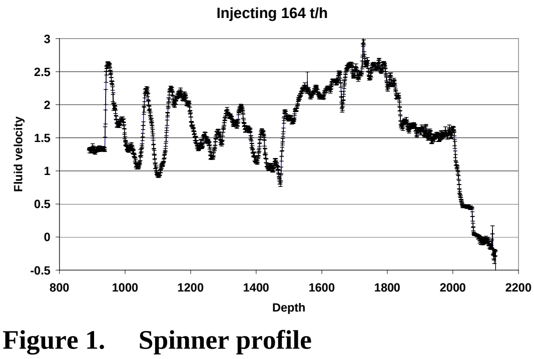

Figure 1. Spinner profile

At each permeable zone there is fluid loss or gain which results in a change in the volume flux of fluid down the well. However, the fluid velocity is the volume flux divided by the wellbore cross-sectional area. If the wellbore diameter varies, this causes changes in fluid velocity.

In the case above, the frequent changes in velocity are presumably the result of changes in wellbore diameter – it is difficult to imagine a succession of inflows and outflows to cause these (although these can be associated with annular flow outside the perforated liner in some cases).

The fluid velocity falls to zero by well bottom, so all fluid has been lost to formation. But how can the velocity reductions caused by fluid loss be separated from the effects of wellbore diameter? As the wellbore is often enlarged at a fracture zone, it is quite common that changes caused by both effects occur together.

In the absence of any other information, the normal interpretation of Figure 1 would be to observe that the velocity around 1700m is about the same as 1100m, so all the variations down to 1700m are probably due to wellbore enlargements, and the wellbore is tight at 1100 & 1700m. The velocity reductions below 1700m would then be explained as fluid losses.

2. THEORY

When there are velocity profiles interpreted from sets of spinner profiles measured at two injection rates, comparison between them can separate the effects of fluid loss or gain, and variation in wellbore diameter. For each profile, the velocity profile $V(z)$ is given by:

$$V(z) = W(z)/A(z)$$

where $W(z)$ is the volume flow as a function of depth, and $A(z)$ is the cross-sectional area of the well. The mass flow is expected to be piecewise constant function of depth, constant between feedzones and changing at each inflow or outflow. If we have two profiles at different flow rates, the cross-sectional area of the well is the same, and so the ratio of the two profiles should be constant, changing at each feedzone;

$$V_1(z)/V_2(z) = W_1(z)/W_2(z)$$

3. APPLICATION

3.1 Data correction

Figure 2 shows profiles at two different injection rates. It can be seen that the details of the variation with depth are similar in the two wells. However closer inspection shows some small differences.

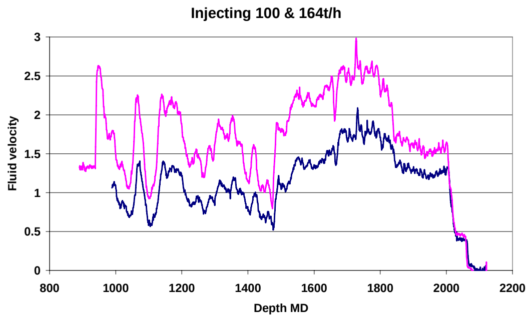

Figure 2. Spinner profiles at two flow rates

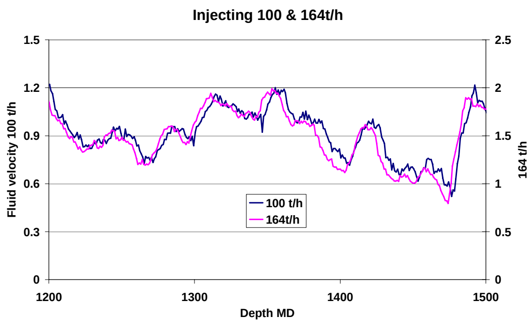

Figure 3. Detail of two profiles.

This shows that one profile is slightly displaced in depth compared to the other. It is necessary to correct the depth to make the peaks and valleys coincide. The displacement is apparently due to tool calibration.

3.2 Data quality

Because the method compares between spinner profiles, it is dependent on good quality spinner data. Such data is now available, but typical data from older runs has proven to be too poor for the method to work.

3.3 Results: injection

Figure 4 below shows the ratio of the velocities at the two rates.

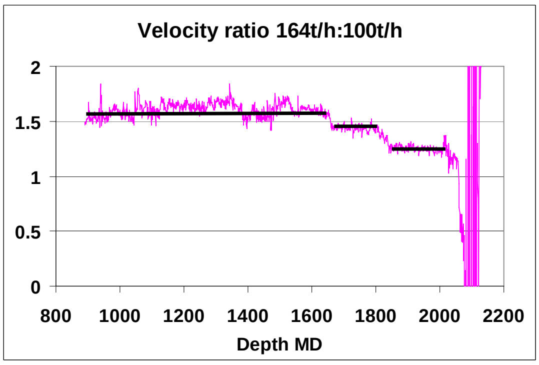

Figure 4. Ratio of velocities at two rates

Loss zones are identified at three depths:

1655-1675m
1800-1855m
Below 2035m.

Note that the first loss zone is not identifiable in the individual spinner profiles.

There is a displacement of 3.5m between the two profiles. This value was found by choosing the displacement that minimised the variance in the interval 900-1500m, where there are no loss zones.

As there is no loss down to 1655m, the wellbore diameter can be computed from the known injection flow rate. This is shown in Figure 5 below.

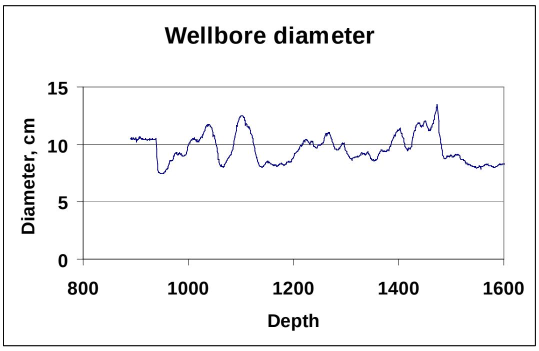

Figure 5. Wellbore diameter.

3.4 Results: discharge

The well was later discharged. Figure 6 shows the discharging and injection profiles, with the injection profile shifted in depth. Many features are common to both profiles, but not all.

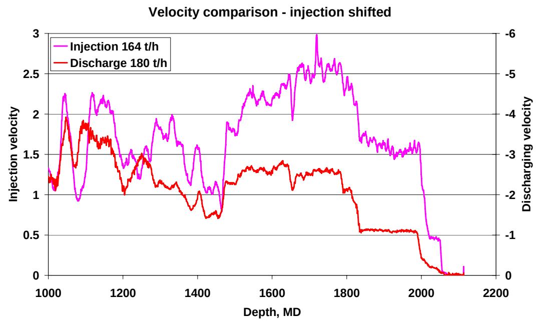

Figure 6. Injection and discharging profiles

Figure 7 shows the ration of the two profiles. There is an excursion at 1200-1300m, circled in red, and inspection of the two profiles in Figure 6 shows that they are indeed diverging here. This is interpreted as a change in wellbore diameter – the wellbore has become reduced at this depth by the discharge.

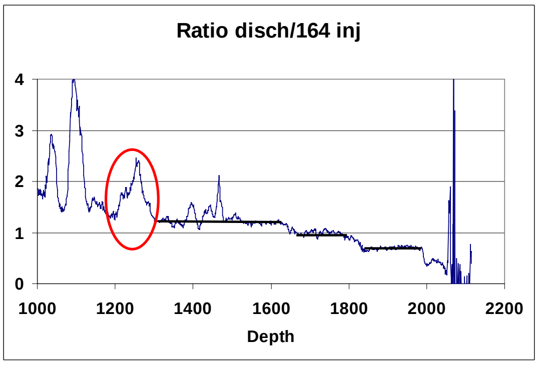

Figure 7. Ratio discharging to injecting.

Over this interval there was a velocity decrease in the injection profile, but there is a velocity increase in the discharging profile. This indicates that there was an oversize wellbore in the injection profile, but a constriction in the discharging profile. At the maximum constriction, the relative velocity has doubled – ie the cross-sectional area available in to the discharging fluid is half what was available to the injection fluid. As there were indications of deposition in this well, this information is very helpful. The flashpoint in the well was at 1325m, coinciding with the start of the interval of reduced diameter. This constriction could not be identified from the discharging profile alone, but can be identified by the cross-comparison between the two wells.
There are further spikes at 1100 and 1040mm but these appear to be artefacts of a further displacement in depth between the two profiles.

CONCLUSION

The "ratio" method provides a way of unequivocally identifying zones of fluid loss or gain in spinner profiles with variable wellbore diameter. It extends the interpretations available from spinner profiles.

ACKNOWLEDGEMENTS

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REFERENCE

Grant, M.A, & Bixley, P.F., 1995 "An improved algorithm for spinner profile analysis" Proc, 17th NZ Geothermal Workshop, Auckland University.