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Asphalt DSR prediction and control

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Much has been written about crude column product separation by APC (advanced process control) but very little about vacuum column APC. Why? Vacuum column separation is important, especially in asphalt mode, when vacuum pitch is sold as a premium product, and controlling asphalt quality is high on the list of economic priorities. My guess is that such APC applications have not been reported because of inability to infer asphalt qualities, and without such inference vacuum column APC would not be effective. Recently I had the opportunity to study and set up asphalt quality inferences at two North American refineries, and this editorial shares some of the findings.

Asphalt quality is typically measured by the DSR (Dynamic Shear Rheometer) apparatus, where the number reported as G*/sine(delta) in KPA is a measure of viscosity at a given temperature. In attempting to infer DSR one could rely on the knowledge that asphalt viscosity correlates with average boiling point and density. The average boiling point can be estimated from column measurements, but as for density we need the aid of a density analyzer. Without online density measurement DSR inference will not likely be successful.

One of the refineries in question had installed a density meter and developed asphalt DSR inference several years ago but the model was less than perfect. It would predict OK for a few days, and then suddenly would have to be biased substantially, even when the crude had not changed. That had caught us by surprise. What was going on here? Operation has not changed much but the lab test is showing a different value all of a sudden? The fog lifted when upon studying the DSR test we realized it is carried out at several defined temperatures of 46, 52, 58 64 or 70 ºC, the specific test temperature being a part of the asphalt specifications. During asphalt runs the schedulers typically switches grade every few days and then indeed, carried out at a different temperature the lab test would yield a different result. Often the operator does not know about the change of DSR test temperature. He / she would view the sudden lab – inference discrepancy as a sign of problematic inference and turn off the APC.

The immediate conclusion from this exercise is that as a minimum, the successful inference would have four different DSR correlations, one for each test temperature, and the correct one for unit control must be chosen based on the lab DSR test temperature.

We took a somewhat different approach. Given the sensitivity of viscosity to temperature, there is a certain temperature called TE, such that if the DSR test were to be carried out at TE the test result would have a value of precisely 1.00 KPA. With knowledge of the viscosity-temperature relation, TE can be calculated from DSR test result at any temperature. In our case the same asphalt sample is DSR tested at different test temperatures and then the calculated TEs should be identical. Figure 1 tests this concept, covering 20 days of TE calculations. The lab tested samples at 46 (TE46_L), 52 (TE52_L), 58 (TE58_L) and 64 (TE64_L) ºC. The reported DSR results are very different at each temperature because viscosity is quite sensitive to temperature, but the calculated TE values co-inside within half a degree. The fifth lab value in figure 1, called DSR_L is a laboratory calculation of TE based on interpolation among the several test results. Finally the blue trend of figure 1 is a TE inference as a function of VGO cutpoint and asphalt analyzer density readings. While not perfect, this inference tracks the lab well and it can reliably be used for control.

We have chosen this approach because one model of TE is to be preferred over four models of DSR at given temperatures, and for calibration this one model is compared against all lab data, regardless what the test temperatures were.

For operator display we convert the TE inference back to the test reading of G*/sine(delta). Figure 2 shows the same 20 days of figure 1, except it is related to the 58 ºC test. If desired then all other lab tests at different temperatures can also be converted to the equivalent of the 58 ºC test. That is not shown for now for fear of confusing the operator. The blue line and orange squares of figure 2 are trends of DSR inference and DSR lab test, both at 58ºC. To further aid the operator figure 2 also shows the asphalt density analyzer trend in brown in API units (left scale), and the VGO cutpoint inference in green (right scale), ºC. Note that API and cutpoint often trend as mirror image, where the gravity changes as a result of cutpoint change, but the mirror image is not perfect because gravity can also change with crude type, and the refinery in question changes the crude mix continuously.

Figure 1. Inference of TE (temperature at which DSR would be 1.00 KPA) versus lab results

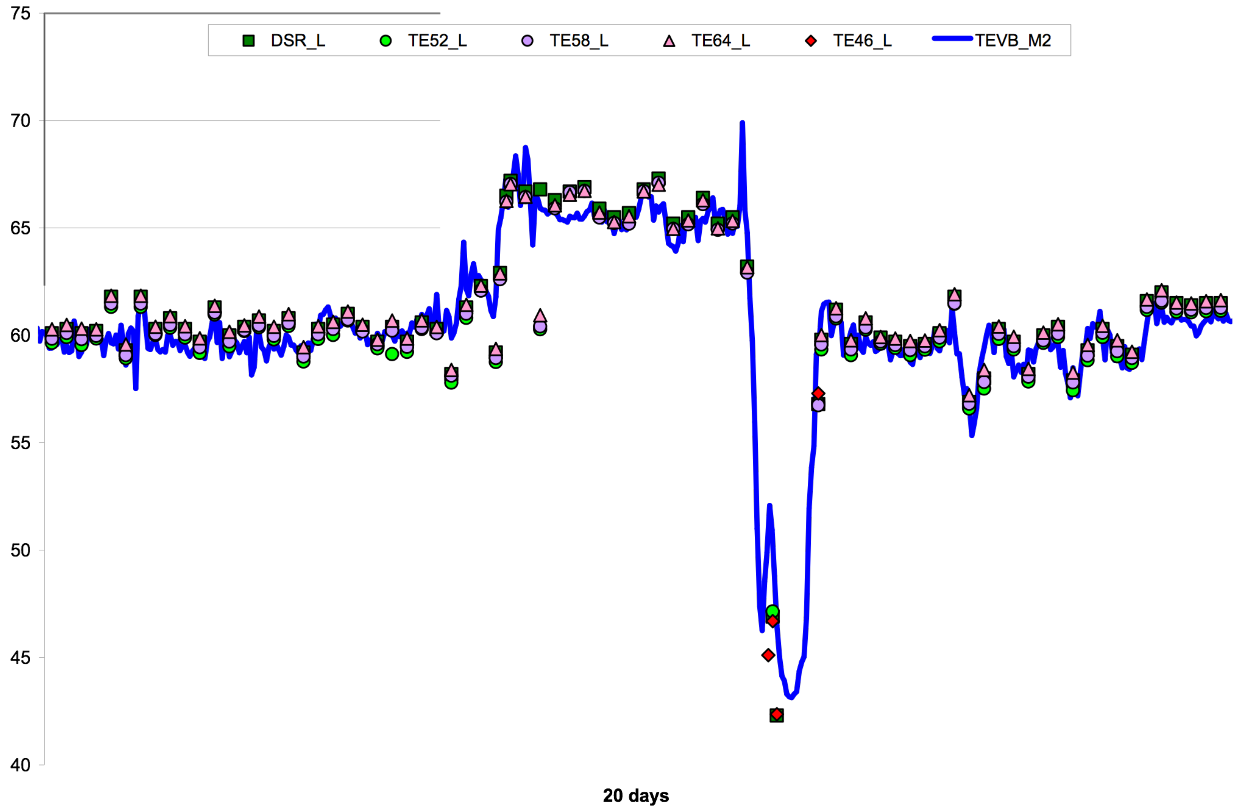

Figure 2. Inference of G*/sine(delta) @ 58 ºC