ACCURATE PROCESS VISCOSITY MEASUREMENT

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INCREASING PRODUCTIVITY AND PROFITABILITY IN ASPHALT AND LUBRICATION OIL REFINERIES

There are more than 700 refineries worldwide, operating in virtually every country on earth, with a capacity to produce 82 million barrels of oil per day. Viscosity is one of the most critical measures of product quality for virtually every refinery product.

In Australia, seven major refineries currently operate, with a capacity to produce 750,000 barrels of oil per day.[1] The demand for energy continues to rise, placing increased pressure on producers to streamline and speed production, increase yield and operate more efficiently.

A barrel of crude oil typically yields 50% gasoline, 15% fuel oil and 12% jet fuel - with the remainder used for diesel, asphalt, lubrication oil and other refined products - but output varies by refinery. Viscosity is one of the most critical measures of product quality for virtually every refinery product. New developments in viscosity measurement are enabling refineries to significantly improve production quality, cost and output. Methods for effectively managing asphalt and lubrication oil viscosity are discussed below.

Asphalt

Asphalt is critical for road paving. Roads are subject to radically different environments worldwide and to seasonal changes that impact road quality. Asphalt must be suitable for local conditions and asphalt suppliers must meet pavement specifications unique to each customer's region.

The raw material for making asphalt is basically what remains in the bottom of a barrel of crude oil when all higher value materials have been extracted and refined. This raw material is typically non-homogenous and may vary radically in make-up from barrel to barrel depending on the source of the crude oil. Variations in refinery process conditions can also have an impact.

Customer specifications are based on international standard test methods that utilise standard laboratory test equipment. These lab tests are done periodically throughout production and the process is adjusted based on the test results. The material is then tested in the storage tank, and re-blended to meet the exact customer specifications. Unfortunately, the asphalt characteristics can vary significantly between lab tests. Therefore, significant post-process blending is typically required to meet customer specifications (see the example in Figure 1).

Since lab analysis is run only a few times per day, refineries utilise inline measurements to enhance production consistency. Three technologies are commonly used for inline viscosity measurements: capillary, vibrational and oscillating piston. All require conditioning of the fluid being tested so that it is as consistent as the lab samples are in terms of temperature, flow and particles. Capillary systems require high-precision pumps for accuracy, as well as frequent and costly maintenance and recalibration. Vibrational-based viscometers can cause resonance frequencies in fluids and are subject to process equipment vibrations, which can lead to inaccurate measurements. The oscillating piston technology is preferred for its accuracy, reliability and ease of installation. In a typical asphalt process, an oscillating piston viscometer is installed in the main asphalt line or in a bypass to the asphalt line (see Figure 2). In this example, the viscometer is located in a 5 cm bypass line of a 30 cm main line and is used to maintain the diluent addition to achieve the ideal customer specification the first time it goes through the process.

Lubrication oil

All lubrication oils are graded and sold based on their viscosity characteristics. Viscosity is the measure of a fluid's resistance to flow, so the ideal lubricant is frequently one that keeps moving parts separated, at the lowest viscwosity possible. The industry typically uses VI, or the viscosity index, to characterise lubricants. The VI is a ratio comparing the viscosity of oil at two different temperatures and is a governing specification for any lubricating oil.

Highly precise viscosity measurements are required for lubricant production. Obvious cost advantages exist from producing lubricants with the specified characteristics the first time they are run through the process, rather than trying to blend them in later. Meeting laboratory results inline typically requires process instruments to be installed in a bypass line that is conditioned for constant temperature and flow and with particulate filtering.

Oscillating piston viscometers, such as those of Cambridge Viscosity by PAC, can offer in-process measurement with a high degree of accuracy - and with results that match the lab for most lube oils. Figure 3 demonstrates the high correlation between Cambridge Viscosity viscometers and the results found during lab analysis.

For higher accuracy, some refineries use dual viscometers at slightly different temperatures and average their results as the basis for each measurement. An example of this is shown in Figure 4. Achieving these results requires viscometers that are extremely accurate and reliable in the widely variable environmental conditions refineries are subject to. Oscillating piston technology is the preferred solution for a growing number of refiners over pressure and vibrational measurement approaches. Sensors utilising oscillating piston technology outperform sensors using the other approaches due to their high accuracy and repeatability, robust design, low maintenance and vibration insensitivity - as well as their inherent small size for ease of installation and reduced sample conditioning costs. In addition, oscillating piston sensors typically offer the lowest total cost of ownership.

Figure 1: Asphalt characteristics can vary significantly between lab tests.

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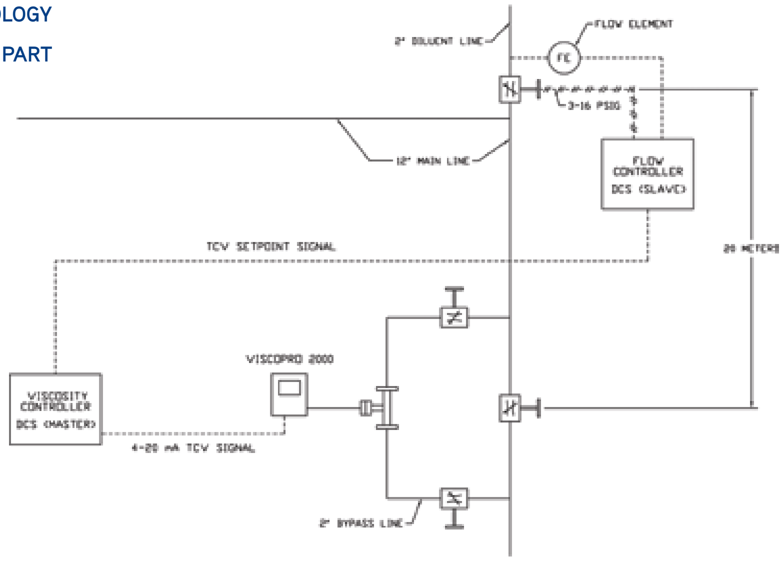

Figure 2: In a typical asphalt process, an oscillating piston viscometer is installed in the main asphalt line or in a bypass to the asphalt line.

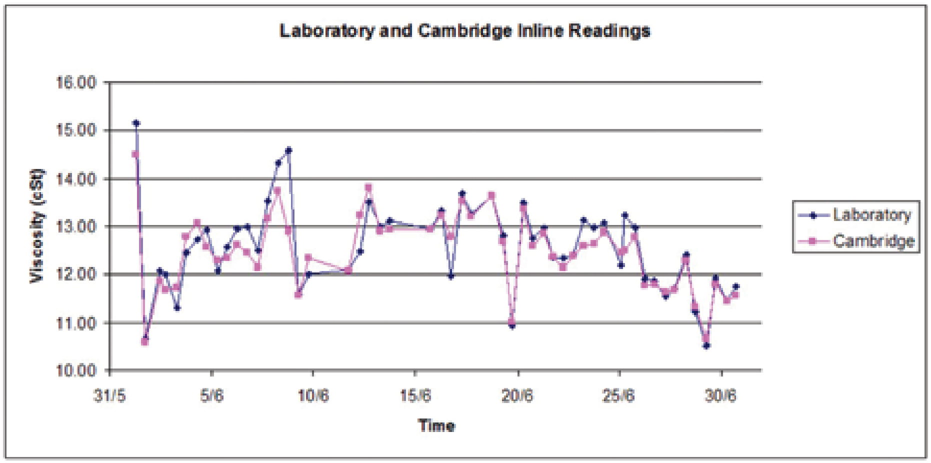

Figure 3: Results from oscillating piston viscometers correlate well with lab tests.

Increase productivity and profitability

The profitability of in-line control for lubricant production is significant. At some refineries, it takes 4-12 hours to realise and correct off-spec production. This can cost a refiner $150,000 per off-spec occurrence for a low-value material, such as asphalt, and up to up to $500,000 for a high-value material like lube oils. Alternatively, installation of an in-line viscometer costs between $25,000 and $50,000 (total installed cost). In addition to this saving, one refinery reports that maintaining tighter control on their lube oil viscosity results in a 0.5% production improvement, or $600,000 in revenue per line, per year.

Combustion products

Precise control of the fuel viscosity is important as well. Viscosity controls the droplet size in fuel atomisation, which is essential for efficient combustion. This includes fuels ranging from heavy fuel oil to diesel and gasoline, plus jet fuels. Real-time monitoring enables producers to meet tight regulatory standards and provides audit trail confirmation of the product quality.

How oscillating piston viscometers work

Oscillating piston viscometers are fundamentally simple, rugged, accurate and repeatable despite operating environments with significant vibration. A key to the technology is its use of a single, non-contact moving part both to clean and measure.

The viscosity measuring technology is based on a simple and reliable electromagnetic concept, as shown in Figure 5. Two coils move a piston back and forth, within a chamber, magnetically at a constant force. The motion of the piston is controlled and the piston's two-way travel time is measured to determine absolute viscosity. As the viscosity is increased, the travel time is also increased.

The motion of the piston is controlled so that it monitors the fluid viscosity and keeps the sensor's measurement chamber clean, so that the sensor requires minimum operator attention. A temperature detector is included in the measurement chamber so that both temperature and viscosity are known for every measurement.

Proprietary circuitry is used to analyse the piston's travel time to measure absolute viscosity and monitor temperature. With all wetted parts stainless steel, the constant motion of the piston

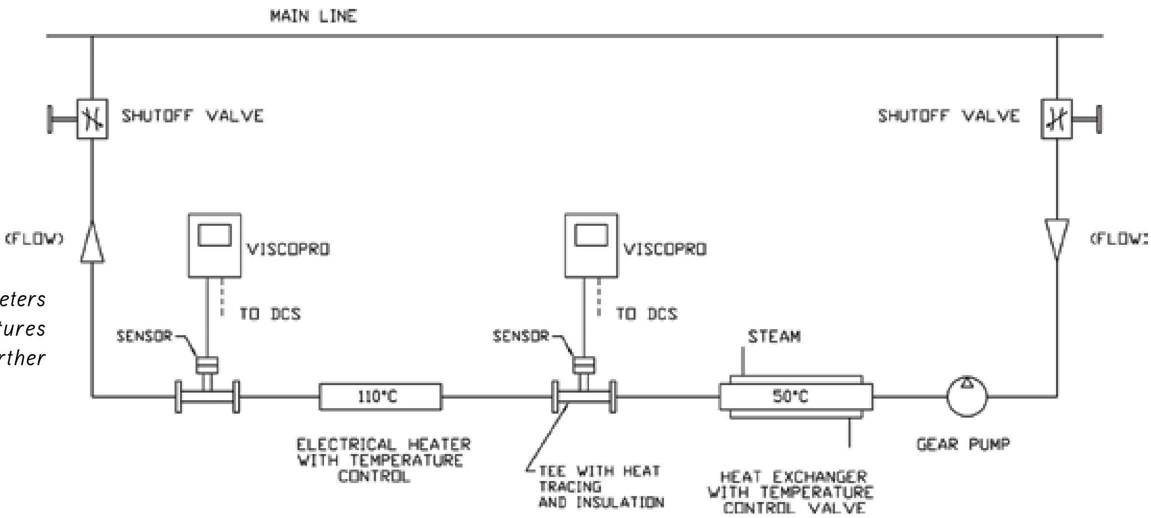

Figure 4: Dual viscometers at different temperatures are often used to further improve accuracy.

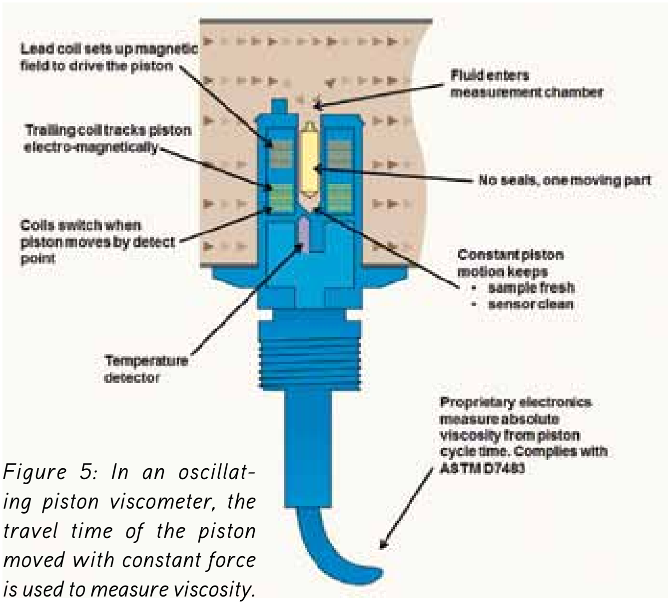

Figure 5: In an oscillating piston viscometer, the travel time of the piston moved with constant force is used to measure viscosity.

Figure 6: A Cambridge Viscosity VISCOpro 2000 oscillating piston viscometer.

keeps the measurement sample fresh while mechanically scrubbing the measurement chamber. An example of an oscillating piston viscometer is the Cambridge Viscosity VISCOpro 2000 (Figure 6). This viscometer, combined with a 392 or 301 sensor, is capable of providing viscosity, temperature, temperature-compensated viscosity (TCV) and optional density readings. It is suitable as an in-tank or inline viscometer for any process environment. Thirteen factory-set standard measurements range from 0.2 to 20,000 cPl. Operating characteristics, control set points and alarms are set using a menu-driven interface with RS232 (standard) and RS485 (optional) communications ports. A built-in 1000-point data logger captures key data in real time that can be readily exported to common graphing programs for analysis. The VISCOpro 2000 can be programmed for up to 40 different fluid settings, enabling rapid changeovers in production processes.

Conclusion

In refinery applications where producing off-spec material can cost hundreds of thousands of dollars per day, refiners are increasingly relying on real-time, continuous inline measurements to extend traditional offline lab tests to assure product quality. With process results that highly correlate to lab results, refineries:

- reduce costs with accurate viscosity measurement
- avoid off-spec materials waste
- quickly detect viscosity deviations
- avoid post-process blending re-work

The return on investment for inline viscosity control is seen within days for asphalts and lubrication oils. Oscillating piston technology offers distinct advantages over pressure and vibrational measurement approaches for inline viscosity management due to its inherent accuracy and reliability, robust design and vibration insensitivity. For refinery operations hard pressed to keep up with demand, streamlining production and maximising efficiency ultimately increases profitability.

Resources

1. Australian Government, Department of Resources, Energy and Tourism http://www.ret.gov.au/resources/fuels/petroleum_refining_and_retail/petroleum_refining_in_australia/Pages/PetroleumRefininginAustralia.aspx

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