::: White Paper

Viscosity Control for the Upstream Market

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Preface

The dramatic drop in oil prices over the last few months, with global oil prices plunging by almost 60 %, have driven oil producers to scale back spending. While lower oil prices will reduce production costs for many sectors and boost consumers' disposable income, upstream spending plans have been the first casualty of the market's collapse. Some of the major oilfield service providers are expecting to lay off thousands of employees while budgets are reduced and projects are postponed, curtailed or canceled.

The analyst's and chief executives predict a 12 to 18 month price dip. Recovery is expected to be slow, as fundamental supply and demand gradually rebalance over this period. With low oil prices expected to persist through 2015, the production rate is expected to continue, but at a slower pace. On the other hand, panelists at the latest International Petroleum Technology Conference have pointed out that low oil prices present opportunities for the oil and gas industry to innovate and strengthen its base for the next phase of industry development

The current period of low prices is an opportunity for long-term investment and efficiency improvements. Providing proper technologies to intensify cost reduction and productivity enhancement are the key challenges for the near future.

In the following paragraphs we will focus on viscosity, one of the basic measurement techniques affecting different key operations within the upstream market.

Upstream

The oil sector comprises various business areas, including oil exploration, drilling, refining, and distribution to consumers. The downstream part involves refining and distribution of the finished products like gasoline and diesel fuel. In this paper we will focus on the upstream segment, which includes drilling (as part of exploration and operation), recovery of the crude oil to the surface and transportation of the crude from the production site to the refinery.

As conventional reservoirs are depleted and more unconventional resources are being exploited, chemicals play an increasingly important role in tackling the upstream challenge. Smarter chemicals and how they are used can boost production, cut costs and reduce environmental impacts.

Online viscosity measurement as well as extensive laboratory rheological evaluations are substantial parts of the main innovation areas, for developing and improving production technologies to extend the lifetime of mature fields, developing exploration and production technologies for unconventional reservoirs and improving the transportation between production and refining.

Why viscosity is important

Dynamic viscosity is an important parameter for quality control in a wide range of industrial processes and is one of the most important fluid properties for the production of many industrially important substances. Non-Newtonian viscous behavior is a property of particular importance regarding a fluid's performance during oil production, completion design or reservoir management. Viscosity controls reservoir productivity and displacement efficiency and influences pump and pipeline design.

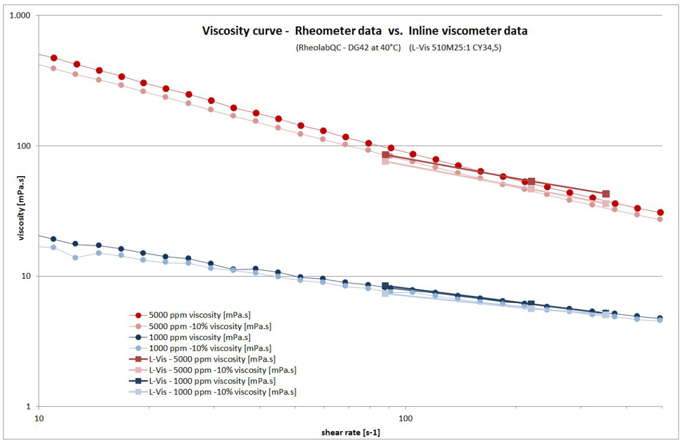

Fig. 1 Example of Non-Newtonian polymer solution measured with laboratory rheometer versus measurement with inline viscometer at three different shear rates

Almost all chemicals of upstream significance, especially those of multi-phase nature (emulsions, dispersions, suspensions and slurries) and polymeric solutions, have a non-Newtonian behavior, meaning that their viscosity is not only influenced by temperature. Generally, we can observe pseudoplastic or shear-thinning properties, based on which fluids' viscosities decrease with the applied shear rate.

Real time viscosity information is of significant importance for production and transportation. The rheologically interesting information found in the low shear rate section of the viscous flow curve is especially important, as it provides feedback with regard to proper formulation for the intended end destination of the fluid (whether just in the bore hole, fracture or some other part of the reservoir).

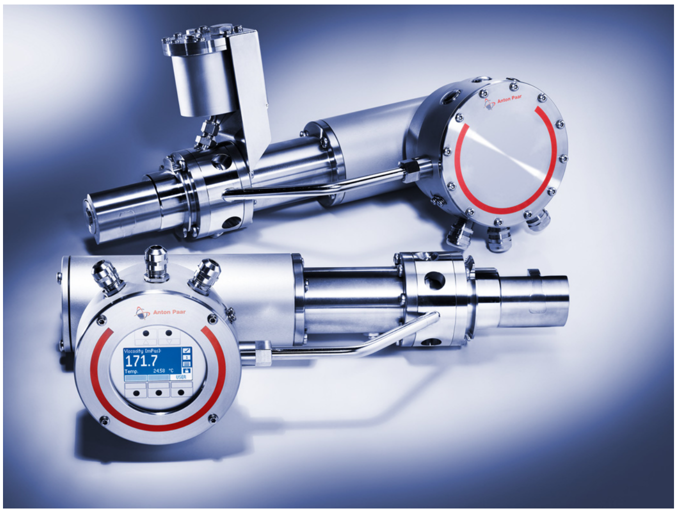

Fig. 2 Inline viscometer suited for non-Newtonian liquids based on measurement of the dynamic fluid pressure

Where viscosity control is crucial

1 Drilling for exploration and production

Drilling is physically creating the borehole in the ground for an exploratory well and associated geological and geophysical surveys, or for what will eventually become an oil or gas well. Any fluid that is used in a drilling operation in which the fluid is circulated or pumped from the surface down the drill string, through the bit, and back to the surface via the annulus is called a drilling fluid or drilling mud.

Drilling fluid design and selection starts with defining the functions that are required of the fluid. The rheological properties of the fluid will influence cleaning, transportation of cuttings, hydraulic power, bit cooling as well as borehole wall support and friction.

Numerous additives are used in order to reach optimized specific purposes which are sometimes contradictory. For example, drilling fluid must be viscous enough to lift the cuttings to the surface, but at the same time its viscosity must not be too high, so that friction pressure losses are kept to a minimum.

Complementing the laboratory sample measurements (which may occur only once per day) with online drilling fluid viscosity measurement provides access to more precise and dependable drilling fluid properties in real time. Data that is vital when crucial decisions are made.

2 Fracturing

Hydraulic fracturing (also known as "fracking") is an important well completion technology for the advance of unconventional resources, such as natural gas that is trapped in shale rock formations. It is used to create a fracture network through which light oil and gas can migrate to the wellbore.
The fracturing fluid used in the well stimulating process is a blend of carrier fluid and a proppant, such as sand or glass beads. The proppant and carrier fluid are blended in specific proportions targeted to the dynamics of each individual well.

In order to carry the correct amount of proppant to the fracturing zone, the viscosity of the carrier fluid must be accurately maintained throughout the stimulation process. One can install an inline viscometer on the low pressure side of the blender, utilizing a slip stream flow through a sample system off the hydration tank, which continuously verifies that the rheology of the fracturing fluid is within

established specifications and generates an alarm indication when it is not.
Based on an accurate and reliable viscosity measurement of the carrier fluid, the operator can maintain the proper suspension of the proppant within the carrier fluid. In addition, real-time viscosity measurement allows the oilfield service company to mix the carrier fluid on-site, thereby reducing fluid availability risks or problems and costs associated with excess fluid disposal.

3 Chemical Enhanced Oil Recovery

Often, when primary production begins to wane, injection wells are drilled to flood the reservoir with water (especially in regions where the injection water is readily available), maintaining pressure and sweeping additional oil into adjacent producing wells. Known as "secondary recovery", water flooding operations have raised average global recovery by 25 % to 35 %. However, these conventional techniques still leave 60 % or more of the oil in the ground.

Enhanced oil recovery (EOR) methods can be implemented to mobilize the oil and displace it towards production wells, e.g. by reducing interfacial tension and capillary contrasts, and/or by increasing the viscosity of the displacing fluid. In this case chemicals that are not naturally present in the reservoir (e.g. surfactants, polymers, acids, etc.) are injected into the reservoir to achieve a higher or faster oil recovery. The most frequently used polymer (by far) in chemical EOR is polyacrylamide. Polymers and other chemicals enable injected water to better match the viscosity of the reservoir oil, which helps the water penetrate the rock pores to improve oil production. If the polymer solution is not balanced for the reservoir oil conditions, production can drop substantially, negating the benefits of the enhanced oil recovery process.

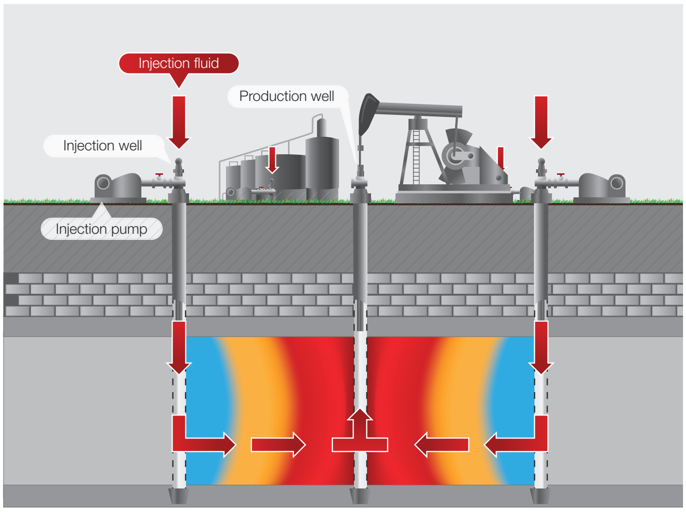

Fig. 3 Basic diagram for Chemical Enhanced Oil Recovery

One of the key factors for a successful polymer flood is the polymer solution viscosity that must remain on target during the transport from the site of its initial preparation to the well head and down to the reservoir. Maximizing oil production while minimizing polymer costs, is one of the key objectives for the operators. Thus, a reliable method is required to measure and monitor the polymer solution viscosity at different points along the dissolution, dilution, mixing and injection lines.

4 Diluted bitumen pipeline transportation

Bitumen is a highly viscous form of crude oil that is derived from the Canadian oil sands in Alberta, Canada. Crude sources are produced from many locations, employing a number of production methods. The bitumen path to market includes mining and upgrading processes, polymer flood production strategies as well as paraffinic and naphthenic froth treatment processes. In order to flow through unheated pipelines, the bitumen must be diluted. The diluted mixture improves the quality of bitumen and allows the crude oil to meet pipeline product quality specifications posted with federal regulators for the crude oil flow through transmission pipelines. Typical diluents include natural gas condensate, naphtha or a mix of other light hydrocarbons. The blend is referred to as “dil-bit” if blended with naphtha based diluents or “syn-bit” if blended with sweet synthetic crude oils. What to use is often determined by diluent pricing, access to logistics, production technologies and producer/refiner economics.
Diluted bitumen has characteristics that are similar to other heavy crudes that are currently transported in pipelines, like heavy crudes from Venezuela, Mexico and California.

To meet pipeline specifications for viscosity and density, and to meet desired refinery heavy crude yields/qualities, a controlled blend with a diluent is produced. A maximum viscosity of 350 cSt (centistokes) at pipeline reference temperature is constraining, with a pipeline reference temperature between 7.5 °C and 18.5 °C changing in bi-weekly increments according to a planned schedule from winter to summer.

Natural variances in bitumen and commercially available diluents can result in a significant number of possible variations of a measured product. Add to that the mix of products at terminals and it soon becomes apparent that the product composition changes and the accompanying potential effects on viscosity measurement are factors with several dynamic variables. The result is a changing fluid composition and the measurement strategy must be able to cope with this fluid variance.

Of course one of the most important factors of viscosity measurement is temperature control. Online instrumentation must have temperature characterization with a quality above that typically found in general instrumentation. Also, its flow loop should be designed to facilitate the best possible temperature control.

The online application of instruments for direct measurement at reference temperature as well as curve or equation methods all have their benefits and drawbacks when considering the challenge presented above. However it is indisputable that pipeline transportation of heavy crude relies on viscosity measurements for both efficient and safe operations.

There is potential for improved process control when exposed to significant variations of the measured product. Based on a direct online measurement at reference temperature, the level of viscosity certainty is increased, and the resulting benefits include substantial savings in processing and transportation as well increased pipeline operation safety.

Conclusion

A closer look at different parts of the upstream chain reveals that online viscosity measurement and control coupled with appropriate laboratory rheological evaluations create substantial innovation opportunities.

The current downturn in the oil and gas industry provides great opportunities for retrenching and focusing on the cost structure, rather than just increasing volume. The implementation of proper technologies to intensify cost reduction and productivity enhancement are the key challenges for the future.

About the author

Miha Zavrsnik is product manager for Process Instruments at Anton Paar GmbH and has worked for the company since 2011. He has more than 20 years of diverse working expertise in team management, product and project management, general sensor and test systems development, information technologies systems, quality assurance and fiber optic communications component development.

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