SPE Brazil Flow Assurance Technology Congress
Rio de Janeiro, Brazil, November 15 – 18 2022

Examination of Non-traditional Wax Management Techniques for Flow Assurance in Petroleum Production

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Abstract
Wax deposition and build-up in reservoirs, wells and pipelines negatively impact asset productivity, integrity and economics. Several flow assurance techniques have been developed to mitigate or remediate waxing problems. Prominent among these are controlling operating conditions, chemical, thermal and mechanical methods. Their major drawbacks have remained exorbitant costs over life-of-field, no single method being sufficient, risk of costly mistakes due to overdesign or underdesign, etc. Some innovative, unconventional solutions were also developed over the past 2 decades, with promising results, though mostly yet to be commercialised. This paper highlights and reflects upon these hitherto standalone technologies given the largely sparse treatise they have received in the literature. The aim is to explore alternative wax management techniques as a means of improving the science of wax deposition and dissolution.
Non-traditional methods were critically examined during a 12-month extensive literature survey. In-depth study of the rationale, principle of operation, results obtained, advantages and limitations of each method was performed. Independent studies using variants of the same method were juxtaposed to ascertain similarities and differences in applicability, with meeting points established to pave the way for future research collaboration. Reflections upon their merits, limitations, areas for improvement, and a case for scale-up are presented.
Some non-traditional techniques have overcome certain perennial constraints of conventional techniques widely used in industry. The wax inhibition tool, for example, has low energy requirements, causes minimal environmental impacts and has relatively low costs. The precious metals and quartz used in making the tool are available locally, the alloys were mixed in the university's materials laboratory using in-house manpower and the flow loop was locally designed and fabricated. Having developed expertise on this project through repeat and improved experiments, preparing and implementing a cost-effective work program for its commercialization is doable by the research group with industry partnership. Adapting oscillatory motion based on Avrami theory to understand mechanism and kinetics of wax crystallization by experiments on North Sea crude had yielded two opposite effects that are interesting to note. Repeat experiments a decade later using synthetic oils from Southeast Asia yielded improved results and better understanding of wax deposition kinetics; an indication that this topic holds promise to unravel some mysteries in the subject, if its deliverables are embraced and implemented.
The expose provided by this paper will hopefully contribute towards available knowledge on wax management. It is expected that conscious follow up on these technologies, some of which are related and could be hybridized, would inform future research directions for both the academia and industry in the field of flow assurance.

Keywords
Wax deposition; non-traditional methods; bench scale; research collaboration; petroleum production systems

Introduction
Energy demand has been forecasted to grow in the next 30 years due to rapid industrialization, especially in developing countries (Dong *et al*. 2017). For oil and gas produced from reservoirs to be useful, they must be efficiently, safely and economically transported from often harsh and remote locations to the points of processing and sale. Transportation of waxy crude oils and gas condensates makes flow through pipelines difficult and challenging. Furthermore, waxy oil transportation from the wellhead to the refinery gate is becoming important with growing complexity in fluid chemistry as their production has to be ensured through improved flow assurance. To maintain safe and cost-efficient production, wax deposition needs to be remediated or avoided wherever possible and feasible. Wax mitigation and remediation techniques are generally termed wax management and have generally been described at various depths in the literature. Wax control methods are often

associated with high costs and conventional methods have their inherent limitations that vary from one field to the other. Other methods have been developed on the bench scale and some trialed in pilots with promising results, but they are yet to be commercialised for wide adoption in the industry. These have generically been termed non-traditional wax management techniques by the author.

Methodology

The various non-traditional wax management techniques were critically examined during a 12-month extensive literature survey. In-depth study of the rationale, principle of operation, results obtained, advantages and limitations of each method was performed. Independent studies using variants of the same method were juxtaposed to ascertain similarities and differences in applicability, with meeting points established to pave the way for future research collaboration. Reflections upon their merits, limitations, areas for improvement, and a case for scale-up will be presented in this paper.

Results and Discussion

Wax inhibiting tool (WIT), a device made of metallic alloys that can alter petroleum properties as the fluid flows through them, was used in production tubings in 5 Niger Delta producing wells (Figure 1). One well had been shut in, a second had reduced throughput in its flowline while a third required monthly pigging due to waxing problems. Field tests showed wax formation to be effectively prevented when WIT is installed 100 - 500 ft below the tubing depth corresponding to the predicted WAT. Having succeeded in the problem wells, the tool was run on the flowlines and significant reductions in wax deposition recorded. Thermodynamic modelling was done to perform wax risk assessment for the remaining 10 wells.

Figure 1. A Silver-Hawg Wax Inhibiting Tool (Sulaimon, et al. 2010:27)

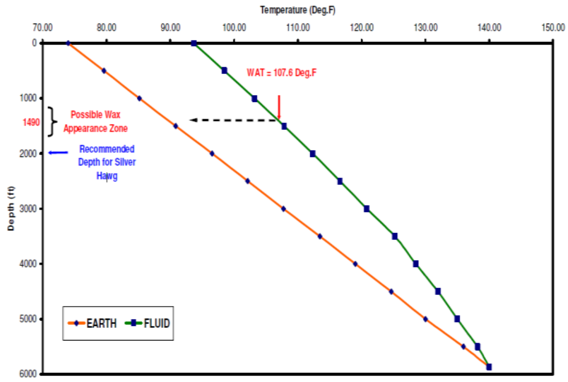


Figure 2. Temperature distribution profiles in production tubing for well 25S (Sulaimon, et al. 2010:32).

Figure 2 illustrates the thermal profile obtained from thermodynamic modelling in the tubing for well 25S, a waxy gas condensate producer. From the results, it was recommended to install WIT just below the possible wax appearance zone. This could potentially serve as a guide for designing management strategies for wax deposition at topside facilities of gas condensate fields. Nevertheless, fluid characterisation and thermohydraulic modelling results specific to the cases handled would determine its feasibility or otherwise in other fields as fluid compositions vary from one asset to the other, affecting wax behaviour and management method selected.

Sulaiman et al. (2011) had developed a WIT variant with an aluminium matrix using a mixture of zinc, lead and quartz, while explaining the mechanisms of application of piezoelectric energy generated in locally sourced materials for wax prevention (Figure 3). The piezoelectric WIT was tested on a flow loop with the zinc-quartz crystal reducing wax deposit by over 32% in the most problematic of the five waxy crude oil samples. The lead-quartz mixture gave 17.9% deposit reduction on the same sample.

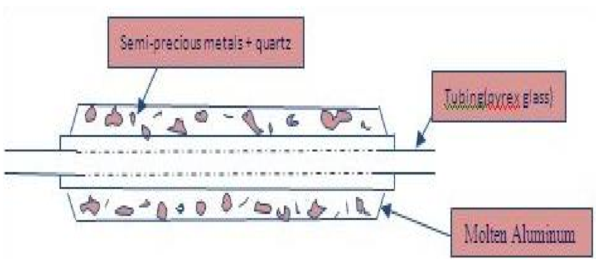
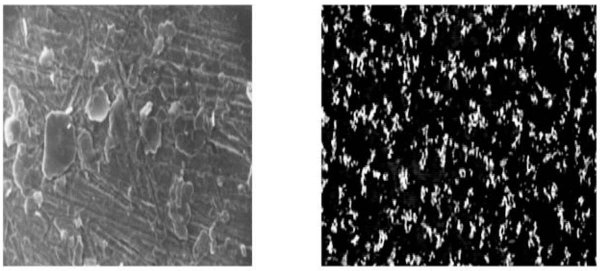


Figure 3. Detailed diagram of fabricated WIT tool (Sulaiman et al. 2011:96)

The study was extended through further experiments in which five screened samples were tested, results showing improved deposit reduction of 58% for the zinc-quartz alloy and 35% for the lead-quartz alloy using the most problematic sample OSS-3 (Figure 4), while various efficiency values were obtained for other samples (Sulaiman, et al. 2014).



a) b)

Figure 4. Photomicrograph of OSS-3 (a) before treatment, 20µm and (b) after treatment, 20µm (Sulaiman, et al. 2014:9)

Hamilton and Herman (2011) had independently developed a different kind of WIT that applies passive energy to reservoir fluids for solids control and viscosity reduction. It is based on the understanding that micellization initiated by electrokinetic effects during fluid flow combines with pressure and temperature fluctuations to induce the deposition of wax, asphaltenes and scale as well as increased viscosity in heavy oils. Case histories of successful deployment in wells at heavy oil fields in Venezuela, Argentina and Canada were reported. There is no published evidence to indicate that this tool is suitable for waxy light oils and gas condensates. Nevertheless, the working principle demonstrated that the effect of pressure on wax deposition and control cannot be neglected; something most wax models tend to do and is probably a source of error in predictions that could negatively impact field development economics. For waxy light oils and gas condensates where the presence of a gas phase makes pressure an important parameter, it is possible that this tool can be useful for both the study of wax kinetics and deposit control as offered by the previously discussed two variants. Empirical proof is needed to confirm this from bench through pilot to field scale, especially as it has the potential to control multiple flow assurance solids – a common phenomenon with complex fluids such as are found in the Brazilian pre-salt, Southeast Asia and some frontier areas in Africa. A synergy between the researchers involved in WIT is thus advocated to cross-fertilize ideas and develop more globally applicable solutions through joint industry-academia projects.

Conclusions

The selection of the appropriate method to treat a given wax situation depends on several factors including the nature of the problem, quantity and thickness of wax deposited, fluid composition, rheological properties, operating conditions, environmental conditions, cost considerations and extant regulations. Experimental and modelling studies often provide useful leads for decision making to minimize uncertainties and wasteful costs, while optimizing production and asset integrity.

As has always been the case with many good studies initiated by the academia, lack of support by the industry to commercialize innovation has remained a bane to the actualisation of non-traditional wax management techniques in practice. For the three WIT variants reviewed and reported to have succeeded in the field, there is great promise for widespread adoption across the industry or at least various assets of the concerned operators. The experiments and trials for qualification in each new case before deployment would serve as learning points for continuous improvement. Communicating the successes and emerging challenges through publications and presentations will contribute to available knowledge. Engaging the academia, engineering firms, service providers and regulators in collaborative projects is also recommended to advance research and development. There has been little research in flow assurance in recent times, which should be revived as oil and gas markets have been lucrative for over a year. With growing global energy security concerns, assuring flow sustainably and economically has become more important than ever. Moreover, the lessons learnt from flow assurance in oil and gas production and transportation systems will guide the development of the practice for renewables as the industry transitions in a just manner.

Responsibility Notice

The authors are the only responsible for the paper content.

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