# Rheological parameters of several bitumen and heavy crude oils by using a piezoelectric quartz resonator

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Due to the increasing demand for oil and to face the depletion of natural resources, the petroleum industry has resorted to exploit non-conventional oil fields, and particularly bitumous sands. These oil reserves are huge but their exploitation has proved to be difficult and very costly so far. The recovery of these extra-heavy oils thus represents a major interest for the oil companies. One of their goals is to develop techniques making it possible to improve the extraction efficiency of these resources. Among these enhanced oil recovery (EOR) methods, injections of hot steam or gases have been performed to decrease the viscosity of these heavy crude oils.

As the solubilization of gas in these heavy oils is very slow, conventional PVT techniques do not allow the accurate measurement of the phase equilibria of these systems. It is thus necessary to work on very small samples. Therefore, a microweighing technique under pressure using quartz crystal resonators has been developed in the Laboratory of Complex Fluids at the University of Pau. This technique was already implemented in the University of Aveiro to study the solubility of carbon dioxide in polymers [1]. It must then be adapted to quantify the solubilization of gas in samples of heavy crude oils. The quartz resonators are also tremendously sensitive to the pressure and the rheological properties of the medium in contact with the crystal.

Based on the piezoelectric effect, the experimental device is composed of a thin AT-cut quartz strip sandwiched between two metallic electrodes. A network analyzer measures the admittance spectrum around the harmonic frequencies. The resonance frequency and the dissipation of the resonator, which is related to the damping in the system, are then derived. According to Sauerbrey's equation, a linear relationship links the frequency changes to the variation of the deposited mass on the surface of an electrode covering the crystal. Mass shifts of about 1 nanogramme can be detected. The Kanazawa's equation allows linking the shifts in frequency and dissipation to the density-viscosity product of the surrounding fluid. In this work, the capacity of the piezoelectric device to determine the shear modulus of viscoelastic systems is used.

The viscosity data of bitumen and heavy crude oils available in the literature were obtained using various types of viscometers and particularly rotational viscometers for which the steady shear mode was employed. Hasan et al. [2] measured the complex viscosity of Athabasca bitumen and Maya crude oil with the oscillatory shear method for frequencies varying between 0.0001 Hz and 100 Hz. Quite the reverse, very few works were performed at higher frequencies, in the kilohertz and megahertz range.

We have determined the storage (elastic) modulus $G'$ and loss (viscous) modulus $G''$ of several bitumen (Athabasca) and heavy crude oils (Maya) by an impedance analysis by measuring the change in resonance frequency and bandwidth on several overtones of a coated quartz resonator vibrating in the thickness shear mode at a fundamental frequency near 5 MHz.

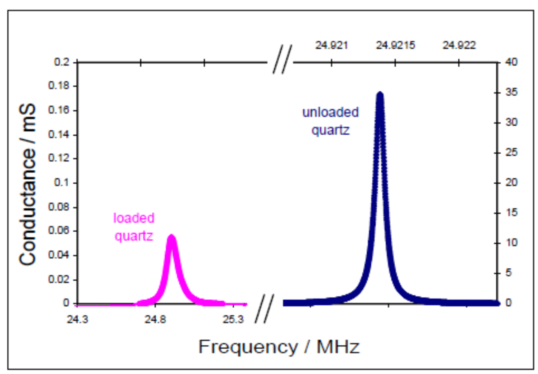


**Fig. 1.** Conductance spectrum around the 5th overtone for a bare 5 MHz quartz crystal and the same crystal loaded with a sample of Maya crude oil.

## References

[1] Oliveira N.S., Dorgan J., Coutinho J.A.P., Ferreira A., Daridon J.L., Marrucho I.M. (2006) Journal of Polymer Science, Part B: Polymer Physics 44 1010-1019.
[2] Hasan M.A., Fulem M., Bazyleva A., Shaw J.M. (2009) Energy and Fuels 23, 5012-5021.