Combined Effect of Pressure and Temperature on Rheological Properties of Water-in-crude Oil Emulsions

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Abstract:
The rheological behavior of emulsions has been extensively investigated through experiments made at atmospheric pressure. This study presents a new experimental characterization of these fluids with measurements performed under pressure and in a large range of temperature. The results show that viscosities obey Barus model that predicts an exponential increase with pressure. The extent of the increase is governed by a unique piezoviscous coefficient. This coefficient exhibits a non monotonous variation with temperature. It has been shown that its thermal dependence and its value can be related to the viscoelastic properties of the fluid. The coefficient is an increasing function of temperature for a solid-like behaviour and a decreasing function of temperature for a liquid-like behaviour. This approach has been applied to heavy crude oils. It has been demonstrated that water droplets and oil composition modify the elastic character of heavy crude oils and as a consequence they modify their piezoviscosity.

Zusammenfassung:
Die rheologischen Eigenschaften von Emulsionen wurden bereits intensiv untersucht, allerdings sind die meisten Experimente unter Standard-Atmosphärendruckbedingungen durchgeführt worden. In dieser Studie präsentieren wir eine neue experimentelle Charakterisierung von Emulsionen, wobei wir den Einfluss vom Druck in einem breiten Temperaturspektrum bestimmen. Die ermittelten Viskositäten nehmen exponentiell mit dem Druck zu, was in Einklang mit theoretischen Vorhersagen durch das Barus Modell steht. Die Stärke der Zunahme wird durch einen einzigen piezoviskosen Koeffizient bestimmt, welcher eine nicht-monotone Temperaturabhängigkeit zeigt. Die Temperaturabhängigkeit dieses Koeffizienten sowie sein Absolutwert könenn mit den viskoelastischen Eigenschaften des Fluids verknüpft werden. Für festkörperähnliche Materialien steigt der piezoviskose Koeffizient mit zunehmender Temperatur, für flüssigkeitsähnliche Materialien sinkt er. Eine derartige Herangehensweise wird hier auf schwere Rohöle angewendet. Es wird gezeigt, dass der Gehalt an Wassertropfen und die Zusammensetzung des Öls das viskoelastische Verhalten von schweren Rohölen und damit deren Piezoviskosität modifiziert.

Résumé:
Le comportement rhéologique des émulsions à largement été étudié à l'aide de mesures réalisées à pression atmosphérique. Cette étude présente l'originalité de le caractériser sous pression et sur une large gamme de température. Les résultats montrent que l'évolution de la viscosité obéit à la loi de Barus prédisant une augmentation exponentielle avec la pression. L'intensité de l'augmentation est gouvernée par un unique coefficient, le coefficient de piezodépendance. Ce coefficient évolue de façon non monotone avec la température. Sa variation a pu être reliée aux propriétés viscoélastiques du fluide: une augmentation de sa valeur est observé avec la température en cas de comportement solide et au contraire une diminution en cas de comportement liquide. Cette approche a été appliquée aux bruts dits lourds. Il a été démontré que la présence de gouttes d'eau et la composition du brut influençaient le comportement élastique du brut et par conséquent sa piezodépendance.

Key words: emulsions, piezodependence, viscoelastic properties, heavy oils

1 INTRODUCTION

The rheological behavior of emulsions needs to be understood in various industrial applications such as cosmetics, food technology and crude oil production. Actually, manufacturing emulsions involves mixing, pumping and processing operations that all require a good characterization of flow properties. Hence many research studies have been performed to predict them as a function of morphological and physico-chemical factors [1 – 7]. The basic rheology-determining parameters (size distribution, deformability, internal

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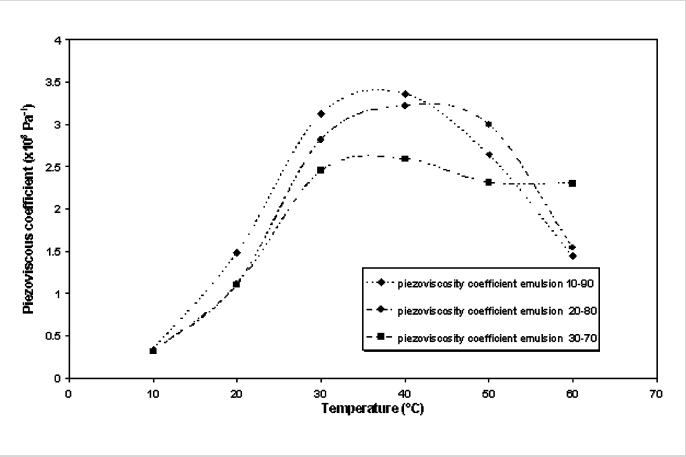

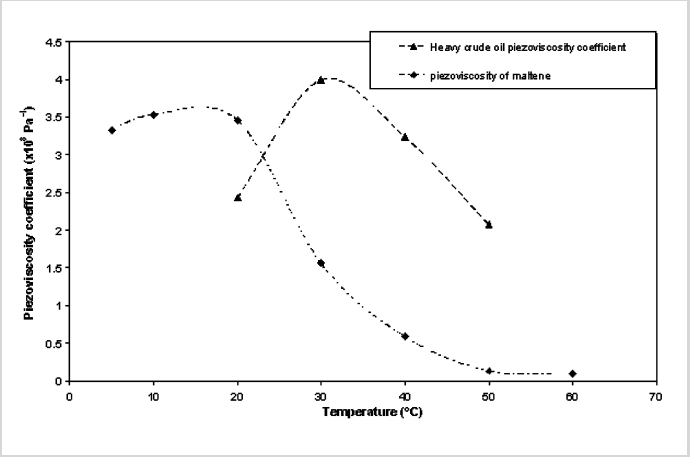

Figure 11 (left): Thermal dependence of piezoviscous coefficients of emulsions.

Figure 12: Thermal dependence of piezoviscous coefficients of the heavy crude oil and its corresponding deasphalted oil.

oil and emulsions. In each case, the Barus model is suitable to describe the relationship between viscosity and pressure. Viscosity increases exponentially with pressure and is simply determined taking into account the viscosity at atmospheric pressure and a piezoviscous coefficient. On the contrary, the combined effect of pressure and temperature is more complex. Actually, we showed that temperature governs in two ways the piezoviscous coefficients: at low temperature, samples get more solid and the piezocoefficient decreases when temperature diminishes. On the opposite; at high temperature the piezocoefficient of the liquid-like sample decreases when temperature rises. The well-defined temperature that separates these two domains depends strongly on the microstructure of the fluid. Water droplets and asphaltenes have been shown to reinforce the elastic character of heavy crude oils and as a result shift this temperature to higher values.

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