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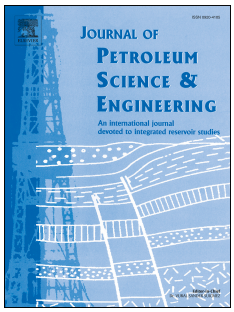

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Development and Calibration of a high pressure high shear rate Capillary Rheometer

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Abstract
For the characterization of the viscosity and the flow behavior of heavy and extra heavy oil, a high pressure, high shear rate capillary rheometer has been developed. Due to the commercial rise in the exploitation of heavy and extra heavy oils, non-Newtonian flow behavior becomes relevant. Information on the flow properties of these heavy oils, particularly at high pressure and high shear rates is essential for recovery and processing methods. The capillary rheometer consists of two high-pressure vessels connected by a tube system including a calibrated capillary. Each vessel is equipped with a hydraulically operated metal bellow that can be varied in size to make oil flow from one vessel, through a capillary, into the other one at a controlled rate of flow. From the measured pressure drop the viscosity of Newtonian fluids is calculated with Hagen-Poiseuille's law. The capillary rheometer is designed for ambient operating conditions up to 1000 bar and 200°C. Fluids with a viscosity between 1 and 100000 mPas can be measured under high shear rates. The maximum possible shear rate depends on the viscosity of the fluid. For fluids with viscosities under 4000 mPas, shear rates up to 50000 1/s are possible. Viscosities up to 100000 mPas still allow shear rates of 4000 1/s. Before being set into operation, the apparatus is calibrated in a range up to 500 bar with viscosity standards that have been independently measured to high-pressure conditions. In this range, the apparatus works with an overall accuracy of about 3%.

Introduction

During the last quarter of the 20th century, the global need for crude oil showed a stable annual growth rate of about 1 % in average [1]. As a result of the economic development and the demographic growth in the emerging economies and the increasing consumption of energy in industrialized countries, this demand has visibly increased during the first years of the 21st century [2].Currently the world's demand for energy increases by 8% each year [3]. Different international studies foresee that in the next 20 years at least 80% of the world energy supply will come from raw fossil fuel materials [4,5,6]. Accordingly, oil will be the most important source of energy for the next decade. Heavy oil represents at least half of the recoverable oil resources of the world [7]. As the available reserves are limited, effective recovery processes gain in importance [8]. It is estimated that there are about 6 trillion barrels of heavy oil reserves, six times the conventional amount [9]. Rheological properties such as the dynamic viscosity as a function of temperature, pressure and shear conditions are vital for Enhanced Oil Recovery (EOR) as well as for transportation and processing of heavy oils. During production and refining, the oil is subject to large variations in temperature resulting in cuts that go form light fuels to asphalt residues which lead to variations in viscosity of orders of magnitude. Nevertheless, the flow behavior of heavy and extra heavy mineral oils is barely investigated. Usually