Journal of Petroleum Science and Engineering 159 (2017) 497–505

Contents lists available at ScienceDirect

Journal of Petroleum Science and Engineering

journal homepage: www.elsevier.com/locate/petrol

Conversion of organic matter in the carbonaceous medium in the supercritical water

S.M. Petrov [a,b], D.A. Ibragimova [a,b], A.G. Safiulina [a,*], B. Tohidi Kalorazi [b], A.V. Vakhin [b], R.C. Okekwe [a], E.A. Karalin [a]

[a] Kazan National Research Technological University, Russia
[b] Kazan Federal University, Russia

ARTICLE INFO

Keywords:
Aquathermolysis
Heavy oil
Supercritical water
Caustobioliths
Nanoparticle
Iron oxide
Component composition
Initial crude oil
Converted oil
Rheological curve

ABSTRACT

The work is based on the modeling of geothermal transformations of hydrocarbons in oil-bearing formations of deep horizons of the earth's crust - under abnormally high pressure, in the presence of aqueous fluid and carbonaceous substances. The pressure and temperature in the experiments are typical for water in the supercritical state. The regularities of the conversion of heavy oil in supercritical water and in the presence of finely dispersed caustobioliths and metal oxides were shown. Aquathermolysis in the presence of proton provides blockage of free radicals of high-molecular weight hydrocarbons and saturation of unsaturated hydrocarbons, produced by cracking reactions, and inhibiting of condensation reactions of aromatic macromolecules. The hydrogen protons also promote hydrogenation reactions in the crude oil. The regularities of changes of the component, structural-group, fractional and elemental compositions of heavy oil during the conversion under the above conditions were established, rheological characteristics of the initial crude oil and converted oil were studied as well. As a result of carrying out aquathermolysis in the supercritical water environment and in the presence of initiating additives, the high-molecular weight components of the initial crude oil were degraded with the formation of light distillate fractions, which were scarcely present in the initial crude oil. Thus, the conversion rate for various samples amounted to 18–29%. It resulted in the significant reduction in the viscosity of the converted oil, up to 96% compared to the initial crude oil.

1. Introduction

Study of conversion of hydrocarbons in the supercritical water environment is nowadays at the stage of collecting experimental data (Vakhinet al, 2015). Therefore, it is difficult to state clearly the interrelation between composition and structure of the initial crude and physic-chemical regularities of its conversion in supercritical aqueous fluids. In this regard, research on conversion of unconventional hydrocarbon feedstock in supercritical aqueous fluids is of high interest. More specifically, certain tendencies in the development of this work can be outlined: research on conversion of coal, as a functional part of the reaction system, in supercritical water; determination on interrelation between its composition and structure; study of kinetics of hydrogen production in the system and desulfurization of the initial crude.

In recent years, interest in supercritical fluids is gaining an increasing scale. Supercritical fluids are used as a component of the reaction mixture in scientific research; pilot plants and industrial units are being built using the same. The application of supercritical aqueous fluids for recycling of organic wastes, including toxic wastes, as well as the production of liquid hydrocarbons during fuel conversion is extensively being investigated (Fedyaeva and Vostrikov, 2012; Fedyaeva et al., 2014; Kotov et al., 2003). These processes are based on the unique properties of water under supercritical conditions. Water is a unique solvent, which is widely used, ecologically pure and practically safe for the environment (Fedyaeva et al., 2014).

The transition of water to supercritical state occurs in a closed space when its temperature increases above 374° C and pressure rises up to 22.6 MPa, whereby the interface between the liquid and the vapor disappears. The new state of water is characterized by low viscosity and high diffusion capacity. In addition, water changes from a polar liquid into non-polar fluid. Scientists from Chinese Academy of Sciences (Yu et al., 2015) studied conversion of lignite charcoal in supercritical water conditions and temperature ranging from 350 to 550° C. Their results clearly indicate that temperature is a key factor influencing the

* Corresponding author.
E-mail address: aliyahanova@mail.ru (A.G. Safiulina).

https://doi.org/10.1016/j.petrol.2017.09.060
Received 23 April 2017; Received in revised form 22 September 2017; Accepted 23 September 2017
Available online 27 September 2017