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High viscosity-reducing performance oil-soluble viscosity reduction agents containing acrylic acid ester as monomer for heavy oil with high asphaltene content

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ABSTRACT

Reducing viscosity of crude oil is a direct means of cutting the cost and increasing the amount of crude oil delivery. It was found that kerosene-dilution can significantly reduce the viscosity of Shengli heavy oil, and the viscosity reduction rate varies little with temperature rises. By measuring the viscosity of the deasphalted oil, it was found that the viscosity of the heavy oil was greatly reduced after deasphalted treatment, and the deasphalted oil showed a good Newtonian fluid, indicating that the high viscosity of the Shengli heavy oil was because of high asphaltene rather than the precipitation of paraffin. Aiming at the high asphaltene of Shengli heavy oil, oil-soluble polymer viscosity reduction agent was used to study the viscosity reduction. Two new monomers, acrylic acid phenethyl alcohol ester and benzyl acrylate were synthesized, and six copolymers were synthesized by free radical copolymerization with styrene, octadecyl acrylate and N-methoxyphenyl maleimide. Through the viscosity-reducing evaluation, the copolymer containing acrylic acid phenethyl alcohol ester and octadecyl acrylate (AD) had best performance. At 70 °C, the AD achieved viscosity reduction rate of 61.74%, which is the result of the matching of aromatics and solubility of monomers. And it is found that the monomer cooperation has an important effect on the viscosity reduction. This provided an important guidance to development of oil-soluble viscosity reduction agent.

1. Introduction

With the increasing demand for crude oil, high quality crude oil has not been enough to meet the needs. The heavy oil production is more and more, and the viscosity reduction of heavy oil is put in front of us (Ge et al., 2012; Martínez-Palou et al., 2011). Pipeline transport of crude oil has always been the safest, lowest cost, the most efficient way of crude oil delivery (Hart, 2014), but in the pipeline transportation process, asphaltene-paraffin interaction makes the crude oil viscosity too high (Plegue et al., 1989), so pipeline energy consumption caused by large transmission resistance and serious pressure drop is markedly increased (Yang et al., 2017). Reducing viscosity of crude oil is a direct means of reducing the cost of crude oil transportation and increase the amount of delivery (Muñoz et al., 2016; Hassanean et al., 2016), especially for heavy oil (Eskin et al., 2011; Hasan et al., 2010).

The Shengli Oilfield is a typical heavy oil field in China, and high viscosity of the produced crude oil has been a major problem plagued the oil production. Varieties of means are used for the viscosity reduction of the Shengli heavy oil. The oil-soluble viscosity reduction agent (VRA) is one of the effective means of heavy oil exploitation and transportation (Homayuni et al., 2012). In recent years, literature have reported the oil-soluble viscosity reduction agent research and application (Hafiz and Khidr, 2007; Li and Ni, 2011; Chávezmiyauchi et al., 2013a; Akinyemi et al., 2016); including of China heavy oil (Zhu et al., 2015; Wu and Gao, 2010; Song et al., 2000a). Among them, there are many studies on the pour point of crude oil with high wax content (Hafiz and Khidr, 2007; Akinyemi et al., 2016; Bello et al., 2006; Taiwo et al., 2009; Oseghale et al., 2012). But the pour point depressant agent is developed for the

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Abbreviation

Monomer

A	acrylic acid phenethyl alcohol ester
B	benzyl acrylate
C	styrene
D	octadecyl acrylate
E	N-methoxyphenyl maleimide
AIBN	2,2-Azobisisobutyronitrile
DMF	dimethylformamide
VRA	viscosity reduction agent
VRR	viscosity reduction rate
FTIR	Fourier transform infrared
ν	Stretching vibration
β	Surface bending vibration
δ(σ)	Shear vibration

heavy oil with the characteristics of high wax content. When the pour point depressant agent was used for heavy oil with features of low wax content and high asphaltene content, the effect of viscosity reduction is not significant (Ding et al., 1999). For heavy oil with high content of asphaltene, the frictional force between asphaltene aggregates is the essential cause of high viscosity (Ghanavati et al., 2013; Luo and Gu, 2007). Therefore, the development of polymers containing aromatic monomers is beneficial to viscosity reduction of this type heavy oil.

At present, there are few kinds of structure of the polymer molecular for viscosity reduction agents, and it is difficult to exhibit good viscosity-reducing performance for various kinds of heavy oil. Therefore, the study of new molecular structure of the viscosity reduction agents is of great significance. By synthesis of novel monomer, screening the polymer monomer species, molecule structure of viscosity reduction agent was carefully screened for the Shengli heavy oil. The research can provide a basis for high efficiency viscosity reduction for heavy oil.

2. Materials and methods

According to literature, octadecyl acrylate (Song et al., 2000b) and N-methoxyphenyl maleimide (Uchoa et al., 2011) were synthesized. Benzene alcohol and acrylic acid as raw materials (1.0: 1.2, in mol), cyclohexane as carrying water agent, hydroquinone as inhibitor (1.0 wt %), p-toluenesulfonic acid as catalyst (0.7 wt %), esterification reaction was used for synthesis of acrylic acid phenethyl alcohol ester at 125 °C for 4 h (yield of 72.89%). Benzyl chloride, acrylic acid (1: 1, in mol) and potassium carbonate (0.2 wt %) as the raw material, DMF as solvent, benzyl acrylate was synthesized at 100 °C for 3 h. After the reaction, the product was slowly dropped into a large amount of methanol by a burette with quickly stirred. After stirring for 2 h, the mixture was filtered with a buchner funnel and dried to obtain the polymer (yield of 54.08%).

Other polymers of acrylic acid phenethyl alcohol ester (A) or benzyl acrylate (B) with styrene (C), octadecyl acrylate (D) or N-methoxyphenyl maleimide (E) were prepared at 70 °C for 5 h in toluene as above process (shown in Fig. 1). The heavy oil for viscosity-reducing evaluation produced from the Linzhong Oil Production Plant of Shengli Oilfield at Dongying of China. The basic physical properties of crude oil are shown in Table 1.

Deasphalted oil of Shengli heavy oil was prepared with reference to the oil and gas industry standard of People's Republic of China (SY/T7550-2004). The brief process is as follows: the heavy oil (m_0) is refluxed for 30 min in a certain amount of n-heptane, and after cooling, is placed in the dark for 1 h. Insoluble matter was filtered with a filter

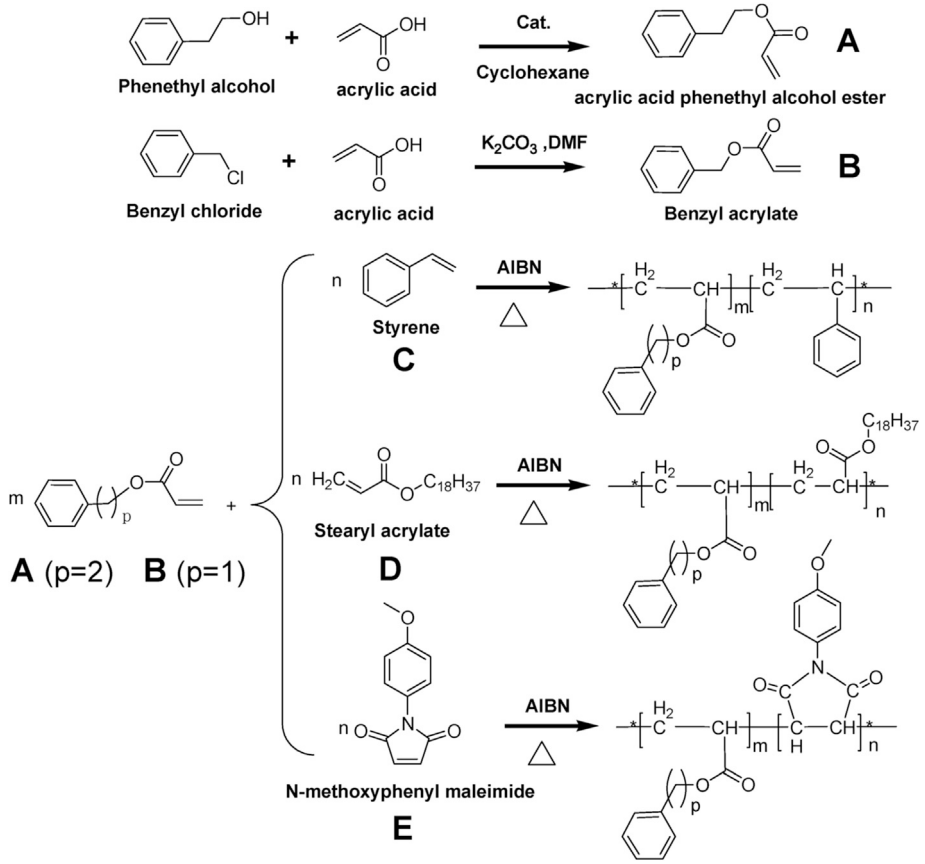

Fig. 1. Synthesis route of monomers and polymers.