A New Type of High Temperature Clean Fracturing Fluid to Enhance Oil Recovery on Bohai Bay, China

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ABSTRACT

This paper introduces a new type of high temperature clean fracturing fluid to enhance oil recovery on Bohai Bay of China. Compared with conventional polymer fracturing fluid, clean fracturing fluid has many advantages, such as few components, easy preparation, good prop-carrying capacity, low treatment friction, no residue, low damage to formation, and automatic gel-breaking. But because its high temperature performance is poor, it limits its application in high temperature reservoir. The current clean fracturing fluid system is only applicable to the reservoir which temperature is below 120°C while high reservoir temperature above 140°C is still one difficult technical problem for fracture engineers. Clean fracturing fluid system VES-140 which could be used in high temperature reservoir has been made through various experiments such as synthesis of main agent VES-140 and optimization of the activator and counter ion. It is indicated by the results of fracturing fluid rheology test that at 140°C, after shear of 2 hours at 170s⁻¹, viscosity of the fracturing fluid is more than 50mPa.s. Storage modulus of the fracturing fluid is 3.5Pa, while loss modulus is 1.5Pa. According to the experiment results it has excellent viscoelasticity and good prop-carrying capacity. This fracturing fluid system has no residue therefore it has no solid-phase damage to reservoir. The fluid damage to formation is around 14.67%, far less than conventional fracturing fluid.

KEY WORDS: 140°C, high temperature clean fracturing fluid, no residue, less damage

INTRODUCTION

Samuel M, et al (Samuel, 1997; Card, 1999; Nelson, 2000) carried out many research regarding Visco-Elastic Surfactant (VES) fracturing fluid which is also named as clean fracturing fluid in 1997. Compared with conventional polymer fracturing fluid, clean fracturing fluid has many advantages, such as few components, easy preparation, good prop-carrying capacity, low treatment friction, no residue, low damage to formation, and automatic gel-breaking (Yang ,2005; Cui,2005; Luo, 2007; Hu, 2011; Li, 2011).

Besides, clean fracturing fluid has one obvious limitation---low heat resistance. Lin (2012) has worked out one fracturing fluid system with high heat-resistance and no residue. This fracturing fluid has been successfully applied in the 140°C reservoir in northeastern block and 154°C reservoir in Zhongyuan oilfield. VES-HT clean fracturing fluid of Schlumberger (Fontana, 2007) has been used in four fracturing treatments in Patagonian well which is located at San Jorgo basin in Argentina. The formation temperature is merely 142.78°C.

This article has discussed molecule structure and synthetic method according to high heat-resistance organism of VES. It has further optimized main additive for high temperature clean fracturing fluid for 140°C formation and evaluated comprehensive properties of fracturing fluid.

FRACTURING FLUID FORMULA RESEARCH

Mechanism of High Temperature Resistance of Clean Fracturing Fluid

Viscoelastic surfactant system always has poor temperature resistance. With the increase of temperature, the rate of the thermal motion of molecules and the solubility increases, the force between molecules weakens and the CMC of surfactants increases geometrically. Therefore the number of micelles at high temperature could not meet the need of forming micelles and the micelles begin to depolymerize, dissolve and the viscosity decreases.

It is believed that during formation of viscoelastic system, surfactants generally go through three critical micelle concentration (CMC) values that is, CMC1: the concentration during formation of the micelles; CMC2 : the concentration during aggregation of the micelles; CMC3 : the concentration during formation of the lamellar micelles. Viscoelastic system could be formed only when CMC1 is low and little difference among CMC1, CMC2, CMC3. It is also believed that the presence of counter ion would influence the formation of the CMC2 and CMC3. The strength of the binding force between the counter ion and the surfactant would affect the gradient between CMC1, CMC2, CMC3. If the strength of the binding force increases, the gradient would decrease and it would be easier to form viscoelastic system. Besides if the binding force is too strong, it would cause dehydration between lamellar micelles and make the surfactant insoluble and even precipitate.

The Structure Design of Main Agent Molecule

The focus of main agent synthesis and selection is mainly concentrated on the surfactant which has carbon chain length ranging from C₁₈ to C₂₄. It includes anionic carboxylate surfactant, cationic surfactant,