ABSTRACT

The quantitative characterization of wax crystals is discussed based on the wax crystal size distribution fractal model of their volume characteristics. The wax crystal structures of two crude oils were tested by using image analysis techniques during their paraffin precipitation, and their wax crystal fractal dimensions were determined based on fractal theory. Meanwhile, the viscosity-temperature characteristics were measured using rheological method. The results show that wax crystal particle fractal dimension can indicate the correlation of the wax crystal number, maximum and minimum particle sizes, and particle projected area. Therefore, the fractal dimension can quantitatively characterize wax crystal morphology.

KEY WORDS: fractal dimension; quantitative characterization; wax crystal; temperature; flow improver.

INTRODUCTION

The rheological study of crude oil has a history of more than 50 years, but the conventional researches are usually routine analyses based on the continuum mechanic theory, and most of them are confined to the effect of external factors such as the thermal history and shear history of the crude oils on their flow properties (Singh et al., 1999). Some experts and scholars are also committed to the composition and microstructure studies on non-Newtonian oils in recent years.

Our preliminary studies have shown that waxy fractions contained in a crude oil is a decisive factor affecting its non-Newtonian properties, and different wax molecules are continuously crystallizing and aggregating when the oil temperature drops below its wax appearance point, then the wax crystal particles can overlap and form a network structure (Jing, 1999). However, the wax crystal particle sizes are usually described by some fuzzy terms such as large, moderate, small, tiny and so on in most of current studies, and the wax crystal shapes are qualitatively characterized by using needle-shape, sheet-shape, cross-shape and other terms. Moreover, the uncertainty of wax particle concentration in waxy oil has not been identified at present.

Hammami (1994) discovered that waxy molecules will continuously overlap on the lattice points of the crystal nucleuses formed previously, and gradually grow and become parts of flake-like structures. It was also noted (Li et al., 2006) that the growth of wax crystals is essentially a process that under the action of van der Waals force, n-alkenes molecules interconnect to become some macromolecules, which gradually form crystalline particles.

Moussa (2003) found wax crystal morphology has some common features as follows: crystal nucleuses are flaky, whose thicknesses are equivalent to those of the molecules, and the further development depends on the crystallization conditions; most of wax crystals are layered while a few of them act as crystal nucleuses under static conditions; but under flow conditions, the growth of single flakes is limited, and they are often dominant at a low crystal concentration while some flocculation and single flakes will co-exist at a high crystal concentration, and then flaky wax crystals will connect each other and form some aggregates.

Liu (1992) pointed out that adding a small amount of a flow improver into a waxy crude oil can not inhibit its wax precipitation and lower its wax appearance temperature, but the ester side chains of the flow improver molecules can be adsorbed on the wax crystal surfaces and co-crystallized with the wax crystals, so that the wax crystal structures are changed and form a dispersive, little and dense tree branch-like or collective crystalline particles, which reduce the amount of oil-in-wax. Therefore, the low-temperature rheological behaviors of the oil are improved.

Hu and Wu (2004) made a real-time micro-observation and study on changes of wax crystals in diesel oil with and without EVA flow improver. The results show that the low-temperature rheological properties of the oil can be effectively improved by changing the dispersity, integrity and crystallinity of the wax crystals.

Singhal (1991) discovered that wax crystal shapes mainly include sheet, needle and cross. There are at least four distinct solid alkenes whose structures can be described as hexagonal, orthorhombic, monoclinic and cubic crystal, which primarily depends on the crystallization conditions such as medium viscosity, carbon number of wax molecule, thermal history, cooling rate and oil purity.

Bao and Hong (2000) studied the changes of the wax crystals of a crude oil and its treated oil with a flow improver by using X-ray diffraction