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Lubricant Enhancement via Hydrodynamic and Acoustic Cavitation

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Abstract

Lubricant plays a vital role in reducing wear, friction and energy consumption in any machinery. It is mainly used in automotive, industrial, processing, and marine. Various types of lubricant were developed from time to time to meet with the market requirement. However, lubricant performance demanded by market changes as the application varies. For instance, lubricant with high thermal stability is required in drilling, which is High Temperature High Pressure (HPHT) condition. Recent studies have revealed that by adding an optimum concentration of nanoparticles into lubricant, the tribological performance of the lubricant can be improved significantly. Viscosity of lubricant is vital in terms of forming lubricating film and reduces friction. In this study, mutliwalled carbon nanotubes were added to lubricants through hydrodynamic and acoustic cavitation. The results indicated that addition of multiwalled CNT definitely improve nanofluids' viscosity. Besides, comparison between methods of preparation showed that hydrodynamic cavitation alone yield best suspension with highest viscosity in both 25ppm and 100ppm cases.

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Keywords: Lubricant Additive; Acoustic Hydrodynamic Cavitation; Kinematic Viscosity

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Nomenclature

CNT	Carbon Nanotube
AC	Acoustic Cavitation
HC	Hydrodynamic Cavitation
AHC	Acoustic and Hydrodynamic Cavitation

Introduction

Environmental awareness and energy conservation are arising as global issues in modern industrial production. The main cause of energy loss is through heat, which caused by friction. Specifically in the process of drilling extended-reach, excessive torque is often reported as one of the most major problems which caused by dog legs, key seats, bit balling and hole instability [1]. The conventional way to reduce wear and friction caused by mechanical movement is using mineral oil-based lubricant.

Addition of nanoparticles into a base fluid, termed 'nanofluid' is gaining more attention due to its great potential application in many fields. Yu.et al stated in their review paper that nanofluid have wide application by citing many researches work. The main application are heat transfer intensification, mass transfer enhancement, energy applications, mechanical applications, biomedical other applications [2]. It is proven that nanofluid can enhance thermal conductivity, reduction in pumping power and better lubrication [3].

Recently, many researchers put effort in studying different combination between nanoparticles and its base fluid prior to their application interest. Some researches introduced functional group as coating on nanoparticles [4], while some synthesize their own desirable nanocomposites subjected to their targeting properties [5-6]. Among most studies on nanofluid, the commonly used nanoparticle was allotropes of carbon, such as graphene and carbon nanotubes and graphene derivative, graphene oxide. It is mainly due to their excellent electronic, optical thermal and mechanical properties [7].

Generally, nanofluid are prepared by two types of method, either single-step or two-step preparation. Single step preparation involves simultaneously making and dispersing the particles within a single process. For example, vacuum-SANSS (submerged arc nanoparticle syntheses system), microwave irradiation and phase transfer method. On the other hand, two-step method involves direct mixing of nanoparticles with base fluids followed by dispersant addition or ultrasonication to ensure well-dispersion. Research up to date stated that the two-step preparations are preferable because it is more economic and it can produce nanofluid in a large scale [2-3].

Despite a lot of studies had revealed significant improvement of base fluid properties after adding respective nanoparticles, dispersion stability still remains as a critical challenge for nanofluid, especially when it is applied in HTHP conditions. Numerous studies had shown different nanofluid prepared by respective method possess varying suspensions duration stability. Ettefaghi et.al found that dispersing fullerene in engine oil through planetary ball mill method can achieve suspension stability up to 720 hours [8]. Meanwhile, Hao et.al managed to achieve 4 months stability by surface capping calcium borate nanoparticles with oleic acid before dispersing in lubricant oil [9]. Therefore, researches are still looking for a more sophisticated method is to produce a more stable nanofluid which has longer duration for transportation and storage.

Therefore, a combination of ultrasonic cavitation and hydrodynamic cavitation technique in series is proposed in this research to study the viscosity enhancement and its suspension stability.

Cavitation is divided into three phases; the generation of bubbles, collapse of cavities, resulting in very high energy release that can enhance homogenization. The pressure associated with bubble collapse is high enough to cause damages towards surface wall [10]. However, a well-controlled cavitation can homogenize the dispersion of nanoparticles in the base fluid and promotes longer suspension stability. In contrast, acoustic cavitation is in smaller unit and portable. Therefore, it is generally being used for mixing chemicals in industries.

In hydrodynamic cavitation, cavities are formed due to the sudden change in pressure in the flowing fluid caused by change in the flow area such as venture and orifice plate [11]. The sudden collapse induces cavities which break the base fluid molecules into smaller pieces and promotes well mixing with the added nanoparticles. Similarly,