**Appendixes**

**Supplemental material for “Enhanced cuttings transport efficiency of water-based muds using (3–Aminopropyl) triethoxysilane on polypropylene-nanosilica composite”**

*Appendix A: Product descriptions of some of the chemicals for the synthesis and modifications of PP-SiO2 NC*

The product information of some of the chemicals used in this research is illustrated in Fig. A.1.

*Appendix B: Characterization methods and discussions of results*

*Appendix B.1: Characterization of PP-SiO2 NC and PP-SiO2 NC-NH2 with FTIR and TGA*

The bonding, functional groups, and temperature resistance of the studied PP-SiO2 NC were conducted as presented herein. To expound the changes in the morphologies and molecular structure of the PP-SiO₂ NC-NH2 and PP-SiO2 NC, Fourier Transform Infrared (FTIR) Spectroscopy examination within the scanning transmittance range of 4, 400 to 400 cm−1 was evaluated to determine the functional groups and interaction between the PP-SiO₂ NC-NH2 and PP-SiO2 NC. In measuring the spectra of the NCs, the FTIR SHIMAD 24 IR Tracer–100 (FTIR instruments, Houston, USA) was used. The temperature resistance of the NCs was measured using thermal gravimetric analysis (TGA) by scanning 0.02 g of dried powder samples of the NCs from 30 °C to 600 °C at a heating rate of 10 °C/minute. The measurement was conducted on a TGA Build 39, Q500V20.13 (TA Instruments, Germany).

*Appendix B.2: FTIR observation on the modified and unmodified PP–SiO2 NC*

FTIR tests were conducted on modified and unmodified PP–SiO2 NC to confirm the presence of amine molecules in the modified product. Fig. B.1 shows the FTIR spectrophotometry of the modified (in red dot line) and unmodified (in blue dot line) NCs with transmittance peaks in the wavelength range of 4, 400 cm-1 to 400 cm-1. The peaks of the unmodified NC in the regions of 3650 cm-1, 3400 cm-1, and 3250 cm-1 (blue dot line) are found shifted to the range of 3669 cm-1, 3435 cm-1, and 3300 cm-1 (red dot line), which showed hydrogen bonding attributed to –OH in both products. The FTIR spectra of both products display strong characteristic peaks of silanols Si-OH vibrations at 1500 cm-1 and 1350 cm-1. A typical siloxane Si–O–Si asymmetrical stretching vibration at 1095 cm-1 also occurred in the modified and unmodified NCs, and the –Si–O stretches occurred at 805 cm-1 and 490 cm-1 ((blue dot line). After modification, these peaks were shifted to 770 cm-1 and 480 cm-1, respectively, due to the complex surface chemical reactions (red dot line) (Cao et al., 2017). This demonstrates the presence of synthesized PP-SiO2 NC in the modified product. The peak that appeared at 971 cm-1 (blue dot line) signifies asymmetric Si-OH bending vibration and the intensity of this peak was reduced to 960 cm-1 by aminosilane (red dot line). Also, the typical characteristic peaks of C–H was observed at 1640 cm-1 and 2900 cm-1 in both products and were attributed to the stretching vibration and bending vibration of alkyl groups, respectively (Xu et al., 2018). In comparing between the modified and unmodified NCs, the two new peaks observed at 2840 cm-1 and 1600 cm-1 are assigned to the N–H bending vibrations and another clear peak that occurred at 1750 cm-1 is attributed to N–H stretching vibration (red dot line) (Rahman et al., 2009). These peaks found in the modified NC (red dot line) are absent in the unmodified product (blue dot line). Thus, through the FTIR analysis, the attachment of APTES onto the synthesized PP-SiO2 NC surface is confirmed.

*Appendix B.3: TGA observation on the modified and unmodified PP–SiO2 NC*

The stability of the modified and unmodified PP–SiO₂ NCs at elevated temperatures is presented in Fig. B.2. The weight loss of both samples emanated from four contributions, and the shapes of their trend lines are similar. The initial contribution started from 30 oC and ended at 190 °C (for unmodified NC) and 160 °C (for modified NC). The next decomposition stage showed a small decrease in weight loss for both nanocomposites at above 190 °C (unmodified NC) and above 160 °C (modified NC). The third stage started around 200 oC and ended in the range of 420‒460 °C (modified) and 420‒460 °C (unmodified) products. The final stage became smooth at temperatures greater than 460 °C. Here, the first stage could be attributed to the evaporation of xylene and the decomposition of other volatile substances in both NC samples. Xylene has a boiling point in the range of 140 oC. The second stage corresponded to the breakdown of nonionic PE-b-PEG and –OH groups (Xu et al., 2018), and –NH2 groups (Cao et al., 2017), respectively. The third stage corresponded to the degradation of the PP backbone and the fourth stage to the disintegration of the structures of the modified and unmodified NCs. In the range of 30‒500 oC, a total weight loss of the unmodified NC was 21.2% while that of the modified product was 26.5% due to an increased number of molecules grafted onto the modified product. This verified that the modified NC has a good property of temperature resistance.

*Appendix C: Cuttings transport parameters and estimations*

*Appendix C.1: Design wellbore flow loop configurations*

The technical specifications of the cuttings transport flow loop used in this study are presented in Table C.1.

*Appendix C.2: Wellbore cleaning calculations*

The schematic of the annular environment used in this study is shown in Fig. C.1

Aann = $A\_{h}-A\_{p}$ = $\frac{π}{4} \left(D\_{h}^{2}-D\_{p (OD)}^{2}\right)$ C.1

$V\_{avg}=\frac{Q}{A} \frac{{ft^{3}}/{s}}{ft^{2}}$ = $\frac{Q\frac{L}{min} × \frac{1 ft^{3} }{28.3168 L} × \frac{1 min}{60 s}}{\frac{πD^{2}}{4 ×144}}$

 $V\_{avg}$ $=\frac{Q}{9.267852667 × D^{2}}$ = $\frac{Q × 0.1078998594}{D^{2}}$ C.2

 $VA\_{mud}=\frac{Q}{9.267852667 × \left(D\_{h}^{2}-D\_{p}^{2}\right)}$ = $\frac{Q ×0.1078998594}{D\_{h}^{2}-D\_{p}^{2}}$ C.3

Where:

Ap = Area of the pipe, in ft2.

Aann = Area of the annulus, in ft2.

Vavg = Average mud velocity inside the pipe, in ft/s.

VAmud = Mud velocity in the annulus, in ft/s.

Q = Pump output, in L/min.

1 litre= 0.0353147 ft3; 1 L/min = 0.000588578 ft3/s; 1 ft/min = 0.0166667 ft/s.

Dh2 = ID2 = Inner diameter of the casing or hole, in.2.

OD2 = Outer diameter of the drill pipe, in.2.

Dp2 = Annular diameter of the drill pipe, in.2.

0.1078998594 = A conversion factor constant used to calculate the volume between the outside of a pipe within the inside of another pipe, using liters.

*Determination of average mud velocity in the pipe:*

Hole dimensions: ID = 2.4 in.; OD = 1.2 in.; Dp = 1.0 in.

 Ap =$\frac{π\left(ID-OD\right)^{2}}{4}= \frac{3.142 × \left(2.4^{2}-1.2^{2}\right)}{4 × 144}$ = 0.023565 ft² C.4

 $V\_{avg}$ = $\frac{Q}{Ap}$ C.5

*Determination of mud velocity in the annulus:*

 Aann = $\frac{π\left(ID-Dp\right)^{2}}{4}= \frac{3.142 × \left(2.4^{2}-1.0^{2}\right)}{4 × 144}$ = 0.02596513889 ft² C.6

 $VA\_{mud} $= $\frac{Q ×0.1078998594}{D\_{h}^{2}-D\_{p}^{2}}$ C.7

**Nomenclature**

FTIR Fourier transform infrared spectroscopy

NCs Nanocomposites

PE-b-PEG Polyethylene-block-poly (ethylene glycol)

PP-SiO2 NC Polypropylene at nanosilica composite

PP-SiO2 NC-NH2 Polypropylene at nanosilica composite with amino group

TGA Thermal gravimetric analysis

**References**

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