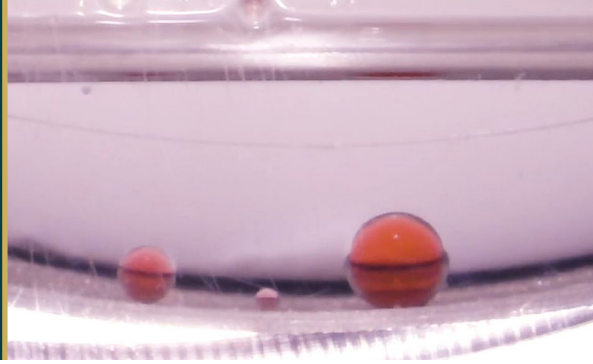
LOTUSFLO™



LotusFlo™ is a super hydrophobic, ultra-thin, internal Diamond-Like Coating (DLC) designed to reduce and possibly eliminate deposition of scale, asphaltenes and wax on tubular surfaces. The coating is molecularly bonded to the tubular's electrically-conducted substrate via a plasma deposition process.

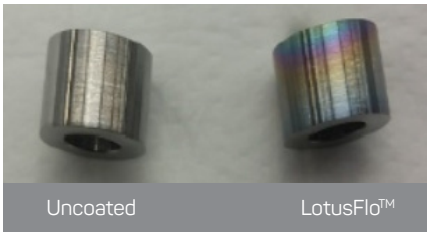


Figure 1. LotusFlo™ DLC coating is an ultra-thin super hydrophobic coating

BENEFITS

- Lower field development costs through deposition mitigation by:
  - Reduced umbilical tubing
  - Reduced remediation frequency
  - Less chemical injection
  - Less workovers / interventions, thus less downtime
- Enables an expanded operating envelope

UNIQUE PROPERTY OF LOTUSFLO™

LotusFlo™ yields water (in oil) contact angles (WCA) exceeding 150°. Hydrophobic properties have long been thought to decrease the adhesion force between a surface and a deposit.

GENERAL PROPERTIES

- Precursor: Organosiloxane based
- Application Process: Plasma deposition
- Contact angle (Water in Oil): WCA ≥ 150°
- Coating thickness: ≤ 0.5 microns
- Substrate roughness: <3 microns
- Compatible with: Corrosion Resistant Alloy (CRA), Carbon Steel (CS), Stainless Steel

PERFORMANCE

LotusFlo™ efficacy potential for flow assurance applications was demonstrated through a combination of:

- Benchtop lab tests
- Flow loop simulation of flow lines
- Pilot field trials

ASPHALTENES

Asphaltene deposition occurs at elevated pressure and temperature, and moderate to low shear conditions in live oil systems.

LotusFlo™ demonstrated to eliminate deposition from a live oil sample in a benchtop couette shear cell that simulates field pressure, temperature and shear conditions.

Shear cell tests on a live problematic oil show that no measurable deposit forms on the coated surface under shear conditions where a significant asphaltene deposit forms on an uncoated surface.

SCALES

Scale deposition occurs when an aqueous solution becomes supersaturated with respect to precipitating salts. This occurs in production systems when the equilibrium of produced water is disturbed by pressure, temperature and/or compositional changes.

The effectiveness of LotusFlo™ as a scale management strategy has been evaluated for three major types of scale: Calcite, Barite, and Halite:

- Calcite: Rotating Cylinder Electrode(RCE) tests coated samples yielded up to 100 % reduction in mass of surface deposits, compared to uncoated coupons.
- Barite: Barite scaling tests were performed in a scale flow loop. Barite deposits formed on the coated tubing were loosely adhered and easily removed by pigging. Barite deposits formed on uncoated tubing under identical conditions could not be removed by pigging.
- Halite: Flow loop tests for halite deposition showed up to a 100% reduction in deposit mass on coated surfaces with oil present and 50 % reduction in deposit mass in pure brine compared to uncoated surfaces.

WAX

Wax deposition occurs when the temperature at the inside wall of the production tubing or flowline drops below wax appearance temperature. The difference between the bulk fluid temperature and inside wall temperature, ΔT, is the driving force for deposition.

48 deposition tests were run in a 2-inch 20-foot test section for a range of ΔT and flow rates. An operational range, where no deposit was observed in a coated test section, was experimentally mapped as a function of ΔT and wall shear stress.

Uncoated test sections had deposits throughout this operational range. Deposits formed on coated surfaces outside of the no-deposit operational range were softer with much higher oil content than those pigged from uncoated experiments.

Pilot field trials in Africa with high wax content, resulted in a 75% reduction in scraping frequency in coated production tubing. The scraped wax was much softer with higher oil content than deposits recovered from uncoated wells. These observations are consistent with conducted flow loop experiments.

DURABILITY

Predicting LotusFlo™ coating durability can be facilitated through review of completed erosion test results. The erosion test entailed subjecting coated coupons to tangential flow of sand slurries inside a specialized flow loop. Mass and water contact angles were measured prior and post-test. A WCA of less than 150° was considered a failure. Depending on flowrate, particle size and sand content, varying duration times can be deduced.

CHEMICAL STABILITY

LotusFlo™ DLC coatings are compatible with most chemistries encountered in completion, stimulation and production. Additional testing may be required for very high temperature, long duration operations with some completion brines and acids.

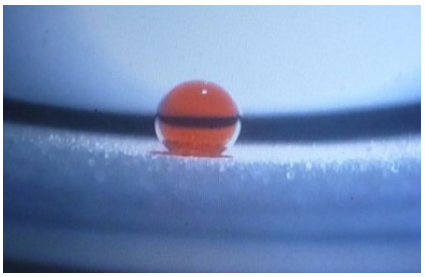


Figure 2. Water droplet in oil medium on coating surface, depicting a water-in-oil contact angle of 169°

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