Methodology for a deeper understanding of the role of wettability on the movement of fines in pore spaces

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Introduction

Movement of small mineral particles in a pore network in response to fluid flow is of great concern in fluid injection operations. As the fine particles migrate, the may become trapped in pore throats and cause formation damage. It is therefore important to understand the properties that may initiate, promote and prevent fines migration in order to mitigate the effect it may have.

Background

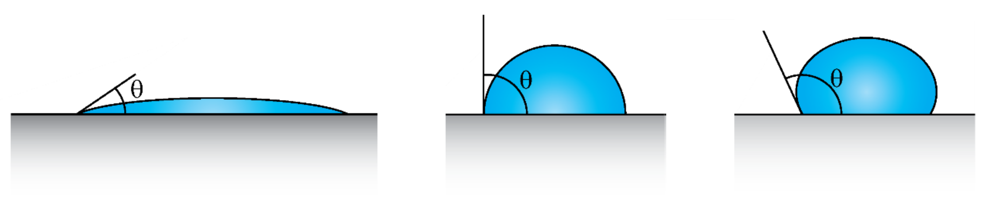
Many previous studies have been carried out on assessing the factors contributing to fines migration

Parameter	Effect
Velocity	↑ velocity, ↑ migration (above CFV)
Salinity	↓ salinity, ↑migration (below CSC)
Temperature	↑ temperature, ↑ migration
pH	↑ pH, ↑ migration
Nature of cation	↑ ionic radius, ↑ migration ↓ charge, ↑ migration
Wettability	Mobilisation if phase that wets fines is mobile

However, the effect of wettability, other than noting that fines will move only if the phase that wets them is mobile, is less well understood. It is therefore the subject of current study.

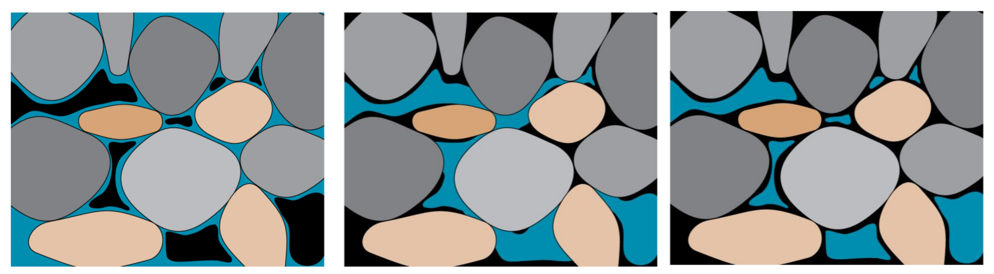
Wettability

Wettability is the tendency of one fluid to spread on or adhere to a solid surface in the presence of other immiscible fluids. This may be illustrated by the shape that a water droplet makes on a surface; the precise measurement of the angle which the droplet makes with the surface is one method of measuring the wettability of a surface.



Water-wet (<90°) Neutral-wet (90°) Oil-wet (>90°)

In an oil reservoir, the surfaces of the grains which make the matrix of the reservoir may be oil-, water- or mixed-wet, illustrated below.



Water-wet Mixed-wet Oil-wet

The fine particles in the pore spaces may have a different wettability to the matrix grains: will the difference in wettability affect the movement of the fines? Will the movement of the fines be affected by a mixed-wet system?

Requirement for Model System

Sandstones are naturally water-wet, but reservoirs have been found to exhibit oil-wet or mixed-wet behavior. Fines in sandstones and reservoirs vary from oil- to water-wet, seemingly regardless of the wettability state of the whole rock. The measurement of wettability on a pore scale is difficult, as the precise nature of the material lining the pore, and hence the wettability may vary from pore to pore. Additionally, pores of different sizes may have different wettabilities in the same rock.

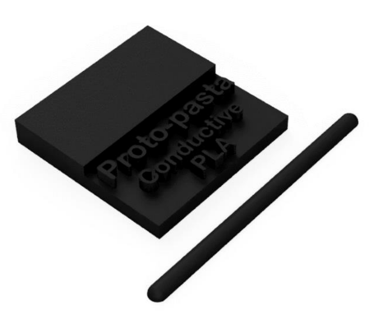
Measurement of wettability directly on a pore scale in a whole rock is challenging and destructive, and visualizing the movement of fines in these pores is equally difficult. It was therefore concluded that a model system should be developed with controllable, measurable wettability and repeatable pore structure.

The obvious technology to use for this is additive manufacturing (commonly termed "3D printing") as using this technology, it should be possible to produce model pore systems with measurable and controllable wettability and geometry.

Methodology

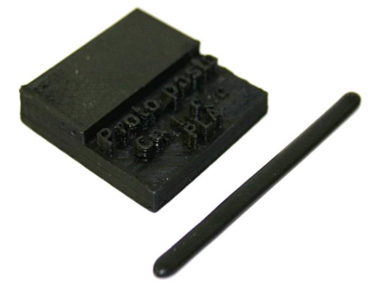
The additive manufacturing technique selected for this study was fused deposition modelling, as a wide variety of materials may be used at low cost on an office desktop machine. The following was used to prepare the test material:

Design Software	Autodesk Fusion 360
Slicing software	Cura 3.2
Printer	Raise3D N1

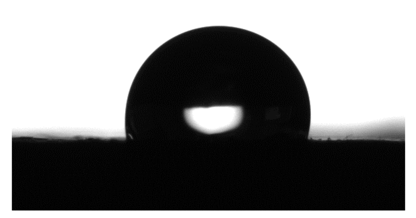


Create suitable test print

Choose material



Print test material



Measure contact angle

Next steps

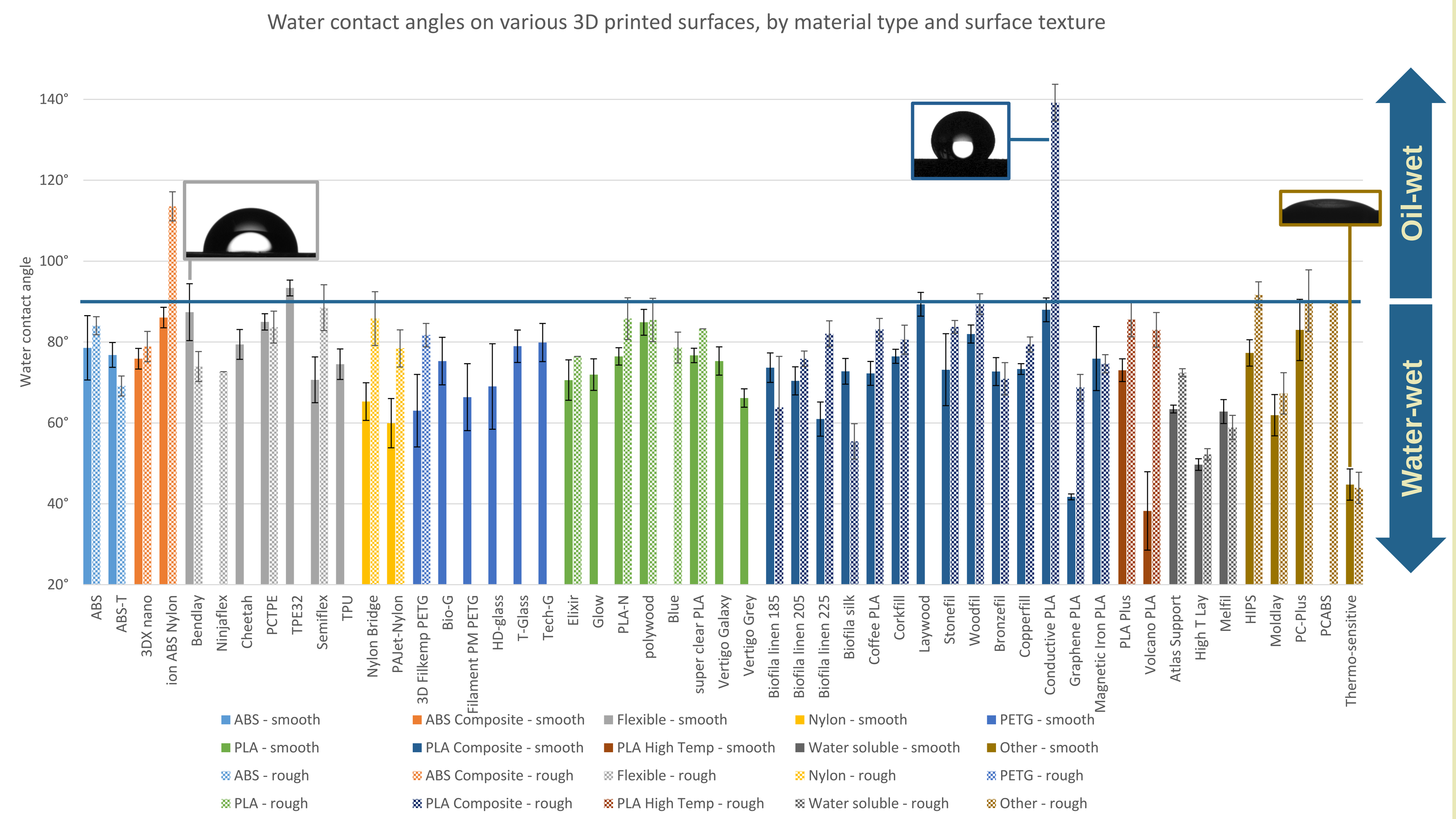
Measure roughness of 3D printed material

Future work

Print pore networks and observe fines flow

Results

49 different materials have been printed and tested. 22 materials are poly-lactic acid (PLA) variants. The other materials are polyethylene terephthalate glycol modified (PETG), thermo-plastic elastomer (TPE), thermoplastic polyurethane (TPU), acrylonitrile butadiene styrene (ABS), nylon, high impact polystyrene (HIPS) and polycarbonate (PC). Contact angle measurements were carried out on the top and bottom surfaces of each test material, testing smooth and rough surfaces respectively.



Conclusions and Further Work

Conclusions

- Models can be created to allow contact angle testing to be carried out
- It is possible to obtain a variety of wettabilities using FDM printing techniques
- Additives in PLA can affect the wettability of the surface
- The surface texture of the 3D printed material can affect the water contact angle.

Ongoing and Future Work

- The roughness of the surfaces needs to be quantified.
- A suitable pore network needs to be designed and printed in a suitably transparent material of the selected wettability
- Apparatus to flow fines through the network must be sought. It is likely that a microscope setup will be used
- The option of modifying the prints after production is also being assessed.

References

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