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Numerical Simulation of the Effects of Slurry Properties on Displacement Efficiency

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Abstract

In the course of cementing, improving the displacement efficiency in the annular is a basic premise to prevent drilling fluid channeling, guarantee the bonding strength of set cement and improve the sealing property of cement sheath. Based on the CFD software of FLUENT, effects of rheological parameters on the displacement efficiency were studied by means of numerical simulation. For Bingham Model or Power Low Model fluid, the simulation results show that increasing consistency coefficient of cement slurry, liquidity index of drilling fluid, plastic viscosity of cement slurry and the yield point of cement slurry or drilling fluid will help to improve the displacement efficiency. On the contrary, increasing liquidity index of cement slurry, consistency coefficient of drilling fluid or increasing plastic viscosity of drilling fluid will decrease the displacement efficiency.

Key words: Displacement efficiency; Slurry properties; Numerical simulation; FLUENT

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INTRODUCTION

Cementing is an essential course in well construction, its success and quality has an important significance on oilfield overall development and construction such as exploration development, timely discovery of hydrocarbon reservoir and so on[1]. Increasing the cementing quality is one of the key technologies to prolong work life of a well, increase the recovery of hydrocarbon reservoir and optimize exploitation of the oilfield[2]. During a cementing operation, improving the mud displacement in the annular is a basic premise to prevent drilling fluid channeling, guarantee the bonding strength of set cement and improve the sealing property of cement sheath, and thus to improve the quality of cementing[3]. So improving the displacement efficiency is of vital importance for cementing.

It is very difficult to make a laboratory experiment on displacement efficiency. Because simulation of actual wellbore condition is impossible, and the ratio of cement in a certain cross section cannot be measured precisely. In addition, accurate measurement of turbulent characteristic of cement slurry during displacement is difficult[4].

For the advantage of easy to use and high precise, numerical simulation software such as ANSYS and FLUENT have widely used in industrial design and performance analysis[5]. Combined with the relevant knowledge on cementing field, the numerical simulation software can simulate the flow field characteristic under the condition of different drilling mud property, cementing slurry property[6], different borehole condition and displacing parameters. The fluid property and displacing parameters could be optimized with the help of the software mentioned above. It has an essential importance to improve displacement efficiency and cementing quality[7].

Effect of the different rheological parameter of drilling mud and cement slurry on displacement efficiency were studied by numerical simulation software FLUENT, and how they affect displacement efficiency were further researched. A more profound understanding of displacement efficiency is learned and cementing quality can be improved correspondingly.

1. EFFECT OF LIQUIDITY INDEX AND CONSISTENCY COEFFICIENT ON DISPLACEMENT EFFICIENCY

1.1 Establishment of Physical Model and Assumption

For the process of cement slurry displacing drilling mud, when the casing is perfectly concentric with the well bore, any cut plane of medial axis of the well bore should be the same and they are all symmetric, so the 3-D simulation can be simplified to 2-D.

Scale of the model

Because of the symmetric analysis above, the 2-D model of displacement of drilling mud with cement slurry can be further simplified by half, scaled 2×200 cm.

Calculation assumption:

Inlet: velocity-inlet.

Outlet: pressure-outlet.

Multiphase flow model: VOF.

Solver: fluent 2-D

Solution methods: first order upwind momentum, SIMPLE velocity-inlet and STANDARD pressure-outlet.

Displacement efficiency is time based during the course of displacement, so the transient solver was applied.

1.2 Effect of Cement Slurry Consistency Coefficient on Displacement Efficiency

To learn the effect of cement slurry consistency coefficient on displacement efficiency, liquidity index and consistency coefficient of drilling mud and liquidity index of cement slurry were set up. The effect of slurry consistency coefficient on displacement efficiency was simulated and analyzed.

Setting:

Consistency coefficient of drilling mud, 1.5 Pa·s^n, liquidity index of drilling mud, 0.8 (dimensionless); liquidity index of cement slurry, 0.5 (dimensionless).

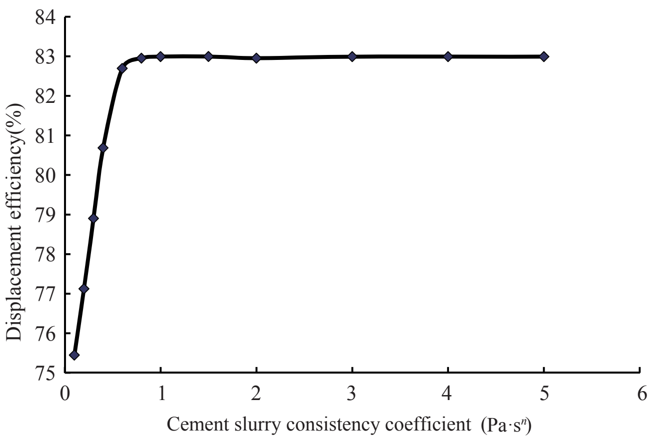

Figure 1
Effect of Cement Slurry Consistency Coefficient on Displacement Efficiency

Conclusion from Figure 1 comes to that, displacement efficiency increases with the increase of consistency coefficient when consistency coefficient of cement slurry is 0.1-0.6 Pa·s^n, while consistency coefficient is 0.6-5 Pa·s^n, displacement efficiency is almost constant.

1.3 Effect of Cement Slurry Liquidity Index on Displacement Efficiency

Setting:

Consistency coefficient of drilling mud, 1.5Pa·s^n, liquidity index of drilling mud, 0.8 (dimensionless); Consistency coefficient of cement slurry, 1 Pa·s^n.

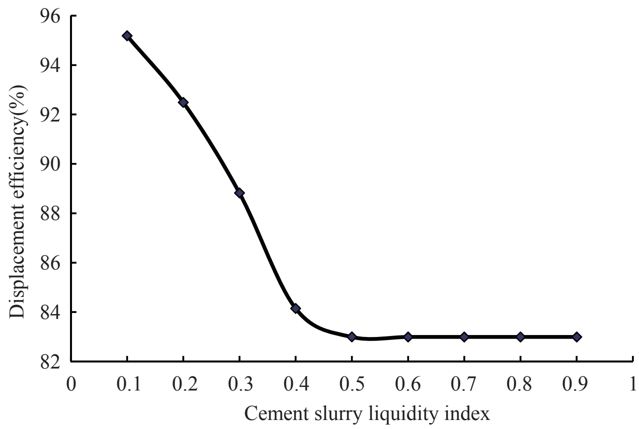

Figure 2
Effect of Cement Slurry Liquidity Index on Displacement Efficiency

Figure 2 shows that displacement efficiency decreases as the liquidity index increases when liquidity index of cement slurry is 0.1-0.5, while when liquidity index is 0.5-0.9, displacement efficiency is almost constant.

1.4 Effect of Drilling Mud Consistency Coefficient on Displacement Efficiency

Setting:

Consistency coefficient of cement slurry, 1.5 Pa·s^n; liquidity index of cement slurry, 0.7 (dimensionless); Liquidity index of drilling mud, 0.8 (dimensionless).

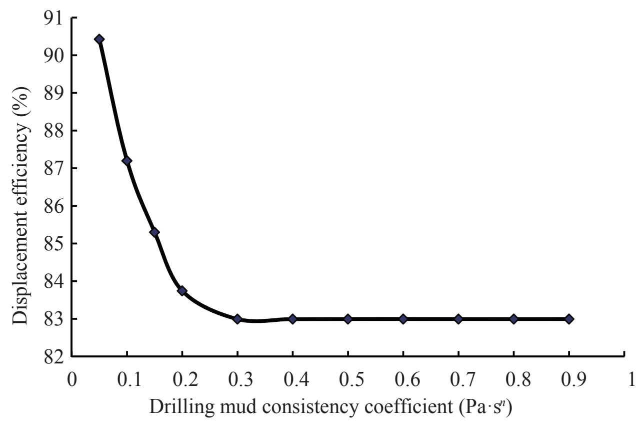

Figure 3
Effect of Drilling Mud Consistency Coefficient on Displacement Efficiency

In Figure 3, the displacement efficiency decreases with the increase of liquidity index when consistency coefficient of drilling mud is 0.1-0.3 Pa·s^n, while when consistency coefficient is 0.3-6 Pa·s^n, displacement efficiency is almost constant.

1.5 Effect of Drilling Mud Liquidity Index on Displacement Efficiency

Setting:

Consistency coefficient of cement slurry, 1 Pa·s^n; liquidity index of cement slurry, 0.7 (dimensionless); Consistency coefficient of drilling mud, 1.5 Pa·s^n.

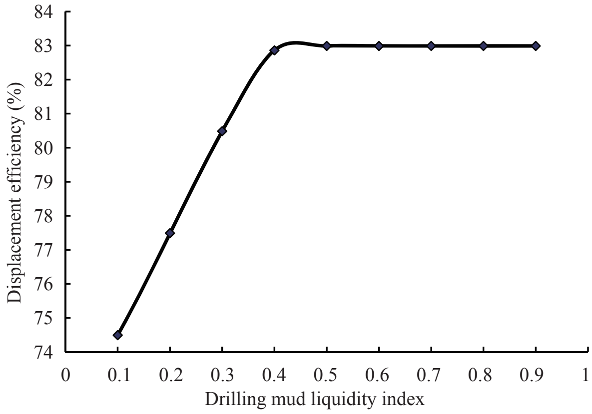

Figure 4
Effect of Drilling Mud Liquidity Index on Displacement Efficiency

As Figure 4 showing, displacement efficiency increases with the increase of liquidity index when liquidity index of drilling mud is 0.1-0.5, while when liquidity index is 0.5-0.9, displacement efficiency is almost steady.

2. EFFECT OF YIELD POINT AND PLASTIC VISCOSITY ON DISPLACEMENT EFFICIENCY

2.1 Effect of Cement Slurry Plastic Viscosity on Displacement Efficiency

Setting:

Yield point of drilling mud, 2 Pa; Plastic viscosity of drilling mud, 0.01 Pa·s; Yield point of cement slurry, 2 Pa.

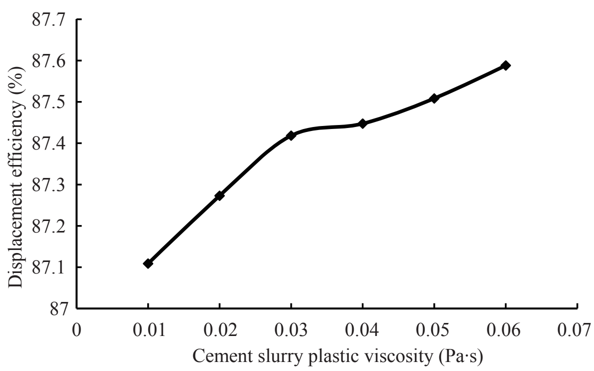

Figure 5
Effect of Cement Slurry Plastic Viscosity on Displacement Efficiency

Conclusion from Figure 5 comes to that, displacement efficiency increases as the plastic viscosity increases when plastic viscosity of cement slurry is 0.01-0.06 Pa·s.

2.2 Effect of Cement Slurry Yield Point on Displacement Efficiency

Setting:

Yield point of drilling mud, 2 Pa; plastic viscosity of drilling mud, 0.01 Pa·s; Plastic viscosity of cement slurry, 0.01 Pa·s.

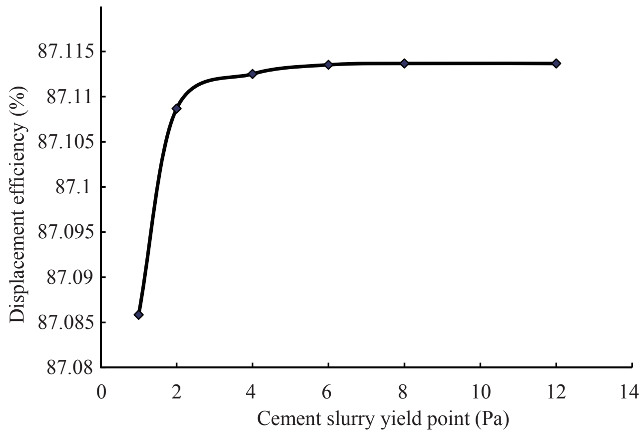

Figure 6
Effect of Cement Slurry Yield Point on Displacement Efficiency

As Figure 6 showing, displacement efficiency increases with the increase of yield point when yield point of cement slurry is 1-8 Pa, while when yield point is 8-14 Pa, displacement efficiency is almost constant.

2.3 Effect of Drilling Mud Plastic Viscosity on Displacement Efficiency

Setting:

Yield point of cement slurry, 2 Pa; plastic viscosity of cement slurry, 0.01 Pa·s; Yield point of drilling mud, 2 Pa.

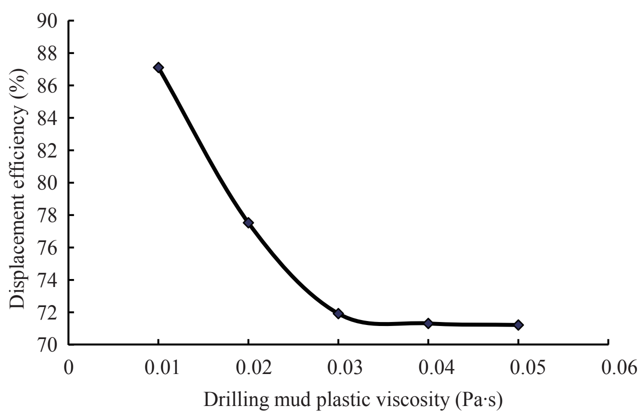

Figure 7
Effect of Drilling Mud Plastic Viscosity on Displacement Efficiency

In Figure 7, displacement efficiency decreases with the increase of plastic viscosity when plastic viscosity of drilling mud is 0.01-0.05 Pa·s.

2.4 Effect of Drilling Mud Yield Point on Displacement Efficiency

Setting:

Yield point of cement slurry, 2 Pa; Plastic viscosity of cement slurry, 0.01 Pa·s; Plastic viscosity of drilling mud, 0.01 Pa·s.

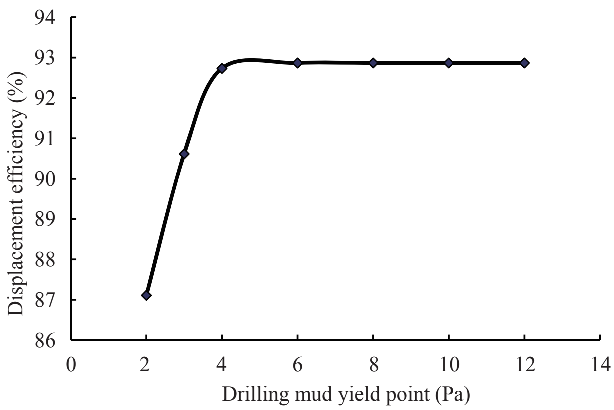

Figure 8
Effect of Drilling Mud Yield Point on Displacement Efficiency

Conclusion from Figure 8 comes to that, displacement efficiency increases with the increase of yield point when yield point of drilling mud is 1-6 Pa, while when yield point is 6-42 Pa, displacement efficiency is almost constant.

CONCLUSION

As a Power-law fluid, cement slurry and drilling mud affect displacement efficiency on the following rules:

(a) Displacement efficiency increases with the increase of consistency coefficient when consistency coefficient of cement slurry is 0.1-0.6 Pa·s^n, while when consistency coefficient is 0.6-5 Pa·s^n, displacement efficiency is almost constant.

(b) Displacement efficiency decreases with the increase of liquidity index when liquidity index of cement slurry is 0.1-0.5, while when liquidity index is 0.5-0.9, displacement efficiency is almost constant.

(c) Displacement efficiency decreases with the increase of liquidity index when consistency coefficient of drilling mud is 0.1-0.3 Pa·s^n, while when consistency coefficient is 0.3-6 Pa·s^n, displacement efficiency is almost constant.

(d) Displacement efficiency increases with the increase of liquidity index when liquidity index of drilling mud is 0.1-0.5, while when liquidity index is 0.5-0.9, displacement efficiency is almost constant.

As a Bingham model fluid, cement slurry and drilling mud affect displacement efficiency on the following rules:

(a) Displacement efficiency increases with the increase of plastic viscosity when plastic viscosity of cement slurry is 0.01-0.06 Pa·s.

(b) Displacement efficiency increases slightly with the increase of yield point when yield point of cement slurry is 1-8 Pa, while when yield point is 8-14 Pa, displacement efficiency is almost constant.

(c) Displacement efficiency decreases with the increase of plastic viscosity when plastic viscosity of drilling mud is 0.01-0.05 Pa·s.

(d) Displacement efficiency increases with the increase of yield point when yield point of drilling mud is 1-6 Pa, while when yield point is 6-42 Pa, displacement efficiency is almost constant.

REFERENCES

[1] Jones, P. H., & Berdine, D. (1940, March). *Oil-well cementing*: *Factors influencing bond between cement and formation*. Drill and Prod. Prac. APl., Dallas.

[2] Howard, G. C., & Clark, J. B. (1948). Factors to be considered in obtaining propercementing of casing. *D.P.P. API*, 257-272.

[3] Parker, P. N, Ladd, B. J., Ross, W. N., & Wahl, W. W. (1965, October). *An evaluation of a primary cementing technique using low displacement rates*. Fall Meeting of the Society of Petroleum Engineers of AIME, Denver, Colorado.

[4] Parker, P. N. (1969). Cementing successful at low displacement rates. *Wor1d Oil J*, 93.

[5] Brice, J. W., & Holmes, R. C. (1964). Engineered casing cementing programs using turbulent flow techniques. *JPT*, 503-508.

[6] Hirt, C. W., & Nichols, B. D. (1981). Volume of fluid (VOF) method for the dynamics of free boundaries. *Journal of Computational Physics*, *39*, 201-225.

[7] Clark, C. R., & Carter, L. G. (1973). Mud displacement with cement slurries. *JPT*, 8-10.