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Modified Wax LCM for the Reservoir: Effective Seal and Simple Removal

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Abstract

Wax materials used to cure lost circulation in the reservoir section of wells can agglomerate and plug drill pipe and hoses when contamination with various types of oil occurs. They are also soft and readily pushed through pore spaces and fractures even at room temperature. This paper shows that a material with a much higher melting point and containing hetero-atoms in the composition helps mitigate these issues.

These changes also increase the effectiveness of the material toward fracture sealing. For example, the volume of fluid lost through a 500-micrometer slot was reduced from 20 mL when using a low-melting wax to 0 mL when using the modified high-melting wax in the plugging formulation at 175°F and 1000 psi differential. Similar trends are seen when these materials are used in inside screen pills. The modified high-melting wax exhibits much lower fluid loss volume.

The modified high-melting wax is readily removed from the wellbore by many base oils at temperatures as low as 150°F. This lost circulation material can be placed in the wellbore to plug pore spaces and/or fractures and remediation can be accomplished using environmentally friendly oil, thus reducing or eliminating the need to acidize the filter cake in order to start production or injection.

Introduction

Lost circulation (LC) costs operators millions of dollars annually and is one of the biggest contributors to drilling non-productive time (NPT). Estimations of the economic impact of LC vary widely, but one could safely say that it represents a very large portion of non-productive expense for drilling a well. As rig rates increase, the impact of NPT increases as well.

Most research in this area has concentrated on quick and efficient combinations for mitigating LC before it is encountered through the use of stress caging or wellbore stress management, or remediating LC after it is encountered.[1,2] Often the materials used are designed to be in place permanently or at least until the problem zone is isolated behind casing. Because of the permanence of these materials, they could certainly reduce the producibility of the hydrocarbon bearing zone when used in a reservoir. The LC materials that are meant to be removed from the wellbore require treatment with either live acid or acid generating material in order to be removed from the producing zone.

Therefore, materials which can be easily removed from the wellbore after curing an LC incident and during production may be of value for solving LC encountered in the reservoir section of a well. Any materials considered here would also have to deform to better fit into and seal the fractures encountered, be soluble in the produced fluid, particularly hydrocarbons, and possibly agglomerate so a wide range of fracture sizes can be sealed.

Wax materials with melting points between about 150°F and 300°F have been used as well stimulation diverting agents for some time now. The first paper to discuss the development of such material was published in 1969 by Gallus and Pye.[3] A second paper by the same authors was published in 1972 covering the field data obtained after treating wells with a wax material during stimulation.[4] Wax buttons were used during fracturing during the early 1990s to divert the fracturing fluid to the areas of the wellbore where fracturing was most needed.[5] Refined wax has been proposed as a lost circulation material particularly to control small amounts of whole fluid lost to the penetrated formation.[6] Mixtures of oil insoluble materials coated with refined wax may be used for more severe fluid losses to the formation.[7]

Several different synthetic wax samples were examined for use as lost circulation material (LCM) with emphasis on fluid loss, cake cleanup, and lubricant compatibility. The sample designations and selected properties are given in Table 1.

Table 1 Wax sample characteristics

Designation	Softening point (°F)	Acid Number
Wax Blend 1	190 – 210	
Wax Blend 2	216 – 238	5 – 9
Wax Blend 3	195 – 220	16 – 19
Ox Wax 1	300 – 350	40 – 50
Ox Wax 2	300 – 350	40 – 50

Experimental

Pore plugging tests were conducted at 175°F over 190 micrometer pore throat disks with 1000 psi overpressure using the Drill-in fluid shown in Table 2. The volume of filtrate collected and the filter cake thickness were recorded in milliliters (mL) and millimeters (mm), respectively. The plugged discs were rinsed gently with water and then placed in a second PPA cell containing 250 mL of either Soltrol 170 or

Diesel. The sample was heated to 250°F and allowed to soak for a total of 1 hour. The oil was then pushed through the disc during a second hour to expose the disc to fresh oil. After cooling, the disc was removed and examined to determine how well it was cleaned.

Table 2 Drill-in Fluid Formulation

Material	Amount
Water, bbl	1
Viscosifier, lb	1.67
Filtration Control Polymer, lb	5.57
Potassium Chloride, lb	9.67
Oxygen Scavenger, lb	0.56

After conducting tests over the ceramic discs, fracture plugging tests using disks with 508 micrometer (µm) wide fractures were used keeping all other conditions the same. Fluid loss tests using 8.5 and 16 gauge screens were also conducted at 150 and 200°F with 1000 psi differential pressure.

Results

Fluid Loss Control

A series of tests were conducted to determine the blend of ground marble (GM) and the ratio of this blend to wax material as shown in Tables 3 and 4. After comparing fluid loss results from Formulations A and C or Formulations B and D, it is clear that a blend of GM 150, 50 and 25 is needed to reduce the fluid loss. A ratio of 1:1 GM blend to wax by volume, Formulation D, or 3:2 by volume, Formulation G in Table 3, seals the ceramic disc effectively with about 60 mL of fluid loss. Of note here is the fact that rounding the mass of the sized GM and the wax to whole numbers resulted in much higher fluid loss. Compare Formulations D and G in Tables 3 and 4 to Formulation H in Table 4 as well as Formulations I and J in Table 5. Formulations D and J contain 1:1 ratio of GM blend to wax by volume; therefore, it was decided to use this ratio for subsequent testing unless otherwise stated.

One can also compare the results obtained for Wax blend 1 in Formulation D to those obtained for Ox wax 1 or 2 in Formulations J and M. Clearly, an oxidized wax shows lower fluid loss values. In the tests conducted over the ceramic disks, there is not a clear best choice between Wax blends 2 and 3 and Ox waxes 1 and 2. Wax blend 2 and Ox wax 2 were used for further testing based on material characteristics.

Table 3 Formulations determining ratio of GM to wax

Formulation	A	B	C	D
Drill-in Fluid	165.2	166.8	165.2	166.8
GM 25	0	0	1.25	1.85
GM 50	0	0	2.5	3.7
GM 150	12.5	18.5	8.75	12.95
Wax blend 1	12.5	6.5	12.5	6.5
Fluid loss through 190 µm disk at 175 °F and 1000 psid				
mL fluid	N/C	N/C	130	55, 45, 85
Cake (mm)			7	0-4.5

Table 4 Formulations determining ratio of GM to wax

Formulation	E	F	G	H
Drill-in Fluid	168.4	165.1	167.4	167.5
GM 25	2.12	1.67	2.02	2
GM 50	4.25	3.33	4.05	4
GM 150	14.88	11.67	14.18	14
Wax blend 1	3.75	8.33	4.75	5
Fluid loss through 190 □m disk at 175 °F and 1000 psid				
mL fluid	65	90	35, 60, 80	100
Cake (mm)	0.-4.5	up to 5	0 - 4	up to 4

Table 5 Formulations determining best wax for fluid loss

Formulation	I	J	K	L	M
Drill-in Fluid	167.5	166.8	166.8	166.8	166.8
GM 25	2	1.85	1.85	1.85	1.85
GM 50	4	3.7	3.7	3.7	3.7
GM 150	14	12.95	12.95	12.95	12.95
Ox wax 1	5	6.5			
Wax blend 2			6.5		
Wax blend 3				6.5	
Ox wax 2					6.5
Fluid loss through 190 □m disk at 175 °F and 1000 psid					
mL fluid	47, 42	10, 12	15, 11	10, 18	20, 28
Cake (mm)	0-5	0-2	0-3	0-3	0-3

The drill-in fluid with 50 lb/bbl GM blend readily plugged a 200 µm slot with 0 mL fluid loss, but had 19 mL fluid loss through the 508 µm slot. The 508 µm slotted disk was used for tests with the wax material. Formulation K had 20.5 mL of fluid loss while Formulation M had 0 mL fluid loss through the slot.

Formulations K and M previously tested over ceramic and slotted discs were also tested using 8.5 and 16 gauge screens. The results are shown in Table 6 and are very good particularly for the formulation containing the Ox wax 2 material at 150°F.

Table 6 Fluid loss through screens

Formulation	K		M		N	O
Drill-in Fluid	321.6		321.6		330.4	330.4
GM 25	3.7		3.7		2.5	2.5
GM 50	7.4		7.4		5	5
GM 150	25.9		25.9		17.5	17.5
Wax blend 2	13				25	
Ox wax 2			13			25
Fluid loss at 150 °F and 1000 psid						
Screen gauge	8.5	16	8.5	16	8.5	16
mL fluid	35	N/C	4	15	N/C	35*

*Conducted at 200 °F

Filter Cake Cleanup

Once the LCM is in place the desire is to remove it with the condensate already in place. Therefore, the second objective of this project was to determine how well the filter cake can be removed from the filter medium in each test using only oil. A majority of these tests utilized Soltrol 170, used to simulate crude oil in return permeability tests. Some results are shown in Figures 1 and 2 for Formulations K and M. Cleanup results for Formulations D, J and L are shown in Figures 3 through 5. Diesel appears to be a good choice to clean the filter cakes as shown by Figures 6 and 7. Diesel was also used to clean the 8.5 and 16 gauge screens as shown in Figures 8 and 9. Unfortunately, the cakes show worm holes and are not evenly removed from the screen during the duration utilized here. Efforts continue for determining the best combination of material and performance of various types of oil.

Figure 1 Formulation K before and after cleanup with Soltrol 170 at 250°F for 2 hours

Figure 2 Formulation M before and after cleanup with Soltrol 170 at 250°F for 2 hours

Figure 3 Formulation D before and after cleanup with Soltrol 170 at 250°F for 2 hours

Figure 4 Formulation J before and after cleanup with Soltrol 170 at 250°F for 2 hours

Figure 5 Formulation L before and after cleanup with Soltrol 170 at 250°F for 2 hours

Figure 6 Formulation K before and after cleanup with Diesel at 250°F for 2 hours

Figure 7 Formulation M before and after cleanup with Diesel at 250°F for 2 hours

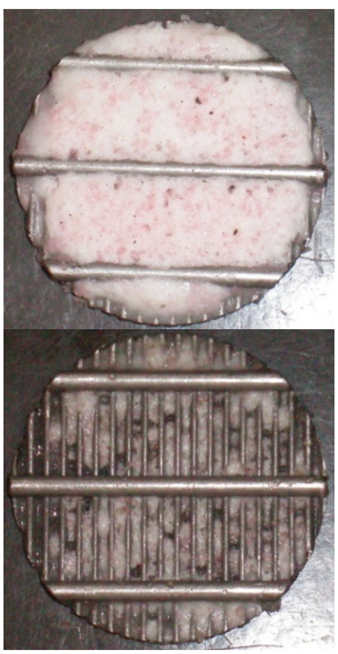

Figure 8 Formulations K and M after cleanup with Diesel at 250°F for 2 hours

Figure 9 Formulation O after cleanup with Diesel at 250°F for 2 hours

Interactions with Lubricants

The wax materials were also examined for their compatibility with various lubricants used to reduce torque and drag in water-based drilling fluids. Fluids with formulation K or M were dynamically aged with 4% lubricant at 150°F for four hours. The wax materials formed into balls when diesel or ester-based lubricant was used. They became sticky when a sulfurized oil was used, and they were unaffected when blends of oil and surfactant were used. Some example images are shown in Figures 10 through 12.

Figure 10 Formulation K interaction with Diesel

Figure 11 Formulation K interaction with sulfurized oil

Figure 12 Formulation K interaction with oil and surfactant blend

Conclusions

- Wax samples Wax blend 1 and Ox wax 2 are particularly good at reducing fluid loss in a variety of situations such as porous formations, fractures and inside screens.
- The same wax samples are removed from the cake after treatment at 250°F in base oil even though some have a melt temperature greater than 300°F.
- The wax samples should be used with lubricants that are blends of surfactant and oil.

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Nomenclature

N/C = No Control

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