TENDEKA

Technical Overview

Improving Matrix Acidizing optimisation by Autonomous flow diverter

Introduction

Acidizing is commonly performed on wells to remove damage and reduce skin to maximize productivity and recovery. Acidizing enhancement technique is still a highly preferred method of damage removal/stimulation adopted for sandstone and carbonate reservoir dating as far back as the nineteenth century. A proper acid design program is critical to success of these types of treatments. However, proper placement technique carries the same importance as the acid design. Using a new placement technique, the entire planned completion interval can be acidizing at sufficient injection rates without exceeding the formation ability to accept fluid below the fracture gradient. When acid is pumped into damaged reservoir for damage removal/stimulation, distorted inflow of acid into formation occurs caused by preferentially traveling into highly permeability regions over low permeability regions or into the path of least resistance. If acid is not effectively diverted in formation with high permeability/fracture anisotropy, some treated zones may become acid sinks while other zones are left with inadequate acid stimulation.

Acidizing Challenge

Reservoir and wellbores are interconnected by pores in the formation. The flow of fluids through these pores is often restricted because of permeability damage in the near wellbore formation caused by drilling fluid invasion, cementing and completion operation that reduce the physical size of pore throats or block the pore space causing impairment to the reservoir permeability that often-called formation damage.

Acid treatment falls into three general categories:

- Wellbore cleanout – remove debris that block pore space during installation
- Matrix acidizing – pump below formation pressure
- Fracture acidizing – pump above formation pressure

Wellbore cleanout is processed to clean the tubular and wellbore with acid to clear out debris that block the pore space due to drilling operation. Matrix acidizing is an acid treatment injection at matrix pressure and staying below formation fracture pressure. In sandstone formation, it is used to remove or dissolve acid removable damage in the formation pore network near wellbore or to remove plugging in the perforation. In carbonate formation, matrix acidizing works by forming conductive channels called worm holes through the formation rock.

There are three type of matrix treatments:

- Near wellbore stimulation – within 2ft to 3ft of the wellbore
- Intermediate matrix stimulation – within 3ft to 6ft of the wellbore
- Extended matrix acidizing – further than 6ft from wellbore and use large volume

Ideally, when acid is pumped into zones of variable permeability, it will distribute equally into all zones. However, in general, acid preferentially flows into path of least resistance which is the high permeability regions over low permeability regions as shown in Figure 1.

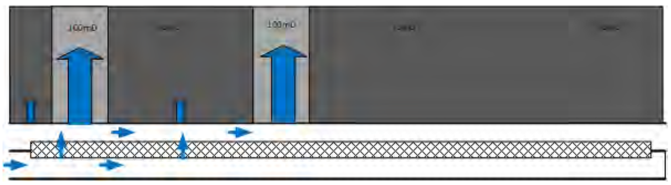

Figure 1. Acid preferentially flows into least resistance path.

When acid is flow into high permeability/fracture zones compared to low permeability zone, consequently the damage in the high permeability zones will be removed at higher rate hence the skin is drastically reduced. Such a distorted flow results into over-threating a high permeability zone leading to poor zonal coverage as shown in Figure 2. In this case, the low permeability zone is poorly treated with acid resulting in poor production recovery. The high permeability zone could also lead to excessive flow contribution that resulting in water or gas conning.

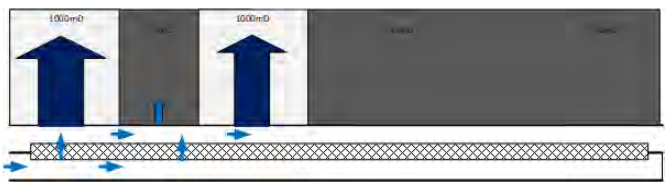

Figure 2. Over threating a high permeability zone resulting in poor distribution to low permeability zone.

FloFuse acidizing technique

Acid diverter is one of the acidizing techniques that could be used to distribute acid in well. The choice of diverter method depends on its applicability, well characteristic and reservoir property. However, existing method need a mechanical isolation device to temporary straddle the fracture zone and this often associated with high cost and more operation time. Limited entry liner is another diversion technique that been adopted in long horizontal well. The limited entry is achieved by proportioning the number of perforations according to the thickness of the pay zone. However, this technique has significant challenge if fracture location is unknows as it unable to isolate the fracture zone.

FloFuse is an autonomous acid divertor device which is biased open valve which enables acid injection at normal distributed rates. The Flofuse is mounted into the basepipe or screen section and required zone isolation to distribute the outflow of the acid as shown in Figure 3. The placement of the flofuse could be simulate in modelling to show equal distribution of acid as shown in Figure 4.

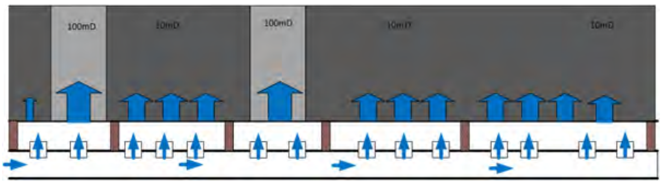

Figure 3. FloFuse placement in a well.

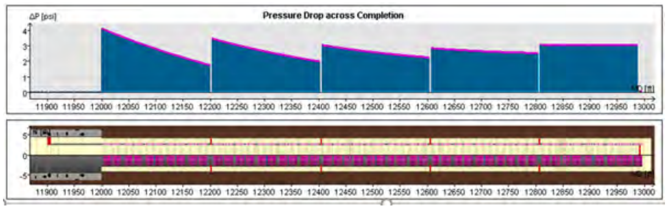

Figure 4. Equal distribution of acid at initial stage.

If the acid is injected into fracture of high permeability zone, the acid will preferentially flow at higher flowrate that will exceeded the 'trigger rate' and choke the valve. Once the FloFuse is triggered, outflow is highly constrained into the 'fused' zone enabling acid injection to be diverted into the other compartments as shown in Figure 5. The fuse zone could be indicate with higher pressure drop due to higher flow rate at fracture zone cause the FloFuse stop flowing to "fuse zone" as shown in Figure 6.

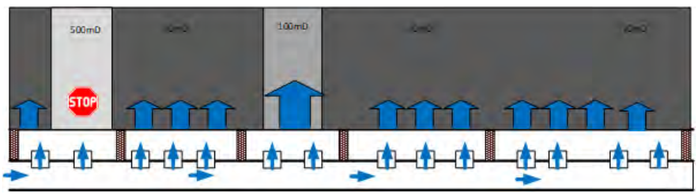

Figure 5. FloFuse stop flowing to "fuse zone" as the permeability increase cause fuse and distribute acids to another zone.

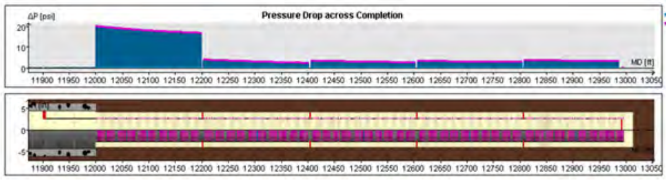

Figure 6. Higher pressure drop indicate higher flowrate at fracture zone cause the FloFuse stop flowing to "fuse zone".

Once the effected flofuse "fuse", it will increase the well head pressure to indicate a particular zone have completed acidizing and the need of reduction of flowrate. The "fuse" process will keep continue as a new zone increase in permeability as shown in Figure 7 and 8.

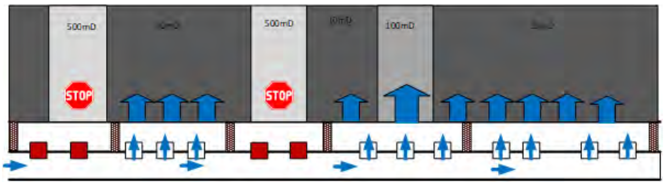

Figure 7. FloFuse stop flowing to next "fuse zone" as the permeability increase cause fuse and distribute acids to other zone.

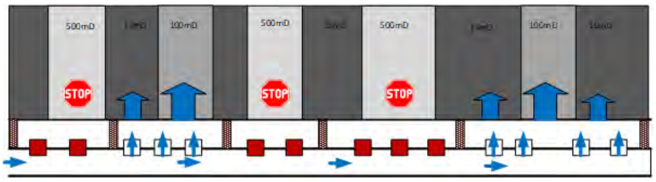

Figure 8. FloFuse stop flowing to most "fuse zone" as the permeability increase cause fuse and distribute acids to other zone.

When all the zone has been given the desired amount of acids treatments and become very permeable zones. All flofuse will be in choke/shut in position as shown in Figure 9. The fuse effect could be observed with rapid increase in well head pressure that indicate all zone have been acidize at optimum rate without over threating any of the zone. This technique will also avoid any excessive use of acid. Figure 10 shows a optimization modelling example between wellhead pressure and injection rate to shows injection process.

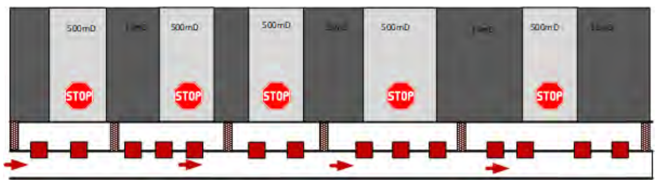

Figure 9. FloFuse stop flowing to all the "fuse zone" as all the zone being threated.

The FloFuse is fully reversable and the valve will re-set if injection is stop and differential pressure across the valve decrease. The acidizing process could be repeated if further acid treatment is desire and the rate become sufficiently distributed again.

Frac Overpressure 3700						1	2	3	4	5	1	2	3	4	5
Trigger 20 psi	Wellhead Pressure	Injection Rate	Injection Rate	Downhole Rate	Well I.I.	Build up Pressure	Build up Pressure	Build up Pressure	Build up Pressure	Build up Pressure	dP Comp	dP Comp	dP Comp	dP Comp	dP Comp
FloFuse 2C x 248 + ICD 3mm x 5	[psi]	[STB/day]	bbl/min	[RB/day]	[STB/day/psi]	[psi]	[psi]	[psi]	[psi]	[psi]	[psi]	[psi]	[psi]	[psi]	[psi]
Pre-Stim Skin=5	2744.45	15000	10.42	14895.1	5.43191	2591	2590	2590	2590	2590	4.1	3.5	3	2.8	3
Pre-Stim 30k bwpd - over frac	5852.62	30000	20.83	29510.5	5.11105	5145	5140	5138	5137	5136	16	13.2	12	11	12
Nominal Stim Perm 3000 mD	2862.26	30000	20.83	29779.5	10.4193	2097.5	2091	2088	2086	2084.5	15.5	13.5	12	11.2	12.3
First Zone Stim	3039.05	20370	14.15	20209.5	6.66545	2704	2717	2717	2717	2717	20	3.75	3.3	3.1	3.33
First Zone Trip	4409.83	20370	14.15	20125.6	4.60148	490	4107	4106	4105	4105	3600	8.3	7.8	7	8
Second Zone Stim	3941.87	18400	12.78	18205.1	4.64779	464	3701	3700	3700	3700	3247	7	6	6	6
Second Zone Stim	3056.47	18730	13.01	18581.4	6.09409	398	2776	2790	2790	2790	2400	20	3.5	3.5	3.6
Second Zone Trip	4787.29	18730	13.01	18484.1	3.89859	517	525	4546	4545.5	4545	4042	4032	9.2	8.6	9.5
Third Zone Stim	3852.29	15455	10.73	15295.4	3.99427	463	470	3700	3700	3700	3245	3237	6.1	6	6.1
Third Zone Stim	3051.82	16950	11.77	16815.8	5.52328	402	408	2826	2842	2842	2449	2441	20	3.5	3.7
Third Zone Trip	5402.24	16950	11.77	16696.3	3.12774	558	566	568	5228	5227	4684	4674	4671	11.5	12.5
Fourth Zone Stim	3777.49	12550	8.72	12423.2	3.30742	463	470	471	3700	3700	3243	3236	3244	6	6.1
Fourth Zone Stim	3012.54	14950	10.38	14833.4	4.93473	403	409	410	2844	2860	2465	2457	2455	20	3.7
Fourth Zone Trip	6706.87	14950	10.38	14668	2.22342	632	641	644	640	6608	5994	5984	5982	5987	20
Fifth Zone Stim	3716.01	9593	6.66	9497.87	2.56977	463	470	471	469	3700	3241	3234	3233	3236	6.4
Fifth Zone Stim	2763.94	12115	8.41	12029.6	4.35643	389	394.5	396	394	2663	2296	2290	2288	2289	20
Fifth Zone Trip	10921.9	12115	8.41	11735.1	1.10752										
Fifth Zone Trip	2764	5748.82	3.99	5708.27	2.06717	398	403	404.5	402.5	404.5	2395	2390	2389	2392	2391

Figure 10. FloFuse optimisation modelling

FloFuse device

The target normal operating rates and degree of outflow control and trigger rates and can be varied by application. Figure 11 show the cross section and key features of the valve in open position.

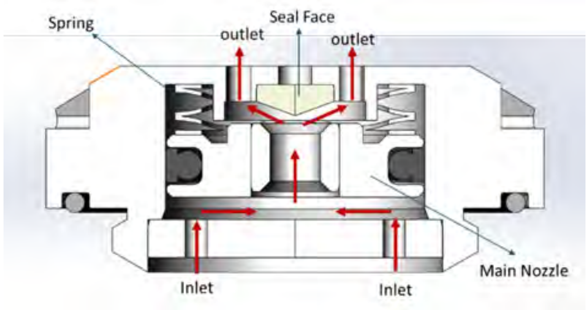

Figure 11. Flofuse construction in open position

If the formation have fracture or high permeability, the injection rate into that compartment will increase. The resultant increased pressure drop through the nozzle acts against the spring until the flow area between the seal face and the nozzle becomes restricted and the valve triggers to the fused position restricting the outflow into that compartment as shown in Figure 12.

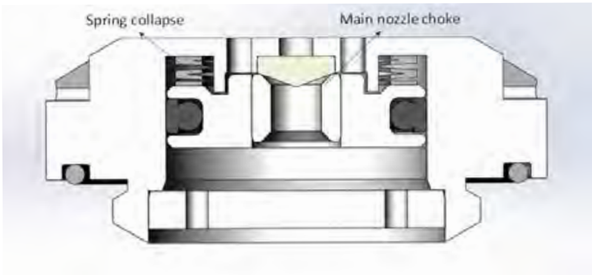

Figure 12. Flofuse in close position, main nozzle slide to sealing face

Under normal operating conditions injection outflow passes through the main nozzle and into the formation. In case sand control is needed, the outflow will be injected into the housing and through the screen as required as shown in Figure 13.

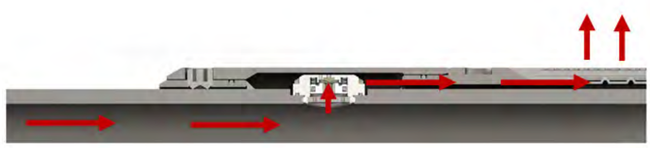

Figure 13. FloFuse mounted in screen housing

Summary

Acidizing of sandstone and carbonate reservoir is a comment practice to ensure high productivity by removing the near wellbore damage. A new autonomous acid stimulation device, FloFuse is developed to choke back the acid injection treatment into natural/induced fractures and mitigate the disproportional injection of acid into the fracture/high permeability zone. Flofuse device improved acidizing treatment efficiency by autonomously shut in the injection into fracture zone and divert the flow to another untreated zone. Flofuse stop over threated to high permeability area or fracture reduce the waste of acid and improved the economic of acidizing. Optimization of Flofuse acid treatment design have been simulated in reservoir modelling.