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Coiled Tubing Acidizing: An Innovative Well Intervention for Production Optimization

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Abstract*—In the Oilfield Services, Coiled Tubing (CT) is considered as one of the most adaptable and flexible technology. Since its introduction, some forty years ago, Coiled Tubing has aggressively evolved in oil and gas industry. Liquid unloading of the wells and sand clean out were the early applications of the Coiled Tubing. Now-a-days, CT is very frequently used in different well interventions, perforating the well and above all the recent developments of the Coiled Tubing Drilling. A lot of other services employed in the past but they showed decline, while CT has shown a growing rate of 10% per year. The speed and convenience of Coiled Tubing has been used to provide benefit to well productivity in different applications. Some common applications of CT are the fracturing, well testing, unloading of the well, acidizing, scale milling and other intervention activities. Today, engineers can change the toughest well into a profitable production well by using the speed and convenience of the CT, strong engineering planning, creative integration and other complementary equipment. In this paper only one application of CT is considered i.e. acidizing. The main purpose of this project was to increase the deliverability of a gas reservoir in which gas production has been reduced due to near well bore damage (skin). The case study is performed for such a well in which production is impaired by skin & reservoir rock is carbonate. The skin value is determined through well testing. The production data before acidizing & well testing has confirmed a high value of skin. Inflow performance relationship at current value of skin is plotted. This plot shows that the production is not up to the mark. To make it economical as well as favorable, stimulation has been performed to reduce the skin. By reducing the skin a considerable increase in production is observed. The entire work has been done on MS Excel. This technique results enhanced productivity of well accelerating hydrocarbons recovery & adding them to the reserves.

Keywords—Coiled Tubing, Matrix Acidizing, Fold of Increase, Skin, IPR, Productivity Index, Absolute Open Flow Potential

I. INTRODUCTION

Coiled tubing was developed in 1944 to serve as a continuous fluid carrying pipeline under the oceans. After world war (II) it starts to be considered for applicability in petroleum industry. The first trial was made by “Bowen Tools” and “Brown Oil Tools”, their continuous efforts resulted in evolution in CT development and they started employing it as a well services tool in 1960’s and 1970’s. Till then it is working as the main component in performing the work over operations and other services of the well.

With time, evolution was continued and CT is gaining widespread popularity in well completion and drilling operations as well. Major factors in rapid developments in CT were the flexibility, continuous, and both the fluid injection capacity as well as tools conveying ability. Most of the time, operator desires to perform any workovers without killing the well that can be achieved by coiled tubing. To carry out the well intervention without killing a well, three developments in CT were needed, these were

1. A continuous conduit that can be pushed into the production string (CT string)
2. During job execution, the running and pulling of the string into the well under the pressure (injector head
3. The equipment that provides the dynamic seal around the string during the performance of job (stripper or pack off device)

II. ADVANRAGES OF COILED TUBING

High speed of running in of hole and pulling out of hole saves time and money, both. It can carry the downhole tools as well as fluid pumping is also possible. These are its major benefits. Also it has small size of unit with very less rig up and rig down time as compared to any fluid injecting equipment. Some of the benefits of CT employment are [1]:

1. Safe and efficient procedures for well intervention (live)
2. Less well site preparation is needed
3. Easy to mobilize and rig-up
4. During RIH/POOH circulation can be continued
5. Reduction in downtime of production because of less trip time
6. Reduced environmental impacts as compared to the conventional methods and less risks associated
7. Less number of working crew or personnel are needed
8. Lowered costs

Now a day, CT applications, at least, use one of the following sorts;

1. The primary and secondary well control systems (stripper and BOP) enables the safe live well intervention i.e. Live Well Operations

2. It could be a High Pressure Conduit as it is high strength and rigid, so it provides a conduit for pressurized fluid movements into the wellbore or the way out. This pressure can further be used to operate the hydraulically operated tools that are powered by the movement of pumped fluid

3. Fluids can be pumped through the Coiled Tubing without any break, even during the running in of the hole as well as pulling out of the hole i.e. Continuous Circulation

4. It is rigid, high strength and flexible at the same time. These qualities enable it to convey the devices and tools in horizontal wells and severely deviated wells i.e. Rigidity and Strength

Coiled tubing has a range of applications and versatile in operations at different locations[3] and wells of diverse and dynamic conditions. It makes difficult to assign standards for equipment and configurations.

III. MAJOR COMPONENTS OF COILED TUBING

The control cabin, power pack, injector head, coiled tubing reel, and pressure control equipment are major components of a coiled tubing unit. Power pack is the energy source for the whole equipment and processes. It provides hydraulic energy for the operation and functioning of CT unit. It further contains diesel engines to drive the hydraulic pumps to provide every component with required pressure energy and the desired flow rate. Control cabin is the control room of a CT unit. It contains the clutches, gears and rest of the stuff to observe and control the performance of the job. CT string is spooled onto the coiled tubing reel. It makes the storage and transportation of CT string a lot easier. When the CT is injected into the well, energy is provided by the injector head and same is the case with retrieving back. For the smooth feeding of CT to well and proper spooling onto the reel, a tension is needed in the string. Injector head consists of two oppositely driven endless chains. Gripper blocks, tubing outer diameter size series of grippers, are mounted on the chains for improved grip. Tubing is held in between the oppositely pressed chains. This arrangement is responsible for carrying the total weight of the CT string in the wellbore. To run or retrieve the tubing, hydraulic motors are used to drive the chains. Stripper and BOP stack come under the heading of pressure control equipment.

Stripper ensures a pressure seal in dynamic string environment that is, during run in and pull out. It is hydraulically operated and controlled from the control cabin. There is a packer in the stripper with inserts that are forced to seal against the tubing string. While the BOP stack consists of Quad and Combi BOPs. They are secondary pressure barrier, usually used as 10,000 psi and H2S resistant Quad or Combi. They are operated by accumulator and hydraulic circuit in the control cabin. A typical Quad BOP consists of the pipe rams, slip rams, shear rams, blind rams, equalizing valves, upper and lower connection ends, a side port and a pressure port. Combi BOP have combined, single ram set of both, the blind ram and shear ram.

IV. CASE STUDY

A well was drilled in a carbonate reservoir and producing less than the anticipated and it was shown from well test that there was some skin. Through well testing, it comes to know that the initial value of skin was 40. At this value of skin, IPR of reservoir has been plotted in which wellbore flowing pressure has been decreased from reservoir pressure to atmospheric pressure to calculate the absolute open flow potential of the well (see Fig. 1). The well data is shown in table 1. To calculate the mentioned properties of reservoir fluid, KAY's correlation in graphical form was employed. Its results are shown in table 2. By using the pseudo steady state equation for gas flow rate[4],

$$q_{sc} = \frac{kh(p_R^{\ 2} - p_{wf}^{\ 2})}{1422T\overline{\mu_g}\,\overline{z}(\ln\frac{r_e}{r_w} - \frac{3}{4} + S)}$$

The calculations of $\mathbf{q_{sc}}$ for skin 40 are given in the table below. The calculations show that, flow rate is not up to the mark. AOFP for this value of skin is 2.61 MMscf/D. The graph is shown in Fig. 1.

Table 1

Average reservoir pressure	P_R	2200 psia
Reservoir net thickness	H	26.5 ft
Permeability of the formation	k	15.5 mD
Reservoir temperature	T	180 ^{0}F
Initial value of skin	s	40
Specific gravity of gas	γ_g	0.64
Radius of well bore	r_w	0.3266 ft
Drainage radius	r_e	2000 ft

Table 2

Compressibility Factor	z	0.88
Viscosity	μ_g	0.0201 cp

Table 3

Pressure (psig)		Flow Rate (MMSCFD)						
p_R	p_{wf}	s=40	s=30	s=20	s=10	s=5	s=0	s=-1
2200	2200	0	0	0	0	0	0	0
2200	2100	0.230	0.291	0.395	0.614	0.850	1.383	1.580
2200	2000	0.450	0.568	0.771	1.200	1.662	2.701	3.088
2200	1900	0.659	0.832	1.129	1.757	2.434	3.956	4.522
2200	1800	0.857	1.083	1.469	2.286	3.166	5.147	5.884
2200	1700	1.045	1.320	1.791	2.787	3.859	6.275	7.172
2200	1600	1.222	1.543	2.095	3.259	4.513	7.338	8.388
2200	1500	1.389	1.753	2.380	3.703	5.128	8.337	9.530
2200	1400	1.544	1.950	2.647	4.118	5.704	9.273	10.599
2200	1300	1.690	2.134	2.896	4.506	6.240	10.144	11.596
2200	1200	1.824	2.303	3.126	4.864	6.737	10.952	12.519
2200	1100	1.948	2.460	3.339	5.195	7.194	11.696	13.369
2200	1000	2.061	2.603	3.533	5.497	7.612	12.376	14.147
2200	900	2.164	2.733	3.709	5.770	7.991	12.992	14.851
2200	800	2.256	2.849	3.866	6.016	8.331	13.545	15.482
2200	700	2.337	2.951	4.006	6.233	8.632	14.033	16.041
2200	600	2.408	3.041	4.127	6.421	8.893	14.458	16.526
2200	500	2.468	3.117	4.230	6.581	9.115	14.818	16.938
2200	400	2.518	3.179	4.315	6.713	9.297	15.115	17.278
2200	300	2.556	3.228	4.381	6.817	9.440	15.348	17.544
2200	200	2.585	3.264	4.430	6.892	9.544	15.517	17.737
2200	100	2.602	3.286	4.460	6.938	9.609	15.622	17.857
2200	0	2.609	3.294	4.471	6.957	9.635	15.664	17.905

Table 4

Skin	Initial AOF	Final AOF	FOI
40	2.61	2.61	1
30	2.61	3.29	1.26274
20	2.61	4.47	1.71388
10	2.61	6.96	2.66656
5	2.61	9.63	3.69295
0	2.61	15.66	6.00393
-1	2.61	17.90	6.86286

As the flow rate from this graph is highly uneconomical, so it was decided to stimulate it to reduce the skin from 40 to 30 and then to 20, 10, 05, 0 and -1 using coiled tubing matrix acidizing. Skin -1 indicates an ideal case when the stimulation job has been done 100% successful.

The calculations for these values of skin are given in table below. After this IPR plot of the well has been plotted to show the increase in well deliverability. The calculations are shown in Table-3.

The **IPR** plot for different values of skin at same wellbore flowing pressure is shown below in Fig. 2.

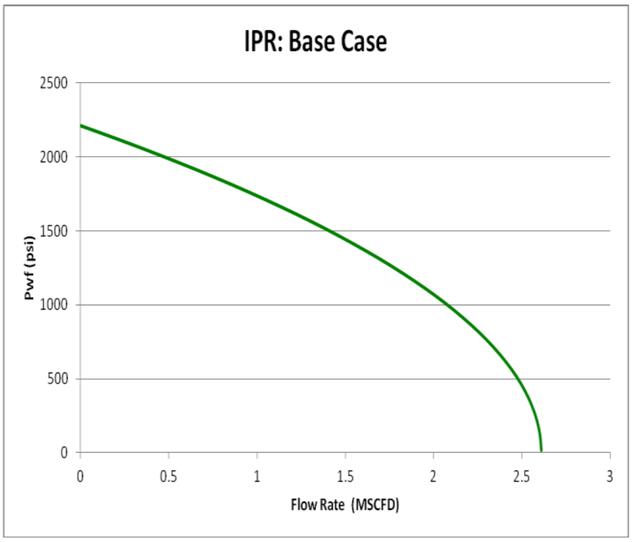

Figure 1

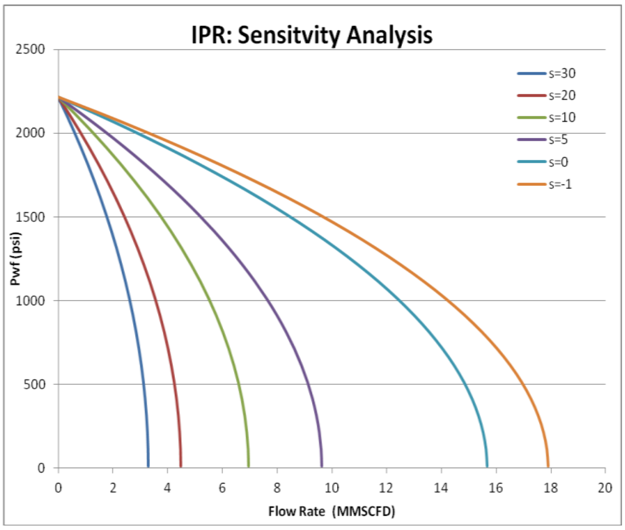

Figure 2

V. RESULTS

A skin of -1 was aimed by acidizing job. The trend of FOI vs. skin removed is shown in a plot between skin vs. FOI in Fig. 3 that helps in operational preparations and target skin value. Our purpose is highlighting the successful results of the acidizing job, not the operational execution. Job was executed and fold of increase (FOI) in production was observed to be 6.8 after achieving skin less than zero. After the successful acidizing job, the increase in productivity has been calculated by using the relation[2]

Where

Ja= productivity index after stimulation

Jb = productivity index before stimulation

The graph in Fig. 4 shows that with increasing removal of skin, FOI increases. At skin removed=40, there is maximum FOI, which is an ideal case representing the 100% successful job of acidizing.

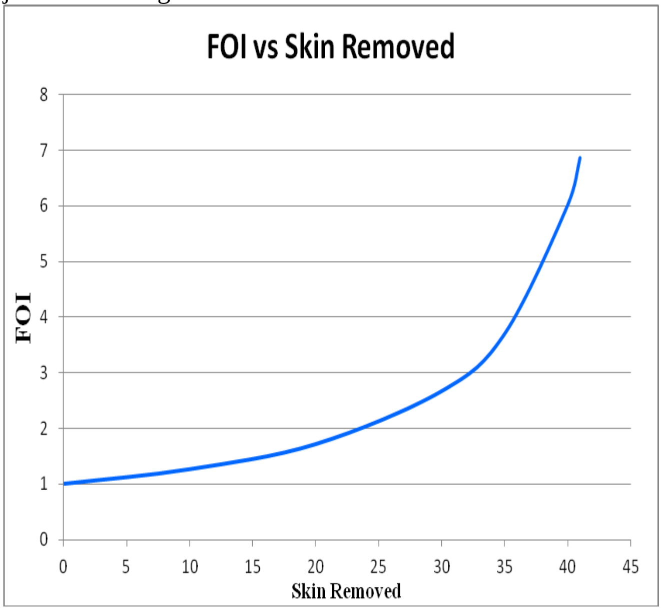

Figure 3

VI. CONCLUSIONS AND RECOMENDATIONS

1. In carbonate reservoirs, matrix stimulation can prove very handy for productivity improvement and permeability impairment.
2. Stimulation is a cure to damaged wells, but once it is performed successfully it is recommended that link the matrix acidizing with the long term development plans.

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