Acidizing Treatment Reconstruction Practice for Limestone Resources

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Abstract. With abundant oil and gas resources, limestone oil and gas resources are characterized by complex composition, uneven distribution, low natural productivity, and susceptibility to contamination, acidizing is an important measure to put this kind of oil and gas wells into production and increase production, but the effect of acidizing measure varies from block to block. This paper attempts to identify the difficulties in acidizing process by analyzing the reservoir character of multiple limestone reservoir systems in D Oilfield region, and to finalize matrix acidizing, retarded acidizing fracturing and multi-stage injection fracturing as three alternatives through single-well and block analysis, according to the permeability, pore throat development and lithological character. After the acidizing measure was implemented, good results were attained.

1. Introduction
As an important reservoir of oil and gas resources, limestone is widely distributed in the Arabian Subbasin (Iran) and the Texas Basin (USA), and its reservoirs have been also found in Tarim, Ordos, Bohai Bay and other marine carbonate basins in China. In Northeast China and North China, Ordovician System is the major target where limestone reservoirs are distributed; in Central South China, East China, and Southwest China, it is mostly distributed in Carboniferous, Permian, and Triassic System. In Northwest China and Tibet Region, it is mostly distributed in Silurian and Devonian System. According to different constituents in ore, limestone can be subdivided into sandy limestone, argillaceous limestone and dolomitic limestone. These reservoirs are rich in oil and gas reserves and feature high productivity, crude oil has better physical properties, but are deeply buried and some reservoirs are accompanied by secondary hydrogen sulfide, carbon dioxide and other gases[1].

Limestone oil and gas resources in D Oilfield region are distributed in multiple reservoir systems geographically from Shahejie Formation to Majiagou formation, where biolithite limestone, grainstone, and micrite limestone are often discovered. The lithological character varies greatly from reservoir to reservoir, and the mineral composition of different reservoirs has some marked difference. The carbonate content is generally high, dolomite and limestone among other mineral components constitute the main components, the overall composition appears to be complex and unevenly distributed, accompanied with gypsum and pyrite. The porosity and permeability range of the reservoir is wide, the original porosity is usually high, and the permeability and connectivity depend on the sediment particles.
2. Principles and Process Difficulties of Acidizing Treatment Reconstruction

Acidizing treatment reconstruction is usually applied for carbonate reservoirs[2]. The hydrochloric acid system is an option with better economic viability, the hydrochloric acid can dissolve the things plugging in the pores and fractures of the formation rock, the wellbore will radially radiate an acid etching passage of certain size and length, thereby enlarging the effective radius of the wellbore and connecting to deep reservoirs and fractures. Generally speaking, acid-rock reaction is a multi-phase reaction process: ① H+ passes to the rock (phase interface); ② H+ reacts with the rock; ③ The resultant of reaction leaves from the phase interface and passes to the residual acid liquid; the step of reaction at the slowest speed controls the reaction speed of the whole process[3].

From the analysis of reaction characteristics, calcite reacts with hydrochloric acid at a faster speed; in contrast, dolomite reacts with hydrochloric acid at a slower speed. These reservoirs are usually buried deep and susceptible to temperature and pressure, the hydrochloric acid reacts at an accelerated speed. For more extensive reconstruction volume, the reaction speed needs to be retarded in Acidizing Treatment reconstruction. A region featuring better porosity and permeability are more likely to allow the intake of more acidizing fluids. However, a single preferential migration passage would be adverse to the connection to more reservoirs, and tend to cause the acceleration rate of water cut from oil and gas producing wells. Given this, more branches should be promoted from the acid etching passage. According to the simulation tests by Fogler, Pichler, Gidley and other engineering technicians, molecular diffusion predominates in the acid rock reaction at a low flow rate; in case of a high flow rate, the acid injection rate was found higher than the reaction rate, so it would be easier to cause a more uniform etching. Since these reservoirs usually have natural fractures, the impact on acid fracturing construction would vary in development state, formation, occurrence and scale of fractures. As a consequence, the complexity of acid fracturing construction is added to some extent[4].

In particular, it is more difficult to control the acidizing fluid loss during acid fracturing construction. As the lithological character is hard and dense, the natural fracture systems at different degrees are usually controlled by regional ground stress and appear to follow certain direction[5]. The oil reservoirs are susceptible to severe water channeling, and some even cause severe flooding in oil wells after a few days of injection, which is supposed to undermine the effect of oilfield development.
In case of micrite limestone reservoirs, the support structure is susceptible to dissolution and mineral powder may easily fall off after the acidizing, so it would be hard to form oil flow passage.

3. Acidizing Treatment Reconstruction practice in D Oilfield

Prior to the acidizing treatment reconstruction, reservoir testing was carried out in the limestone reservoir of D Oilfield at 80 wells/reservoir, and the industrial oil output at 46 wells/reservoir was obtained, in which 35 wells were subject to the acidizing measure, 27 wells were found effective. After the acidizing measure was taken, the output became 4.07-78.7t, 5 wells were found with an increase of oil production over 20t, 2 were found with an increase of 10-20t, 4 were found with an increase of 5-10t, and 7 were founded with an increase of 0-5t. The number of wells which were under the pre-stage construction was counted with block, process, acid type, and acidizing strength treated as impact factors for analysis. According to the results of analysis, each of these impact factors was found correlated with the post-acidizing production, but the goodness of fit was lower and $P > 0.05$, it is impossible to ascertain the relation between each factor and increased oil production.

| Response          | Factor | P      | R-sq  |
|-------------------|--------|--------|-------|
| Post-acidizing production | Block  | 0.469  | 16.06%|
|                   | Process| 0.094  | 11.23%|
|                   | Acid type | 0.58  | 24.62%|
Based on single well and block analysis, the general reconstruction framework can be identified by permeability, pore throat development and lithological character:

In case of high-permeability reservoirs with developed caves and fractures, such as caved-fractured reservoirs or caved reservoirs and certain kinds of micrite limestone reservoirs, the main object of acidizing treatment reconstruction is to unplug and restore the flow conductivity in the vicinity of wellbore. Acidizing scale should be selected to the extent that the acid etching distance is not unduly pursued, but organic acid or fluoroboric acid acidizing measures is preferably used.

| Character of reservoir          | Fluoroboric acid-based acidizing + hydraulic pump discharge fluid |
|--------------------------------|---------------------------------------------------------------|
| Acidizing scale                | 50m³                                                          |
| Pre-acidizing condition        | Daily fluid production: 0.55m³                                |
| Post-acidizing effect          | Daily fluid production: 46m³                                  |

In case of medium-developed reservoirs, such as pored-fractured reservoirs, the reconstruction work should be carried out in a certain range. To attain some length of acid-etched fractures and improve the flow conductivity of fracture opening, it is preferable to apply gelling acid and other retarded acids.

| Character of reservoir          | Gelling acid fracturing                                      |
|--------------------------------|-------------------------------------------------------------|
| Acidizing scale                | 220m³                                                       |
| Pre-acidizing condition        | Daily water production: 0.14m³                              |
| Post-acidizing effect          | Daily water production: 24.1m³, daily oil production: 7.1m³ |

In case of low permeability reservoirs with underdeveloped fractures, such as pored reservoirs, the reconstruction work should be intensified. The main object of acidizing treatment reconstruction is to pursue longer and deeper acid-etched fractures and communicate with the matrix, and enhance the flow conductivity of fracture opening. It is preferable to apply multi-stage injection acid fracturing method.

| Character of reservoir          | Multi-stage injection acid fracturing                       |
|--------------------------------|-------------------------------------------------------------|
| Acidizing scale                | 345m³                                                       |
| Pre-acidizing condition        | No natural productivity                                     |
| Post-acidizing effect          | Daily gas production: 21.3×10⁴m³                             |

### 4. Conclusion

As limestone oil and gas resources are characterized by complex composition, uneven distribution, low natural productivity, and susceptibility to contamination, acidizing is an important measure to put this kind of oil and gas wells into production and increase production. Considering the character of reservoir, process parameters should be more particular and the adaptability of acidizing measure should be
improved, to the extent that the requirement for high flow conductivity and low damage would be satisfied.

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