Improving equipment and technology for selective acid treatment of wells

M Ya Khabibullin

Ufa State Petroleum Technological University, Branch of the University in the City of Oktyabrsky, 54a, Devonskaya St., Oktyabrsky, Republic of Bashkortostan, 452607, Russian Federation

E-mail: m-hab@mail.ru

Abstract. This method is based on the following effect. A channel in the selected formation layer or section is formed by sandblasting. The acid solution is pumped into the channel through the nozzle of the perforator. The stream of acidic solution entering the channel prevents this solution from leaving the channel. In order to increase the acid depletion time, i.e. to slow down the reaction rate, it is necessary to add special reagents to the solution. Syntanol DS-10 TU 2483-016-71150986-2012 (a non-ionic surfactant used as an effective surfactant) is a very effective reaction rate reducer. Adding it in an amount of 0.5% (by weight of the volume of the solution) one can reduce the reaction rate by 2.7 times. It is much more difficult to increase the rate of acid solution injection into highly drained formations of low-production wells (up to 5–10 tons of fluid per day) with a low reservoir pressure due to the insufficient capacity of acid aggregates.

1. Introduction
This method is based on the following effect. A channel in the selected formation layer or section is formed by sandblasting. The acid solution is pumped into the channel through the nozzle of the perforator. The stream of acidic solution entering the channel prevents this solution from leaving the channel. As a result, the abnormal channel pressure is always greater than the reservoir pressure in this zone

$$\Delta p = p_{ch} - p_{sq},$$

where $\Delta p$ – difference between channel pressure and reservoir pressure in the zone of channel formation; $p_{ch}$ – channel pressure; $p_{sq}$ – channel formation zone pressure.

Due to the difference $\Delta p$, the acid solution in the channel is filtered into its walls and processes the zone around the channel. Only part of the acid solution flows from the channel into the production string, falling into another, more drained zone of the reservoir. Thus, this method allows for strictly selective acid treatment (as well as any other type of treatment) with an accuracy of a few centimeters, determined by the accuracy of the control over the installation of the perforator.

2. Results and discussion
An experimental study of the channel pressure during spot sandblasting was carried out on a bench shown in Figure 1. It consists of a device simulating the channel in the rock, which is enclosed in casing 1, recording pressure gauges 2, pneumatic pressure compensators 3 and pump 4 with a system
of manifolds.

The scheme of the device modeling the channel is shown in Figure 2. Thick-walled sub 1 and nut 7 are attached to base 4 by welding. The body of hammer drill 3 with nozzle 2 is screwed into sub 2. 500 mm pipe 8 made of 60-mm pump tube is screwed into nut 7. On the one hand, the pipe is closed by plug 10; on the other hand, it has threaded sleeve 6. Fitting 5 is screwed into the sleeve, simulating the entrance to the channel.

![Figure 1](image1.png)

**Figure 1.** The bench for studying channel pressure changes during hydro-sandblasting of the formation

![Figure 2](image2.png)

**Figure 2.** The device simulating processes in the channel

On pipe 8, the pressure gauge is connected to coupling 9. The axis of the nozzle coincides with the axis of the fitting. In order to avoid splashing of the liquid, the device is enclosed in a casing. During the study, nozzles with a diameter of \(d_1 = 4.5\) mm and \(d_2 = 6\) mm were used.

Since the diameter of the hole in the casing is approximately 2.5–3.0 of the diameters of the nozzle during water-jet sandblasting, nozzles with a diameter of \(D_1 = 11.5\) mm, \(D_2 = 15\) mm and \(D_3 = 22\) mm were used. The distance from the nozzle to the entrance to the channel \(l\) was varied from 5 to 100 mm by rotating nozzle 8 in nut 7.

### 3. Experiment

The experimental technique is as follows. In the device, a nozzle and a fitting of diameters \(d\) and \(D\) were installed at the required distance between them. The pump pumped the liquid at a pressure in front of nozzle \(p_1\) and fixed the pressure inside the nozzle \(p_2\). In the experiments, water and an aqueous solution of sulfite-alcohol stillage (SAS) with a viscosity of 12.65 cPz at a temperature of 20 °C were used as working fluid.

Table 1 shows that in the studied area of change in the distances from the nozzle to the entrance to channel \(l\) from 5 to 100 mm, three features of the change in \(p_2\) are observed depending on the ratio of the diameter of the hole to the channel to the diameter of the nozzle \(D/d\). At a ratio \(D/d > 2.55\), with an increase in \(d\), \(p_2\) increases. At \(D/d < 2.55\), \(p_2\) decreases with increasing \(d\). At \(D/d ≈ 2.55\) with increasing \(d\), \(p_2\) first increases and then decreases.

The dependence \(p_2 = f(p_1)\) is always such that when \(p_1\) increases, \(p_2\) increases. However, the nature of this change depends on the \(D/d\) ratio, as can be seen from the following data (Table 2).

It should be noted that during the bench experiments, it was difficult to record \(p_2\) recording. Despite two high-pressure pneumatic compensators and tubular compensators, strong fluctuations in pressure...
p$_2$ were observed. They did not allow us to accurately record its average value (the absence of backpressure at the jet exit from the nozzle was significant).

**Table 1.** The nature of changes in channel pressure depending on the distance between the nozzle and the inlet $p_2 = f(l)$ for various $D/d$ ratios

| No of the experiment | Working liquid | Fitting diameter D mm | Nozzle diameter d mm | Ratio $D/d$ | Nature of dependence $p_2 = f(p_1)$ |
|----------------------|----------------|-----------------------|----------------------|------------|-------------------------------------|
| 1.                   | water          | 11.5                  | 4.5                  | 2.55       | $p_2$ first increases and then decreases |
| 2.                   | water          | 15.0                  | 4.5                  | 3.33       | $p_2$ first increases and then decreases |
| 3.                   | water          | 22.0                  | 4.5                  | 4.88       | $p_2$ decreases                      |
| 4.                   | water          | 15.0                  | 6.0                  | 2.50       | $p_2$ first decreases and then increases |
| 5.                   | water          | 22.0                  | 6.0                  | 3.67       | $p_2$ first decreases and then increases |
| 6.                   | SAS solution   | 11.5                  | 4.5                  | 2.55       | $p_2$ decreases                      |
| 7.                   | SAS solution   | 15.0                  | 4.5                  | 3.33       | $p_2$ increases                      |
| 8.                   | SAS solution   | 22.0                  | 4.5                  | 4.88       | $p_2$ increases                      |
| 9.                   | SAS solution   | 11.5                  | 6.0                  | 1.91       | $p_2$ decreases                      |
| 10.                  | SAS solution   | 15.0                  | 6.0                  | 2.50       | $p_2$ decreases                      |
| 11.                  | SAS solution   | 22.0                  | 6.0                  | 3.67       | $p_2$ decreases                      |

**Table 2.** The nature of dependence of $p_2 = f(p)$ on the ratio $D/d$

| Dependence $D/d$ | Value $p_2/200$ |
|------------------|-----------------|
| 1.91             | 0.85            |
| 2.5              | 0.36            |
| 2.55             | 0.32            |
| 3.33             | 0.094           |
| 3.67             | 0.09            |
| 4.88             | 0.03            |

It is possible to obtain very high excess pressures, up to 31% of pressure in front of the nozzle, which are sufficient for selective acid treatment and selective hydraulic fracturing. For example, with a pressure drop equal to 20.0 MPa and a diameter of 4.5 mm, the overpressure can be 6.2 MPa. These works can be carried out in production cores with a minimum strength and large diameters, i.e. where it’s not even possible to install packers. The process of selective acid treatment is as follows (Figure 3).

Sandblasting hammer drill 2 is lowered into the well, setting against the selected treatment interval, and hydraulic clamps are used for strict retention of the perforator. The displacement of the latter eliminates the possibility of selective treatment.

**Figure 3.** Selective acid treatment: 1 - fixator; 2 - punch; 3 - channel; 4 - low-permeability area; 5 - well permeable layer
After sandblasting and flushing the well from sand, without changing the position of the perforator, an acid solution is pumped into the pipes and filtered through its walls into the treated section of the formation. The part of the acid accumulated in the wellbore is forced into the formation by squeezing fluid through the annular space. The FG clamp prevents breakage, relieves tensile stresses in the pipe string during hydraulic sandblasting, and fixes it when centering the punch in a given treatment interval.

Sometimes acid treatment is unsuccessful, since the bottomhole zone is very clogged. In these cases, an acid gap is used. However, it is limited by high pressures required for forcing acid through the poorly permeable zone, or it requires special equipment (packers, anchors, wellhead fittings, high pressure pump units, etc.).

Particularly significant pressures, dangerous for the tightness of the production string can be observed in wells of great depths with dense, low-permeability reservoirs. In order to ensure that the pressure does not exceed the strength of the equipment, a multiple acid treatment method was used.

First, the filtered area is cleaned of sand plugs, then the tubing is lowered to the filter (Figure 4), and the wellhead is equipped with appropriate fittings designed for high pressure. After that, 3-4 m³ of acid solution (Figure 4, a) and squeezing liquid (Figure 4, b) are pumped. Then, air or gas is pumped into the tubing and annulus (to the maximum pressure in the distribution box). In this state, the well is left under pressure for 20 hours (Figure 4, c), after which the well is drained to extract reaction products to the surface. Repeated hydro-acid treatment of the bottom-hole zone is carried out.

An analysis of the results of multiple (threefold) hydro-acid treatment shows (Figure 5) that after the first stage of treatment of the well, the initial injection pressure of the acid solution was reduced by 24%, and after the second treatment - by 55%. The production rate of well 172 increased from 3.8 to 6.3 t/day. Conventional hydroacid treatment did not give similar results.

Figure 4. The technological scheme of one cycle of multiple hydro-acid treatment: 1 - water; 2 - air under pressure; 3 - oil; 4 - acid solution
Figure 5. Pressure change during multiple (threefold) hydro-acid treatment in well 172: 1 - injection of acid solution into the well; 2 - the well is closed under excess pressure.

Before injecting an acid solution, preventive measures are often taken to reduce wellhead pressure during treatment; one of them is an instant decrease in bottomhole pressure.

The effective penetration of an acid solution into the formation is determined by a number of factors:
- during the depletion of acid solution in reservoir conditions;
- the speed of its injection into the reservoir.

It should be noted that after complete depletion of acid solution, its further penetration into the formation is not beneficial and even harmful, since the depleted solution fills pore channels.

4. Conclusion
In order to increase the acid depletion time, i.e. to slow down the reaction rate, it is necessary to add special reagents to the solution. Syntanol DS-10 TU 2483-016-71150986-2012 (a non-ionic surfactant used as an effective surfactant) is a very effective reaction rate reducer. Adding it in an amount of 0.5% (by weight of the volume of the solution) one can reduce the reaction rate by 2.7 times.

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