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HIGHLY PRESSURIZED HYDRAULIC FRACTURING FLUID BEHAVIOR IN OIL-BEARING ROCKS

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ABSTRACT

The article is focused on hydraulic fracturing (HF) of oil-bearing rocks demonstrated on three practice tests showing that the application of this method is not possible in underground rock formations. It is established that the fluid injected into the oil reservoir under pressure spreads along numerous grooves radially mixing with reservoir fluids.

Key words: Hydraulic fracturing, Underground rock formation, Injected fluid, Well, Oil reservoir.

INTRODUCTION

There are many published works devoted to oil hydraulic fracturing tests proving that formation of vertical and horizontal cracks around the well when using this technique (HF) is inevitable. This article presents three examples proving the contrary of a statement - the impossibility of induced formation of vertical and horizontal cracks at HF.

EXPERIMENTAL

Example 1. Let us assume that a well is H = 2000 m deep; h =10 m – thickness of a bed at fracturing pressure P = 140 MPa (a top hydraulic pressure cited in print sources). Lets find γ H - overlying pressure[1-7]:

$$\gamma H = \frac{2{,}7\text{m} \cdot 2000}{\text{m}^2} = \frac{2{,}7 \cdot 1000 \cdot 2000\ \text{Kgf}}{10^4\,\text{cm}^2} = 54\,(\text{MPa})$$

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The thing is that oil-bearing rocks having a tensile strength σ_{comp} < 140 MPa when under an induced HF pressure of γ H = 54 MPa on the surface which spreads at a distance "a" from disintegrative zones around the well and also experiencing a rib-side pressure P = 140 MPa are expected to be completely disintegrated. But behind the disintegration zones the rock condition is rather complex. The rocks at depth are under confining pressure due to the immense load caused by the overlying rock strata and a downward-lateral-borehole pressure. With a borehole pressure P = 140 MPa the rock fracturing along AB and CD lines (see Fig. 1) will be impossible despite of a tensile strength being τ < 140 MPa. First of all rock particles have no space to move and secondly when P = 140 MPa on walls of cylindrical surfaces is $S = 2\pi\ (r + a)\cdot h$ (wherein π = 3.14 constant; r-well radius) with pressure P weak points between hydrocarbon solid layers are likely to disintegrate and it is the beginning of grooves formation, which expanding in a zigzag and radially manner from a borehole axis multiplies the length of growth grooves, the latter being depended on pumping time P = 140 MPa (i.e., running time of a pump). On the lateral land surface with area of $S = 2\pi\ (r + a)\cdot h$, there begins a generation of numerous grooves or passages lets name it *n*, associated with naturals cracks enabling fracturing fluid and liquid to flow into the well pores.

Thus, there happens a continuous distribution of top feeding fluids along n-passages, natural cracks and rock strata s around the well. At this an initial bottom pressure upto P = 140 MPa may slightly fall.

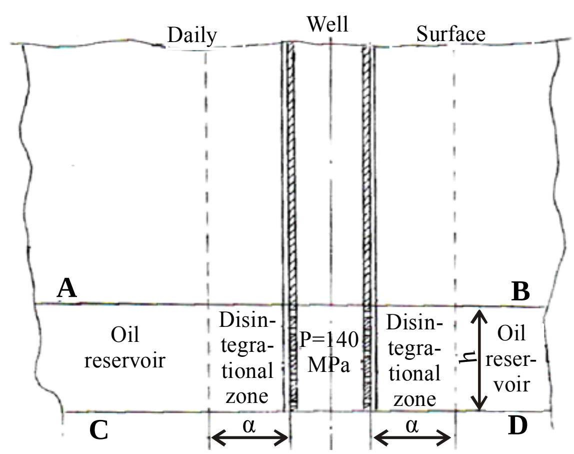


Fig. 1: Oil reservoir and the well in the process of HF

When changing a pump duty or in case of its replacement by a more powerful tube of flow with just new parameters a liquid volume ΔQ passing in regular intervals Δt through any of its section will be the same i.e. a liquid flow rate through sections of various kinds will be constant.

Example 2. There is a belief that HF doesn't generate "vertical cracks" which can be disproved by the formula of fracturing wells (cylindrical cup-test specimen) by method of coaxial punches:

$$\sigma_p = \frac{P \cdot d}{D - d} \quad \ldots(1)$$

Where σ_p is the ultimate tensile strength of the rock, and P – well pressure; d-entrance hole diameter; D- outer diameter of a cylindrical cup-test specimen (Fig. 2).

When using a HF method a size of D in the rock mass are not limited i.e. D tends to a ∞. The Eq. (1) shows that even at high pressure values P in the well a denominator greatly depends on D (for the mass of native rock $D \rightarrow$ to ∞) and fraction will have a very small value, therefore rocks having small and constant power of resistance σ_p will not disintegrate and not form "vertical HF cracks" neither "Horizontal HF cracks" can appear because one cannot lift or shift upwards all the overlying rock strata γ H (Table 1). But in sedimentary rocks the fluid can freely leak into layers and it won't be a "hydraulic fracturing" of rocks, because there occurs no up-down vertical displacement of rock particles.

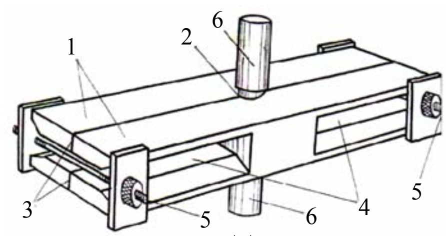
Table 1: Calculated overburden pressure with H upto 6000 m

Depth: H (m)	300	500	1000	1500	2000	2500	3000	3500	4000	5000	6000
Value: γH (MPa)	8.1	13.5	27.0	40.5	54.0	67.5	81.0	94.5	108.0	135.0	162.2

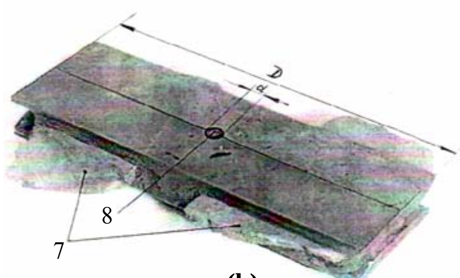
Print sources state that usually HF treatment is being conducted at large values of a tensile strain P compared with γH, i.e. a tensile strain on carrying on HF jobs at any depth should be $P > \gamma H$. Cylindrical and disk cup-test rock specimen tests showed the results achieved greatly depend on the outer diameter D of a specimen [Fig. 2 (b)]. In Fig. 2 (a) details of a device offered for testing large rock specimens are shown. Detail 1-body halves, 2-a hole, 3-specimen plane of fracture, 4-slots for placing twin specimens 5-coupling screws and nuts for holding a specimen tight to bevel surface of the body by epoxy and sand mixture, 6-coaxial punches.

Calculated data in Eq. (1) show that a breaking central hole force with a diameter (d) that integrates a specimen with an height (h) will be equal to the thrust of a specimen i.e. force $F_2 = \sigma_p (D - d) \cdot h$ or $F_1 = F_2 = P \cdot dh = \sigma_p (D - d) \cdot h$. The later permits to derive a Eq. (1)

wherein P – an ultimate value of pressure inside a slot ; σ_p - an ultimate value of rock tensile strength; d·h - diametrical section of a slot; (D – d)·h - specimen area of rupture as there always happens a a specimen disintegration into two parts. In Fig. 3 a photo of tested specimens is shown. To find out the effect of diameter D on rocks tensile strength there was designed a device[8] allowing to test twing specimens put along diameter D. At that a rigidity of the device with a length D = 1 m enabled to disintegrate twin specimens put along the whole length D in a moment and study size effects on the results. Concerning negative opinions on use of HF method it should be noted that: when conducting tests in device[8] with large specimens, it was noticed that in a central hole with a diameter d (In Fig. 2 (b), there created a rather high pressure though a specimen parameter D had a load pressure limit D = 1 m. Thus, the experiment results showed that under the given conditions it is impossible to disintegrate a massive parameter D → ∞ with fracturing injected into the well therefore vertical cracks also cannot be formed.



(a)



(b)

Fig. 2: Device for testing a tensile strain of large twin rock specimens by coaxial punch method

Fig. 3: Cylindrical and disk cup-test rock specimen tests by coaxial punch method

There are a lot of print works have been devoted to hydraulic fracturing of formation[9-19].

Example 3. Fig. 4 shows a scheme of fluid fracturing (a) and oriented fluid fracturing (b) manifestation in a rock mass[20].

Fig. 4 (a) shows a correct way of injected fluid flow into natural cracks of a borehole between its structural blocks. Fig. 4 (b) shows a model of horizontal crack formation after making cracks on wellbore walls. A sharp apex of this artificial gap is perpendicular to the hole axis declaredly resulting in the occurrence of a horizontal crack for a fluid to flow in. The mistake is in the fact that the fluid, [Fig. 4 (a)], while flowing many times meets variously inclined cracks located in structural blocks. The author believes that the fluid doesn't spread out into those multiple cracks but continues to form a long horizontal crack. But in reality when meeting interblock cracks the fluid should enter the cracks and repeat the example in Fig. 4 (a). As for Fig 4 (b), one can see the author's pure fiction[3].

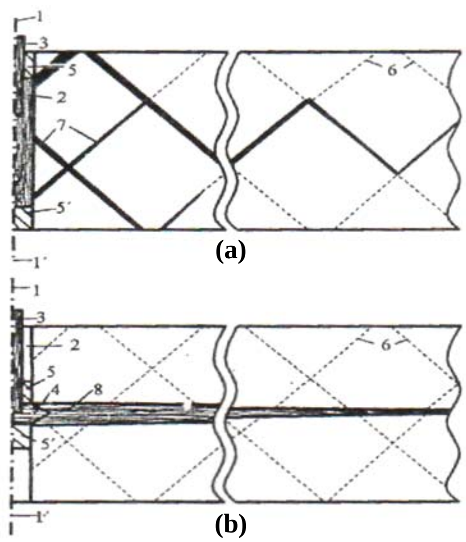


Fig. 4: Scheme of fluid dismemberment (a) and oriented of fluid fracture (b) in the rock mass: 1-1'- a well axis; 2- a well; 3- a pipe for fluid pumping; 4- an initiating gap; 5-5'- upper and lower packers sealing well working space; 6- natural crack systems, 7-cracks of fluid dismemberment, 8- hydrofracturing cracks

CONCLUSION

During the completion of low pressure wells the water pumped into the injection well raises pressure in the reservoir to pump oil from recovery wells. At that a producible oil index is within 30 ÷ 33 %.

The paper analyzes a HF method when the fluid injected into the well under a pressure P = 140 MPa. A downward pressure on formation is γH. The analysis deals with oil reservoirs being under confining pressure: A downward pressure on top of the layer is γH; side pressure and a borehole pressure is 140 MPa. At hydrofracturing treatment random reservoir pieces and rocks from disintegration zone with a compressive strength less than 140 MPa will be completely destroyed. It forms a cylindrical lateral surface in a reservoir 2π (r + a) h, wherein r – a well radius; A- a disintegration zone radius; h – an oil reservoir size\thickness, π = 3,14 – constanta. This surface originates numerous groves that allow injected fluids to flow in. The process of formation of each groove is as follows: the fracturing fluid pushes on oil in pore spaces. At that weak sections of pores in a borehole wall collapse, fluid of two pores unite, push on the wall and look for a way to unite with a third fluid and etc. Thus a formation of grooves in a zigzag and radial manner will continue until a pump is switched off. That is why the length of their radii (along the line) stated in print works is various or different.

The second example dealing with the analysis of experimental data and a device for creating vertical fractures in twin specimens brings about a conclusion-during hydrofracturing vertical cracks in oil reservoir cannot be formed.

The third example is taken from some article devoted to HF. It clearly says that horizontal cracks or fractures are unable to form.

There is a little positive effect in terms of vertical cracks formation but it is associated just with the formation in a reservoir of numerous long and short grooves, the author of article acknowledges this fact.

Thus, we can say that obtained results described in the article just confirm a fact of channel formation in pores of a well and completely deny the possibility of crack formation in rocks at HF.

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