

Choice of bottom-hole filter construction for viscous fluid filtration

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Abstract – Determination of filters resistance value with net filtering surface and block types is rather difficult mathematically. It is caused by a great amount of parameters, influencing cage filtration capacity. In net filters, depending on the type of weaving, they are different: wire diameter of the strand and the base, different diameters in horizontal and vertical planes, frame construction which is considered a unit with the net. In block constructions they are: sizes and homogeneity of particles composition, filtration cage thickness, geometry of filtration channels etc. That is why, it is better to estimate efficiency of these filters by their permeability. The most perspective are frame-filters with horizontal gaps, whose resistance and gaps interference effect are less. It should be noted that thanks to peculiarities of screen construction the inlet area is greater than in other constructions with the same minimal value of holes sizes. Recommendations on inlet area and filter gap size should take into account factors of well production rate, layer fluid viscosity, granular composition of layers, consolidation of the bottom-hole zone, clogging and bridging of the deposits.

Keywords – hydraulic, loss, resistance, inlet area, frame, block

I. INTRODUCTION

There is a shortcoming in extracting wells equipped with filters. This shortcoming is with the degree and character of layer formation exposing, which depends on filter construction placed in the well [1, 2]. According to [3] in calculations total filtration resistance should be divided onto peculiar, corresponding to different zones of filtration. If the well bottom-hole design does not influence flow character in the zone distant from the well, in the zone near filter and on the filter itself there are additional hydraulic losses which should be treated as dimensionless parameters, influencing total extracted fluid flow resistance.

Additional resistance according to the common flow schema is introduced as in [3]:

$$\zeta = \zeta_1 + \zeta_2 \quad (1)$$

where ζ_1 and ζ_2 are resistance conditioned by the degree and character of formation exposing. Estimation of well imperfection influence by formation exposing degree, with the account of inflow to it depending on the relation l/m (where l is filter length, and m is total capacity of the productive formation) and the graphs for determining resistance ζ_1 are given in [4].

Resistance ζ_2 is a complex characteristic, depending on the quality of well completion, filter hydraulic peculiarities, conditioned by the construction, as well as filter cage clogging and break down of linear mode of filtration That is why value ζ_2 can be determined:

$$\zeta_2 = \zeta_{2\phi} + \zeta_{2\pi} + \zeta_{2\pi\pi}, \quad (2)$$

where $\zeta_{2\phi}$, $\zeta_{2\pi}$, $\zeta_{2\pi\pi}$ are resistances determined by filter, deposits character, and deviation from linear mode of filtration.

Filtration of viscous fluid through porous media with comparatively small pores goes according to Darcy's linear law [5] and the value of total resistance can be determined:

$$\zeta_2 = \zeta_{2\phi} + \zeta_{2\pi}. \quad (3)$$

Here we can see that filters hydraulic parameters are crucial in the choice of filter optimal constructions and their elements. They are determined by filter resistance, and when a filter functions in semi consolidated and soft formations or in gravel package contact pressure loss in filter-rock zone and sand-holding ability of the filter cage are important.

II. MATERIALS AND METHODS

Hydraulic parameters of a rock-filter system (at other conditions) are consequence of geometric filter cage parameters, forming mutual position of gaps and influencing flow resistance by destructing its linearity, its diffraction and so on.

Enhancing permeability of the filter caging with the same gap size by porosity increase in near-filter zone lessens losses in the filter-rock contact zone. Also, the form and mutual position of filter cage elements, influencing creating bridges of large sand fractions or gravel pack hold the particles forming layer frame with simultaneous colmatant pass.

Nowadays different filters are used. There are ones with round gaps, vertical or horizontal spills, whose length is different and can be equal to layer thickness, with filtering surface of nets, and block filters. After analyzing similar solutions suggested by M. Mason, V.I. Shurov constructed

revised graphs of the dependence (picture 1) $\zeta_{2\phi}$ on the parameters for filters with round gaps [6]:

$$\alpha = d_0 / \Delta \text{ и } \beta = n \Delta, \quad (4)$$

where d_0 is filter gaps diameter;

n their amount per length unit;

Δ is filter diameter.

As parameters α and β are parameters of relative inlet area, then the graph shows that with the increase of inlet area filter resistance lowers $\zeta_{2\phi}$.

M. R. Harris theoretical investigations [7] show that total efficiency of round gaps groups to the flow coefficient depends on their mutual position. Some results are given on the graph (picture 2).

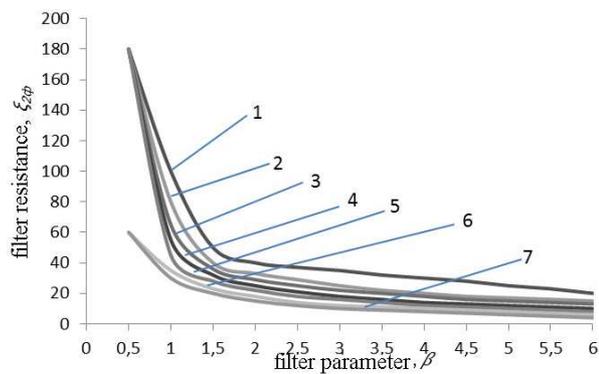


Fig. 1. Dependence graph $\zeta_{2\phi}$ on parameters $\beta = 0,01n\Delta$ and α for round gaps filters: 1- $\alpha=0,03$; 2- $\alpha=0,04$; 3- $\alpha=0,05$; 4- $\alpha=0,06$; 5- $\alpha=0,07$; 6- $\alpha=0,08$; 7- $\alpha=0,09$

Graphs are constructed with the account of the following conditions:

- supply contour radius is 200 m;
- cemental ring external radius is 76 mm;
- perforated channel length is 30,5 cm;
- perforated channel diameter 12,7 mm;
- perforator bullet penetration over the top cement 300 mm.

These results show there is lesser pressure change at the given expenditure when the gaps are positioned uniformly round the surface in the horizontal plane, and the pressure change is the greatest along vertical plane along one general line.

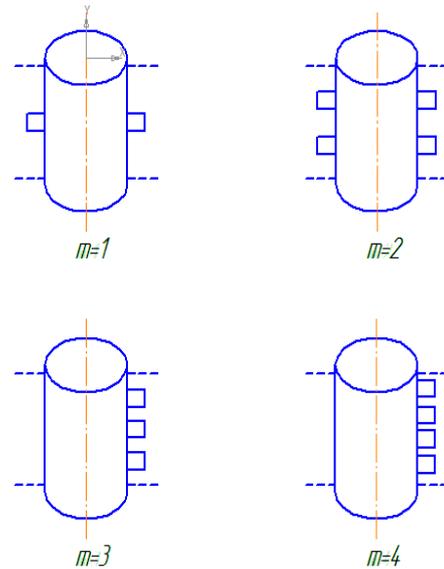
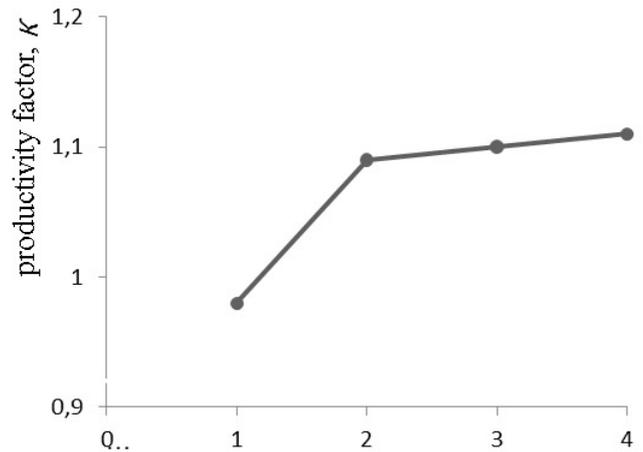


Fig. 2. Efficiency coefficient dependence (κ) on the perforation scheme and amount of perforations (m) planned

Resistance values $\zeta_{2\phi}$ for filters, whose length is equal to layer thickness, placed vertically along generating of the pipe, have rather approximate results when determine them by different methods. V.T. Cordwell and S.K. Dodson [8] suggested the expression:

$$\zeta_{2\phi} = \frac{2}{n} \cdot \ln \frac{2}{\pi \eta}, \text{ with } \eta = 0,3, \quad (5)$$

where n is amount of gaps; η is inlet area.

V.P. Pilatovskiy [9] received an expression of dimensionless hydraulic pressure in the form:

$$\zeta_{2\phi} = \frac{4}{n} \cdot \ln \sin \frac{n^1 \alpha}{2}, \quad (6)$$

where n^1 is an amount of solid plates; α – is a central angle determining the size of the spill.

Graphic dependences (see. Picture 1), based on the results of formula calculation (6), allow finding value $\zeta_{2\phi}$ of rod frames and filter constructions similar to them.

In [10] it is proved that resistance value for filters, whose vertical spills length is restricted, can be determined by graph dependencies (picture 1). These dependences are suitable for filters with round holes. For rectangular holes interpolation to round holes can be done with the account of equivalent total area of cross section.

III. RESULTS AND DISCUSSIONS

Recommended radii of addition depend on relation of the pass length l to its width b . At relation $l/b \leq 3$, it is preferable to add areally and the radius of the added hole is expressed by the dependence:

$$r_{\text{onnp}} = \sqrt{\frac{b \cdot l}{\pi}} \quad (7)$$

a at $l/b > 3$ (long and narrow spills):

$$r'_{\text{onnp}} = \frac{b \cdot l}{2\pi} \quad (8)$$

That is radius is determined by the perimeter. As we can see from the graph dependences (picture 3), filter resistance with vertical spills decreases with total inlet area, as well as with spills width lessening with the same filtering inlet area.

For filters with pass holes, placed horizontally, the same solution, at relatively big values r/d , is given by A.L. Hein:

$$\zeta_{2\phi} = \frac{d^3}{\pi^2 r_c b^2} \left[6,835 \cdot \frac{b}{d} \left(1 - \frac{b}{d} \right) - 2L_i \cdot \left(\pi \cdot \frac{b}{d} \right) + \chi \left(\frac{b}{d}; \frac{2r_c}{d} \right) \right] \quad (9)$$

where d is distance between neighboring passes centers;

b is pass height;

r_c is current radius;

$\left(\frac{b}{d}; \frac{2r_c}{d} \right)$ is a tabulated function, whose values are given in [10].

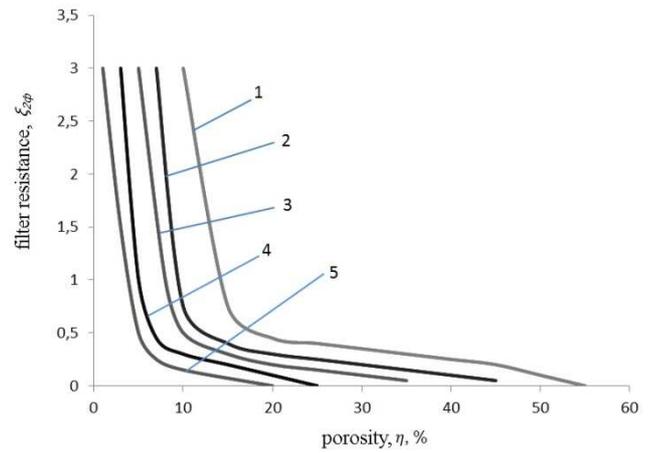


Fig. 3. Graph dependencies $\zeta_{2\phi}$ from inlet area \square for all layer thickness with spills 168 mm in diameter. Pass width: 1 – 10 mm; 2 – 5 mm; 3 – 3 mm; 4 – 1 mm; 5 – 0,5 mm.

In the work [11] M.N. Tikhonov gives solutions, according to which filter resistance value with horizontal passes is approximately 20% less, than that one of filters with cylindrical holes, shown in graph dependences (picture 1).

Determining $\zeta_{2\phi}$ of filters with net filtering surfaces and block filters is mathematically difficult. It is explained by large amount of parameters influencing filtration capacity of the cage. In net filters depending on the weaving - they are different wire diameter of the strand and the base, different diameters in horizontal and vertical planes, frame construction which is considered as a unit with the net. In block constructions they are sizes and homogeneity of particles composition, filtration cage thickness, geometry of filtration channels etc [12]. That is why it is better to estimate efficiency of these filters by their permeability according to Darcy's formula [5].

For radial filtration through ring sample:

$$K = \frac{\mu_f \cdot Q_f \cdot \ln \frac{r_{\text{ex}}}{r_{\text{in}}}}{20 \cdot \pi \cdot h \cdot (P_{\text{ex}} - P_{\text{in}})} \quad (10)$$

Where Q_f is expenditure, cm^3/s ;

μ_f is dynamic viscosity, $\text{MPa} \cdot \text{s}$;

$P_{\text{ex}}, P_{\text{in}}$ is difference between external and internal surfaces pressure, MPa ;

$R_{\text{ex}}, r_{\text{in}}$ are external and internal radii, cm ;

h is sample height, cm .

The formula shows permeability functionally depends on pressure difference which is determined by filter resistance $\zeta_{2\phi}$.

Filter hydraulics of different constructions was investigated by D. Klotz [12] and the results of filter

permeability estimation depending on their inlet area are given in fig. 4.

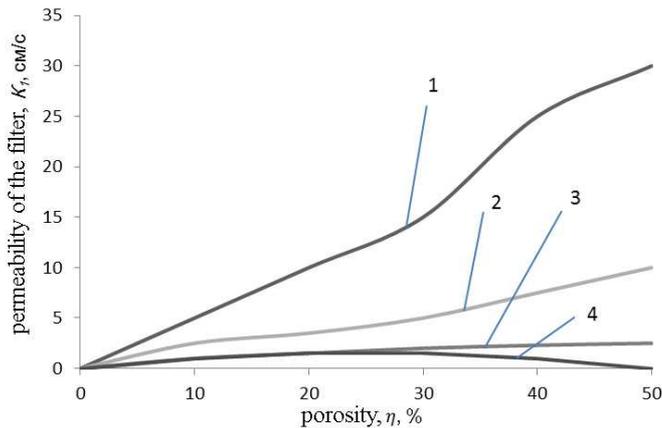


Fig. 4. Graph dependence of filter permeability on their inlet area [according to Klotz]: 1 – frame-wired; 2 – with bridge holes; 3 – slotted with open perforation; 4 – nets with galooned wiring.

IV. CONCLUSION

Let's draw the conclusion:

1. Formation fluid production rate increases with filter inlet area increase.
2. Filter resistance at constant inlet area increases with lessening of its holes size.
3. Filter resistance with different perforation is nearly the same if the inlet area is similar.
4. Small vertical holes interference is greater than those of horizontal ones placed at the same distance along the parallel that is why total expenditure through filters with horizontal holes is 20...30% greater

As we can see, filters-frames with horizontal spills with less resistance and holes interference are more perspective. It should be noted that thanks to peculiarities of frame-rod filter construction greater inlet area is fulfilled than in other constructions, with the same minimal size of holes.

Recommendations on the choice of inlet area and holes size should take into account well production rate, layer fluid viscosity, layer granular composition, degree of consolidation of the near-bottom zone, clogging and arching of the rock. These parameters as well as filter-rock contact losses can be determined only experimentally on laboratory or full-scale models.

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