N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 2, Number 440 (2020), 81 – 86 **https://doi.org/10.32014/2020.2518-170X.34**

UDC 622.24

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METHODS FOR CALCULATING CAVITATORS FOR DEVICES DESIGNED BY SATBAYEV UNIVERSITY FOR CLEANING OIL AND GAS WELLS

Abstract. The article says that with long-term exploitation of oil and gas wells, production wells lose design capacity over time, and injection wells lose injectivity. After a certain period of time, these wells undergo repair and restoration work in order to restore the project flow rate and injectivity. One of the reasons for the failure of the wells is the overfilling of the filter zone with products of chemical and mechanical mudding and the deposition of mechanical suspensions in the well sump, as a result of which the productivity of the wells decreases below the permissible limits required by the production regulations.

It is proposed to use special shells designed by Satbayev University for cleaning oil and gas wells using cavitated liquid as a cleaning agent.

A technique is proposed for calculating the cavitators of these devices for oil and gas wells depending on the number of cavitation, the flow rate of the flushing fluid, the hydrostatic pressure of the fluid in the well, and the working pressure of the flushing pump. An example of the calculation of cavitators for the wells of the fields of JSC "Ozenmunaygas" is given.

Key words: Well productivity, throttle response, repair work, cavitation, hydrostatic pressure.

With long-term exploitation of oil and gas wells, production wells lose design capacity over time, and injection wells lose injectivity. After a certain period of time, these wells undergo repair and restoration work in order to restore the project flow rate and injectivity. One of the reasons for the failure of the wells is the overfilling of the filter zone with products of chemical and mechanical mudding and the deposition of mechanical suspensions in the well sump, as a result of which the productivity of the wells decreases below the permissible limits required by the production regulations.

At the Department of Petroleum Engineering, Satbayev University, in the course of research work, shells were developed for cleaning geotechnological wells that are used for underground leaching of uranium ores [1,2]. As a cleaning agent, cavitated process water was used. Production tests of these devices have shown their high efficiency [3,4].

Given the positive effect of the use of these shells, the authors recommend the use of these shells for cleaning oil and gas wells.

However, due to the fact that the geological and technical conditions of oil wells are fundamentally different from geotechnological wells (large depths, diameters, used equipment, etc.), there is a need for theoretical studies to calculate certain units of the device for oil and gas wells.

Special devices create cavitation using sound waves in a fluid. Cavitation bubbles, collapsing, give rise to shock waves, which destroy particles of contaminants or separate them from the surface. Thus, the need for hazardous and unhealthy cleaning substances is reduced in many industrial and commercial processes where cleaning is required as a stage of production.

Cavitation number. The cavitation flow is characterized by a dimensionless parameter (cavitation number) [5]:

$$K = \frac{P_0 - P_H}{\left(\frac{\rho v_0^2}{2}\right)} \qquad (1)$$

where P_0 is hydrostatic pressure of the oncoming flow, Pa; P_H is pressure of saturated vapor of a liquid at a certain ambient temperature, Pa; ρ is the density of the medium, kg/m³; v_o is flow rate at the system inlet, m/s.

The cavitation number can take different values, but cavitation occurs only in the range K = 0.1 - 0.6. It is known that cavitation occurs when the flow reaches the boundary velocity, when the pressure in the flow becomes equal to the vaporization pressure (saturated vapor). The boundary value of the cavitation criterion corresponds to this speed.

For well conditions, the flow pressure depends on the operating pressure of the pump P_p, the hydrostatic pressure of the fluid P_h located in the well, and the pressure loss in the pipelines P_l, through which the working fluid is transported to the working body, that is:

$$P_0 = P_p - (P_h + P_l) \qquad (2)$$

Naturally, the magnitude of the hydrostatic pressure of the fluid P_h located in the well should be less than the value of the working pressure of the pump and it is determined:

$$P_h = \rho g H \qquad (3)$$

where, ρ is the density of the fluid in the well, kg/m³; g is the acceleration of gravity, m/s²; H is the depth of the well at which hydrostatic pressure is measured, m.

The magnitude of the pressure loss in the pipelines through which the working fluid is transported to the working body can be determined by the method described in [5] and the program developed at the former Department of Technology and Technique for Drilling Wells of KazNRTU named after K. Satbayev [7].

Due to the fact that process water is used as a cleaning agent (possibly heated to clean tar and paraffin deposits), the pressure values of saturated vapor of a liquid at a certain ambient temperature are given in the table below [8].

With an interval of one degree, the pressure (P) of water vapor from the melting point to critical is given. Up to 100 ° C, the table contains the value of P, expressed in kPa and mmHg, above 100 ° C, the P value is indicated only in kPa.

Table 1 – Saturated vapor pressure of water from 0 ° C to 374 ° C

t, °C	P		t, °C	P		t, °C	P	
	kPa	mmHg		kPa	mmHg		kPa	mmHg
0	0.61129	4.585	34	5.3229	39.93	68	28.576	214.3
1	0.65716	4.929	35	5.6267	42.20	69	29.852	223.9
2	0.70605	5.296	36	5.9453	44.59	70	31.176	233.8
3	0.75813	5.686	37	6.2795	47.10	71	32.549	244.1
4	0.81359	6.102	38	6.6298	49.73	72	33.972	254.8
5	0.87260	6.545	39	6.9969	52.48	73	35.448	265.9
6	0.93537	7.016	40	7.3814	55.37	74	36.978	277.4
7	1.0021	7.516	41	7.7840	58.38	75	38.563	289.2
8	1.0730	8.048	42	8.2054	61.55	76	40.205	301.6
9	1.1482	8.612	43	8.6463	64.85	77	41.905	314.3
10	1.2281	9.212	44	9.1075	68.31	78	43.665	327.5
11	1.3129	9.848	45	9.5898	71.93	79	45.487	341.2
12	1.4027	10.52	46	10.094	75.71	80	47.373	355.3
13	1.4979	11.24	47	10.620	79.66	81	49.324	370.0
14	1.5988	11.99	48	11.171	83.79	82	51.342	385.1

15	1.7056	12.79	49	11.745	88.09	83	53.428	400.7
16	1.8185	13.64	50	12.344	92.59	84	55.585	416.9
17	1.9380	14.54	51	12.970	97.28	85	57.815	433.6
18	2.0644	15.48	52	13.623	102.2	86	60.119	450.9
19	2.1978	16.48	53	14.303	107.3	87	62.499	468.8
20	2.3388	17.54	54	15.012	112.6	88	64.958	487.2
21	2.4877	18.66	55	15.752	118.1	89	67.496	506.3
22	2.6447	19.84	56	16.522	123.9	90	70.117	525.9
23	2.8104	21.08	57	17.324	129.9	91	72.823	546.2
24	2.9850	22.39	58	18.159	136.2	92	75.614	567.2
25	3.1690	23.77	59	19.028	142.7	93	78.494	588.8
26	3.3629	25.22	60	19.932	149.5	94	81.465	611.0
27	3.5670	26.75	61	20.873	156.6	95	84.529	634.0
28	3.7818	28.37	62	21.851	163.9	96	87.688	657.7
29	4.0078	30.06	63	22.868	171.5	97	90.945	682.1
30	4.2455	31.84	64	23.925	179.5	98	94.301	707.3
31	4.4953	33.72	65	25.022	187.7	99	97.759	733.3
32	4.7578	35.69	66	26.163	196.2	100	101.32	760.0
33	5.0335	37.75	67	27.347	205.1			

t, °c	**P, kPa**	**t, °c**	**P, kPa**	**t, °c**	**P, kPa**	**t, °c**	**P, kPa**
100	101.32	147	438.67	194	1368.0	241	3403.9
101	104.99	148	450.75	195	1397.6	242	3463.9
102	108.77	149	463.10	196	1427.8	243	3524.7
103	112.66	150	475.72	197	1458.5	244	3586.3
104	116.67	151	488.61	198	1489.7	245	3648.8
105	120.79	152	501.78	199	1521.4	246	3712.1
106	125.03	153	515.23	200	1553.6	247	3776.2
107	129.39	154	528.96	201	1586.4	248	3841.2
108	133.88	155	542.99	202	1619.7	249	3907.0
109	138.50	156	557.32	203	1653.6	250	3973.6
110	143.24	157	571.94	204	1688.0	251	4041.2
111	148.12	158	586.87	205	1722.9	252	4109.6
112	153.13	159	602.11	206	1758.4	253	4178.9
113	158.29	160	617.66	207	1794.5	254	4249.1
114	163.58	161	633.53	208	1831.1	255	4320.2
115	169.02	162	649.73	209	1868.4	256	4392.2
116	174.61	163	666.25	210	1906.2	257	4465.1
117	180.34	164	683.10	211	1944.6	258	4539.0
118	186.23	165	700.29	212	1983.6	259	4613.7
119	192.28	166	717.83	213	2023.2	260	4689.4
120	198.48	167	735.70	214	2063.4	261	4766.1
121	204.85	168	753.94	215	2104.2	262	4843.7
122	211.38	169	772.52	216	2145.7	263	4922.3
123	218.09	170	791.47	217	2187.8	264	5001.8
124	224.96	171	810.78	218	2230.5	265	5082.3
125	232.01	172	830.47	219	2273.8	266	5163.8
126	239.24	173	850.53	220	2317.8	267	5246.3
127	246.66	174	870.98	221	2362.5	268	5329.8
128	254.25	175	891.80	222	2407.8	269	5414.3
129	262.04	176	913.03	223	2453.8	270	5499.9

130	270.02	177	934.64	224	2500.5	271	5586.4
131	278.20	178	956.66	225	2547.9	272	5674.0
132	286.57	179	979.09	226	2595.9	273	5762.7
133	295.15	180	1001.9	227	2644.6	274	5852.4
134	303.93	181	1025.2	228	2694.1	275	5943.1
135	312.93	182	1048.9	229	2744.2	276	6035.0
136	322.14	183	1073.0	230	2795.1	277	6127.9
137	331.57	184	1097.5	231	2846.7	278	6221.9
138	341.22	185	1122.5	232	2899.0	279	6317.0
139	351.09	186	1147.9	233	2952.1	280	6413.2
140	361.19	187	1173.8	234	3005.9	281	6510.5
141	371.53	188	1200.1	235	3060.4	282	6608.9
142	382.11	189	1226.9	236	3115.7	283	6708.5
143	392.92	190	1254.2	237	3171.8	284	6809.2
144	403.98	191	1281.9	238	3228.6	285	6911.1
145	415.29	192	1310.1	239	3286.3	286	7014.1
146	426.85	193	1338.8	240	3344.7	287	7118.3
288	7223.7	310	9860.5	332	13187	354	17348
289	7330.2	311	9995.8	333	13357	355	17561
290	7438.0	312	10133	334	13528	356	17775
291	7547.0	313	10271	335	13701	357	17992
292	7657.2	314	10410	336	13876	358	18211
293	7768.6	315	10551	337	14053	359	18432
294	7881.3	316	10694	338	14232	360	18655
295	7995.2	317	10838	339	14412	361	18881
296	8110.3	318	10984	340	14594	362	19110
297	8226.8	319	11131	341	14778	363	19340
298	8344.5	320	11279	342	14964	364	19574
299	8463.5	321	11429	343	15152	365	19809
300	8583.8	322	11581	344	15342	366	20048
301	8705.4	323	11734	345	15533	367	20289
302	8828.3	324	11889	346	15727	368	20533
303	8952.6	325	12046	347	15922	369	20780
304	9078.2	326	12204	348	16120	370	21030
305	9205.1	327	12364	349	16320	371	21283
306	9333.4	328	12525	350	16521	372	21539
307	9463.1	329	12688	351	16725	373	21799
308	9594.2	330	12852	352	16931	373.98	22055
309	9726.7	331	13019	353	17138		

To determine the flow rate at the system inlet, we proceed from the following considerations.

It is known that the flow rate depends on the fluid flow rate and the cross-sectional area along which the flow moves and is determined from the known expression

$$Q = FV, \tag{4}$$

where Q is the fluid flow rate (pump capacity), m^3/h; F is the cross-sectional area along which the flow moves ($F = 0.785D^2$), m^2; V is the fluid velocity, m/h; D is the diameter of the input section of the cavitator, m.

Moreover, given that the fluid moves in a circular section (cavitators have a cylindrical shape), the speed will be equal to

$$V = \frac{4Q}{\pi D^2} \tag{5}$$

Substituting expressions (5) and (2) in (1), and solving with respect to D, we obtain the required diameter of the inlet of the cavitator system

$$D = \sqrt{\frac{Q}{\pi}\sqrt{\frac{8 \cdot K \cdot \rho}{(P_0 - P_H)}}} \quad (6)$$

Based on the foregoing theoretical calculations, a calculation was made to determine the diameter of the cavitator for a projectile for cleaning oil and gas wells for the conditions of Ozenmunaygas JSC fields. In order to reduce the time for hoisting operations for cleaning, it is recommended to use a coiled tubing installation, and for supplying a cleaning agent, it is recommended to use a cementing unit CA - 320 (ANTs-320), with a maximum discharge pressure of 40 MPa and a maximum ideal flow rate of 26 dm^3 /from.

The calculation of the input diameter for the cavitation number 0.1 is 6.6 mm, and for the cavitation number 0.6 is 10.5 mm. Thus, the input diameter of the cavitator system for the conditions of the deposits of Ozenmunaygas JSC should be in the range of 6.6 to 10.5 mm.

Conclusions. 1. Based on the foregoing, a methodology has been proposed for determining the geometric dimensions of cavitators depending on the pressure of the pump, hydrostatic pressure of the fluid, the wells located, and the number of cavitation.

2. The input diameter of the cavitator system for the conditions of the deposits of Ozenmunaygas JSC was determined.

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МҰНАЙГАЗ ҰҢҒЫЛАРЫН ТАЗАЛАУҒА АРНАЛҒАН SATBAYEV UNIVERSITY ҚҰРЫЛҒЫСЫ ҮШІН КАВИТАТОРЛАРДЫ ЕСЕПТЕУ ӘДІСТЕМЕСІ

Аннотация. Мақалада мұнай-газ ұңғыларын ұзақ қолдану барысында пайдалану ұңғыларының жобалық өнімділігі, ал айдау ұңғыларының қабылдауы төмендейтіні жөнінде айтылады. Жобалық өнімділік пен қабылдауын қалпына келтіру мақсатында бұл ұңғыларда біршама уақыттан кейін жөндеу-қалпына келтіру жұмыстары жүргізіледі.Ұңғылардың істен шығу себептерінің бірі – сүзгі маңы аймағының химиялық және механикалық кольматация өнімдерімен тұтасып қалуы және ұңғы түбінде механикалық тұнбалардың шөгуі болып табылады, оның нәтижесінде ұңғы өнімділігі өндіру регламентімен талап етілетін шекті мәннен азайып кетеді.

Мұнай-газ ұңғыларын тазалауға Satbayev University құрылымымен тазалау агенті ретінде кавитация-ланған сұйықпен жұмыс істейтін арнайы снарядтарды қолдану ұсынылады.

Бұл снарядтар «Қазатомпром» КЕАҚ нысандарында уран рудаларын жерасты сілтілендіру мақсатында бұрғыланған геотехнологиялық ұңғыларды аяқтау кезеңінде, сондай-ақ қолданыстағы шығару және айдау ұңғыларында жөндеу-қалпына келтіру жұмыстарын (ЖҚКЖ) жүргізуде өндірістік сынақтан өткізілді.

Өндірістік сынақтар олардың жұмысқа жарамдылығын және геотехнологиялық ұңғыларды тазалау кезінде тиімділігінің жоғары екенін көрсетті.

Мұнай-газ ұңғыларының геология-техникалық шарттары геотехнологиялық ұңғылардан құрылысы бойынша, қабат қысымының мәні, ұңғы тереңдігі, қолданылатын жабдық бойынша ерекшеленетіндіктен мұнай-газ ұңғылары жағдайына арналған снаряд элементтерін есептеу қажеттілігі туындайды.

Мұнай-газ ұңғымалары жағдайында осы құрылғылардың кавитаторларын кавитация санынан, жуу сұйығының шығынынан, ұңғыдағы сұйықтың гидростатикалық қысымынан, жуу сорабының жұмыстық қысымынан тәуелді есептеу әдістемесі ұсынылған. «Өзенмұнайғаз» АҚ кен орнының ұңғылары үшін кавитаторларды есептеу мысалы берілген.

Түйін сөздер: ұңғының өнімділігі, қабылдауы, жөндеу-қалпына келтіру жұмыстары, кавитация, гидростатикалық қысым.

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МЕТОДИКА РАСЧЕТА КАВИТАТОРОВ ДЛЯ УСТРОЙСТВ КОНСТРУКЦИИ SATBAYEV UNIVERSITY ПО ОЧИСТКЕ НЕФТЕГАЗОВЫХ СКВАЖИН

Аннотация. В статье говорится, что при длительной эксплуатации нефтегазовых скважин со временем эксплуатационные скважины теряют проектную производительность, а закачные скважины – приемистость. Эти скважины через определенный промежуток времени подвергаются проведению ремонтно-восстановительных работ с целью восстановления проектного дебита и приемистости. Одной из причин выхода скважин из строя является зарастание прифильтровой зоны продуктами химической и механической кольматации и осаждением механических взвесей в отстойник скважины, в результате чего производительность скважин снижается ниже допустимых пределов, требуемых регламентом добычи.

Предлагается для чистки нефтегазовых скважин использовать специальные снаряды конструкции Satbayev University с использованием в качестве очистного агента кавитированную жидкость.

Эти снаряды прошли промышленные испытания на объектах НАО «Казатомпром» на стадии заканчивания геотехнологических скважин, пробуренных с целью подземного выщелачивания урановых руд, а также при проведении ремонтно-восстановительных работ (РВР) эксплуатируемых откачных и закачных скважин.

Промышленные испытания показали их работоспособность и высокую эффективность при чистке геотехнологических скважин.

В связи с тем, что геолого-технические условия нефтегазовых скважин отличаются от геотехнологических скважин по их конструкции, величин пластового давления, глубин скважин, применяемого оборудования появляется необходимость проведения расчетов элементов снаряда с целью получения кавитированной жидкости для условий нефтегазовых скважин.

Предложена методика расчета кавитаторов этих устройств для условий нефтегазовых скважин в зависимости от числа кавитации, расхода промывочной жидкости, гидростатического давления жидкости находящегося в скважине, рабочего давления промывочного насоса. Приведен пример расчета кавитаторов для скважин месторождений АО «Озенмунайгаз».

Ключевые слова: производительность скважины, приемистость, ремонтно-восстановительные работы, кавитация, гидростатическое давление.

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