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**Korolov O.,
Pavlishin P.,
Titlov O.,
Mironchuk V.**

EXPERIMENTAL STUDY OF THE TRANSITION OF TWO TYPES OF WEDGE GATE VALVES

Об'єктом дослідження є вид енергетичної арматури – засувка або клинова арматура. Засувки або клинова арматура займає провідне місце серед енергетичної арматури. Вона має мінімальний гідравлічний опір, практично лінійну залежність витрати від ступеня відкриття та має широке застосування на трубопровідних системах широкого призначення. Одним із проблемних місць такої арматури є втрата герметичності або пропуск клинових засувок. Крім цього, більш складна конструкція підвищує ймовірність відмови такої арматури. Для вирішення цієї проблеми пропонується виконати експериментальне дослідження пропуску засувок в залежності від зусилля їх закриття, а також дослідження тренда цієї залежності.

Дослідження проводилися на стенді, що забезпечує тиск повітря до 3,0–3,5 МПа та укомплектований чавунною та латунною засувками. Пропуск повітря вимірювали об'ємним способом, витісняючи воду з вимірювальної комірки. Для створення зусилля на штоку, що замикає арматуру, використовувався динамометрический ключ КД-230 (Росія), що дозволяє вимірювати крутний момент до 230 Н·м. Методика експерименту полягала в наступному. Динамометричним ключем необхідним зусиллям закривали арматуру, потім включали компресор і досягали необхідного тиску. Пропуск повітря вимірювали заповненням вимірювальної комірки за час, що фіксується секундоміром.

Обробка отриманих експериментальних даних дозволила отримати наступні залежності відносного пропуску арматури від величини крутного моменту для чавунної засувки: $(Q/\sqrt{\Delta P})=3458\cdot M^{(-1,069)}$ та для латунної засувки: $(Q/\sqrt{\Delta P})=6893\cdot M^{(-2,435)}$. Показано, що засувки так само як і раніше досліджені клапани та вентилі мають один тренд: $(Q/\sqrt{\Delta P})=C\cdot M^{(-g)}$. Показник ступеня крутного моменту показує, чим він більший за абсолютним значенням, тим запірні характеристики арматури – кращі. Так, для забезпечення однакового пропуску повітря, крутний момент на чавунній арматурі повинен мати більші значення, ніж для досліджуваної латунної засувки.

Ключові слова: *клинова арматура, крутний момент, відносний пропуск повітря, герметичність арматури, чавунна засувка, латунна засувка.*

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1. Introduction

The reliability of pipeline valves in general determines the reliability of any equipment. Timely detection of valve damage will help to avoid unplanned stops and accidents of the heat-power equipment of the station [1–3]. Conversely, failure of critical valves can lead to serious events. One can recall the failure of the pulse valve of the pressure compensator at the Three Mile Island NPP (nuclear power plant) [4], which ended in the first serious accident at world nuclear power plants. A similar failure of the PC PRV (pulse pressure relief valve of the pressure compensation system) was noted at the Rivne NPP, Ukraine, but it was detected and eliminated in time. Failure of valves in refrigeration equipment also leads to serious consequences [5]. Thus, the object of this study is the type of power valves – gate valve or wedge valve.

Gate valves or wedge valve take a leading place among power valves. Firstly, when the rod is fully raised, it has the minimum hydraulic resistance, among other types of valves [6, 7]. Secondly, the almost linear dependence of the flow rate on the level of the rod lift provides it with a place in automatic control systems or supporting costs, for example, in drainage systems of heaters, on heating mains of heating systems [3]. In addition, such valve has two seating surfaces in series, which increases the reliability of its closure. However, this design is more complex compared, for example, with the design of the valve, which increases the likelihood of failure of such valves [3, 6].

The relevance of the work is due to the practical absence of such studies of valve. Analysis of publications on this topic showed the presence of a limited number of works devoted to it [8–10]. Therefore, it seems relevant to expand the study of the tightness of valves with various closing efforts on wedge gate valves. So, *the aim of this research* is to study the tightness of wedge gate valves with different closing forces by constructing the dependence of the relative valve tolerance on the closing force and analyzing this dependence.

2. Methods of research

Experimental studies were carried out on a bench that provides air pressure with an AK-50 compressor (USSR) up to 3.0–3.5 MPa (Fig. 1).

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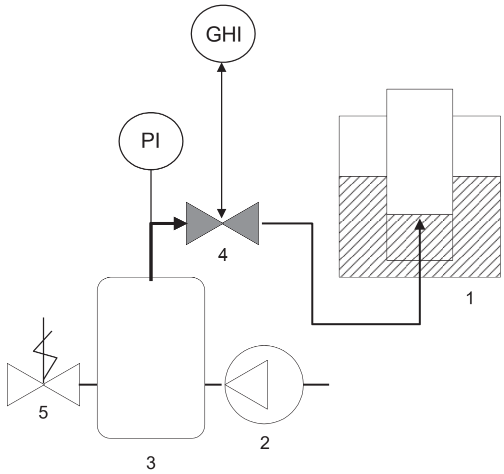


Fig. 1. Scheme of the experimental stand:
1 – measuring cell; 2 – AK-50 compressor A; 3 – receiver;
4 – studied valve; 5 – safety valve; PI – pressure gauge;
GHI – torque wrench

For a smooth air supply to the latch 4, the compressor 2 worked on the receiver 3, with a volume of about 5 liters. Air flow was measured in a volumetric way, displacing water from measuring cell 1. To create a force on the rod that closes the valve 4, let's use a KD-230 torque wrench (Russia), which allows measuring torque up to 230 N·m.

The experimental technique was as follows. The valve 4 was closed with a torque wrench with the required force, then the compressor 3 was turned on and the required pressure was reached. Air transition was measured by filling the measuring cell over a period of time, which was recorded by a stopwatch. The experimental results are presented in Tables 1, 2.

Table 1

Air transition by the cast iron gate valve

V_{air}, ml	t, s	Q, ml/min	ΔP, atm	M, N·m	$(Q/P)^{0.5}$
1	2	3	4	5	6
150	27.12	331.8584	2.4	9.2	214.2137
150	12.07	745.6504	3.2	9.2	416.8312
150	8.63	1042.874	4	9.2	521.4368
150	6.99	1287.554	5.2	9.2	564.6296
150	6.48	1388.889	6.4	9.2	549.0065
150	6.06	1485.149	7.2	9.2	553.4822
150	5.59	1610.018	8	9.2	569.2273
150	4.98	1807.229	8.8	9.2	609.2167
150	4.85	1855.67	9.6	9.2	598.915
150	4.6	1956.522	10.4	9.2	606.6916
150	4.52	1991.15	11.2	9.2	594.97
150	4.41	2040.816	12	9.2	589.1329
280	15.46	1086.675	2.4	4	701.4459
280	12.15	1382.716	3.2	4	772.9618
280	10.26	1637.427	4	4	818.7135
280	8.01	2097.378	5.2	4	919.7612
280	7.63	2201.835	6.4	4	870.3516
280	7.08	2372.881	7.2	4	884.3207
280	6.56	2560.976	8	4	905.4416
280	5.89	2852.292	8.8	4	961.5074

Continuation of Table 1

1	2	3	4	5	6
280	5.48	3065.693	9.6	4	989.4483
280	5.05	3326.733	10.4	4	1031.576
280	4.81	3492.723	11.2	4	1043.651
280	4.65	3612.903	12	4	1042.955
280	18.26	920.0438	2.4	5.2	593.8857
280	13.1	1282.443	3.2	5.2	716.9073
280	11.28	1489.362	4	5.2	744.6809
280	9.36	1794.872	5.2	5.2	787.1034
280	7.75	2167.742	6.4	5.2	856.8752
280	7.45	2255.034	7.2	5.2	840.4014
280	6.83	2459.736	8	5.2	869.6482
280	6.55	2564.885	8.8	5.2	864.6227
280	6.38	2633.229	9.6	5.2	849.871
280	6.2	2709.677	10.4	5.2	840.2353
280	5.95	2823.529	11.2	5.2	843.6908
280	5.66	2968.198	12	5.2	856.8449
280	20.2	831.6832	2.4	5.7	536.8492
280	14.62	1149.111	3.2	5.7	642.3725
280	11.63	1444.54	4	5.7	722.27
280	9.68	1735.537	5.2	5.7	761.0834
280	8.79	1911.263	6.4	5.7	755.493
280	7.86	2137.405	7.2	5.7	796.5637
280	6.73	2496.285	8	5.7	882.5701
280	6.43	2612.753	8.8	5.7	880.7588
280	5.79	2901.554	9.6	5.7	936.4727
280	5.95	2823.529	10.4	5.7	875.5393
280	5.56	3021.583	11.2	5.7	902.8705
280	6.1	2754.098	12	5.7	795.0397
280	29.06	578.1142	2.4	6.9	373.1711
280	22.72	739.4366	3.2	6.9	413.3576
280	17.15	979.5918	4	6.9	489.7959
280	13.43	1250.931	5.2	6.9	548.5694
280	10.58	1587.902	6.4	6.9	627.6733
280	9.93	1691.843	7.2	6.9	630.5126
280	9.08	1850.22	8	6.9	654.1516
280	8.5	1976.471	8.8	6.9	666.2681
280	7.6	2210.526	9.6	6.9	713.4443
280	7.29	2304.527	10.4	6.9	714.6034
280	7.02	2393.162	11.2	6.9	715.094
280	6.82	2463.343	12	6.9	711.1059
150	18.33	490.9984	2.4	8	316.9381
150	11.12	809.3525	3.2	8	452.4418
150	9.05	994.4751	4	8	497.2376
150	7.32	1229.508	5.2	8	539.175
150	6.27	1435.407	6.4	8	567.3943
150	5.97	1507.538	7.2	8	561.8261
150	5.4	1666.667	8	8	589.2557
150	4.83	1863.354	8.8	8	628.1365
150	4.67	1927.195	9.6	8	621.9995
150	4.51	1995.565	10.4	8	618.7986
150	4.43	2031.603	11.2	8	607.0574
150	4.25	2117.647	12	8	611.312

Note: V_{air} – air volume; t – transit time of the air volume; M – torque; Q – air consumption (transition); ΔP – pressure drop across the gate valve; $(Q/P)^{0.5}$ – complex

Table 2

Air transition be the brass gate valve

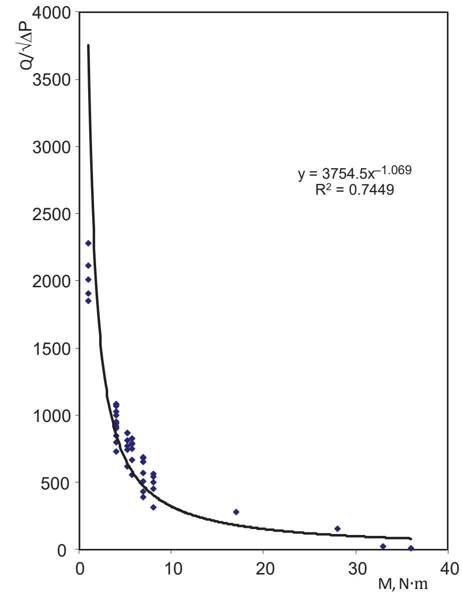
V_{air}, ml	t, s	Q, ml/min	ΔP, atm	M, N·m	$(Q/P)^{0.5}$
290	15.46	1125.485	2.4	4	726.4975
290	12.15	1432.099	3.2	4	800.5675
290	10.26	1695.906	4	4	847.9532
290	8.01	2172.285	5.2	4	952.6098
290	7.63	2280.472	6.4	4	901.4356
290	7.08	2457.627	7.2	4	915.9036
290	6.56	2652.439	8	4	937.7788
290	5.89	2954.16	8.8	4	995.847
290	5.48	3175.182	9.6	4	1024.786
290	5.05	3445.545	10.4	4	1068.418
290	4.81	3617.464	11.2	4	1080.924
290	4.65	3741.935	12	4	1080.204
290	18.26	952.9025	2.4	5.2	615.0959
290	13.1	1328.244	3.2	5.2	742.5111
290	11.28	1542.553	4	5.2	771.2766
290	9.36	1858.974	5.2	5.2	815.2142
290	7.45	2335.57	7.2	5.2	870.4157
290	20.2	861.3861	2.4	5.7	556.0224
290	14.62	1190.15	3.2	5.7	665.3143
290	11.63	1496.131	4	5.7	748.0653
290	9.68	1797.521	5.2	5.7	788.265
290	8.79	1979.522	6.4	5.7	782.4748
290	7.86	2213.74	7.2	5.7	825.0124
290	6.1	2852.459	12	5.7	823.434
290	29.06	598.7612	2.4	6.9	386.4987
290	22.72	765.8451	3.2	6.9	428.1204
290	17.15	1014.577	4	6.9	507.2886
290	13.43	1295.607	5.2	6.9	568.1612
290	10.58	1644.612	6.4	6.9	650.0902
290	9.93	1752.266	7.2	6.9	653.0309
290	9.08	1916.3	8	6.9	677.5142
290	8.5	2047.059	8.8	6.9	690.0634
150	18.33	490.9984	2.4	8	316.9381
150	11.12	809.3525	3.2	8	452.4418
150	9.05	994.4751	4	8	497.2376
150	7.32	1229.508	5.2	8	539.175
150	5.97	1507.538	7.2	8	561.8261
290	17.81	976.9792	12	17	282.0296
290	32.43	536.5402	12	28	154.8858
20	15.76	76.14213	12	33	21.98034
20	37.59	31.92338	11.2	36	9.538935
250	2.1	7142.857	14	1	1909.009
250	2.2	6818.182	10.4	1	2114.228
250	2.87	5226.481	8	1	1847.84
250	3.05	4918.033	6	1	2007.778
250	3.14	4777.07	4.4	1	2277.379

Note: V_{air} – air volume; t – transit time of the air volume; M – torque; Q – air consumption (transition); ΔP – pressure drop across the gate valve; $(Q/P)^{0.5}$ – complex

The tabular presentation of the results is important for checking the data, but does not give an idea of the nature of the valve transition. For this, it is advisable to process the experimental data according to previously obtained criteria [8].

3. Research results and discussion

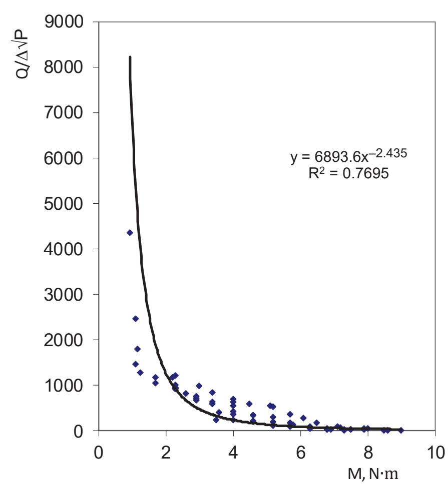
Processing the obtained experimental data allows to obtain the following dependences (Fig. 2, 3).



a

b

Fig. 2. Cast iron gate valve: *a* – dependence of the relative gap of the valve on the magnitude of the torque; *b* – appearance



a

b

Fig. 3. Brass gate valve: *a* – dependence of the relative gap of the valve on the magnitude of the torque; *b* – appearance

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The experiment showed that the gate valves, just as previously studied valves [8] and valves have one trend, namely, obey the equation:

$$(Q/\sqrt{\Delta P}) = C \cdot M^{(-g)},$$

where Q – air consumption (transition), ml/s; ΔP – pressure drop across the gate valve, MPa; C – coefficient; M – torque, N·m; g – exponent with M.

It is also possible to see that the indicator of the degree of torque is 1.069 for cast iron valve, and 2.435 for brass valve. This means that in order to ensure the same transmission of air, the torque on cast iron valve must have larger values than for the brass.

A visual examination of these gate valves shows that cast iron valve is in operation, while brass valve is brand new. That is, an indicator of the degree of torque allows to evaluate the quality of the seating surfaces of the gate valves.

The dimensional coefficient C also indicates the quality of the seating surfaces, directly relating the valve transition to its value, however, a solid indicator has a significantly greater effect.

4. Conclusions

An experimental study confirms that the gate valves also obey the previously established criteria dependencies [8]. The influence of the coefficients and exponents in the obtained dependence on the quality of the seating surfaces and the valve tolerance is shown. This study leads to the need to expand the incoming control of valves on such stands.

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Korolov Oleksander, *Doctor of Technical Sciences, Professor, Department of Nuclear Power Plants, Odessa National Polytechnic University, Ukraine, ORCID: http://orcid.org/0000-0002-4158-7966, e-mail: korol118@ukr.net*

Pavlyshin Pavel, *Acting President, National Nuclear Energy Generating Company «Energoatom», Kyiv, Ukraine, ORCID: http://orcid.org/0000-0002-3417-4346*

Titlov Alexander, *Doctor of Technical Sciences, Professor, Head of Department of Heat-and-Power Engineering and Oil-and-Gas Transportation and Storing, Odessa National Academy of Food Technologies, Ukraine, ORCID: http://orcid.org/0000-0003-1908-5713, e-mail: titlov1959@gmail.com*

Mironchuk Valentin, *Department of Nuclear Power Plants, Odessa National Polytechnic University, Ukraine, ORCID: https://orcid.org/0000-0002-4630-5331, e-mail: mironchikvalik@gmail.com*