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Investigation of velocity modes of liquid flows around electric motors of submersible pumps

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Abstract. Water supply and wastewater disposal refers to industries with intensive use of pumping equipment, the share of electricity consumed by pumps is more than 50% of the total energy consumption. Therefore, the issue of improving the energy efficiency of water supply is, first of all, the rational operation of pumping equipment. One of the reasons for the reduction of technical and economic performance of submersible pumping units is the failure of electric pump motors due to overheating during operation. In any electric motor during operation, even with the highest efficiency part of the electrical energy supplied goes to heating, so that the motors do not overheat and do not fail, they need to be cooled. Motors for well pumps unlike surface pumps have a different design, and they do not have a fan, but they also need to be cooled during operation. But in order for the motor to be cooled properly, the necessary fluid velocity must be determined around the motor. This velocity can be provided by means of cooling hoods. This issue is particularly relevant when submersible pumps are used to pump water from tanks, cisterns or open ponds, where the use of cooling covers is mandatory. Manufacturers of submersible pumps specify in their technical data the minimum permissible liquid velocity for cooling the motor casing. If the flow velocity of the pump motor is less than that specified in the technical data of the equipment, it is necessary to determine the minimum permissible velocity of the liquid flow around the pump motor. In this connection substantiation and development of methods of research and calculation of parameters of liquid flow around the pump motor, is an actual scientific and practical task, having branch importance. At the same time, at the present stage, the existing methods and two ways of determining the velocity of the fluid flow around the submersible pump motor: calculation - by means of analytical formulae and graphical - by means of charts of rational areas of application of cooling covers do not provide a sufficiently complete solution of the problem of providing a turbulent vortex flow along the motor, preventing the formation of deposits and providing cooling of the motor regardless of the type of formed deposits of minerals, bacteria or metals. The article proposes an improved method of modelling the fluid flow around the electric motor housing of a submersible pump using the SolidWorks software package, which allows to solve the problem of cooling the motor by justifying the design parameters of cooling covers. The aim of the work is to provide conditions of stable cooling of pumping unit motors at which the temperature of electric motor windings will be within permissible limits, which is the main point in the durability of submersible pumps. To achieve this goal, the task of developing a methodology for modelling the turbulent vortex fluid flow along the electric motor of a submersible pump and studying the design parameters of cooling covers is solved. The research methodology included both numerical modelling methods and experimental studies. The obtained results allowed to characterize in detail the fluid velocity fields around the pump unit, to reveal the features of the hydrodynamic behavior of the system and to determine the parameters influencing the durability of submersible pump units.

Keywords: *flow velocity, liquid, submersible pump, electric motor, hydrodynamics, design optimization, efficiency of operation, productivity, energy losses, velocity fields, liquid flow*.

1. Introduction

The overall energy consumption in industries depends in no small measure on the performance of pumping equipment. The efficiency of a pumping station is often lower than the efficiency of the individual pumps installed in the station. The reason for the low energy efficiency is a mismatch in the operating characteristics of the equipment. To improve the efficiency of pumping plants, it is necessary to reduce the operating costs of the pumping equipment.

In an electric motor, during high-efficiency operation, part of the electrical power input is used for heating. Heating the motor reduces its efficiency, which is often accompanied by power overruns. At the same time, cooling the motor increases the service life of the pump unit. Surface motors have a fan on the shaft, which cools the motor with air flow when the motor is switched on. Motors for borehole pumps have a different design, and they do not have a fan, but they also need to be cooled by any means during operation. When the motor is working in the well, usually the water temperature ranges from 8-14°C, and it is this water that will cool the motor [2]. Due to improper selection and operation of the pumping unit in some wells the motors are cooled normally, and in others they fail due to overheating. In surface motors, a fan creates sufficient airflow to extract the heat generated by the motor during operation. Similarly, well motors are cooled by the flow of the pumped fluid. A certain flow velocity around the pumping unit makes it possible to cool and operate the motors normally. In some cases, the fluid flow velocity along the submersible pump motor is not sufficient. In such cases, the liquid flow velocity can be ensured by means of cooling shrouds. In addition, very often borehole pumps are used to supply water from tanks, cisterns or open ponds, where the use of cooling covers is mandatory. Manufacturers of borehole pumps specify in the technical data the minimum permissible liquid velocity for cooling the motor housing. Some manufacturers also specify the maximum operating time of the motor when the valve is closed [3].

Submersible pumps are used in demanding applications. They are constantly exposed to water pressure, vibration, high temperatures, abrasive particles, etc. Therefore, the pump units are manufactured with a large safety margin, but over time they develop various failures. The main failures of electric submersible pump units and their causes can be divided as follows:

1. Decrease in insulation resistance:

a. mechanical damage to the cable insulation when the submersible pump is lowered, due to violation of the rate of descent of the unit or presence of foreign objects in the well;

b. displacement of current-carrying conductors of the extension or main cable running to the check valve, due to poor installation during operation;

2. Infiltration of formation or purge fluid into the motor cavity, frontal part or outlet ends (non-tightness of mechanical seals, tightness failures in the places of current input or flange connection motor - waterproofing), due to vibration or atmospheric precipitation during installation;

3. Motor overheating due to violation of the cooling mode [4, 5].

The considered reasons of failure of electric motor of submersible pumps are connected mainly with its overheating. Insufficient pump cooling occurs when a small diameter pump is installed in a well with too large a diameter or, even worse, in an open well. [6] When the well diameter is slightly larger than the pump, the water cools the motor housing, protecting it from overheating. It is recommended that the difference between the internal diameter of the borehole and the diameter of the pump should be at least 4 mm and not more than 100 mm. In addition, very often borehole pumps are used to supply water from tanks, cisterns or open ponds, where the use of cooling covers is mandatory. Cooling covers for submersible pumps allow a part of the pumped liquid or external liquid to circulate around the stator housing of the electric motor. In doing so, excess heat is absorbed by forced convection, providing effective cooling of the pump. They provide additional cooling of the motor when the pumped liquid is warm or the pumps have to run continuously. During the operation of a borehole pump, its service life is directly dependent on the cooling of the motor. Therefore, it is very important for the operation of a downhole pump to provide the necessary temperature and rational speed of the turbulent vortex fluid flow along the electric motor of the submersible pump [7].

2. Materials and methods

In practice, the surface temperature of some modern pump motors can reach 90°C (194°F). At elevated temperatures, many materials begin to char and become conductive. All materials become brittle from prolonged exposure to elevated temperatures long before charring, easily break down and lose their insulating properties. This process is called thermal ageing. [8,9,10]

In most modern designs of submersible pumps their water intake part is located above the electric motor. This technical solution ensures high pump performance, but under some conditions (installation of a narrow pump in a well with too large a diameter) it can lead to overheating of the electric motor.

When the electric motor is located above the water intake part of the pump, the entire pump unit is mounted in a casing so that the flowing water cools the electric motor. This solution leads to a reduction of the impeller diameter, which in turn reduces the pump performance.

Increase of productivity can be achieved in a similar way by increasing the speed of rotation of the motor, but increasing the speed of rotation of the electric motor will require an increase in the frequency of the power supply network more than 50 Hz, which in turn does not allow to develop the speed of rotation of the motor more than 3000 min-1. Therefore, today the task of eliminating the processes of overheating of submersible pump motors is urgent and in demand. [11] The set task is achieved by the fact that a cooling casing is installed on the upper part of the suction pipe of a submersible pump. When entering the device, the liquid passes close to the motor part, thus increasing the speed of the liquid flow entering the pump, improving the cooling process of the electric motor (Figure 1).

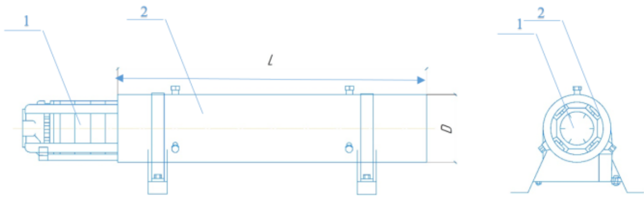

Figure 1. Schematic diagram of the pump unit cooling jacket: 1-pump; 2-cooling jacket

It is recommended to install cooling hoods when the cooling of the electric motor is insufficient [12]. This increases the life of the motor. Cooling covers are recommended when:

- the borehole pump is subjected to high thermal loads due to e.g. asymmetrical current consumption, dry running, overloads, high ambient temperatures and poor cooling;

- the pump is pumping corrosive liquids, as the corrosion rate doubles when the temperature rises by 10°C.

3. Results and discussion

Figure 2 shows the general view of the process well and the principle of operation of the cooling shroud in wells. The device consists of an electric submersible pump unit (1), cooling shroud (2), suction pipe of the submersible electric pump (3), casing (4), process well (5), fluid bed (6), motor part of the submersible pump (7) and fluid flow (8). The cooling shroud is attached to the top of the suction pipe, with its length exceeding the length of the pump unit motor by 20-50 cm. A gap of 20-30 mm in diameter is left between the pump unit and the end of the blind pipe.

It is recommended to use a cooling jacket made of PVC material, as this type of material is low cost and lightweight compared to a stainless-steel sheet construction, making it more cost effective.

By using a suction cooling shroud, the motor operates at a reduced temperature and does not overheat during continuous operation. During pump shutdowns, the cooling jacket absorbs residual heat from the motor, thus preventing thermal effects. This prolongs the intervals between the necessary cleaning of the well from mineral crust.

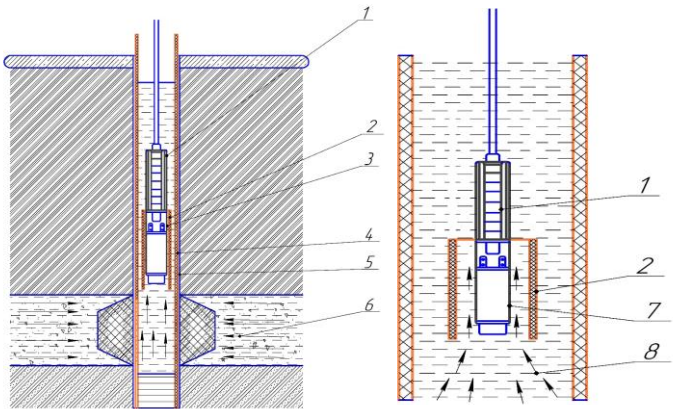

Figure 2. General view of the process well: a - scheme of installation of downhole submersible pump; b - principle of operation of submersible pump with cooling casing

Danger of localised heating of the pump motor, especially in horizontal pump installations and where several units are located close to each other. In such cases, cooling hoods should always be used on the suction side.

Examples of options for installing cooling covers on submersible pumps installed in open water bodies, cisterns, tanks, wells and boreholes with inlets above the suction inlets, where cooling of the submersible pump motor is only provided by free convection, are shown in Figure 3.

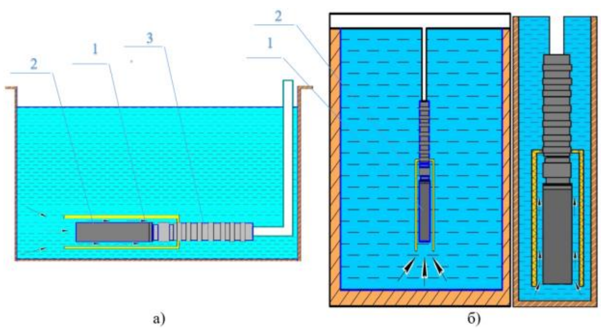

Figure 3. Examples of installation of the cooling jacket for: a) Horizontal installation of the pump; b) Vertical installation of the pump: 1-electric motor; 2- cooling jacket; 3-pump

If the flow velocity of the pump motor is less than that specified in the equipment data sheet, the use of cooling covers is mandatory.

The following formula is used to calculate the cooling rate [13]:

$$v \approx \frac{353 \cdot Q}{D^2 - d^2} \quad \text{[m/s]},$$

Q- flow rate (minimum pump capacity is required for calculation), m^3/h;

D - nominal diameter of the well, mm;

d - nominal diameter of the electric motor, mm.

At carrying out mathematical calculations and experimental works we have chosen 2 types of technological wells (well diameter Dsk =159 mm and Dsk =195 mm), 2 types of submersible pumps (USK408/42 pump motor diameter Ddv =93 mm and URN 6 25/14 pump motor diameter Ddv =145 mm). As they are frequently used types of equipment at industrial enterprises. The results of the performed calculations are given in Table 1.

Table 1. Rational casing diameters for submersible pumps

Flow rate Q, m^3/h	Well diameters Dsk,mm	Pump motor diameters Ddv,mm	Suggested diameters of cooling hoods, mm	Flow cooling velocities of motors,m/s
8	159	93	113	0.6
			123	0.43
			133	0.31
			143	0.23
			159	0.19
25	195	145	165	1.42
			170	1.12
			175	0.91
			180	0.77
			185	0.66
			195	0.51

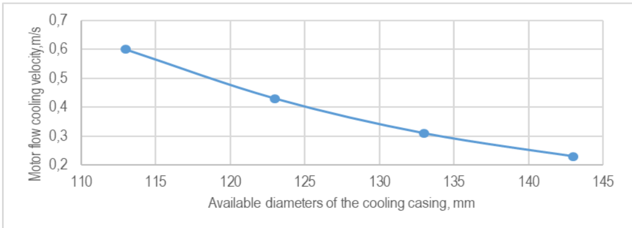

Figure 4. Dependence of change of flow cooling velocities on internal diameters of cooling casings. (well diameter Dsk =159 mm, pump motor diameter Ddv =93 mm)

The velocity of the liquid flow around the electric motor should be in the range from 0.15 to 3 m/s to ensure optimum operating conditions for the pump.

On the basis of the obtained data, studies were carried out by modelling the hydrodynamic processes during the operation of the submersible pump and the cooling shroud using the KOMPAS software package (Figure 6).

Experimental work to investigate the changes in the flow cooling rate using the recommended cooling shroud was carried out using SolidWorks software. The obtained results are shown in Figure 7.

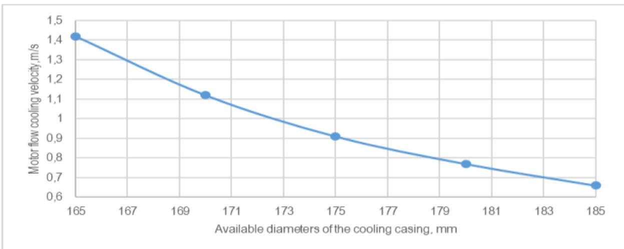

Figure 5. Dependence of flow cooling velocity variation on the internal diameter of the cooling casing. (borehole diameter Dsk =195 mm, pump motor diameter Ddv =145 mm)

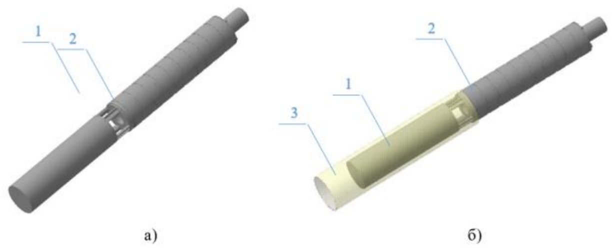

Figure 6. Submersible electric pump: a) General view of the submersible electric pump without cooling jacket; b) Submersible electric pump with cooling jacket: 1-electric motor; 2-pump; 3-cooling jacket

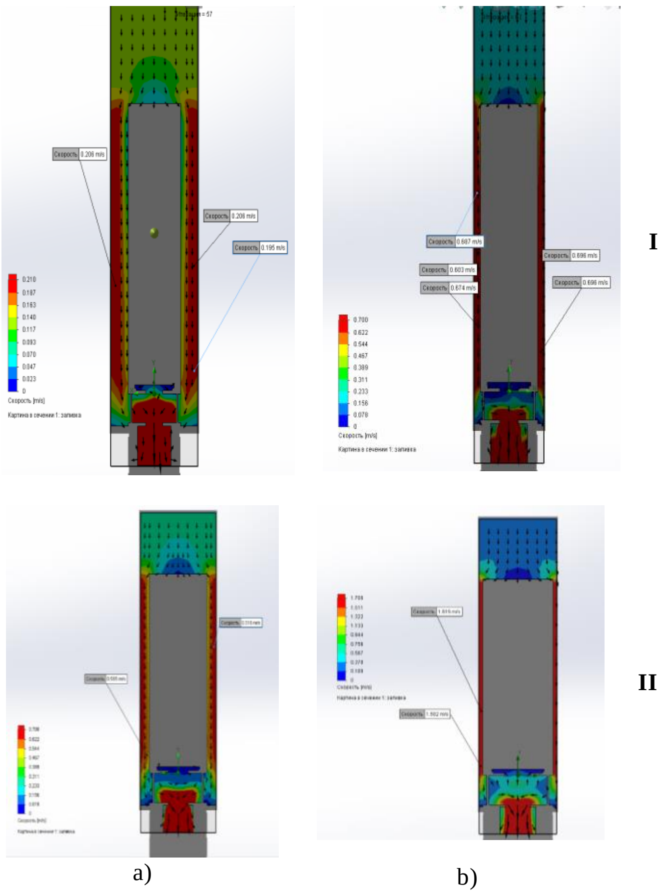

Figure 7. Results of experimental work in SolidWorks software

I- at borehole diameter Dsk =159 mm, pump motor diameter Ddv =93 mm; II- at borehole diameter Dsk =195 mm, pump motor diameter Ddv =145 mm;

A) Submersible electric pump without cooling casing. B) Submersible electric pump with a cooling casing.

Analysis of the results shown in the graphs indicates that in order for the motor to cool normally, it is necessary to provide a certain speed of the fluid flow around it. This velocity can be achieved by means of cooling shrouds.

4. Conclusions

To establish the technical and economic efficiency of using the results of research on the application of the recommended cooling device for submersible pump motors, the following calculations were made.

Annual power consumption of the used pumping equipment without application of the recommended cooling device of the submersible pump motor:

$W_{noun\ op} = P_a \cdot EUR \cdot t = 7.4 \cdot 0.85 \cdot 8760 = 55100.4$ kW·h/year;

where: P_a – actual capacity of pumping equipment at pump capacity $Q_{cr} = 8$ (m^3/hour);

EUR = 0.85 equipment utilization rate over time;

t = 8760 operating time of pumping equipment relative to the billing period, hour/year;

Annual electricity consumption when using the recommended cooling device for the submersible pump motor

$W_{prelim.ver} = P_a \cdot EUR \cdot t = 7 \cdot 0.85 \cdot 8760 = 52122$ kW·h/year;

where: EUR = 0.85 equipment utilization rate over time;

t = 8760 operating time of pumping equipment relative to the billing period, hour/year;

P_a – actual capacity of pumping equipment at pump capacity $Q_{cr} = 8$ (m^3/hour);

The electrical resistance of conductors increases with increasing temperature and decreases with decreasing temperature. At very low temperatures, the resistance of some metals and alloys drops to zero (superconductivity). When heated, the vibrations of metal ions in the nodes of the metal lattice increase, so the free space for the movement of electrons becomes smaller. The electrons are more likely to be thrown back, so the value of current decreases and the value of resistance increases, from this we can conclude that, when the temperature of the motor increases, the power consumption of the submersible pumping equipment increases. [4]

Energy saving by using a cooling device for the submersible pump motor

$\Delta W = W_{noun\ op} - W_{prelim.ver} = 55100.4 - 52122 = 2978.4$ kW·h/year.

Calculated data and obtained performance indicators of pumping units at application of submersible pump motor cooling device are given in Tables 2, 3, 4, and changes of energy efficiency of submersible pump motor cooling device application by years of operation are shown in Figure 8.

As a result of the conducted researches, it has been established that it is expedient and economically reasonable to install cooling covers in case of: insufficient cooling; high ambient temperature; pumping of aggressive liquid; sludge (deposits on the electric motor). At the same time, the cooling cover provides a longer life of the electric motor by increasing the velocity of the fluid flow along the motor and contributes to increasing the energy efficiency of the pumping unit by 5-7 %.

Table 2. Capital cost per submersible pump

№	Expenses	Thousand dollars
1	Cost of the submersible pump motor cooling unit	350
2	Installation work (17%)	60
3	Delivery to (10%)	35
	Total amount in dollars:	445
	Total amount in tenge:	217 572

Table 3. Costs per submersible pump

Name	Units of measurement	Per 1 submersible pump
Annual electricity consumption of the pumping equipment in use		
Annual electricity consumption	kWh/year	55100.4
Cost of 1 kWh of electricity including VAT	Dollars/kWh	450

Cost of consumed electricity	million USD/year	27.8
Annual electricity consumption by pumping equipment under the proposed variant		
Annual electricity consumption	kW·h/year	52122
Cost of 1 kWh of electricity including VAT	million Dollars/year	23.5
Electricity saving	million USD/year	4.3

Table 4. Calculation of cumulative cash flow and equipment payback period

Indicators of economic efficiency	Unit	Years				
		2024	2025	2026	2027	2028
Operating cost variance	Million. Mln.	4.3	4.3	4.3	4.3	4.3
Depreciation and amortisation	Mln. Dollars	-	0.9	0.9	0.9	0.9
Net profit	Mn. Dollars	4.3	3.4	3.4	3.4	3.4
Capital expenditure	Mln. Dollars	0.45	0.0	0.0	0.0	0.0
Net cash flow	Million Dollars	3.85	3.4	3.4	3.4	3.4
Cumulative cash flow	Million Dollars	3.85	7.25	10.65	14.05	17.45
Payback period	Year	2				

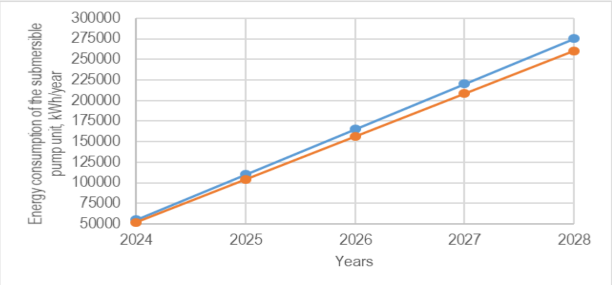

Figure 8. Change in energy efficiency of the application of the submersible pump motor cooler by year of operation

Cooling casing is a space formed between the body of the cooling casing and the stator surface of the electric motor in which there is a single-phase, turbulent, vortex motion of the fluid flow along the electric motor with convective heat exchange.

It has been experimentally established that there are several main reasons for the equipment of additional cooling jacket (cooling shrouds): to ensure the required fluid flow velocity; to prevent the formation of deposits of components (iron, manganese, fluid salts, bacteria or minerals, etc.) in the well water and to ensure uniform cooling of the electric motor; to reduce the growth of corrosive activity of water by eliminating the increase in temperature of the electric motor; to absorb heat and prevent the thermal effect.

The results of numerical simulation and experimental work performed to investigate the changes in the flow cooling rate using the recommended cooling casing allowed to characterise in detail the velocity fields around the pump unit, to identify the features of the hydrodynamic behaviour of the system and to establish the dependence of the change in the flow cooling rate on the internal diameter of the cooling casing.

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Суасты сорғыларының электр қозғалтқыштарының айналасындағы сұйықтық ағындарының жылдамдық режимдерін зерттеу

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Аңдатпа. Сумен жабдықтау және су бұру сорғы жабдықтарын қарқынды пайдаланатын өнеркәсіп салаларына жатады, сорғылар тұтынатын электр энергиясының үлесі жалпы энергия тұтынудың 50% - дан астамын құрайды. Сондықтан сумен жабдықтаудың энергетикалық тиімділігін арттыру мәселесі, ең алдымен, сорғы жабдықтарын ұтымды пайдалану болып табылады. Суасты сорғы қондырғылары жұмысының техникалық-экономикалық көрсеткіштерінің төмендеуінің себептерінің бірі жұмыс процесінде қызып кетуден сорғылардың Электр қозғалтқыштарының істен шығуы болып табылады. Кез-келген электр қозғалтқышында, тіпті ең жоғары тиімділікте де, қозғалтқыштар қызып кетпеуі және істен шықпауы үшін, электр энергиясының бір бөлігі жылытуға кетеді, оларды салқындату керек .Ұңғыма сорғыларына арналған қозғалтқыштар, жер үсті сорғыларынан айырмашылығы, басқа дизайнға ие және желдеткіші жоқ , бірақ оларды пайдалану кезінде де салқындату қажет. Бірақ қозғалтқыштың қалыпты салқындауы үшін оның айналасында сұйықтық ағынының қажетті жылдамдығын анықтау керек. Бұл жылдамдықты салқындатқыш қаптамалардың көмегімен қамтамасыз етуге болады. Бұл мәселе әсіресе суасты сорғылары салқындатқыш қаптамаларды қолдану қажет болатын контейнерлерден, цисцерналардан немесе ашық су қоймаларынан су беру үшін пайдаланылған кезде өте маңызды.Суасты сорғыларын шығаратын зауыттар техникалық сипаттамаларда электр қозғалтқышының корпусын салқындату үшін сұйықтықтың минималды рұқсат етілген жылдамдығын көрсетеді. Егер сорғылардың электр қозғалтқышының айналу жылдамдығы Жабдықтың техникалық сипаттамаларында көрсетілгеннен аз болса, онда сорғы қозғалтқышының айналасындағы сұйықтық ағынының минималды рұқсат етілген жылдамдығын анықтау қажет. Осыған байланысты сорғы қозғалтқышының айналасындағы сұйықтық ағынының параметрлерін зерттеу және есептеу әдістерін негіздеу және дамыту салалық маңызы бар өзекті ғылыми және практикалық міндет болып табылады. Сонымен қатар, қазіргі кезеңде суасты сорғысының қозғалтқышының айналасындағы сұйықтық ағынының жылдамдығын анықтаудың қолданыстағы әдістері мен екі әдісі: есептелген-аналитикалық формулалар мен графикалық-салқындатқыш қаптамаларды қолданудың ұтымды бағыттарының графиктерін қолдана отырып , шөгінділердің пайда болуына жол бермейтін және қозғалтқыштың салқындатылуын қамтамасыз ететін электр қозғалтқышы бойымен турбулентті құйынды ағынды қамтамасыз ету мәселесін толық шешуді қамтамасыз етпейді. минералдардың ,бактериялардың немесе металдардың түзілген шөгінділерінің түрлері. Мақалада SolidWorks бағдарламалық кешенін қолдана отырып, суасты сорғысының электр қозғалтқышының корпусының айналасындағы сұйықтық ағынын модельдеудің жетілдірілген әдісі ұсынылған, бұл салқындатқыш қаптамалардың құрылымдық параметрлерін негіздеу арқылы қозғалтқышты салқындату мәселесін шешуге мүмкіндік береді. Жұмыстың мақсаты электр қозғалтқышы орамаларының температурасы рұқсат етілген шектерде болатын сорғы қондырғыларының қозғалтқыштарын тұрақты салқындату жағдайларын қамтамасыз ету болып табылады, бұл суасты сорғыларының ұзақ қызмет етуінің негізгі сәті болып табылады. Осы мақсатқа жету үшін суасты сорғысының электр қозғалтқышы бойымен сұйықтықтың турбулентті құйынды ағынын модельдеу және салқындатқыш қаптамалардың құрылымдық параметрлерін зерттеу әдісін әзірлеу міндеті шешілуде. Зерттеу әдістемесі сандық модельдеу әдістерін де, эксперименттік зерттеулерді де қамтыды. Алынған нәтижелер сорғы қондырғысының айналасындағы сұйықтық жылдамдығының өрістерін егжей-тегжейлі сипаттауға, жүйенің гидродинамикалық мінез-құлқының ерекшеліктерін анықтауға және суасты сорғы қондырғыларының ұзақ жұмыс істеуіне әсер ететін параметрлерді анықтауға мүмкіндік берді.

Негізгі сөздер: *ағын жылдамдығы, сұйықтық, суасты сорғысы, электр қозғалтқыш, гидродинамика, құрылымды оңтайландыру, жұмыс тиімділігі, өнімділік, энергия шығыны, жылдамдық өрісі, сұйықтық ағыны.*

Исследование скоростных режимов потоков жидкости вокруг электродвигателей погружных насосов

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Аннотация. Водоснабжение и водоотведение относится к отраслям промышленности с интенсивным использованием насосного оборудования, доля электроэнергии, потребляемой насосами, составляет более 50% от общего энергопотребления. Поэтому вопрос повышения энергетической эффективности водоснабжения заключается, прежде всего, в рациональной эксплуатации насосного оборудования. Одной из причин снижения технико-экономических показателей работы погружных насосных установок является выход из строя электродвигателей насосов из-за перегрева в процессе работы. В любом электрическом двигателе во время работы даже с самым высоким КПД часть подводимой электрической энергии идет на нагрев, чтобы двигатели не перегревались и не выходили из строя их нужно охлаждать .Двигатели для скважинных насосов в отличие от поверхностных имеют иную конструкцию, и у них нет вентилятора , но их во время эксплуатации тоже необходимо охлаждать. Но для того, чтобы двигатель нормально охлаждался, вокруг него должна быть определена необходимая скорость потока жидкости. Эту скорость можно обеспечить при помощи охлаждающих кожухов. Особенно актуален этот вопрос, когда погружные насосы используются для подачи воды из емкостей, цистерн или открытых водоемов, где применение охлаждающих кожухов обязательно. Заводы производители погружных насосов в технических характеристиках указывают минимально допустимую скорость жидкости для охлаждения корпуса электродвигателя. Если скорость обтекания электродвигателя насосов меньше, чем указано в технических характеристиках на оборудования, то необходимо определять минимально допустимую скорость потока жидкости вокруг двигателя насоса. В этой связи обоснование и развитие методов исследования и расчета параметров потока жидкости вокруг двигателя насоса, является актуальной научной и практической задачей, имеющей отраслевое значение. Вместе с тем , на современном этапе существующие методы и два способа определения скорости потока жидкости вокруг двигателя погружного насоса: расчетный- при помощи аналитических формул и графический - при помощи графиков рациональных областей применения охлаждающих кожухов не обеспечивают достаточно полного решения задачи обеспечения турбулентного вихревого потока вдоль электродвигателя , препятствующего образованию отложений и обеспечивающего охлаждение двигателя независимо от вида образовавшихся отложений минералов, бактерий или металлов. В статье предлагается усовершенствованная методика моделирования потока жидкости вокруг корпуса электродвигателя погружного насоса с использованием программного комплекса SolidWorks, позволяющая решить задачу охлаждения двигателя путем обоснования конструктивных параметров охлаждающих кожухов. Целью работы является обеспечение условий устойчивого охлаждения двигателей насосных установок, при которых температура обмоток электродвигателя будет находится в допустимых пределах, что является основным моментом в долговечности работы погружных насосов. Для достижения поставленной цели решается задача разработки методики моделирования турбулентного вихревого потока жидкости вдоль электродвигателя погружного насоса и исследования конструктивных параметров охлаждающих кожухов. Методика исследования включала как численные методы моделирования, так и экспериментальные исследования. Полученные результаты позволили детально охарактеризовать поля скоростей жидкости вокруг насосного агрегата, выявить особенности гидродинамического поведения системы и определить параметры, влияющие на долговечность работы погружных насосных установок.

Ключевые слова: *скорость потока, жидкость, погружной насос, электродвигатель, гидродинамика, оптимизация конструкции, эффективность работы, производительность, потери энергии, поля скоростей, течение жидкости.*

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