**UDC** 521.597
**DOI** 10.52171/2076-0515_2024_16_04_08_16

# Forced Air-nano-fluid Cooling of Friction Pairs of Disc-pad Brake Devices

**A.Kh. Janahmadov[1], D.A. Volchenko[2], M.Ya. Javadov[3], N.A.Volchenko[4], V.S. Skrypnyk[5], A.V. Vozniy[6]**

*[1]Azerbaijan National Aviation Academy (Mardakan ave., 30, Baku, AZ1045, Azerbaijan)*
*[2]Ivano-Frankivsk National Technical University of Oil and Gas (Karpatska st. 15, Ivano-Frankivsk, 76019, Ukraine)*
*[3]Azerbaijan Engineering Academy (Mardakan ave., 30, Baku, AZ1045, Azerbaijan)*
*[4]Kuban State Technological University (Moskovskaya st., 2, Krasnodar, 350072, Russia)*
*[5]Vocational College of the National Transport University (Sobornaya st. 117, Nadvirnaya, Ivano-Frankivsk, 78400, Ukraine)*
*[6]Kharkov National Automobile and Highway University (Yaroslav Mudryi st. 25, Kharkiv, 61002, Ukraine)*

**For correspondence:** Vozniy Andrey / e-mail: andrii.voznyi@gmail.com

**Abstract**

The development of designs and the theoretical studies of tubular type disk-pad brakes of draw-works with the forced air-nanofluid cooling of their friction pairs allowed to establish the following: improved wear-friction properties of friction pairs were achieved due to operation in a temperature range below the permissible for the materials of friction linings and, as a result, braking qualities for the lifting shaft of the drilling rig; nanopowder of fusible metals are applied to the liquid, diluted with water or acetone, which allowed to significantly increase the thermal conductivity coefficient of the nanoliquid and thus improve the efficiency of forced cooling of the friction belts of the brake discs; it is necessary to observe the condition that the volumes of nanofluid in the evaporation zones are much larger than in the zones of its condensation, which intensifies the heat exchange in different aggregate states of the nanofluid due to increased cycles of its circulation; accelerators of nanofluid movement in any aggregate state between the evaporation and condensation zones in their heated state are diffusers, and retarders are confusors acting as a transport zone, as well as non-continuous slits in the lower ring of the main disk, which cause changes in the gradients of speed, pressure and temperature in nanofluid layers; the surface-volume gradient of the temperature of the friction belts during braking in the main disk of the tubular structure is insignificant, and the depth gradient is small in magnitude.

**Keywords:** drawwork, serial disk-pad brake; forced air cooling, forced nanoliquid cooling, disk-pad brake.

***Received*** *05.07.2024*
***Revised*** *13.12.2024*
***Accepted*** *16.12.2024*

**For citation:**
*A.Kh. Janahmadov, D.A. Volchenko, M.Y. Javadov, N.A. Volchenko, V.S. Skrypnyk, A.V. Vozniy*
[Forced Air-nano-fluid Cooling of Friction Pairs of Disc-pad Brake Devices]
*Herald of the Azerbaijan Engineering Academy,* 2024, vol. 16, № 4, pp. 8-16 *(in English)*

## Diskli-kündəli əyləclərin sürtünmə cütlərinin hava-nanomaye ilə məcburi soyudulması

**Ə.X. Canəhmədov[1], D.A. Volçenko[2], M.Ya. Cavadov[3], N.A. Volçenko[4], V.S. Skrıpnık[5], A.V. Voznıy[6]**
[1]*Azərbaycan Milli Aviasiya Akademiyası (Mərdəkan pr. 30, Bakı, AZ1045, Azərbaycan)*
[2]*İvano-Frankivsk Milli Texniki Neft və Qaz Universiteti (Karpatska küç. 15, İvano-Frankivsk, 76019, Ukrayna)*
[3]*Azərbaycan Mühəndislik Akademiyası (Mərdəkan pr. 30, Bakı, AZ1045, Azərbaycan)*
[4]*Kuban Dövlət Texnologiya Universiteti (Moskovskaya küç. 2, Krasnodar, 350072, Rusiya)*
[5]*Milli Nəqliyyat Universitetinin İxtisaslaşdırılmış Kolleci (Soborna küç. 117, Nadvirna, İvano-Frankivsk vilayəti, 78400, Ukrayna)*
[6]*Xarkov Milli Avtomobil və Yol Universiteti (Yaroslav Mudri küç. 25, Xarkov, 61002, Ukrayna)*

**Xülasə.** Sürtünmə cütlərinin məcburi hava-nanomaye ilə soyudulması zamanı qazıma bucurqadının diskli (boru tipli)-kündəli əyləclərin konstruktor işlənməsi və nəzəri tədqiqatları aşağıdakıları müəyyən etməyə imkan verdi: sürtünmə cütlərinin təkmilləşdirilmiş yeyilmə-sürtünmə xassələri friksion kündə materialları üçün buraxıla bilən temperaturdan aşağı temperatur diapazonunda istismar nəticəsində əldə edilmiş və nəticədə, qazıma qurğusunun qaldırıcı valının əyləc keyfiyyətlərinə nail olunub; mayelər üçün su və ya aseton ilə həll olunmuş asan əriyən metalların nanotozlarından istifadə edilmişdir ki, bu da nanomayenin istilik keçiricilik əmsalını əhəmiyyətli dərəcədə artırmağa və əyləc disklərinin sürtünmə kəmərlərinin məcburi soyudulmasının səmərəliliyini yaxşılaşdırmağa imkan verib; nanomayelərin hərəkət sürətləndiriciləri buxarlanma və kondensasiya zonaları arasında istənilən aqreqasiya vəziyyətində onların qızdırıldığı zaman – diffuzorlar, gecikdiriciləri isə nəqliyyat zonası rolunu oynayan – konfuzorlar, həmçinin əsas diskin aşağı halqasında nanomaye laylarında sürət, təzyiq və temperatur qradiyentlərində dəyişikliklərə səbəb olan kəsikli yuvalardır; boru konstruksiyasının əsas diskində əyləcləmə zamanı sürtünmə kəmərlərinin səthi-həcmi temperatur qradiyenti aşağı səviyyədədir, dərinlik qradiyenti isə kiçikdir.
**Açar sözlər:** qazıma bucurqadı, seriyalı diskli-kündəli əyləc, məcburi hava soyudulması, məcburi nanomaye soyudulması, diskli-kündəli əyləc.

---

## Принудительное воздушно-наножидкостное охлаждение пар трения дисково-колодочных тормозных устройств

**А.Х. Джанахмедов[1], Д.А. Вольченко[2], М.Я. Джавадов[3], Н.А. Вольченко[4], В.С. Скрыпнык[5], А.В. Возный[6]**
[1]*Азербайджанская Национальная академия авиации (пр. Мардакан, 30, Баку, AZ1045, Азербайджан)*
[2]*Ивано-Франковский национальный технический университет нефти и газа ((ул. Карпатская, 15, г. Ивано-Франковск, 76019, Украина))*
[3]*Азербайджанская Инженерная академия (пр. Мардакан, 30, Баку, AZ1045, Азербайджан)*
[4]*Кубанский государственный технологический университет (ул. Московская, 2, Краснодар, 350072, Россия)*
[5]*Специализированный колледж Национального транспортного университета (ул. Соборная, 117, Надворная, 78400, Украина)*
[6]*Харьковский национальный автомобильно-дорожный университет (ул. Ярослава Мудрого, 25, Харьков, 61002, Украина)*

**Аннотация.** Конструкторские разработки и теоретические исследования дисково-колодочных (трубчатого типа) тормозов буровых лебедок при принудительном воздушно-наножидкостном охлаждении их пар трения позволили установить следующее: достигнуто улучшение износо-фрикционных свойств пар трения за счет эксплуатации в интервале температур ниже допустимых для материалов фрикционных накладок и, как следствие, тормозных качеств для подъемного вала буровой установки; для жидкости применены нанопорошки легкоплавких металлов, разбавленные водой или ацетоном, что позволило значительно увеличить коэффициент теплопроводности наножидкости и улучшить эффективность принудительного охлаждения поясов трения дисков тормоза; ускорителями движения наножидкости в любом агрегатном состоянии между зонами испарения и конденсации при их нагретом состоянии являются диффузоры, а замедлителями – конфузоры, выступающие в роли транспортной зоны, а также несплошные прорезы в нижнем кольце основного диска, которые вызывают изменения градиентов скорости, давления и температуры в слоях наножидкости; поверхностно-объемный градиент температуры поясов трения при торможении в основном диске трубчатой конструкции является незначительным, а глубинный градиент по величине маленький.
**Ключевые слова:** буровая лебедка, серийные дисково-колодочные тормоза; вынужденное воздушное охлаждение, принудительное наножидкостное охлаждение, дисково-колодочные тормоза.

## Introduction

The basis of lowering and lifting operations (SPO) of the drill pipe column is the effective and safe operation of the winch equipped with a pair of belt-pad brakes (main) and hydrodynamic or electrodynamic brakes (auxiliary). When braking by friction pairs of the brake of a moving string of drill pipes to a depth of 4.0-5.0 km, $4 \cdot 10^8$ J of energy is generated, and the surface-volume temperatures of the surface and subsurface layers of the friction nodes reach up to 1000°C on their adjacent surfaces, which leads to the deterioration of wear and friction properties and a decrease in the main operational parameters. It was established that the replacement of friction linings with metal pads in six calipers of disc-pad brakes with hydraulic drives takes only 1.0 hours, and the replacement of 44 linings with uneven wear of their working surfaces on brake bands takes 6.0 hours. It is not for nothing that disc-pad brakes with hydraulic drives of drilling winches are technologies of the present century, which ensure the energy intensity and efficiency of their friction pairs with locally adjustable specific loads and braking moments.

**Analysis of literary data and formulation of the problem.** The work [1] is devoted to increasing the energy capacity of wheel brakes by introducing a reverse friction pair with liquid cooling of discs. The proposed liquid cooling system is cumbersome and suitable only for laboratory studies. Means of increasing the efficiency of forced air cooling of disk-pad brakes of vehicles are considered in work [2]. Different types of air flow turbulizers directed at the friction belts of the discs were used for cooling. The efficiency of such cooling averaged 6.0%.

Forced liquid cooling of the belt-pad brake tribosystem of a drilling winch is presented in [3]. The system consisted of cameras located under the rim of the pulley. Water was used as a heat carrier. The efficiency of such a system was no more than 12.5%.

The increase in energy consumption of friction disk-pad brakes of drilling winches for lowering and lifting operations over a string of drill pipes into a well is shown in [4]. Designs of disc-pad brakes with a hydraulic drive for drilling winches, providing SPO at various drilling depths, are given.

Similarly, in the materials of the article, there are no graphic regularities connecting the dynamic, thermal, and structural parameters of the disc-pad brakes of the drilling complex with the depth of the well and with the weight of the drill pipe string.

The paper [5] is devoted to thermoelastic contact problems in tribology. The latter refers to ideal and non-ideal contacts at the expense of ohmic, neutral and blocking contacts, which differ in terms of the release of particles from conjugated metal-polymer surfaces during electro-thermomechanical friction.

The work [6] is devoted to the methods of studying the contact interaction of thermoelastic bodies based on the condition of local friction, taking into account frictional heating and wear. It was necessary to introduce forced and forced air cooling into the research, which would increase the practical value.

**The purpose of the work** is to generate heat on the local areas of the contacts of the microprotrusions of the friction pairs of the new disk (tubular) - pad brake of forced air-liquid cooling for the drilling winch.

**Heat generation during electrothermomechanical friction on local areas of contact of microprotrusions of friction nodes.** It is known that when two metal microprotrusions rub together, electrical and thermal energy is generated. Subsequently, electrical energy turns into thermal energy and thus increases it. During the frictional interaction of metal microprotrusions of friction pairs, only local ohmic contacts with high thermal conductivity arise.

Modern ideas about heat generation from the action of constant and variable frictional forces are based on the fact that during the relative sliding of two bodies in contact, on the one hand, elastic and plastic deformations of the contacting micro-uniformities take place, and on the other hand, their molecular interaction is overcome, and all this together leads to chaotic (thermal) movement of electrons and ions in thin near-surface layers of interacting bodies. The electric and thermal component formed in this way spreads from the contact spots of the microprotrusions into the depth of the body. Heat flows between bodies are distributed depending on their thermophysical properties, their sizes and conditions of heat dissipation. Part of the heat dissipates into the environment by convective and radiative heat exchange. The intensity of the heat flow generated at the contacts of the microprotrusions depends on many factors, in particular, the impulse friction forces, the stress-strain state of the bodies at the local areas of the contacts, the speed of the relative movement of the bodies, the thermophysical and geometric parameters of the friction unit.

Therefore, the problem of frictional contact interaction of two bodies, taking into account heat generation from the action of constant and variable impulse frictional forces, should be considered as a limiting problem of thermoelasticity for these bodies under the influence of distributed heat sources of unknown intensity on the contact areas.

Since in the future we will consider the problems of local frictional contact interaction of microprotrusions of bodies taking into account heat generation from the action of impulse friction forces, we will present the thermal conditions at the contact spots of microprotrusions. The first time they were formulated by F.F. Lingom in 1969. He assumed that two conditions are met in each contact point of microprotrusions: the sum of the intensities of the heat flows going to the contact microprotrusions is equal to the specific work of the friction forces; surface and bulk temperatures are equal. That is $q_1 + q_1 = v_0\tau_0$, $t_1 = t_2$ on $A$ (contact spot area).

Since $q_1 = \lambda_1 \frac{\partial t_1}{\partial v}$, $q_2 = -\lambda_2 \frac{\partial t_2}{\partial v}$, the preliminary relations have the form

$$\lambda_1 \frac{\partial t_1}{\partial v} - \lambda_2 \frac{\partial t_2}{\partial v} = v_0\tau_0,\ t_1 = t_2 \text{ on } A. \quad (1)$$

In conditions (1) $v_0$ is the sliding speed of microprotrusion spots on the surfaces of others on separate areas of contact; $\tau_0$ - tangential stresses on given spots of contact of microprotrusions; $t_i$ and $\lambda_i$ ( $i$ = 1, 2), respectively, surface-volume temperatures and their thermal conductivity coefficients; $v$ - normal to the surface of a separate contact area.

If there is no heat generation on a separate section of microprotrusions of the contact, then the right-hand side in the first ratio of conditions will be equal to zero and there will be the usual conditions for an ideal thermal contact of microprotrusions.

In reality, the surface-volume temperatures of touching microprotrusions at local areas of contact spots will be different, which is due to a number of reasons, in particular, the characteristics of the roughness of microprotrusions, at which their surface-volume temperatures experience jumps at local areas of contacts, called non-ideal or imperfect.

We present the conditions of non-ideal thermal contact in the form of a ratio

$$q_1 + q_1 = v_0\tau_0,\ q_1 - q_1 = h(t_2 - t_1) \text{ on A,} \quad (2)$$

where: $h$ is the coefficient of thermal conductivity of local contact microprotrusions, W/(m$^2$ ·°C).

The latter depends on many factors: the materials of the microprotrusions of the friction pairs and the cleanliness of their surface treatment, the thermal conductivity coefficients of the touching spots of the microprotrusions, the impulse specific loads between them, the average surface-volume temperature in the local area of contact, etc. The coefficient specified above is determined on the basis of theoretical and experimental studies. In the limiting case, when h → ∞, from conditions (2), we obtain conditions for ideal thermal contact of microprotrusions (1).

The inverse value of $h$ is called the thermal resistance of the local area of contact of microprotrusions.

If we take into account the dependences between the heat fluxes and the derivatives along the normal of the local areas of the contacts of the microprotrusions and the corresponding surface and volume temperatures, which are written before conditions (1), then relations (2) have the form

$$\lambda_1 \frac{\partial t_1}{\partial v} - \lambda_2 \frac{\partial t_2}{\partial v} = v_0\tau_0,$$

$$\lambda_1 \frac{\partial t_1}{\partial v} + \lambda_2 \frac{\partial t_2}{\partial v} + h(t_1 - t_2) = 0 \text{ on } A. \quad (3)$$

If we consider that $q_1 = -\lambda_1 \frac{\partial t_1}{\partial v}$, and $q_2 = \lambda_2 \frac{\partial t_2}{\partial v}$, then conditions (3) will be written by the following relations:

$$\lambda_1 \frac{\partial t_1}{\partial v} - \lambda_2 \frac{\partial t_2}{\partial v} = -v_0\tau_0,$$

$$\lambda_1 \frac{\partial t_1}{\partial v} + \lambda_2 \frac{\partial t_2}{\partial v} - h(t_1 - t_2) = 0 \text{ on } A. \quad (4)$$

Conditions (3) and (4) are equivalent. Analytical calculations of temperature fields of local areas use both one and the other. In our case, we will use conditions (3).

Ya.S. Pidstrigach [7] established the thermal contact conditions of metallic microprotrusions connected to each other by a third body through a thin intermediate layer, which is endowed with its thermophysical properties, different from those of metallic microprotrusions. From the mentioned conditions, under certain assumptions, it is possible to obtain dependences (4) on the local section of microprotrusion contacts. The performed calculations showed that the average surface-volume temperature at the local area of contacts is equal to $t = \frac{1}{2}(t_1 + t_2)$, found using conditions (4) with a wide range of variation of the parameter $h$, slightly different from the surface-volume temperature of microprotrusions at the local area of friction, determined under the condition of ideal thermal contact.

When assessing the energy activity of local contact interaction of microprotrusions of friction pairs, contacts are formed under variable specific loads and surface-volume temperatures in relation to the work function of a mixture of electron-ion particles from the surface working layers of metal friction elements ($W_m$) and polymer coating ($W_n$), accord-

ingly, with ohmic, neutral, and blocking contacts under the following conditions:
$W_m > W_n$ – intensive heat dissipation occurs from the surfaces of the metal element; $W_m = W_n$ – quasi-stationary energy loading of the interface surface is observed; $W_n > W_m$ – the working surface of the metal element is shielded locally, which leads to a noticeable increase in the heat capacity and coefficient of thermal conductivity of its material, and as a result, a new phenomenon arises - superconductivity [8].

**The design and operation of a disc (tubular type) – pad brake with a hydraulic drive of a drilling winch.** Serial drilling winch 1 consists of a pair of disc-pad brakes 2, which have brake discs with friction belts 3, which are covered by calipers 4 with friction linings 5 on a metal base and ring holders 6, installed by spring devices 7 and hydraulic drives 8 (Fig. 1 a, b).

The disk-pad brake with forced air cooling works during lowering and lifting operations of the drill pipe string depending on its weight in aperiodic cyclic and long-term braking modes. Disc-pad brakes 2 are installed on both sides of the drum 1 of the drilling winch. They have solid metal discs 3, on the friction belts of which there are calipers 4, which have pincer holders 5 of two-way action, which are friction pads 5 on metal substrates. Spring devices 7 for switching on and off the supports 4 are placed on top. At the same time, calipers 4 have individual hydraulic drives 8.During braking, a large amount of heat is generated in the couplings of the friction pairs of brakes, which cannot be additionally diverted to the environment from the matte and polished surfaces of the brake discs. To intensify the forced air-nanofluid cooling of the friction pairs of the disk-pad brake of the drilling winch, the present system is proposed (Fig. 2 a, b). The scheme of arrangement of brake calipers with pincer holders is presented in Fig. 3.

According to fragments of a new type of disc-pad brakes with a forced air-nano-liquid cooling system, we have the following. The structure is tubular. The main brake disk with friction belts 1 rests on solid 7 and with non-solid slots 8 rings. There are overlapping zones with friction linings 2. The main 1 and additional 9 discs have chambers, the volumes of which are connected to each other on semicircles by diffusers 4 and baffles 3.

With extremely strong heat generation on the friction surface of the discs in the brakes, the ordinary liquid in the chambers of their volumes can almost instantly turn into steam, which will cause an explosion in them. An illustrative example is the amount of water that is released to evaporate 6 gallons of water (27.0 L) per minute. As coolants in the chambers of the main and additional disks in the cooling system, low-melting metals Na ($t_n$= 97.79°C) and Li ($t_n$ =180.5°C) in the form of powders mixed with water, which are called nanofluids, are used. The latter is used depending on the energy load of friction pairs of disc-pad brakes of drilling winches. Lithium powder (Li) in nanofluids (50% lithium powder and 50% water) is used for both the main and additional brake discs, capable of removing significant heat flows (of the order of 15.0 kW/cm$^2$ at the surface-volume temperature of friction pairs of 800° WITH). Filling the cooling system is done through a hole with a closable plug (not shown in Fig. 2 a, b) on ¾ of the volume of the disc chambers. In addition, the nanofluid itself in the cooling system is not shown due to its aggregate state.

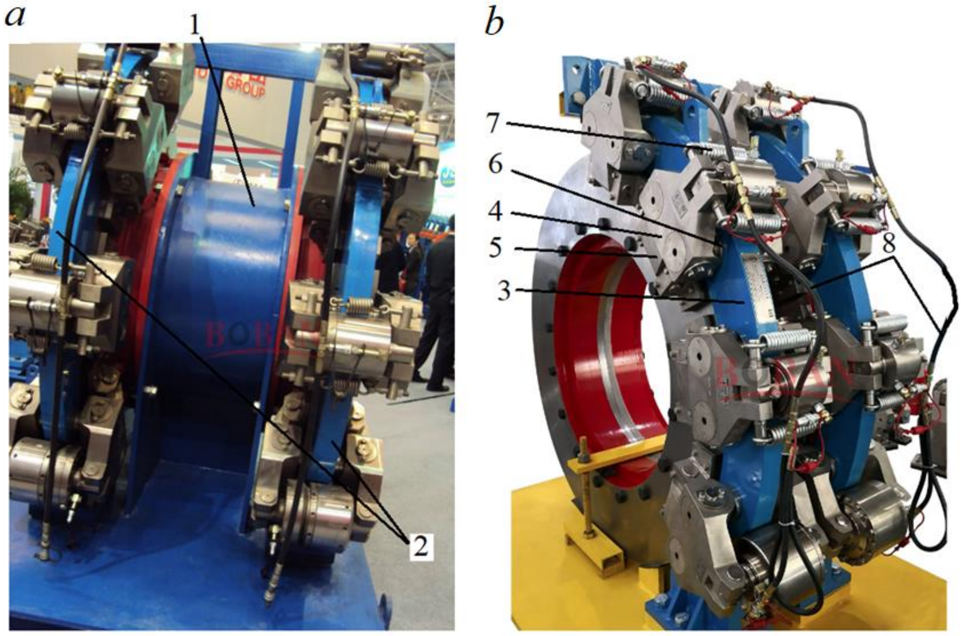


**Figure 1 a, b –** Drilling winches with serial air-cooled disc–pad brakes (a) and hydraulically driven dis –pad brakes (b): 1 – winch drum; 2 – disc-pad brakes; 3 – solid disks; 4, 5 and 6 calipers with pincer holders and linings with a metal backing; 7 – spring device; 8 – hydraulic drive

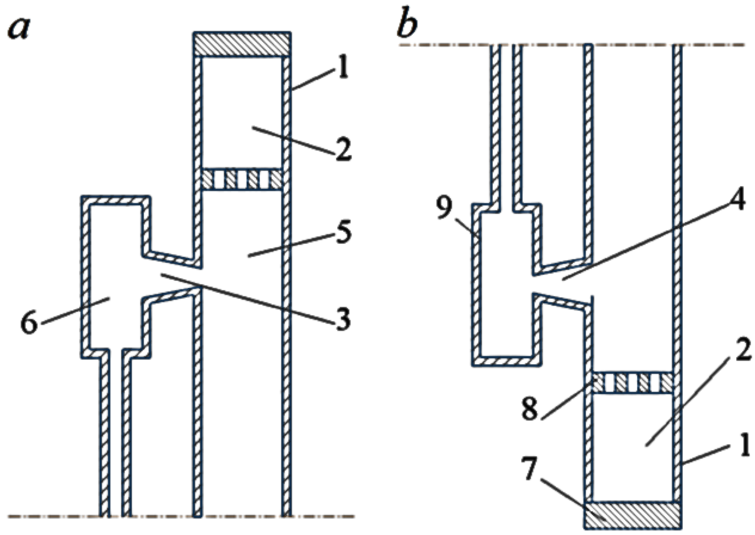


**Figure 2 a, b** – Combined disc-pad brake friction belt with a forced air-nanofluid cooling system:
1 – friction belt; 2 – overlap zones with friction overlays; 3 – confusors; 4 – diffusers;
5, 6 – zones: evaporation, condensation; 7 - solid slots rings; 8- non-solid slots rings; 9 - additional discs.
*a* and *b* – the upper and lower parts of the tubular system, which is not filled with nanofluid.

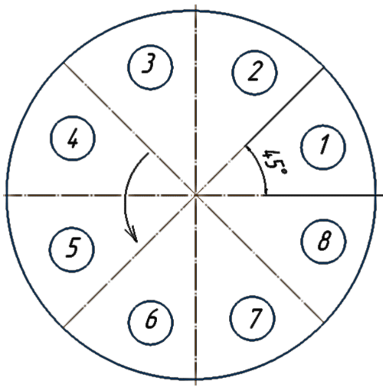


**Figure 3** – Scheme of arrangement of brake calipers with clamp holders when drilling a deep well with a drilling rig model PS440-9000

The driving force in the processes of heating and cooling of the friction belts of the brake discs are the temperature gradients of the nanofluid layers, which take place in the zones of evaporation 5, condensation 6 and transport (confusers 3, diffusers 4), located in the volumes of the chambers and their connecting main 1 and additional 9 discs . When the latter rotate, the centrifugal force drives the nanofluid to the inner walls of the disk chambers. Non-continuous slits in the lower ring of the chamber of the main disc are recognized as a retarder of the nanofluid's residence time in the evaporation zone.

The method of forced air-nanofluid cooling of friction pairs of a disc-pad brake of a drilling winch consists in the fact that the evaporation zone 5 of the nanofluid is the volume of the main brake disc 1, and its condensation zone 6 is the volume of the additional disc 9, and at the same time, the diffusers 4 and confusors 3 perform functions of the transport zone between them, as well as accelerators and decelerators of internal heat exchange processes associated with different aggregate states of the nanofluid, and the external system of forced cooling of the matte and polished surfaces of the rotating disks 1 and 9 is subject to convective and radiative heat exchange, washed by the air flows of the environment.

## Discussion of the results

Design and theoretical studies of disc (tubular type) - pad brakes of drilling winches with forced air-nanofluid cooling of their friction pairs allowed us to establish the following:

- improved wear-frictional properties of friction pairs due to operation in the temperature range lower than permissible for materials of friction linings [9], as a result, braking qualities for the lifting shaft of the drilling rig;

- applied to the liquid nanopowder of fusible metals, diluted with water or acetone, which made it possible to significantly increase the coefficient of thermal conductivity of the nanoliquid and thereby improve the efficiency of forced cooling of the friction belts of the brake discs;

- it is necessary to observe the condition that the volumes of nanofluid in the evaporation zones are much larger than in the zones of its condensation, which intensifies the heat exchange in different aggregate states of the nanofluid due to increased cycles of its circulation;

- the forced air heat exchange with the surrouRnding environment of the matte and polished surfaces of the main and additional disks by heat conduction, convection and radiation was taken into account, which allowed to determine a smaller part of the heat removed from their surfaces during braking;

- the accelerators of nanofluid movement in any aggregate state between the evaporation and condensation zones in their heated state are diffusers, and the retarders are confusors acting as a transport zone, as well as non-continuous slots in the lower ring of the main disk, which cause changes in the gradients of velocity, pressure and temperatures in nanofluid layers;

- the surface-volume gradient of the temperature of the friction belts during braking in the main disk of the tubular structure is insignificant, and the depth gradient is small in magnitude.

**Conclusion**

Thus, the intensification of heat sink cycles "evaporation zone - transport zone - condensation zone" of nanofluid in any state of aggregation in the volumes of the chambers of the main and additional disks will allow to increase the efficiency of the braked disk-pad brakes of the drilling winch when the drill pipe column is lowered into the well.

**Conflict of Interests**

The authors declare there is no conflict of interests related to the publication of this article.

## REFERENCES

**1. Datsdyn S.I.** Increasing the energy intensity of wheel brakes by introducing a reverse friction pair with liquid-cooled discs / S.I. Datsdyn (abstract of candidate of technical sciences). M.: *MGAAiTM*, 1994. – 23 p. *(in English)*

**2.** Patent of the Russian Federation, according to application No. 2000101434/28, cl. F16D65/80, Method for cooling a disc brake mechanism, patent holder V.A. Makarov, 2001. – 5 p. *(in English)*

**3.** Forced cooling of the tribosystem of the band-block brake of a drilling drawworks / A. Kh. Janahmadov, A.I. Volchenko, E.S. Perverdiev [and others] // *Herald of the Azerbaijan Engineering Academy*. 2018, vol. 10, №. 2. Pp. 7-19. *(in English)*

**4. Aliev A.M.** Increasing the energy intensity of friction brakes for lowering and lifting operations. *Herald of the Azerbaijan Engineering Academy*. 2018, vol. 10, №. 4. Pp. 17-22. *(in Azerbaijani)*

**5. Grilitsky D.V.** Thermal contact problems in tribology. - Kiev. 1996. – 200 p. *(in Russian)*

**6. Evtushenko O.O.** Methods for monitoring the contact interaction of thermospring bodies for local rubbing due to frictional heating and wear: dis. doc. Physics and Mathematics Sciences: 01.02.04. Lviv, 2000. – 342 p. *(in Russian)*

**7. Podstrigach A.S.** Temperature field in a system of solids conjugated using an intermediate layer. Inzh., 1963. T.6. №. 10. pp. 129-136. *(in Russian)*

**8. Janahmadov A.Kh., Volchenko D.A., Volchenko N.A. [etc.].** Disc and disc-pad brakes in mechanical engineering. 2021. Vol.2. Baku: *Apostrof-A.* – 392 p. *(in Russian)*

**9.** Handbook of tribology: In 3 volumes. Under the general editorship. M. Hebty, A.V. Chichinadze. – T.1. Theoretical foundations. – M.: *Mechanical Engineering*, 1989. – 400 p. *(in English)*