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Selection of Materials and Interrelation of Operating Parameters of Friction Pairs of a New Type of Disc-Shoe Brake of a Drilling Winch

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Abstract

Experimental design developments and theoretical studies of disk (tubular type) - shoe brakes of drilling drawworks with forced air cooling of their friction pairs made it possible to establish the following: a method for selecting materials for friction pairs based on their dynamic and thermal energy loading was proposed; the average radius of the disk friction belt and their mutual overlap coefficient were introduced to the known design parameters of friction pairs; the influence of the design parameters of a serial disk brake on the weight of the drill pipe string lowered into the well and its operating parameters, from which the braking torque was extracted; the influence of constant and variable design and operating parameters on the braking torque and a comparison of its value for different cases.

Keywords: new disc-shoe brake, friction pair, design and operational parameters, relationship of parameters.

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Qazıma bucurqadının yeni növ diskli-kündəli əyləcinin sürtünmə cütlərinin materiallarının və istismar parametrlərinin qarşılıqlı əlaqəsinin seçilməsi

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Xülasə

Məqalədə sürtünmə cütləri üçün materialların dinamik və istilik enerjisi yükü əsasında seçilməsi metodu təklif olunub. Sürtünmə cütlərinin məlum konstruksiya parametrlərinə diskin sürtünmə kəmərinin orta radiusu və onların qarşılıqlı örtmə əmsalı əlavə edilib. Seriyalı disk əyləcinin konstruksiya parametrlərinin quyuya endirilən qazıma borularının çəkisinə təsiri və onun əyləc momentinin istismar parametrləri nəzərdən keçirilib. Sabit və dəyişən konstruksiya və istismar parametrlərinin əyləc momentinə təsiri öyrənilib və müxtəlif hallar üçün qiymətlərinin müqayisəsi verilib.

Açar sözlər: yeni diskli-kündəli əyləc, sürtünmə cütü, konstruksiya və istismar parametrləri, parametrlərin qarşılıqlı əlaqəsi.

Выбор материалов и взаимосвязь эксплуатационных параметров пар трения нового типа дисково-колодочного тормоза буровой лебедки

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Аннотация

В статье предложен метод выбора материалов пар трения, исходя из их динамической и тепловой энергонагруженности. К известным конструктивным параметрам пар трения введены средний радиус пояса трения диска и их коэффициент взаимного перекрытия. Рассмотрено влияние конструктивных параметров серийного дискового тормоза на вес колонны бурильных труб, спускаемых в скважину, и его эксплуатационные параметры, из которых выделен тормозной момент. Изучено влияние на тормозной момент постоянных и переменных конструктивных и эксплуатационных параметров и дано сравнение его значений для различных случаев.

Ключевые слова: новый дисково-колодочный тормоз, пара трения, конструктивные и эксплуатационные параметры, взаимосвязь параметров.

Introduction

With the current level of development of computer technology, which allows even on a personal computer to simulate objects with a total number of degrees of freedom of the order of hundreds of thousands using the finite element method (FEM), there are still many unsolved technical problems, including in the field of drilling winches, such as the conditions of frictional interaction of the friction belt of the brake disk with the working surface of the friction lining, the problem of a comprehensive study of the braking process in the relationship of design and operational parameters affecting the energy capacity of a new type of disc-shoe brake of a drilling winch.

In the work [1] a comparison of foreign models of disc-shoe brakes with hydraulic drive PS440-9000 and PS40-900 of drilling rigs ZJ12 and ZJ15 was made. It was found that in order to increase the braking torque by 11 times, the diameter of the brake disc is increased by 1.7 times, the number of brake units is increased from 2 to 7, during sharp braking from 1 to 3, and the pressure in the hydraulic system increases from 7.0 to 8.0 MPa.

Based on a systems approach, the possibility of forming equivalent series of friction pairs of modular disc-shoe brakes of mine hoisting machines of various lifting capacities has been demonstrated [2], using brake friction pairs in them, which have been tested and studied on vehicles as a dynamic model.

The method of forced air-nano-liquid cooling of friction pairs of a drilling winch disc-shoe brake [3] consists in the fact that the evaporation zone of the nano-liquid is the volume of the main brake disc, and the zone of its condensation is the volume of the additional disc, and at the same time, diffusers and confusers perform the functions of a transport zone between them, as well as accelerators and retarders of internal heat exchange processes associated with different aggregate states of the nano-liquid, and the external system of forced cooling of matte and polished surfaces of rotating discs is subject to convective and radiation heat exchange, washed by air flows of the environment.

In [4], it was proven that the thickness of the brake disc has an uneven effect on the surface-volume temperatures and equivalent stresses that arise during electro-thermomechanical friction. In a 45.0 mm thick disc, the surface-volume temperatures are somewhat lower due to its metal content than in a 35.0 mm thick disc. In the first disc, high equivalent stresses arise due to a more uneven distribution of the surface-volume temperature in it. In the second disc, the surface-volume temperature was higher, but lower equivalent stresses arise in it.

The work [5] is devoted to the development of a disc-shoe brake for high-speed rail transport. It addressed the issue of increasing the traction and motor-car rolling stock while maintaining a high level of safety.

The aim of the work is to establish a connection in the selection of materials and design and operational parameters of new types of disc-shoe brakes for drilling winches when lowering pipe candles into a well.

Interrelation of operational parameters of disk (tubular type) - shoe brakes of drilling winches when choosing materials of their friction pairs. According to fragments of a new type of disk-shoe brakes

with a forced air-nano-liquid cooling system, we have the following (Fig. 1). The design is tubular. The main brake disk with friction belts 1 rests on strength solid 7 and with non-solid cuts 8 rings. Here are also located the overlap zones of friction linings 2. The main 1 and additional 9 disks have chambers, the volumes of which are connected to each other on semicircles by diffusers 4 and confusers 3.

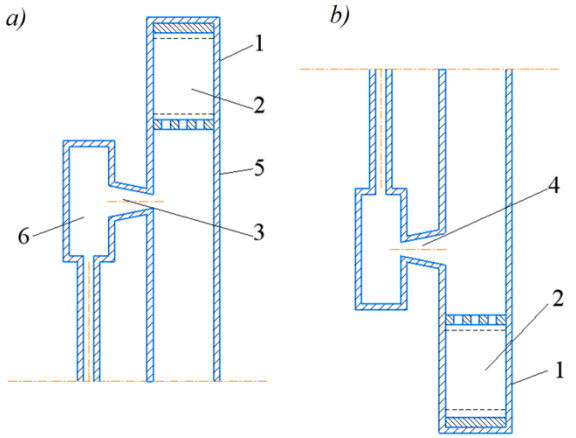

Figure 1 a, b – Combined friction belt of a disc-shoe brake with a forced air-nano-liquid cooling system: 1 – friction belt; 2 – zones of overlapping by friction linings; 3 – confusers; 4 – diffusers; 5, 6 – zones: evaporation, condensation; a and b – upper and lower parts of the tubular system, which is not filled with nano-liquid

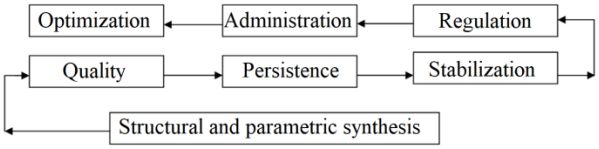

Figure 2 – Structural-parametric synthesis of brake friction pairs

When selecting materials for the friction pair of a tribosystem, it is necessary to adhere to its structural-parametric synthesis (Fig. 2).

Selection of materials for the friction pair of the tribosystem:

- according to reference data, using the HB (Brinell hardness) and δ_p (linear elongation at break) criteria, the most wear-resistant counterbody material is selected in proportion to this criterion);

- based on a comparison of the friction heat resistance curves in the form of dependencies of the dynamic friction coefficient μ and wear intensity I on the maximum friction surface temperature t_{max} (below and above the permissible temperature for friction lining materials) $\mu = \mu\ (W, N, t_{max})$ and $I = I\ (W, N, t_{max})$ (where W - friction power; N - normal clamping force; p - pulse specific load), a friction pair is determined that meets the technical conditions;

- select the design of the friction unit (single- or multi-pair) and the type of loading (aperiodic, cyclic or long-term), ensuring pulsed or long-term heat supply (one-sided or two-sided) to the friction surfaces, the dynamic coefficient of mutual overlap $K_{вз}$ *and* the design dimensions of the friction pair, as well as the duration of their indirect forced cooling by heat carriers having different states of aggregation;

- assessment of the thermal balance of the serial and main brake disc using the temperature method, measuring the surface temperatures of their working surfaces with sliding thermocouples during cyclic braking with a disc-shoe brake, determining the efficiency of forced air-nano-liquid cooling; in the case of cooling of heated brake discs, the efficiency of their natural cooling is determined;

- determine the rates of heating and cooling, surface and deep temperature gradients, and, as a consequence, thermal stresses of the discs of serial and developed brake discs;

- carry out an energy assessment of the resource of the working surfaces of friction linings in various models of disc-shoe brakes of drilling rig winches.

The relationship between the design and operational parameters of various models of disc-shoe brakes with hydraulic drive of drilling rig winches. According to work [1] from which Table 1 is borrowed and supplemented by two design parameters: the average radius of the disk friction belt and the dynamic coefficient of mutual overlap of friction pairs. The first characterizes the average value of the large and small radii, indicating what part of the disk's metal capacity affects temperature gradients. The second parameter characterizes the energy load of a single support. The values of surface and depth temperature gradients are influenced by the location of the calipers around the circumference of the main brake disc (Table 2).

Let us analyze the results presented in Table 3.

With one number of paired supports (n) at variable values of the dynamic friction coefficients (μ) at constant values of the pulse specific loads (p , MPa), a new parameter was obtained - the weight of the drill string falling on a unit area of the working surface of the friction linings (G , N/mm2). In this case, for each of their paired supports (n), the ratio of the maximum to minimum values of G was [6].

This circumstance indicates uniform wear of the working surfaces of the linings frictionally interacting with the friction belts of the main disks of the drilling winches when lowering the tool into the well.

Table 1 – Main design parameters of drilling rig models with winches equipped with serial disc-shoe brakes with hydraulic drive

Model	PS440-9000	PS295-6700	PS240-4500	PS165-3150	PS60-1350	PS40-900
Drilling rig	ZJ120	ZJ90	ZJ70	ZJ50	ZJ20	ZJ15
Braking torque, kNm	440	295	240	165	60	40
Bending moment at rest kNm	245	160	120	85	40	25
Sharp bending moment kNm	685	455	360	250	100	65
Brake disc diameter	2100	1900	1600	1500	1400	1200
Average radius of disc friction belts, mm	820	720	570	520	470	370
Number of supports	7	5	4	4	3	2
Number of calipers during hard braking	3	3	2	2	1	1
System pressure , MPa	8	8	8	7	7	7
Coefficient of mutual overlap of friction pairs	0.41	0.33	0.34	0.37	0.30	0.26

Table 2 – The arrangement of the calipers around the circumference of the main brake disc

Number of supports							
1	2	3	4	5	6	7	8
Location of calipers:							
symmetrical							
-	2	-	4	-	6	-	8
asymmetrical							
-	-	3	-	5	-	7	-

Table 3 – The weight of the drill string per unit area of the working surface of the friction linings

n	*μ*	*p*, MPa	*G* , N/ mm^2	*n*	*μ*	*p*, MPa	*G* , N/ mm^2
2	0.3	2.0	1.8	6	0.3	2.0	5.4
		2.4	2.16			2.4	6.48
		2.8	2.52			2.8	7.56
		3.2	2.88			3.2	8.64
	0.35	2.0	2.1		0.35	2.0	6.3
		2.4	2.52			2.4	7.56
		2.8	2.94			2.8	8.82
		3.2	3.36			3.2	10.08
	0.4	2.0	2.4		0.4	2.0	7.2
		2.4	2.88			2.4	8.64
		2.8	3.36			2.8	10.08
		3.2	3.84			3.2	11.52
	0.45	2.0	2.7		0.45	2.0	8.1
		2.4	3.24			2.4	9.72
		2.8	3.78			2.8	11.34
		3.2	4.32			3.2	12.96
4	0.3	2.0	3.6	8	0.3	2.0	7.2
		2.4	4.32			2.4	8.64
		2.8	5.04			2.8	10.08
		3.2	5.76			3.2	11.52
	0.35	2.0	4.2		0.35	2.0	8.4
		2.4	5.04			2.4	10.08
		2.8	5.88			2.8	11.76
		3.2	6.72			3.2	13.44
	0.4	2.0	4.8		0.4	2.0	9.6
		2.4	5.76			2.4	11.52
		2.8	6.72			2.8	13.44
		3.2	7.68			3.2	15.36
	0.45	2.0	5.4		0.45	2.0	10.8
		2.4	6.48			2.4	12.96
		2.8	7.56			2.8	15.12
		3.2	8.64			3.2	17.28

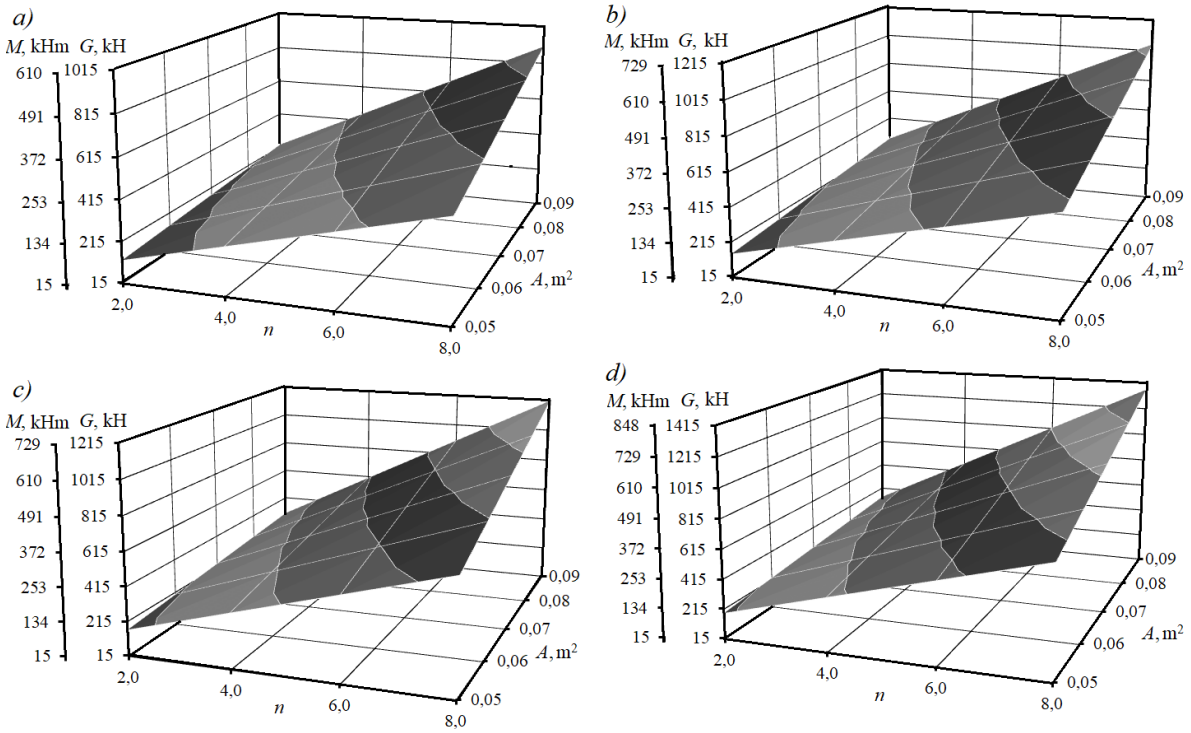

Figure 3 a, b, c, d – Patterns of change in the braking torque M, developed by friction pairs of disk (tubular type) - shoe brakes of drilling winches and the weight of the pipe column G from the number of supports n and a constant working area of the linings A with a constant dynamic coefficient of friction μ = 0.35 and different pulse specific loads: a - p = 2.0 MPa; b – p = 2.4 MPa; c – p = 2.8 MPa; G - p = 3.2 Mpa

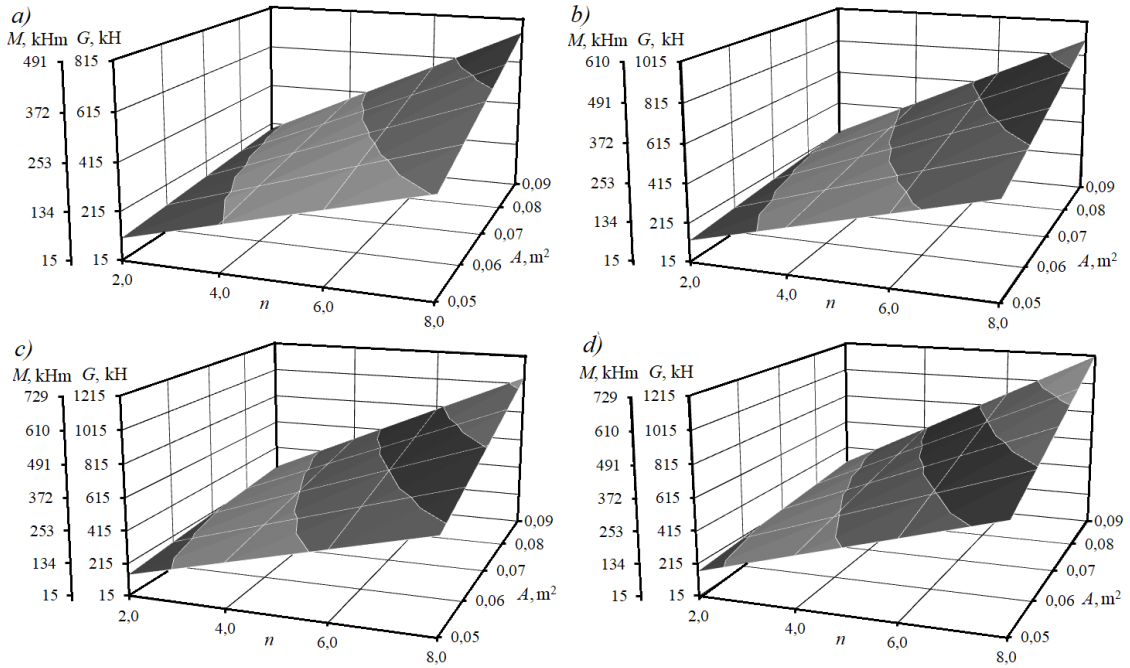

Figure 4 a, b, c, d – Patterns of change in the braking torque M, developed by friction pairs of disk (tubular type) - shoe brakes of drilling winches and the weight of the pipe column G from the number of supports n and a constant working area of the linings A at constant pulse specific loads p = 2.8 MPa and different dynamic friction coefficients μ: a – μ = 0.3 b –μ =0.35 v – μ =0.4 g – μ = 0.45

Let us analyze the graphical dependencies shown in Fig. 3 and 4, concerning the change in braking torque by friction pairs of disc (tubular type) - shoe brakes with their forced air cooling:

3 a, b, c, d – with an increase in the weight of the drill pipe column G with an even number of supports n and constant working areas of the pads A and dynamic coefficient of friction μ at different pulse specific loads p, the braking torque increased from 491.0 to 729.0 kNm;

4 a, b, c, d – with an increase in the weight of the drill pipe column G with an even number of supports n and constant working area of the pads A and pulse specific load p with different dynamic friction coefficients μ, the braking torque increased from 610.0 to 848.0 kNm. Moreover, the initial and final values of the braking torque in the first case were 24.1% and 16.3% less than in the second case.

Experimental design developments and theoretical studies of disk (tubular type) - shoe brakes of drilling winches with forced air cooling of their friction pairs allowed us to establish the following: a method for selecting materials for friction pairs based on their dynamic and thermal energy load is proposed; the average radius of the friction belt of the disk and their mutual overlap coefficient were introduced to the known design parameters of friction pairs; the influence of the design parameters of a serial disc brake on the weight of the drill pipe column lowered into the well and its operating parameters, from which the braking torque is extracted; the influence of constant and variable design and operational parameters on the braking torque and compare its value for different cases.

Conclusion

Thus, the choice of friction pair materials has been made and the relationship between the design and operational parameters of various models of disc-shoe brakes with hydraulic drive of drilling rig winches has been established.

Conflict of interests

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

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