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Experimental Determinations Regarding the Behaviour of Spiral Screw Pumps Stators under Erosion Wear

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Abstract

The experimental determinations which were made had as a purpose the study of the peculiarities of the stator rubbers, regarding their behaviour when dealing with erosion wear, for the pumps with bolt. Three types of rubber were used, which were injected inside the stators, laboratory experiments were conducted, where there was used a device for the examination of rubber under erosion wear, made at SC UPETROM Ploiesti. The diagrams for the dissymmetry points were traced, according to the irregularity of the steel containers used during the experiment. The behaviour when being eroded includes an assessment of the length, width and depth of the fissure. The testing for erosion consists of measuring the depth of penetration of oil in the rubber, which a contact force is applied on. The experimental study of the well rubber was made in order to establish the working parameters for erosion wear research of the spiral screw pumps, used for crude oil recovery [1, 2].

Key words: *rubber, stator, steel containers, dissymmetry point, irregularity, fissure depth*

Introduction

For the experimental testing rubber stator sections were used, from three helical pumps, as well as metal containers which acted as a rotor. The helical pumps are a part of the volume pumps with rotation category. The pump only has one rotor which is placed irregularly in an helical stator which has two opening points. The rotor will perform a rolling movement on the stator surface, and the rotor spirals will determine closed volumes which move along the axis. The rubber of the helical pump follows the pump's working conditions: the fluid used is fuel oil, the fluid temperature is 60 °C and the contents of solid particles. The stator is vulcanized on the inside with a rubber resistant to oil products. The rubber is made out of: 6% zinc oxide; 4% antioxidants; 1,5% stearic acid; 65% carbon black; 15% plastifier; 0,5% sulphur; 4% accelerators, which give the rubber a good resistance. On a world scale, there is the Hottnin helical pump, where the screws do not push each other; the two axles are bound through a coupling. These pumps are able to use any kind of heavy viscous oil products: bitumen, molasses, greasing oil. Also on a world scale, there are the Nemo pumps which can be set horizontally, vertically or in any other required position.

In the experimental determinations what is relevant is the behaviour under abrasive wear, where the repeated impact of the small particles set in motion by the fluid (fuel oil) induces a shifting away from the rubber, on that particular surface. The hard particles of different forms and sizes, hit repeatedly the targeted surfaces with a velocity ranging from 10 to 500 m/s and under angles ranging from 0° to 90°. According to the SR ISO 7743-A1/1995 standard, the determination of the peculiarities of effort – deflection is established, for the vulcanised rubber erosion wear, using different types of containers. Repeated bending or flexing of the rubber, leading to developing fissures, is the cause of enlarging the fissure in a direction perpendicular on the effort. Some soft vulcanised rubbers, like the ones obtained out of butadiene styrene rubber, present a better resistance to fissures, but it is possible to present a weaker resistance to the spreading of the fissures [5, 6].

Stages: the laboratory experimental testing was made on three types of rubber, the testing machine was calibrated, the tensiometric indicators were set on the research device for rubber erosion; a tensiometric axle was employed, using 100 ml of fuel oil instead of well oil. Then the machine is left to work in sets of 30 minutes, showing graphs after every 30 minutes, with the dissymmetry points on paper [3, 4].

The researcher attention was turned to the study of the influence that the abrasive wear factors have, with the purpose of stating their importance, their degree of generalization as well as their applicability limits.

Description of the Installation

In order to carry out the experiments an installation was used which consists of: a testing machine, a device for the research of rubber erosion, a tensiometric axle, the paper data register, 100 ml fuel oil. For the experiment, the apparatus below was used. In Figure 1 is the tensiometric bridge at connects graphs register.

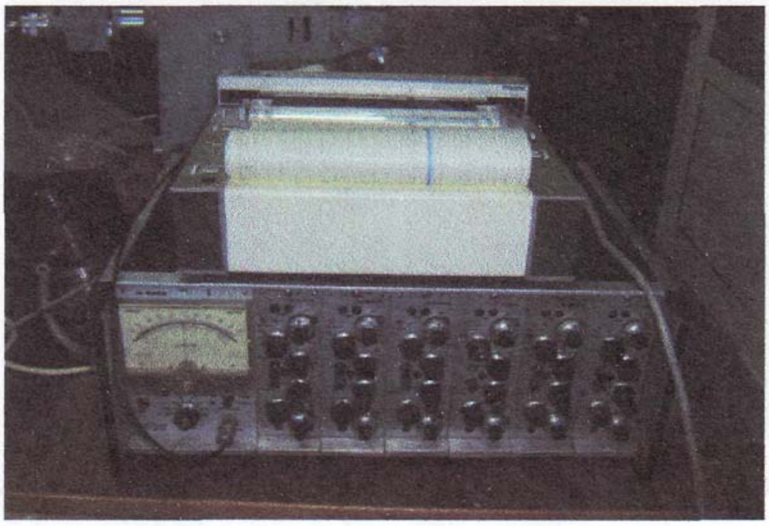

Fig. 1. Tensiometric bridge and graphs register

In Figure 2 is the device for the research of rubber erosion assembles on a testing machine.

Two tensiometric marks were set on position number 20 on the device for the research of rubber erosion. The indicators were connected to the tensiometric axle. The device for the research of rubber erosion also has among its components a lid which during the experiments screws and unscrews, in order to make the operations of setting the stator sections, the containers and filling with the fuel oil. At the bottom of the device there is a rubber hose through which the fuel oil is released after each testing. This device is set on the motherboard of the testing machine, in 4 screws; the head of the machine is centred by descent in the axis of the device, operating with a force. The electric wires from the tensiometric indicators are set on the tensiometric axle. Not only the axle, but also the graphs register and the testing machine are connected to a power source. The voltage on the axle is stabilized U = 0,1V; the volume of fuel oil is determined V = 100 ml and also the segment interval on the graphs register [5].

Fig. 2. The device set on the testing machine

The following segment intervals are taken into account: 0-10; 10-20; 20-30; 30-40; 40-50; 50-60; 60-70; 70-80; 80-90; 90-100.

In Figure 3 is the device for the research of rubber erosion.

Methodology

In order to conduct the experiments on the 3 (three) types of rubber, namely NBR80 (NP), NBR75 (B1) AND NBR70 (AS) firstly, the testing machine was calibrated. In this respect, two tensiometric indicators were pasted on the device for the research of rubber erosion in position number 20; indicators which are connected to the tensiometric axle [7, 8].

The indicator needle is set on the tensiometric axle at 0 µm/m, and the voltage on the axle is U = 0.1 V. The volume of crude oil is 100 ml fuel oil. The segment interval for each stator section is settled on paper, as well as the velocity of the registration needle v = 200 mm/min. The lid of the device for the research of rubber erosion is unscrewed, stator sections with different rubber injections are being gradually introduced, steel containers are gradually being set for each experiment, the previously set fuel oil volume (V = 100 ml) is added, the lid is screwed, the lid of the machine is centred in the axis of the device for the research of rubber erosion and the power button of the testing machine is pressed. It is left to function for t = 1 minute, then the graphs register is turned off and the machine is left to function for 30 minutes, then the graph is registered for t = 1 minute. The dissymmetry point on the graphs is measured at the peaks shown by the registration needle on paper. The device for the research of rubber erosion was made at S.C. UPETROM PLOIESTI S.A. The lid of the device for the research of rubber erosion is then unscrewed and each section is taken and the mark left through the friction with the container introduced at the beginning of the experiment is measured. For the mark on the stator, the length and the width are measured with the slide rule, and the depth is measured with the comparative dial clock [9].

The comparative dial clock has a circular palpator with a diameter of 4 mm and a flat inflexible slide which puts an applied pressure of 22 kPa. The dial clock must be adjusted to laboratory temperature use and also calibrated.

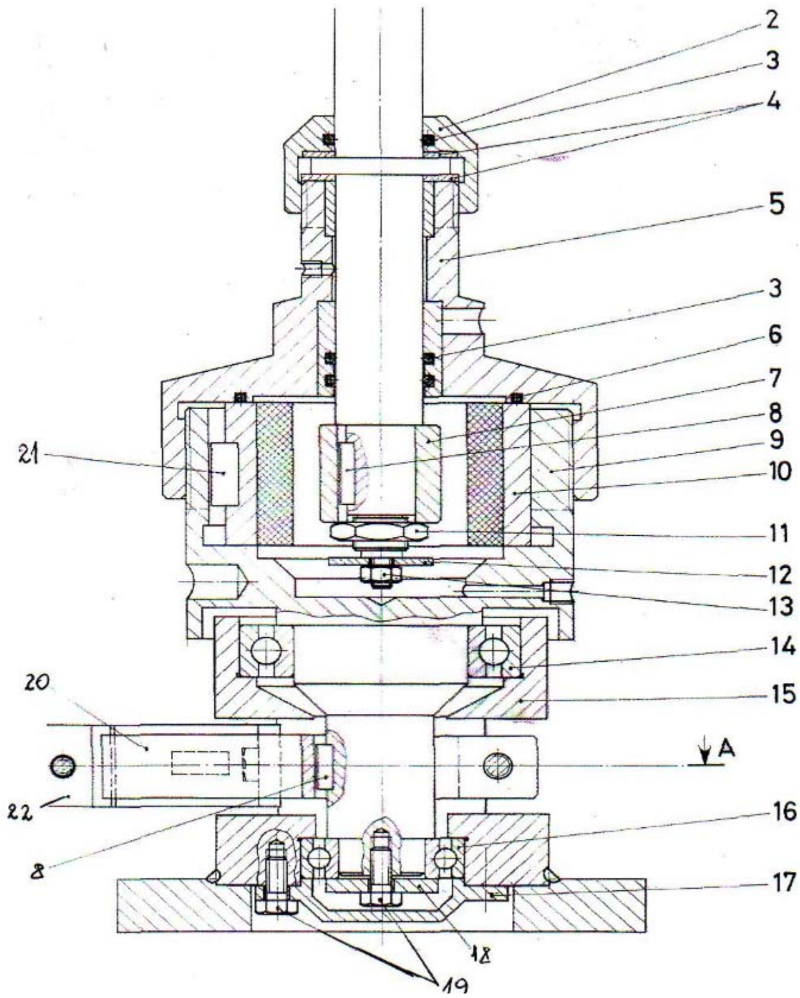

Fig. 3. Device for the research of rubber erosion:
1- axle; 2- nut; 3 -"O''316 collar; 4 - sheave; 5 - cover; 6 -"O''316 collar; 7 - box; 8 - cotter; 9 - axle test piece; 10 - tire test; 11 - M16 nut;12 - blade; 13 - M6 nut;14 - bearing; 15 - cover bearing; 16 - bearing; 17 - cover bearing; 18 - sheave; 19 - M 6x15 bolt; 20 - carrier; 21- cotter; 22 - clamp; 23 - M 6x35 bolt; 24 -M 8x20 bolt.

Experimental Determinations

In order to conduct the laboratory experiments five stators with an injection of three types of rubber were used [9].

In table 1 are shown the physical-mechanical characteristics of the types of rubbers.

Firstly, the testing machine was calibrated. In this respect, two tensiometric indicators were pasted on the device for the research of rubber erosion in position number 20.

For the calibration of the machine the data in the table below was used:

In table 3 are the dissymmetry points: the initial moment (I_m), the moment after 30 minutes, the moment after 60 minutes and the depth of the mark after 60 minutes, measures with comparative dial clock.

In table 4 are the dissymmetry points: the initial moment (I_m), the moment after 30 minutes, the moment after 60 minutes and the depth of the mark after 60 minutes, measures with comparative dial clock.

In table 5 are the dissymmetry points: the initial moment (I_m), the moment after 30 minutes, the moment after 60 minutes and the depth of the mark after 60 minutes, measures with comparative dial clock.

Table 1. Rubber testing bulletin

Physical-mechanical characteristics	UM	Type of test mixture		
		NBR 80 (NP) – marked stator I	NBR 75 (B1)- marked stator II	NBR 70(AS)- marked stator III
Elasticity module 100%	MPa	4.2	3.6	1.7
Elasticity module 300%	MPa	16.0	15.0	7.0
Resistance to breaking	MPa	24.0	26.0	18.0
Elongation to breaking	%	420	480	560
Hardness	ºSh A	79	75	69

Table 2. The calibration of the machine

Mt=Fx0,3x10[Nm]	Weight[daN]	Axle[segments]	xy[segments]
0	0	0	0
2.49	0.8	3	47.5
5.49	1.8	7	48.5
8.49	2.8	15	52
14.49	4.8	17	55
22.8	7.6	25	56
30.78	10.3	35	59.5
34.89	11.6	42	62.5
39.09	13	45	63

Table 3. The dissymmetry points, the irregularity and the depth of the mark from the experiments for stator I

Stator	Irregularity i [mm]	The initial moment Im [Nm]	The moment after 30 minutes [Nm]	The moment after 60 minutes [Nm]	The depth of the mark after 60 minutes [mm]
Stator I	i=1.1	0.30	0.25	0.24	-
Stator I	i=4.4	0.35	0.35	0.40	d=0.10
Stator I	i=4.3	0.30	0.25	0.45	d=0.20
Stator I	i=1.95	0.25	0.30	0.30	-
Stator I	i=1.95	0.25	0.30	0.30	d=0.24
Stator I	i=2.00	0.30	0.35	0.35	d=0.34

Table 4. The dissymmetry points, the irregularity and depth of the mark from the experiments for stator II

Stator	Irregularity i [mm]	The initial moment Im [Nm]	The moment after 30 minutes [Nm]	The moment after 60 minutes [Nm]	The depth of the mark after 60 minutes [mm]
Stator II	concentric	0.10	0.10	0.05	d=0.12
Stator II	i=4.3	0.35	0.20	0.35	d=0.18
Stator II	i=2.0	0.30	0.35	0.35	d=0.20
Stator II	i=1.95	0.30	0.35	0.35	d=0.14
Stator II	concentric	0.40	0.40	0.30	d=0.13
Stator II	i=1.05	0.45	0.30	0.35	-
Stator II	i=1.00	0.30	0.30	0.35	-
Stator II	i=1.10	0.30	0.25	0.25	-

Table 5. The dissymmetry points, the irregularity and depth of the mark from the experiments for stator III

Stator	Irregularity i [mm]	The initial moment Im [Nm]	The moment after 30 minutes [Nm]	The moment after 60 minutes [Nm]	The depth of the mark after 60 minutes [mm]
Stator III	i=4.30	0.20	0.20	0.25	d=0.20
Stator III	i=4.45	0.25	0.20	0.15	d=0.12
Stator III	i=3.10	0.25	0.20	0.20	d=0.13

Conclusions

For the rubber injected in Stator I, there are determined different values for the mark left. The depth of the erosion wear varies from d = 0.10 - 0.35 mm.

For the rubber injected in Stator II, there are determined different values for the mark left. The depth of the erosion wear varies from d = 0.12 - 0.20 mm.

For the rubber injected in Stator III, there are determined different values for the mark left. The depth of the erosion wear varies from d = 0.13 - 0.20 mm.

The behaviour of the erosion wear includes an appreciation of the length, the width and the depth, as well as of the number of fissures.

The results from the experimental data show that if the erosion wear for rubber fissure is larger than 3 mm, then the fissure is a degree 6.

In table 3 this value of 3 mm is exceeded, therefore the fissure is a degree 6 for the section of Stator I, with a 2 mm irregularity.

The erosion wear testing consists of measuring the penetration depth of the crude oil in the rubber, on which a contact force is applied.

As the stator is being eroded, the cover is tightened with some clamps and thus making the stator coat the rotor even tighter, assuring the tightness. The abrasive wear particle is present as a result of the mechanical action of the abrasive particles on surfaces. This produces the micro chipping and micro cracking of the employed material layer, which in this case is rubber.

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Determinări experimentale privind comportarea la uzură a statorilor pompelor elicoidale (cu şurub)

Rezumat

Lucrarea prezinta rezultatele cercetarii experimentale, privind comportarea la uzura a statorilor pompelor elicoidale. Incercarile experimentale au fost efectuate pe epruvete, cu diverse excentricitati, iar statorii injectati cu cele 3 tipuri de cauciuc, au fost taiati asa incat fiecare tronson sa corespunda dispozitivului de incercari. S-a utilizat de fiecare data o cantitate de 100 ml pacura, la fiecare excentricitate introdusa in interiorul tronsonului de stator. Studiul experimental al uzurii cauciucului folosit la pompele cu surub din sondele de extractie, a fost realizat in scopul stabilirii conditiilor/parametrilor de lucru al cercetarii comportarii la uzura a pompelor de extractive cu surub.