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SOME ASPECTS CONCERNING THE OPERATING WEAR AND RELIABILITY OF THE RHAC TYPE BOREHOLE PUMPS

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Abstract

The borehole pumps are important equipment used for the secondary oil recovery. In their structure, there are friction couples, which are strongly stressed at wear like cylinder-piston and the valves. The operating durability of the borehole pumps is practically determined by the reliability of these couples, which are made from different metallic materials depending on the work conditions.

The paper presents a study concerning the operating reliability of those friction couples. The paper conclusions can be used both of the design and of the exploitation of these pumps.

Key Words: *Borehole pumps, operating reliability, great wear couples*

1. INTRODUCTION

The deep-well pumping system is used for the oil wells exploitation. In Romania, this system is used at least for 75 % of the oil wells. The deep-well pumping exploitation is applied in a finally phase, when the natural energy of the stratum decreased and its value is insufficiently for surface oil ascending, or in the case when the artificial lifting can't be done. The efficiency of the deep-well pumping system is influenced by the working life of the pumps and by the consumption of the great wear repair parts (liners, pistons and valves).

The borehole pumps working life depends on: the service conditions (the depth of the hole, the aggressiveness of the pumped fluids, the pumping parameters a.s.o.); the borehole pumps construction (the type of the pump, the materials used at pumps construction, the quality of the manufacture etc.); the maintenance activities. Regarding the borehole pumps operating durability, it can be done the remark that this is determined mainly by the great wear couples, which are: liner-piston, pump valve and piston valve. The shutdown of these couples implies the borehole pump replacement.

Taking into account of the above statements, it can be concluded that it is necessary to determine the operating reliability of these couples and in this way practically the pump reliability.

The paper aim is to present a study concerning the determination of the borehole pumps operating reliability. The considered borehole pump in this study are RHAC 2 7/8 x 1 ¾ in type and it equips the oil wells of the Boldesti oil field. The paper results can be used at the design, exploitation and maintenance of the borehole pumps.

2. THE CONSTRUCTION AND THE WORKING OF THE RLAC BOREHOLE PUMP

According A.P.I. Std.11 Ax standard the RHAC 2 7/8 x 1 ¾ in is a borehole pump, which is introduced in oil well with the sucker rods.

This kind of pump has the cylinder barrel heavy wall and its fastening device is with scoops, which it lies at the superior part of the pump. The external diameter of the tubing is 2 7/8 in., the internal diameter of the pump is 1 ¾ in. The construction and working principle of the bore-pumps is presented in Figure 1. In this figure, it can be observed the great wear couples of the borehole pumps: liner-piston, pump valve and piston valve.

The pump working is characterized by two strokes: one for the upward of the piston and the other for the downward of the piston.

At the upstroke of the piston, the pump valve is opened and the piston valve is closed. Thus, the fluid enters in pump and the fluid, which is situated inside of the piston, is pushed up. At the down stroke of the piston, the pump valve is closed and the piston valve is opened. Thus, the fluid enters in piston chamber because of the pressure, which appears in the pump chamber.

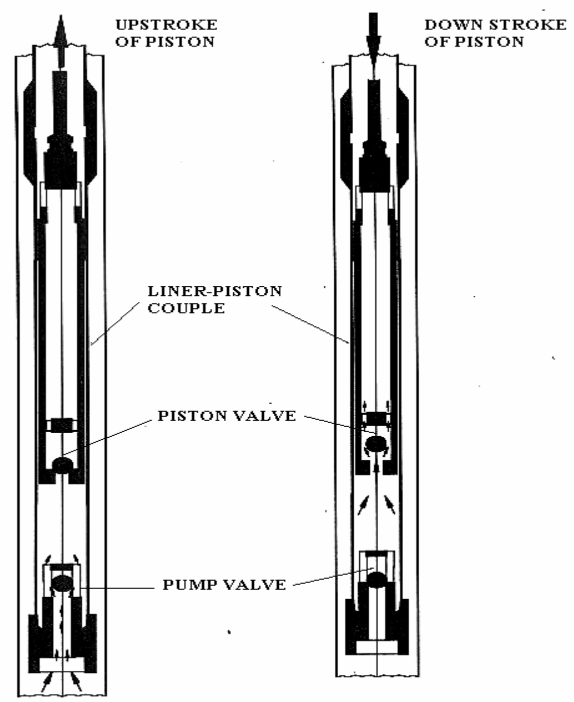


Figure 1: *The construction and the working principle of the bore-hole pumps*

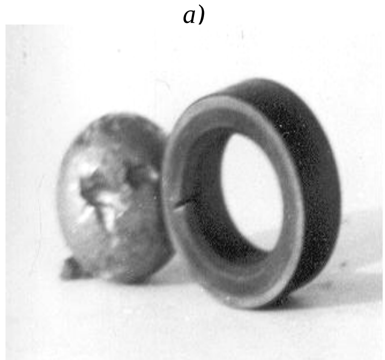
The barrel, which constitutes the pump cylinder, can be made from steel (carbonitrated, carbonized, nitrated, non-hardened low-alloy), plated steel (chrome, heavy chrome, nickel carbide) or Ni/Cu alloy.

The piston is made from steel, which it can has on the friction surface hard-chromium plating or spray metal coating.

The valves of the pump and of the piston are globe valve type. The component parts of the valves (the valve seat and the globe) are made from anticorrosive alloy steel, cobalt alloy or carbides.

The borehole pumps working in different agents, which are characterized by the fluid properties (the content of impurities, the corrosiveness etc.).

a)



b)

c)

Figure 2: *Some examples concerning the working damage of the barrel l(cylinder) (a) and the valves (b, c)*

In Figure 2 there are represented some examples concerning the damage of the pump cylinder and the valves. From this figure, it can be observed that the cylinder can be damaged by abrasion and cracking, while the valves can be failed by erosion and abrasion. The wear of the borehole couples implies the decrease of the flow and, so, the durability decrease.

3. RELIABILITY MODELING OF THE GREAT WEAR COUPLES OF THE BOREHOLE PUMPS

The reliability modeling of the great wear couples of the borehole pumps was done using the data concerning the working durability of these. So, there were taken into consideration the data, which were obtained, from 29 borehole pumps used in the oil field Boldesti. These pumps are characterized by the next characteristics concerning the construction and the working:

- type of the pumps RHAC 2 7/8 x 1 ¾ in;
- the type of the barrels – carbonized;
- the type of the pistons - hard-chromium plating;
- the anchorage depth between 1900 and 2600 m;
- the flow rate in the range of 5…30 m^3/24 hours;
- the double strokes number in the range of 6.5…10.5;
- the working time in the range of 96…1080 hours;
- the type of the agent – hybrid (mixed).

For the modeling the survival processes which are characteristics of bore-hole pumps wear couples it was used the Weibull partition law with two parameters [1, 2, 3]. The probability density of this law is:

$$f(x,\beta,\lambda) = \beta \cdot \lambda \cdot x^{\beta-1} \exp\left(-\lambda \cdot x^{\beta}\right) \qquad (1)$$

where: x is the taken into account variable ($x > 0$); λ, β - the two law parameters ($\lambda > 0$, $\beta > 0$).

The Weibull partition function with two parameters is:

$$F(x,\beta,\lambda) = \int_0^x f(x,\beta,\lambda)\,dx = 1 - \exp\left(-\lambda \cdot x^{\beta}\right) \qquad (2)$$

The relation gives the reliability:

$$R(x,\beta,\lambda) = 1 - F(x,\beta,\lambda) = \exp\left(-\lambda \cdot x^{\beta}\right) \qquad (3)$$

and shows the well working probability in the variable range of (0, x).

For the borehole pumps the "x" Weibull variable is the total length L, which is covered by the pump piston:

$$L = 2D \cdot n \cdot l \qquad (4)$$

where: L is the total length, km; D – the working time until the cutting out of action of the pump, min; n–the double stroke number on the minute; l – the length of a double stroke, km.

4. RESULTS AND DISCUSSIONS

For the great wear couples of the analyzed borehole pumps it were calculated the empiric reliabilities, which were compared with the reliabilities, obtained using the analytical method. Therefore, they were taken into account the next parts of the borehole pump: the cylinder, the piston, the pump valve and the piston valve. It must to be mentioned that the cylinder and the piston were considered separately because there were many cases when just one of them was damaged, while for the valve usually both parts were damaged (the seat and the globe).

In Figures 3, 4, 5, 6 they are represented the reliability of the pump cylinder, the pump piston, the pump valve and the piston valve. For each case it was represented by points the empiric reliability and it was plotting the analytical curve based on the parameters values, which were determined using the regression analysis. The parameter values and the correlation coefficients for each case are presented in Table 1. Thus, it can be remarked for each situation the high values of the correlation coefficient.

Table 1: The results of the regression analysis concerning the Weibull law parameters

The part of the couple/ the couple	The Weibull law parameters values		Corre-lation coeffi-cient
	β	λ	
Cylinder	1.9573	0.000000646	0.9416
Piston	1.819	0.000001769	0.9571
Pump valve	1.9447	0.000000783	0.9692
Piston valve	1.9808	0.000000595	0.9712

The total reliability of the borehole pump practically depends on the each great wear part reliability. The cutting out of action of one part (cylinder, piston, pump valve, piston valve) implies the end of the pump working time.

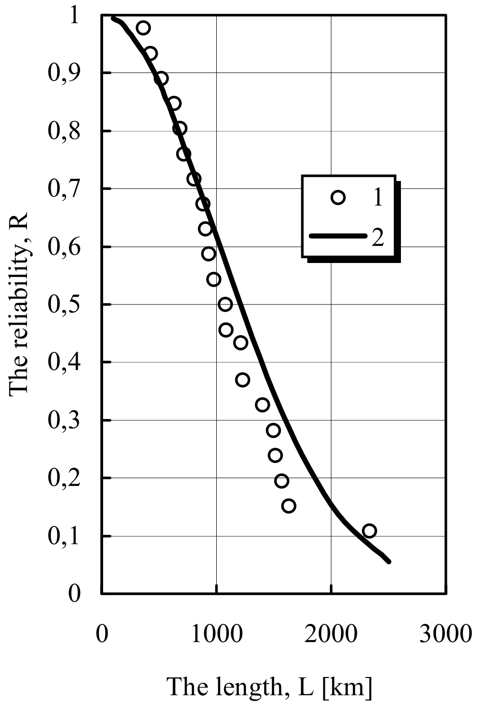


Figure 3: *The empiric reliability (1) and analytical reliability (2) vs. the length covered by the piston for the borehole pump cylinder*

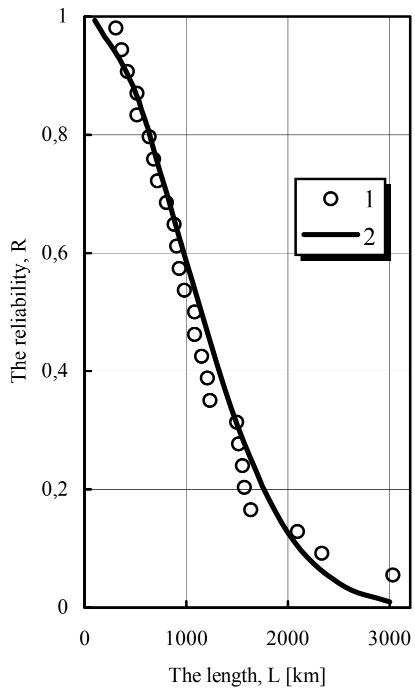


Figure 5: *The empiric reliability (1) and analytical reliability (2) vs. the length covered by the piston for the borehole pump valve*

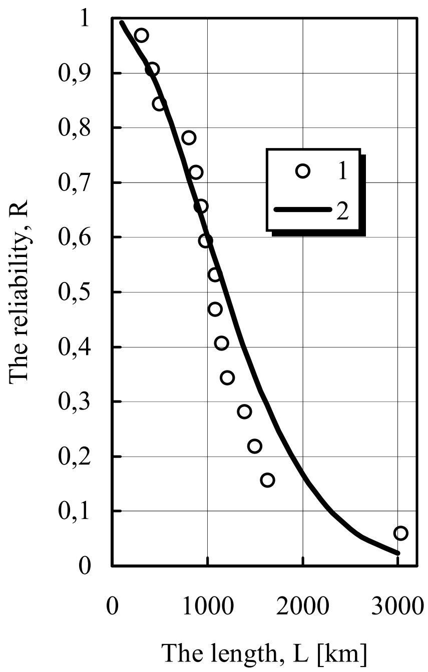


Figure 4: *The empiric reliability (1) and analytical reliability (2) vs. the length covered by the piston for the borehole pump piston*

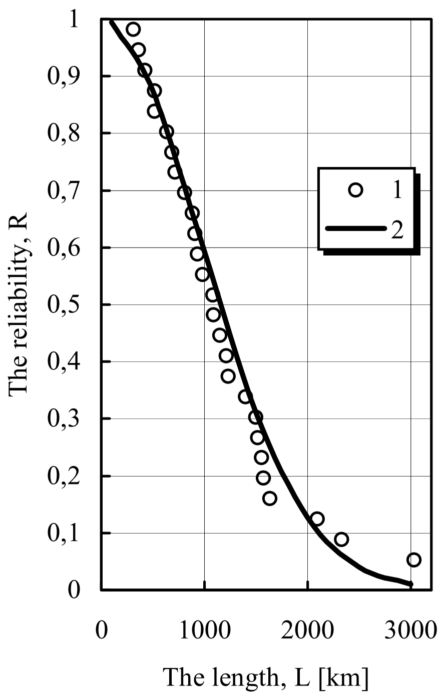


Figure 6: *The empiric reliability (1) and analytical reliability (2) vs. the length covered by the piston for the borehole piston valve*

Therefore, the pump assembly can be considered like a serial system. This kind of system will be defective when one element will be damaged.

The total reliability of this serial system can be calculated with the relation:

$$R_t(L) = R_c(L) \cdot R_p(L) \cdot R_{v1}(L) \cdot R_{v2}(L) \qquad (5)$$

where: R_t is the total reliability of the pump; R_c – the cylinder reliability; R_p – the piston reliability; R_{v1} – the pump valve reliability; R_{v2} – the piston valve reliability.

In Figure 7 is shown the total reliability of the borehole pump, which was calculated with the relation (5) for the working conditions above presented. In addition, on the same figure it is represented using points the empiric total reliability.

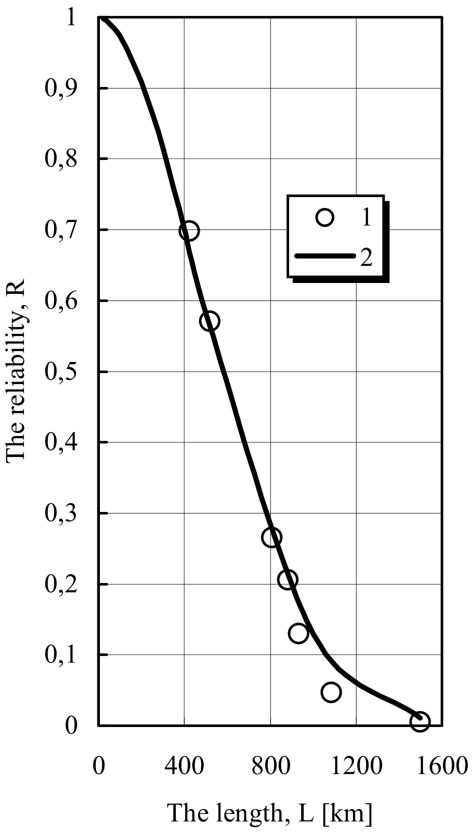


Figure 7: *The total reliability of the borehole pump RHAC 2 7/8 x 1 ¾ in type: 1-empiric total reliability; 2 – analytical total reliability.*

From Figure 8 it can be observed that after 400 km (approximately 200 hours of working) covered length by the piston the total reliability decrease very much.

5. CONCLUSIONS

The main conclusions, which can be detached from this paper, are:

- the paper presents a case study which is imposed to be done for every borehole pump type, because of the working conditions which are different from an oil field to another;
- the reliability calculus manner which was presented in this paper can be used for each type of borehole pump;
- the results obtained can be used at the designing, the exploitation and the maintenance of the RHAC 2 7/8 x 1 ¾ in borehole pump.

6. REFERENCES

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