DETERMINATION OF THE FUNCTION OF RELIABILITY AND THE POSSIBILITY OF FAILURE-FREE OPERATION OF A JAW CRUSHER TYPE CJ615:01

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ABSTRACT. The distribution of failures of an element or a machine from a specific technological line is an attempt for a mathematical description of their lifetime. The distribution mode affects the analytical form of this distribution. In the present study an attempt was made to determine the distribution of failures of the basic elements of a jaw crusher with complex swinging of the mobile jaw used for coarse crushing and to determine the probability of a faultless operation of the machine. In this case, the chosen crusher has six elements and in case of failure of any of them, its operation stops for repair works for its replacement. That is why, it is natural to consider the crusher as a system of six elements, connected in a series. This means, that if any of its components is damaged, there is a failure. The required number of statistic data has been collected and processed, which, after using some elements of the reliability theory, describes the behavior in regard to the reliability of its individual elements and the crusher as a whole. The possibility of failure-free operation of the whole crusher for a given quantity of processed ore is determined by the probability multiplication theorem, thus allowing the forecast of machine failures and the amount of spare lining plates necessary for the next year. The obtained results after the processing of the statistics unambiguously prove the correct choice of the jaw crusher under its conditions of operation.

Keywords: crusher, jaw, lining, reliability, failure.

ОПРЕДЕЛЯНЕ НА ФУНКЦИЯТА НА НАДЕЖДНОСТТА И ВЕРОЯТНОСТТА ЗА БЕЗОТКАЗНА РАБОТА НА ЧЕЛЮСТНА ТРОШАЧКА ТИП CJ615:01

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РЕЗЮМЕ. Разпределението на отказите на един елемент или една машина от дадена технологична линия е опит да се опише математически продължителността им на живот. Начинът на разпределението се отразява на аналитичния вид на това разпределение. В настоящата разработка е направен опит да бъде определено разпределението на отказите на основните елементи на челюстна трошачка със сложно люлеене на подвижната челюст използвана за едро трошене и да бъде определена вероятността за безотказна работа на машината. В настоящия случай избраната трошачката има шест елемента, като при повреда на всеки един от тях - спира да работи и започват ремонтни дейности по подмяната му. Ето защо е естествено трошачката да бъде разглеждана като система от шест елемента, които са последователно свързани. Това означава, че който и от елементите ѝ да се повреди, има наличие на отказ. Събрани са и са обработени необходимият брой статистически данни, които след използване на някои елементи от теорията на надеждността, описват поведението по отношение на надеждността на отделните ѝ елементи и на трошачката в съвкупност. Вероятността за безотказна работа на цялата трошачка за дадено количество преработена руда е определена от теоремата за умножение на вероятностите, като по този начин могат да бъдат прогнозирани отказите на машината и количеството на резервните облицовъчни плочи, необходими за година напред. Получените резултати след обработката на статистическите данни недвусмислено доказват правилния избор на челюстната трошачка за условията ѝ на експлоатация.

Ключови думи: Трошачка, челюстна, облицовка, надеждност, отказ.

Introduction

The object of the study is a jaw crusher type SANDVIK CJ615:01. The investigated jaw crusher has a complex swinging of the mobile jaw and works under extreme external conditions - high humidity and temperature underground in "Chelopech" mine. The sectional view of the 3D model of the machine, showing the main crusher nodes, is presented on Figure 1. The main elements and nodes that lead to the crusher outages (refusals) are: the mobile jaw lining 1, the stationary jaw lining 2, the lower lining plate on the left side 3, respectively the lower lining plate on the right side, the top lining plate on the left side 4, respectively - the top lining plate on the right side. This is due to the high abrasion of the ore and the relative vertical movement of the moving jaw towards the stationary one, leading to the grinding of the material in the crushing area, as well as the high quality of the design and production of the machine.

The main question that may be set in the present study is if there is a possibility to describe the behavior of a machine for the disclosure of mineral beads (jaw crusher) and to make a forecast of its failures for the planning of the necessary spare parts and upcoming repairs through the methods of the theory of probability and reliability.

The companies that exploit such machines are restocked with spare parts due to the fact that these machines are single and they determine the productivity of the whole enterprise in order to reduce the outages for the repairs. The mode of forecasting is brought to the arithmetic average of the required

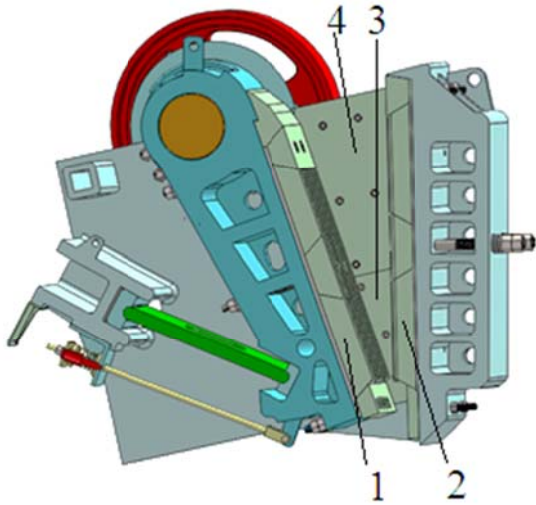number of input nodes and elements based on a previous year.

Fig. 1. A section of a jaw crusher type CJ615:01

The best solution in this case is to determine the parameters of the crusher's operational safety based on the reliability theory. A major problem for such a survey would appear during the statistics collection when the machine is supplied with spare parts and nodes from different manufacturers and of different quality. In the present study this problem is avoided.

It can be expected the present study to prove that the reliability theory can also be used to solve similar engineering tasks in the mining industry.

Summary

The aim of the present study is to investigate the regularities of altering the quality indicators over time by examining the effect of external and internal impacts on the operation of a machine for the disclosure of mineral beads - a jaw crusher, to create methods and means for forecasting the technical condition and to increase the reliability of such machines under operational modes.

Hypothesis of the research. In the present study are used some elements of the reliability theory to describe the behavior of the crusher in terms of the reliability of its separate elements.

In most cases in the literature the operational time without stops is accepted as an argument. Here, however, it is considered that it is more appropriate to choose the quantity of processed ore, indicated with $q \geq 0$ as an argument.

An element starts working at a zero initial quantity of processed ore and works until some quantity of ore is treated. Once a randomly selected quantity of ore is processed, a refusal occurs. It is assumed that the quantity of processed ore is a random variable, characterized by its distributional function $Q(q) = P(\chi < q)$. The probability of reliable operation of an element is expressed by the function $P(q) = 1 - Q(q)$. It is

called a function of reliability and expresses the probability (within a range of quantities of processed ore) not to occur a refusal $P(q) = 1 - Q(q)$. The graph of the probability of reliable operation is a monotonically decreasing function. Its boundary values are $P(0) = 1, P(\infty) = 0$.

The density of the distribution function will look like this.

$$f_X(q) = \lambda e^{-\lambda q} \qquad (1)$$

The function of distribution itself is:

$$F_X(q) = \int_{-\infty}^{q} f_X(s)ds = \int_{0}^{q} f_X(s)ds = \int_{0}^{q} \lambda e^{-\lambda s}ds =$$

$$= -\int_{0}^{q} e^{-\lambda s}d(-\lambda s) = -\left(e^{-\lambda q} - e^{-\lambda 0}\right) = 1 - e^{-\lambda q}, q \geq 0 \qquad (2)$$

The mathematical expectation (the first initial moment) of the random magnitude is:

$$M(X) = \int_{-\infty}^{\infty} sf_X(s)ds = \int_{0}^{\infty} sf_X(s)ds = \int_{0}^{\infty} s\lambda e^{-\lambda s}ds =$$

$$-\int_{0}^{\infty} se^{-\lambda s}d(-\lambda s) = -\int_{0}^{\infty} sd\left(e^{-\lambda s}\right) = -se^{-\lambda s}\Big|_{0}^{\infty} + \int_{0}^{\infty} e^{-\lambda s}ds =$$

$$= \int_{0}^{\infty} e^{-\lambda s}ds = -\frac{\lim\limits_{q\to\infty} e^{-\lambda q} - 1}{\lambda} = \frac{1}{\lambda} \qquad (3)$$

The second initial moment is:

$$M(X^2) = \int_{-\infty}^{\infty} s^2 f_X(s)ds = \int_{0}^{\infty} s^2 f_X(s)ds = \int_{0}^{\infty} s^2 \lambda e^{-\lambda s}ds =$$

$$= -\int_{0}^{\infty} s^2 e^{-\lambda s}d(-\lambda s) = -\int_{0}^{\infty} s^2 d\left(e^{-\lambda s}\right) - s^2 e^{-\lambda s}\Big|_{0}^{\infty} + =$$

$$= +2\int_{0}^{\infty} se^{-\lambda s}ds = -\frac{2}{\lambda}\int_{0}^{\infty} sde^{-\lambda s} =$$

$$= -\frac{2}{\lambda} se^{-\lambda s}\Big|_{0}^{\infty} + \frac{2}{\lambda}\int_{0}^{\infty} e^{-\lambda s}ds = -\frac{2}{\lambda}\frac{e^{-\lambda s}\Big|_{0}^{\infty}}{\lambda} = \frac{2}{\lambda^2} \qquad (4)$$

Then the dispersion and the mean squared deviation are respectively: $D(X) = M(X^2) - M^2(X) = \frac{2}{\lambda^2} - \frac{1}{\lambda^2} = \frac{1}{\lambda^2}$;

$$\sigma(X) = \sqrt{D(X)} = \sqrt{\frac{1}{\lambda^2}} = \frac{1}{\lambda}.$$

In this case, the crusher has six elements, and in case of failure of any of them the machine stops working. Therefore, it is natural for the crusher to be considered as a system of six

elements that are bonded in a series. This means that if any of its components fails, the entire machine stops to operate. Therefore, the probability of faultless operation of the entire crusher for a given quantity of processed ore is determined by the probability multiplication theorem:

$$P_T(q) = P_1(q)P_2(q)P_3(q)...P_6(q) = \prod_{k=1}^{6} P_k(q) \qquad (5)$$

where $P_k(q)$ is the probability of faultless operation of the k-th element.

Further, the exponential distribution is perceived. In the case of exponential distribution law, the following expressions are used:

$$P_T(q) = e^{-\lambda_1 q}e^{-\lambda_2 q}e^{-\lambda_3 q}e^{-\lambda_4 q}e^{-\lambda_5 q}e^{-\lambda_6 q} = e^{-q\sum_{k=1}^{6}\lambda_k} \qquad (6)$$

For the statistical evaluation of each of the numbers according to the law of large numbers the arithmetic average of the measurements of failures of each detail of the crusher is used:

$$\frac{1}{\lambda_k} = \sum_{i=1}^{m_k} X_i^k \Rightarrow \lambda_k = \frac{1}{\sum_{i=1}^{m_k} X_i^k} \qquad (7)$$

$(k = 1,2,...,6)$ is the number of measurements for the k-th element of the jaw crusher.

Methodology used in processing the collected statistical information. The collected statistical data includes the quantity of processed ore up to the refusal of the relevant element and are shown in tables for each element separately. The recovery time is not taken into account, because it does not affect the parameters of the technological scheme in which the jaw crusher is included (the productivity of the crusher significantly exceeds that of the subsequent machine).

A new table is created for each element, where the following parameters are calculated:
$\overline{X}$ – quantity of processed ore;
f_i – frequencies of failures;
$P_i = \frac{f_i}{n}$ – probability in the selected range;
$C_i = \sum_{i=1}^{n} f_i$ - commutative frequencies;
$F_x(q) \, P_n = P_{n-1} + p_n$ – distribution function of the number of failures.

Finally, the mean squared processings of the relevant defected element $\sum_{i=1}^{n}\overline{X}$ are calculated and its frequency of failure $\lambda_i = \frac{1}{\frac{1}{n}\sum_{i=1}^{n}\overline{X}}$. The function of the failures distribution is then shown graphically.

Results

Table 1.
Processing to failure of the lining of the mobile jaw, t

260000	2588282	4751942
430000	2716170	4884806
741000	2853338	5040704
946000	3000961	5149226
1155000	3279603	5384500
1288222	3393323	5428150
1634000	3508533	5612515
1780400	3672893	5747326
1906672	3880059	5877240
2016404	3391411	5986908
2151443	4122638	6153689
2292018	4385294	6471889
2398073	4542166	

Table 2.
Processing of the data on the mobile jaw lining

$\overline{X}$	f_i	P_i	C_i	$F_x(q) \, P_n = P_{n-1} + p_n$
up to 100 thousands tones	0	0	0	0
100 - 300	1	0.066667	1	0.026316
300 - 500	1	0.066667	2	0.052632
500 - 700	0	0	2	0.052632
700 - 900	1	0.066667	3	0.078947
900 - 1100	1	0.066667	4	0.105263
1100 - 1300	2	0.133333	6	0.157895
1300 - 1500	0	0	6	0.157895
1500 - 1700	1	0.066667	7	0.184211
1700 - 1900	1	0.066667	8	0.210526
1900 - 2100	2	0.133333	10	0.263158
2100 - 2300	2	0.133333	12	0.315789
2300 - 2500	1	0.066667	13	0.342105
2500 - 2700	1	0.066667	14	0.368421
2700 - 2900	2	0.133333	16	0.421053
2900 - 3100	1	0.066667	17	0.447368
3100 - 3300	1	0.066667	18	0.473684
3300 - 3500	1	0.066667	19	0.5
3500 - 3700	2	0.133333	21	0.552632
3700 - 3900	1	0.066667	22	0.578947
3900 - 4100	1	0.066667	23	0.605263
4100 - 4300	1	0.066667	24	0.631579
4300 - 4500	1	0.066667	25	0.657895
4500 - 4700	1	0.066667	26	0.684211
4700 - 4900	2	0.133333	28	0.736842
4900 - 5100	1	0.066667	29	0.763158
5100 - 5300	1	0.066667	30	0.789474
5300 - 5500	2	0.133333	32	0.842105
5500 - 5700	1	0.066667	33	0.868421
5700 - 5900	2	0.133333	35	0.921053
5900 - 6100	1	0.066667	36	0.947368
6100 - 6300	1	0.066667	37	0.973684
6300 - 6500	1	0.066667	38	1
over 6500	0	0	38	1

The mean squared processing of the lining of the mobile jaw is determined according to the expression:

$$\sum_{i=1}^{n} \overline{X_1} = 3289588t \qquad (8)$$

The frequency of failures of the mobile jaw lining is determined according to the expression:

$$\lambda_i = \frac{1}{\frac{1}{n}\sum_{i=1}^{n}\overline{X}} = \frac{1}{3289588} = 0,00000030399 \qquad (9)$$
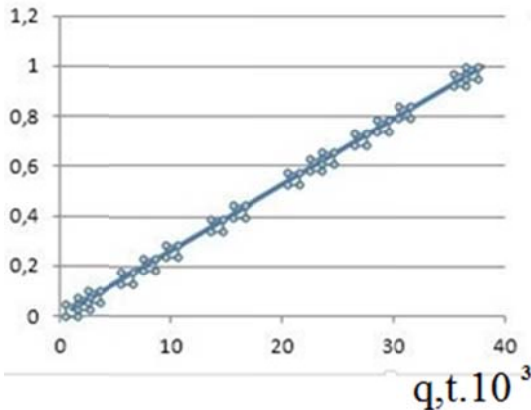
Fig. 2. Function of the failures distribution of the mobile jaw lining

Table 3.

Processing to failure of the stationary jaw lining, t

100000	2431687	4900638
170000	2507385	5009915
291000	2583882	5053807
390000	2653345	5074524
460000	2853338	5149226
600000	2938659	5223573
741000	3010407	5283548
831000	3183316	5360643
920000	3243216	5418268
998000	3307835	5486365
1088000	3367021	5543771
1155000	3424785	5603909
1222199	3496647	5671541
1288222	3551239	5723326
1380000	3632654	5797534
1453000	3704199	5859750
1520100	3787659	5223573
1589222	3875345	5903612
1653032	3959052	5956928
1734904	4038317	6020321
1823087	4122638	6074115
1901672	4203058	6145988
1922872	4279537	6208227
2016404	4347190	6348133
2071144	4439932	6377159
2134132	4502920	6440220
2193903	4578009	6499980
2262885	4658993	6567663
2321950	4746682	
2370520	4826970	

Table 4.

Processing of the data on the stationary jaw lining

$\overline{X}$	f_i	P_i	C_i	$F_x(q)\ P_n = P_{n-1}+p_n$
Up to 100 000 tones	1	0.011111111	1	0.011111111
100 -300	2	0.022222222	3	0.033333333
300 - 500	2	0.022222222	5	0.055555556
500 -700	1	0.011111111	6	0.066666667
700 - 900	2	0.022222222	8	0.088888889
900 - 1100	3	0.033333333	11	0.122222222
1100 - 1300	3	0.033333333	14	0.155555556
1300 - 1500	2	0.022222222	16	0.177777778
1500 - 1700	3	0.033333333	19	0.211111111
1700 - 1900	3	0.033333333	22	0.244444444
1900 - 2100	4	0.044444444	26	0.288888889
2100 - 2300	3	0.033333333	29	0.322222222
2300 - 2500	3	0.033333333	32	0.355555556
2500 - 2700	3	0.033333333	35	0.388888889
2700 - 2900	3	0.033333333	38	0.422222222
2900 - 3100	2	0.022222222	40	0.444444444
3100 - 3300	2	0.022222222	42	0.466666667
3300 - 3500	4	0.044444444	46	0.511111111
3500 - 3700	2	0.022222222	48	0.533333333
3700 - 3900	3	0.033333333	51	0.566666667
3900 - 4100	2	0.022222222	53	0.588888889
4100 - 4300	3	0.033333333	56	0.622222222
4300 - 4500	2	0.022222222	58	0.644444444
4500 - 4700	3	0.033333333	61	0.677777778
4700 -4900	3	0.033333333	64	0.711111111
4900 - 5100	3	0.033333333	67	0.744444444
5100 - 5300	3	0.033333333	70	0.777777778
5300 - 5500	3	0.033333333	73	0.811111111
5500 - 5700	3	0.033333333	76	0.844444444
5700 - 5900	3	0.033333333	79	0.877777778
5900 - 6100	4	0.044444444	83	0.922222222
6100 - 6300	2	0.022222222	85	0.944444444
6300 - 6500	4	0.044444444	89	0.988888889
over 6500	1	0.011111111	90	1

The mean squared processing of the stationary jaw lining is determined according to the expression:

$$\sum_{i=1}^{n} \overline{X_1} = 3450952t \qquad (10)$$

The frequency of failures of the stationary jaw lining is determined according to the expression:

$$\lambda_i = \frac{1}{\frac{1}{n}\sum_{i=1}^{n}\overline{X}} = \frac{1}{3450952} = 0,00000029 \qquad (11)$$

Table 5.

Processing until failure of the lower lining plate on the left side,t

330000	2016404	4077326
741000	2398073	4578009
1033000	2853338	5149226
1288222	3279603	5612515
1734904	3704199	6020321

Table 6.
Processing of the data on lower lining plate on the left side

$\overline{X}$	f_i	P_i	C_i	$F_x(q)\ P_n = P_{n-1}+p_n$
up to100 thousands tones	0	0	0	0
100 -300	0	0	0	0
300 - 500	1	0.0666667	1	0.066667
500 -700	0	0	1	0.066667
700 - 900	1	0.0666667	2	0.133333
900 - 1100	1	0.0666667	3	0.2
1100 - 1300	1	0.0666667	4	0.266667
1300 - 1500	0	0	4	0.266667
1500 - 1700	0	0	4	0.266667
1700 - 1900	0	0	4	0.266667
1900 - 2100	1	0.0666667	5	0.333333
2100 - 2300	0	0	5	0.333333
2300 - 2500	1	0.0666667	6	0.4
2500 - 2700	0	0	6	0.4
2700 - 2900	1	0.0666667	7	0.466667
2900 - 3100	0	0	7	0.466667
3100 - 3300	1	0.0666667	8	0.533333
3300 - 3500	0	0	8	0.533333
3500 - 3700	0	0	8	0.533333
3700 - 3900	1	0.0666667	9	0.6
3900 - 4100	1	0.0666667	10	0.666667
4100 - 4300	0	0	10	0.666667
4300 - 4500	0	0	10	0.666667
4500 - 4700	1	0.0666667	11	0.733333
4700 -4900	0	0	11	0.733333
4900 - 5100	0	0	11	0.733333
5100 - 5300	1	0.0666667	12	0.8
5300 - 5500	0	0	12	0.8
5500 - 5700	1	0.0666667	13	0.866667
5700 - 5900	0	0	13	0.866667
5900 - 6100	1	0.0666667	14	0.933333
6100 - 6300	0	0	14	0.933333
6300 - 6500	1	0.0666667	15	1
over 6500	0	0	15	1

Table 8.
Processing of the data on lower lining plate on the right side

$\overline{X}$	f_i	P_i	C_i	$F_x(q)\ P_n = P_{n-1}+p_n$
up to100 thousands tones	0	0	0	0
100 -300	0	0	0	0
300 - 500	1	0.0666667	1	0.066667
500 -700	0	0	1	0.066667
700 - 900	1	0.0666667	2	0.133333
900 - 1100	1	0.0666667	3	0.2
1100 - 1300	1	0.0666667	4	0.266667
1300 - 1500	0	0	4	0.266667
1500 - 1700	0	0	4	0.266667
1700 - 1900	0	0	4	0.266667
1900 - 2100	1	0.0666667	5	0.333333
2100 - 2300	0	0	5	0.333333
2300 - 2500	1	0.0666667	6	0.4
2500 - 2700	0	0	6	0.4
2700 - 2900	1	0.0666667	7	0.466667
2900 - 3100	0	0	7	0.466667
3100 - 3300	1	0.0666667	8	0.533333
3300 - 3500	0	0	8	0.533333
3500 - 3700	0	0	8	0.533333
3700 - 3900	1	0.0666667	9	0.6
3900 - 4100	1	0.0666667	10	0.666667
4100 - 4300	0	0	10	0.666667
4300 - 4500	0	0	10	0.666667
4500 - 4700	1	0.0666667	11	0.733333
4700 -4900	0	0	11	0.733333
4900 - 5100	0	0	11	0.733333
5100 - 5300	1	0.0666667	12	0.8
5300 - 5500	0	0	12	0.8
5500 - 5700	1	0.0666667	13	0.866667
5700 - 5900	0	0	13	0.866667
5900 - 6100	1	0.0666667	14	0.933333
6100 - 6300	0	0	14	0.933333
6300 - 6500	1	0.0666667	15	1
over 6500	0	0	15	1

The mean squared processing of the lining of the lower lining plate on the left side is determined according to the expression:

$$\sum_{i=1}^{n}\overline{X_1} = 29877743t \qquad (12)$$

The frequency of failures of the lower lining plate on the left side is determined according to the expression:

$$\lambda_i = \frac{1}{\frac{1}{n}\sum_{i=1}^{n}\overline{X}} = \frac{1}{29877743} = 0{,}000000335 \qquad (13)$$

The mean squared processing of the lining of the lower lining plate on the right side is determined according to the expression:

$$\sum_{i=1}^{n}\overline{X_1} = 3396065t \qquad (14)$$

The frequency of failures of the lower lining plate on the right side is determined according to the expression:

$$\lambda_i = \frac{1}{\frac{1}{n}\sum_{i=1}^{n}\overline{X}} = \frac{1}{3396065} = 0{,}000000294 \qquad (15)$$

Table 7.
Processing until failure of the lower plate on the right side, t

330000	2016404	3704199	5612515
741000	2398073	4077326	6020321
1033000	2853338	4578009	6359732
1288222	3279603	5149226	

Table 9.
Processing until failure of the upper lining plate on the left side, t

741000	3279603	6020321
1653032	4077326	
2398073	5149226	

Table 10.
Processing of the data on the upper lining plate on the left side

$\overline{X}$	f_i	P_i	C_i	$F_x(q)\ P_n = P_{n-1}+p_n$
Up to 100 thousands tones	0	0	0	0
100 -300	0	0	0	0
300 - 500	0	0	0	0
500 -700	0	0	0	0
700 - 900	1	0.142857	1	0.142857
900 - 1100	0	0	1	0.142857
1100 - 1300	0	0	1	0.142857
1300 - 1500	0	0	1	0.142857
1500 - 1700	1	0.142857	2	0.285714
1700 - 1900	0	0	2	0.285714
1900 - 2100	0	0	2	0.285714
2100 - 2300	0	0	2	0.285714
2300 - 2500	1	0.142857	3	0.428571
2500 - 2700	0	0	3	0.428571
2700 - 2900	0	0	3	0.428571
2900 - 3100	0	0	3	0.428571
3100 - 3300	1	0.142857	4	0.571429
3300 - 3500	0	0	4	0.571429
3500 - 3700	0	0	4	0.571429
3700 - 3900	0	0	4	0.571429
3900 - 4100	1	0.142857	5	0.714286
4100 - 4300	0	0	5	0.714286
4300 - 4500	0	0	5	0.714286
4500 - 4700	0	0	5	0.714286
4700 -4900	0	0	5	0.714286
4900 - 5100	0	0	5	0.714286
5100 - 5300	1	0.142857	6	0.857143
5300 - 5500	0	0	6	0.857143
5500 - 5700	0	0	6	0.857143
5700 - 5900	0	0	6	0.857143
5900 - 6100	1	0.142857	7	1
6100 - 6300	0	0	7	1
6300 - 6500	0	0	7	1
over 6500	0	0	7	1

The mean squared processing of the lining of the upper lining plate on the left side is determined according to the expression:

$$\sum_{i=1}^{n}\overline{X_1} = 333127t \tag{16}$$

The frequency of failures of the upper lining plate on the left side is determined according to the expression:

$$\lambda_i = \frac{1}{\frac{1}{n}\sum_{i=1}^{n}\overline{X}} = \frac{1}{333127} = 0,0000003 \tag{17}$$

Table 11.
Processing until failure of the upper lining plate on the right side, t

741000	3279603	6020321
1653032	4077326	
2398073	5149226	

Table 12.
Processing of the data on the upper lining plate on the right side

$\overline{X}$	f_i	P_i	C_i	$F_x(q)\ P_n = P_{n-1}+p_n$
Up to 100 thousands tones	0	0	0	0
100 -300	0	0	0	0
300 - 500	0	0	0	0
500 -700	0	0	0	0
700 - 900	1	0.142857	1	0.142857
900 - 1100	0	0	1	0.142857
1100 - 1300	0	0	1	0.142857
1300 - 1500	0	0	1	0.142857
1500 - 1700	1	0.142857	2	0.285714
1700 - 1900	0	0	2	0.285714
1900 - 2100	0	0	2	0.285714
2100 - 2300	0	0	2	0.285714
2300 - 2500	1	0.142857	3	0.428571
2500 - 2700	0	0	3	0.428571
2700 - 2900	0	0	3	0.428571
2900 - 3100	0	0	3	0.428571
3100 - 3300	1	0.142857	4	0.571429
3300 - 3500	0	0	4	0.571429
3500 - 3700	0	0	4	0.571429
3700 - 3900	0	0	4	0.571429
3900 - 4100	1	0.142857	5	0.714286
4100 - 4300	0	0	5	0.714286
4300 - 4500	0	0	5	0.714286
4500 - 4700	0	0	5	0.714286
4700 -4900	0	0	5	0.714286
4900 - 5100	0	0	5	0.714286
5100 - 5300	1	0.142857	6	0.857143
5300 - 5500	0	0	6	0.857143
5500 - 5700	0	0	6	0.857143
5700 - 5900	0	0	6	0.857143
5900 - 6100	1	0.142857	7	1
6100 - 6300	0	0	7	1
6300 - 6500	0	0	7	1
over 6500	0	0	7	1

The mean squared processing of the lining of the upper lining plate on the right side is determined according to the expression:

$$\sum_{i=1}^{n}\overline{X_1} = 3331226t \tag{18}$$

The frequency of failures of the upper lining plate on the right side is determined according to the expression:

$$\lambda_i = \frac{1}{\frac{1}{n}\sum_{i=1}^{n}\overline{X}} = \frac{1}{3331226} = 0,0000003 \tag{19}$$

Determination of the probability of failure of the jaw crusher. The probability of faultless operation of the entire crusher for a given quantity of processed ore is determined by the multiplication probability theorem:

$$P_T(q) = e^{-q\lambda_1} . e^{-q\lambda_2} . e^{-q\lambda_3} . e^{-q\lambda_4} . e^{-q\lambda_5} . e^{-q\lambda_6} =$$
$$= e^{-q\sum_{k=1}^{6}\lambda_k} \qquad (20)$$

Therefore, there is obtained:

$$P_T(q) = e^{-q(0.00000034+0.00000029+0.00000335+0.000000294+0.0000003+0.0000003)} = e^{-q(0.0000001823)} \qquad (21)$$

The probability of failure of the entire jaw crusher in the average work until failure of the examined elements:

$$\sum_{i=1}^{n} \overline{X_i} = 3297800t \quad \text{- the processed ore equals to:}$$

$$P_T(q) = e^{-3297800(0.00000034+0.00000029+0.00000335+0.000000294+0.0000003+0.0000003)} =$$
$$= e^{-3297800(0.0000001823)} = 0,548 \qquad (22)$$

Conclusions

In conclusion, it can be said that through the methods of the theory of probability and reliability the behavior of machines for the disclosure of mineral beads (in this case jaw crusher) can be expressed, and the failures for planning of the necessary spare parts and upcoming repairs can be predicted.

From the last parameter it can be concluded that the probability of the crusher to fail in its annual operating is about 50%.

All this leads to the conclusion that this machine is very reliable and with high operational safety parameters and two sets of spare parts are necessary per year.

As a further task, heuristic algorithms and computer programs for analyzing and accumulating data, characterizing the life cycle of machines and systems used in the mining industry can be created.

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