World Journal of Advanced Research and Reviews

eISSN: 2581-9615 CODEN (USA): WJARAI

Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://wjarr.com/

(Research Article)

Check for updates

Reliability assessment of mobile pumping units

Ahmadov Ali Hikmat Soltan Ahmad *

Department of Industrial Machines, Azerbaijan State Oil and İndustry University, Azerbaijan.

World Journal of Advanced Research and Reviews, 2024, 24(03), 1150–1154

Publication history: Received on 03 November 2024; revised on 11 December 2024; accepted on 13 December 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.24.3.3806

Abstract

An analytical formula for determining the mathematical expectation and variance is derived . functions reliability mobile pumping units, allowing evaluate residual development With taking into account their technical condition at the start of the next process. An analytical expression was determined For definitions mathematical expectations And differences V safe functions, which allows mobile pumping units to calculate the residual period at the beginning of the process taking into account its technical condition. The problem of trouble-free operation of mobile pumping units at any point in time taking into account their technical condition requires a new approach to assessing the level of reliability in order to ensure uninterrupted performance of the function as intended. Analysis of work in this area shows that to date their technical condition at the time of the start of operation is not taken into account. Therefore, when assessing the failure-free function, it is necessary to take into account that the mobile pumping unit at the time of its entry into operation has some random operating time " η " , preceding the moment of the start of the next operation. In other words, the mobile pumping unit begins to function with varying degrees of risk of failure.

The above indicates the need to conduct a calculation assessment of the level of failure-free operation of mobile pumping units before its operation. The importance of assessing the random time of a mobile pumping unit , taking into account some developed random operating time, dictates the need to develop new calculation models for their definition. Below is a mathematical formulation and solution to this problem.

According to the obtained results of the statistical study, the type of the considered probability function of failure-free operation of the mobile pumping unit obeys the Weibull distribution law. Then the probability of failure-free operation is expressed as a pump that has worked without failure for $\eta = \mathrm{x}$ a time, according to the stated requirement, will still function for u time, i.e. until the moment of time $[\mathrm{u} \in \{\mathrm{x};\infty\}]$, characterizing the moment of failure. Then, the probability of this event, according to the definition of the conditional distribution function /1/: the average time before failure, under the condition $(\xi > \mathrm{x})$ we denote by $M_{\mathrm{x}}\xi$.

Keywords: Mobile pumping unit; Failure-free Operation; Reliability; Torque

1. Introduction

The problem of trouble-free operation of mobile pumping units at any given time, taking into account their technical condition, requires a new approach to the problems.

The problem of trouble-free operation of mobile pumping units is an assessment of the level of reliability in order to ensure the uninterrupted performance of the function as intended.

* Corresponding author: Ali Hikmat Ahmadov

Analysis of works in this direction shows that today their technical condition at the moment of the beginning of operation is not taken into account. Therefore, when assessing the failure-free function, it is necessary to take into account that the mobile pumping unit at the moment of its entry into operation has some random operating time " η ", preceding the moment of the beginning of the next operation. In other words, the mobile pumping unit begins to function with varying degrees of risk of failure [1].

The above indicates the need to conduct a calculation assessment of the level of failure- free operation of a mobile pumping unit before its operation. The importance of assessing the random time of failure-free operation, taking into account some developed random operating time, dictates the need to develop new calculation models for their definition [2].

Below is the mathematical formulation and solution of this problem.

Let us denote the ξ random time of failure-free operation of the pumping unit. Let us express $F_{\xi}(\mathrm{u})$ - the distribution function of a random variable ξ.

According to the obtained results of the statistical study, the type of the considered function of the probability of failure-free operation of mobile pumping units obeys the Weibull distribution law. Then the probability of failure-free operation is expressed as:

$$P\{\xi > \mathrm{x}\}=1\text{-}\mathrm{F}(\mathrm{x}) \overset{def}{\equiv} \overline{\mathrm{F}}(\mathrm{x}) = \exp\{-\alpha \mathrm{x}^{\beta}\} \qquad (1)$$

A mobile pumping unit that has worked without failure for a period $\eta = \mathrm{x}$ of time, according to the stated requirement, is still in operation for u time, i.e. until the moment in time $[\mathrm{u} \in \{\mathrm{x};\infty\}]$ characterizing the moment of failure [3].

Then, the probability of this event, according to the definition of the conditional distribution function /1/, can be written:

$$P\{\xi < \mathrm{u} / \xi > \mathrm{x}\}$$

The average time to failure, given , $(\xi > \mathrm{x})$ is denoted by $M_{\mathrm{x}}\xi$. Then, the definition of mathematical expectation will be presented as:

$$M_{\mathrm{x}}\xi = \int_{\mathrm{x}}^{\infty} \mathrm{u} p\{\xi \in d\mathrm{u} / \xi > \mathrm{x}\} \qquad (2)$$

Let's introduce following designation :

$$P(\mathrm{u},\mathrm{x}) \overset{def}{\equiv} P\{\xi > \mathrm{u} / \xi > \mathrm{x}\} = \frac{P\{\xi > \mathrm{u}, \xi > \mathrm{x}\}}{P\{\xi > \mathrm{x}\}} = \frac{P\{\xi > \mathrm{u}\}}{P\{\xi > \mathrm{x}\}}, \quad \mathrm{u} \in (\mathrm{x}, \infty)$$

We calculate the entered function taking into account the distribution according to the Weibull law:

$$P(\mathrm{u},\mathrm{x}) = \exp\{\alpha \mathrm{x}^{\beta}\} \cdot \exp\{-\alpha \mathrm{u}^{\beta}\} \qquad (3)$$

Having produced replacement variable $\alpha \mathrm{x}^{\beta} = T_{\mathrm{x}}$, we get :

$$P(\mathrm{u},\mathrm{x})=\exp\{T_{\mathrm{x}}\}\cdot\exp\{-\alpha\mathrm{u}^{\beta}\} \qquad (4)$$

It is obvious that:

$$P\{\xi\in d\mathrm{u}/\xi>\mathrm{x}\}=\frac{P\{\xi\in d\mathrm{u};\xi>\mathrm{x}\}}{P\{\xi>\mathrm{x}\}}=\frac{P\{\xi\in d\mathrm{u}\}}{P\{\xi>\mathrm{x}\}}=-\left(\frac{P\{\xi>\mathrm{u}\}}{P\{\xi>\mathrm{x}\}}\right)'_{\mathrm{u}}d\mathrm{u}=-P'_{\mathrm{u}}(\mathrm{u},\mathrm{x})d\mathrm{u}, \qquad (5)$$

After substituting (5) into equation (2), taking into account the substitutions made and calculating the derivative with respect to u, we obtain:

$$M_{\mathrm{x}}\xi=-\int_{\mathrm{x}}^{\infty}\mathrm{u}P'_{\mathrm{u}}(\mathrm{u},\mathrm{x})d\mathrm{u}=\exp(T_{\mathrm{x}})\int_{\mathrm{x}}^{\infty}\mathrm{u}\{-\alpha\beta\mathrm{u}^{\beta-1}\cdot\exp(\alpha\mathrm{u}^{\beta})\}d\mathrm{u}=\alpha\beta\cdot\exp(T_{\mathrm{x}})\int_{\mathrm{x}}^{\infty}\mathrm{u}^{\beta}\exp(-\alpha\mathrm{u}^{\beta})d\mathrm{u}, \qquad (6)$$

By entering designations:

$$\alpha\mathrm{u}^{\beta}=\upsilon;\quad 1/\beta=\gamma$$

$$\mathrm{u}=\left(\frac{\upsilon}{\alpha}\right)^{1/\beta};\ d\mathrm{u}=\gamma\left(\frac{\upsilon}{\alpha}\right)^{\upsilon-1}\frac{d\upsilon}{\alpha},$$

$$\alpha\mathrm{u}^{\beta}=\upsilon;\quad 1/\beta=\gamma$$

$$\mathrm{u}=\left(\frac{\upsilon}{\alpha}\right)^{1/\beta};\ d\mathrm{u}=\gamma\left(\frac{\upsilon}{\alpha}\right)^{\upsilon-1}\frac{d\upsilon}{\alpha},$$

expression (6) can be written as:

$$M_{\mathrm{x}}\xi=\alpha\beta\exp(T_{\mathrm{x}})\int_{T_{\mathrm{x}}}^{\infty}\frac{\upsilon}{\alpha}\exp(-\upsilon)\gamma\left(\frac{\upsilon}{\alpha}\right)^{\upsilon-1}\frac{d\upsilon}{\alpha} \qquad (7)$$

After the appropriate transformation, the dependence expressing the mathematical expectation of the random time of failure-free operation under the condition $\{\xi>\mathrm{x}\}$ will have the following form:

$$M_{\mathrm{x}}\xi=\frac{1}{\alpha^{\beta}}\exp(T_{\mathrm{x}})\bar{\Gamma}\left(\frac{1}{\beta}+1;T_{\mathrm{x}}\right). \qquad (8)$$

Here

$$\bar{\Gamma}(\gamma+1,T_{\mathrm{x}})=\int_{T_{\mathrm{x}}}^{\infty}\upsilon^{\gamma-1}\exp(-\upsilon)d\upsilon=\Gamma(\gamma)-\Gamma(\gamma;T_{\mathrm{x}}), \qquad (9)$$

Where,

$\Gamma(\gamma)=\int_{0}^{\infty}\upsilon^{\gamma-1}\exp(-\upsilon)d\upsilon$ - gamma function

$\Gamma(\gamma;T_x)=\int_0^T \upsilon^{\gamma-1}\exp(-\upsilon)d\upsilon$ - incomplete gamma function, tabulated /2/.

Similarly, to determine the dispersion of $(D_x\xi)$ the failure-free operation time of a pumping unit, given $\{\xi > x\}$, we calculate $M_x^2\xi$.

$$M_x^2\xi=\int_x^\infty u^2P\{\xi\in du/\xi>x\}$$

After applying the above transformations, we obtain:

$$M_x^2\xi=\frac{1}{\alpha^{2\beta}}\exp(T_x)\overline{\Gamma}(\frac{2}{\beta}+1;T_x), \tag{10}$$

It is known that dispersion is determined How

$$D_x\xi=M_x[\xi-M_x\xi]^2$$

Then, taking into account expressions (8) and (10), the variance of the random time of failure-free operation will be represented as:

$$D_x\xi=M_x^2\xi-(M_x\xi)^2=a^2\exp(T_x)\overline{\Gamma}(1+\frac{2}{\beta};T_x)-a^2\exp(2T_x)[\overline{\Gamma}(1+\frac{2}{\beta};T_x)]^2.$$

Here It was taken into account that :

$$a=\frac{1}{\alpha^{1/\beta}}$$

So,

$$D_x\xi=a^2\exp(T_x)\{\overline{\Gamma}(1+\frac{2}{\beta};T_x)-\exp(T_x)[\overline{\Gamma}(1+\frac{1}{\beta};T_x)]^2\} \tag{11}$$

Note that the obtained expressions for the mathematical expectation and dispersion can be applied when, at the moment in question, the installation has some operating time.

If the mobile pumping unit begins operation after the reliability level has been fully restored as a result of replacing parts that are damaged or have largely exhausted their service life (X=0), then expressions (8) and (11) will take the following form:

$$M_0\xi=\frac{1}{\alpha^{1/\beta}}\Gamma(\frac{1}{\beta}+1) \tag{12}$$

$$D_0\xi=\frac{1}{\alpha^{1/\beta}}[\Gamma(\frac{2}{\beta}+1)-\Gamma(\frac{1}{\beta}+1)] \tag{13}$$

2. Conclusion

An analytical formula has been derived for determining the mathematical expectation and variance of the failure-free function of mobile pumping units, which allows estimating the residual operating time taking into account their technical condition at the start of the next process.

References

[1] J. M. Bergada, Sushil Kumar, J. Watton: Aksial Piston Pump, New Trends and Development. - 2012 Nova Science Publishers, Inc. (pp.1-157)

[2] Hongbin Tang, Zheng Fu, Yi Huang: A fault diagnosis method for loose slippery failure of piston pump in construction machinery under changing load.–2020

[3] Jessica Gissella Maradey Lázaro, Carlos Borrás Pinilla: A methodology for detection of wear in hydraulic axial piston pumps. – 2020