

# Identification and evaluation of reliability factors of main oil pumps

V S Tynchenko<sup>1</sup>, V V Bukhtoyarov<sup>1</sup>, V V Tynchenko<sup>1</sup>, V V Kukartsev<sup>1</sup> and N A Shepeta<sup>1</sup>

<sup>1</sup>Siberian Federal University, 79, Svobodny pr., Krasnoyarsk, 660041, Russia

E-mail: vadimond@mail.ru

**Abstract.** Preventative maintenance systems today are not always able to achieve projected levels of the main pumps use because of the presence of random technical, technological and statistical errors. It is necessary to identify the mean time between failures, reducing factors in situations where exploitative parameters are within the normal limits. It is offered to use statistical indexes and standard parameters for the analysis. Factor analysis defines a moderate negative correlation between the vibration velocity of the fixed pumps' parts and the mean time between failures. Also, a weak positive correlation between vibration velocity and other parameters has been determined. The results can be used to improve preventive maintenance systems, as well as to choose the most reliable structural performance.

## 1. Introduction

At present, preventative maintenance systems are used in exploitation of the main pumps, with which it is possible to make a timely diagnosis of the equipment, and thus predict and minimize equipment failures. However, when evaluating the reliability parameters, it is often difficult to consider all the factors that influence the occurring failures. Despite the fact that the equipment operating time is determined by standards, failures still occur due to the technological, exploitation and other errors admission [1, 2]. Such errors, seeming minor, lead to the changes of parameters that have a direct impact on the reliability of the all technical systems and as a result reduce its resource [3].

The exploitative parameters of the pumps in the standard range are not always the norm in terms of equipment work resources. In other words, the time between failures can greatly decrease even in cases where the operational parameters do not exceed the standards' specified limits [4, 5]. In these cases, it becomes difficult to predict equipment failures by the operating time and the current state due to reduced possibility of detecting early failures because exploitative parameters do not exceed the norm in accordance with the technological regulations and standards for a given type of equipment [6, 7]. It is therefore necessary to identify the factors of reliability which directly affect the actual operating time of the main oil pumps [8]. It will help to estimate the technical risks in situations where exploitative parameters are not out of the specified limits.

## 2. Main pumps and its parameters

Main pumps are basic equipment that is used for the transport of separator oil by pipelines after its extraction from wells, preparation and water release. Ensuring the smooth operation of pumps requires a high level of reliability that is not only set in the production, but also depends on the operating

conditions [9, 10]. Standard GOST 12124-87 - "Centrifugal pumps for oil trunk pipelines" covers centrifugal pumps for supply of oil and oil products (including natural gas liquids) in pipeline systems. The standard requires 23 types, for which the following parameters are set up: pressure, flow (main indicator of productivity), limiting pressure, net positive suction head (NPSH), efficiency, frequency of rotation and mass. Thus, the choice of the equipment brand from presented types is possible and it is based not only on frequency of rotation, mass and productivity parameters, but also on their combinations that are most convenient for the particular technological objects.

Standard GOST 32601-2013 "Centrifugal pumps for petroleum, petrochemical and natural gas industries. General specifications" implies an additional requirement according to which vibration velocity of fixed pump elements should be between 2.8 to 7.6 mm /sec and the operating time of the pumps should be at least 40,000 hours. However, taking into consideration factors of errors origin in production, installation, commissioning and exploitation, the operating time indicator is practically 1.5-2 times less. That leads to increased costs for capital unscheduled repairs of equipment. To achieve set-up in the standard rates of operating time, it is necessary to identify those factors that have a direct impact on the reliability. So, having a technique to detect and prevent possible failures, for example such as a preventative maintenance system, it will help to minimize technical risks.

### **3. Indexes of main pumps reliability**

Reliability indexes quantitatively characterize the extent of certain object properties that determine reliability of any technical system [11]. The basis for all further identified reliability parameters will be system infallibility because in our research we consider indexes during operation. Infallibility of the technical system, according to the theory of reliability, is an object ability to continuously maintain usable state for some time or operating time [12, 13].

The main indicator of reliability is a time between failures, which is calculated and set up in manufacturing in accordance with the standards. Nevertheless, the real operating time values can significantly differ in mean occurrence of random errors, which is not possible to identify at certain stages of technical system cycle's life [14].

### **4. Factor analysis of reliability indexes**

To evaluate the factors that lead to a decrease in reliability indexes, we have collected data on the operating time before the first main pumps failure of all types and calculated mean time between failures (MTBF) for each of them. The choice of different pumps' types is caused by the fact that certain exploitative parameters can be repeated for different types in the presence of differences in other parameters. Also, in accordance with the standards we have collected data on the mean values of vibration pumps velocity during their operating time and, thereafter, obtained the mean values for the different types of the main pumps. Thus, with the data on the operating time, vibration velocity and exploitative parameters that are set up in the standards, for which the manufacturing process regulations are found, we have obtained data sampling to assess all the factors of the operating time as the main indicator of exploitative reliability.

Evaluating all the parameters that might be suitable for reliability analysis, it is necessary to note that we have excluded those parameters, whose values are calculated from other known parameters. That fact can be explained by their impact on the operating time, which will be based on the parameters of their components. As a result, for implementation of the factorial analysis we have used the data presented in table 1.

Correlation analysis is used as a method of factor analysis in order to find out how the factors affect the operating time. Analysis was performed in a software package Statistica. Such program package provides powerful and easy-to-use tools for statistical and graphical analysis, predicting, data mining, creating one's own custom applications, integration, collaboration and web-based access [15].

Thus, the correlation matrix of parameters is presented in table 2 as a result of such analysis.

**Table 1.** Parameters data for different main pump.

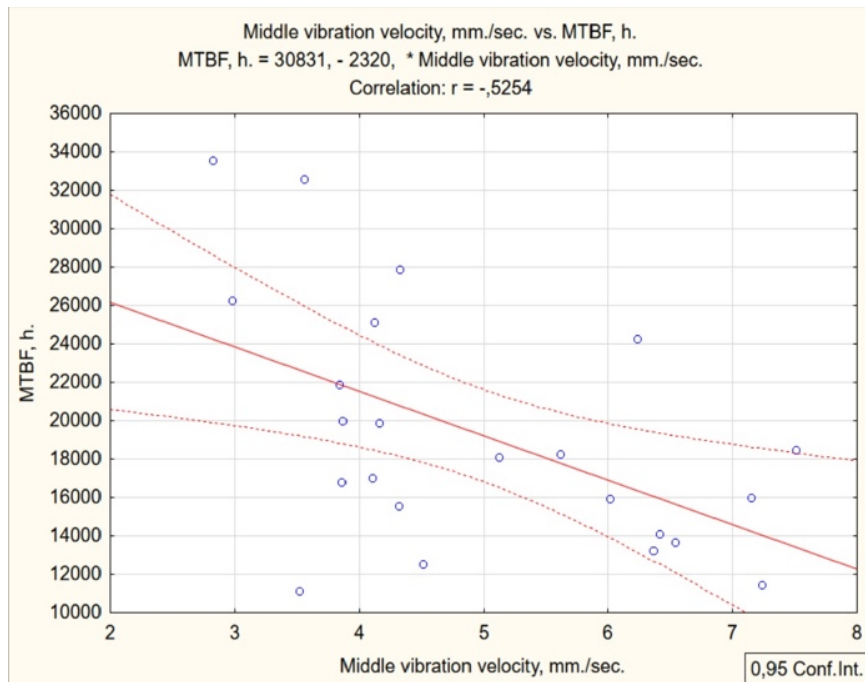
---

Types	Parameters					
	MTBF, h	Productivity, cbm/h	Pressure, m	Frequency, rpm	NPSH, m	Middle vibration velocity, mm/sec.
NM 125-550	18256	125	550	3000	4	5.62
NM 180-500	26251	180	500	3000	4	2.98
NM 250-475	33594	250	475	3000	4	2.83
NM 360-460	11445	360	460	3000	4.5	7.24
NM 500-300	27892	500	300	3000	4.5	4.33
NM 710-280	15951	710	280	3000	6	6.01
NM 1250-260	32584	1250	260	3000	18	3.56
NM 2500-230	16845	2500	230	3000	32	3.86
NM 3600-230	25114	3600	230	3000	35	4.12
NM 7000-210	21891	7000	210	3000	52	3.84
NM 10000-210	14125	10000	210	3000	65	6.41
NPV 150-60	16032	150	60	3000	3	7.15
NPV 300-60	13252	300	60	3000	4	6.36
NPV 600-60	17052	600	60	1500	4	4.11
NPV 1250-60	11151	1250	60	1500	2.2	3.52
NPV 2500-80	19913	2500	80	1500	3.2	4.16
NPV 3600-90	20021	3600	90	1500	4.8	3.87
NPV 5000-120	12576	5000	120	1500	5	4.51
NOU 50-350	18127	50	350	3000	3	5.12
NM 200-800	15602	200	800	3000	4	4.32
NM 500-800	13685	500	800	3000	4.5	6.54
NM 1250-400	24251	1250	400	6000	60	6.24
NM 2500-710	18514	2500	710	8200	160	7.51

**Table 2.** Correlation table.

Variable	MTBF, h	Productivity, cbm/h	Pressure, m	Frequency, rpm	NPSH, m	Middle vibration velocity, mm/sec.
MTBF, h	18256	125	550	3000	4	5.62
Productivity, cbm/h	17052	600	60	1500	4	4.11
Pressure, m	15602	200	800	3000	4	4.32
Frequency, rpm	13685	500	800	3000	4.5	6.54
NPSH, m	24251	1250	400	6000	60	6.24
Middle vibration velocity, mm/sec.	18514	2500	710	8200	160	7.51

For visual presentation, a graph was drawn between the time of work and the most significant factor – vibration velocity (figure 1).



**Figure 1.** Correlation graph of MTBF and middle vibration velocity.

According to the correlation matrix and the graph, it is obvious that the MTBF is the moderate negative expressed dependence of the mean vibration. The correlation matrix shows that the middle vibration velocity has a weak positive correlation with such factors as the NPSH and rotation frequency.

## 5. Results discussion

As a result of the factor analysis, we have revealed the dependence between the middle vibration velocity, during the operating time, of the fixed parts of the main pumps and MTBF of each pump type. The resulting dependence can be interpreted as a moderate expressed. This gives us a reason to consider that the resource of the main pumps can significantly change even within a normal range of the vibration velocity values that are set up by standards. Despite the fact that the same extent expressed dependences between operating time and other factors have not been identified, it is possible to estimate that the parameters such as NPSH and rotation frequency of working pumps part are weak correlated with the mean value of the vibration velocity. This fact allows one to conclude about the forming factors of vibration velocity that are the presentation of reliability parameters. From this we can report that the embodiments of the main pumps with similar parameters may be factors of reliability.

There are qualitative parameters of main pumps which are the embodiment's variants. Thus, changes in rotation frequency will lead to lack of productivity changes. One method to implement such parameter combination is the facing of pump impellers [10]. According to this method you can change the vibration velocity of the pumps without affecting their productivity that will ensure higher levels of reliability.

## 6. Conclusion

The article reports about the factors affecting reliability of the main pumps. We have found the dependence between the vibration velocity of fixed parts of the pumps and MTBF. In this way, we have identified the vibration velocity dependences from the operating parameters that can be selected on the assumption of the necessary reliability indexes and embodiments.

Analysis of factors has shown the parameters that do not exceed the normal limits, can significantly reduce the reliability of the technical system. The results of this study make it possible to select the most appropriate embodiment solutions that will have the lowest negative impact on the reliability indexes. In addition, the results may be used in order to predict the pumps conditions in the analysis of technical risks [16]. Based on the assessment of relationships between factors, it is possible to improve the system of preventative maintenance and avoid a number of failures.

## 7. Acknowledgments

The study has been undertaken as part of the research into the subject MK-1574.2017.8 “Designing the expert system of the analysis and control of reliability, risks and emergencies in support of the operation of petroleum refinery equipment” funded by the Grant Advisory Board for the President of the Russian Federation in a bid to provide governmental support for young Russian scientists.

## References

- [1] Severtsev N A 1989 *Reliability of Complex Systems for the Management and Testing* (Moscow: Higher School)
- [2] Bobrowski S A and Sokolovsky S M 1972 *Hydraulics, Pumps and Compressors* (Moscow: Nedra)
- [3] Harlamenco V I and Golub M V 1978 *Operation Pump Oil Pipelines* (Moscow: Nedra)
- [4] *Pumps and Pump Systems*, available at: [http://intech-gmbh.ru/equip\\_pumps/](http://intech-gmbh.ru/equip_pumps/)
- [5] Lobanoff V S and Ross R R 2013 *Centrifugal Pumps: Design and Application* (Amsterdam: Elsevier)
- [6] Calixto E 2016 *Gas and Oil Reliability Engineering: Modeling and Analysis* (Cambridge: Gulf Professional Publishing)
- [7] Youngk R D 2000 Automobile engine reliability, maintainability and oil maintenance *Reliability and Maintainability Symposium. Proceedings. Annual* pp 94-99
- [8] Gumerov A G, Kolpakov L G, Bazhaykin S G and Vekshteyn M G 1999 *Centrifugal Pumps in the System-Stroke Collection, Preparation and the Main Trans-Port Oil* (Moscow: Nedra)
- [9] Leontiev I A and Zhuravlev I G 1975 *Fundamentals of Reliability of Gas Extraction Systems* (Moscow: Nedra)
- [10] Bukhtoyarov V V, Petrovskiy E A, Tynchenko V S, Zhukov V G and Smirnov A I 2016 Workpiece surface technological quality assurance with levitation tool modules *Indian Journal of Science and Technology* **9(29)** 1-16
- [11] Albrecht P F, Appiarius J C, McCoy R M, Owen E L and Sharma D K 1986 Assessment of the reliability of motors in utility applications *IEEE Transactions on Energy conversion* **1** 39-46
- [12] Rausand M and Vatn J 2008 *Reliability Centred Maintenance. Complex System Maintenance Handbook* (London: Springer)
- [13] Percy D F and Alkali B M 2007 Scheduling preventive maintenance for oil pumps using generalized proportional intensities models *International Transactions in Operational Research* **14(6)** 547-563
- [14] Seo J H, Jang J S and Bai D S 2003 Lifetime and reliability estimation of repairable redundant system subject to periodic alternation *Reliability Engineering & System Safety* **80(2)** 197-204
- [15] *Review on the Statistica program system*, available at: <http://statsoft.ru/products/overview/>
- [16] Bukhtoyarov V V, Tynchenko V S, Petrovskiy E A, Tynchenko V V and Zhukov V G 2018 Improvement of the methodology for determining reliability indicators of oil and gas equipment *International Review on Modelling and Simulations* **11(1)** 37-50