African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 4, Issue 1, January - March 2025
Page No: 225-232
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2024: 0.877 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62

Vibrations Diagnosis and Condition Monitoring of Centrifugal Pumps at Al-Brega Oil Company

Ezedine G. Allaboudi [1 *], Khaled M. Ahmida [2]
[1,2] Department of Mechanical and Industrial Engineering, Faculty of Engineering, University of Tripoli, Libya

تشخيص الاهتزازات ومراقبة الحالة لمضخات الطرد المركزي بشركة البريقة للنفط

عزالدين جمعة اللبودي [1 *]، خالد محمد احميده [2]
[2،1] قسم الهندسة الميكانيكية والصناعية، كلية الهندسة، جامعة طرابلس، ليبيا

[*]Corresponding author: e.allaboudi@uot.edu.ly

Received: November 23, 2024	Accepted: January 27, 2025	Published: February 08, 2025

Abstract:
This study focuses on diagnosing and analyzing faults in centrifugal pumps at Al-Brega Oil Company using vibration monitoring techniques. It primarily identifies common issues such as misalignment, imbalance, and bearing failures, which can cause significant operational inefficiencies and expensive repairs. The research methodology employs overall velocity, shock pulse, and spectrum analysis via the VIBXpert device, demonstrating effectiveness in early fault detection before problems escalate. Results are compared against ISO standards to evaluate the condition and performance of the pumps. The findings highlight the importance of routine monitoring to minimize downtime and maintenance costs by detecting faults early. Moreover, the study offers valuable insights into enhancing maintenance strategies for more reliable and efficient operation of industrial pumping systems.

Keywords: Centrifugal pump, Vibration monitoring, Fault diagnosis, Spectrum analysis.

الملخص
تستعرض هذه الدراسة تشخيص وتحليل الأعطال لمضخات الطرد المركزي المستخدمة في شركة البريقة للنفط - طريق المطار- من خلال مراقبة الاهتزازات الميكانيكية الناتجة من ظروف التشغيل. تركز الدراسة بشكل أساسي على تحديد المشكلات الشائعة في المضخات مثل عدم المحاذاة، وعدم التوازن، وفشل المحامل، وهي مشكلات يمكن أن تؤدي إلى انخفاض كفاءة التشغيل وتكاليف صيانة مرتفعة. أظهرت المنهجية المعتمدة في هذه الدراسة فعاليتها في اكتشاف هذه الأعطال في مراحلها المبكرة، قبل أن تتفاقم وتصبح أكثر صعوبة وتكلفة في الإصلاح. تم إجراء عمليات القياس، بما في ذلك سرعة الاهتزاز العامة، نبض الصدمة، وتحليل الطيف باستخدام جهاز VIBXpert . سمحت هذه التقنيات بتقييم شامل لحالة المضخات، ومن تم تمت مقارنة النتائج مع معايير ISO لتقييم أداء المضخات وملاءمتها لأفضل الممارسات الصناعية. تؤكد النتائج على أهمية إجراء فحوصات روتينية للمضخات، مشيرة إلى أن المراقبة المنتظمة يمكن أن تقلل بشكل كبير من فترات التوقف وتكاليف الصيانة من خلال اكتشاف الأعطال في مراحلها المبكرة. علاوة على ذلك، تقدم الدراسة رؤى قيمة لتحسين استراتيجيات الصيانة لأنظمة المضخات الصناعية، مما يضمن تشغيلًا أكثر كفاءة وموثوقية على المدى الطويل.

الكلمات المفتاحية: مضخة الطرد المركزي، مراقبة الاهتزازات، تشخيص الأعطال، تحليل الطيف.

Introduction

Condition monitoring refers to the process of continuously assessing the health and performance of machinery and equipment in real-time, often using various sensors and diagnostic tools. Condition monitoring and fault diagnosis utilizing advanced science and technology serve as effective methods for predicting potential faults and minimizing the costs associated with machine malfunctions. This approach, known as mechanical equipment fault diagnosis technology, has emerged over the past three decades [1, 2].

Centrifugal pumps are widely used in industrial production, particularly in the oil industry [3,4]. During the operation of centrifugal pumps, failures such as bearing wear and impeller imbalance often occur due to factors such as equipment deterioration and environmental conditions. These failures are frequently accompanied by an increase in local temperature and pump vibration [5]. By monitoring physical parameters such as vibration and temperature, the operating condition of the equipment can be assessed, the health status of the centrifugal pump can be analyzed, and fault diagnosis and prediction for malfunctioning equipment can be performed. This facilitates predictive maintenance [6,7], ensuring the safety of both equipment and personnel [8]. In the industry, the widely used method for vibration monitoring is the measurement of acceleration on the bearings [9, 10]. This technique is mostly applied because of its simple and straightforward utilization. The bearing is an important component of the centrifugal pump, which is responsible for supporting the rotor. Bearing failures can occur due to many factors, such as inadequate lubrication, overload, and other causes. These failures lead to issues such as pitting, peeling, wear, and other forms of damage to the rolling bearing components, resulting in bearing wear, vibration, and impact [11,12,13]. As wear progresses and worsens, it is often accompanied by an increase in temperature. This can be monitored and assessed using the overall vibration value, vibration at narrow-band frequencies, and the kurtosis index, which reflects the impact characteristics [14].
The aim of this paper is to monitor and diagnose faults in centrifugal pumps at Al-Brega Oil Company. This will help identify underlying problems and enable the implementation of maintenance procedures to ensure that the pumps operate under optimal performance conditions.

Devices used
The VIBXpert II, shown in Figure 1, is a portable vibration analyzer used to measure and analyze vibrations in machinery and equipment in industrial settings. It is designed to identify potential faults or defects in the machine and provide recommendations for maintenance and repair. The device is equipped with advanced features, such as a high-resolution color display, multiple measurement channels, and various analysis functions, to enable accurate and efficient monitoring of equipment.
The VIBXpert II is typically connected to the equipment being monitored via a sensor. The device then measures and records vibration data, which can be analyzed using various analysis functions and parameters. The device also includes a high-resolution color display that allows operators to monitor vibration patterns in real-time and provides immediate feedback on any changes or irregularities.
In addition to its hardware components, VIBXpert II also uses software to perform various analysis functions and generate reports. The device comes with the OMNITREND software suite, which allows operators to manage and analyze vibration data collected from the device. The software includes various modules, such as the balancing module, the spectrum module, and the time signal module, that enable operators to perform a detailed analysis of vibration data and generate comprehensive reports.

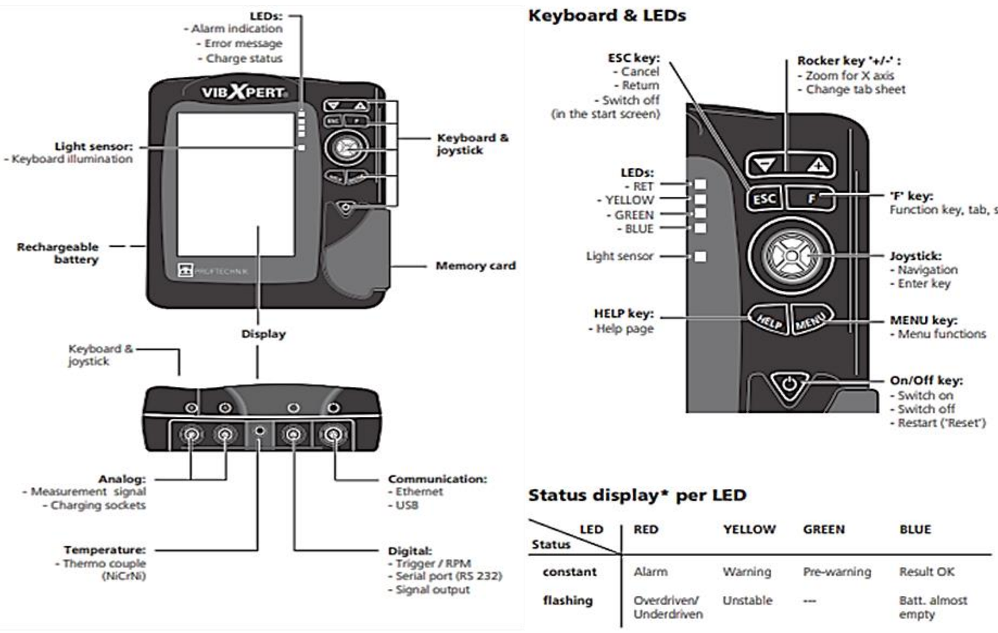

Figure (1): Overview of the VIBXpert II device.

Case study
This investigation was carried out on centrifugal pumps at Al-Brega Company (Figure 2). The study focused on two main pumps from the production line, namely pump 101-A and pump 206-A centrifugal pumps.

Figure (2): Foundation of a Centrifugal Pump at Al-Brega Company.

Measurement sensors were connected to the pumps (Figure 3), and through the application of specific measurement procedures using the VIBXpert device, the pump conditions were diagnosed to identify any faults that could potentially affect their performance during operation.

Figure (3): Sensor located in the horizontal direction.

Once the results are obtained in a correct format, the comparison with ISO standards is conducted to identify, detect, and address any issues with the pumps under inspection (101-A and 206-A). Tables 1 and 2 show the results of the overall velocity measurements of the motor tested on pump 101-A and pump 206-A respectively. When compared to the vibration limits outlined in Table 3 (ISO 10816-3), it is obvious that the readings for axial vibration at the drive end of the motor are very close to the recommended values, which could potentially lead to undesirable issues in the future. Note that NDE refers to the Non-Drive End and DE refers to the Drive End.

Table (1): motor over all velocity for pump 101-A.

Overall velocity (mm/s)	Motor	
	NDE	DE
Horizontal	1.44	2.7
Vertical	1.43	1.35
axial	0.49	4.33

Table (2): motor over all velocity for pump 206-A.

Overall velocity (mm/s)	Motor	
	NDE	DE
Horizontal	1.64	2.1
Vertical	2.07	2.72
axial	0.68	4.11

Table (3): ISO 10816-3.

Iso vibration monitoring standard (mm/s)	Pre-warning	Warning	Alarm
motor	1.4	2.8	4.5

Tables 4 and 5 show the results of the overall velocity measurements of the pump 101-A. and pump 206-A respectively. Compared to the allowable values in Table 6, the results indicated that no problems were found, although some warnings were observed, regarding the overall velocity of both pumps 101-A and 206-A.

Table (4): Pump 101-A. Over all velocity

Overall velocity(mm/s)	Pump 101-A	
	NDE	DE
Horizontal	1.43	2.61
Vertical	2.71	3.53
axial	1.53	1.31

Table (5): Pump 206-A. Over all velocity

Overall velocity(mm/s)	Pump 206-A	
	NDE	DE
Horizontal	1.52	3.41
Vertical	1.37	1.51
axial	1.19	0.92

Table (6): ISO 10816-3.

Iso vibration monitoring standard (mm/s)	Pre-warning	Warning	Alarm
pump	2.3	4.5	7.1

After the warning was detected, a detailed examination of the shock pulse readings was carried out to further investigate the source of the fault, with the readings obtained from the bearings, as shown in Table 7 and Table 8.

Table (7): Shock Pulse measurement of pump 101-A.

Shock pulse (db)		Motor		Pump	
		NDE	DE	DE	NDE
Horizontal	Carpet	7	10	32	21
	Max	17	20	35	18
Vertical	Carpet	4	8	28	24
	Max	14	20	40	19
Axial	Carpet	-5	16	32	22
	Max	1	26	30	18

Table (8): Shock Pulse measurement of pump 101-A.

Shock pulse (db)		Motor		Pump	
		NDE	DE	DE	NDE
Horizontal	Carpet	10	-6	12	7
	Max	16	-1	14	17
Vertical	Carpet	-5	-5	10	1
	Max	4	0	20	9
Axial	Carpet	-6	-6	6	3
	Max	-2	0	16	17

Table (9): PRÜFTECHNIK bearing standard.

Severity level and alarm status(db)	Carpet		Max	
	Warning	Alarm	warning	alarm
	10	15	25	35

Compared to Table 9, the readings indicated damage to the bearing at the driving end of pump 101-A. Additionally, the readings from pump 206-A showed signs of friction caused by insufficient lubrication in the bearing. Therefore, the use of spectrum analysis is crucial for accurately identifying and detecting the problem. The comparison process with the spectrum standard was initiated, and the following figure 4 displays the spectrum for pump 101-A (DEH), while figure 5 shows the spectrum for pump 101-A (DEA).

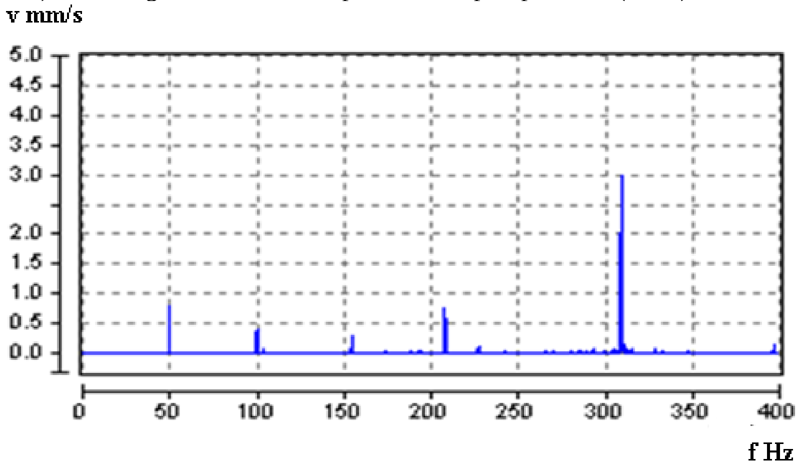

Figure (4): DEH spectrum of pump 101-A.

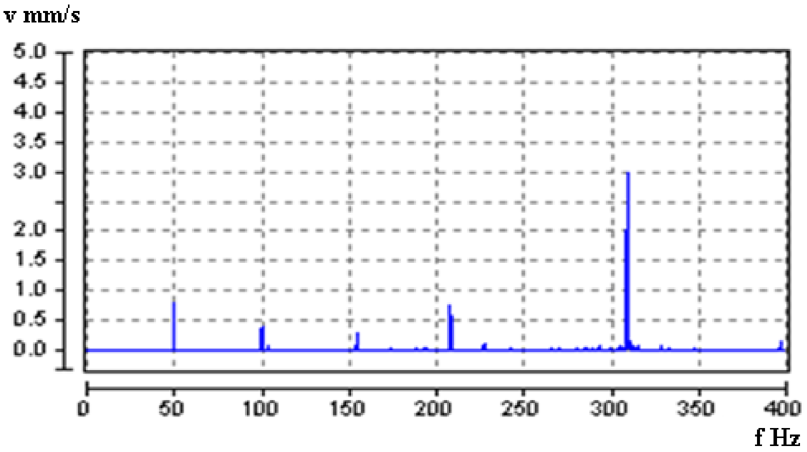

Figure (5): DEA spectrum of pump 101-A.

Compared to the Mobius Institute standard shown in Figs. 6 and 7, the bearing issue is classified as bearing stage 5. This is due to its alignment with the peaks in the results spectrum, appearing as a decreasing wave that starts with the first peak (1x) and the 2x peak, disappearing at the 3x peak. The peak between 3x and10 x indicates the harmonics, especially when sidebands are present, revealing visible wear on the bearing. Therefore, replacing the bearing is the recommended solution to address the issue. In addition, angular misalignment creates a bending moment on each shaft, leading to strong vibrations at 1X and some vibrations at 2X in the axial direction at both bearings. The results indicated that the angular misalignment is relatively small when compared to the ISO standard.

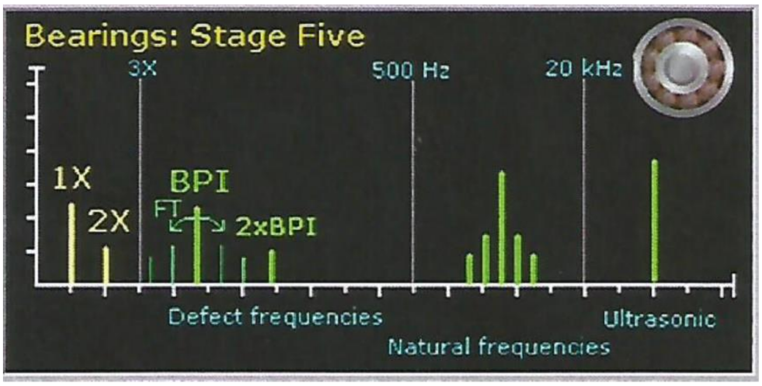

Figure (6): Mobius institute standard for bearing stage five.

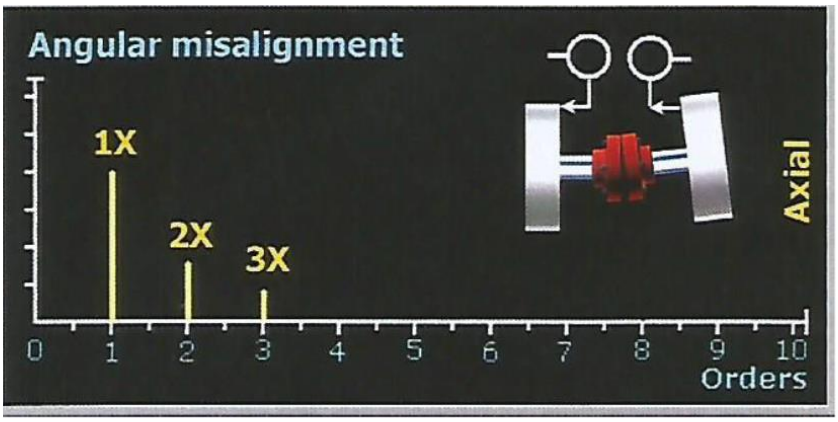

Figure (7): Mobius institute standard (Angular misalignment).

Similarly, the comparison process with the spectrum standard for pump 206-A was initiated, and figure 8 displays the spectrum for pump 206-A (DEV), while figure 9 shows the spectrum for pump 206-A (DEA).

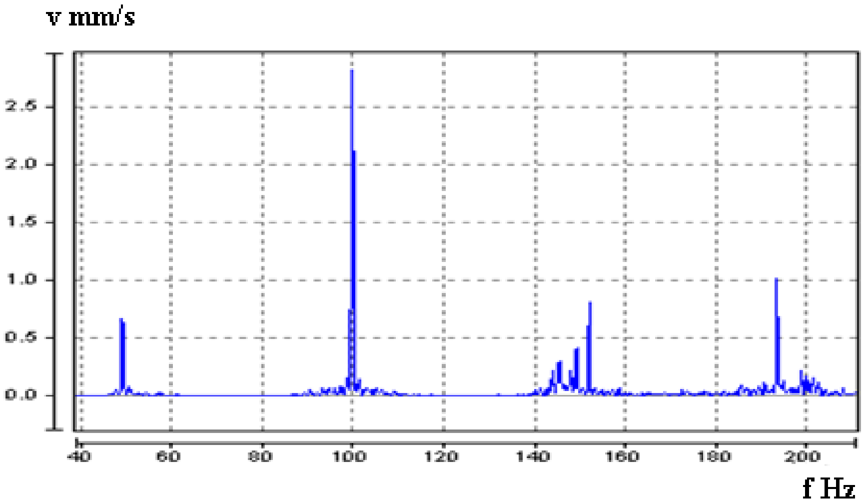

Figure (8): DEV motor spectrum of pump 206-A.

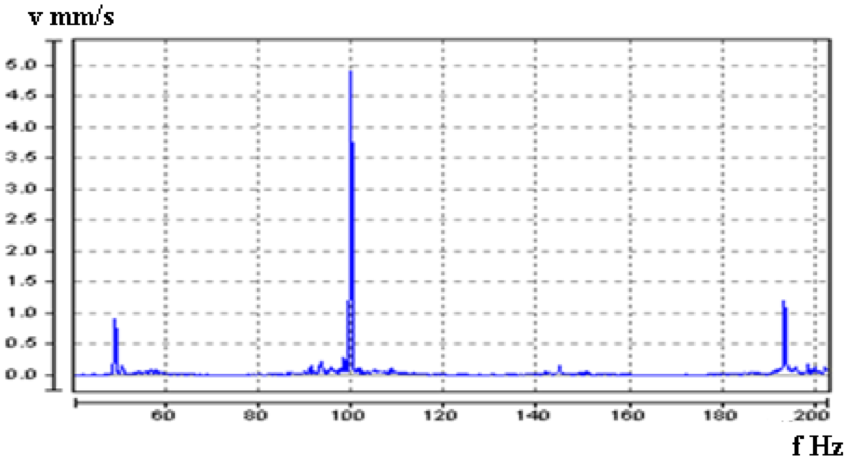

Figure (9): DEA motor spectrum of pump 206-A.

In comparison to Figure 10, parallel misalignment creates both shear and bending moments at the coupled end of each shaft. This causes higher vibration levels at 1X and 2X in the radial directions (vertical and horizo7ntal) on the bearings on both sides of the coupling. The axial vibration levels at 1X and 2X are generally low in the case of pure parallel misalignment.

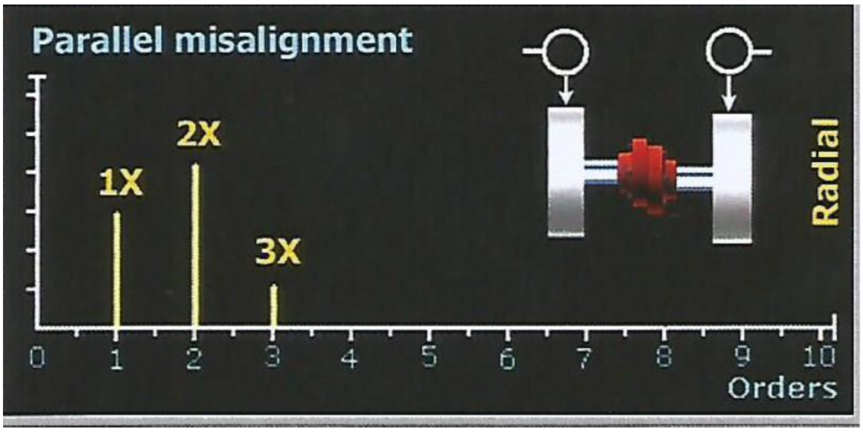

Figure (10): Mobius institute standard (Parallel misalignment).

After completing the analysis, the recommendations were given to the maintenance team to carry out the necessary maintenance to address the identified issues. Once the maintenance team completed their tasks, diagnostic procedures for pump 206 were repeated, and the results obtained in Tables 10 and 11 showed that the pump problem was resolved.

Table (10): Overall velocity of pump 206-A.

Overall velocity(mm/s)	Motor		Pump	
	NDE	DE	NDE	DE
Horizontal	2.39	2.25	1.4	0.8
Vertical	0.75	0.71	0.57	0.69
axial	0.34	0.92	0.42	0.46

Table (11): Shock Pulse measurement of pump 206-A.

Shock pulse (db)		Motor		Pump	
		NDE	DE	DE	NDE
Horizontal	Carpet	2	4	2	2
	Max	16	14	13	14
Vertical	Carpet	2	2	0	2
	Max	19	5	10	12
Axial	Carpet	-2	8	0	9
	Max	5	18	12	22

Conclusions

The inspection and fault diagnosis of centrifugal pumps at Al-Brega Oil Company – Airport Road (pumps 101A and 206A) were conducted by analyzing data from the VibXpert device and comparing the results with ISO 10816 standards. For pump 101A, a warning was observed regarding overall velocity, accompanied by high vibration readings in the axial direction of the motor section, suggesting potential bearing issues. Shock pulse inspection revealed friction and damage in the bearings caused by lack of lubrication. Spectrum analysis identified the bearing problem as stage 5, leading to the decision to replace the bearing. Angular misalignment was found to be within acceptable limits. For pump 206A, a similar warning regarding overall velocity was detected. High vibration readings in the motor section and friction due to lack of lubrication were observed. Spectrum analysis identified parallel misalignment, resulting in high vibration at 1X and 2X in the radial direction and low axial levels. The shock pulse measurement confirmed a lack of lubrication in both the motor and pump bearings. In summary, the diagnosis revealed bearing-related issues, such as friction and damage due to insufficient lubrication, as well as misalignment problems. These issues were corrected and follow-up measurements confirmed that the pumps were operating in compliance with ISO standards. The study emphasized the importance of routine vibration monitoring to detect early signs of wear and misalignment, ensuring optimal performance of the pumps.

References

[1] Wu XK. “The fault diagnosis based on information fusion theory and its application in internal combustion engine”. Ph.D. thesis, Wuhan University of Technology, 1998.

[2] Chen YR. “Modern signal processing technology in the application of vibration diagnosis of internal combustion engine”. Ph.D. thesis, Wuhan University of Technology, 1998.

[3] Sakthivel, N.R.; Sugumaran, V.; Babudevasenapati, S. “Vibration Based Fault Diagnosis of Monoblock Centrifugal Pump Using Decision Tree. Expert Syst”. Appl. 2010, 37, 4040–4049.

[4] Rapur, J.S.; Tiwari, R. “Experimental Fault Diagnosis for Known and Unseen Operating Conditions of Centrifugal Pumps Using MSVM and WPT Based Analyses”. Measurement 2019, 147, 106809.

[5] Zhao, W.; Egusquiza, M.; Valero, C.; Valentín, D.; Presas, A.; Egusquiza, E. “On the Use of Artificial Neural Networks for Condition Monitoring of Pump-Turbines with Extended Operation”. Measurement 2020, 163, 107952.

[6] Mobley, R.K. (Ed.) 4”Benefits of Predictive Maintenance. In An Introduction to Predictive Maintenance”, 2nd ed.; Plant Engineering; Butterworth-Heinemann: Burlington, NJ, USA, 2002; pp. 60–73; ISBN 978-0-7506-7531-4.

[7] Lee, J.; Wu, F.; Zhao, W.; Ghaffari, M.; Liao, L.; Siegel, D. “Prognostics and Health Management Design for Rotary Machinery Systems,Reviews, Methodology and Applications”. Mech. Syst. Signal Process. 2014, 42, 314–334.

[8] Bousdekis, A.; Lepenioti, K.; Apostolou, D.; Mentzas, G. “Decision Making in Predictive Maintenance”: Literature Review and Research Agenda for Industry 4.0. IFAC-Papers OnLine 2019, 52, 607–612.

[9] Behzad, M., Bastami, A. R., Maassoumian, M. "Fault Diagnosis of a Centrifugal Pump by Vibration Analysis". In Volume 3 (pp. 221–226). ASME. 2004. DOI:10.1115/ESDA2004-58534.

[10] Albraik, A., Althobiani, F., Gu, F., Ball, A. "Diagnosis of Centrifugal Pump Faults Using Vibration Methods". Journal of Physics: Conference Series, 364, pp. 012139. 2012. DOI:10.1088/1742-6596/364/1/012139.

[11] Sakthivel, N.R.; Sugumaran, V.; Babudevasenapati, S.” Vibration Based Fault Diagnosis of Monoblock Centrifugal Pump Using Decision Tree”. Expert Syst. Appl. 2010, 37, 4040–4049.

[12] Rapur, J.S.; Tiwari, R. “Experimental Fault Diagnosis for Known and Unseen Operating Conditions of Centrifugal Pumps Using MSVM and WPT Based Analyses”. Measurement 2019, 147, 106809.

[13] Cao, R.; Yuan, J.; Deng, F.; Wang, L. “Numerical Method to Predict Vibration Characteristics Induced by Cavitation in Centrifugal Pumps”. Meas. Sci. Technol. 2021, 32, 115109.

[14] Al-Braik, A.; AlThobiani, F.; Gu, F.; Ball, A.” Diagnosis of Centrifugal Pump Faults Using Vibration Methods”. J. Phys. Conf. Ser. 2012, 364, 012139.