

ENGINEER



international scientific journal

ISSUE 3, 2026 Vol. 4

E-ISSN

3030-3893

ISSN

3060-5172



SLIB.UZ
Scientific Library of Uzbekistan



A bridge between science and innovation



**TOSHKENT DAVLAT
TRANSPORT UNIVERSITETI**

Tashkent state
transport university



ENGINEER

A bridge between science and innovation

E-ISSN: 3030-3893

ISSN: 3060-5172

VOLUME 4, ISSUE 3

SEPTEMBER, 2026



engineer.tstu.uz

TASHKENT STATE TRANSPORT UNIVERSITY

ENGINEER

INTERNATIONAL SCIENTIFIC JOURNAL
VOLUME 4, ISSUE 3 SEPTEMBER, 2026

EDITOR-IN-CHIEF

SAID S. SHAUMAROV

Professor, Doctor of Sciences in Technics, Tashkent State Transport University

Deputy Chief Editor

Miraziz M. Talipov

Doctor of Philosophy in Technical Sciences, Tashkent State Transport University

Founder of the international scientific journal “Engineer” – Tashkent State Transport University, 100167, Republic of Uzbekistan, Tashkent, Temiryo‘lchilar str., 1, office: 465, e-mail: publication@tstu.uz.

The “Engineer” publishes the most significant results of scientific and applied research carried out in universities of transport profile, as well as other higher educational institutions, research institutes, and centers of the Republic of Uzbekistan and foreign countries.

The journal is published 4 times a year and contains publications in the following main areas:

- Engineering;
- General Engineering;
- Aerospace Engineering;
- Automotive Engineering;
- Civil and Structural Engineering;
- Computational Mechanics;
- Control and Systems Engineering;
- Electrical and Electronic Engineering;
- Industrial and Manufacturing Engineering;
- Mechanical Engineering;
- Mechanics of Materials;
- Safety, Risk, Reliability and Quality;
- Media Technology;
- Building and Construction;
- Architecture.

Tashkent State Transport University had the opportunity to publish the international scientific journal “Engineer” based on the **Certificate No. 1183** of the Information and Mass Communications Agency under the Administration of the President of the Republic of Uzbekistan. **E-ISSN: 3030-3893, ISSN: 3060-5172.** Articles in the journal are published in English language.

3	
engineer.tstu.uz	A bridge between science and innovation

An intelligent diagnostic approach based on oil analysis for assessing the technical condition of diesel locomotive engines

O.R. Khamidov¹^a, B.I. Gayratov¹^b, Sh.I. Kudratov¹^c, F.R. Djuraev¹

¹Tashkent state transport university, Tashkent, Uzbekistan

Abstract:

A new intelligent diagnostic method for assessing the technical condition of diesel locomotive engines using the lubricating oil condition monitoring system is presented in this paper. The proposed method incorporates key oil condition parameters such as kinematic viscosity, iron (Fe) and copper (Cu) wear particle concentrations, soot content and water contamination as indicators of engine health. These parameters are useful for understanding the lubrication performance, wear of the components and potential defects in the engine that may arise during operation. In order to increase the diagnostic accuracy, an Adaptive Neuro-Fuzzy Inference System (ANFIS) was designed to study the collected data and classify the engine condition based on the technical state. The proposed model has applied artificial neural network capability to learn the relationship and fuzzy logic to reason the relationship between oil properties and engine degradation, which makes it effective in identifying the complex nonlinear relations between them. The intelligent diagnostic system developed allows to identify early abnormal operating conditions, facilitates the planning of predictive maintenance actions and decreases the risk of unexpected engine failures. Consequently, maintenance expenses can be kept at low levels and locomotives can be made more available, reliable and service life extended. The proposed approach is also shown to be suitable for implementation at the real time condition monitoring system, and it is a powerful tool for maintaining and managing the assets of modern railways.

Keywords:

diesel engine, condition assessment, oil analysis, intelligent diagnostics, ANFIS, fuzzy logic, operational reliability, predictive maintenance

1. Introduction

The reliable and efficient operation of diesel locomotives used in railway transport ensures not only the continuity of the passenger and freight transportation system but also operational safety. It works at a high load regime, at high temperatures, and does not stop, therefore it can quickly wear out and unforeseen failures or other breakdowns begin to occur. The technical condition of the engine should be monitored regularly and faults should be detected early enough as a means of enhancing operational efficiency [1]

Traditional maintenance methods are usually carried out without a set schedule or on a calendar basis. This approach does not take into account the actual technical condition of the engine and increases the risk of failing to detect malfunctions in time. For this reason, in recent years, a predictive diagnostics approach has been widely implemented.

Engine oil analysis is one of the most promising methods of predictive technical diagnostics. Oil is a medium that is in direct contact with all working elements of the engine, and changes in its physicochemical and elemental composition provide important information about the technological processes inside the engine. For example, metal particles in oil provide information about decay processes, while oxidation indicators provide information about the degree of oil wear[2].

In this article, diagnostic parameters based on oil analysis are selected when assessing the technical condition of diesel engines. Based on parameters, a basis is created for intelligent approaches (for example, ANFIS, fuzzy logic) aimed at identifying possible engine failures. The results of the article will serve as a methodological basis for the subsequent development and practical implementation of algorithmic models

2. Research methodology

The selected methodological approach for evaluating the technical condition of diesel engines through oil analysis is primarily based on assessing the physicochemical and elemental composition of the oil. Such a method indirectly indicates the wearing, oxidizing, and infiltration of foreign matter that take place in the actual operating environment. The chosen parameters are based on international standards, scientific literature, and advanced practices in the field of technical diagnostics [3]. The following table 1 presents the main indicators selected for the diagnostic model.

As a research methodology, the relationship of parameters with the corresponding diagnostic models, the degree of their sensitivity, and the coefficients of variability are analyzed.

^a <https://orcid.org/0000-0003-0821-5754>

^b <https://orcid.org/0009-0005-3957-337X>

^c <https://orcid.org/0009-0007-6396-7699>



Table 1

Physicochemical and elemental oil parameters selected for the diesel engine diagnostic model

№	Parameter title	Measurement unit	Analysis method	Diagnostic importance
1	Viscosity	mm ² /s (cSt)	Capillary viscometer (ASTM D445)	Lubrication performance, protection against wear
2	Iron (Fe)	ppm	ICP-OES spectroscopy	Wear of cylinder-liner assembly and crankshaft components
3	Copper (Cu)	ppm	ICP-OES	Bearing wear and surface degradation
4	Sediment (Soot)	%	Thermogravimetric analysis (TGA)	Poor combustion, filter saturation
5	Oxidation index	Arbitrary unit	IR-spectroscopy (FTIR)	Chemical degradation of oil, resistance in oxidative environment
6	Water mixing	%	Karl Fischer titration	Cooling system malfunction, condensation, corrosion risk

As a research methodology, the relationship of parameters with the corresponding diagnostic models, the degree of their sensitivity, and the coefficients of variability are analyzed. The above-mentioned methods can be used for oil analysis in laboratory conditions, which are selected based on international standards (ASTM, ISO, GOST) [4].

Basics of the model

Within the framework of this study, an intelligent forecasting model based on the Adaptive Neuro - Fuzzy Inference System (ANFIS) was developed to assess the technical condition of diesel locomotive engines and ensure their operational reliability. ANFIS is a robust tool having ability of neural network self learning with the advantages as fuzzy logic fuzzy and complex system modeling. It provides a high degree of accuracy in determining fuzzy and nonlinear relationships between parameters [5].

The model consists of the next steps:

- Determining parameters of input: simple physicochemical parameters of the engine oil, such as: kinematic viscosity, the total acid number (TAN) and the content of metal particles (Fe, Cu, Al) and sediment concentration (soot);
- Decomposition into fuzzy categories: each input parameter is represented based on such fuzzy categories as "low", "medium", and "high";
- Formation of the rule base: a set of fuzzy rules of the form "If..., then...", in which the technical condition of the engine (for example, good, average, bad) is determined based on a combination of parameters;
- Training of the ANFIS-based model: Through the data base available and applying some optimization method, trained and optimized ANFIS model has been achieved.

- Formation of output results: based on new data, the technical condition of the engine is predicted by the model.

The model is based on the Fuzzy Logic Toolbox and Neural Network Toolbox libraries of the MATLAB program, which allows the user to load data through an intuitive interface, configure fuzzy categories, and effectively practice the model [6].

Figure 1 presents a general representation of the ANFIS model proposed here.

Assessment criteria

In an attempt to quantitatively evaluate the correctness and diagnostic performance of the model, following statistical criteria were applied: Mean Squared Error (MSE): This criterion is the square of difference between predicted model value and observed value of the experiment. The lesser MSE is, the more predictive is the model [7].

Coefficient of Determination (R² - Coefficient of Determination): This criterion gives the degree to which the model is able to explain the overall variance. When the R² value approaches 1, then the accuracy is high. ROC-AUC (Receiver Operating Characteristic - Area Under Curve):

The performance of the model in terms of classifications is measured by the AUC. AUC value varies between 0 and 1, and the higher the value, the higher the sensitivity and proper functioning of the diagnostic model. The results, in the case of the AUC above 0.9 are highly sensitive, and the diagnostic model functions properly. According to these assessments, model accuracy was checked in the scenario of training and testing which proved that it yields consistent outcomes in a real condition of operation as well [8].

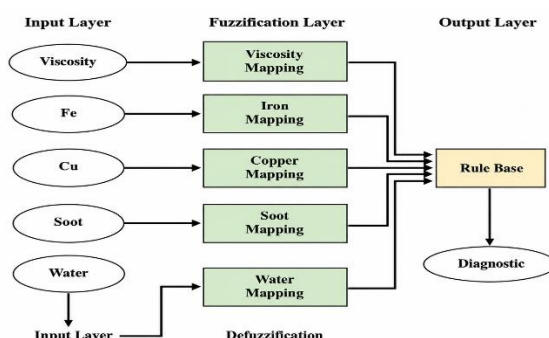


Fig. 1. Block diagram of the ANFIS model, which assesses the state of the engine based on oil analysis

3. Results and discussion

ANFIS model developed in the course of the research proved to be a useful instrument in evaluating the technical state of the diesel locomotive engines and malfunctions predictions. Parameters contained in the model were chosen as iron (Fe), copper (Cu), kinematic viscosity, sediment content (hours), and water mixture due to their most significant indicators that determined oil analysis. These parameters directly reflect the disruptions in the performance of tribotechnological processes and functional components within the engine [9].

The ANFIS model had the following statistical indicators that determined its diagnostic accuracy: Mean Square Error (MSE) = 0.083

$$R^2 = 0.912 \quad AUC = 0.95$$

These findings show the model is highly accurate and a useful method in forecasting. In particular, such indicators as viscosity and the content of metal particles (Fe, Cu) give a clear picture of the wear conditions and degradation of oil properties occurring in the internal parts of the engine.

During the discussion, the following main observations were noted:

An increase in the amount of sediment may be associated with an imbalance in the combustion process, a violation of the fuel-air ratio, or wear of the piston rings;

A rise in the level of iron and copper is a definite indicator of wear of the crank shaft, bearing, bed surfaces and other parts that move;

Any reduction in the viscosity to a high extent means that the oil has expired and should be replaced;

The presence of a water mixture indicates technical problems in the engine's cooling system[9].

Also, unlike classical statistical methods, the ANFIS model showed high efficiency in determining fuzzy and nonlinear relationships between diagnostic indicators. This enables a need-based and continuous and correct determination of the engine status in operation conditions.

In general, the research results have proven that the predictive diagnostic model developed on the basis of ANFIS is of great importance in extending the reliability of diesel engines, increasing operational safety, and optimizing maintenance costs [10].

Comparative Analysis

The research results were compared with previously conducted scientific developments. For example:

The diagnostic model developed by Zaharia et al. (2017) based on metal elements (Fe, Cu) in diesel engine oil has an indicator of AUC = 0.87.

In the work of Clenci et al. (2018), the root mean square error in the neural model based on viscosity and oxidation parameters was MSE = 0.14.

In our study, high indicators such as MSE 0.083 and AUC 0.95 were achieved through the integration of several parameters (viscosity + Fe + Cu + soot + water) and a fuzzy logic-based approach.

This proves the effectiveness of the ANFIS model in complex, fuzzy, and multi-parameter environments compared to classical neural networks [11-12].

4. Conclusion

Within the framework of this study, a predictive diagnostic approach was developed, aimed at assessing the

technical condition of diesel locomotive engines and increasing their operational reliability. Based on the proposed method, engine wear processes were modeled using the ANFIS (Adaptive Neuro-Fuzzy Inference System) model, relying on the main physicochemical parameters of engine oil (viscosity, sediment (soot), metal impurities - in particular, the content of iron and copper, as well as water concentration).

The analysis results showed that the recorded changes in the oil samples are highly correlated with the technical condition of the engine's internal parts, and the intelligent model built on the basis of these parameters has high accuracy in determining the real operational state of the engine. The ANFIS model's root mean square error rate (MSE) is 0.083 and the ROC AUC value is 0.95, which confirms its effectiveness. This allows the model to be implemented in real-time technical diagnostic systems.

The study has the following major findings:

The diagnostic method based on oil analysis serves as an effective tool as a non-invasive method of technical inspection of diesel engines;

The artificial intelligence approach based on the ANFIS model makes it possible to assess the functional state of engine components with high accuracy;

This strategy will play a crucial role in the optimization of maintenance period and aversion of technological failures as well as operating expenses. During additional work, an automated system of diagnosing vehicles is going to be developed by modifying the model to a variety of engines and increasing the data set, as well as combining it with IoT devices.

References

- [1] Gayratov, B., & Insapov, D. (2025, June). On the kinematic parameters of the movement of a freight train on various sections of railways. In AIP Conference Proceedings (Vol. 3286, No. 1, p. 060007). AIP Publishing LLC.
- [2] Khamidov O, Zayniddinov N, Kudratov S, Erkinov B. Analysis of malfunctions that occur in the crankshaft of locomotive thermal power plants during operation. In: E3S Web of Conferences. Proceedings of the E3S Conference; 2024; CONMECHYDRO 2024. – Vol. 538. – 01027. – P. 1 –6. <https://doi.org/10.1051/e3sconf/202453801027>
- [3] Khamidov O, Kudratov S, Khamidov O, Turdimurodov B, Norbotayeva M. Improvement of Diagnostics and Analysis of Malfunction of the Crankshaft of Locomotive Power Plants. AIP Conference Proceedings. – Problems in the Textile and Light Industry in the Context of Integration of Science and Industry and Ways to Solve Them PTLICISIWS-2. – 2022. – Vol. 3045 B. – 050030. – P. 1 – 5.
- [4] Fedotov, M. V. (2021). Предиктивная диагностика оборудования тепловоза на основе интеллектуального анализа данных.* [PhD dissertation, Petersburg State Transport University (PGUPS)]. DisserCat.
- [5] Gayratov, B., Khamidov, O., Kudratov, S., & Samatov, S. (2026, May). The ANFIS anticipation of diesel locomotive engine on the improvement of lubricating oil analysis. In AIP Conference Proceedings (Vol. 3447, No. 1, p. 040008). AIP Publishing LLC.
- [6] Khamidov O, Zayniddinov N, Kudratov S, Erkinov B. Analysis of malfunctions that occur in the



crankshaft of locomotive thermal power plants during operation. In: E3S Web of Conferences. Proceedings of the E3S Conference; 2024; CONMECHYDRO 2024. – Vol. 538. – 01027. – P. 1–6. <https://doi.org/10.1051/e3sconf/202453801027>

[7] Khamidov O, Kudratov S, Khamidov O, Turdimurodov B, Norbotayeva M. Improvement of Diagnostics and Analysis of Malfunction of the Crankshaft of Locomotive Power Plants. AIP Conference Proceedings. – Problems in the Textile and Light Industry in the Context of Integration of Science and Industry and Ways to Solve Them PTLICISIWS-2. – 2022. – Vol. 3045 B. – 050030. – P. 1 – 5.

[8] Wang, H., Liu, J., & Zhang, X. (2020). Hybrid fault diagnosis of engine systems using fuzzy logic and neural networks. Mechanical Systems and Signal Processing, 140, 106653.

[9] Pourramezan, M.-R., & Rohani, A. (2004). Improved monitoring and classification of engine oil condition through two machine learning techniques. SAE International. <https://doi.org/10.4271/04-18-01-0005>

[10] Dey, S., & Roy, R. (2019). Condition monitoring and maintenance management of industrial equipment using internet of things and big data analytics: A review. Journal of Manufacturing Systems, 53, 261-272. doi:10.1016/j.jmsy.2019.06.006

[11] Wakiru, James M.; Pintelon, Liliane; Muchiri, Peter N.; Chemweno, Peter K. (2019). A review on lubricant condition monitoring information analysis for maintenance decision support. Mechanical Systems and Signal Processing, 118(), 108–132. doi:10.1016/j.ymssp.2018.08.039

[12] Agarwal, A., “Experimental investigations of the effect of biodiesel utilization on lubricating oil tribology in

diesel engines”, Proceed. Instit. Mech. Eng., Vol. 219, pp. 703-713, 2005.

Information about the author

Otabek Khamidov	Tashkent State Transport University Professor, Department of Locomotives and Locomotive Establishment E-mail: otabek.rustamovich@yandex.ru Tel.:+99890 811 21 00 https://orcid.org/0000-0003-0821-5754
Bakhodir Gayratov	Tashkent State Transport University Doctoral student, Department of Locomotives and Locomotive Establishment E-mail: bgayratoff@gmail.com Tel.:+99894 134 54 27 https://orcid.org/0009-0005-3957-337X
Shohijakhon Kudratov	Tashkent State Transport University Associate Professor, Department of Locomotives and Locomotive Establishment E-mail: kudratov.shohijaxon@bk.ru Tel.:+99890 788 85 83 https://orcid.org/0009-0007-6396-7699
Firuz Djuraev	Tashkent State Transport University Doctoral student, Department of Locomotives and Locomotive Establishment Tel.:+99899 512 45 00



Kh. Tuychiev, Kh. Tuychiev

Assessment and improvement of constructive safety of the Damas light passenger vehicle.....5

A. Azizov, F. Sindarov

Comparison of the switch control circuit with main supply and central supply circuit, and analysis of the sequence of operation of the HIIC block.....10

O. Khamidov, B. Gayratov, Sh. Kudratov, F. Djuraev

An intelligent diagnostic approach based on oil analysis for assessing the technical condition of diesel locomotive engines.....14