Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 02, May, 2025
Website: usajournals.org

APPLICATION OF THE VIBRATION-ACOUSTIC METHOD IN DIAGNOSING DRIVE AXLES OF LIGHT VEHICLES

O. Odilov
PhD, Associate Professor,
Fergana State Technical University, Fergana, Uzbekistan
E-mail: odiljonodilov5@mail.ru

D. A. Sheraliyev
Fergana State Technical University, Fergana, Uzbekistan
E-mail: diyorbeksheraliyev222@gmail.com

R. Rapiqjonov
Fergana State Technical University, Fergana, Uzbekistan
E-mail: rahmonjonrapiqjonov@gmail.com

Abstract:
This article is devoted to the study of vibroacoustic diagnostic methods for identifying defects in the drive axles of wheeled vehicles. The aim of the research is to evaluate the applicability of existing vibration-acoustic diagnostic techniques for assessing the technical condition of these critical components. The vibration-acoustic method allows for non-destructive analysis of the axle assemblies by examining the sound waves generated within the vehicle's suspension system. This approach is grounded in acoustic and mechanical principles initially explored in materials science and structural engineering.
By applying this method, it is possible to determine the condition and assess the serviceability of the vehicle's bridge structures. The implementation of such advanced and effective diagnostic tools in the automotive industry plays a significant role in enhancing vehicle reliability and preventing mechanical failures. The method also offers prospects for real-time, in-service monitoring using modern acoustic sensors and spectral analysis techniques.

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 02, May, 2025
Website: usajournals.org

Keywords: Suspension system; moving joint assemblies; typical units; structural integrity; wave propagation amplitude; spectroscopy; sonic measurements; analytical data; acoustic sensors.

1. Introduction

Bridges are fundamental elements of transport infrastructure, and regular assessment of their technical condition is crucial for ensuring operational safety [1]. Early detection of deformation or structural damage is essential to prevent accidents and maintain uninterrupted vehicle flow. Among various diagnostic techniques, the vibration-acoustic method (VAM) offers a promising solution for assessing the operational state of such structures [2].

This study focuses on the application of VAM to diagnose the drive axles of light vehicles—components responsible for transmitting torque from the engine to the wheels. These axles contain motion-coupling joints that experience progressive wear over time [3]. Any failure in the drive axle can lead to the complete loss of vehicle drivability. Hence, the development of reliable, real-time diagnostic tools for these units is imperative.

VAM is considered advantageous due to its non-destructive nature, its ability to operate without halting vehicle use, and its lower implementation costs compared to traditional methods [4]. Unlike visual inspection, which often misses sub-surface or early-stage defects, acoustic analysis allows detection based on structural response patterns under load.

2. Essence of the Vibration-Acoustic Method

The vibration-acoustic method is a non-invasive diagnostic tool used to assess mechanical and structural integrity. It is based on analysing the sound waves and vibration signatures that emerge during dynamic loading [5]. When applied to drive axles and bridge assemblies, the method provides the following capabilities:

- Detecting internal cracks, voids, and material degradation;
- Evaluating the stiffness, elasticity, and fatigue resistance of materials;
- Measuring the natural frequencies and mode shapes of structural components [6].

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 02, May, 2025
Website: usajournals.org

The main advantage lies in its minimal-contact implementation, enabling diagnostics without the need for disassembly. First introduced in bridge diagnostics in Europe and North America in the late 20th century, VAM is now widely adopted in civil, aerospace, and automotive engineering for its reliability and precision [7].

3. Advantages and Limitations of the Vibration-Acoustic Method

Advantages:

- High sensitivity – Capable of identifying microscopic and sub-surface defects;
- Fast processing – Rapid acquisition and analysis of acoustic data;
- Non-intrusive – No structural damage during measurement;
- Scalability – Can be integrated into AI-assisted monitoring systems for automated analysis [8].

Limitations:

- High initial costs – Requires specialised, high-resolution acoustic sensors and recording equipment;
- Complex data interpretation – Needs sophisticated signal-processing software and expert input for accurate results.

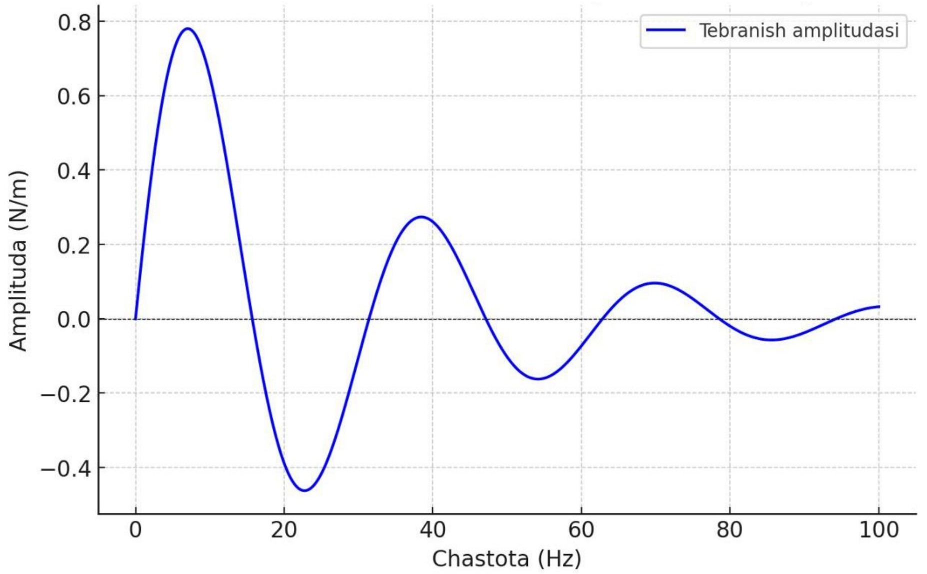

Figure 1. Frequency-Response Graph Demonstrating the Operating Principle of the Vibration-Acoustic Method

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 02, May, 2025
Website: usajournals.org

4. Vibration-Acoustic Method: Operating Principle and Theoretical Foundations

The graph above demonstrates the operating principle of the vibration-acoustic method. It presents the vibration amplitude as a function of frequency (Hz). As the frequency increases, the amplitude decreases — a physically natural process, as high-frequency waves are more easily attenuated due to internal resistances within the material [5].

Sinusoidal variations in the graph may indicate resonance points or transient processes within the structure. The general trend of the amplitude curve is significant because it allows the identification of structural deformations and internal defects during diagnostics.

4.1. Theoretical Basis of the Vibration-Acoustic Method

The vibration-acoustic method is widely applied as a non-invasive diagnostic technique for evaluating the condition of structural systems by analysing acoustic waves and vibrations. It is particularly effective for detecting internal flaws in materials and assessing structural integrity. In the context of light vehicles, drive axles — also known as "leading bridges" — play a critical role in the safe and effective functioning of the vehicle. Hence, a clear understanding of the theoretical principles underlying this method is essential [6].

The theoretical foundations of the vibration-acoustic method are rooted in the principles of acoustics and mechanics. When acoustic waves propagate through a material, their velocity and amplitude depend on the properties of the material and any existing defects. The presence of cracks, voids, or stress concentrations alters wave propagation characteristics, which can be detected through precise measurement and analysis [7].

To perform diagnostics using this method, it is first necessary to generate acoustic signals. These waves, when passing through the drive axle or bridge, respond differently depending on the structural state — such as the presence of fatigue, cracks, weakening zones, or deformation. Numerous techniques are employed to analyse the signals, including spectroscopy, sonic measurements, and other acoustic evaluation methods [8].

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 02, May, 2025
Website: usajournals.org

By measuring vibration and acoustic behavior, the mechanical characteristics of the bridge — including stiffness, elasticity, and structural response — can be effectively assessed. The propagation and reflection of acoustic waves within the material reveal the existence of internal flaws. The state of the axle and its mechanical properties are examined using modern sensor-based technologies and advanced acoustic equipment.

4.2. Advantages in Vehicle Diagnostics

The vibration-acoustic method offers several important advantages in the diagnostics of vehicle components:

- **Non-destructive testing**: Enables evaluation without damaging the structural integrity of the component.
- **Fast and accurate results**: Provides immediate feedback on the condition of the bridge or axle.
- **Minimal contact requirements**: Diagnostics can be carried out with limited physical interaction.
- **Integration with AI**: Enables large-scale data processing and automated interpretation through modern algorithms.

In addition, acoustic diagnostics is especially effective when implemented as part of real-time monitoring systems. It supports preventive maintenance strategies and improves vehicle reliability.

4.3. Limitations and Challenges

Despite its benefits, the method also presents some limitations:

- **High initial equipment cost**: High-precision sensors and acoustic systems can be expensive.
- **Expertise required**: Accurate interpretation of signal data requires trained personnel and specialised software.
- **Design-dependent variability**: Structural differences among vehicle models may influence acoustic wave behaviour, potentially affecting diagnostic consistency.

Therefore, to ensure accurate and standardised application, specific calibration protocols and reference models are needed for different vehicle designs.

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 02, May, 2025
Website: usajournals.org

4.4. Future Prospects in Automotive Applications

Applying the vibration-acoustic method for diagnosing the condition of drive axles in light vehicles offers great potential for future advances in the automotive industry. Further development and implementation of this method will enhance technical maintenance and road safety.

The efficiency of acoustic diagnostics benefits both manufacturers and consumers by reducing repair frequency and preventing unexpected failures. Moreover, such systems contribute to prolonged service life and improved sustainability of mechanical components.

The method relies on vibration sensors that detect oscillations across the bridge structure. These signals are analysed using mathematical models and data processing algorithms, enabling accurate identification of anomalies. By understanding material behavior and acoustic properties, manufacturers can ensure higher structural integrity and product durability.

Modern mobile acoustic devices can now localise defect zones rapidly and accurately. This reduces service time and costs, contributing to optimised repair logistics and operational efficiency.

Figure 2. Stand for vibroacoustic diagnostics of drive axles of passenger cars

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 02, May, 2025
Website: usajournals.org

However, there are some limitations to the use of acoustic methods. For example, the propagation of acoustic signals can vary depending on the structure of the material and specific conditions, which can affect the reliability of the results. Also, it is necessary to have special knowledge and skills to correctly interpret acoustic data.

In general, the use of acoustic methods in the analysis of bridges is important in the process of technical control of passenger cars. This method allows you to assess the condition of bridges, identify potential problems early and increase safety. The use of acoustic methods contributes to the development of the automotive industry and the introduction of new solutions necessary for the effective management of passenger cars.

Bridges in passenger cars are mainly made of different materials, each of which has its own characteristics. One of the most common problems is material fatigue and mechanical damage during the service life of bridges. Therefore, regular inspection of the condition of bridges increases their reliability and prevents potential failures.

Conclusion

The significance of the vibration-acoustic method in diagnosing the drive axles of light vehicles lies primarily in its efficiency and non-destructive nature. This study examined the theoretical foundations of the method, its application to bridge diagnostics in light vehicles, and the practical benefits of acoustic techniques in structural health evaluation.

The method presents unique advantages in assessing the condition of suspension systems and determining the structural integrity of vehicle axles. Through detailed analysis, it was found that the vibration-acoustic method enables faster and more effective diagnostics compared to conventional techniques.

The findings indicate that applying this method significantly contributes to vehicle safety by providing timely detection of defects and reducing the risk of critical failures. It holds substantial potential for enhancing predictive maintenance and ensuring long-term operational reliability in automotive engineering.

Modern American Journal of Engineering, Technology, and Innovation
ISSN(E): 3067-7939
Volume 01, Issue 02, May, 2025
Website: usajournals.org

References

1. O'zbekiston Respublikasi Avtomobil va Yo'l Transporti Vazirligi. (2022). Yengil avtomobillarni diagnostikasi uchun akustik metodlar. Toshkent: O'zbekiston.
2. Jalilov, A. (2023). Akustik metodlar va ularning avtomobil sanoatidagi o'rni. Avtomobil va transport, Toshkent.
3. Mirzaev, B. (2021). Yengil avtomobillarni ko'priklarini diagnostikalashda akustik metodlardan foydalanish. O'zbekiston mexanika jurnali.
4. Rahimov, T. (2020). Tebranma akustik metodlar: nazariy asoslar va amaliy qo'llanilishi. O'zbekiston ilmiy jurnali.
5. Khamdamov, N. (2023). Avtomobillarni akustik diagnostikasi: muammolar va yechimlar. Avtomobil texnologiyalari konferensiyasi. Toshkent.
6. Kuznetsov, E. S., Boldin, A. P., & Vlasov, V. M. (2004). Tekhnicheskaya ekspluatatsiya avtomobiley (Technical operation of automobiles). Moscow: Nauka.
7. Didmanidze, O. N. (2017). Tekhnicheskaya ekspluatatsiya avtomobiley (Ed. FGBNU "Rosinformagrotekh"). Moscow.
8. Akopov, V. A. (1995). Ochistka avtomobilnykh vozdushnykh fil'trov [Cleaning automobile air filters]. Tashkent: Fan.
9. Balakrishnan, A. (1988). Teoriya filtratsii Kalmana [Kalman filtering theory] (Trans. from English). Moscow: Mir.
10. Vlasov, V. M., Zhankaziev, S. V., & Kruglov, S. M. (2017). Tekhnicheskoe obsluzhivanie i remont avtomobiley [Technical maintenance and repair of automobiles]. Moscow: Academia.
11. Renetskiy, V. P. (1980). Ekspluatatsiya vozdukhoochistiteley s bumazhnymi filtrpatronami [Operation of air filters with paper cartridges]. Tekhnika v selskom khozyaystve, (11), 46–47.