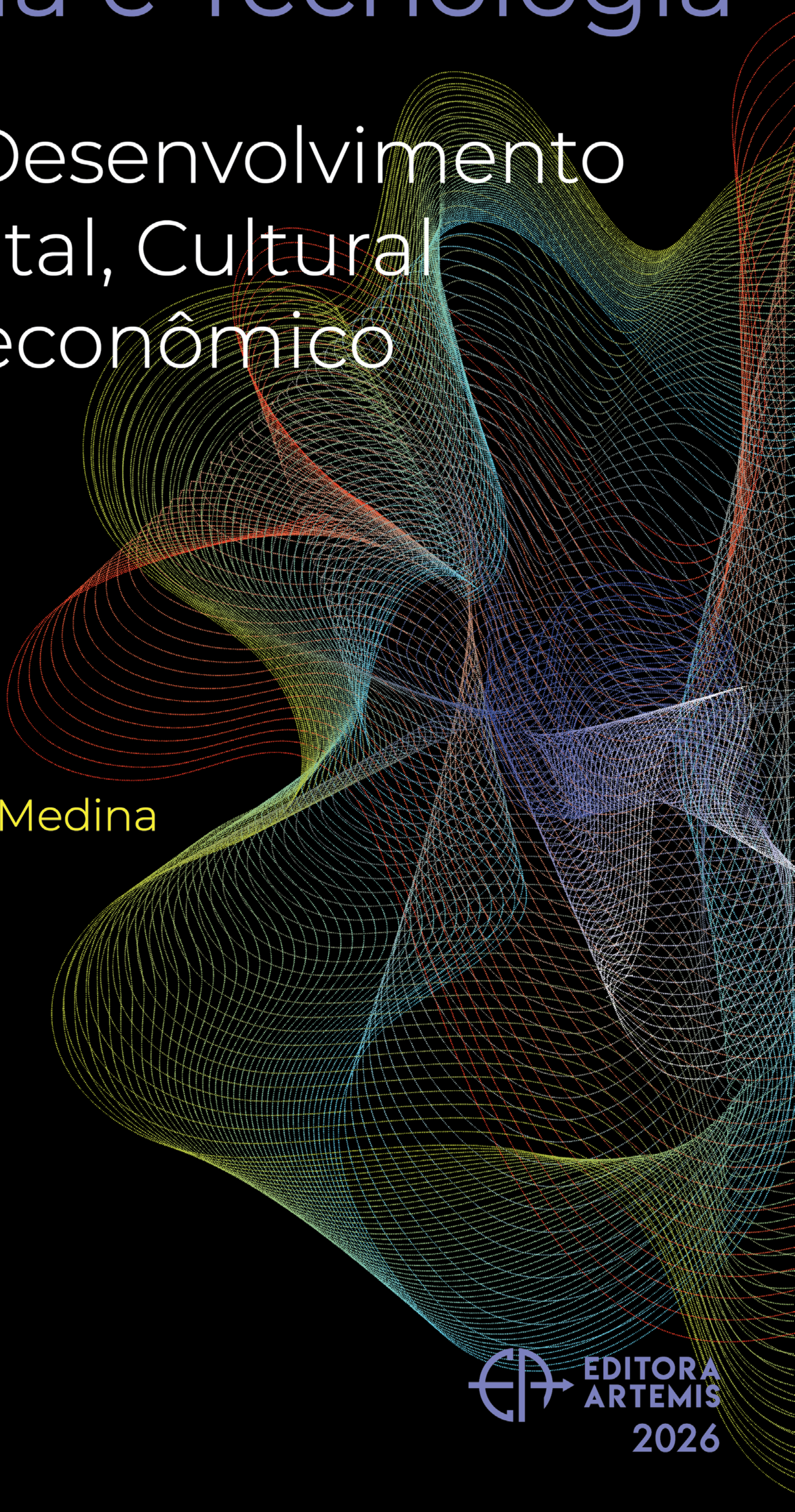
Ciência e Tecnologia

Para o Desenvolvimento Ambiental, Cultural e Socioeconômico



Xosé Somoza Medina
(organizador)

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PRÓLOGO

Un nuevo volumen de la serie ***Ciência e Tecnologia para o Desenvolvimento Ambiental, Cultural e Socioeconômico***, el noveno ya, nos permite volver a reflexionar sobre los avances científico-tecnológicos y la transferencia de conocimientos a la sociedad. La ciencia y la tecnología ocupan hoy un lugar central en la comprensión y transformación de los distintos ámbitos de la vida contemporánea, pero tan importante es el avance en sí como la creciente posibilidad de difusión de esas innovaciones. El desarrollo actual no se limita a la creación de nuevos dispositivos, procesos o sistemas, sino que se manifiesta también en la capacidad de analizar problemas complejos, optimizar recursos, generar soluciones sostenibles, fortalecer la formación científica y ampliar las formas de interacción entre conocimiento, sociedad y desarrollo. Este libro es un buen ejemplo de esto último.

El presente volumen, ***Ciência e Tecnologia para o Desenvolvimento Ambiental, Cultural e Socioeconômico IX***, reúne investigaciones que reflejan esta diversidad de aplicaciones a la sociedad de diferentes avances científicos y técnicos. Los capítulos aquí presentados abordan problemas y aplicaciones diversas, pero comparten una misma orientación: la búsqueda de respuestas actuales a situaciones problemáticas fundamentadas desde la ingeniería, la innovación tecnológica, la ciencia de materiales, la energía, el ambiente, la inteligencia artificial, la formación científico-tecnológica, o la comunicación de la ciencia.

La obra se organiza en tres grandes ejes temáticos.

El primero, "**Ingeniería, Metodologías y Procesos Tecnológicos**", reúne seis trabajos vinculados con modelado dinámico, robótica, diagnóstico técnico mediante vibraciones, procesos de corte y manufactura, mejora de la productividad industrial, estudio de materiales y biopolímeros y metodología de investigación en ingeniería. Estos capítulos evidencian el papel de la tecnología en la modelización, experimentación y optimización de procesos y la importancia de los avances metodológicos en el desarrollo de soluciones aplicadas a contextos industriales y científicos.

El segundo eje, "**Energía y Sostenibilidad**", integra cinco investigaciones relacionadas con la generación de energía mediante microturbinas hidráulicas, el aprovechamiento de la energía de las mareas, la exposición a contaminantes derivados del uso de biomasa como fuente de energía, la importancia de las plantas medicinales en la dieta y en la cultura tradicional y los nuevos enfoques de la comunicación pública sobre energía nuclear. En conjunto, estos estudios muestran cómo la energía, cualquier tipo de energía, es un ámbito del conocimiento científico y técnico de importancia clave en nuestra sociedad actual. La energía importa, más que nunca, y la ciencia y la tecnología pueden contribuir tanto al aprovechamiento responsable de los recursos naturales como a la comprensión de sus impactos ambientales y sociales.

El tercer eje, "**Formación y Comunicación en la era de la Inteligencia Artificial**", amplía el campo de análisis hacia otro ámbito de total actualidad científica y tecnológica, la Inteligencia Artificial. Los seis trabajos reunidos en esta sección examinan el rendimiento académico a través de análisis estadísticos avanzados, el uso de podcasts como herramientas de desarrollo socioemocional docente, la aplicación de la inteligencia artificial en la gestión pública, las dificultades en el aprendizaje por la falta de pensamiento lógico-matemático en una muestra de estudiantes de ingeniería de sistemas computacionales, un modelo de análisis multivariante para evaluar el proceso de aprendizaje y el uso de mundos virtuales para mejorar las capacidades del profesorado. Este conjunto de contribuciones permite observar cómo las tecnologías digitales y la Inteligencia Artificial no solo modifican procedimientos técnicos, sino también las formas de enseñar, aprender y construir significado en el mundo académico.

La diversidad de enfoques presente en esta obra constituye uno de sus principales aportes. Lejos de entender la ciencia y la tecnología como campos aislados, los trabajos aquí reunidos muestran su carácter transversal y su capacidad para dialogar con cuestiones ambientales, educativas, sociales, productivas y culturales.

Esperamos que este volumen contribuya al intercambio de conocimientos, al fortalecimiento de nuevas investigaciones y a la difusión de experiencias y propuestas capaces de ampliar las posibilidades de desarrollo científico y tecnológico en diferentes contextos.

Xosé Somoza Medina

Universidad de León, Espanha

SUMÁRIO

ENGENHARIA, METODOLOGIAS E PROCESSOS TECNOLÓGICOS

CAPÍTULO 2

APPLICATION OF VIBRATION EFFECTS IN TECHNICAL DIAGNOSTICS AND IDENTIFICATION

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ABSTRACT: Vibration phenomena, traditionally regarded as undesirable effects in mechanical systems, can also provide valuable information for the development of advanced diagnostic and identification techniques. This paper explores the application of vibration-based methods in technical diagnostics and parameter identification of engineering systems. The study discusses functional and testing vibrodiagnostic approaches for detecting structural damage, including defects in machine components, aircraft structures, and mechanical elements, through the analysis of vibration responses and natural frequency variations. In addition, vibration-based identification techniques are presented as indirect measurement methods for estimating relevant parameters of technical objects, including tire pressure and the quantity of materials stored in reservoirs. Experimental examples demonstrate the potential of frequency-based approaches for reliable condition assessment and monitoring without direct intervention in the analyzed systems. The results highlight the versatility of vibration effects as informative signals for non-destructive testing, predictive maintenance, and the development of innovative engineering solutions.

KEYWORDS: vibration diagnostics; structural health monitoring; non-destructive testing; vibration-based identification; frequency analysis; mechanical systems; predictive maintenance.

APLICACIÓN DE LOS EFECTOS DE LA VIBRACIÓN EN EL DIAGNÓSTICO Y LA IDENTIFICACIÓN TÉCNICA

RESUMEN: Los fenómenos vibratorios, tradicionalmente considerados efectos indeseables en los sistemas mecánicos, también pueden proporcionar información valiosa para el desarrollo de técnicas avanzadas de diagnóstico e identificación. Este trabajo analiza la aplicación de métodos basados en vibraciones para el diagnóstico técnico y la identificación de parámetros en sistemas de ingeniería. Se presentan enfoques de vibrodiagnóstico funcional y de ensayo para la detección de daños estructurales, incluyendo defectos en componentes de máquinas, estructuras aeronáuticas y elementos mecánicos, mediante el análisis de respuestas vibratorias y variaciones de

frecuencias naturales. Asimismo, se describen técnicas de identificación basadas en vibraciones como métodos de medición indirecta para estimar parámetros relevantes de objetos técnicos, incluyendo la presión de neumáticos y la cantidad de materiales almacenados en depósitos. Los ejemplos experimentales demuestran el potencial de los enfoques basados en frecuencia para la evaluación confiable del estado de los sistemas y su monitoreo sin intervención directa sobre los elementos analizados. Los resultados evidencian la versatilidad de los efectos vibratorios como señales informativas para ensayos no destructivos, mantenimiento predictivo y el desarrollo de soluciones innovadoras en ingeniería.
PALABRAS CLAVE: diagnóstico de vibraciones; monitoreo de la integridad estructural; ensayos no destructivos; identificación basada en vibraciones; análisis de frecuencia; sistemas mecánicos; mantenimiento predictivo.

1. INTRODUCTION

Most of us are familiar with vibration from everyday life. For example, when a pendulum is set in motion, it vibrates. A stretched guitar string also vibrates. And when a vehicle drives on uneven dirt road, it begins to vibrate intensely, creating a discomfort for passengers. But geological activity can cause strong vibrations in the form of earthquakes.

In industry, there is a special type of vibration: machine vibration. In most cases, machine vibration is unwanted. Most machine vibrations are caused by repetitive forces, such as the rotation of unbalanced, misaligned, worn, or improperly driven machine components. Two examples of unwanted machine vibrations are shown in Fig. 1 and 2.

Fig. 1. Vibrating motor.

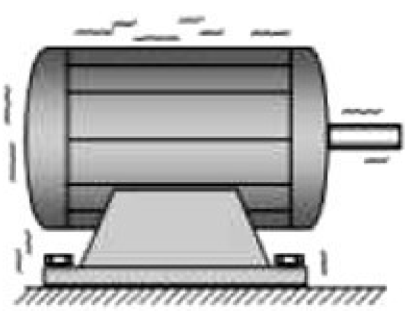
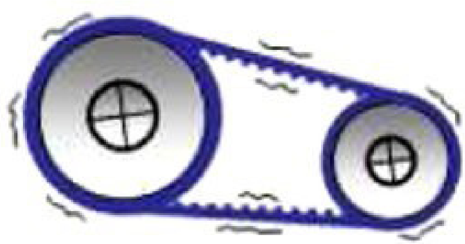


Fig. 2. Vibrating belt.



In the examples presented, vibration is a harmful phenomenon that must be combated. Many methods and technical means have been developed to suppress or completely eliminate vibrations in machines [1]. This article presents other area of vibration engineering, which considers vibration effects as useful phenomena, when the use of vibration allows the development of new original machines and technologies. Further, various vibration technologies will be analyzed here, aimed at solving problems such as detection of damage in machines, identification of parameters of technical objects, etc.

2. VIBRATION DIAGNOSTICS

Vibration diagnostics is a system of methods and technical means, intended for damage detection in technical objects by the analysis of their vibrations [2]. And characteristics of the studied oscillatory process in machine, containing information on its technical condition, are usually called as diagnostic signs of defects. A defect in machine or structure is understood as any discrepancy between the parameters and characteristics of an object with their specified or required values. A defect is understood as any discrepancy between the current (measuring) characteristics of testing object and their specified or required values. Typical examples of defects are as follows: fatigue cracks (Fig. 3); violation of the integrity of the adhesive joint in multilayer structures (Fig. 4); changes in the physical and mechanical properties of the material during use (Fig. 5); and a number of other deviations of the operational characteristics of the object from its standard values.

Fig. 3. Fatigue crack.

Fig. 4. Poorly adhered layers of material in a multilayer compound. (1 – working head; 2, 4 – layers of material; 3 – adhesive).

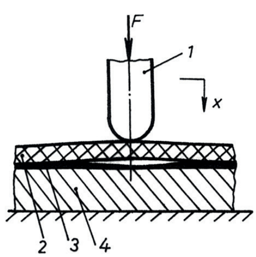


Fig. 5. Pipe corrosion.

Depending on the nature of testing object, the vibration control procedure can be based on either functional diagnostics or test diagnostics.

2.1. FUNCTIONAL DIAGNOSTICS

Functional diagnostics is based on the registration and analysis of vibration signals emitted by a testing object during its operation. Typical objects diagnosed functionally are rolling bearings (Fig. 6). Excitation of vibrations in bearings is caused by the waviness and ovality of the running tracks, the faces of the rolling elements (balls) and the spread of their diameters. Besides, wear of the bearings causes an increase in the gap, which leads to impact interaction between the shaft and the rolling elements, which contributes to an increase in the amplitude of the vibration signal.

Fig. 6. Damage in rolling bearing.

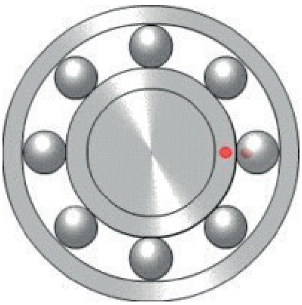
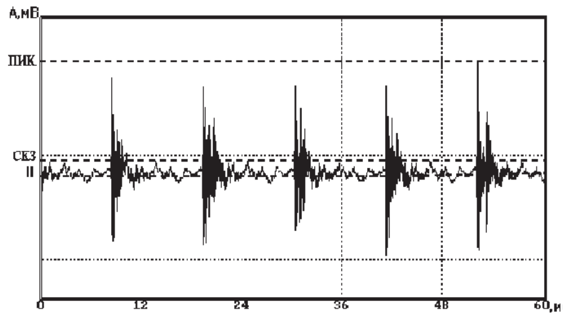


Fig. 7. Characteristic vibration time response of the damaged bearing.



Wear of balls, rollers or raceway causes an increase in the gap, which leads to impact interaction between the shaft and the rolling elements of bearing. This is the reason of shock interaction of shaft with bearing, which contributes to the appearance of characteristic peak pulses on the recorded time response (Fig. 7).

Another example of an object diagnosed functionally is gear transmission (Fig. 8). Vibration excitation in operating gear transmission can be caused by a variable loading of gear tooth with the so-called “tooth” frequency, imbalance of rotating parts, kinematic errors, etc. To detect damages in gear transmission, vibration monitoring in gear box is used (Fig. 9). Typical signs of damages in gear teeth and kinematic meshing errors can be realized in the redistribution of energy across frequencies, changes in spectral power density (Fig. 10).

Fig. 8. Gear transmission: 1, 2 – gear wheels.

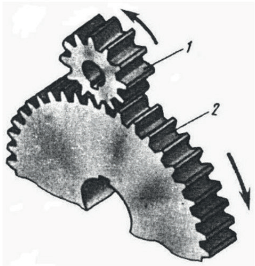


Fig. 9. Vibration monitoring in gear box.

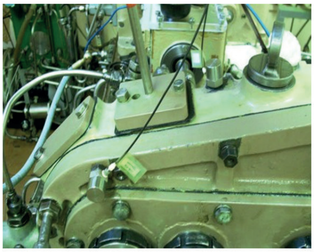
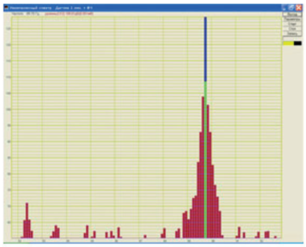


Fig. 10. Damage detection by the analysis of spectral power density.



But not all testing objects generate vibration during operation, and even if vibration is generated, it is often of low intensity, which makes it difficult to measure and identify. Taken together, all this limits the practical application of functional vibration diagnostics methods.

2.2. TESTING VIBRODIAGNOSTICS

Testing vibrodiagnostics is based on a special action on an object of diagnose with the external standard vibration signal (for example, harmonic signal) and on further analysis of this signal transformation. The parameters of the test excitation are specially selected so as, on the one hand, to increase the informativeness and sensitivity of diagnostic signs, and on the other hand, not to cause irreversible changes in the technical condition of the system being diagnosed. Test diagnostic methods are used in cases where the object either does not emit vibration at all during operation, or if recording and analysis of vibration characteristics in operating mode is difficult or even impossible. Typical engineering objects of testing vibrodiagnostics are aircraft structures, pipelines, rod structures and trusses, multilayer materials and others.

Examples of characteristic defects detected by testing diagnostic methods are fatigue cracks in elements of aircraft structures and trusses (Fig. 11), slackening of bolted joints (Fig. 12), destruction of rivetted joints, etc.

Fig. 11. Crack detection in cantilever beam.

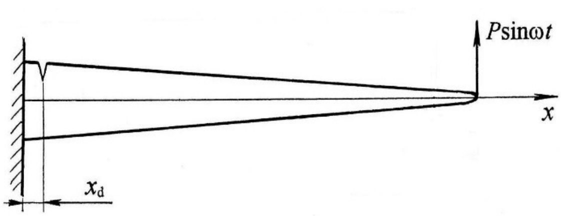
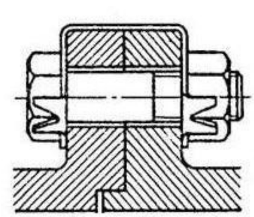


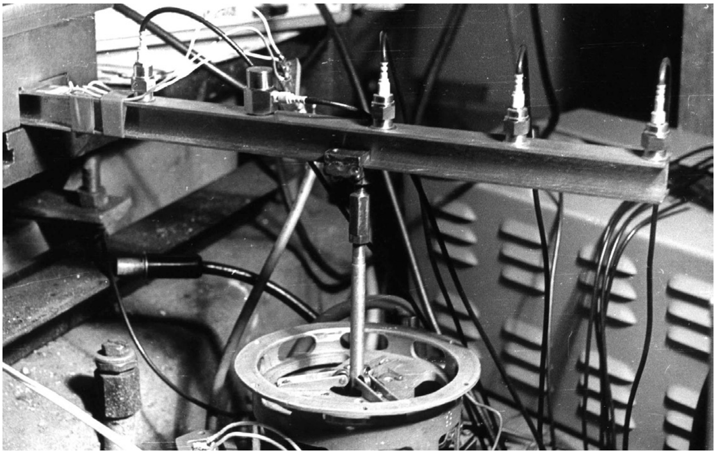
Fig. 12. Slackening of bolted joints.



To detect damage, it is necessary to act on a testing object with the external testing harmonic force $P\sin\omega t$ and to analyze the variation in system's vibration response. In all above-mentioned examples appearance of defect is accompanied with reduction of rigidity k of testing object. But the total mass m of the system practically is not changed. Therefore, using the simplified model with one degree of freedom, it can be concluded that due to the defect a reduction in the natural frequency $\omega_0 = \sqrt{k/m}$ is expected. This property is used as a principal basis for diagnostics of defects. The relevant method of non-destructive testing is called as the frequency method [3].

The advantage of the frequency method lies in the invariance of testing results to possible variation of damping level in the system under study. In accordance with many experiments on real structures [3], in most cases appearance of defect promotes not only rigidity reduction, but also no predicted change (increase or decrease?) of damping level. For example, such conclusion was made on the base of laboratory experiments on crack detection in flange beam (Fig. 13). Therefore, as diagnostic sign of defects it was proposed to use natural (or resonant) frequencies which respond to system's rigidity reduction and simultaneously don't respond to variation of interference factor – damping.

Fig. 13. Experiments on crack detection in flange beam.

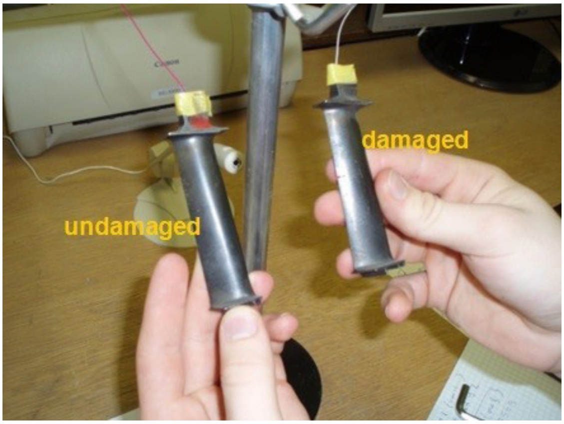


Damage diagnostics is based on monitoring of resonant frequencies' changing while the structure is in use. In the case of damage in typical engineering structures, its resonant frequency usually is reduced by 1-1.5%. Therefore, to identify such small changes of resonant frequencies, high-precision and expensive instrumentation has to be used.

For stable and reliable detection of small developing defects in structural elements, a programmable diagnostic system (PDS) equipped with a specialized computer program HA has been developed at the Riga Technical University [4]. PDS was successfully used in several aviation companies for damage detection in stringers and airframes of aircrafts, stabilizer spar of helicopters, etc.

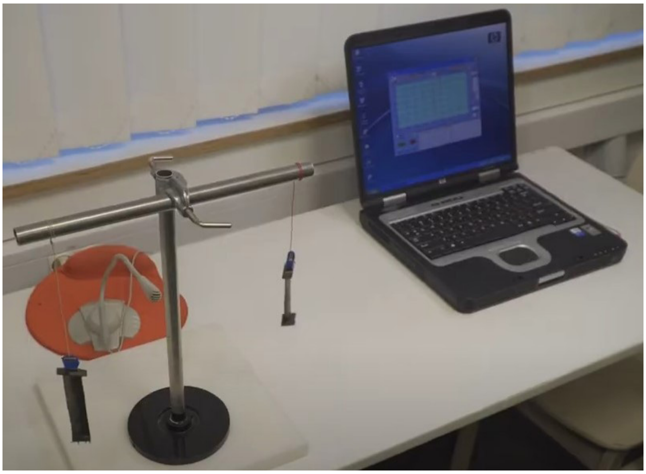
In this paper, the capabilities of PDS are demonstrated on the example of student's research work on damage detection in turbine blades. Two identical turbine blades, made of the same material, with the same shape and dimensions, are used for laboratory experiments. The first blade does not contain a visually visible defect, but the second blade has a specially created damage that occupies about 14% of the cross-sectional area of an undamaged blade (Fig. 14).

Fig. 14. Turbine blades (damaged and undamaged) for laboratory experiments.



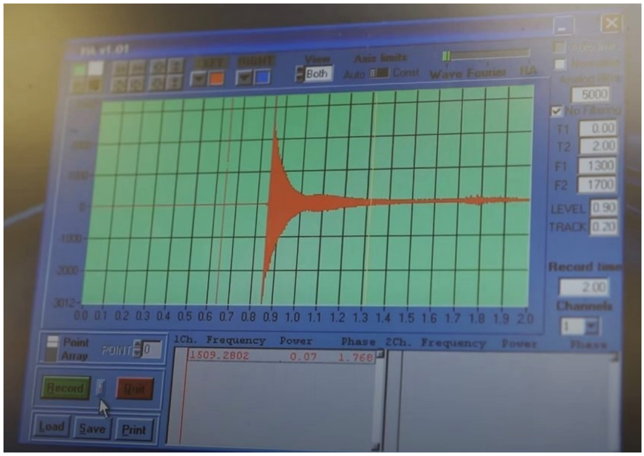
Each blade with a thread is suspended in a special stand (Fig. 15). Free elastic oscillations in the blade material can be induced by a light impact using a small hammer. At the same time, free acoustic oscillations are induced in the surrounding air environment. Furthermore, the dominant frequency of the acoustic oscillations is the same as the frequency of internal elastic oscillations in blade's material. Therefore, to determine the natural frequency of the blade, it is possible to record and analyze acoustic oscillations using a microphone sensor. The sensor is connected to a personal computer equipped with specialized software HA.

Fig. 15. Laboratory stand.



On the computer screen (Fig. 16), it is possible to see the main window of the HA program and the recorded process of damped acoustic oscillations for the undamaged blade. Qualitatively the same is a process of damped acoustic oscillations that occurs as a result of an impact on the side surface of a damaged blade.

Fig. 16. Damped acoustic oscillations recorded by the computer program HA.



Using the HA program, the blades' natural frequencies corresponding to the recorded damped acoustic oscillations were determined. Pictures taken from computer screen are shown in Fig. 17 and Fig. 18.

Fig. 17. Determination by the HA program of natural frequency f_o of the undamaged blade.

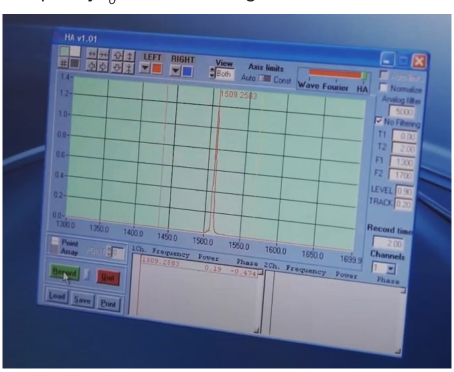
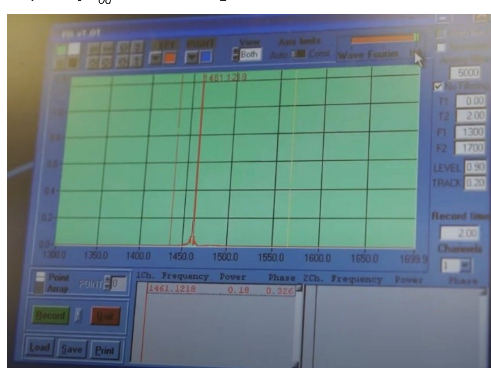


Fig. 18. Determination by the HA program of natural frequency f_{od} of the damaged blade.



Experiments with undamaged and damaged blades were repeated 10 times to assess the effect of random factors on the distribution of results. Mean values of natural frequencies are as follows: for the undamaged blade $\overline{f}_0$ = 1507.4389 Hz; for the damaged blade $\overline{f}_{0d}$= 1461.8532 Hz. Relative deviation between the mean values of frequencies $\overline{f}_0$ and $\overline{f}_{0d}$ is about 3%. Besides, after mathematical processing of the experimental data, using the Student's *t*-distribution [5], it can be concluded that with confidence 95% the natural frequencies f_{0d} and f_0 of the damaged and undamaged blades are in the following ranges:

$$1460{,}64 < f_{od} < 1463{,}06 \text{ (Hz) and } 1506{,}69 < f_0 < 1508{,}19 \text{ (Hz)}.$$

Therefore, the frequency intervals do not overlap. This means that a damaged blade can be reliably distinguished from an undamaged one using the frequency method.

It should be noted, however, that the practical implementation of frequency methods involves the need to use particularly precise (and therefore very expensive) control and measuring instrumentation. This significantly limits the scope of application of these methods. Moreover, in recent years, nonlinear nondestructive testing methods have become increasingly popular, and the essence of nonlinear approach to diagnostics is described in specialized literature [3, 6-8].

3. VIBRATION IDENTIFICATION OF PARAMETERS OF TECHNICAL OBJECTS

The tasks of technical diagnostics are closely interrelated and are often intertwined with parametric identification problems. Vibration identification means solving the problem of synthesis a model of an object based on data of its dynamic behavior under the known external vibration excitation. Based on vibration methods, parameters of a mathematical model that describe the dynamic behavior of an object can be identified (parametric identification).

Parametric identification may be defined as a form of indirect mechanical measurement. Some practical examples of vibration identification are discussed below.

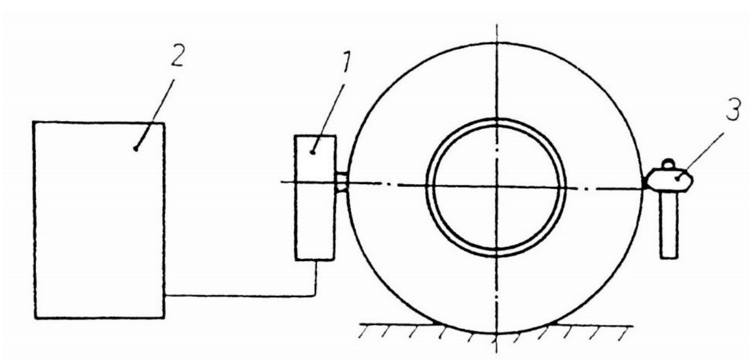
3.1. MEASURING OF AIR PRESSURE IN PNEUMATIC TIRES

The economical operation of a vehicle is largely determined by fuel consumption, the need for which, in addition to other factors (vehicle design and weight, speed, tire design, road condition), significantly depends on the air pressure in the tires. According to work [9], a decrease in air pressure in vehicle tires by 10–15% (against the value recommended by the manufacturer) leads to an increase in driving resistance and an increase in fuel consumption by 3.5–4%. In addition, prolonged use of tires with reduced air pressure leads to their premature destruction, reduces the reliability and service life of the vehicle, significantly impairs its handling and reduces road safety. Therefore, the current rules for operating vehicles do not allow the air pressure in tires to deviate from the nominal value by more than ±0.02 MPa for trucks and ±0.01 MPa for passenger cars. To meet existing requirements, it is necessary to monitor systematically the air pressure in vehicle tires.

The traditional method of measuring pressure, which involves opening the valve on each of the monitored tires and then using a standard pressure gauge, is very labor-intensive. The complexity of control increases even more when determining the air pressure in the internal pneumatic tires of the paired wheels of trucks, buses, trolleybuses, since in this case it additionally becomes necessary to remove the outer wheels from the vehicle to provide access to internal tire valves. Taking into account the above, the development of methods and means for operational express pressure testing that do not require opening the valve is of great importance (especially for large automobile enterprises).

The proposed express control method is based on the dependence of the tire stiffness in the radial direction on the air pressure in it. A change in rigidity, in turn, leads to a change in the frequency of free vibrations of the system consisting of an elastic wall of the tire and the mass of the tip applied to it from the outside. The block diagram of a device for measuring air pressure in tires is shown in Fig. 19. The measuring tip contains a piezoelectric accelerometer, which converts vibrations of the elastic shell into a proportional electrical signal. The control unit records the free oscillation frequency of the tire-measuring tip system, the value of which is uniquely related to the air pressure in the tire.

Fig. 19. Block diagram of the device for measuring air pressure in tires: 1 – measuring tip; 2 – control unit; 3 – hammer.



When a tire is pulsed with shock loading, as experimental studies have shown, several modes of its free vibrations are excited at once. However, the most intense oscillations are in the first proper mode (see Fig. 20). Therefore, it was decided to take the frequency characteristics of this mode as the basis for the diagnostic procedure.

Typical time curve for damped free oscillations of pneumatic tire in the x direction is shown in Fig. 21. Air pressure measurement is based on recording of period T or frequency $f = 1/T$ during service of transport vehicle and comparison of measurement results with the tire calibration curve preliminary constructed.

Fig. 20. The first natural mode of elastic vibrations of a tire.

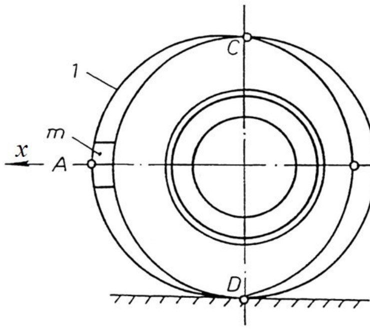
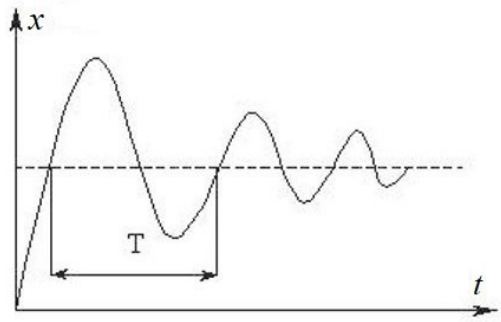


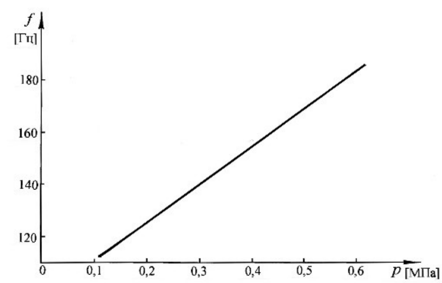
Fig. 21. Damped free oscillations of pneumatic tire in the x direction.



Based on the dynamic analysis of the system "tire-measuring tip", a device for express monitoring of air pressure in tires was developed in Riga Technical University [3]. The general view of the device is shown in Fig. 22.

Fig. 22. General view of the device for express monitoring of air pressure in tires.

Fig. 23. Calibration curve for measuring air pressure *p* in the tire of model 8A.



To operate the device, you must first calibrate it for each type of tire. This is due to the significant difference between tires of different sizes, both in their rigidity characteristics and in the required nominal pressure. As an example, Fig. 23 shows a calibration curve obtained for the tire with standard sizes 900 x 300 (model 8A) from the landing gear of an aircraft. The calibration curve can be entered in electronic form into the device's memory, which allows the readings to be displayed directly in pressure units (for example, in MPa).

Tests of the device carried out at motor transport and aviation enterprises of Latvia for various types of tires confirmed its reliability and acceptable measurement accuracy. Statistical analysis of the measurement results shows that for all tire models considered, the relative measurement error does not exceed ±5%, which is less than the maximum errors of standard pressure gauges.

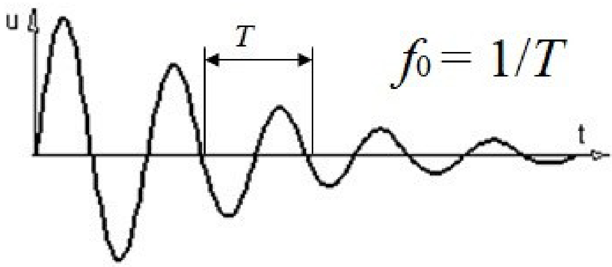
3.2. DETERMINATION OF AMOUNT OF LIQUID OR GRANULAR MATERIALS KEPT IN STORAGE TANKS

In industry and technology, it is very often necessary to determine the amount of liquid or bulk material in various types of reservoirs (cisterns, tanks, cans, gas cylinders, etc.). Traditional methods involve opening the cover of the cistern (or another reservoir) (see Fig. 24), which is inconvenient and time-consuming. Another approach to determining the amount of material in reservoirs is proposed, and it is based on the analysis of the frequency characteristics of the testing reservoir.

Fig. 24. Tank with liquid.

The testing procedure is performed by striking the wall of the tank with a hammer, which induces system's free damped elastic oscillations (see Fig. 25) with natural frequency f_0. When the amount of material inside the tank changes, the equivalent mass *m* of the system will change, but the stiffness *k* practically remains the same (the stiffness *k* mainly depends on the reservoir material properties and its dimensions). Therefore, using the simplified model of the reservoir with one degree of freedom ($f_0 = \frac{1}{2\pi}\sqrt{k/m}$), it can be concluded that as the amount of material *m* inside the tank increases, the natural frequency f_0 of the system is expected to decrease.

Fig. 25. Damped free elastic oscillation of tank's wall.



This vibration effect is used as an informative vibration sign for determining the amount of material in different types of reservoirs. The corresponding measurement algorithm is called the frequency method. In this paper, the capabilities of frequency method are demonstrated on the example of student's research work on determination of amount of water in a glass vessel.

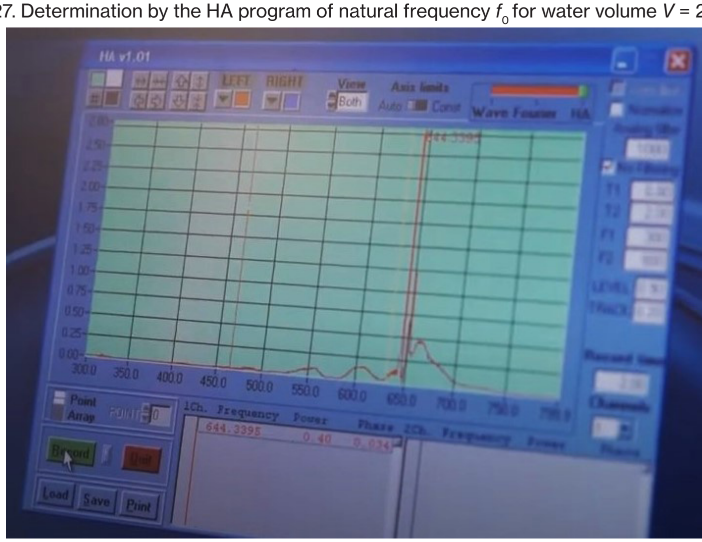
For conducting laboratory experiments, a glass vessel with milliliter divisions on the surface (Fig. 26), which allows to determine approximately the amount of water inside the vessel. The purpose of the experiments is to obtain initial data for the construction of the calibration curve, i.e. relationships between the water volume V in the vessel and the natural frequency f_0 of the system.

Fig. 26. Laboratory experiments with a glass vessel filled with water.

The experiments were carried out with the empty vessel and with vessel filled with different volumes of water. Free elastic oscillations in the vessel material were induced by a light lateral impact using a small hammer (Fig. 26). At the same time, free acoustic oscillations are induced in the surrounding air environment. Furthermore, the dominant frequency of the acoustic oscillations is the same as the frequency of internal elastic oscillations in the vessel's material. Therefore, to determine the natural frequency of the vessel with water, it is possible to record and analyze acoustic oscillations using a microphone sensor. The sensor is connected to a personal computer equipped with specialized software HA [4].

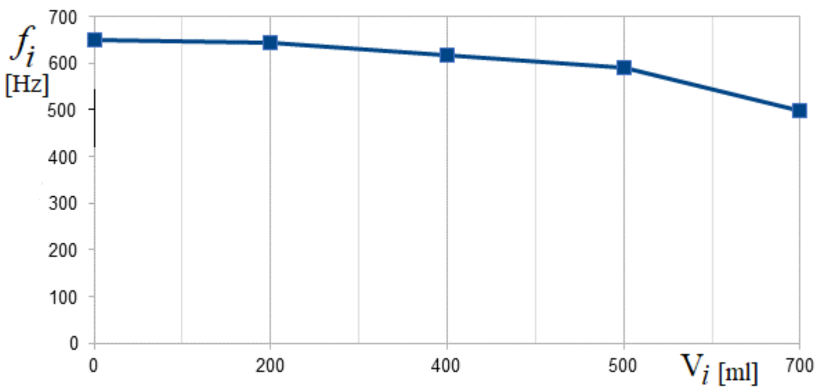
Using the HA program, the natural frequencies of vessel with different amount of water were determined. Experiments with each water volume V were repeated 10 times to assess the effect of random factors on the distribution of results. As an example, Fig. 27 presents main screen of the HA program with the testing result for volume V = 200 ml (in this experiment f_0 = 644.3395 Hz).

Fig. 27. Determination by the HA program of natural frequency f_0 for water volume V = 200 ml.



After mathematical processing of experimental data, a calibration curve was drawn – the relationship between the volume of water V_i in the vessel and the mean value of the natural frequency f_{0i} (Fig. 28). As it is seen, in the volume interval 0 - 200 ml, the curve $V(f_{0i})$ is very flat, which indicates the relatively low accuracy of the frequency method in this volume V interval. The frequency method ensures sufficient increasing of measurement accuracy at larger amounts of water in the vessel (V > 200 ml).

Fig. 28. Calibration curve for the glass vessel filled with water.



In general, laboratory experiments confirm the performance of the proposed frequency method and the possibility of its use in various engineering applications.

4. CONCLUSION

The paper discusses a number of examples on practical application of vibration effects to solve problems of technical diagnostics and identification. However, the possibilities for using vibration are much wider and are not limited to the examples considered here. In accordance with experimental and theoretical studies [10, 11], vibration also can be useful in different technological processes (for example, vibration compaction and processing of granular material and soils, vibration cleaning of details, vibration emptying of loading hoppers, vibration transporting of materials, etc.).

Artificial intelligence (Chat GPT) can be used when developing new vibration devices. For example, engineers and designers can use GPT to generate and explore a wide range of design options for their vibration device. By providing specific design criteria, the model can generate possible solutions that meet those requirements, helping to accelerate the design process.

Besides, GPT can assist in researching the market potential for a new vibration device, identifying potential competitors, and assessing the demand for such a device.

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SOBRE O ORGANIZADOR

Xosé Somoza Medina (1969, Ourense, España) Licenciado con Grado y premio extraordinario en Geografía e Historia por la Universidad de Santiago de Compostela (1994). Doctor en Geografía e Historia por la misma universidad (2001) y premio extraordinario de doctorado por su Tesis "Desarrollo urbano en Ourense 1895-2000". Profesor Titular en la Universidad de León, donde imparte clases desde 1997. En la Universidad de León fue Director del Departamento de Geografía entre 2004 y 2008 y Director Académico de la Escuela de Turismo entre 2005 y 2008. Entre 2008 y 2009 ejerció como Director del Centro de Innovación y Servicios de la Xunta de Galicia en Ferrol. Entre 2007 y 2009 fue vocal del comité "Monitoring cities of tomorrow" de la Unión Geográfica Internacional. En 2012 fue Director General de Rehabilitación Urbana del Ayuntamiento de Ourense y ha sido vocal del Consejo Rector del Instituto Ourensano de Desarrollo Local entre 2011 y 2015. Ha participado en diversos proyectos y contratos de investigación, en algunos de ellos como investigador principal, con temática relacionada con la planificación urbana, la ordenación del territorio, las nuevas tecnologías de la información geográfica, el turismo o las cuestiones demográficas. Autor de más de 100 publicaciones relacionadas con sus líneas de investigación preferentes: urbanismo, turismo, gobernanza, desarrollo, demografía, globalización y ordenación del territorio. Sus contribuciones científicas más importantes se refieren a la geografía urbana de las ciudades medias, la crisis del medio rural y sus posibilidades de desarrollo, la evolución del turismo cultural como generador de transformaciones territoriales y más recientemente las posibilidades de reindustrialización de Europa ante una nueva etapa posglobalización. Ha participado como docente en masters y cursos de especialización universitaria en Brasil, Bolivia, Colombia, Paraguay y Venezuela y como docente invitado en la convocatoria Erasmus en universidades de Bulgaria (Sofia), Rumanía (Bucarest) y Portugal (Porto, Guimarães, Coimbra, Aveiro y Lisboa). Ha sido evaluador de proyectos de investigación en la Agencia Estatal de Investigación de España y en la Organización de Estados Iberoamericanos (OEI). Como experto europeo en Geografía ha participado en reuniones de la Comisión Europea en Italia y Bélgica. Impulsor y primer coordinador del proyecto europeo URBACT, "come Ourense", dentro del Programa de la Unión Europea "Sostenibilidad alimentaria en comunidades urbanas" (2012-2014). Dentro de la experiencia en organización de actividades de I+D+i se pueden destacar la organización de diferentes reuniones científicas desarrolladas dentro de la Asociación de Geógrafos Españoles (en 2002, 2004, 2012 y 2018).

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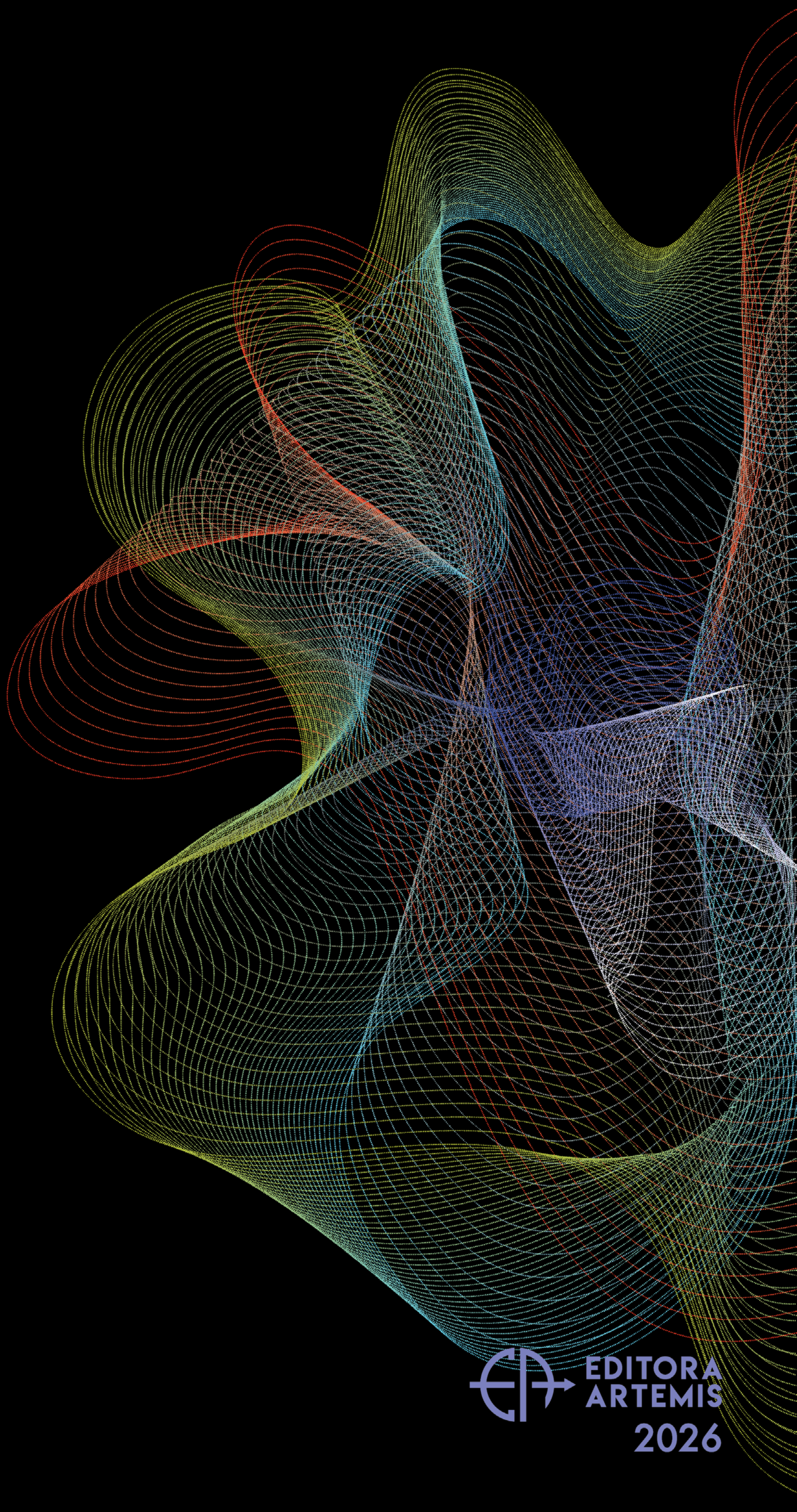

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