Review Article

Journal of Material Sciences & Applied Engineering

Exploring Forced-damped Vibrations: Analysis, Modeling, and Medical Applications

Zine Ghemari

Mohamed Boudiaf University of M'sila, M'sila, Algeria

***Corresponding author:** Zine Ghemari, Mohamed Boudiaf University of M'sila, M'sila, Algeria.

Submitted: 12 February 2024 **Accepted:** 19 February 2024 **Published:** 26 February 2024

***Citation:** Zine Ghemari (2024) Exploring Forced-Damped Vibrations: Analysis, Modeling, and Medical Applications. J Mat Sci Apl Eng 3(1), 01-08.*

Abstract

Forced-damped vibrations play a significant role in various medical applications, such as studying the mechanical properties of tissues, designing medical devices, and understanding the behavior of biological systems. Analyzing and modeling forced-damped vibrations in medicine involves a combination of physics, engineering, and biology. Forced-damped vibrations refer to the dynamic motion of a system that is subjected to both external forcing and damping. In this type of vibration, an external force or input continuously acts on the system, and damping influences the rate at which the system dissipates energy. Forced-damped vibrations are prevalent in various engineering applications and systems where an external force continually drives the motion.

In essence, the application of damped vibrations in medicine underscores its significance in advancing diagnostics, treatment, and research. The nuanced consideration of damping properties has led to innovative technologies and methodologies that enhance our ability to comprehend and interact with the complex mechanical dynamics of biological tissues. As technology continues to evolve, the integration of damped vibrations is likely to play an increasingly critical role in shaping the future of medical practices and healthcare solutions.

Introduction

Vibration is a common phenomenon observed in various natural and man-made systems. It refers to the repetitive back-and-forth or oscillatory motion of an object or system about an equilibrium position. Vibrations can occur in a wide range of scales, from microscopic particles to massive structures, and can be experienced in various forms, including mechanical, acoustic, and electromagnetic vibrations [1-10].

Vibrations can be classified into different types based on their characteristics and underlying mechanisms. Some common types include free vibrations, forced vibrations, damped vibrations, and resonance vibrations [11-18].

Free vibrations occur when a system is set into motion and left to oscillate without any external forces acting on it. This type of vibration is characterized by the natural frequency of the system, which is determined by its mass and stiffness properties [19-27].

Forced vibrations occur when an external force or excitation is applied to a system, causing it to vibrate at a frequency different from its natural frequency. This type of vibration can be periodic or non-periodic, and the response of the system depends on the characteristics of the forcing function and the properties of the system [28-34].

Damped vibrations involve the presence of damping forces that resist the motion of the system, gradually reducing its amplitude and bringing it to a state of equilibrium. Damping can arise from sources such as friction, air resistance, or energy-absorbing materials [35-40].

Resonance vibrations occur when a system is subjected to an external force or excitation at its natural frequency. This leads to a significant amplification of the vibrations and can result in excessive vibrations, which can be detrimental to the system if not properly controlled.

Understanding and analyzing vibrations are crucial in various scientific, engineering, and industrial applications. Engineers use vibration analysis to design structures that are resistant to vibrations, optimize machinery performance, and ensure the safety and reliability of systems. Additionally, researchers use vibration analysis to study the dynamic behavior of materials, characterize the properties of various systems, and develop techniques for vibration control and mitigation.

Forced-damped vibrations are a type of motion exhibited by mechanical systems that are subjected to external forces and also influenced by damping effects. These vibrations occur when a system is forced to oscillate due to the application of an external force, while simultaneously being damped by the presence of resistance or damping factors [41-47].

In a forced-damped vibration scenario, the system experiences an external force that can be periodic or non-periodic. The external force can arise from various sources, such as an applied force, vibrations from machinery, or external disturbances. The system responds to this force by oscillating around its equilibrium position [48-53].

Damping is another crucial factor that affects forced-damped vibrations. Damping refers to the dissipation of energy within the system, which opposes the motion and reduces the amplitude of vibrations over time. Different forms of damping can be present in a system, such as friction, fluid resistance, or energy-absorbing materials. The presence of damping affects the behavior of the system, gradually bringing it to a state of equilibrium and reducing the amplitude of the vibrations [54-58].

Forced-damped vibrations can be found in various mechanical systems, including springs, pendulums, bridges, buildings, and machines. Understanding the behavior of forced-damped vibrations is fundamental in engineering and physics as it helps in designing structures, analyzing the response of machinery to external forces, and predicting the behavior of systems under different conditions.

Mathematical models, such as differential equations, are used to describe forced-damped vibrations. By solving these equations, engineers and scientists can analyze the system's dynamics, including its transient and steady-state responses, resonance frequencies, and other properties. Techniques like Fourier analysis and numerical methods are often employed to study forced-damped vibrations and extract useful information. Overall, understanding forced-damped vibrations is crucial for designing robust and efficient mechanical systems that can withstand external forces while maintaining stable operation [59-62].

The integration of damped vibration in medicine stands at the crossroads of engineering ingenuity and healthcare advancement. Characterized by controlled and subdued oscillations, damped vibrations play a versatile and invaluable role across various medical realms. From diagnostic instruments to therapeutic strategies, the incorporation of damped vibrations underscores a collaborative, multidisciplinary approach dedicated to elevating patient care, refining diagnostic capabilities, and propelling the evolution of medical technologies. This exploration meticulously examines the multifaceted contributions of damped vibrations, emphasizing their pivotal role in diagnostics, treatments, and the overarching pursuit of optimal patient outcomes within the dynamic landscape of medical practices [63-64].

Furthermore, the field of tissue engineering and regenerative medicine exploits controlled vibrations to stimulate cell growth and guide tissue regeneration. The application of damped vibrations in biomechanics research contributes to a deeper understanding of human movement, aiding in the development of rehabilitation strategies and orthopedic interventions [65-68].

Application of Damped Vibration in Medicine

Damped vibrations find versatile applications in medicine, ranging from diagnostic imaging and medical devices to tissue engineering and biomechanics research. The careful consideration and utilization of damping properties contribute significantly to advancements in medical technology, diagnosis, and therapeutic interventions [63].

Here are some specific applications:

- **Medical Imaging:** Damped vibrations are employed in medical imaging techniques to enhance diagnostic capabilities. Techniques such as elastography use damped vibrations to assess tissue stiffness. By inducing and monitoring vibrations in tissues, medical professionals can obtain information about the tissue's mechanical properties. This is particularly useful in detecting abnormalities or pathologies in organs such as the liver, where stiffness variations can indicate diseases like cirrhosis [63].
- **Ultrasound Imaging:** Damped vibrations play a role in ultrasound imaging where acoustic waves are used to create images of internal body structures. Understanding the damping characteristics of tissues helps in optimizing imaging techniques (see Figure 1) [64].

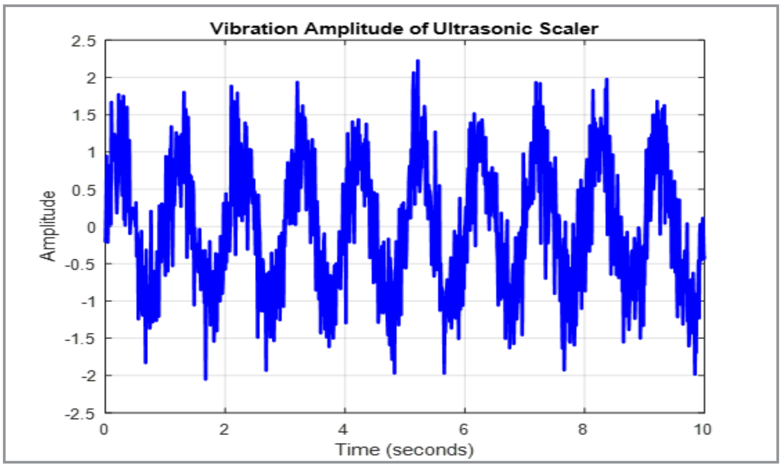

Figure 1: Vibration amplitude of ultrasonic scaler

- **Magnetic Resonance Imaging (MRI):** In MRI, knowledge of damped vibrations is essential for designing pulse sequences and optimizing image quality.
- **Biomechanics and Tissue Characterization:** Damped vibrations are extensively used in biomechanics research to study the movement and mechanical behavior of the human body. This includes analyzing the damping properties of joints, bones, and soft tissues. Such research is vital for developing rehabilitation techniques, understanding injury mechanisms, and optimizing the design of orthopedic implants [63].
- **Soft Tissue Analysis:** Utilizing damped vibrations, researchers investigate the mechanical properties of soft tissues, gaining valuable insights into their elasticity, viscosity, and overall biomechanical behavior. This analysis holds significance, particularly in fields such as orthopedics and rehabilitation [64].
- **Tissue Stiffness Measurement:** Elastography techniques use damped vibrations to assess tissue stiffness, aiding in the diagnosis of conditions such as liver fibrosis or breast tumors.

Analyzing tissue stiffness measurements using MATLAB involves processing data obtained from mechanical tests or imaging modalities such as ultrasound or magnetic resonance elastography (see Figure 2)

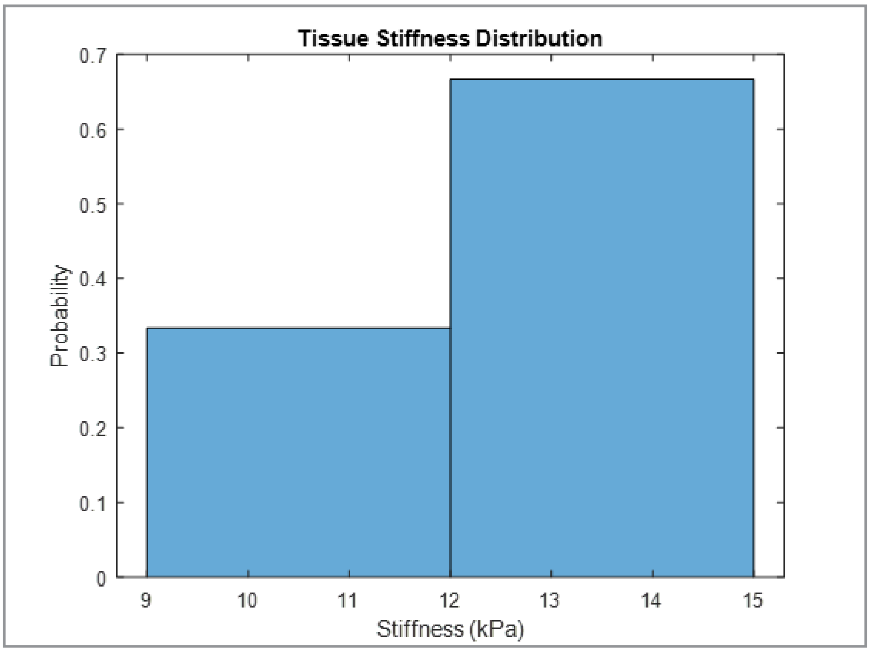

Figure 2: Tissue stiffness distribution

In this Figure:
- Sample tissue stiffness data is loaded or generated.
- Basic statistics such as mean, standard deviation, maximum, and minimum stiffness are calculated.
- The stiffness data is visualized using a histogram to show the distribution of tissue stiffness measurements.
- Additional analyses, such as statistical tests or trend analysis, can be performed based on specific research questions or objectives.

Medical Devices

Surgical Tools: Damped vibrations are considered in the design of surgical tools and instruments to minimize tissue damage during procedures.
- **Prosthetics and Implants:** Understanding damping properties is vital in designing prosthetics and implants to ensure compatibility with the natural mechanical behavior of tissues and prevent adverse reactions.
- **Vibration Therapy:** Understanding the damping properties of tissues is essential in the field of tissue engineering and regenerative medicine. Researchers utilize controlled vibrations to stimulate cell growth and guide tissue regeneration. This approach is applied in the development of strategies for healing musculoskeletal injuries or promoting the regeneration of damaged tissues.
- **Physical Therapy:** In the realm of physical therapy, controlled damped vibrations play a crucial role in therapeutic interventions. These strategically applied vibrations are instrumental in addressing a spectrum of conditions, contributing to tissue healing, improving blood circulation, and alleviating pain for individuals undergoing rehabilitation [65].
- **Whole Body Vibration (WBV):** Whole Body Vibration, facilitated by specialized platforms, represents a promising avenue in the realms of fitness, health, and rehabilitation. As research and understanding of its mechanisms progress, WBV stands as a dynamic modality with the potential to positively impact muscle strength, bone density, and overall well-being [65].

Cardiovascular Applications
- **Blood Flow Analysis:** Damped vibrations play a role in understanding blood flow dynamics, especially in the study of arterial elasticity and the design of cardiovascular devices.

- **Heart Valve Dynamics:** Analyzing the damped vibrations in heart valves aids in understanding their function and contributes to the development of artificial heart valves.

Drug Delivery Systems

- **Ultrasonic Drug Delivery:** Damped vibrations can enhance drug penetration through tissues in targeted drug delivery systems, improving the efficiency of treatments.

Diagnostics

- **Vibration-based Diagnostics:** Abnormalities in tissue vibrations can serve as diagnostic indicators. For example, changes in vocal cord vibrations can be indicative of certain medical conditions.

Modeling of Forced-Damped Vibrations

Forced-damped vibrations refer to a system's motion subject to both a forcing function (external force) and damping (resistance) factors. These vibrations typically occur in mechanical systems such as springs, pendulums, or vibrating structures.

In forced-damped vibrations, the system experiences an external force that causes it to oscillate. This force can be periodic or non-periodic, depending on the nature of the system and the source of the force. For example, a spring-mass system subjected to a periodic driving force will exhibit forced-damped vibrations.

Damping is an important factor in forced vibrations as it determines how the system dissipates energy and affects the amplitude of the vibrations. Damping can be achieved through various means, such as air resistance, friction, or energy-absorbing materials. The presence of damping opposes the motion of the system, reducing the amplitude and gradually bringing it to a state of equilibrium.

Forced-damped vibrations can be described mathematically using differential equations, typically using second-order differential equations. The equation of motion for a forced-damped system can be represented as: $M(d^2x/dt^2) + c(dx/dt) + kx = F(t)$ (1)

Where:
M is the mass of the system,
C is the damping coefficient,
K is the spring constant,
X is the displacement of the system from its equilibrium position,
t is time, and
F(t) is the forcing function.
Solving this equation of motion allows us to determine the behavior of the system under forced-damped vibrations and how it responds to the forcing function and damping. The response of the system can be characterized by its steady-state response, transient response, resonance frequencies, and other dynamic properties.

Understanding forced-damped vibrations is essential in various engineering applications, such as designing structures to withstand external forces or analyzing the behavior of machines subjected to periodic or random vibrations. Engineers and scientists often employ techniques like Fourier analysis, complex numbers, and numerical methods to study and analyze forced-damped vibrations.

Magnification Factor

The magnification factor in the context of forced-damped vibrations refers to the ratio of the amplitude of the system's response to the amplitude of the applied external force. It is a measure of how much the amplitude of the system's vibrations is magnified or attenuated due to the influence of the external force.

For a linear, single-degree-of-freedom system undergoing forced-damped vibrations, the magnification factor (M) is often expressed as the ratio of the amplitude of the response (X) to the amplitude of the applied force (F0) (see Figure 3). Mathematically, it can be represented as: $M = X/F0$ (2)

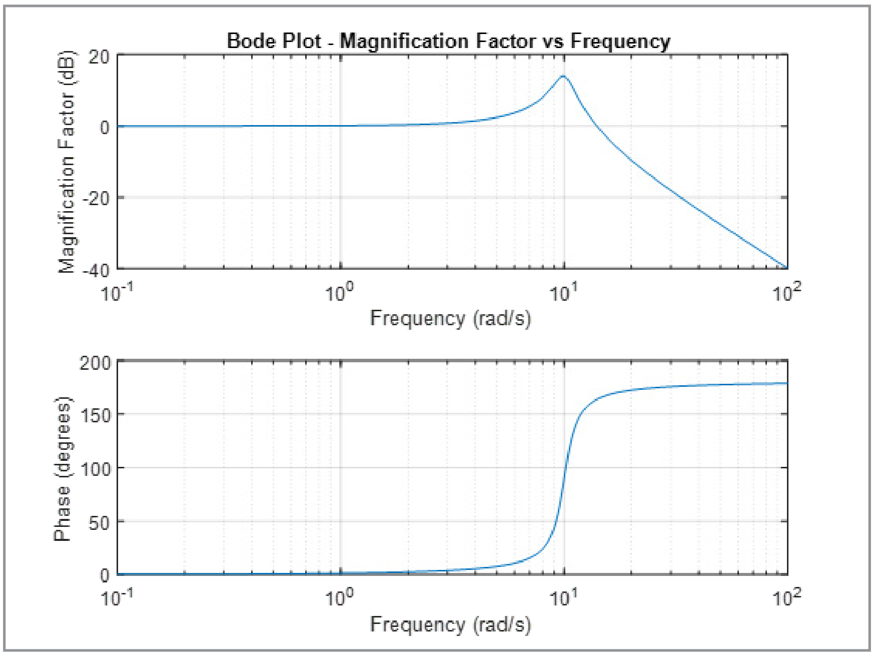

Figure 3: Magnification factor as a function of Frequency

This factor is frequency-dependent, and it provides insights into the system's response to different frequencies of the external force. The magnification factor is commonly used in the analysis of resonance, a condition where the excitation frequency closely matches the natural frequency of the system.

The relationship between the magnification factor and frequency is typically plotted on a graph called the frequency response curve. This curve helps engineers and analysts understand how the amplitude of the system's response changes across different frequencies, revealing the resonance peaks and regions of significant vibration.

Transmissibility

Transmissibility is a concept used in the analysis of forced-damped vibrations, particularly in the context of mechanical and structural engineering. It refers to the ratio of the amplitude of vibration at a certain point in a structure (or a system) to the amplitude of an external force applied at the same frequency. Transmissibility is a valuable metric for understanding how a structure responds to dynamic loading.

Mathematically, transmissibility (T)is defined as:

T=Amplitude of vibration /Amplitude of applied force (3)

The transmissibility can be frequency-dependent, and it is often expressed in terms of the excitation frequency. Engineers commonly use the transmissibility concept to assess how structures respond to harmonic or periodic loading, especially in the analysis of resonance conditions (see figure 4).

Mathematically, transmissibility is often expressed using the following formula:

$T(\omega)= X(\omega) /F0$ (4)

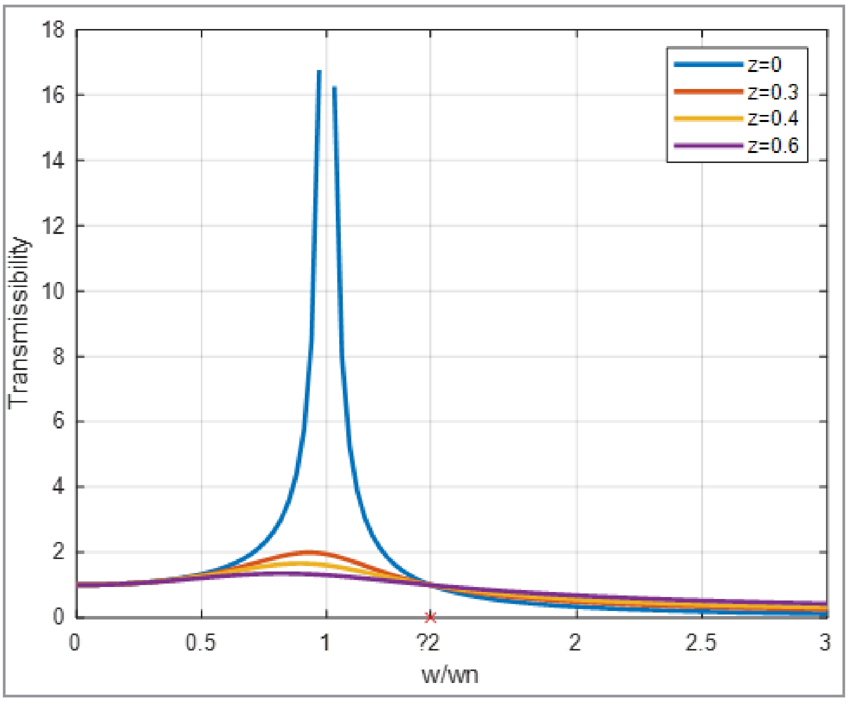

Figure 4: Transmissibility as a function of frequency margin

Transmissibility is often expressed as a function of frequency in vibration analysis. This function helps engineers understand how a system responds to different excitation frequencies. The transmissibility ratio is typically plotted against frequency to create a frequency response curve.

The term "frequency margin" might refer to the difference between the natural frequency of a system and the excitation frequency. In forced vibrations, the system is more responsive and can exhibit resonance when the excitation frequency closely matches the natural frequency.

Combining these concepts, one might consider evaluating transmissibility over a range of frequencies, and the "frequency margin" could be the difference between the excitation frequency and the natural frequency.

If the frequency margin is positive, the system is operating away from its natural frequency, reducing the risk of resonance. If the frequency margin is negative or close to zero, it indicates a proximity to resonance, which could lead to significant amplification of vibrations.

A practical consideration is to design systems with enough frequency margin to avoid resonance and ensure stable operation. Engineers often analyze frequency response curves and adjust system parameters to achieve a safe margin away from resonance conditions.

Conclusion

Damping plays a crucial role in forced-damped vibrations by dissipating energy and reducing the amplitude of oscillations over time. Different forms of damping, such as friction or fluid resistance, can be present in a system, affecting its response and bringing it to a state of equilibrium. Mathematical models, typically represented by differential equations, are used to describe forced-damped vibrations. Analyzing these equations allows engineers and scientists to understand the dynamics of the system, including its steady-state and transient responses, resonance frequencies, and other properties.

By studying forced-damped vibrations, engineers can design structures that can withstand external forces, improve the efficiency of machines, and ensure stable and safe operation of various mechanical systems.

The application of damped vibration in medicine represents a multifaceted and essential aspect of healthcare and biomedical research. The incorporation of damped vibrations into various medical contexts has yielded significant advancements and benefits. The understanding of the mechanical properties of biological tissues, facilitated by the study of damped vibrations, plays a pivotal role in diverse medical applications.

Reference

1. Liu Q, He S, Chen Z, Peng W Zhang (2020) Time-Varying Motion Filtering for Vision-Based Nonstationary Vibration Measurement, in IEEE Transactions on Instrumentation and Measurement 69: 3907-3916.
2. Ma Z, Luo Y, Xie S, Zhang Y (2022) Active Vibration Control of Cantilever Beam in fast Maneuvering Flight Environment. 2022 16th Symposium on Piezoelectricity, Acoustic Waves, and Device Applications (SPAWDA) 351-355.
3. Li C, Li J, Fang XL, Tang Y, Deng T, et al. (2022) Application of a Method of Identifiying Instantaneous Shaft Speed from Spectrum in Aeroengine Vibration Analysis. 2022 Global Reliability and Prognostics and Health Management (PHM-Yantai) 1-7.
4. Zhao M, Shen X, Jiang F (2023) Research on Mechanical Vibration Measurement Method Based on Event Camera. 2023 3rd International Conference on Energy Engineering and Power Systems (EEPS) 528-532.
5. Li S, Xiong Y, Ren Z, Gu C, Peng Z (2020) Ultra-micro Vibration Measurement Method Using CW Doppler Radar. 2020 International Conference on Sensing, Measurement & Data Analytics in the era of Artificial Intelligence (ICSMD) 235-237.
6. Li S, Xiong Y, Zhou P, Ren Z, Peng Z (2022) mmPhone: Sound Recovery Using Millimeter-Wave Radios With Adaptive Fusion Enhanced Vibration Sensing. IEEE Transactions on Microwave Theory and Techniques 70: 4045-4055.
7. Reguieg Salima Khaoula, Zine Ghemari, Tarak Benslimane (2018) Extraction of the relative sensitivity model and improvement of the piezoelectric accelerometer performances. 2018 International Conference on Signal, Image, Vision and their Applications (SIVA), Guelma, Algeria.
8. Zine Ghemari, Salah Saad (2019) The use of mechanical sensitivity model to enhance capacitive sensor characteristics Analog Integrated Circuits and Signal Processing 99: 349-357.
9. Zine Ghemari, Salah Saad (2019) Enhancement of capacitive accelerometer operation by parameters improvement. International Journal of Numerical Modelling Electronic Networks Devices and Fields 32: 2568.
10. Zine Ghemari, Saad Salah, Mabrouk Defdaf (2021) Appropriate Choice of Damping Rate and Frequency Margin for Improvement of the Piezoelectric Sensor Measurement Accuracy. Journal of Advanced Manufacturing Systems 20: 537-548.
11. Xiangyi Z, Guohe J, Linchang Y, Baogang L (2021) Surface vibration and noise analysis of POD Propeller of Construction Scientific Research Ship. 2021 6th International Conference on Power and Renewable Energy (ICPRE) 1519-1523.
12. Berta S, Goga V, Murín J (2022) Active Vibration Damping of Cantilever Beam using LabVIEW. 2022 Cybernetics & Informatics (K&I), Visegrád, Hungary 1-6.
13. Xiong Y, Liu Z, Li S, Meng G, Peng Z (2023) Scanning Microwave Vibrometer: Full-Field Vibration Measurement via Microwave Sensing With Phase-Encoded Beam Scanning. IEEE Transactions on Instrumentation and Measurement 72: 1-11.
14. Cao H, Huang T, Lu L, Xie Z (2021) Research on Quasi-zero Stiffness Vibration Isolation Technology of Distribution Transformer. 2021 IEEE 4th International Conference on Automation, Electronics and Electrical Engineering (AUTEEE), Shenyang, China 613-617.
15. Zine Ghemari, Salah Saad (2017) Parameters improvement and suggestion of new design of capacitive accelerometer. Analog Integrated Circuits and Signal Processing 92: 443-451.
16. Ghemari Z, Saad S, Amrouche A, Lakehal A (2015) New model of piezoelectric accelerometer relative movement modulus. Transactions of the Institute of Measurement and Control 37: 932-941.
17. Zine Ghemari, Salah Saad (2013) Modeling and enhancement of mechanical sensitivity of vibration sensor. Journal of Vibration and Control 20: 2234-2240.
18. Zine Ghemari, Fethi Chouaf, Salah Saad (2017) New Formula for the Piezoresistive Accelerometer Motion Acceleration and Experimental Validation. Journal of Advanced Manufacturing Systems 16: 57-65.
19. Zine Ghemari, Lakehal A (2015) Minimisation of resonance phenomena effect of piezoresistive accelerometer. 2015 4th International Conference on Systems and Control (ICSC), Sousse, Tunisia 243-246.
20. Zine Ghemari, Salah Saad (2013) Improvement of piezoresistive accelerometer performance. 3rd International Conference on Systems and Control, Algiers, Algeria 759-762.
21. Wang D (2022) Analysis and Solution of Abnormal Vibration of Elevator Box Based on Information Technology. 2022 International Conference on Artificial Intelligence in Everything (AIE), Lefkosa, Cyprus 306-309.
22. Zhu M, Feng Y, Zhang Y, Zhang Q, Shen T, et al. (2022) A Noval Building Vibration Measurement system based on Computer Vision Algorithms, 2022 IEEE 17th Conference on Industrial Electronics and Applications (ICIEA), Chengdu, China 1146-1150.
23. Lin F, Zheng H, Xiang B, Xu R, Jiang W, et al. (2021) Vibration-Induced Noise in Extremely Low Frequency Magnetic Receiving Antennas. IEEE Antennas and Wireless Propagation Letters 20: 913-917.
24. G. Long, Kaixin Zheng, Yan Liu, Yang Zou, Sifan Yuan, et al. (2022) Experimental Study on Vibration Mechanism and Prevention Technology of Heavy Load Switchgear. 2022 IEEE International Conference on High Voltage Engineering and Applications (ICHVE), Chongqing, China 1-4.

25. Zine Ghemari (2018) Analysis and optimization of vibration sensor. IEEE International Conference on Smart Materials and Spectroscopy (SMS'2018), Yassmine Hammamet (Tunisia).
26. Zine Ghemari (2016) Upgrading of piezoresistive accelerometer response. 2016 8th International Conference on Modelling, Identification and Control (ICMIC).
27. Zine Ghemari, Salah Saad (2014) Reducing the Measurement Error to Optimize the Sensitivity of the Vibration Sensor. IEEE Sensors Journal 14: 1527-1532.
28. Zine Ghemari, Salah Saad (2019) Defects diagnosis by vibration analysis and improvement of vibration sensor measurement accuracy. Sensor Letters 17: 608-613.
29. Zine Ghemari (2018) Decrease of the resonance phenomenon effect and progress of the piezoelectric sensor correctness. 2018 International Conference on Electrical Sciences and Technologies in Maghreb (CISTEM), Algiers.
30. Zine Ghemari, Salah Saad (2017) Simulation and Experimental Validation of New Model for the Piezoresistive Accelerometer Displacement. Sensor Letters 15: 132-136.
31. Lakehal A, Ghemari Z (2016) Suggestion for a new design of the piezoresistive accelerometer. Ferroelectrics 493: 93-102.
32. Saad S, Ghemari Z, Herous L, Hadjadj OE (2007) Transducer (Accelerometer) Modeling and Simulation. Asian Journal of Information Technology 6: 54-57.
33. Mudit Mishra, Chitrance Kumar Srivastav, Sandeep Kumar (2023) Free vibration analysis using dynamic stiffness method and first-order shear deformation theory for a functionally graded material plate. Materials Today: Proceedings.
34. Khan N U, Ahmad S, Janjua MM, Mennad A (2022) The Design of Vibration Nomograph for the Vehicle Vibrations Affecting Man. Advances in Science and Engineering Technology International Conferences (ASET), Dubai, United Arab Emirates 1-7.
35. Noubissi R K, Daosheng L, Boxue D (2023) Study on Harmonic Response Analysis and Vibration Reduction of Amorphous Metal Alloy Transformer. IEEE 4th International Conference on Electrical Materials and Power Equipment (ICEMPE), Shanghai, China 1-4.
36. 36. Pan K, Zhang W (2020) Dynamic modeling and vibration reduction analysis of a negative Poisson's ratio honeycomb foundation support. 5th International Conference on Mechanical, Control and Computer Engineering (ICMCCE), Harbin, China 524-527.
37. Zine Ghemari, Abdelaziz Lakehal (2014) Vibration sensor mechanical sensitivity improvement. International Conference on Electrical Sciences and Technologies in Maghreb, Tunis.
38. Ghemari Z Modélisation (2013) simulation et analyse expérimentale du capteur de vibration (accéléromètre) Thèse de doctorat, Université de M'sila.
39. Ghemari Z, Belkhiri S, Saad S (2023) Improvement of the relative sensitivity for obtaining a high performance piezoelectric sensor IEEE Instrumentation & Measurement Magazine 26: 49-56.
40. Lakehal A (2015) Proposal of a new formula for accelerating movement for the accelerometer 3rd International Conference on Maintenance and Industrial Safety, Skikda, Algeria.
41. Okada T, Isobe M, Kosaka T, Steinmann P, Matsumori H, et al. (2023) Study on Electric Motor Vibration Suppression by Active Dynamic Vibration Absorber. IEEE International Electric Machines & Drives Conference (IEMDC), San Francisco, CA, USA 1-7.
42. Xu C, Yin Z, Li X, Luo M (2021) Remote control of eddy current damping vibration experiment system. International Conference on Cyber-Physical Social Intelligence (ICCSI), Beijing, China 1-5.
43. Yan H, Zhang C, Wang G (2023) Experimental Study on Dual-channel Active Control Method for Transverse Vibration of Ship Propulsion Shaft System. 7th International Conference on Transportation Information and Safety (ICTIS), Xi'an, China 1353-1356.
44. Zine Ghemari, Salah Belkhiri (2021) Capacitive Sensor Accuracy Optimisation by the Frequency Range Appropriate Choice Preprint, doi.org/10.21203/rs.3.rs-863179/v1.
45. Zine Ghemari (2019) Enhancement of the vibratory analysis technique by the accelerometer characteristics evolution. The 7th International Conference on Control Engineering & Information Technology October. Tetouan – Morocco 24-26.
46. Zine Ghemari, Salah Belkhiri , Salah Saad (2023) A capacitive sensor with high measurement accuracy and low electrical energy consumption. Applied Physics A 129: 362.
47. Zine Ghemari, Salah Belkhiri, Morakchi M R (2022) Improvement of the vibration analysis technique by optimizing the parameters of the piezoelectric accelerometer. IEEE 21st international Ccnference on Sciences and Techniques of Automatic Control and Computer Engineering (STA), Sousse, Tunisia 183-186.
48. Ghemari Z, Salah belkhiri, Saad salah (2023) A piezoelectric sensor with high accuracy and reduced measurement error. Preprint in Research Square.
49. Neamtu A, Simoiu D, Ursu A R, Bereteu L (2022) Analysis of the Relaxation Effect by Vibrations on Some Rheological Models of Tissues. IEEE 16th International Symposium on Applied Computational Intelligence and Informatics (SACI), Timisoara, Romania 000204-000206.
50. Hao C, Xinyu D, Ling L, Cai W (2023) Test and Analysis of Acoustic and Vibration Characteristics of Transformer in Winding and Iron Core Loose. IEEE 3rd International Conference on Power, Electronics and Computer Applications (ICPECA), Shenyang, China 1644-1647.
51. Mistry C, Ghosh S K (2020) Effect of Vibration on the Cathode Lead of Electron Gun Assembly of the Travelling Wave Tube. URSI Regional Conference on Radio Science (URSI-RCRS), Varanasi, India 1-2.
52. Zheng L, Chen W, Huo D, Lyu X (2020) Design, Analysis, and Control of a Two-Dimensional Vibration Device for Vibration-Assisted Micromilling. IEEE/ASME Transactions on Mechatronics 25: 1510-1518.
53. Ghemari Z Salah Belkhiri, Salah Saad (2023) Appropriate choice of Capacitive sensor bandwidth. Preprint in Research Square.
54. Song H, Song E, Liu Y, Wang B, Wang Q, Wang Z (2023) Miniature FBG Vibration Sensor With High Performance and Low Angle Dependence for Two-Dimensional Vibration Measurement. IEEE Transactions on Instrumentation and Measurement 72: 1-11.

55. Wang B, Zhang H, Cao M, Qian Z, Zhou D (2022) Parameter analysis and experimental verification of dynamic vibration absorption design for transformer tank wall. 7th Asia Conference on Power and Electrical Engineering (ACPEE), Hangzhou, China 830-837.
56. Li H, Deng Z, Zhao J, Wang J, Wang S, Wang L (2021) Influence of Electromagnetic Shunt Damper on Nonlinear Vibration of HTS Maglev System. IEEE Transactions on Applied Superconductivity 31: 1-4.
57. Ding Y, Zhong Y, Wang X, Hao J, Jiang X (2021) Difference and Analysis of Mechanical Vibration Signal Characteristics between Mechanical Defects and Partial Discharge Defects of Gas Insulated Switchgear. IEEE 5th International Conference on Condition Assessment Techniques in Electrical Systems (CATCON), Kozhikode, India 211-214.
58. Xiao Y, Cao J, Xiong X, Zhu L, Ji S (2020) Research on Vibration Measurement Method and Analysis of Air-core Reactor. IEEE International Conference on High Voltage Engineering and Application (ICHVE), Beijing, China 1-4.
59. Wang Y, Xia Z, Xie R (2022) Vibration control technology of ship transmission based on machine learning. International Conference on Artificial Intelligence in Everything (AIE), Lefkosa, Cyprus 580-584.
60. Sheng ZY, Yongsheng L, Shihui L (2021) Vibration analysis of IEC 61373 standard based on measured data. 7th International Symposium on Mechatronics and Industrial Informatics (ISMII), Zhuhai, China 20-23.
61. Wang Q, Lei X (2020) The Method for Identifying Rotating Blade Asynchronous Vibration and Experimental Verification. 11th International Conference on Prognostics and System Health Management (PHM-2020 Jinan), Jinan, China 564-568.
62. Qi L, Chujun F, Wang Y, Jianli Z, Yingjie W (2022) Simulation Analysis of Transmission Wire Breeze Vibration. 6th International Conference on Power and Energy Engineering (ICPEE), Shanghai, China 163-168.
63. Tabatabai H, Oliver DE, Rohrbaugh JW, Christopher padadopoulos (2013) Novel Applications of Laser Doppler Vibration Measurements to Medical Imaging. Sens Imaging 14: 13-28.
64. Nastar C, Ayache N (1996) Frequency-based nonrigid motion analysis: application to four dimensional medical images. In IEEE Transactions on Pattern Analysis and Machine Intelligence 18: 1067-1079.
65. Raoul Saggini (2017) The Mechanical Vibration: Therapeutic Effects and Applications. Physical and rehabilitation Medicine, Department of Medical Oral and Biotechnological.
66. Issurin VB (2005) Vibrations and their applications in sport: A review. Journal of Sports Medicine and Physical Fitness,-Turin 45: 324-436.
67. Zine Ghemari (2024) Navigating Fatigue Analysis with Rain flow Counting. A Practical Overview. Nov Joun of Appl Sci Res 1: 01-06.
68. Zine Ghemari et al (2024) Application of the FMECA method for optimizing the reliability of the 1600T press. Journal of Advanced Manufacturing Systems.