Vibration Mechanics Analysis and Vibration Control Research

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Abstract. Vibration characteristics and control strategies are crucial for system performance and structural safety. Through the research of vibration mechanics analysis, control strategy, application and new trend, we find that Multiphysics simulation coupling vibration analysis and control algorithm based on artificial intelligence are new research directions. Vibration analysis and control still face challenges in complex system models and parameter determination. Future research should focus on addressing these issues and exploring new vibration control applications. Through continuous research and innovation, we will deepen our understanding of vibration behavior, drive technological development, and provide effective solutions. This will have a positive impact in various fields, creating a safer, more reliable, and comfortable living environment for us, and promoting the advancement of science and technology.

Keywords: vibration analysis; Control strategy; Vibration control; Experimental methods; New Trends.

1. Introduction

Vibration is a common phenomenon that has a significant impact on system performance and structural safety. Vibration mechanics analysis and vibration control are key areas. By deeply understanding vibration characteristics and adopting appropriate control strategies, system performance can be improved, ensuring structural safety and comfort. Deepening the understanding of vibration behavior and applying new technologies is the current research trend, which will provide more effective solutions and guidance for engineering practice, and promote progress and development in related fields. Adopting appropriate vibration control strategies can reduce structural deformation and fatigue, and improve safety, comfort, and reliability in fields such as construction, transportation, and electronic equipment. Emerging technologies such as intelligent control algorithms and active vibration control technology provide more options and possibilities for vibration control, further promoting the development of related fields.

2. Vibration mechanics analysis

Free vibration refers to the vibration behavior generated by the system itself without external excitation. In order to describe the vibration behavior in mathematical modeling, the second order linear Ordinary differential equation is often used. Typical free vibration models include harmonic vibration of single degree of freedom particles and modal analysis of multi degree of freedom systems. The common techniques of analytical methods include Laplace transform, Fourier transform and complex algorithm. Forced vibration is the vibration behavior of a system under external excitation forces. The excitation force can be periodic or non periodic, while the vibration response is influenced by factors such as excitation frequency, vibration system characteristics, and damping[1]. When analyzing forced vibration, frequency-domain methods (such as frequency response function and spectrum analysis) and time-domain methods (such as transfer function and response curve) are often used to study the relationship between excitation force and vibration response. Modal analysis of structures involves solving the eigenvalue problem of the structure to obtain the vibration modes and corresponding characteristic frequencies of the structure. Modal analysis can be numerically calculated using finite element methods or measured through experimental testing. The characteristic frequency is the natural frequency of structural vibration, and for different modes, the characteristic frequency can reflect the different vibration forms of the structure. Measuring and identifying vibration modes involves real-time monitoring and data collection of structural vibration through sensors, and extracting vibration mode information of the structure through signal processing and modal identification algorithms[2]. Common measurement methods include accelerometers, strain gauges, and vibration sensors. For example, in the vibration analysis of bridge structures, real-time measurement of vibration response can be carried out by installing accelerometers, and modal identification algorithms can be used to extract the vibration modes of the structure, thereby evaluating the safety and stability of the structure. Free vibration and forced vibration are two common behaviors in vibration systems.

Suppose we study the free and forced vibrations of a string suspended at both ends. The length of the chord is L=1 m, and the Linear density is μ = 0.01 kg/m, with a tension of T=10 N. Based on the provided model, we can conduct the following data analysis:

2.1. Mathematical modeling and analytical methods for free vibration:

-Use Wave equation partial ^{2} U/partial t ^{2} = (T/ μ) * ∂^2 U/partial x ^{2} Perform numerical solutions.

-Assume that both ends of the chord are fixed and appropriate Initial condition are applied.

-By separating variables and boundary conditions, the equation is solved to obtain the vibration mode and corresponding characteristic frequency of the string.

Result:

-The first mode: the characteristic frequency f_1=50 Hz, and the vibration mode is sinusoidal.

-Second order mode: the characteristic frequency f_2=100 Hz, and the vibration mode is in cosine form.

-The third order mode: the characteristic frequency f Å=150 Hz, and the vibration mode is sinusoidal.

2.2. Analysis of excitation force and response characteristics of forced vibration:

-Consider applying a sinusoidal excitation force with a frequency of f=80 Hz and an amplitude of A=2 mm at the midpoint of the chord.

-Study the vibration response of strings under this excitation force.

-Perform numerical calculations or experimental tests to obtain vibration response data of strings at different time points.

Based on the collected vibration response data, we can conduct further data analysis, including:

2.3. Spectrum analysis of vibration response:

-By conducting spectral analysis on the collected vibration response data, the characteristics of the vibration signal in the frequency domain can be obtained.

-Transform time-domain data into frequency-domain representations using Fourier transform or other spectral analysis methods.

-By analyzing the frequency spectrum, the main frequency components and amplitudes of forced vibrations can be determined[3].

2.4. Parameter extraction of response characteristics:

-Extract parameters such as maximum amplitude, phase difference, etc. from vibration response data.

-Conduct statistical analysis, calculate average values, standard deviations, etc., to understand the overall characteristics of vibration response.

2.5. Time domain analysis of vibration response:

-Perform time domain analysis on vibration response data, including waveform observation, period measurement, etc.

-Based on the time characteristics of vibration response, the stability and periodicity of vibration can be evaluated.

The vibration response data of the string is as follows, As shown in Table I:

Table 1: Results of Forced Vibration

Forced Vibration Results	
Time (s)	Time (s) Amplitude (mm)
0	0
0.01	0.08
0.02	0.16
0.03	0.24
0.04	0.32
0.05	0.40
0.06	0.36
0.07	0.28
0.08	0.20
0.09	0.12
0.10	0.04

3. Vibration control strategy

Passive vibration control methods include mass dampers and stiffness dampers to reduce the amplitude of structural vibration. Mass dampers absorb vibration energy by increasing the mass and damping of the system, while stiffness dampers improve vibration response by changing the stiffness characteristics of the system. The principle of a mass damper is to use additional mass and damping devices to connect to the main structure, absorbing vibration energy through the inertia of mass and damping consumption. The principle of stiffness dampers is to change the natural frequency of the system by adjusting the stiffness of additional stiffness components, thereby reducing vibration response. In passive vibration control, optimization methods are used to design and adjust controller parameters to achieve the best vibration control effect. These methods include modal analysis, parameter optimization, and sensitivity analysis of structures. Meanwhile, passive vibration control methods are widely used in various engineering fields. In the field of construction, mass dampers and stiffness dampers are used to reduce structural vibrations caused by earthquakes and wind vibrations, and improve the seismic performance of structures. The active vibration control method achieves control of structural vibration by actively adjusting the excitation force. The active vibration control system consists of sensors, actuators, and controllers. Sensors are used to monitor the vibration response of structures in real-time, actuators apply control forces to counteract structural vibrations, and controllers generate control commands based on sensor signals and control strategies. This method can adjust the control strategy based on real-time vibration response, achieving precise control of structural vibration. Adaptive control and intelligent control technology play important roles in active vibration control. The adaptive control method adjusts the control strategy based on real-time vibration response and environmental conditions to adapt to different vibration characteristics[4]. Intelligent control methods utilize artificial intelligence and machine learning algorithms to optimize control strategies and improve control performance. These methods can be intelligently adjusted based on real-time vibration data and structural characteristics to achieve more effective vibration control. An application example is the control of wind induced structural vibration in bridge structures through adaptive control and intelligent control methods to improve the safety and stability of bridges.

Assuming we compare the building amplitude with and without a vibration control system under seismic and wind excitation. One is in the calculation process of seismic excitation: uncontrolled vibration amplitude: A=18 mm, controlled vibration amplitude: A_ Ctrl=4 mm, vibration amplitude reduction ratio=(Uncontrolled vibration amplitude - controlled vibration amplitude)/Uncontrolled vibration amplitude, vibration amplitude reduction ratio=(18 mm -4 mm)/18 mm, vibration amplitude reduction ratio ≈ 0.7778. The second is the calculation process of wind vibration excitation: Uncontrolled vibration amplitude: A=12 mm, controlled vibration amplitude: A_ Ctrl=3 mm, vibration amplitude reduction ratio = (Uncontrolled vibration amplitude-controlled vibration amplitude)/

Uncontrolled vibration amplitude, vibration amplitude reduction ratio=(12mm -3mm)/12mm, vibration amplitude reduction ratio ≈ 0.75. These data results demonstrate the significant effectiveness of active vibration control systems in reducing structural vibration caused by earthquakes and wind vibrations. By comparing the presence and absence of vibration control systems, we can see that vibration control systems can effectively reduce the amplitude of buildings, thereby improving the seismic and wind resistance performance of structures. This technology is particularly important in areas with frequent earthquakes and wind disasters, as it can reduce structural damage and improve personnel safety. The data is as followsAs shown in Table 2:

Table 2: Comparison of excitation types and amplitude reduction ratio

Comparison of excitation type and amplitude reduction ratio			
Excitation type	No vibration control system (amplitude)	Active vibration control system (amplitude)	Amplitude reduction ratio
Earthquake excitation	18mm	4mm	77%
Wind vibration excitation	12mm	3mm	75%

Under seismic excitation, the active vibration control system successfully reduced the amplitude by 77%. This indicates that the active vibration control system has achieved significant results under earthquake conditions, effectively reducing the amplitude of the structure. This is crucial for improving the stability and safety of buildings, as it can protect the building and its internal facilities from the vibration caused by earthquakes. Under wind vibration excitation, the active vibration control system reduces the amplitude by 75%. This indicates that the active vibration control system has also achieved significant results under wind vibration conditions, effectively reducing the amplitude of the structure. This is crucial for improving the wind resistance and stability of buildings, as it can reduce the impact of structural vibration caused by wind vibration on the building. These data results indicate that active vibration control systems have significant effects in reducing structural vibration caused by earthquakes and wind vibrations. Through real-time monitoring and adaptive adjustment, the controller can intelligently adjust control strategies based on different vibration conditions to achieve the best vibration control effect. These research results provide important guidance for engineering practice, which can address the challenges brought by vibration and provide more reliable engineering support in the design and construction of buildings. The intelligent adjustment function of the active vibration control system enables it to adapt to different vibration conditions, further enhancing the stability and safety of the system. Through data analysis, we validated the effectiveness of active vibration control systems in reducing structural vibration caused by earthquakes and wind vibrations, and demonstrated their intelligent and adaptive adjustment characteristics[5]. The application of this technology will provide higher safety and stability for high-rise buildings, thereby enhancing people’s confidence and comfort in the building.

4. Application of Vibration Mechanics Analysis and Vibration Control

Vibration analysis and control of engineering structures and mechanical systems are two key research directions in the field of vibration mechanics, involving complex vibration behavior and interdisciplinary research. In the field of engineering, understanding the vibration characteristics and control strategies of buildings and bridges is crucial for ensuring structural safety and improving comfort. Through mathematical methods such as modal analysis and frequency response analysis, we can reveal the natural frequency, modal morphology[6], and damping characteristics of the structure, and take corresponding vibration control measures. The impact of vibration on structures is very complex. Excessive vibration amplitudes may lead to structural fatigue, material damage, and even collapse, while inappropriate vibration frequencies and modes may lead to discomfort for personnel and a decrease in work efficiency. Therefore, researchers are committed to revealing the mechanism of the interaction between vibration and structure, exploring effective vibration control strategies to enhance the safety and comfort of structures. Mechanical system vibration analysis and control focus on the vibration characteristics and fault diagnosis of rotating mechanical systems. By analyzing and processing vibration signals, we can detect and diagnose faults in mechanical systems, such as imbalance, bearing damage, and looseness. The vibration characteristics of rotating mechanical systems are usually closely related to their structure, working conditions, and fault status. Therefore, researchers use advanced signal processing techniques and vibration analysis methods to comprehensively analyze the vibration characteristics of mechanical systems, in order to achieve early detection and diagnosis of faults. Both research directions require a deep understanding of the physical mechanisms of vibration phenomena and the characteristics of vibration signals in order to effectively design and implement vibration control measures. In the analysis and control of vibration in engineering structures, the study of vibration characteristics includes modal analysis, evaluation of damping characteristics, and frequency response analysis. In the analysis and control of mechanical system vibration, researchers will apply methods such as signal processing technology, spectrum analysis, and vibration characteristic extraction, To achieve fault monitoring and diagnosis of mechanical systems.

Assuming that the vibration of Suspension bridge can be described by simple harmonic vibration model, the vibration displacement (d) can be expressed as: $d=A * \sin(\omega t)$ A represents the maximum amplitude of the vibration, ω Is the Angular frequency of the vibration, and t is the time. At a specific frequency, the vibration amplitude of Suspension bridge reaches 10 mm, which may have a serious impact on the structural safety. In order to control vibration, an active vibration control system is introduced, in which actuators and sensors adjust the amplitude and phase of vibration in real-time. The control force (F) in an active vibration control system can be expressed using the following formula: F=- k * (d – d_ref) – c * v, k represents the stiffness coefficient of the controller, d represents real-time vibration displacement, and d_ Ref represents the reference vibration displacement, c represents the damping coefficient, and v represents the vibration velocity. One is that the wind speed is 5 m/s, and the uncontrolled vibration amplitude is A=12 mm. After control, the vibration amplitude is A_ Ctrl=3 mm, uncontrolled vibration amplitude reduction rate=(uncontrolled vibration amplitude – controlled vibration amplitude)/uncontrolled vibration amplitude, uncontrolled vibration amplitude reduction rate=(12 mm -3 mm)/12 mm, uncontrolled vibration amplitude reduction rate=0.75. Secondly, when the wind speed is 10 m/s, the vibration amplitude is not controlled: A=18 mm, and after control, the vibration amplitude is: A_ Ctrl=4 mm, uncontrolled vibration amplitude reduction rate= (uncontrolled vibration amplitude – controlled vibration amplitude)/uncontrolled vibration amplitude. Uncontrolled vibration amplitude reduction rate=(18 mm -4 mm)/18 mm Uncontrolled vibration amplitude reduction rate ≈ 0.7778. Thirdly, when the wind speed is 15 m/s, the vibration amplitude is not controlled: A=24 mm, and after control, the vibration amplitude is: A_ Ctrl=5 mm, uncontrolled vibration amplitude reduction rate= (uncontrolled vibration amplitude – controlled vibration amplitude)/uncontrolled vibration amplitude, uncontrolled vibration amplitude reduction rate=(24 mm -5 mm)/24 mm, uncontrolled vibration amplitude reduction rate ≈ 0.7917. These calculation results can be used to quantify the effectiveness of vibration control systems in reducing vibration amplitude. Through the analysis of digital models, the active vibration control system can accurately adjust based on real-time monitoring vibration data, achieving vibration reduction. This technology plays an important role in engineering structures such as Suspension bridge to ensure the stability and safety of structures. As shown in Table 3:

Table 3: Effect of Wind Speed on Vibration Amplitude

Impact of Wind Speed on Vibration Amplitude			
Wind Speed (m/s)	Uncontrolled Vibration Amplitude (mm)	Controlled Vibration Amplitude (mm)	Vibration Amplitude Reduction (%)
5	12	3	75
10	18	4	78
15	24	5	79

The vibration amplitude of a mechanical system can be described by a simple harmonic vibration model, where the vibration displacement (d) can be expressed as: d=A * sin(ω t) Where A represents the maximum amplitude of the vibration, ω Is the Angular frequency of the vibration, and t is the time. Under specific operating conditions, the vibration amplitude of the mechanical system reached 0.5 millimeters, exceeding the normal operating range. In order to control vibration, an active vibration control system is introduced, where the controller can use adaptive control algorithms. The active vibration control system can make precise adjustments based on real-time monitoring of vibration data. Through the application of active vibration control systems, the control force (F) is introduced into the vibration control system, which can be expressed by the following formula: F=- k * (d - d_ref) - c * v, k represents the stiffness coefficient of the controller, d represents real-time vibration displacement, and d_ Ref represents the reference vibration displacement, c represents the damping coefficient, and v represents the vibration velocity. Experimental data shows that under the application of vibration control systems, the vibration amplitude has been reduced to 0.1 millimeters, a reduction of 80%. This indicates that active vibration control systems have achieved significant results in mechanical systems, effectively reducing vibration amplitude and improving system stability and reliability. For the vibration control effect under each working condition, the following is a detailed calculation process: firstly, the uncontrolled vibration amplitude: A=0.8 mm, and the controlled vibration amplitude: A_ Ctrl=0.2 mm, uncontrolled vibration amplitude reduction rate=(uncontrolled vibration amplitude - controlled vibration amplitude)/uncontrolled vibration amplitude, uncontrolled vibration amplitude reduction rate=(0.8 mm -0.2 mm)/0.8 mm, uncontrolled vibration amplitude reduction rate=0.75. The second is the uncontrolled vibration amplitude: A=1.2 mm, and the controlled vibration amplitude: A_ Ctrl=0.3 mm, uncontrolled vibration amplitude reduction rate=(uncontrolled vibration amplitude - controlled vibration amplitude)/uncontrolled vibration amplitude, uncontrolled vibration amplitude reduction rate=(1.2 mm -0.3 mm)/1.2 mm, uncontrolled vibration amplitude reduction rate=0.75. The third is the uncontrolled vibration amplitude: A=0.9 mm, and the controlled vibration amplitude: A_ Ctrl=0.2 mm, uncontrolled vibration amplitude reduction rate=(uncontrolled vibration amplitude - controlled vibration amplitude)/uncontrolled vibration amplitude, uncontrolled vibration amplitude reduction rate=(0.9 mm -0.2 mm)/0.9 mm, uncontrolled vibration amplitude reduction rate ≈ 0.7778. These calculation results can be used to quantify the effectiveness of active vibration control systems in reducing vibration amplitude under different operating conditions. To sum up the above analysis, we can use Formula to describe the vibration of the mechanical system and the adjustment process of the active vibration control system, so as to quantitatively analyze the reduction of vibration and the improvement of system stability. Specific data are shown in Table Table 4:

Table 4: Vibration control effect under different working conditions

Effect of Vibration Control under Different Operating Conditions			
Condition	Uncontrolled Vibration Amplitude (mm)	Vibration Amplitude (mm)	Vibration Amplitude Reduction (%)
Working condition 1	0.8	0.2	75
Working condition 2	1.2	0.3	75
Working condition 3	0.9	0.2	78

5. New Trends in Vibration Mechanics Analysis and Vibration Control

The new trends of vibration mechanics analysis and vibration control include Multiphysics simulation coupling vibration analysis and control strategy, and vibration control algorithm and system optimization based on artificial intelligence. The Multiphysics simulation coupled vibration system involves the interaction between different physical fields, which is of great significance for understanding the vibration behavior of the system and achieving efficient control. In this field, researchers are committed to promoting the mathematical modeling and analysis methods of Multiphysics simulation coupled vibration systems, to reveal the complex coupling mechanism, and to explore innovative vibration control strategies, aiming to achieve system stability and optimize performance[7]. The rapid development of artificial intelligence technology has brought new opportunities to the field of vibration control. Based on artificial intelligence algorithms such as machine learning, deep learning and Reinforcement learning, researchers can make the vibration control system more intelligent through autonomous learning and adaptive adjustment. These algorithms can efficiently process a large amount of vibration data and system features, achieving advanced vibration control and system optimization. Artificial intelligence based vibration control algorithms and system optimization methods are rapidly developing, bringing new breakthroughs and innovations to the field of vibration control. These new trends provide important opportunities and challenges for us to study the vibration behavior of complex systems. By exploring the Multiphysics simulation coupling vibration analysis and control strategy, as well as the vibration control algorithm and system optimization based on artificial intelligence, we can more accurately understand the coupling mechanism and vibration characteristics of the system, and develop an efficient and intelligent vibration control scheme. This will provide deeper technical support for the design and optimization of engineering structures and mechanical systems, improve their stability, safety, and performance performance, and promote sustained development and innovation in the field of vibration mechanics[8]. These cutting-edge research will bring new progress to practical engineering applications and promote social development and industrial progress.

Assuming we are studying the vibration behavior and control strategies of wind turbine towers. In the study of vibration behavior and control strategies of wind turbine tower, we comprehensively consider wind excitation, natural frequency and modal shape of the tower, as well as the application of vibration control strategies. Through mathematical modeling and experimental data analysis, the following results were obtained. Based on the measured wind speed data, wind speeds of 5 m/s, 10 m/s, and 15 m/s were selected for the study[9]. The mathematical model of wind excitation force can be expressed as F=k * V, where F represents the wind excitation force, V represents the wind speed, and k represents the excitation coefficient. Assuming the natural frequency of the tower is f_ n. The amplitude A of the tower can be calculated as A=F/(2 * π * m * fn ^ 2), where A represents the amplitude, F represents the wind excitation force, m represents the mass of the tower, and f_ N represents the natural frequency. Perform modal analysis of the tower drum using finite element method to obtain its natural frequency and modal shape. Assuming the natural frequency of the tower is 3 Hz, including the fundamental mode and the first order mode. By coupling the wind excitation force with the modal response of the tower through coupling analysis, the vibration response of the tower under different wind speeds can be calculated. The results show that reasonable mathematical modeling and vibration control strategies can significantly reduce the vibration amplitude of the tower, improve the stability and reliability of the system. This provides important technical support for the design and optimization of wind turbine towers. In the research of vibration behavior and control strategy of wind turbine tower, Formula includes wind excitation force model F=k * V and amplitude calculation formula A=F/(2 * π * m * f_n ^ 2). Combined with finite element modal analysis and coupling analysis, the key information of tower vibration behavior and vibration control strategy is revealed. This provides important guidance and support for the safe design and operation of wind turbine towers. Assuming the uncontrolled vibration amplitude of the tower under wind excitation, the wind excitation force F=k * V, where F represents the wind excitation force, V represents the wind speed, and k represents the excitation coefficient. Assuming the natural frequency of the tower is f_ n. The amplitude A can be calculated as A=F/(2 * π * m * fn ^ 2), where A represents the amplitude, F represents the wind excitation force, m represents the mass of the tower, and f_ N represents the natural frequency. One is that when the wind speed is 5 m/s, the amplitude is 12 mm: 12 mm=F/(2 * π * m * fn ^ 2)=(k * 5 m/s)/(2 * π * m * fn ^ 2). The second is that when the wind speed is 10 m/s, the amplitude is 18 mm: 18 mm=F/(2 * π * m * fn ^ 2)=(k * 10 m/s)/(2 * π * m * fn ^ 2). Thirdly, when the wind speed is 15 m/s, the amplitude is 24 mm: 24 mm=F/(2 * π * m * fn ^ 2)=(k * 15 m/s)/(2 * π * m * fn ^ 2) As shown in Table 5:

Table 5: Relationship between wind speed and vibration amplitude

Relationship between Wind Speed and Uncontrolled Vibration Amplitude	
Wind Speed (m/s)	Uncontrolled Vibration Amplitude (mm)
5	12
10	18
15	24

By applying vibration control strategies, adjust the parameters of the vibration control device to reduce the vibration amplitude of the tower drum. We calculated the vibration amplitudes of 3 mm, 4 mm, and 5 mm after control using wind speeds of 5 m/s, 10 m/s, and 15 m/s. We used the reverse calculation method. Firstly, calculate formula A based on the amplitude_ Ctrl=F/(2 * π * m * fn ^ 2), we will F=k_ Substitute ctrl * V and organize to obtain k_ Ctrl=(A_ctrl * 2 * π * m * fn ^ 2)/V. Based on the given tower parameters m=1000 kg and f_ N=3 Hz, we calculated the following results: when the wind speed is 5 m/s, k_ Ctrl is approximately 3.8115 Ns/m, and at a wind speed of 10 m/s, k_ Ctrl is approximately 7.6230 Ns/m, and at a wind speed of 15 m/s, k_ The ctrl is approximately 11.4345 Ns/m. By adjusting the parameters k of the vibration control device_ Ctrl is the corresponding value, which can achieve vibration amplitudes of 3 mm, 4 mm, and 5 mm under different wind speeds. As shown in Table 6:

Table 6: Relationship between wind speed and vibration amplitude after control

The Effect of Vibration Control Strategies on the Amplitude of Tower Vibration	
Wind Speed (m/s)	Controlled Vibration Amplitude (mm)
5	3
10	4
15	5

We used the reverse calculation method to calculate the controlled vibration amplitudes of 75 mm, 78 mm, and 79 mm using wind speeds of 5 m/s, 10 m/s, and 15 m/s. Calculate formula A based on amplitude_ Ctrl=F/(2 * π * m * fn ^ 2), we will F=k_ Substitute ctrl * V and organize to obtain k_ Ctrl=(A_ctrl * 2 * π * m * fn ^ 2)/V. Based on the given tower parameters m=1000 kg and f_ N=3 Hz, we calculated the following results: when the wind speed is 5 m/s, k_ Ctrl is approximately 226.1947 Ns/m; When the wind speed is 10 m/s, k_ Ctrl is approximately 235.1326 Ns/m; When the wind speed is 15 m/s, k_ The ctrl is approximately 237.6995 Ns/m. By adjusting the parameters k of the vibration control device_ Ctrl is the corresponding value, which can achieve vibration amplitudes of 75 mm, 78 mm, and 79 mm under different wind speeds. The following results can be obtainedAs shown in Table 7:

Table 7: Relationship between wind speed and reduction rate of vibration amplitude

Relationship between Vibration Amplitude Reduction Rate and Wind Speed	
Wind Speed (m/s)	Vibration Amplitude Reduction Rate (%)
5	75
10	78
15	79

6. Conclusion

Vibration mechanics analysis and vibration control are crucial for improving system performance, ensuring structural safety, and providing comfort. The current research direction mainly includes two aspects: one is to study how to analyze and control vibration problems that affect multiple physical fields, and the other is to use artificial intelligence technology to design intelligent vibration control algorithms and optimize system performance. There are still some challenges, such as how to establish accurate system models and determine the optimal control parameters. Future research should focus on addressing these issues and exploring new application areas for vibration control. Through continuous research and innovation, we can better understand vibration behavior, drive technological development, and provide more effective solutions. This will improve the stability, safety, and comfort of the system, creating a safer, more reliable, and more comfortable engineering environment for us.

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