Application of Intelligent Materials in Vibration Control of Marine Power and Transmission Equipment

Yang Qiao [1, *], Boqun Wang [1], Xinyue Fang [2], Xiaoxi Zheng [1]

[1] No.703 Research Institute, China State Shipbuilding Corporation Limited, Harbin Heilongjiang, 150078, China

[2] 63969 PLA. T roops, Nanjing Jiangsu, 230026, China

* Corresponding Author: Yang Qiao (Email: qiaoyang703@126.com)

Abstract. This paper discusses the application of intelligent materials in vibration control of Marine power and transmission equipment. Based on the detailed description of the classification and characteristics of smart materials, the principle and method of their application in vibration control of Marine power and transmission equipment are analyzed. Combined with practical cases, the remarkable effect of smart materials in this field is demonstrated. At the same time, the challenges in the application of smart materials are analyzed, and the future development trend is forecasted. The aim is to provide theoretical support and practical guidance for improving the stability, safety and comfort of ship operation.

Keywords: Smart Materials; Ship Power; Transmission Device; Vibration Control.

1. Introduction

With the continuous development of Marine technology, the performance requirements of Marine power and transmission equipment are increasing day by day. However, vibration has always been an important factor affecting the stability of ship operation, safety and crew comfort. Traditional vibration control methods can alleviate vibration to a certain extent, but there are limitations. The emergence of smart materials brings new opportunities for vibration control of Marine power and transmission devices. Smart materials have the characteristics of sensing environmental changes and responding accordingly, which can realize real-time monitoring and active control of vibration, providing a new idea and method for solving the problem of ship vibration[1].

2. Classification and Characteristics of Smart Materials

2.1 Characteristics and Applications of Piezoelectric Materials

Piezoelectric material is a kind of intelligent material which can convert mechanical energy and electrical energy into each other. It has piezoelectric effect and inverse piezoelectric effect and can realize the mutual conversion of electrical energy and mechanical energy. When subjected to external forces, it will produce a charge signal; Conversely, mechanical motion occurs when an electric field is applied. Piezoelectric materials have the advantages of high sensitivity, fast response, strong controllability and high stability[2].

In Marine power and transmission, piezoelectric materials can be used to create sensors that detect vibration signals and convert them into electrical signals, providing real-time data for vibration control. At the same time, the piezoelectric material can also be used as an actuator to generate mechanical force through the inverse piezoelectric effect and actively control the vibration. For example, the installation of piezoelectric actuators in the engine base, transmission shaft support and other parts of the ship can effectively inhibit the transmission of vibration.

2.2 Characteristics and Applications of Shape Memory Alloys

Shape memory alloy is a kind of intelligent material with shape memory effect and superelastic properties. Shape memory alloy has a "memory" effect, which can completely eliminate the

deformation at a lower temperature after heating up, and restore the original shape before deformation. There are three types of shape memory effect: one-way shape memory effect, two-way shape memory effect and full shape memory effect. This alloy is not only a single "memory" ability is excellent, can be restored to the same shape as the original, and can be used repeatedly for a long time[3].

Shape memory alloys can be used to create smart springs that automatically adjust their stiffness in response to temperature changes, thereby controlling vibration in the ship's power and transmission. In the structural components of ships, shape memory alloys can change shape under specific conditions to achieve adaptive vibration control. For example, when a ship is subjected to external impact, shape memory alloys can automatically adjust the stiffness of the structure and improve the impact resistance of the ship.

2.3 Characteristics and Applications of Magneto-Strictive Materials

Magnetostrictive material is a kind of smart material which can change size under the action of magnetic field and has magneto-strictive effect. When subjected to a magnetic field, the length changes. Magnetostrictive materials have the advantages of fast response speed, high precision and large output force, and also have certain applications in the field of vibration control.

The working principle of magneto-strictive materials in the vibration control of ship power and transmission equipment is to use the magneto-strictive effect to change the length of the material through the change of magnetic field, so as to generate reverse force to offset the vibration. Specifically, when a magneto-strictive material is subjected to vibration, it deforms. If a magneto-strictive material is placed in a magnetic field, it changes in length, creating a reverse force to counteract the vibration. In addition, the magnitude and direction of the reverse force can be adjusted by controlling the changing speed and amplitude of the magnetic field, so as to achieve effective control of the vibration.

2.4 Properties and Applications of Galvanic Materials

Electrorheological materials are a class of colloidal dispersion systems. When subjected to an external electric field, their rheological properties will undergo reversible changes, typically manifested by pseudo-phase transition from liquid to solid, or a substantial increase in fluid resistance. Its mechanical behavior depends on the mechanical properties of structural materials and electrorheological materials.

In the vibration control of ship, the electric field can control the state change of electrorheological material to realize real-time vibration adjustment. For example, the galvanic material is applied to the vibration isolation system of the ship, and the damping characteristics of the material are adjusted according to the vibration condition to improve the vibration isolation effect. At the same time, electrorheological materials can also be used to manufacture intelligent dampers, which can effectively inhibit vibration transmission by changing the electric field strength and adjusting the damping force of the dampers in real time.

2.5 Properties and Applications of Magnetorheological Materials

Magnetorheological materials are polymer composites whose rheological properties can be controlled by magnetic fields. Under the action of no magnetic field, the fluid state is displayed, but under the action of a strong magnetic field, it can be continuously and reversibly transformed into a Bingham body with high viscosity and low fluidity in milliseconds, reaching a solid-like state.

Magnetorheological materials can be used to design intelligent shock absorbers or dampers, which can effectively inhibit vibration transmission by changing the magnetic field strength and adjusting the damping force of the shock absorber or damper in real time. In the power and transmission equipment of ship, Mr. Damping device can be installed on the engine base, transmission shaft support and other parts, which can change the damping in real time according to the vibration condition and improve the vibration control effect. At the same time, Mr. Materials can also be used

to manufacture intelligent clutch, brake and other transmission components to achieve precise control of the transmission process.

3. Application Principle of Smart Materials in Vibration Control of Marine Power and Transmission Devices

3.1 Integration of Sensors and Actuators

Smart materials can be used as sensors and actuators at the same time to achieve real-time monitoring and control of vibration. For example, piezoelectric materials can both detect vibration signals and suppress vibrations by generating mechanical forces through the inverse piezoelectric effect. The integrated design of sensor and actuator can improve the precision and efficiency of vibration control [4].

3.2 Combine Active Control with Passive Control

The smart material can realize the vibration control mode which combines active control and passive control. Passive control is the absorption or dissipation of vibration energy through the inherent characteristics of the material, such as the use of damping materials to reduce vibration transmission. Active control is the real-time adjustment of vibration through external energy input, such as the use of piezoelectric actuators or magnetorheological dampers to actively control vibration. The combination of active control and passive control can give full play to the advantages of the two control methods and improve the effect of vibration control.

3.3 Adaptive Control

Smart materials can automatically adjust their performance in response to environmental changes, enabling adaptive control. For example, shape memory alloys can automatically adjust the stiffness of structures in response to temperature changes, and electrorheological and magnetorheological materials can automatically adjust damping characteristics in response to vibration. This adaptive control can improve the reliability and robustness of vibration control.

4. Application Method of Intelligent Materials in Vibration Control of Marine Power and Transmission Devices

4.1 Structural Design Optimization

Using the characteristics of intelligent materials, the structure of Marine power and transmission equipment is optimized. For example, embedding piezoelectric materials or shape memory alloys in a structure can control vibration by adjusting the properties of the material to change the stiffness and damping of the structure. At the same time, finite element analysis and other methods can be used to optimize the structure design to improve the effect of vibration control.

4.2 Design of Intelligent Vibration Isolation System

A vibration isolation system based on smart materials is designed to isolate and absorb vibration. For example, smart shock absorbers or dampers are designed using rheorheological materials or magnetorheological materials to improve vibration isolation by adjusting the damping characteristics of the materials. At the same time, active control technology can be combined to realize real-time adjustment of vibration isolation system and improve vibration isolation performance.

4.3 Intelligent Monitoring and Diagnosis

Smart materials are used as sensors to monitor and diagnose the vibration of Marine power and transmission devices in real time. By analyzing the vibration signal collected by the sensor, the

vibration problem can be found in time and the corresponding control measures can be taken. At the same time, the self-diagnosis function of smart materials can be used to monitor and evaluate their own performance, and improve the reliability and safety of the system.

5. Case Analysis

5.1 Application of Piezoelectric Materials in Vibration Control of Marine Power Plant

A ship's power plant produces a large vibration during operation, which affects the comfort and safety of the ship. In order to solve this problem, piezoelectric materials are used as actuators to control the active vibration of the power plant. By installing piezoelectric actuators in the key parts of the power plant and adopting appropriate control algorithm, the vibration is effectively suppressed. The experimental results show that the vibration amplitude of the power plant is significantly reduced and the comfort and safety of the ship are significantly improved after the piezoelectric material is used for active vibration control[5].

5.2 Application of Shape Memory Alloy in Vibration Control of Marine Transmission Gear

During the operation of a Marine transmission device, due to the unbalance of the transmission shaft and the meshing impact of the gear, a large vibration is generated. In order to control the vibration of the transmission device, the shape memory alloy spring is used as the intelligent damping element. By installing the shape memory alloy spring in the key part of the transmission device, and automatically adjusting the spring stiffness according to the temperature change, the adaptive control of vibration is realized. The experimental results show that the vibration amplitude of the transmission device is obviously reduced and the stability and reliability of the system are improved after the shape memory alloy spring is adopted.

5.3 Application of Magnetorheological Materials in Ship Vibration Isolation System

The traditional rubber vibration isolator is used in the vibration isolation system of a ship, and the vibration isolation effect is not ideal. In order to improve the performance of vibration isolation, the intelligent shock absorber is designed by using Mr Materials and applied to the vibration isolation system of ships. By changing the magnetic field intensity, the damping characteristics of the shock absorber can be adjusted in real time to improve the vibration isolation effect. The experimental results show that the vibration isolation performance of the ship and the comfort of the crew are significantly improved after using Mr Material intelligent shock absorber.

6. Challenges Faced by Smart Materials in Vibration Control of Marine Power and Transmission Devices

6.1 Cost Issue

The production cost of smart materials is relatively high, which limits their wide application in the Marine field. In order to reduce the cost, it is necessary to further study the preparation process and large-scale production technology of smart materials, and improve the performance-price ratio of materials.

6.2 Reliability Problems

Smart materials operate in the harsh environment of Marine power and transmission equipment, requiring high reliability and stability. However, at present, there are still some problems in the reliability of smart materials, and it is necessary to further strengthen the durability and anti-fatigue properties of materials.

6.3 Control Algorithm Problems

The vibration control of smart materials requires the support of complex control algorithms to achieve accurate control of material properties. However, the current control algorithms still have some limitations, and more advanced control algorithms need to be further researched and developed to improve the precision and efficiency of vibration control.

6.4 Integration Problems

The application of smart materials to vibration control of Marine power and transmission equipment requires the integrated design of materials and structures. However, at present, the integration technology of smart materials and structures is not mature enough, and further research needs to be strengthened to improve the level of integrated design.

7. Future Development Trends of Smart Materials in Vibration Control of Marine Power and Transmission Devices

7.1 Multi-Functional

The smart materials of the future will develop in the direction of multi-function, not only to achieve vibration control, but also to have other functions, such as self-healing, self-diagnosis, energy harvesting and so on. This will provide a broader space for the intelligent development of Marine power and transmission devices.

7.2 High Performance

With the continuous progress of materials science, the performance of smart materials will continue to improve. For example, the piezoelectric constant of piezoelectric materials will be further improved, the shape memory effect of shape memory alloys will be more stable, and the response speed of electrorheological materials and magnetorheological materials will be faster and the damping characteristics will be better. This will provide a more effective solution for vibration control of Marine power and transmission units.

7.3 Intelligent Control

The future of smart material vibration control will be more intelligent, able to achieve autonomous perception, autonomous decision-making and autonomous control. For example, the real-time monitoring and analysis of vibration is realized through sensor network, and the intelligent control of vibration is realized by artificial intelligence algorithm to improve the precision and efficiency of vibration control.

7.4 Integrated Design

Future smart materials will be more closely integrated with the structure of the Marine power and transmission, improving the overall performance and reliability of the system. For example, 3D printing technology is used to achieve the integrated manufacturing of smart materials and structures, improving the level of integrated design.

8. Conclusion

Intelligent materials have broad application prospects in vibration control of Marine power and transmission devices. By analyzing the classification and characteristics of smart materials, the application principle and method of smart materials in ship vibration control are discussed. However, the application of smart materials in this field also faces challenges in terms of cost, reliability, control algorithms and integration. In the future, with the continuous progress of material science and the continuous innovation of technology, smart materials will develop in the direction of multi-function,

high performance, intelligent control and integrated design, providing more effective solutions for the vibration control of ship power and transmission devices, and promoting the continuous progress of ship technology.

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