Active Vibration Control of Flexible Beam Based on Intelligent Materials

Hongbin Yang[1*], Huixia Ding[2]

[1]School of Energy Engineering, Yulin University, Yulin, Shaanxi, 719000, China

[2]Yulin Shenhua Energy Company Limited Information Centre, Yulin, Shaanxi, 719000, China

*Corresponding Author

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Abstract: Structural Vibration is a Common Problem in Many Engineering Fields Such as Aerospace, Machinery, Civil Engineering and Environment. Passive Vibration Reduction, Isolation and Elimination Have Been the Main Methods Used by Engineers and Technicians for Many Years. Larger Size, Lower Stiffness and Flexibility Are Important Development Trends of Spacecraft Structures. Flexible Members Also Have Shortcomings, That is, They Are Easy to Produce Elastic Vibration When Moving or Positioning, and Also Produce Residual Vibration At the End of the Movement. the Vibration Caused Has a Great Impact on the Stability of the Movement and Positioning Accuracy. the Proposal, Application and Development of the Concept of Intelligent Material Structure Have Brought New Ideas to the Active Vibration Control Technology and Opened Up New Directions. the Research on Vibration Control of Flexible Structures Has Important Theoretical Significance and Practical Value. in This Paper, the Flexible Beam is Selected as the Research Object, and the Theoretical and Experimental Research on the Active Vibration Control of Piezoelectric Flexible Beam Based on Smart Material is Analyzed.

1. Introduction

Structural Vibration is a Common Problem in Many Engineering Fields Such as Aerospace, Machinery, Civil Engineering and Environment. Passive Vibration Reduction, Isolation and Elimination Have Been the Main Methods Used by Engineers and Technicians for Many Years [1]. with the Rapid Development of Science and Technology, the Rapid Development of Aerospace Technology and the Increasing Scale of Space Activities, the Requirements for Aerospace Technology and Space Structure Are Becoming More and More Strict [2]. Larger Size, Lower Stiffness and Flexibility Are Important Development Trends of Spacecraft Structures. Large Structure Can Increase the Function of Space Structure, for Example, Large Solar Cell Array Can Provide More Sufficient Energy for Space Structure [3]. However, It Also Brings a Series of New Problems to the Design, Manufacture and Use of the Structure. Flexible Members Also Have Shortcomings, That is, They Are Easy to Produce Elastic Vibration When Moving or Positioning, and Also Produce Residual Vibration At the End of the Movement. the Vibration Caused Has a Great Impact on the Stability of the Movement and Positioning Accuracy [4]. Compared with Passive Control of Vibration, Active Control Takes Modern Control Theory as the Main Tool, Which Has Greater Flexibility and Good Suppression Effect of Low Frequency Vibration. the Use of Flexible Members Not Only Increases the Flexibility of Spacecraft Design and Manufacturing, But Also Reduces the Cost of Launching. Therefore, the Widespread Adoption of Flexible Components is an Inevitable Trend [5].

The Proposal, Application and Development of the Concept of Intelligent Material Structure Have Brought New Ideas to the Active Vibration Control Technology and Opened Up New Directions [6]. Large Structures Can Add Space Structure Functions. for Example, a Large Solar Array Can Provide More Energy for the Space Structure, and a Lightweight Structure Can Increase the Weight of the Payload and Improve the Efficiency of the Vehicle. the Development of Modern Industry and the Advancement of Engineering Application Technology Have Led to the Expansion of Vibration Control Research from the Aerospace Field to Other Engineering Fields [7]. in the

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Field of Mechanical Engineering, the Active Control of the Flexible Arm of the Robot Effectively Solves the Vibration Problem Brought about by the Development of Rigidity to Flexibility. the Intelligent Material Structure Not Only Can Bear the Load Like the General Material, But Also Has Many Functions Such as Self-Identification, Analysis, Processing and Control [8]. Flexible Beams Will Be Used More and More in Aerospace, Modern Engineering and Other Fields, But Its Shortcomings Are Also Very Obvious. the Flexible Beam is Easy to Produce Elastic Vibration, and the Residual Vibration is Difficult to Eliminate At the End of the Motion, and the Elastic Vibration Has a Great Influence on Its Precise Positioning [9]. the Research on Vibration Control of Flexible Structures Has Important Theoretical Significance and Practical Value. in View of the Important Research Significance of the Vibration Control of Flexible Members, This Paper Selects Flexible Beams as the Research Object, and Analyzes the Theoretical and Experimental Research on the Active Vibration Control of Piezoelectric Flexible Beams Based on Smart Materials.

2. Smart Structures and Smart Material Components

The General Definition of Intelligent Material Structure: the Material with Life-Like Function is Integrated into the Matrix Material to Make the Components Have the Expected Intelligent Function. This Structure is Called Intelligent Material Structure. Flexible Rods in Practical Applications Are Elastic Systems with Continuous Distribution of Mass, Stiffness and Damping, and Have Infinite Degrees of Freedom. the Flexible Beam is Slender in Shape and Has the Advantages of Light Weight, Small Inertia, Low Energy Consumption and the Like. Since the Multi-Degree-of-Freedom System is a Lumped Parameter Model Composed of Lumped Mass and Elastic Elements without Mass, Its Motion Equation is Mathematically Expressed as a Set of Second-Order Ordinary Differential Equations with Equal Number of Equations and Degrees of Freedom [10]. Continuous System is a Distributed Parameter Model Composed of Distributed Mass and Distributed Elasticity, So Its Motion Equation is Mathematically Expressed as a Partial Differential Equation of Multivariate Function Depending on Coordinates and Time. Since the Length of the Axially Moving Beam Changes with Time, the Frequency and Mode Shape of Its Vibration Change with Time, So the Transverse Vibration of the Axially Moving Beam is a Nonlinear Vibration Problem of Variable Structure. Highly Integrated Control Logic, Signal Conditioning and Power Amplification Electronic Device Components Can Sense Changes in External or Internal States and Characteristics, and Can Identify Causes of Changes According to Specific Characteristics of Changes, Thus Adopting Corresponding Optimal or Near-Optimal Control Strategies to Make Reasonable Responses.

For Most Engineering and Technical Problems, There Are Few Analytical Solutions Because the Geometry of the Object is Complex or Some Characteristics of the Problem Are Nonlinear. Project Quality Control Refers to the Control over the Progress of Each Stage and the Deadline for the Final Completion of the Project during the Implementation of the Project. Figure 1 Shows the Planning Results of Critical Chain Method.

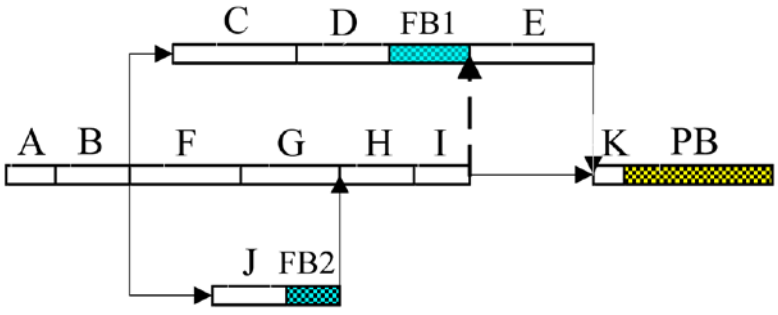

Fig.1 Key Chain Method Planning Results

The finite element model provides accurate data for the calculations. The error of these input data will directly determine the accuracy of the calculation results. Filling various fillers in smart materials has gradually become a modified product performance, as shown in Figure 2 is a viscous

model of smart materials.

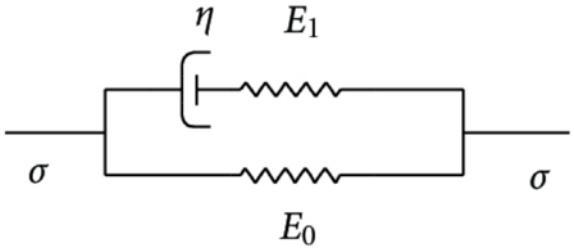

Fig.2 Viscous Model of Smart Materials

The smart material structure integrates the driving element and sensing element closely into the structure, and also integrates the control circuit, logic circuit, signal processor, power amplifier, etc. into the structure. The research on active vibration control technology of flexible composite barrel involves the cross-disciplinary and coordinated development of weapon science, intelligent structure and active vibration control technology. Piezoelectric effect refers to the effect that materials generate electrical signals under the action of pressure or mechanical deformation of materials under the action of electric field [11]. When a piezoelectric crystal is deformed by an external force, charge accumulation linearly proportional to the external force will occur on some of its surfaces. Piezoelectric materials have reversible characteristics. Under the action of electric field, strain-type deformation will occur, which is proportional to the strength of electric field. With the lightweight of mechanical structures and aerospace systems and the continuous improvement of requirements for dynamic characteristics, the traditional passive control technology is difficult to meet the requirements, forcing people to further seek new ways of vibration control [12]. Like ordinary elastic materials, piezoelectric materials will deform when subjected to external force, and the stress and strain are proportional to each other under the premise of small deformation, which is the mechanical behavior of piezoelectric materials. Active vibration control is a new and high technology in the field of vibration engineering. It is a synthesis of dynamics, control, computer, testing technology and material science.

3. Modeling of Flexible Component System

Flexible member is a complex dynamic system, and its dynamic characteristics are quite different from those of ordinary rigid bodies. The difference lies in the strong coupling of dynamic equations and the complexity of models. Active vibration control technology for intelligent structures integrates sensors, actuators, controllers and structures into a whole to reflect external vibration, change mechanical and physical characteristics such as stiffness and damping of structures, suppress structural vibration and make structures in the best working state. The sensing element is a kind of measuring device, and the ideal sensing element should be able to directly output the state changes inside the structure in the form of electrical signals. In addition to having the same mechanical properties as common materials, piezoelectric materials have their unique electrical behaviors. Without external force, the electrical behavior of piezoelectric materials can be described by electric field strength and electric displacement under the action of external electric field. For example, the physical parameters of some actual systems in the project are unevenly distributed. Components with large inertia and rigidity can be regarded as particles and rigid bodies with concentrated mass. Components with small inertia and strong elasticity are abstracted as massless springs [13]. Unlike lumped mass method, which transforms the distributed mass of continuous system into a finite lumped mass, the assumed modal method uses a finite number of known modal functions to determine the motion law of the system.

In order to effectively suppress the vibration of the barrel under external load, the traditional passive vibration control method can no longer meet the requirements. Active vibration control technology is introduced into the vibration control of flexible composite barrel. With the rapid development of machining enterprises and the characteristics of machining workshops themselves. To make the work of product quality management in machine processing workshop backward and the

development of enterprise scale and society. The company's cost in the market will increase and its core competitiveness will decline. Processing control personnel must strengthen the control and strict control of materials and their use on the processing site. Using the existing technology to establish a multi-mode collaborative work environment. Collaborative work support platform with integrated multimedia mode. The cooperative design and operation process is shown in Figure 3.

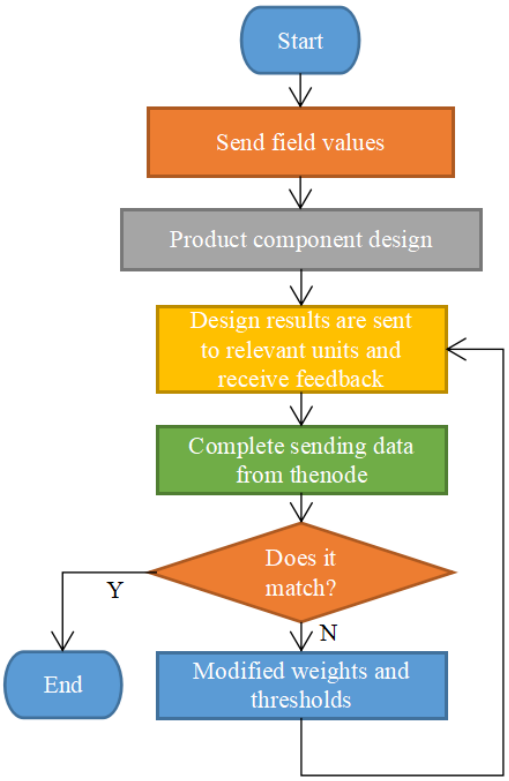

Fig.3 Mechanical Processing Cooperation Design Operation Process

Machining quality control system is a part of alliance management in networked manufacturing environment. This prototype system can be used as a platform to complete the task planning, member evaluation and selection, and member processing quality control. Aiming at the medium access constraints of wireless communication networks, an agent node scheduling protocol is designed using binary sequences. The scheduling protocol is used to schedule the agent nodes that meet the conditions to access the network at the sampling time. Figure 4 shows the structure of an agent node.

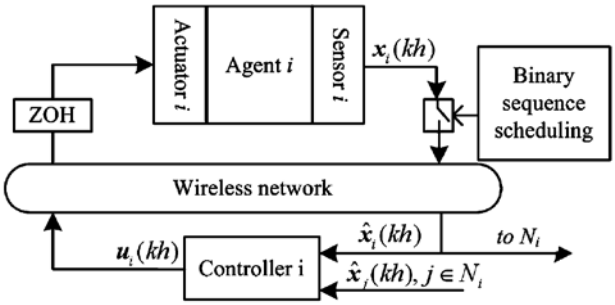

Fig.4 Structure of the Agent Node

As one of the important components in the active vibration control system, the role of the actuator is to apply a control signal to the system to change the response of the system to meet the needs of the actual application. Considering the particularity of space applications, the control input energy is limited by the energy supply. Therefore, the limited energy should be transmitted to the controlled object, that is, the flexible rod. According to different control adjustment methods, structural vibration control can also be divided into open loop control, closed loop control, open and

closed loop control. Although the piezoelectric strain relationship of piezoelectric materials is three-dimensional, there are many piezoelectric constants corresponding thereto, but usually only the piezoelectric strain relationship in one direction is used. One way to realize the hybrid control of piezoelectric intelligent structure is to replace the traditional uncontrollable constrained layer with a controllable piezoelectric material, and actively adjust the axial deformation of the piezoelectric constraining layer through feedback control. In addition, the active and passive hybrid control of the piezoelectric intelligent structure can be realized by adjusting the parameters of the resistance and inductance in the passive control network in real time, that is, the structural vibration control is realized by the branch piezoelectric damping method. Relatively speaking, the active control has greater flexibility, the active control has strong adaptability to the environment, the correction design is convenient, the low frequency effect is good, and the uncertainty of the unknown disturbance and the system parameters can be adapted.

4. Conclusion

Flexible components are the hotspots in the fields of aerospace, robotics, etc., and vibration control is one of the key technologies of flexible components. With the wide application of flexible components in industrial, medical, aerospace and other fields, the vibration control of flexible components The research is bound to deepen. Applying intelligent structural vibration active control technology to weapon system design and performance improvement is a new topic, involving many problems. The state space model can well realize the feedback control of the system, and it is convenient to compare the control or not and the influence of different control parameters on the final state response of the system. Because the optimal control requires all the state information of the system, and it is difficult to measure all the state variables of the axially moving beam in the actual measurement process, the suboptimal control scheme of the system is given in this paper. The vibration control strategy can be improved, for example, more actuators and sensors are used to control higher-order models, so that the vibration control is more effective and faster. The vibration of flexible structure of spacecraft is actively controlled by intelligent structure. The system composition of intelligent structure should be analyzed, and sensors and controllers made of intelligent materials suitable for space control environment should be selected and studied, their electromechanical characteristics should be studied, and their function or operation scope should be determined.

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