RESEARCH ON INTEGRATED DESIGN TECHNIQUE OF ACTIVE VIBRATION ISOLATING PLANT OF MARINE HIGH-SPEED DIESEL FOR APPLYING ABOARD

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Marine diesel engine is one of main mechanical noise sources of modern ship. It is an important approach to improve the acoustic concealment of ship to control the vibration transmission of marine diesel. Active vibration isolating plant can effectively reduce the low-frequency noise transmission of the diesel engine as one advanced technology of vibration isolation. The technical problems are discussed to meet the engineering application requirements when the active vibration plant is used for ship, such as the realization of three directions active vibration isolation effect, the control of installation size and weight, engineering reliability, the configuration of active and passive vibration isolation components, anti-shock measures, electromagnetic shielding measures, external interfaces, and so on. Finally, the shipment measures of active vibration plant are advised in this paper. The results of the study in this paper can be applied to marine active vibration plant design.

1. Introduction

Active vibration isolation is one advanced technology to reduce the transmission of marine diesel vibration. In recent years, the theoretical and experimental research on active vibration isolation of marine diesel is carried out mainly in laboratory, and the active vibration product meeting the requirements of engineering application does not occur. Aiming at marine high-speed diesel, the technical problems are discussed to meet the engineering application requirements when the active vibration plant is used for ship, such as the realization of three directions active vibration isolation effect, the control of installation size and weight, engineering reliability, the configuration of active and passive vibration isolation components, anti-shock measures, electromagnetic shielding measures, external interfaces, and so on. The results of the study in this paper can be applied to marine active vibration plant design.

2. Background of active vibration isolation for marine diesel

The passive isolation vibration plants such as single-stage, double-stages, floating raft vibration isolation device are usually used for marine high-speed diesel engine currently, and the elastic components of which are adopted including rubber isolators, air springs. The vibration isolating effect of 10~40 dB can be acquired by applying the passive vibration isolating device in the frequency range of 300Hz~10KHz, However it has not enough vibration isolating effect on the
order frequencies below 300Hz. For example, the passive vibration isolating device almost have no effect on the low order frequencies of 30Hz, 60Hz, 90 Hz and 120Hz for the high-speed marine diesel of 1800 r/min. [1-3]

High-speed marine diesels are usually used for main propelling power or generators of warships. The order frequencies below 300Hz are the main frequencies concentrating the vibration energy of marine diesel. On the particular low order frequencies, the active vibration isolating plants have good effect on high-speed marine diesel, and can effectively compensate for the shortcomings of passive vibration device.

3. The design requirements of active actuator for diesel

Active actuators are the most important components of active plants which make controlling counterforce, and should have the characteristics of wide frequency range, fast response, large output force, simple structure, good linearity, little size, light weight and high control precision. [4-5]

3.1 Category of active actuators for diesel

Active actuators mainly include pneumatic type, hydraulic type, giant magnetostrictive type, electromagnetic type and other types. Electromagnetic and giant magnetostrictive actuators are usually used for active vibration isolation according to the characteristic of marine diesel. [7]

Electromagnetic active actuators have the strongpoints of fast response, easy installation, good linearity, compact structure, and have the shortcomings of moderate output force (less than 300N), moderate size and weight. Those actuators are usually used for the little and medium marine diesel of the weight less than 5t.

Giant magnetostrictive actuators (GMA) are made of rare earth alloys, and have the strongpoints of little size, light weight, fast response, easy installation, compact structure and large output force (more than 500N). However GMA have the shortcomings of poor tensile and shear resistance, strong nonlinearity and expensive cost. Those actuators are usually used for the large marine diesel of the weight more than 5t, which are showed in figure 1. [8]

![Electromagnetic Active Actuator](image1)

![Giant magnetostrictive actuator (GMA)](image2)

3.2 Rated load of active actuators for diesel

Marine high-speed diesels weigh 1.5~8t according to the power. For at least four actuators should be mounted on the feet of diesel, the rated load of actuator should be controlled between 0.3 t and 0.8 t considering the limited installation space and the size of active actuators.

3.3 Output force of active actuators for diesel

The output force of active actuators is prescribed according to the actual force tested with force sensors on the mounting feet of diesel. For little and medium power diesel, the output force of active actuators is 100N~500N, as shown in figure 3. For large power diesel, the output force of
active actuators is 500N~1000N. The active actuators meeting engineering application should have three-direction output force capacity including vertical, horizontal, longitudinal directions.

**Figure 3.** Required counterforce of one diesel

**Figure 4.** Linearity curve of active actuator

### 3.4 Amplitude-frequency characteristic and integrated design of active actuator

The active actuators should have good amplitude-frequency characteristic and linearity in the frequency range of 20~350 Hz in the main loading direction, as shown in figure 4.

The integrated design of active actuators and passive isolators should be adopted for enhancing the reliability of diesel active plant. When the active actuators are destroyed temporarily, the passive isolators also act normally. The active actuators have good vibration isolating effect in the low frequency range, and the passive isolators have good vibration isolating effect in medium and high frequency range. The active actuators and passive isolators are usually integrated in series for engineering application. [6]

### 4. The design requirements of active diesel plant

#### 4.1 Vibration isolating effect requirement of active plant

The vibration isolating effect target of active diesel plant meet engineering application is to realize at least 10 dB on single prescribed frequency and more than 5 orders frequencies control below the frequency of 300 Hz in three loading directions.

#### 4.2 Size and weight requirement of active plant

The diesel active plant should be designed as single-stage vibration isolating device for lower mounting height to meet the space requirement of warship cabins. The total height of diesel active plant should not exceed 80% of the original passive two-stage vibration isolation device.

The metal material of low-density and high-intensity should be applied to reduce the weight of diesel active plant. The total weight of diesel active plant should not exceed 70% of the original passive two-stage vibration isolation device.

#### 4.3 Reliability and durability requirement of active plant

Diesel plant durability test of more than 900 hours in different loading conditions including 10%, 25%, 50%, 75% and 100% loading should be carried out, before the active plant design is finalized on diesel test-bed. The vibration isolation effect test should also be made to determine the vibration and noise indicators of diesel plant. The passive rubber isolators should be applied to the active plant for ensuring vibration isolation and anti-shock protection when the active actuators are damaged.
4.4 Anti-shock capacity requirement of active plant

The active diesel plant should have sufficient anti-shock resistance, and the rubber isolators, elastic limits, damping buffer should be installed in the active plant for the shock safety of the power system of warship.

The anti-shock design and test of diesel active plant should meet the requirements of military standards such as “the shock test requirements of marine machinery, plant and systems” (MIL series standards) and “shock safety design of marine equipment” (BV series standards).

For the small marine diesel active plant weighing less than 2.7 tons, shock testing machines onshore are adopted to assess the anti-shock threshold and weakness of marine diesel plant, which include drop shock test machine and charpy shock test machine. For the large marine active plant weighing more than 2.7 tons, shock test should be carried out using ship shock trial according to military standards or the anti-shock indicators prescribed by ship overall design department.

4.5 Electromagnetic compatibility and installation process requirement of active plant

For the electromagnetic and magnetostrictive actuators are used for diesel plant, the electromagnetic leakage should be prevented during the design of plant. The electromagnetic compatibility should be guaranteed. The low-magnetic metal material should be applied to the diesel plant, and the degaussing should be carried out especially for special warships such as minesweeper, submarine, and so on. External interface and installation process of active diesel plant should meet the requirements of military and marine standards.

5. Engineering prototype of marine diesel active plant

One engineering prototype of little marine diesel active plant was built in Shanghai Marine Diesel Engine Research Institute, and active vibration isolation of marine diesel was fulfilled. The active vibration isolating effect came to 10 dB on single prescribed frequency, and more than 5 orders frequencies control below the frequency of 200 Hz in only vertical loading direction, as shown in figure 5.

Another engineering prototype of medium marine diesel active plant was also built in Shanghai Marine Diesel Engine Research Institute, and active vibration isolation of marine diesel was fulfilled. The active vibration isolating effect came to 12 dB on single prescribed frequency, and more than 8 orders frequencies control below the frequency of 350 Hz in the vertical, horizontal, longitudinal loading directions, as shown in figure 6.

![Figure 5](image5.png) Diesel active plant (150KW)  
![Figure 6](image6.png) Diesel active plant (300KW)

6. Conclusions

In this paper, several key technical problems are discussed to meet the engineering application requirements when the active vibration plant is used for ship, such as the realization of
three directions active vibration isolation effect, the control of installation size and weight, engineering reliability, the configuration of active and passive vibration isolation components, anti-shock measures, electromagnetic shielding measures, external interfaces, and so on. Finally, the shipment measures of active vibration plant are advised in this paper. The results of the study in this paper can be applied to marine active vibration plant design.

REFERENCES