Experimental Study on the Mn-Based Damping Alloys

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Abstract. More and more attention has been paid to Mn-based damping alloy because of its excellent cold and hot processing properties, high damping performance, and good tensile strength. In this paper, the influence of temperature, frequency and stress on the damping capacity of the damping alloy is analyzed by using DMA method, and the relations between damping parameters and temperature and frequency are obtained. Taking a Marine centrifugal fan as the parent type, the Mn-based damping alloy volute is designed, the dynamic characteristics of Mn-based damping alloy volute are analyzed, and the influence of the damping structure on the vibration of the whole structure is studied. The results show that the mechanical properties of the Mn-based damping alloy are excellent, the damping loss factor is 10 times higher than the Q235 material, and the vibration acceleration of the volute and the machine feet can be reduced more than 5dB by using the Mn-based damping alloy. Therefore the vibration reduce can be realized by using Mn-based damping alloy.

1. Introduction
Since Mn-based damping alloy has good cold and hot processing performance, high damping performance and good tensile performance, more and more attention has been paid to it \(^1\). Using Mn-based damping alloy to manufacture related components can effectively solve the vibration and noise problems in the field of mechanical manufacturing. The vibration and noise produced by the fan during operation is always a difficult problem in industrial production. Existing studies have shown that\(^2,3\), because of the strong unsteady interference between the wake air flow at the outlet of the impeller and the volute, the centrifugal fan and the volute tongue become the main noise source of the fan. Changing the structure of the volute is a targeted method to reduce vibration and noise.

In this paper, a Marine centrifugal fan volute is taken as the parent type to design the Mn-based damping alloy volute, the damping performance of Mn-based damping alloy is studied, and the influence of the damping structure on the vibration of the whole structure of the volute and the fan is analyzed.

2. Properties of Mn-Based Damping Alloys

2.1. Mechanical Properties of Mn-Based Damping Alloys
The main mechanical properties of Mn base damping alloy are shown in the following table.

| Material | Mn-Based | Q235 |
|----------|----------|------|
| Mechanical Properties of Mn-Based Damping Alloys and Q235 | | |
| Damping Alloy | Density / (kg/m³) | 7330 | 7800 |
|--------------|------------------|------|------|
|              | Rockwell Hardness / HRC | 77~82 | —    |
|              | Elastic Modulus / GPa | 84.6~98.5 | 200~210 |
|              | Tensile Strength / MPa | 500~510 | 375~460 |
|              | Yield Strength / MPa | 205~215 | 235 |
|              | Elongation/ % | 31.5~33.0 | 26 |

It can be seen from table 1 that the yield strength of Mn-base damping alloy is equal to Q235, and the tensile strength is better than that of Q235. Mn-base damping alloy will not be damaged in assembly, lifting and other environments, which can meet the use demand and can be used as engineering materials. However, due to the large linear expansion coefficient, it should be avoided to apply to the positioning parts.

2.2. Damping Properties of Mn-Based Damping Alloys

Mn-based damping alloy is one of the typical twin-type damping alloys [4]. Mn-based damping alloys can form lean and rich Mn phases after proper heat treatment. Due to the formation of the rich Mn area, the microscopic inhomogeneity is produced, and the rich Mn area has anti-ferromagnetic transformation and martensite transformation at room temperature. When the lattice distortion caused by anti-ferromagnetic transition and martensite phase transition is more than 5‰, a large number of twin crystal structures will be formed. The formation of twin leads to the release of the internal stress caused by antiferromagnetic transition and martensite transformation. Under the action of cyclic stress, a large number of twin boundary planes will rearrange and produce inelastic strain, thus the external vibration energy is dissipated [5-8].

In order to compare the damping properties of Mn-based damping alloy and Q235, the damping loss factors of Mn-based damping alloy and Q235 are measured in this paper, and the damping properties of the two materials are compared under the same test conditions. Firstly, the sample is installed vertically, the upper end is clamped rigidly, and the lower end is free, forming the cantilever beam to measure the loss factor. The loss factor test adopts the half-power point method, first finding the resonant frequency of the strip beam sample in the range of measured frequency, then finding the half-power point of each resonance curve, calculating the half-power bandwidth, and finally calculating the loss factor of each resonant frequency of the sample. The test frequency range is 10Hz-2000Hz, test materials are Mn-based damping alloy and Q235, test environment temperature is 25±1℃, the humidity is 54%, the test result is shown as below.

![Figure 1. The Damping Loss Factor of Slab Beam](image_url)

It can be seen the frequency of each order of Mn-based damping alloy is lower than Q235. The loss factor of Mn-based damping alloy slab-beam is higher than Q235. On this base, the modal damping loss factor of structure can be effectively increased by using Mn-based damping alloy.

The damping capacity of Mn-based damping alloy is greatly affected by the test conditions. In this paper, DMA method is used to analyze the influence of the damping capacity at different temperatures,
frequencies and stresses. The relation between damping parameters and temperature, frequency, stress are obtained, and the dynamic viscoelasticity of the material is studied in a wide range.

![Figure 2. Damping Loss Factor dependencies of Temperature](image2)

![Figure 3. Damping Loss Factor dependencies of Strain Amplitude](image3)

![Figure 4. Damping Loss Factor dependencies of Frequencies](image4)

It can be seen from figure 1, the damping loss reduces with temperature rise gradually, then the damping loss drops rapidly after 50 °C. When the temperature is above 80°C, the damping loss of Mn-based damping alloy is on the same order of magnitude as Q235, Mn-based damping alloy no longer has advantage in terms of damping. It can be seen from figure 2 that the damping loss of the alloy increases significantly with the increase of strain amplitude, indicating that the damping capacity of the alloy increases significantly. It can be seen from figure 3 that within the vibration frequency of 0.1~10Hz, the damping capacity of the alloy decreases gradually with the increase of frequency, while the damping capacity hardly changes with frequency when the vibration frequency is above 10Hz. Based on the above results, Mn-based damping alloy should be used in the case of small temperature range to achieve optimal performance.

3. Design and Experiment of Alloy Volute
The studies have showed that wall surface of centrifugal fan is main source area of aerodynamic vibration noise. Damping is very important to the radiation of vibration and acoustic. Increasing the damping of solid structure can obviously restrain the bending vibration of thin plate structure and reduce the radiative noise. In this paper a certain type of fan is taken as the research object, the damping alloy volute is processed refereeing to the existing spiral case, and the dynamic characteristic and vibration characteristic are compared with the ordinary material, the vibration reduction effect of the damping alloy is studied.
3.1. Modal Test of the Volute

In this paper, LMS test.lab is used to test the volute mode of the two materials, and the dynamic characteristics of the two materials are compared. In this test, the free boundary condition is adopted, and the excitation method is hammer. The test results are shown as follows. Among them, the material of volute I is Mn-based damping alloy, and material of volute II is Q235.

![Frequency Response Function of Volute](image)

### Figure 5. Frequency Response Function of Volute

| Order | Modal Frequency /Hz | Modal Damping /% |
|-------|---------------------|------------------|
|       | Damping Alloy       | Q235             |
|       |                     | Damping Alloy    | Q235             |
| 1     | 55.04               | 75.52            | 1.06             | 0.93             |
| 2     | 71.72               | 87.37            | 0.54             | 0.37             |
| 3     | 84.4                | 107.77           | 0.33             | 0.48             |

It can be seen from results that the frequency of each mode of the Mn-based damping alloy volute is lower than Q235, and the damping of each mode is higher than that of Q235. The modal frequency of both materials can avoid the main excitation frequency of the fan.

3.2. Vibration Absorption Experiment on Mn-based Damping Alloy Volute

In order to verify the Vibration Absorption effect of Mn-based damping alloy volute, LMS test lab is used in this paper to measure the vibration velocity and acceleration response of fan volute, volute tongue and machine feet. At the time of measurement, the fan speed is 1500r/min, the test results are as follows.
It can be seen that, although the vibration velocity of the Mn-based damping alloy volute is amplified at 25 Hz, the vibration velocity responses at other excitation frequencies are much smaller than Q235. The RMS (10~1000Hz) of Mn-based damping alloy is only 80% of Q235 volute. Using Mn-based damping alloy can reduce the vibration speed of the volute surface and reduce the external radiation of energy, thus the air noise of centrifugal fan is reduced.

The results of acceleration response are similar to velocity effect. The Mn-based damping alloy has 5dB amplification at 25 Hz, but it has absorption effect of more than 6dB at other excitation frequencies, so that the Mn-based alloy volute has more than 10dB absorption effect at all frequency bands.

4. Conclusion
In this paper, the performance of Mn-based damping alloy is studied by experiment, the following conclusions can be drawn:

(1) Mn-based damping alloy has excellent mechanical performance and processing performance, which can be used as engineering materials.

(2) The damping loss factor of Mn-based damping alloy is 10 times higher than Q235. The use of this material can effectively increase the modal loss factor of the structure.

(3) The damping loss reduces with temperature rise gradually. When the temperature is above 80°C, the damping loss of Mn-based damping alloy is on the same order of magnitude as Q235, the alloy is suitable for the occasion of small temperature change.

(4) The Mn-based damping alloy can reduce the vibration acceleration of the volute and the mounting feet more than 5dB. Using the Mn-based damping alloy, the vibration and noise reduction of the centrifugal fan volute can be effectively achieved.

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