ASSESSMENT METHOD OF VIBRATION REDUCTION OF DAMPING MATERIAL BASED ON MODE ANALYSIS

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Assessment method of vibration reduction of damping material based on mode analysis has been discussed in this article. The method given in the article takes rectangular flat plates covered with different damping materials as research object, excite the flat plates with force hammer, get the frequency response function between excitation points and response points, analyze the mode parameters of all rectangular flat plates, compare the amplitudes of frequency response function in which frequencies the rectangular flat plates are in the same mode. The result shows that the method based on mode could not only provide advice for damping material selection in design phase, it could also assess the vibration reduction of natural frequency. For that reason, the method could evaluate the property of damping material scientifically

Keywords: mode analysis; vibration reduction; frequency response; damping material

1. Introduction

In order to decrease the vibration and sound radiation of the ship, two methods, eliminating excitation source and increasing the damping rate of vibration transmission, are usually used. To lay damping material on the base of machine could increase the energy loss during the vibration transmission. In China, damping material to decrease vibration had been studied in 1960s, and it becomes a useful way in submarine's invisibility design nowadays[1].

In order to evaluate the capability of damping material, many research have been done, Wang Guoqing[2] lay different damping materials on plates, measured vibrations and frequency response of the plates, took damping ratio to evaluate the capability of damping material. However, the designers concern more on the vibration reduction after using damping materials, but the relationship between damping materials and vibration reduction is not clear[3], so it's hard to predict the vibration reduction precisely based only by damping ratio. To reach that purpose, many tests on product must be done, which usually have a lot cost both in money and time [4]. The tests on Geiger plate to evaluate the capability of damping materials have been widely used in American car industry [5], by that way, damping materials are lay on a rectangle plate which is hanged through four angle suspension, the decay rate of vibration, taken as a key factor of damping materials, could be obtained by measuring the vibration after exciting the plate, but it's very hard to obtain the vibration reduction in frequency domain in this way.

Wen Huabing [6] who took ship models as the research object analyzed variation of damping ratio of different models in the same mode, and compared the vibration level difference of different damping models when the machine operating, through that, he evaluated the damping performance of damping with great cost. Xiao Shaoyu[7] introduce the amplitude frequency response function average attenuation parameters into damping evaluation, he compared the damping effect of different damping materials in a specific frequency band without considering the interference of anti resonance peaks, which also cannot directly reflect the damping effect of damping component natural frequencies. The vibration reduction of natural frequency can evaluate the damping materials more effectively since the damping effect of damping is mainly to reduce the vibration near to inherent vibration frequency. Wang Hao[8] fastened the edge of damped composite plate structure, excited plate structure with hammer, evaluated the damping material with the transfer function between the access point and vibration response points to evaluate the damping material, this method avoids the evaluation deviation due to different excitation force, but the method of plate structure installation requirements more stringent, it is difficult to ensure the installation conditions of each test plate structure in the process of the same.

In this paper, taking flat structure of different types of constrained damping material as the research model, getting transfer function by the hammer test and getting mode of different damping materials by modal analysis, comparing the vibration of the same modes under different damping materials, the method can avoid the anti resonance peak interference effectively, and describe the damping effect of damping material directly.

2. Basic theory

2.1 Evaluation method

In this paper, the parameters of damping material properties are as follows: damping ratio and vibration decrement at natural frequency.

The damping ratio is dimensionless, which indicates the attenuation of the vibration of the structure after excitation, the value is the ratio of damping coefficient to critical damping coefficient:

$$\xi = \frac{\Delta f_i}{2 f_i} \qquad (1)$$

Δf_i indicate natural frequency half power width of order i, f_i indicate the natural frequency of order i.

The force signal F and the vibration signal X could be measured by the force driven rectangular plate test, and the transfer function between the excitation force and the vibration response could be obtained according to the formula (2).

$$H = \frac{X}{F} \qquad (2)$$

The vibration reduction at the natural frequency is shown in the formula (3)

$$\Delta_i = H_1(f_i) - H_2(f_i) \qquad (3)$$

$H_1(f_i)$ indicate frequency response function of undamped plate at the natural frequency of order i, $H_2(f_i)$ indicate frequency response function of damped plate at the natural frequency of order i.

1.2 Test process

The rectangular plate is suspended in the air through an elastic rope, and the natural frequency of the rope-plate system is less than 1/5 of the first natural frequency of the rectangular plate. 16 vibration sensors are uniformly placed on the rectangular plate to obtain the vibration which could be used to analyze the mode of the rectangular plate, the test point of number 4 and number 7 is the excitation point. When tested, there is no abnormal vibration interference, the ambient temperature fluctuation is not more than 5℃. Figure 1 shows the transducer placement of rectangular plate.

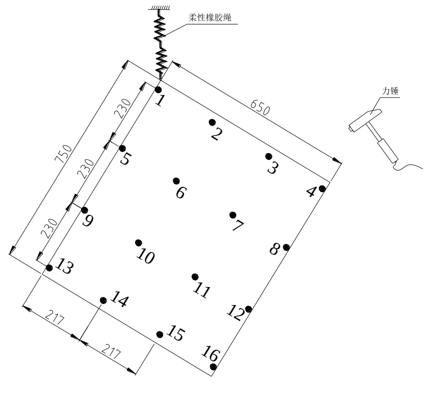


Figure 1 the transducer placement of rectangular plate

4 different rectangular plates are tested, and the relevant information is shown in Table 1.

Table 1 Structural parameters of rectangular plates

No.	plate	size
B-1	Undamped plate	Metal plate only：650×750×14
B-2	plate with damping material A	Metal plate：650×750×14 Damping material A：650×710×3
B-3	plate with damping material B	Metal plate：650×750×14 Damping material B：650×710×3
B-4	plate with damping material C	Metal plate：650×750×14 Damping material C：650×710×3

1 Test result

The transfer function between the excitation point and the response point is obtained by the hammer test, and the transfer function of the excitation point 4 and the response point 1 is shown in figure 2.

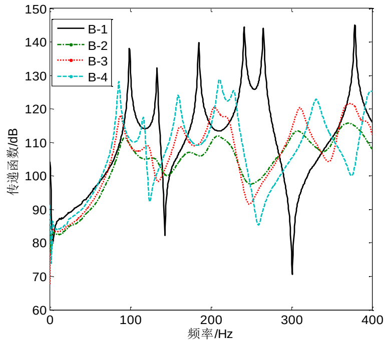


Figure 2 the transfer function of different plates

As can be seen from Figure 2, after the laying of different damping materials, the transfer function curve changes slowly, the natural frequency of the rectangular plate is shifted to the lower frequency, the resonance peak becomes smaller, and some of the anti resonance peaks become larger. The damping effect of damping material is not obvious at the frequency range less than the first order natural frequency.

Through the modal analysis, the first three modes of each plate are obtained, and the damping ratio of the structure under the same mode is compared to evaluate the damping effect of damping materials. The corresponding mode shapes are shown in figure 3 to figure 7. The natural frequency and damping ratio are shown in Table 2.

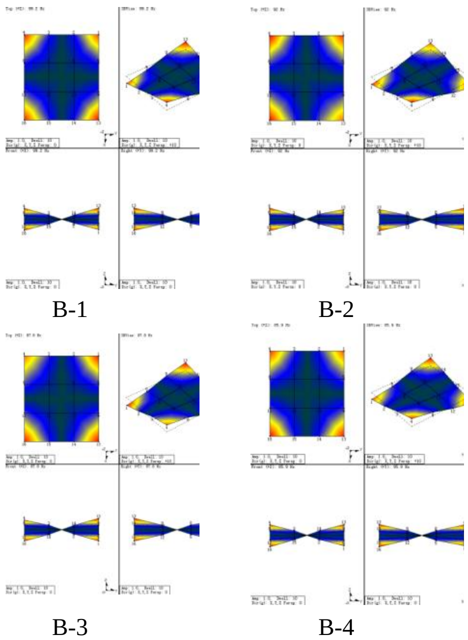
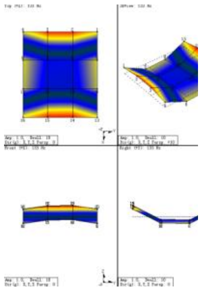
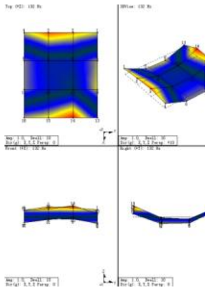
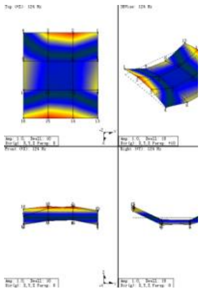
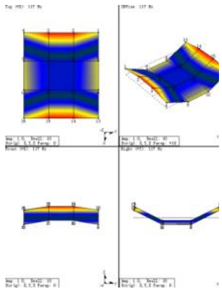


Figure 3 the first order mode shape

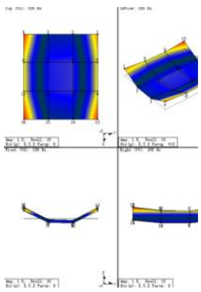
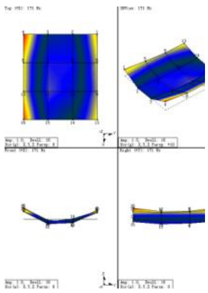



B-1 B-2

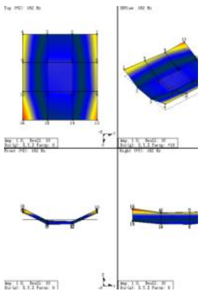
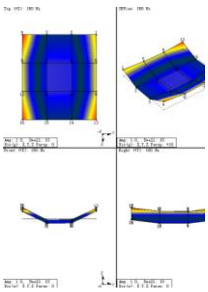



B-3 B-4

Figure 4 the second order mode shape

B-1 B-2

B-3 B-4

Figure 5 the third order mode shape

Table 2 natural frequency and damping ratio of rectangular plates

Order		1	2	3
B-1	Natural frequency	99.2	134	185
	Damping ratio	0.60%	0.40%	0.30%
B-2	Natural frequency	92	132	171
	Damping ratio	7.10%	7.60%	8.10%

B-3	Natural frequency	87.8	124	162
	Damping ratio	3.70%	4.40%	3.60%
B-4	Natural frequency	85.9	117	160
	Damping ratio	1.50%	1.50%	1.50%

From figure 2~ Figure 7, it shows that different rectangular plates each modal similarity, that corresponding modes are the same order mode, we can see from table 2, in the same mode. The damping ratio is from large to small: B-2, B-3, B-1. This method is very useful in the selection of damping material, but it can not be used to evaluate the damping effect. In order to predict the damping effect of damping material, it is necessary to know the vibration attenuation.

In the test, the peak attenuations of the transfer function of the rectangular plate at the first three natural frequencies are shown from table 3 to table 5.

Table 3 transfer function attenuation at the first order natural frequency

point	B-2 /dB	B-3 /dB	B-4 /dB
1	27	20	10
2	26	20	9
3	27	20	10
4	27	20	10
5	26	19	9
6	26	19	10
7	23	18	8
8	25	19	9
9	27	20	10
10	26	19	9
11	27	20	11
12	26	20	10
13	27	20	10
14	26	19	9
15	28	20	11
16	27	21	10
average	26	20	10

Table 4 transfer function attenuation at the second order natural frequency

Point	B-2 /dB	B-3 /dB	B-4 /dB
1	27	24	15
2	32	25	15
3	30	25	14
4	27	24	15
5	28	24	14
6	29	26	16
7	25	24	17
8	32	26	15
9	35	26	15
10	29	24	14

11	29	25	15
12	31	26	15
13	0	25	14
14	30	25	15
15	31	25	15
16	25	23	15
average	28	25	15

Table 5 transfer function attenuation at the third order natural frequency

point	B-2 /dB	B-3 /dB	B-4 /dB
1	33	25	16
2	23	21	17
3	23	21	16
4	30	24	15
5	31	24	15
6	32	24	15
7	30	23	14
8	31	25	15
9	32	25	15
10	32	24	15
11	30	24	14
12	33	25	15
13	29	24	15
14	26	24	20
15	27	26	14
16	31	24	15
average	30	24	15

Table 3~ table 5, the attenuations are compared in the same mode, it shows that damping effects of damping materials B at the first three order natural frequency can reach 26~30dB, damping effects of damping materials C at the first three order natural frequency can reach 20~25dB, and damping effects of damping materials D at the first three order natural frequency are about 10~15dB. It can be seen that the attenuation at the natural frequency can not only provide the basis for the selection of damping material, but also can get the corresponding damping effect at the natural frequency.

2 Conclusion

In this paper, the modal analysis was introduced into the damping effect evaluation of damping materials, obtained the modal of rectangular plate through modal analysis, calculated the attenuation of the transfer function at the natural frequencies, get the damping effect of damping material on the natural frequencies. The conclusions are as follows:

(1) After the laying of damping materials, the transfer function curve changes slowly, the natural frequency of the rectangular plate is shifted to the lower frequency, the resonance peak becomes smaller, and some of the anti resonance peaks become larger. The damping effect of damping material is not obvious at the frequency range less than the first order natural frequency.

(2) The attenuation of the transfer function at the natural frequency can evaluate the damping materials more effectively since the damping effect of damping is mainly to reduce the vibration near to inherent vibration frequency.

(3) The method of attenuation at the natural frequency to evaluate damping material can not only provide the basis for the selection of damping material, but also can get the damping effect at the natural frequency. It could

also avoid the effect of the anti resonance peak on the damping material evaluation, which makes it evaluate the damping materials more scientifically.

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