Natural Vibration Analysis of a Simple Vibration Absorber

Peng Wang [a], Heyun Cao [b], Xingxing Feng [c], Han Wang [d], Hao Zhang *

Wuhan Second Ship Design and Research Institute, Wuhan 430205, China

[a] 1025500148@qq.com, [b] caoheyun@tom.com, [c] 1310231571@qq.com, [d] 327684188@qq.com,
*Corresponding Author Email: zhyf1408@126.com

Abstract. The slender rod + mass block system is a typical elastic vibration absorber structure, with a simple structural form and strong design ability. It has wide application in engineering. This paper focuses on the inherent vibration characteristics of elastic structures and discusses the effects of gravity and typical geometric parameters on the modal frequency of the absorber structure. The calculation results show that, under the action of gravity, the overall strain rate is very low, and the impact of gravity on the structure's vibration characteristics can be ignored. With the increase of the length of mass block, length of slender rod, and the diameter of the mass block or with the decrease of diameter of slender rod, modal frequency of the elastic structure gradually decreases. The research conclusions can provide reference for the optimization design of simple elastic structures in engineering projects.

Keyword: vibration absorber, modal frequency, modal shape.

1. Introduction

Vibration absorber is a efficient method to reduce the vibration level of equipment. One typical structure for absorber is the spring system. In engineering, the spring could be a slender rod, and the mass could be a fat cylindrical rob. The structure is quite simple and design is in control, so it has wide application in engineering.

Many researchers have conducted works on vibration absorber. Warburton [1] obtained the optimize parameters for vibration absorber used in a two-degree system without damping effect. Brock [2] take the effect of damping into consideration, and give the formula to predict the proper parameters for vibration absorber. Omiondroy and DenHartong [3] conducted theoretical analysis on dynamic problem of one-degree system with absorber in consideration. D. Young [4] applied vibration absorber to solve the vibration problem of cantilever beam. Snowdon [5] point out that, the vibration of system with absorber will be quite complex while the damping effect is under consideration. Jacquot [6] combined modal method to optimize the design for the system of beam and vibration absorber with structural damping effect in consideration. It should be noted that, for above work, the gravity effect is no considered, and parameter analysis for absorber will help to give a better design for vibration absorber in engineering.

In this work, the natural vibration of vibration absorber is studied, gravity effect is taken into consideration, and parameter analysis is also conducted.

2. Model description

2.1 Vibration absorber

This work mainly focuses on a simple vibration absorber, it’s made up of a thin rob and a cylindrical mass, as is shown in Fig.1. There are four main parameters in this model, the length of slender rod L_2, the diameter of slender rod D_2, the length of cylindrical rod L_1, the diameter of cylindrical rod D_1.

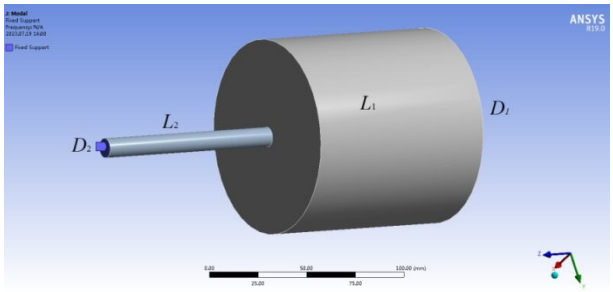


Fig. 1 A simple vibration absorber

2.2 Boundary condition

For absorber considered in this work will be welt to structures, so fixed support boundary condition is applied at the end of thin rob in numerical simulation, as is shown in Fig.1.

2.3 Parameters

Material for absorber is steel, the density is 7850kg/m^3, Elastic module is 2.1E11Pa, the Poisson's ratio is 0.3, Gravity acceleration is 9.8m/s^2.

Geometry parameter for absorber model is L_1=0.1m, L_2=0.1m, D_1=0.1m, D_2=0.01m.

3. Natural vibration

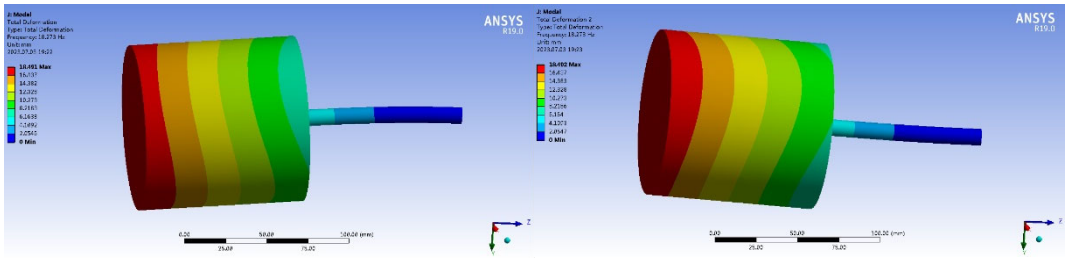
3.1 Modal frequency and modal shape

The first six modal frequencies are obtained from numerical simulation, and are given in Table 1. And the modal shapes for first six modes are also plotted in Fig.2.

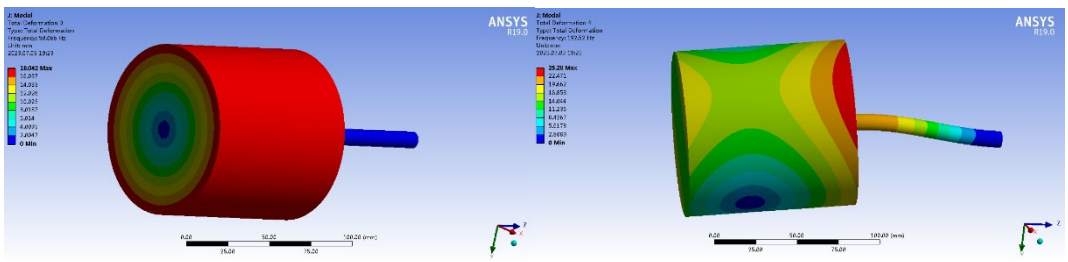
It's noted that, the first and second modes represent transverse vibration modes, the third mode represent the torsional vibration mode, and the sixth mode represent the axial vibration mode

Table 1. First six modal frequency of absorber

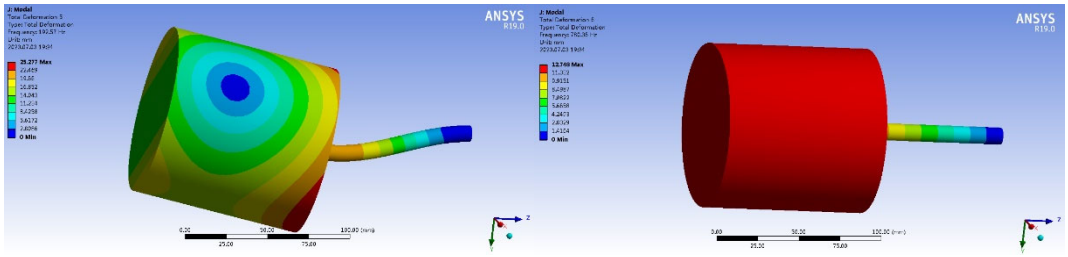
Mode order	Modal frequency
1	18.27
2	18.27
3	50.07
4	192.52
5	192.57
6	780.36



(a) first mode; (b) second mode



(c) third mode; (d) fourth mode



(e) fifth mode; (f) sixth mode

Fig. 2 The first six mode shapes of absorber

3.2 Effect of gravity

Numerical analysis is conducted to study the effect of gravity on natural vibration of vibration absorber. The first six modal frequencies are given in Table.2 in case of absorber with or without gravity.

It's noted that, the presence of gravity makes no difference on modal frequency from absorber. To give a better understanding of this phenomenon, the stain of absorber is also plotted in Fig.3. It can be noted that, with gravity in consideration, the strain of absorber is quite small, and the maximum strain is less than 0.04%, the change of stiffness of absorber is also quite small. Therefore, gravity effect result in little change of modal frequency of absorber.

Table 2. effect of gravity on modal frequency of absorber

Mode order	With gravity effect	Without gravity effect
1	18.27	18.27
2	18.27	18.27
3	50.07	50.07
4	192.52	192.52
5	192.57	192.57
6	780.36	780.36

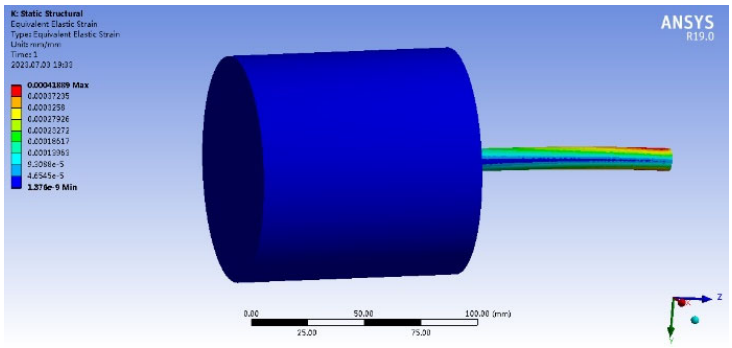


Fig. 3 strain status of absorber with gravity effect in consideration

4. Parameter analysis

4.1 Effect of length L_1

To get clear influence of the parameter L_1 on structural natural vibration, the first six modal frequencies from vibration absorber in case of different L_1 are given for comparative analysis, which is shown in Table 3.

It's noted that, with the increase of parameter L_1, modal frequencies from vibration absorber will correspondingly decrease. Since the increase of L_1 will make structure more slender, and the flexural stiffness will decrease and structural modal frequency will finally be reduced.

Table 3. effect of L_1 on modal frequency

L_1	1	2	3	4	5	6
0.03	48.98	48.98	91.38	343.43	343.49	1414.95
0.04	39.92	39.92	79.15	304.44	304.48	1230.76
0.05	33.66	33.66	70.80	275.70	275.86	1102.46
0.06	29.02	29.03	64.63	253.14	253.25	1007.03
0.07	25.44	25.44	59.85	234.42	234.57	932.66
0.08	22.57	22.57	55.98	218.42	218.53	872.49
0.09	20.23	20.23	52.78	204.70	204.77	822.66
0.1	18.27	18.27	50.07	192.52	192.57	780.36
0.11	16.62	16.62	47.74	181.87	181.96	744.05

4.2 Effect of length L_2

To reveal the effect of parameter L_2 on structural natural vibration, the first six modal frequencies from vibration absorber in case of different L_2 are listed in Table 4 for comparative analysis.

The data show that, with the increase of parameter L_2, modal frequencies from vibration absorber will correspondingly decrease. Since the increase of L_2 will make structure more slender, and the flexural stiffness will decrease and structural modal frequency will finally be reduced.

Table 4. effect of L_2 on modal frequency

L_2	1	2	3	4	5	6
0.5	2.69	2.69	22.50	49.33	49.33	192.87
0.4	3.63	3.63	25.16	59.17	59.18	292.36
0.3	5.28	5.28	29.03	74.15	74.15	456.75
0.2	8.67	8.67	35.52	102.72	102.74	557.93
0.1	18.27	18.27	50.07	192.52	192.57	780.36
0.08	22.51	22.52	55.88	241.11	241.24	867.35
0.05	33.30	33.30	70.32	398.53	398.72	1077.81
0.03	47.81	47.83	89.97	696.28	696.84	1349.58
0.01	88.78	88.82	149.30	1861.49	1862.61	2051.12

4.3 Effect of diameter D_1

To analyze the influence of D_1 on natural vibration of vibration absorber, the first six modal frequencies from vibration absorber in case of different D_1 are listed in Table 5 for comparative analysis.

Results show that, with the increase of parameter D_1, every modal frequency from vibration absorber will decrease. For the reason, the increase of D_1 will lead to the increase of total mass, and the flexural stiffness of slender rod remain the same, finally it will result in the reduction of modal frequencies.

Table 5. effect of D_1 on modal frequency

D_1	1	2	3	4	5	6
0.12	15.06	15.07	34.76	149.21	149.25	650.48
0.11	16.53	16.53	41.37	168.79	168.88	709.59
0.1	18.27	18.27	50.07	192.52	192.57	780.36
0.09	20.40	20.40	61.84	221.70	221.79	866.92
0.08	23.05	23.05	78.30	258.29	258.38	975.29
0.07	26.44	26.44	102.35	304.61	304.65	1113.98
0.06	30.96	30.96	139.49	365.36	365.44	1298.88
0.05	37.26	37.26	201.19	446.75	446.86	1555.74
0.04	46.71	46.71	315.29	561.87	562.15	1937.92

4.4 Effect of diameter D_2

To study the influence of D_2 on natural vibration of vibration absorber, the first six modal frequencies from vibration absorber in case of different D_2 are given for comparative analysis, as is shown in Table 6.

It's noted that, with the increase of parameter D_2, every modal frequency from vibration absorber will increase. It can be explained as follow, the increase of D_2 will lead to the increase of flexural stiffness of slender rod, and the total mass for whole system change a little, and finally it will result in the reduction of modal frequencies.

Table 6. effect of D_2 on modal frequency

D_2	1	2	3	4	5	6
0.02	72.46	72.46	197.22	705.89	706.03	1523.41
0.018	58.78	58.78	160.11	582.89	583.04	1377.80
0.016	46.51	46.51	126.81	468.81	468.93	1230.56
0.014	35.66	35.66	97.35	365.14	365.25	1081.93
0.012	26.25	26.25	71.77	272.81	272.85	931.96
0.01	18.27	18.27	50.07	192.52	192.57	780.36
0.008	11.74	11.74	32.27	125.31	125.34	627.13
0.006	6.64	6.64	18.38	71.75	71.78	471.61
0.004	2.98	3.00	8.40	32.72	32.74	313.91

5. Conclusion

This paper focuses on the inherent vibration characteristics of a simple vibration absorber. The calculation results show that, 1) under the action of gravity, the overall strain rate is very low, and the impact of gravity on the structure's vibration characteristics can be ignored. 2) With the increase of the length of mass block, length of slender rod, and the diameter of the mass block or with the decrease of diameter of slender rod, the mode frequency of the elastic structure gradually decreases. The research conclusions of this paper can provide reference for the optimization design of simple elastic structures in engineering projects.

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