August 27-31, 2023
FLORENCE - ITALY
16th International Conference on Wind Engineering
ICWE 16

Study on mass-damping characteristics of typical cross-section elastic suspension system in still air

Xin Chen [1], Rong Xian[2], Cunming Ma [3]

[1]*Southwest Jiaotong University, Chengdu, China, chenxin2016@my.swjtu.edu.cn*
[2]*Guangdong Highway Construction Co., Ltd., China, 4216148@qq.com*
[3]*Southwest Jiaotong University, Chengdu, China, mcm@swjtu.edu.cn*

SUMMARY:
Vortex-induced vibration is a common wind-induced vibration phenomenon in engineering. For engineering structures, vortex-induced vibration at low wind speeds will have an impact on the safety and durability of structures. For a specific section, the mass damping characteristics of the system have a decisive influence on the vortex induced vibration characteristics. In order to accurately study the vortex-induced vibration of the structure, it is necessary to study the damping characteristics of the structure in depth. Conventional wind tunnel tests usually measure the damping of the system through the damped-free vibration of the spring suspension system in still air, while not considering the influence of the fluid on the mass and damping characteristics of the system. However, the structural frequency and damping obtained in this way is often the result of the joint action of the suspension system and the fluid, without distinguishing the effects of the fluid and the suspension system. In this paper, using the method of computational fluid dynamics, for two typical blunt body sections, the numerical simulation of free attenuation vibration in still air is carried out. In order to exclude the coupling effect of the suspension system and the fluid action, numerical simulations of 3 different mechanical damping (damping is constant) were carried out, and the aero-mass aero-dam characteristics of the system were studied in detail.
Keywords: vortex-induced vibration, numerical simulation, aero-mass, aero-damp.

1. INTODUCTION

Previous studies have found that the frequency damping of structures in stationary fluids has a certain amplitude dependence. This dependence on the amplitude is actually the performance of the nonlinear effect of the fluid on the structure on the structural vibration. The frequency damping of the structure has a crucial influence on the various forms of vibration of the structure. In order to accurately and fully study various fluid-induced coupling vibrations of structures under the action of fluids, it is necessary to study the dynamic characteristics of structures in fluids first, and to distinguish the mechanical behavior of structures in fluids from the fluid-solid coupling behavior. Especially vortex-induced vibration has a significant dependence on structural damping. The inaccurate prediction of vortex-induced vibration by various existing vortex-induced models under different mass damping parameters may be related to the in-depth study of the damping characteristics of the structure. Now based on the research of vibratory vortex-induced vibration wind tunnel tests, the attenuation of free vibration in static fluid is generally regarded as the result of mechanical damping, especially for bridge girder sections. The mechanical damping identified in this way is often too large. Various vortex-induced force models identified under excited vibration may lead to errors in model parameters due to inaccurate identification of system mechanical damping, resulting in failure of prediction of vortex-induced vibration. In this paper, through CFD numerical simulation, the dynamic mesh technology is used to simulate the free attenuation vibration of elastic suspension systems with two typical sections in still air, and the influence of fluid on the mass damping of the system in still air is studied.

2.SECTION DESCRIPTIONS AND NUMERICAL SIMULATION CASES

The numerical simulation adopts two typical sections. Section 1 is a 5:1 rectangle, and Section 2 is a typical bridge girder section in an actual project, as shown in Figure 1. In order to fully capture the boundary layer characteristics of the section, the body-fitted grid of the section is refined, and the local characteristics of the grid are shown in Figure 2 and Figure 3. And the grid is validated numerically. In order to ensure that the fluid has the correct turbulence characteristics when the system vibrates freely, as shown in Figure 4, the system is first forced to vibrate for 20 cycles with a circular frequency of ω_0, and then released to allow it to vibrate freely in the fluid.

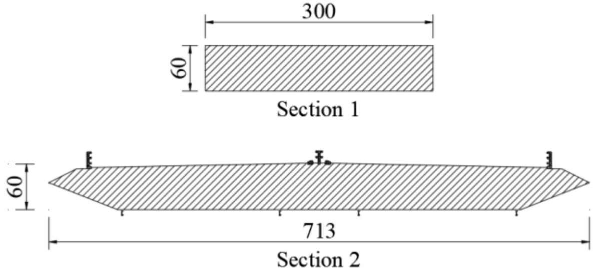

Figure 1. Sections for numerical simulation.

Figure 2. Grid scheme for section 1.

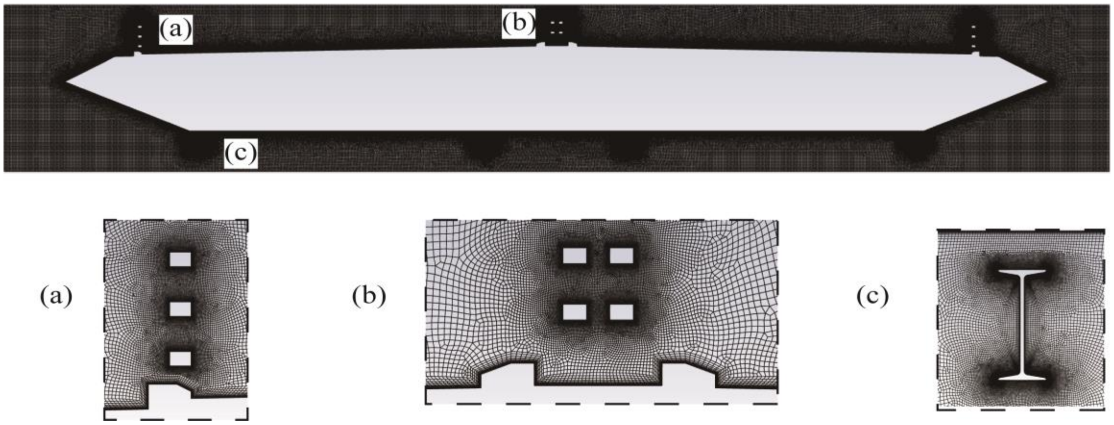

Figure 3 Grid scheme for section 2.

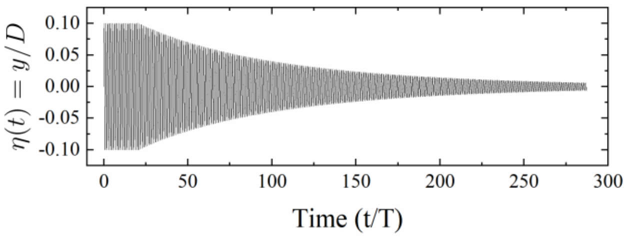

Figure 4. Vibration of system for fluid-structure simulation.

3.RESULTS AND ANALYSES

The free vibration attenuation time histories of the two cross-sections are obtained through the dynamic mesh technology, as shown in Figure 5. Through further analysis of the vibration time history, the system frequency and damping under the action of fluid are obtained, as shown in Figure 6 and Figure 7. Deducting the mechanical damping of the system gives the aerodynamic damping shown in Figure 8.

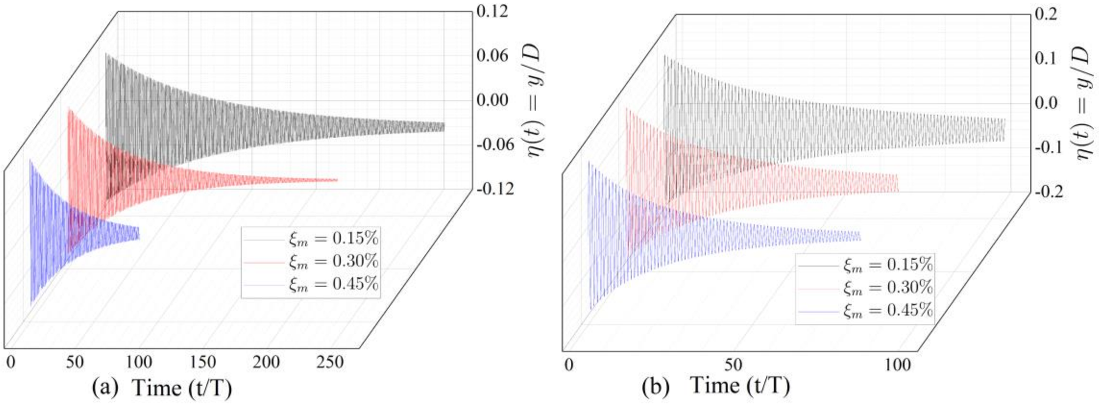

Figure 5. Damped-vibration of systems: (a) section 1; (b) section 2

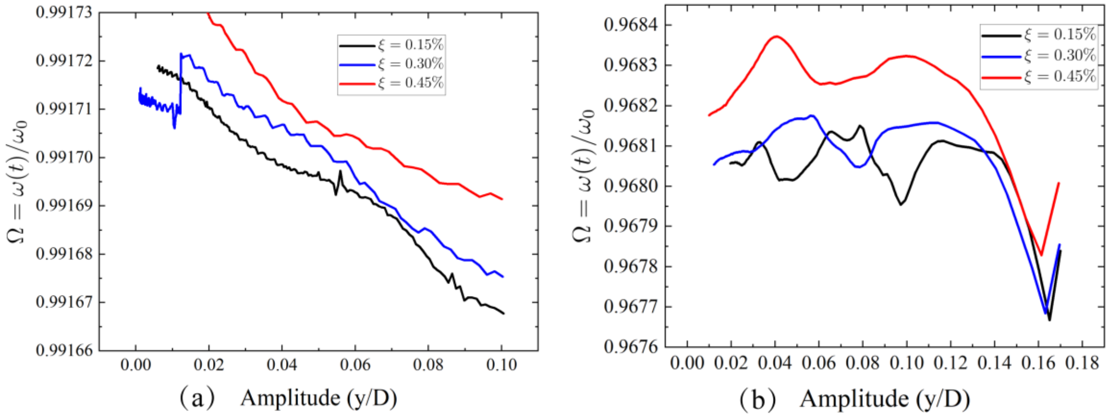

Figure 6. Amplitude-dependent frequency of systems: (a) section1; (b) section 2.

4. CONCLUSIONS

The results show that the free attenuation vibration in still air will add a certain amount of additional mass to the system, and with the increase of the amplitude, the additional aerodynamic mass tends to increase, but its magnitude varies little with the amplitude and can be regarded as a constant. For the additional aerodynamic damping, as the amplitude increases, the aerodynamic damping shows an obvious increasing trend. And for different cross-section forms, the size of additional aerodynamic damping is obviously different. The additional aerodynamic damping of the 5:1 rectangle is significantly lower than that of the main beam section. And there is no mutual coupling between the mechanical damping of the spring suspension system and the aerodynamic damping under the action of fluid.

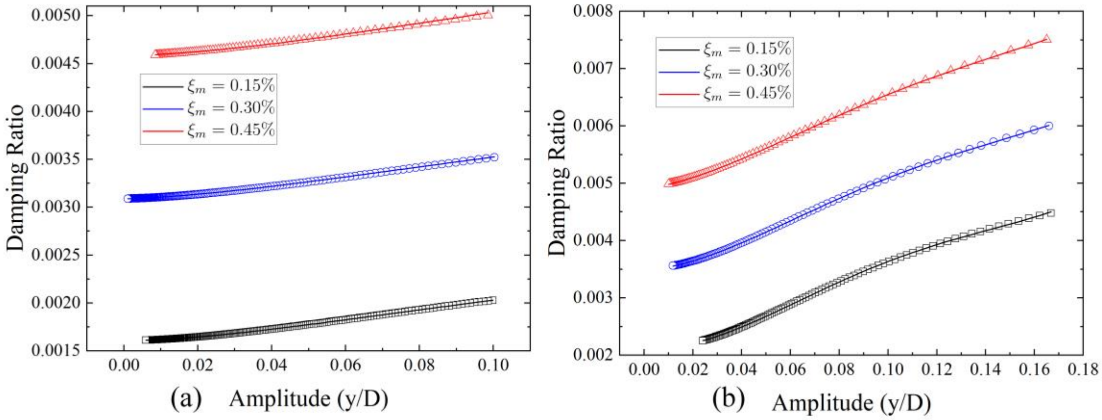

Figure 7. Damping ratio of systems: (a) section 1; (b) section 2.

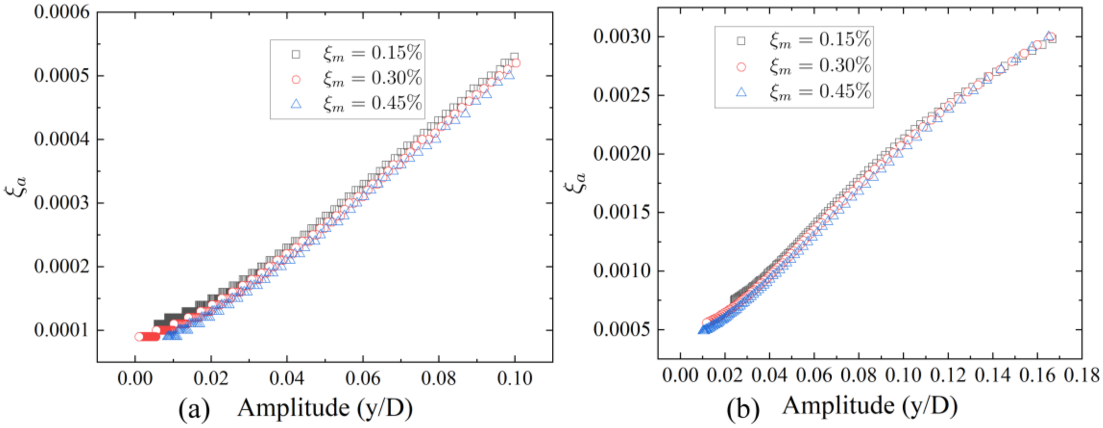

Figure 8. Aero-damping of systems: (a) section 1; (b) section 2.

ACKNOWLEDGEMENTS

This project was supported by the National Natural Science Foundation of China (Grant number 52078438)

REFERENCES

Bruno L, Maria VS, Francesco R. 2014. Benchmark on the Aerodynamics of a Rectangular 5:1 Cylinder: An overview after the first four years of activity. Journal of Wind Engineering and Industrial Aerodynamics 126:87-106.

Cao F, Ge Y. 2017. Air-induced nonlinear damping and added mass of vertically vibrating bridge deck section models under zero wind speed. Journal of Wind Engineering and Industrial Aerodynamics 169:217-231.

Xu F, Zhang Z. 2018. Numerical simulation of windless-air-induced added mass and damping of vibrating bridge decks. Journal of Wind Engineering and Industrial Aerodynamics 180:98-107.