

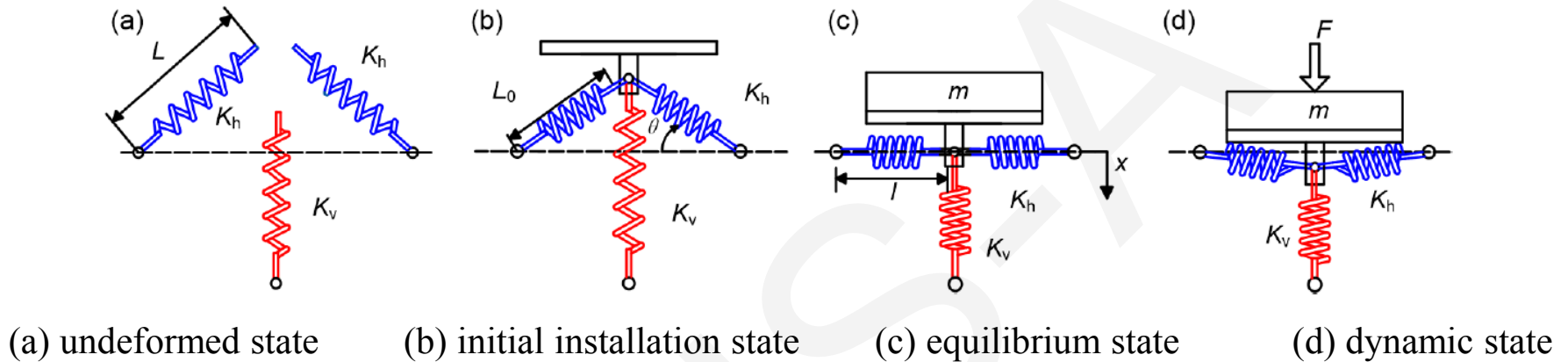
# Vibration response analysis of floating slab track supported by nonlinear quasi-zero-stiffness vibration isolators

Ze-ming ZHAO, Kai WEI\*, Juan-juan REN, Gao-feng XU, Xiang-gang DU, Ping WANG

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# QZS isolation system model diagram



**Fig. 1 QZS isolation system model diagram**

$$F = K_v x - n K_h \left( L - \sqrt{x^2 + l^2} \right) \frac{x}{\sqrt{x^2 + l^2}}$$

$$\hat{F} = \hat{x} + \alpha \hat{x} \left( \frac{1}{\sqrt{\hat{l}^2 - \hat{x}^2}} - 1 \right)$$

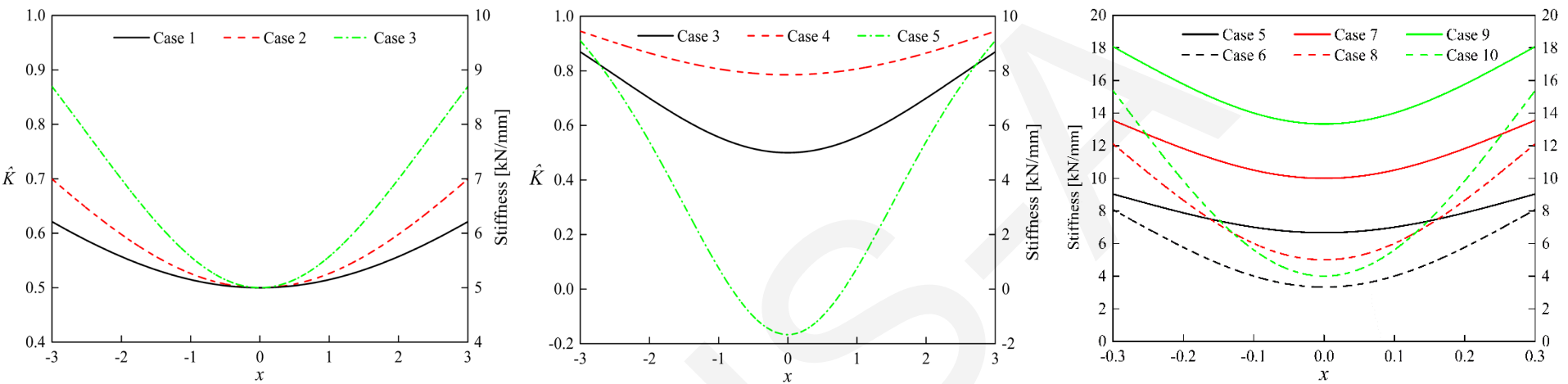
$$K = K_v + n K_h \left( 1 - \frac{L l^2}{(x^2 + l^2)^{\frac{3}{2}}} \right)$$

$$\hat{K} = 1 + \alpha \left( 1 - \frac{\hat{l}^2}{(\hat{l}^2 + \hat{x}^2)^{\frac{3}{2}}} \right)$$

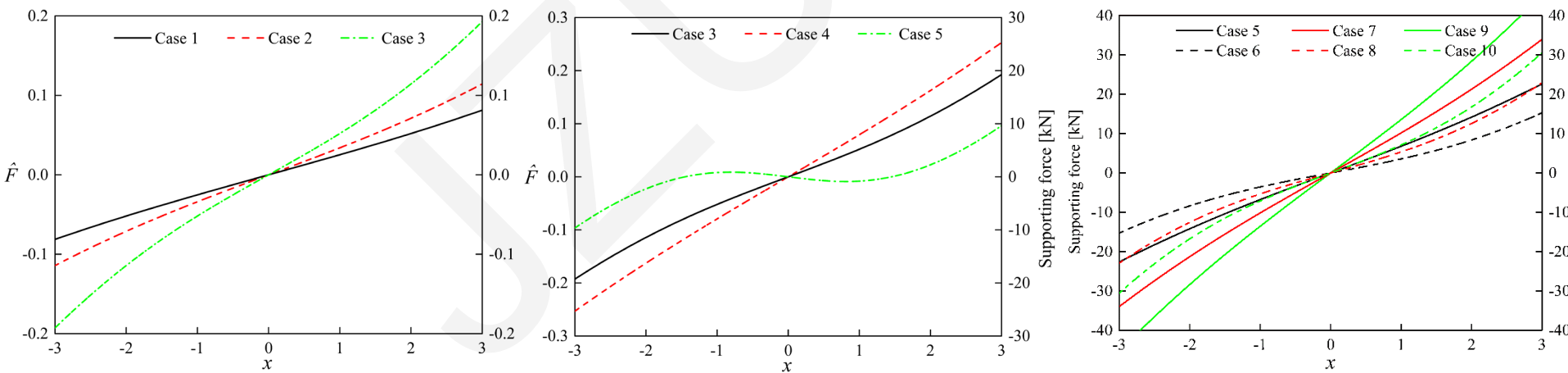
Key parameter matching design:

1. the PSEs and NSEs stiffness;
2. the original length of the NSEs;
3. the compression length of NSEs at the equilibrium position

# Design of vibration isolator parameters

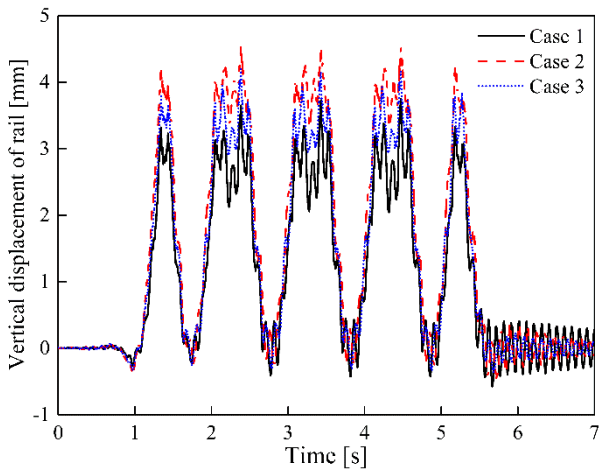


**Fig. 2 Nonlinear stiffness characteristics**

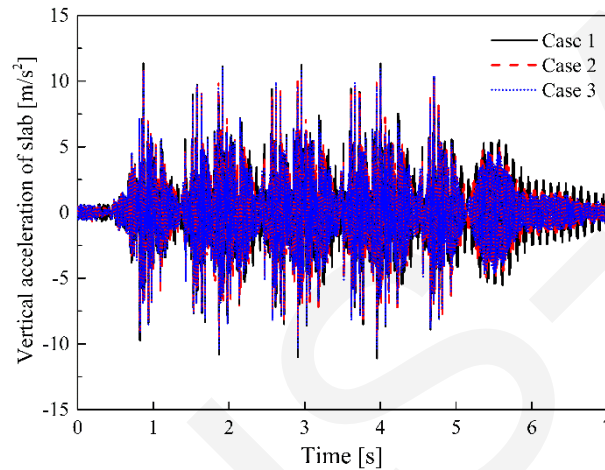


**Fig. 3 Nonlinear bearing capacity characteristics**

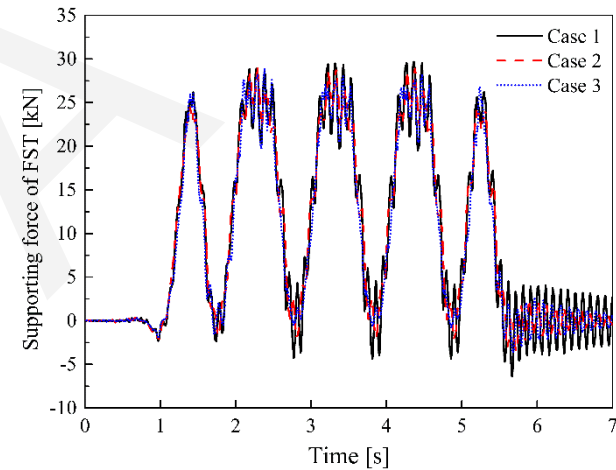
# Effect evaluation



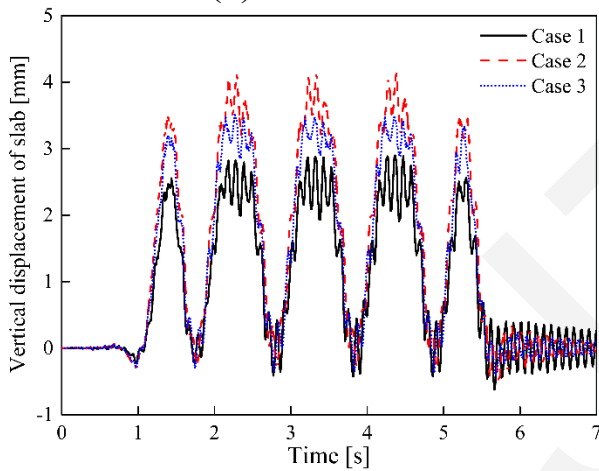
(a) Rail



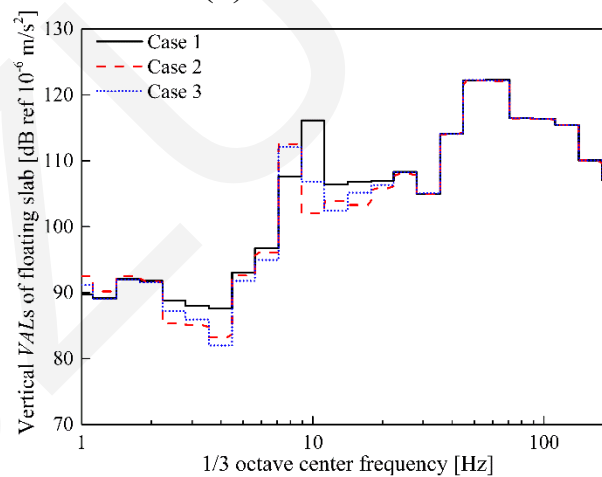
(a) Time domain



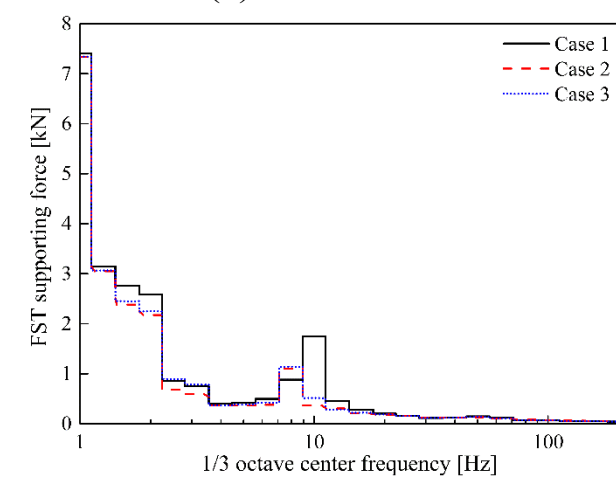
(a) Time domain



(b) Floating slab



(b) Frequency-domain



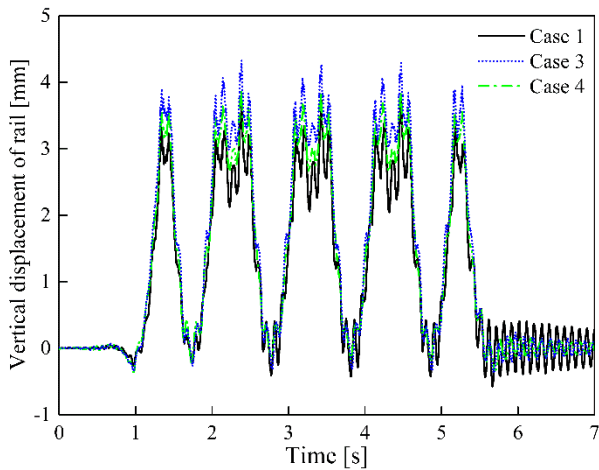
(b) Frequency-domain

**Fig. 4** Dynamic displacements

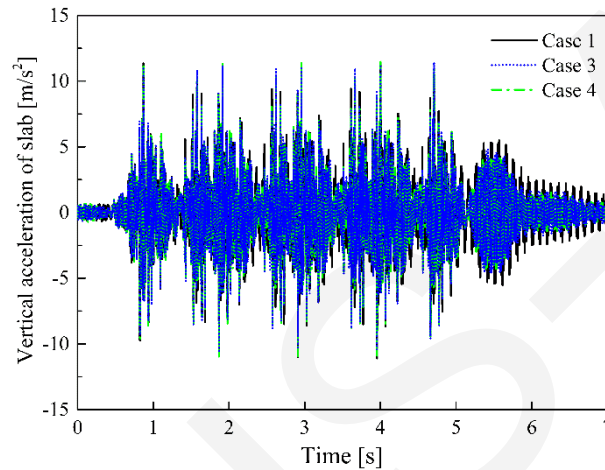
**Fig. 5** Vertical acceleration

**Fig. 6** Supporting force

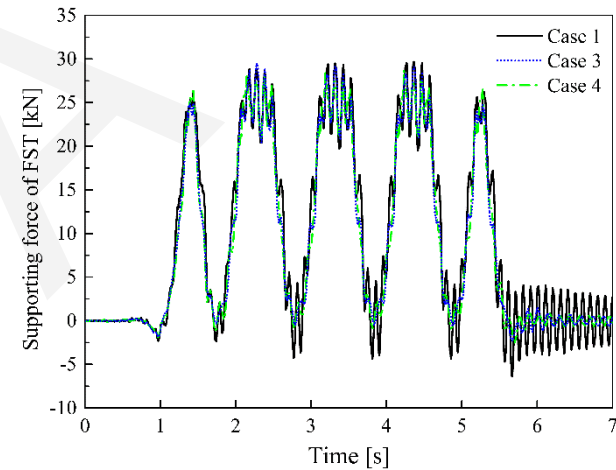
# Effect evaluation



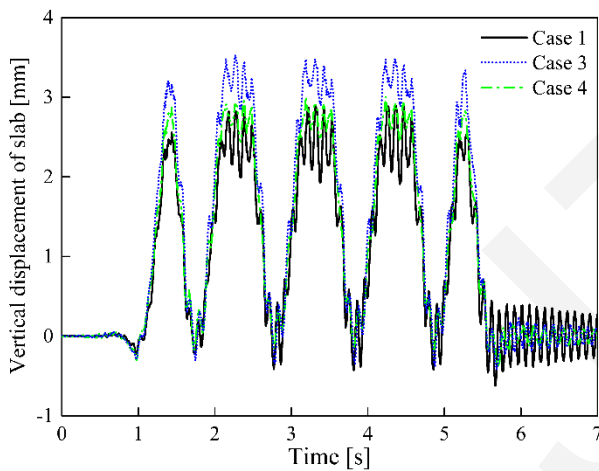
(a) Rail



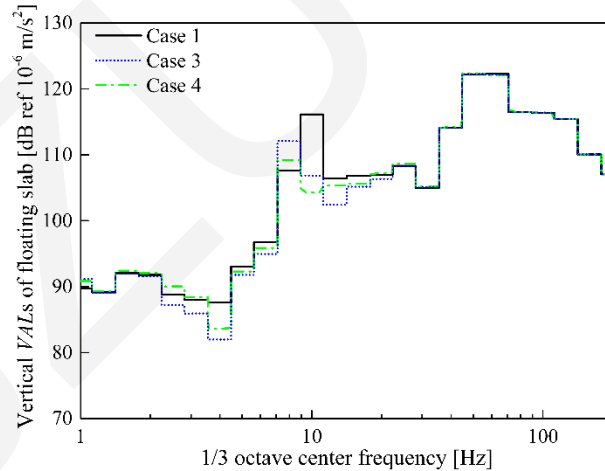
(a) Time domain



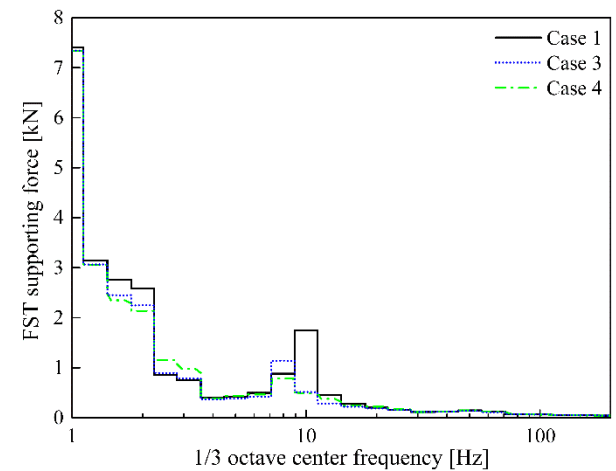
(a) Time domain



(b) Floating slab



(b) Frequency-domain



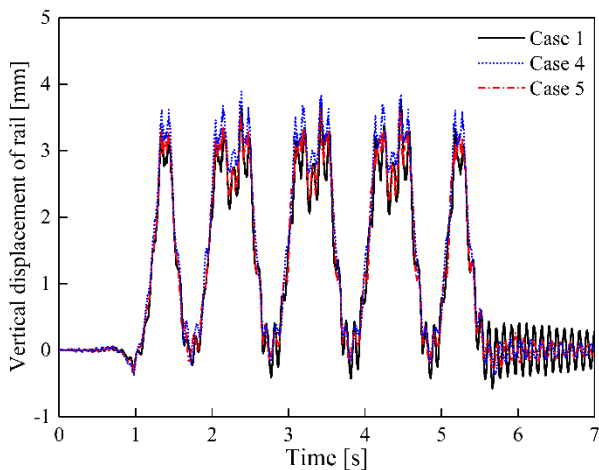
(b) Frequency-domain

**Fig. 7** Dynamic displacements

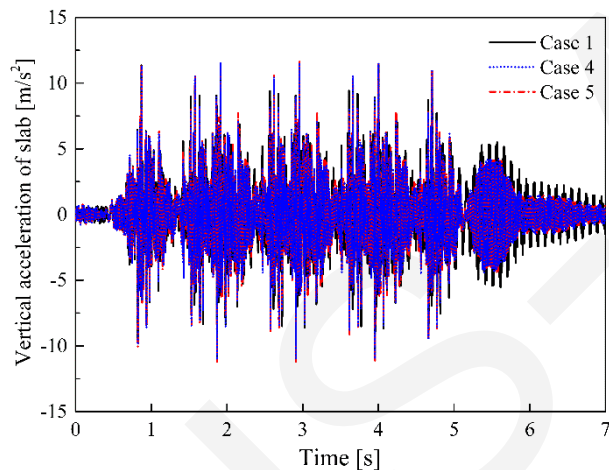
**Fig. 8** Vertical acceleration

**Fig. 9** Supporting force

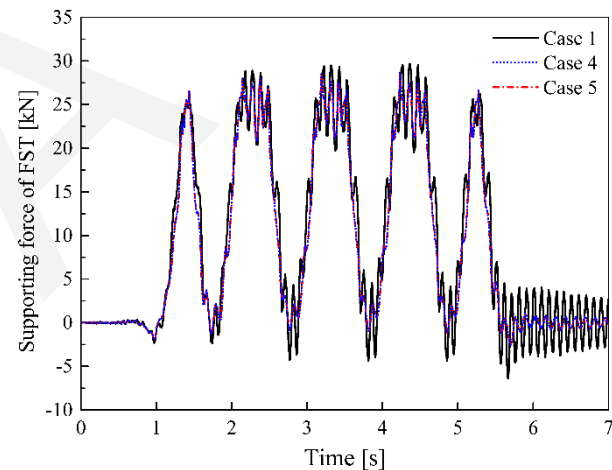
# Effect evaluation



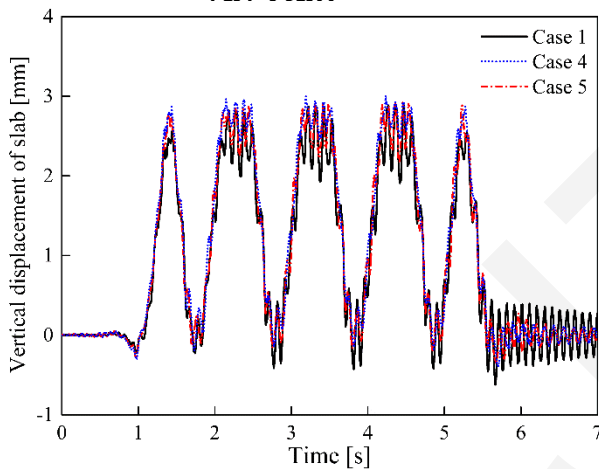
(a) Rail



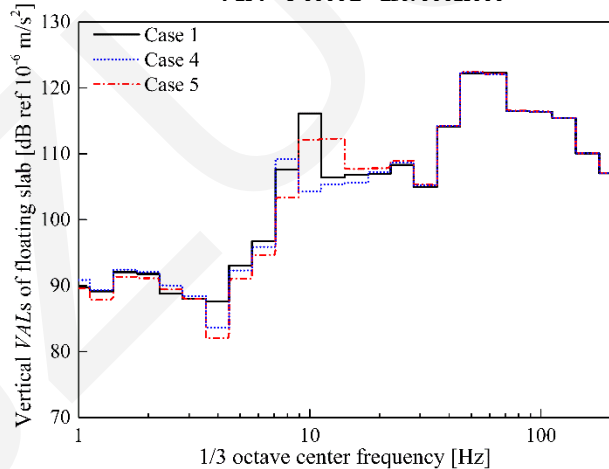
(a) Time domain



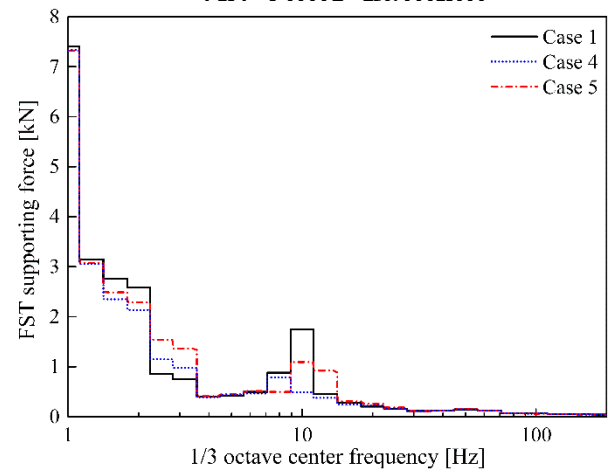
(a) Time domain



(b) Floating slab



(b) Frequency-domain



(b) Frequency-domain

**Fig. 10** Dynamic displacements

**Fig. 11** Vertical acceleration

**Fig. 12** Supporting force

# Conclusions

1) Within the millimeter-level dynamic displacement limit of the FST, the original length of the NSEs chiefly determines the stiffness nonlinearity level. The original length of the NSEs should not be too large, otherwise the high-static-low-dynamics-stiffness cannot be achieved.

2) The compression length of NSEs at the FST equilibrium position determines the low-dynamic stiffness of the floating slab on which none vehicle is. However, in order to ensure the dynamic displacement limit of FST, the stiffness of the PSEs needs to be increased correspondingly to obtain the high-static-stiffness under the vehicle load.

3) Various stiffness groups with different stiffness nonlinearity levels are capable of providing the same bearing capacity, and yet have a significant difference in the vibration-reduction effect near FST natural frequency. When the stiffness nonlinearity level of QZS vibration isolators is too small, the FST dynamic responses are just those of traditional linear steel-spring FST. When the stiffness nonlinearity level of QZS isolators is too high, the vibration responses slightly higher than the natural frequency are amplified.