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2、由专家评审组遴选出优秀论文（必须是全文格式投稿），具体表彰办法如下：

1）一等奖：所有参赛论文数的前 5%名；

二等奖：所有参赛论文数的前 5%-15%名；

三等奖：所有参赛论文数的前 15%-30%名。

2）获一、二、三等奖获得者均由组委会颁发荣誉证书以及奖金，其中获一、二等奖获得者需准备 10 分钟 PPT，现场做口头报告陈述研究成果。

3、由专家评审组投票遴选出优秀墙报。

五、论坛相关事项说明

1、论坛形式

论坛包括大会主题报告（邀请海内外知名专家学者作大会主题报告）、分论坛研究生口头报告及墙报交流，具体安排另行通知。

2、其它

1）本届学术论坛获奖者在“国家奖学金”、“校内奖学金”等各项奖学金评定时，同等条件下优先考虑；获得一、二等奖者评奖时视同发表一篇 CSCD-E 论文。

2）本届学术论坛获奖者可优先推荐参加“研究生优秀干部”、“三好研究生”、“优秀毕业生”等奖项评比。

3）本院在校研究生未参加一次学术论坛(以论文投稿为准)原则上不得申请毕业答辩。

六、重要日期

提交论文截止日期：2020 年 12 月 10 日

论文录用通知日期：2020 年 12 月 15 日

学术论坛举办日期：2020.12.19 - 2020.12.20

七、相关事宜咨询人联系方式

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欢迎广大博士、硕士研究生同学踊跃投稿、积极参与！

机械工程学院

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Influence of Excitation Amplitude and Load on the Characteristics of a Quasi-zero Stiffness Isolator( )

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Abstract( ) An Euler buckled beam formed negative stiffness mechanism is proposed and the static characteristic of which is analyzed. A quasi-zero stiffness isolator is designed by parallel connected the negative stiffness mechanism and a linear isolator. The Euler buckled beam structure functions as a stiffness corrector to lower the stiffness of the linear isolator. If the load is chosen properly, the equilibrium point will be set at the zero stiffness point, any changes of the load will lead the equilibrium point deviating from the zero stiffness point. The dynamic model is built considering the load effect and the Harmonic balance method is employed to solve for the dynamic response of the system. Force transmissibility of the zero stiffness isolator is defined and compared with that of an equivalent linear one. The effect of excitation amplitude and load on the performance is analyzed. The results show that the force excitation amplitude and load can change the characteristic of the nonlinear isolator from a hardening stiffness system to a softening stiffness system and even a mixed softening-hardening stiffness system. The excitation amplitude and load also have great affection on the transmissibility performance. ( )

Key words( ) Negative stiffness Vibration isolation Nonlinear systems Harmonic balance method

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PLATUS [1-2]

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CARRELLA [3-4]

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YANG [7]

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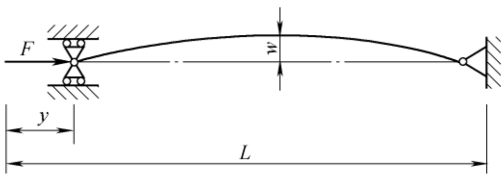
$w_0 = q_0$ [11]

$$F = P_e\left[1-\pi\left(\frac{q_0}{L}\right)\left(\left(\pi^2\left(\frac{q_0}{L}\right)^2\right)+4\left(\frac{y}{L}\right)\right)^{-1/2}\right]$$

$$\left[1+\frac{\pi^2}{8}\left(\frac{q_0}{L}\right)^2+\frac{1}{2}\left(\frac{y}{L}\right)\right] \quad (1)$$

(1) $(\,y/L<20\%\,)$ $P_e = EI$ $(\pi/L)^2$

L y



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( ) $\left((\ )^2\ (\ )\right)^{1/2}$

$$\left[2\tilde{\varepsilon}-\frac{12+\left(\pi\tilde{q}_0\right)^2}{2}\right]\left(\frac{\tilde{u}}{\tilde{\varepsilon}}\right) \quad (2)$$

$\tilde{F}$ $\tilde{F}=F/P_e$ $\tilde{u}$

$\tilde{u}=u/L$ $\tilde{q}_0$

$\tilde{q}_0 = q_0/L$ $\tilde{\varepsilon}=\sqrt{\tilde{u}^2+\gamma^2}$ $\gamma=\cos\theta$ (2)

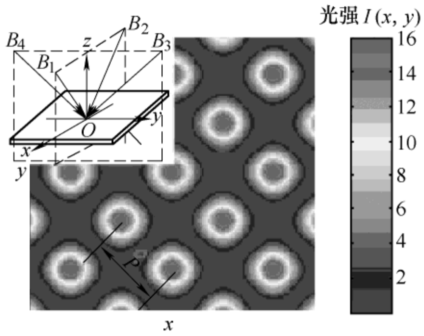
$\tilde{u}=0$

$$\tilde{F}(u)\approx -k_1\tilde{u}+k_3\tilde{u}^3 \quad (3)$$

k_1 $k_1=\left(\frac{a-b}{a\gamma}\right)\left(\frac{b^2}{2}-2\gamma+6\right)$ k_3 3 2

$\left(\frac{a-b}{2\gamma^3 a}+\frac{b}{\gamma^2 a^3}\right)\left(\frac{b^2}{2}-2\gamma+6\right)$ a, b

$a=\sqrt{(\pi^2\tilde{q}_0^2-4\gamma+4)}$ $b=\pi\tilde{q}_0$



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( )	1	2	3	4
/V	1 050	1 000	950	900
/V	275	250	350	300
/Pa	35	30	45	40
/mm	15	20	25	22.5

(3)

2 k

c m

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$$\tilde{F}_n = k_1'\tilde{u}+k_3'\tilde{u}^3+\sqrt{1-\gamma^2} \quad (4)$$

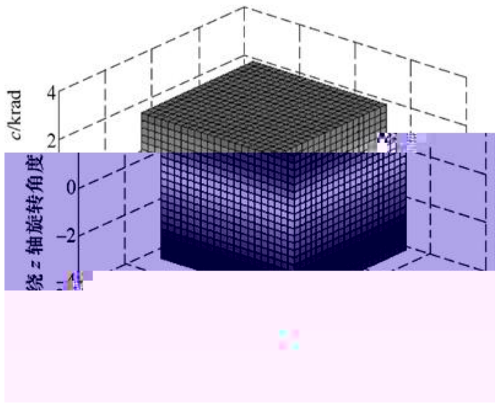
$\tilde{F}_n$ $\tilde{F}_n = F_n/kL$ $k_1'=(1-k_1\lambda)$ $k_3'=\lambda k_3$ λ

$\lambda = P_e/kL$ $\lambda=1/k_1$

$k_1'=0$ 3

$$\tilde{F}_n = \alpha\tilde{u}^3+\sqrt{1-\gamma^2} \quad (5)$$

α $\alpha = k_3/k_1$



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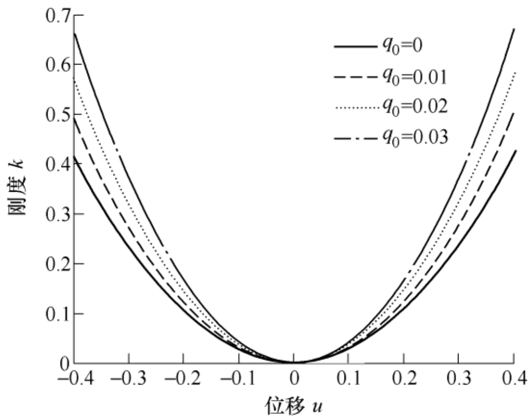
$\tilde{u}=0$

$\theta=25^{\circ}$

4(q_0

) α



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$\tilde{u}=0$

3 $\tilde{u}=0$

3 m

1%m $\tilde{u}=0.16$

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m

$\tilde{u}_0>0$

$$kL\left(\alpha\left(\tilde{u}_0\right)^3+\sqrt{1-\gamma^2}\right)=mg \quad (7)$$

$$m\frac{\mathrm{d}^2x}{\mathrm{d}t^2}+c\frac{\mathrm{d}x}{\mathrm{d}t}+kL\left[\alpha\left(\tilde{x}+\tilde{u}_0\right)^3+\sqrt{1-\gamma^2}\right]= F_0\cos\omega t+mg \quad (8)$$

$$\omega_n=\sqrt{\frac{k}{m}}\quad \varOmega=\frac{\omega}{\omega_n}\quad \tau=\omega_n t\quad \zeta=\frac{c}{2m\omega_n}\quad f_0=\frac{F_0}{\omega_n^2 mL}$$

(7) (8)

$$\frac{\mathrm{d}^2\tilde{x}}{\mathrm{d}\tau^2}+2\zeta\frac{\mathrm{d}\tilde{x}}{\mathrm{d}\tau}+\alpha_1\tilde{x}+\alpha_2\tilde{x}^2+\alpha_3\tilde{x}^3=f_0\cos\left(\varOmega\tau\right) \quad (9)$$

$\alpha_1=3\alpha\tilde{u}_0^2\quad \alpha_2=3\alpha\tilde{u}_0\quad \alpha_3=\alpha$ (9)

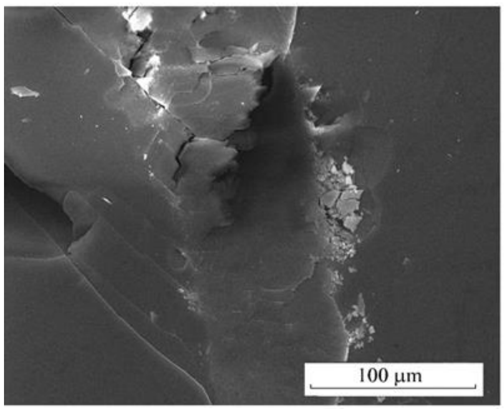
[12-14]

[15] ((9)

$$\frac{\mathrm{d}^2\tilde{x}^*}{\mathrm{d}\tau^2}+2\zeta\frac{\mathrm{d}\tilde{x}^*}{\mathrm{d}\tau}+b_1\tilde{x}^*+b_3\tilde{x}^{*3}=f_0\cos\left(\varOmega\tau\right)+b_0 \quad (10)$$

$b_0=\alpha_2/(3\alpha_3)-\left(2\alpha_2^3\right)/\left(27\alpha_3^2\right)$ $b_1=\left[\alpha_1-\alpha_2^2/(3\alpha_3)\right]$ $b_3=\alpha_3$ [16] (10)

$$\tilde{x}^*(\tau)=A_0+A_1\cos\left(\varOmega\tau+\varphi\right) \quad (11)$$



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(11) (10)

$$\begin{cases} b_1A_0+b_3A_0^3+\dfrac{3}{2}b_3A_0A_1^2=b_0 \\ -\Omega^2A_1+b_1A_1+3b_3A_0^2A_1+\dfrac{3}{4}b_3A_1^3=f_0\cos\varphi \\ -2\zeta\Omega A_1=f_0\sin\varphi \end{cases} \tag{12}$$

(12) A_0

$$25b_3^3A_0^9+\left(35b_1b_3^2-20\Omega^2b_3^2\right)A_0^7-15b_0b_3^2A_0^6+\left(11b_1^2b_3+4\Omega^4b_3+16\zeta^2\Omega^2b_3-24b_1b_3\Omega^2\right)A_0^5+\left(2b_0b_1b_3+16\Omega^2b_0b_3\right)A_0^4+\left(b_1^3-4b_1^2\Omega^2+4\Omega^4b_1+16\zeta^2\Omega^2b_1-9b_0^2b_3+6b_3f_0^2\right)A_0^3+\left(b_0b_1^2-4\Omega^4b_0-16\zeta^2\Omega^2b_0\right)A_0^2+\left(4b_0^2\Omega^2-b_0^2b_1\right)A_0-b_0^3=0 \tag{13}$$

(12) A_0

[13]

$$A_{0p}^6+\frac{6b_1}{5b_3}A_{0p}^4-\frac{4b_0}{5b_3}A_{0p}^3+\left(\frac{b_1^2}{5b_3^2}+\frac{3a_0^2}{20b_3\zeta^2}\right)A_{0p}^2-\frac{b_0^2}{5b_3^2}=0 \tag{14}$$

$$\Omega_{0p}=\sqrt{\frac{b_1}{2}+\frac{5}{2}b_3A_{0p}^2+\frac{b_0}{2A_{0p}}} \tag{15}$$

(14)

(15)

(12) (7) (15)

(7)

$\tilde{u}_0=0$

$$\frac{\mathrm{d}^2\tilde{x}}{\mathrm{d}\tau^2}+2\zeta\frac{\mathrm{d}\tilde{x}}{\mathrm{d}\tau}+\alpha\tilde{x}^3=f_0\cos\left(\Omega\tau\right) \tag{16}$$

(16)

$$\tilde{x}\left(\tau\right)=A_1\cos\left(\Omega\tau+\varphi\right) \tag{17}$$

$$A_1^2\Omega^4+\left(4\zeta^2A_1^2-\frac{3}{2}\alpha A_1^4\right)\Omega^2+\frac{9}{16}\alpha^2A_1^6-f_0^2=0 \tag{18}$$

$$A_{1p}=\sqrt{\frac{2\zeta^3+\sqrt{4\zeta^6+3\alpha f_0^2}}{3\alpha\zeta}} \tag{19}$$

$$\Omega_{1p}=\frac{1}{2}\sqrt{3\alpha A_{1p}^2-8\zeta^2} \tag{20}$$

(18) $\tilde{u}=0$

(19) (20)

$\tilde{u}=0$

$\tilde{u}=\tilde{u}_0$

[17]

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α $\tilde{u}_0$

f_0

6 7

α $\tilde{u}_0$

A_0 A_1

$A_0=0$ 6 7

6 7

$\tilde{u}_0$ A_0

$\tilde{u}_0$ A_0

A_1 ( )

6 7 $\tilde{u}_0$

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α) α

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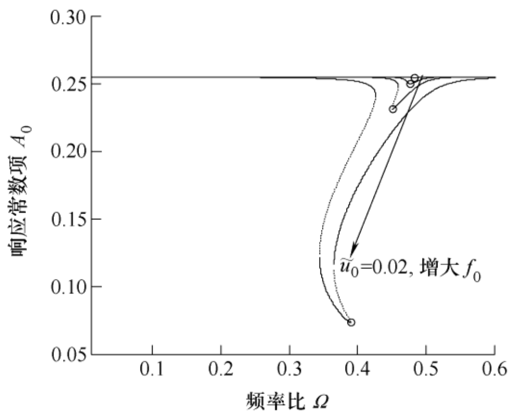
$T_f = F_t / F_0$ F_t

F_{te} F_{td}

90° $F_t = \sqrt{F_{te}^2 + F_{td}^2}$



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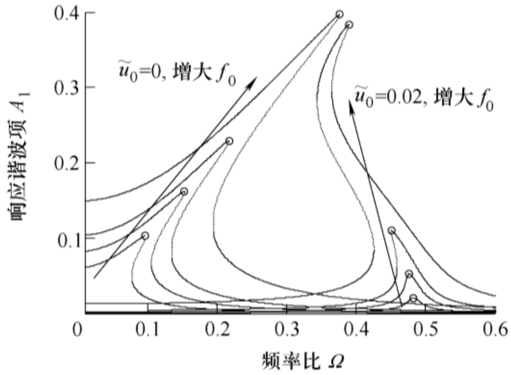

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$$T_{fn} = \frac{\sqrt{\left(\alpha A_1^3\right)^2 + \left(2\zeta\Omega A_1\right)^2}}{f_0} \tag{21}$$

(9)

$$\tilde{x}(\tau) = A_0' + A_1\cos(\Omega\tau + \varphi) \tag{22}$$

$A_0' = A_0 - \alpha_2/(3\alpha_3)$

$$F_{te} = \alpha_1\tilde{x} + \alpha_2\tilde{x}^2 + \alpha_3\tilde{x}^3 \tag{23}$$

(22) (23)

$$F_{te} = F_{t0} + F_{t1}\cos(\Omega\tau + \varphi) \tag{24}$$

$$F_{t0} = \alpha_1 A_0' + 2\alpha_2 A_0' A_1 + \frac{3\alpha_2 A_1^2}{2} + \alpha_3 A_0'^3 + \frac{3\alpha_3 A_0' A_1^2}{2}$$

$$F_{t1} = \alpha_1 A_1 + 2\alpha_2 A_0' A_1 + \frac{3}{4}\alpha_3 A_1^3 + 3\alpha_3 A_0'^2 A_1$$

$$T_{fn} = \frac{\sqrt{\left(F_{t1}\right)^2 + \left(2\zeta\Omega A_1\right)^2}}{F_0} \tag{25}$$

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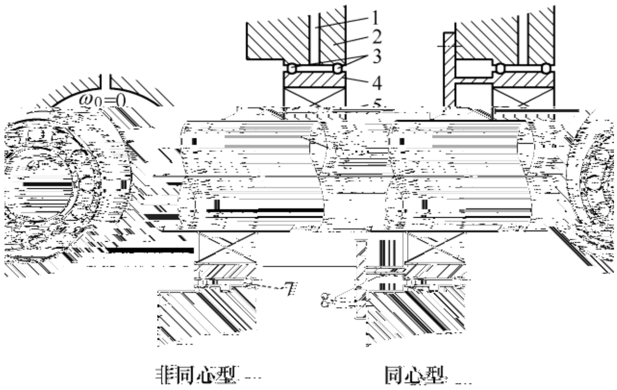

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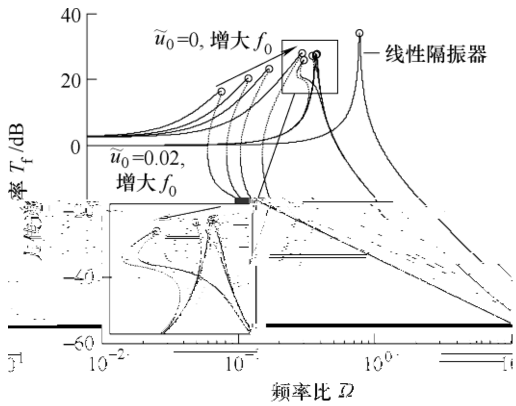

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$\tilde{u}_0 = 0$

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