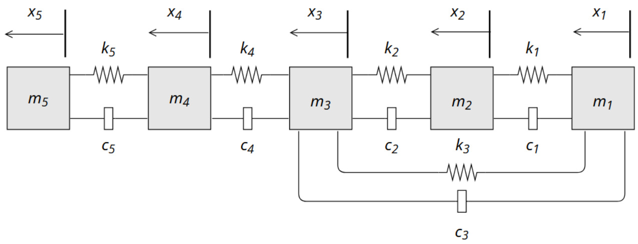
inter.noise

21-24 AUGUST
SCOTTISH EVENT CAMPUS
GLASGOW
2022

m_2 , m_1

m_3 m_4 m_5



$$L = T - V$$
$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{x}_i}\right) - \frac{\partial L}{\partial x_i} = Q_i$$

T V Q T V Q

$$\{\ddot{x}\} + [M]^{-1}[C]\{\dot{x}\} + [M]^{-}1[K]\{x\} = [M]^{-}1\{F\}$$

$$[M] = \begin{bmatrix} m_1 & 0 & 0 & 0 & 0 \\ 0 & m_2 & 0 & 0 & 0 \\ 0 & 0 & m_3 & 0 & 0 \\ 0 & 0 & 0 & m_4 & 0 \\ 0 & 0 & 0 & 0 & m_5 \end{bmatrix} [K] = \begin{bmatrix} k_1 + k_3 & -k_1 & -k_3 & 0 & 0 \\ k_1 & k_1 + k_2 & -k_2 & 0 & 0 \\ -k_3 & -k_2 & k_2 + k_3 + k_4 & -k_4 & 0 \\ 0 & 0 & -k_4 & k_4 + k_5 & -k_5 \\ 0 & 0 & 0 & -k_5 & k_5 \end{bmatrix}$$

$$[C] = \begin{bmatrix} c_1 + c_3 & -c_1 & -c_3 & 0 & 0 \\ c_1 & c_1 + c_2 & -c_2 & 0 & 0 \\ -c_3 & -c_2 & c_2 + c_3 + c_4 & -c_4 & 0 \\ 0 & 0 & -c_4 & c_4 + c_5 & -c_5 \\ 0 & 0 & 0 & -c_5 & c_5 \end{bmatrix} [F] = \begin{bmatrix} F_p \\ 0 \\ F_p \\ F_p \\ F_{medic} \end{bmatrix} [x] = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{bmatrix}$$

k_5 k_4

k_3

k_2 k_1

$$x_m = \begin{bmatrix} x \\ \dot{x} \end{bmatrix}$$

$$\dot{x_m} = A_m x_m + B_m F_m$$

$$A_m = \begin{bmatrix} 0_{5X5} & I_{5X5} \\ -M^{-1}K & -M^{-1}C \end{bmatrix} \; B_m = \begin{bmatrix} 1/m_1 & 0 & 1/_m3 & 1/m_4 & 0 & 0_{1X5} \\ 0 & 0 & 0 & 0 & -1/m_5 & 0_{1X5} \end{bmatrix} \; F_m = [F_P]$$

ǒ C_{AS}

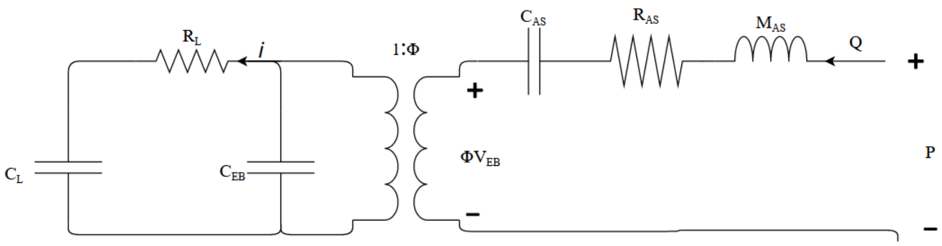
M_{AS} P R_{AS}

Q

ǒ C_{EB}

R_L C_L

ū



C_L C_{EB} R_L .
V_{EB}

$$\dot{V_{EB}} = R_L \frac{di}{dt} + (\frac{1}{C_L} + \frac{1}{C_{EB}})i$$

V_{EB}

$$\frac{di}{dt} = \frac{\Phi}{R_L C_{EB}} Q - \frac{1}{R_L}(\frac{1}{C_L} + \frac{1}{C_{EB}})i$$

$$\ddot{Q} = -\frac{1}{M_{AS}}(\frac{\phi^2}{C_{EB}} + \frac{1}{C_{AS}})Q - \frac{R_{AS}}{M_{AS}}\dot{Q} + \frac{\phi}{M_{AS}C_{EB}}i + \frac{\dot{P}}{M_{AS}}$$

C_{AS} M_{AS} R_{AS} , d_A
w r

s
c

$$\frac{dN_r}{dr} + \frac{N_r - N_\theta}{r} = 0$$

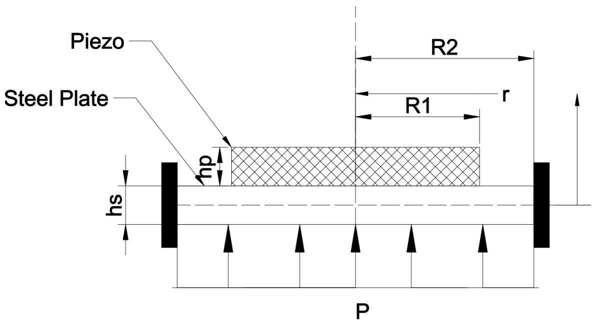
$$Q_r = \frac{dM_r}{dr} + \frac{M_r - M_\theta}{r}$$

N_r N M_r
M Q_r

P

$Q_r = \frac{\partial N}{C}$

u r u r



$$\frac{d^2\theta}{dr^2} + \frac{1}{r}\frac{d\theta}{dr} - \frac{\theta}{r^2} = -\frac{Q_r}{D_{11}^r}$$

$$\frac{d^2u}{dr^2} + \frac{1}{r}\frac{du}{dr} - \frac{u}{r^2} = -\frac{Q_r\alpha}{D_{11}^r}$$

D^r_{11}

u r

$$w^c(r) = c_1^c\left(\frac{r^2 - R_2^2}{2}\right) - \frac{P(r^4 - R_1^4)}{64D_{11}^{r(c)}} + c_1^s\left[\frac{R_1^2 - R_2^2}{2} - R_2^2 ln\left(\frac{R_1}{R_2}\right)\right] + \frac{P}{64D_{11}^{(s)}}\left[4R_2^4 ln\left(\frac{R_1}{R_2}\right) - R_1^4 + R_2^4\right]$$

$$w^s(r) = c_1^s\left[\frac{r^2 - R_2^2}{2} - R_2^2 ln\left(\frac{r}{R_2}\right)\right] + \frac{P}{64D_{11}^{(s)}}\left[4R_2^4 ln\left(\frac{r}{R_2}\right) - r^4 + R_2^4\right]$$

$$x_c = \begin{bmatrix} x_m \\ x_e \end{bmatrix}$$

$$\dot{x}_c = A_c x_c + B_c F_m$$
$$V = C_c x_c$$

V

$$A_c = \begin{bmatrix} A_m & 0_{8X3} \\ B_e C_m A_m & A_e \end{bmatrix} \quad B_c = \begin{bmatrix} B_m \\ B_e C_m B_m \end{bmatrix} \quad C_c = \begin{bmatrix} 0_{1X8} & C_e \end{bmatrix}$$

$$x_e = \begin{bmatrix} Q \\ \dot{Q} \\ i \end{bmatrix} \quad A_e = \begin{bmatrix} 0 & 1 & 0 \\ -\frac{1}{M_{AS}}(\frac{\phi^2}{C_{EB}}\frac{1}{C_{AS}}) & -\frac{R_{AS}}{M_{AS}} & \frac{\phi}{M_{AS}C_{EB}} \\ \frac{\Phi}{R_L C_{EB}} & 0 & -\frac{1}{R_L}(\frac{1}{C_L}+\frac{1}{C_{EB}}) \end{bmatrix} \quad B_e = \begin{bmatrix} 0 \\ \frac{1}{M_{AS}} \\ 0 \end{bmatrix}$$

$$C_e = \begin{bmatrix} 0 & 0 & R_L \end{bmatrix} \quad C_m = \frac{1}{A_s}\begin{bmatrix} k_1 & -k_1 & 0 & 0 & 0 & c_1 & -c_1 & 0 & 0 & 0 \end{bmatrix}$$

V

F_m H_p

H_p o o ᴗ ∫ o o ∫ ɔ ɔ л

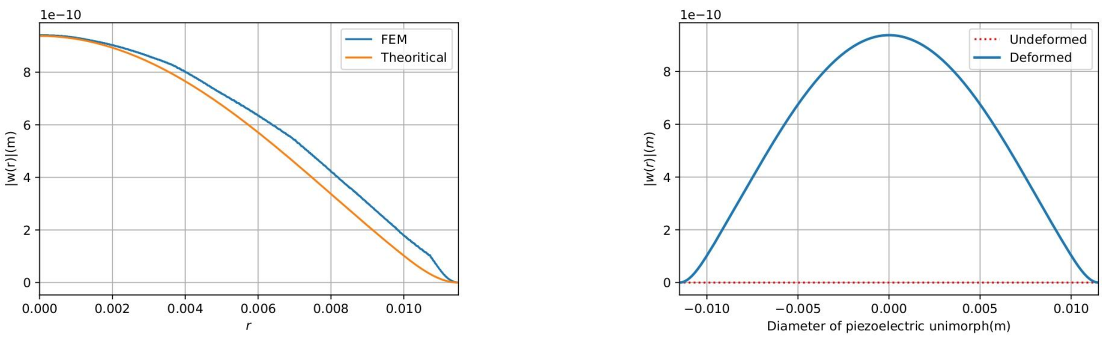
$l\,o\,g_{10}\,H_p$

w r

r

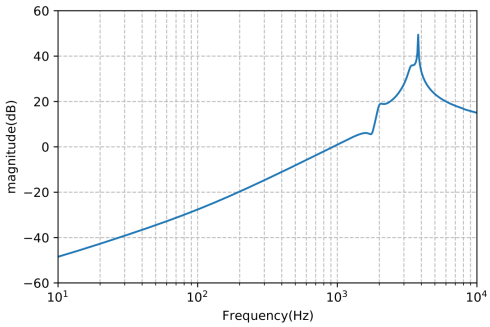
R_2	
R_1	
h_s	
h_p	

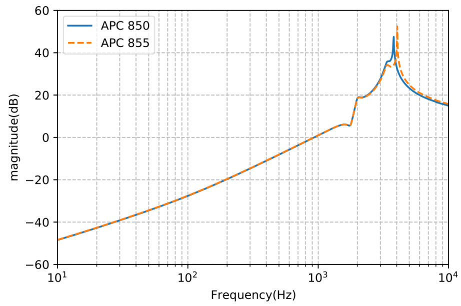
E_s
E_p
s
p



1e−10
FEM
Theoritical
|w(r)|(m)
0
2
4
6
8
0.000
0.002
0.004
0.006
0.008
0.010
r
1e−10
Undeformed
Deformed
|w(r)|(m)
0
2
4
6
8
−0.010
−0.005
0.000
0.005
0.010
Diameter of piezoelectric unimorph(m)

w


60
40
20
0
−20
−40
−60
magnitude(dB)
10^1
10^2
10^3
10^4
Frequency(Hz)


APC 850
APC 855
60
40
20
0
−20
−40
−60
magnitude(dB)
10^1
10^2
10^3
10^4
Frequency(Hz)