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Digital twins for intelligent production of submarine optical fibers

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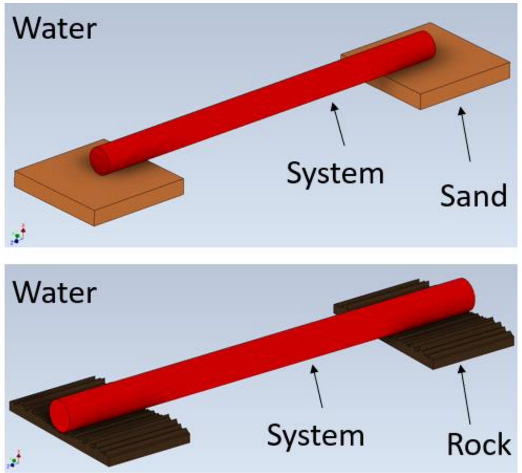
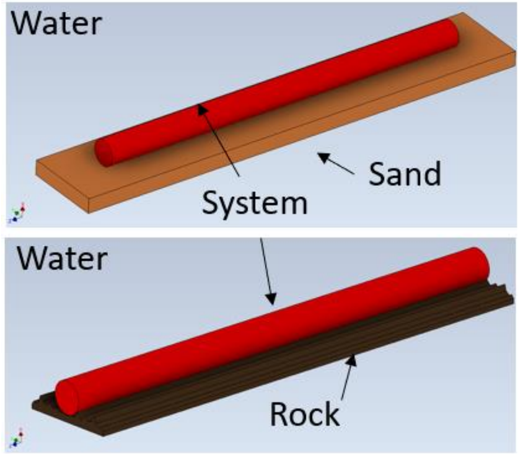
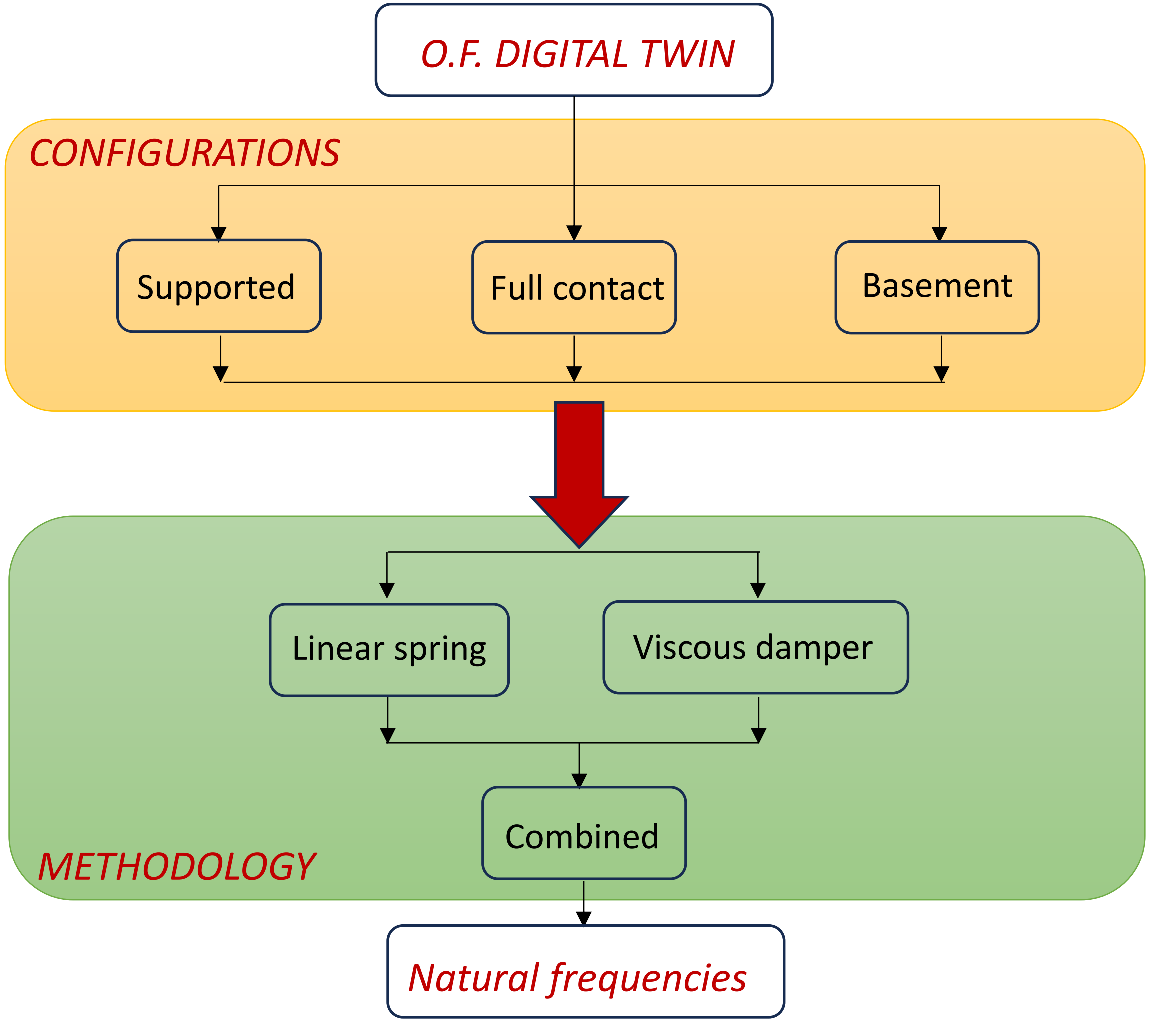
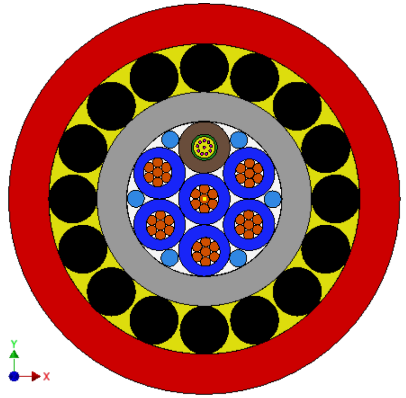
Study methodology



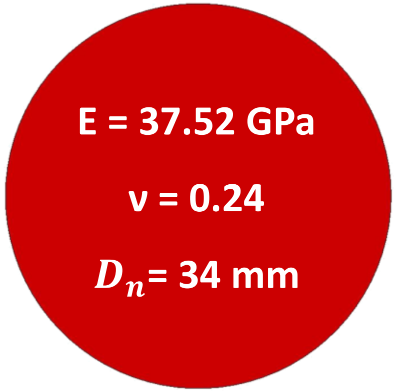




Real Model



Study Model



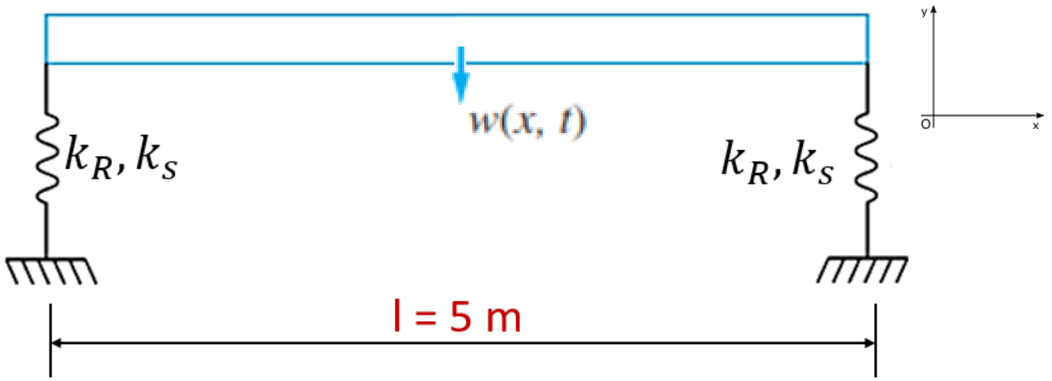
Study Model: Supported

$$\frac{\partial^2 \omega}{\partial t^2}+\frac{\partial^4 \omega}{\partial x^4}=\frac{f_m L^3}{EI} f(x,t) \;\Rightarrow\; \omega(x,t)=X(x)\cdot T(t) \;\xrightarrow{\text{f = 0 (Free vibration)}}\; \frac{1}{T(t)}\frac{d^2T}{dt^2}=-\frac{1}{X(x)}\frac{d^4X}{dx^4}$$

$$T(t)=A\cos\sqrt{\lambda}+B\sin\sqrt{\lambda}$$

$$X(x)=C_1\cos\lambda^{\frac{1}{4}}+C_2\sin\lambda^{\frac{1}{4}}+C_3\cosh\lambda^{\frac{1}{4}}+C_4\sinh\lambda^{\frac{1}{4}}$$

Linear spring:



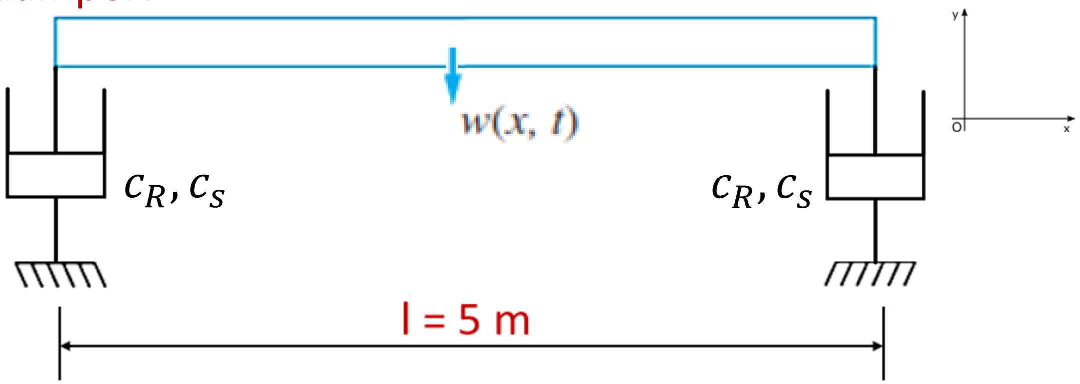
Boundary Condition

$$x=0 \rightarrow \frac{\partial^2\omega}{\partial x^2}=0 \quad and \quad \frac{\partial^3\omega}{\partial x^3}=-\beta\omega$$

$$x=5 \rightarrow \frac{\partial^2\omega}{\partial x^2}=0 \quad and \quad \frac{\partial^3\omega}{\partial x^3}=\beta\omega$$

$$\beta=\frac{kL^3}{EI}$$

Viscous damper:



Boundary Condition

$$x=0 \rightarrow \frac{\partial^2\omega}{\partial x^2}=0 \quad and \quad \frac{\partial^3\omega}{\partial x^3}=-\beta\frac{\partial\omega}{\partial t}$$

$$x=5 \rightarrow \frac{\partial^2\omega}{\partial x^2}=0 \quad and \quad \frac{\partial^3\omega}{\partial x^3}=\beta\frac{\partial\omega}{\partial t}$$

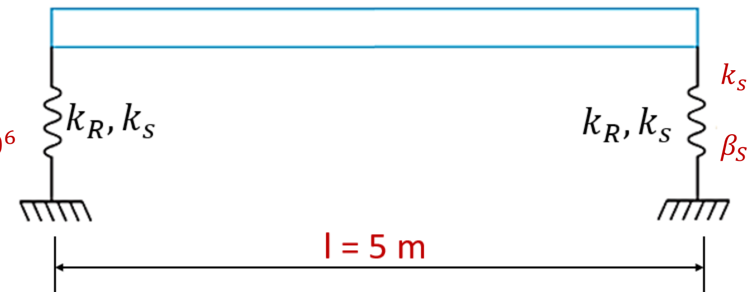
$$\beta=\frac{cL}{\sqrt{\rho EIA}}$$

Study Model: Supported

Linear spring:

$k_R = 5 \; x \; 10^7 \, \frac{N}{m}$

$\beta_R = \frac{kL^3}{EI} = 2.4 \; x \; 10^6$



$k_s = 1.5 \; x \; 10^5 \, \frac{N}{m}$

$\beta_S = \frac{kL^3}{EI} = 7.62x10^3$

$$\begin{pmatrix} -\sqrt{L} & 0 & \sqrt{L} & 0 \\ B & -L^{3/4} & -B & L^{3/4} \\ -\sqrt{L}\cos(\sigma_1) & -\sqrt{L}\sin(\sigma_1) & \sqrt{L}\cosh(\sigma_1) & \sqrt{L}\sinh(\sigma_1) \\ L^{3/4}\sin(\sigma_1) - B\cos(\sigma_1) & -B\sin(\sigma_1) - L^{3/4}\cos(\sigma_1) & L^{3/4}\sinh(\sigma_1) - B\cosh(\sigma_1) & -B\sinh(\sigma_1) - L^{3/4}\cosh(\sigma_1) \end{pmatrix}$$

[A]: Coefficient Matrix

where $\sigma_1 = 5\, L^{1/4}$

Natural frequencies

$$\det[A] = 0 \rightarrow 2\,L^{5/2} - 2\,L^{5/2}\cosh(\sigma_1)^2 + 2\,B\,L^{7/4}\cos(\sigma_1)\sinh(\sigma_1) - 2\,B\,L^{7/4}\cosh(\sigma_1)\sin(\sigma_1) = 0$$

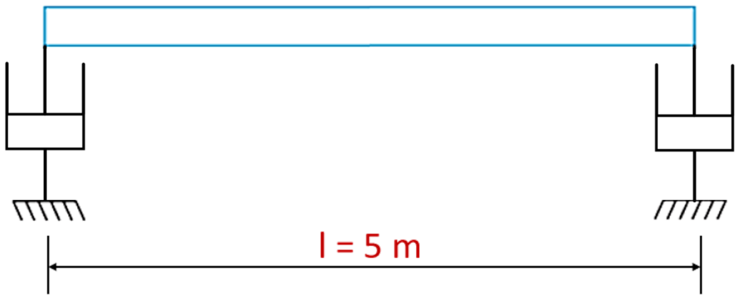
$$\lambda_R = 0.38, 3.99, 17.62, 40.51 \rightarrow \omega = \sqrt{\frac{\lambda EI}{\mu L^4}} \rightarrow \boldsymbol{\omega_R = 1 - 3.24 - 6.8 - 10.31} \left[\frac{rad}{s}\right]$$

$$\lambda_S = 0.38, 3.71, 17.62, 40.51 \rightarrow \omega = \sqrt{\frac{\lambda EI}{\mu L^4}} \rightarrow \boldsymbol{\omega_R = 1 - 3.12} \left[\frac{rad}{s}\right]$$

Viscous damper:

$c_r = 2 \; x \; 10^4 \, \frac{Ns}{m}$

$\beta_R =$



$c_s = 10^3 \, \frac{Ns}{m}$

$\beta_S =$

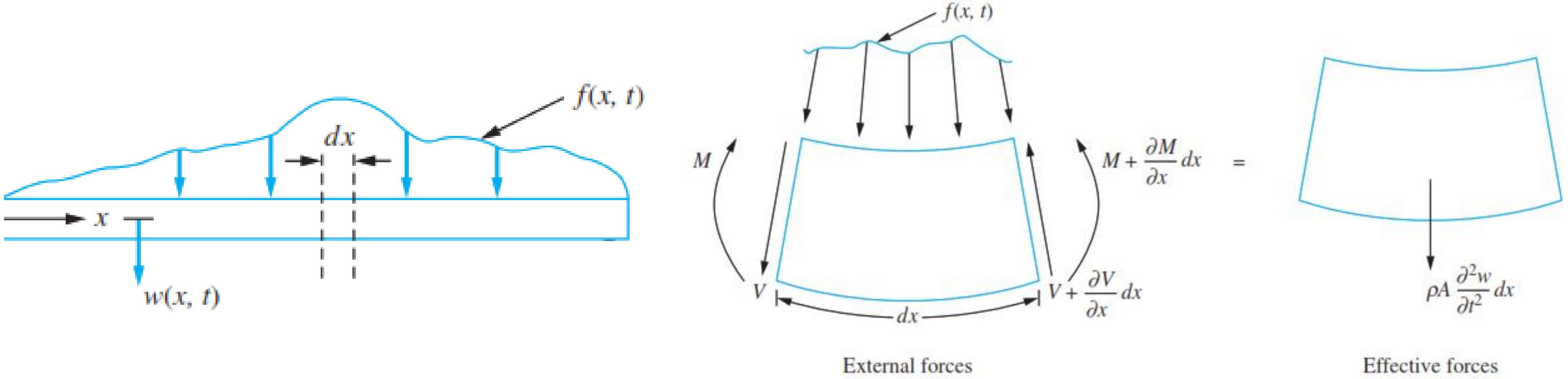
Natural frequencies

$$\beta = \frac{cL}{\sqrt{\rho EIA}} = XXX$$

$$\det[A] = 0 \rightarrow WORK\ IN\ PROGRESS$$

Future developments

- Finite element analysis to verify the analytical model
- If working, FEM analysis to the other case studies (faster analysis)
- Calculation of the value of f(x, t) in the different study configurations



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Thank you for your attention