

# P-4F Electromechanical characteristics matrix

Stiffness coefficient matrix

$$\begin{bmatrix} C_{11}^E & C_{12}^E & C_{13}^E & 0 & 0 & 0 \\ C_{12}^E & C_{11}^E & C_{13}^E & 0 & 0 & 0 \\ C_{13}^E & C_{13}^E & C_{33}^E & 0 & 0 & 0 \\ 0 & 0 & 0 & C_{44}^E & 0 & 0 \\ 0 & 0 & 0 & 0 & C_{55}^E & 0 \\ 0 & 0 & 0 & 0 & 0 & C_{66}^E \end{bmatrix} = \begin{bmatrix} 20.3 & 13.6 & 11.8 & 0 & 0 & 0 \\ 13.6 & 20.3 & 11.8 & 0 & 0 & 0 \\ 11.8 & 11.8 & 13.5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2.5 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2.5 & 0 \\ 0 & 0 & 0 & 0 & 0 & 3.4 \end{bmatrix} \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \left. \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \right]^E 10^{10} N/m^2$$

$$\begin{bmatrix} C_{11}^D & C_{12}^D & C_{13}^D & 0 & 0 & 0 \\ C_{12}^D & C_{11}^D & C_{13}^D & 0 & 0 & 0 \\ C_{13}^D & C_{13}^D & C_{33}^D & 0 & 0 & 0 \\ 0 & 0 & 0 & C_{44}^D & 0 & 0 \\ 0 & 0 & 0 & 0 & C_{55}^D & 0 \\ 0 & 0 & 0 & 0 & 0 & C_{66}^D \end{bmatrix} = \begin{bmatrix} 22 & 15.2 & 10 & 0 & 0 & 0 \\ 15.2 & 22 & 10 & 0 & 0 & 0 \\ 10 & 10 & 17.4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 5.3 & 0 & 0 \\ 0 & 0 & 0 & 0 & 5.3 & 0 \\ 0 & 0 & 0 & 0 & 0 & 3.4 \end{bmatrix} \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \left. \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \right]^D 10^{10} N/m^2$$

Elastic Flexibility Coefficient Matrix

$$\begin{bmatrix} S_{11}^E & S_{12}^E & S_{13}^E & 0 & 0 & 0 \\ S_{12}^E & S_{11}^E & S_{13}^E & 0 & 0 & 0 \\ S_{13}^E & S_{13}^E & S_{33}^E & 0 & 0 & 0 \\ 0 & 0 & 0 & S_{44}^E & 0 & 0 \\ 0 & 0 & 0 & 0 & S_{55}^E & 0 \\ 0 & 0 & 0 & 0 & 0 & S_{66}^E \end{bmatrix} = \begin{bmatrix} 11.1 & -3.6 & -6.5 & 0 & 0 & 0 \\ -3.6 & 11.1 & -6.5 & 0 & 0 & 0 \\ -6.5 & -6.5 & 18.8 & 0 & 0 & 0 \\ 0 & 0 & 0 & 39.4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 39.4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 29.5 \end{bmatrix} \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \left. \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \right]^E 10^{-12} m^2/N$$

$$\begin{bmatrix} S_{11}^D & S_{12}^D & S_{13}^D & 0 & 0 & 0 \\ S_{12}^D & S_{11}^D & S_{13}^D & 0 & 0 & 0 \\ S_{13}^D & S_{13}^D & S_{33}^D & 0 & 0 & 0 \\ 0 & 0 & 0 & S_{44}^D & 0 & 0 \\ 0 & 0 & 0 & 0 & S_{55}^D & 0 \\ 0 & 0 & 0 & 0 & 0 & S_{66}^D \end{bmatrix} = \begin{bmatrix} 9.4 & -5.4 & -2.5 & 0 & 0 & 0 \\ -5.4 & 9.4 & -2.5 & 0 & 0 & 0 \\ -2.5 & -2.5 & 9.5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 19 & 0 & 0 \\ 0 & 0 & 0 & 0 & 19 & 0 \\ 0 & 0 & 0 & 0 & 0 & 29.5 \end{bmatrix} \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \left. \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \right]^D 10^{-12} m^2/N$$

Piezoelectric constant matrix

$$\begin{bmatrix} 0 & 0 & 0 & 0 & d_{15} & 0 \\ 0 & 0 & 0 & d_{24} & 0 & 0 \\ d_{31} & d_{31} & d_{33} & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 580 & 0 \\ 0 & 0 & 0 & 580 & 0 & 0 \\ -160 & -160 & 350 & 0 & 0 & 0 \end{bmatrix} \quad 10^{12} \text{C/N}$$

$$\begin{bmatrix} 0 & 0 & 0 & 0 & g_{15} & 0 \\ 0 & 0 & 0 & g_{24} & 0 & 0 \\ g_{31} & g_{31} & g_{33} & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 34.7 & 0 \\ 0 & 0 & 0 & 34.7 & 0 & 0 \\ -12 & -12 & 26.4 & 0 & 0 & 0 \end{bmatrix} \quad 10^{-3} \text{Vm/N}$$

$$\begin{bmatrix} 0 & 0 & 0 & 0 & e_{15} & 0 \\ 0 & 0 & 0 & e_{24} & 0 & 0 \\ e_{31} & e_{31} & e_{33} & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 14.9 & 0 \\ 0 & 0 & 0 & 14.9 & 0 & 0 \\ -11 & -11 & 11.3 & 0 & 0 & 0 \end{bmatrix} \quad \text{C/m}^2$$

$$\begin{bmatrix} 0 & 0 & 0 & 0 & h_{15} & 0 \\ 0 & 0 & 0 & h_{24} & 0 & 0 \\ h_{31} & h_{31} & h_{33} & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 18.3 & 0 \\ 0 & 0 & 0 & 18.3 & 0 & 0 \\ -16 & -16 & 17 & 0 & 0 & 0 \end{bmatrix} \quad 10^8 \text{V/m}$$

Clamped dielectric constant Matrix

$$\begin{bmatrix} \epsilon_{11}^S/\epsilon_0 & 0 & 0 \\ 0 & \epsilon_{11}^S/\epsilon_0 & 0 \\ 0 & 0 & \epsilon_{33}^S/\epsilon_0 \end{bmatrix} = \begin{bmatrix} 920 & 0 & 0 \\ 0 & 920 & 0 \\ 0 & 0 & 750 \end{bmatrix}^S$$

Free dielectric constant matrix

$$\begin{bmatrix} \epsilon_{11}^T/\epsilon_0 & 0 & 0 \\ 0 & \epsilon_{11}^T/\epsilon_0 & 0 \\ 0 & 0 & \epsilon_{33}^T/\epsilon_0 \end{bmatrix} = \begin{bmatrix} 1910 & 0 & 0 \\ 0 & 1910 & 0 \\ 0 & 0 & 1490 \end{bmatrix}^T$$

