

# P-4D Electromechanical characteristics matrix

Stiffness coefficient matrix

$$\begin{bmatrix} C_{11}^E & C_{12}^E & C_{13}^E & 0 & 0 & 0 \\ C_{12}^E & C_{11}^E & C_{13}^E & 0 & 0 & 0 \\ C_{13}^E & C_{13}^E & C_{33}^E & 0 & 0 & 0 \\ 0 & 0 & 0 & C_{44}^E & 0 & 0 \\ 0 & 0 & 0 & 0 & C_{55}^E & 0 \\ 0 & 0 & 0 & 0 & 0 & C_{66}^E \end{bmatrix} = \begin{bmatrix} 15.8 & 9.7 & 9.2 & 0 & 0 & 0 \\ 9.7 & 15.8 & 9.2 & 0 & 0 & 0 \\ 9.2 & 9.2 & 12.3 & 0 & 0 & 0 \\ 0 & 0 & 0 & 4.4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 4.4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 3.1 \end{bmatrix} \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \left. \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \right]^E \quad 10^{10} N/m^2$$

$$\begin{bmatrix} C_{11}^D & C_{12}^D & C_{13}^D & 0 & 0 & 0 \\ C_{12}^D & C_{11}^D & C_{13}^D & 0 & 0 & 0 \\ C_{13}^D & C_{13}^D & C_{33}^D & 0 & 0 & 0 \\ 0 & 0 & 0 & C_{44}^D & 0 & 0 \\ 0 & 0 & 0 & 0 & C_{55}^D & 0 \\ 0 & 0 & 0 & 0 & 0 & C_{66}^D \end{bmatrix} = \begin{bmatrix} 16.2 & 10.1 & 8.1 & 0 & 0 & 0 \\ 10.1 & 16.2 & 8.1 & 0 & 0 & 0 \\ 8.1 & 8.1 & 16.2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 8.6 & 0 & 0 \\ 0 & 0 & 0 & 0 & 8.6 & 0 \\ 0 & 0 & 0 & 0 & 0 & 3.1 \end{bmatrix} \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \left. \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \right]^D \quad 10^{10} N/m^2$$

Elastic Flexibility Coefficient Matrix

$$\begin{bmatrix} S_{11}^E & S_{12}^E & S_{13}^E & 0 & 0 & 0 \\ S_{12}^E & S_{11}^E & S_{13}^E & 0 & 0 & 0 \\ S_{13}^E & S_{13}^E & S_{33}^E & 0 & 0 & 0 \\ 0 & 0 & 0 & S_{44}^E & 0 & 0 \\ 0 & 0 & 0 & 0 & S_{55}^E & 0 \\ 0 & 0 & 0 & 0 & 0 & S_{66}^E \end{bmatrix} = \begin{bmatrix} 12.4 & -4 & -6.3 & 0 & 0 & 0 \\ -4 & 12.4 & -6.3 & 0 & 0 & 0 \\ -6.3 & -6.3 & 17.5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 22.9 & 0 & 0 \\ 0 & 0 & 0 & 0 & 22.9 & 0 \\ 0 & 0 & 0 & 0 & 0 & 32.8 \end{bmatrix} \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \left. \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \right]^E \quad 10^{-12} m^2/N$$

$$\begin{bmatrix} S_{11}^D & S_{12}^D & S_{13}^D & 0 & 0 & 0 \\ S_{12}^D & S_{11}^D & S_{13}^D & 0 & 0 & 0 \\ S_{13}^D & S_{13}^D & S_{33}^D & 0 & 0 & 0 \\ 0 & 0 & 0 & S_{44}^D & 0 & 0 \\ 0 & 0 & 0 & 0 & S_{55}^D & 0 \\ 0 & 0 & 0 & 0 & 0 & S_{66}^D \end{bmatrix} = \begin{bmatrix} 11 & -5.4 & -2.9 & 0 & 0 & 0 \\ -5.4 & 11 & -2.9 & 0 & 0 & 0 \\ -2.9 & -2.9 & 9.5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 11.7 & 0 & 0 \\ 0 & 0 & 0 & 0 & 11.7 & 0 \\ 0 & 0 & 0 & 0 & 0 & 32.8 \end{bmatrix} \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \left. \begin{matrix} \\ \\ \\ \\ \\ \\ \end{matrix} \right]^D \quad 10^{-12} m^2/N$$

Piezoelectric constant matrix

$$\begin{bmatrix} 0 & 0 & 0 & 0 & d_{15} & 0 \\ 0 & 0 & 0 & d_{24} & 0 & 0 \\ d_{31} & d_{31} & d_{33} & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 380 & 0 \\ 0 & 0 & 0 & 380 & 0 & 0 \\ -140 & -140 & 310 & 0 & 0 & 0 \end{bmatrix} \quad 10^{12} \text{C/N}$$

$$\begin{bmatrix} 0 & 0 & 0 & 0 & g_{15} & 0 \\ 0 & 0 & 0 & g_{24} & 0 & 0 \\ g_{31} & g_{31} & g_{33} & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 29.4 & 0 \\ 0 & 0 & 0 & 29.4 & 0 & 0 \\ -11 & -11 & 25.8 & 0 & 0 & 0 \end{bmatrix} \quad 10^{-3} \text{Vm/N}$$

$$\begin{bmatrix} 0 & 0 & 0 & 0 & e_{15} & 0 \\ 0 & 0 & 0 & e_{24} & 0 & 0 \\ e_{31} & e_{31} & e_{33} & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 16.7 & 0 \\ 0 & 0 & 0 & 16.7 & 0 & 0 \\ -5.2 & -5.2 & 13.9 & 0 & 0 & 0 \end{bmatrix} \quad \text{C/m}^2$$

$$\begin{bmatrix} 0 & 0 & 0 & 0 & h_{15} & 0 \\ 0 & 0 & 0 & h_{24} & 0 & 0 \\ h_{31} & h_{31} & h_{33} & 0 & 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 & 25.2 & 0 \\ 0 & 0 & 0 & 25.2 & 0 & 0 \\ -8 & -8 & 21.4 & 0 & 0 & 0 \end{bmatrix} \quad 10^8 \text{V/m}$$

Clamped dielectric constant Matrix

$$\begin{bmatrix} \epsilon_{11}^S/\epsilon_0 & 0 & 0 \\ 0 & \epsilon_{11}^S/\epsilon_0 & 0 \\ 0 & 0 & \epsilon_{33}^S/\epsilon_0 \end{bmatrix} = \begin{bmatrix} 750 & 0 & 0 \\ 0 & 750 & 0 \\ 0 & 0 & 730 \end{bmatrix}^S$$

Free dielectric constant matrix

$$\begin{bmatrix} \epsilon_{11}^T/\epsilon_0 & 0 & 0 \\ 0 & \epsilon_{11}^T/\epsilon_0 & 0 \\ 0 & 0 & \epsilon_{33}^T/\epsilon_0 \end{bmatrix} = \begin{bmatrix} 1470 & 0 & 0 \\ 0 & 1470 & 0 \\ 0 & 0 & 1350 \end{bmatrix}^T$$

