

## Matrixes of DL-54HD

### Stiffness Matrix

$$\begin{pmatrix} C_{11} & C_{12} & C_{13} & 0 & 0 & 0 \\ C_{12} & C_{11} & C_{13} & 0 & 0 & 0 \\ C_{13} & C_{13} & C_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & C_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & C_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & C_{66} \end{pmatrix}^E = \begin{pmatrix} 17.6 & 12.5 & 11.6 & 0 & 0 & 0 \\ 12.5 & 17.6 & 11.6 & 0 & 0 & 0 \\ 11.6 & 11.6 & 13.1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 2.7 & 0 & 0 \\ 0 & 0 & 0 & 0 & 2.7 & 0 \\ 0 & 0 & 0 & 0 & 0 & 2.5 \end{pmatrix}^E 10^{10} N/m^2$$

$$\begin{pmatrix} C_{11} & C_{12} & C_{13} & 0 & 0 & 0 \\ C_{12} & C_{11} & C_{13} & 0 & 0 & 0 \\ C_{13} & C_{13} & C_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & C_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & C_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & C_{66} \end{pmatrix}^D = \begin{pmatrix} 19.0 & 13.9 & 10.7 & 0 & 0 & 0 \\ 13.9 & 19.0 & 10.7 & 0 & 0 & 0 \\ 10.7 & 10.7 & 16.2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 6.1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 6.1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 2.5 \end{pmatrix}^D 10^{10} N/m^2$$

### Elastic Matrix

$$\begin{pmatrix} S_{11} & S_{12} & S_{13} & 0 & 0 & 0 \\ S_{12} & S_{11} & S_{13} & 0 & 0 & 0 \\ S_{13} & S_{13} & S_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & S_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & S_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & S_{66} \end{pmatrix}^E = \begin{pmatrix} 15.1 & -4.7 & -9.2 & 0 & 0 & 0 \\ -4.7 & 15.1 & -9.2 & 0 & 0 & 0 \\ -9.2 & -9.2 & 23.9 & 0 & 0 & 0 \\ 0 & 0 & 0 & 36.3 & 0 & 0 \\ 0 & 0 & 0 & 0 & 36.3 & 0 \\ 0 & 0 & 0 & 0 & 0 & 39.6 \end{pmatrix}^E 10^{-12} m^2/N$$

$$\begin{pmatrix} S_{11} & S_{12} & S_{13} & 0 & 0 & 0 \\ S_{12} & S_{11} & S_{13} & 0 & 0 & 0 \\ S_{13} & S_{13} & S_{33} & 0 & 0 & 0 \\ 0 & 0 & 0 & S_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & S_{55} & 0 \\ 0 & 0 & 0 & 0 & 0 & S_{66} \end{pmatrix}^D = \begin{pmatrix} 12.5 & -7.2 & -3.5 & 0 & 0 & 0 \\ -7.2 & 12.5 & -3.5 & 0 & 0 & 0 \\ -3.5 & -3.5 & 10.8 & 0 & 0 & 0 \\ 0 & 0 & 0 & 16.4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 16.4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 39.4 \end{pmatrix}^D 10^{-12} m^2/N$$

### Matrix of Clamp Dielectric Constant

$$\begin{pmatrix} \epsilon_{11} & 0 & 0 \\ 0 & \epsilon_{11} & 0 \\ 0 & 0 & \epsilon_{33} \end{pmatrix}^s = \begin{pmatrix} 1660 & 0 & 0 \\ 0 & 1660 & 0 \\ 0 & 0 & 1710 \end{pmatrix}^s$$

### Matrix of Free Dielectric Constant

$$\begin{pmatrix} \epsilon_{11} & 0 & 0 \\ 0 & \epsilon_{11} & 0 \\ 0 & 0 & \epsilon_{33} \end{pmatrix}^T = \begin{pmatrix} 3680 & 0 & 0 \\ 0 & 3680 & 0 \\ 0 & 0 & 4600 \end{pmatrix}^T$$

### Piezoelectric Constant Matrixes

$$\begin{pmatrix} 0 & 0 & 0 & 0 & d_{15} & 0 \\ 0 & 0 & 0 & d_{24} & 0 & 0 \\ d_{31} & d_{31} & d_{33} & 0 & 0 & 0 \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 0 & 805 & 0 \\ 0 & 0 & 0 & 805 & 0 & 0 \\ -320 & -320 & 730 & 0 & 0 & 0 \end{pmatrix} 10^{-12} C/N$$

$$\begin{pmatrix} 0 & 0 & 0 & 0 & g_{15} & 0 \\ 0 & 0 & 0 & g_{24} & 0 & 0 \\ g_{31} & g_{31} & g_{33} & 0 & 0 & 0 \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 0 & 24.7 & 0 \\ 0 & 0 & 0 & 24.7 & 0 & 0 \\ -7.9 & -7.9 & 17.9 & 0 & 0 & 0 \end{pmatrix} 10^{-3} Vm/N$$

$$\begin{pmatrix} 0 & 0 & 0 & 0 & e_{15} & 0 \\ 0 & 0 & 0 & e_{24} & 0 & 0 \\ e_{31} & e_{31} & e_{33} & 0 & 0 & 0 \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 0 & 21.7 & 0 \\ 0 & 0 & 0 & 21.7 & 0 & 0 \\ -11.6 & -11.6 & 21.4 & 0 & 0 & 0 \end{pmatrix} C/m^2$$

$$\begin{pmatrix} 0 & 0 & 0 & 0 & h_{15} & 0 \\ 0 & 0 & 0 & h_{24} & 0 & 0 \\ h_{31} & h_{31} & h_{33} & 0 & 0 & 0 \end{pmatrix} = \begin{pmatrix} 0 & 0 & 0 & 0 & 15.1 & 0 \\ 0 & 0 & 0 & 15.1 & 0 & 0 \\ -6.8 & -6.8 & 12.1 & 0 & 0 & 0 \end{pmatrix} 10^8 V/m$$