Question 7

Q: How to input the parameters of anisotropic materials?

A: Please refer to the next slides.

Additional Information

Murata Software

- Piezoelectric material is anisotropic. Input elastic and piezoelectric properties, and permittivity in the form of a matrix.
- Be aware that the suffix for the compliance matrix may be represented as S, and the suffix for the stiffness matrix may be represented as C in the material supplier's data sheets. This is due to their technological background.
- The matrix has a symmetry. The elements only in the lower triangular matrix are required for setting material properties. The elements in gray on the right diagram are not required.
- Material data sheets may not always list all the values of elements. Required properties may need to be calculated using some laws with respect to those properties.
- Femtet may already specify the default value of 0 to some elements. The value other than 0 is special.

*In the event of quartz or other single crystals, a value other than 0 may be specified to an element that would have a default value of 0.

Elasticity (Compliance) Matrix

S11					
S21	S22				
S31	S32	S33			
0.0	0.0	0.0	S44		
0.0	0.0	0.0	0.0	S55	
0.0	0.0	0.0	0.0	0.0	S66

Piezoelectricity Matrix

0.0	0.0	0.0	0.0	d15	0.0
0.0	0.0	0.0	d24	0.0	0.0
d31	d32	d33	0.0	0.0	0.0

Relative Permittivity Matrix

ε11		
0.0	ε22	
0.0	0.0	C33

Additional Information

Murata Software

Example: Piezoelectric Ceramic (Hexagonal Crystal) d-Form

- The input locations in a matrix differ due to the varying symmetry of material properties based on the type of piezoelectric material or crystal system.
- The relations below are known when d-form is used for piezoelectric ceramics.

  S22=S11

  S32=S31

  S55=S44

  d32=d31

  d24=d15

  ε22=ε11

Elasticity (Compliance) Matrix (S^E)

S11					
S21	S11				
S31	S31	S33			
0.0	0.0	0.0	S44		
0.0	0.0	0.0	0.0	S44	
0.0	0.0	0.0	0.0	0.0	S66

Piezoelectricity Matrix (d)

0.0	0.0	0.0	0.0	d15	0.0
0.0	0.0	0.0	d15	0.0	0.0
d31	d31	d33	0.0	0.0	0.0

Relative Permittivity Matrix (ε^T)

ε11		
0.0	ε22	
0.0	0.0	C33

Additional Information

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Example: Quartz (Trigonal Crystal) e-Form

- The input locations in a matrix differ due to the varying symmetry of material properties based on the type of piezoelectric material or crystal system.

- The relations below are known when e-form is used for quartz.

  C22=C11
  C32=C31
  C55=C44
  C42=-C41
  C65=C41
  C66=0.5*(C11-C12)
  e12=-e11
  e25=-e14
  e26=-e11
  ε22=ε11

Elasticity (Stiffness) Matrix (C^E)

C11					
C21	C11				
C31	C31	C33			
C41	-C41	0.0	C44		
0.0	0.0	0.0	0.0	C44	
0.0	0.0	0.0	0.0	C41	C66

Piezoelectricity Matrix (e)

d11	-d11	0.0	d14	0.0	0.0
0.0	0.0	0.0	0.0	-d14	-d11
0.0	0.0	0.0	0.0	0.0	0.0

Relative Permittivity Matrix (ε^S)

ε11		
0.0	ε22	
0.0	0.0	C33