Piezoelectric material properties from datasheet to one in COMSOL Multiphysics

2023-01-17

Vibration and Acoustic Transducers Laboratory

Pohang University of Science and Technology

Woongji Kim

wj.kim@postech.ac.kr

References

https://www.comsol.com/blogs/piezoelectric-materials-understanding-standards/

https://doc.comsol.com/5.5/doc/com.comsol.help.sme/sme_ug_theory.06.23.html#3440115

https://support.onscale.com/hc/en-us/articles/360002073378-Calculating-Piezoelectric-Material-Properties-from-Material-Datasheet

https://www.efunda.com/formulae/solid_mechanics/mat_mechanics/hooke_orthotropic.cfm

https://www.efunda.com/formulae/solid_mechanics/mat_mechanics/strain.cfm#engstrain

from Datasheet

```
cE = Inf(6);
dET = zeros(3,6);
% Fuji ceramics, C-21
cE(1,1) = 8.3e10;
cE(3,3) = 6.4e10;
cE(5,5) = 2.3e10;
nu      = 0.29;
dET(3,1)= -131e-12;
dET(3,3)= 288e-12;
dET(1,5)= 634e-12;

% % Fuji ceramics, C-6
% cE(1,1) = 6.2e10;
% cE(3,3) = 4.9e10;
% cE(5,5) = 1.9e10;
% nu      = 0.32;
% dET(3,1)= -210e-12;
% dET(3,3)= 472e-12;
% dET(1,5)= 758e-12;
```

Strain-charge form

Compliance matrix, s_E

```
cE(2,2) = cE(1,1);
cE(4,4) = cE(5,5);
cE(6,6) = cE(1,1)/(2*(1+nu));

sE_T = cE.^(-1);
sE_T(2,3) = -nu*sE_T(3,3);
sE_T(1,3) = sE_T(2,3);
sE_T(1,2) = -nu*sE_T(2,2);

sE = sE_T + triu(sE_T,1)'
```

```
sE = 6×6
10^-10 ×
    0.1205   -0.0349   -0.0453         0         0         0
   -0.0349    0.1205   -0.0453         0         0         0
   -0.0453   -0.0453    0.1562         0         0         0
         0         0         0    0.4348         0         0
         0         0         0         0    0.4348         0
         0         0         0         0         0    0.3108
```

```
% for COMSOL Multiphysics
sE_C = strings(1,21);
k = 1;
for i=1:6
    for j=1:i
        sE_C(k) = strcat(num2str(sE(i,j)), "[1/Pa]");
        k = k + 1;
    end
end
sE_C = strjoin(sE_C,',')
```

```
sE_C =
"1.2048e-11[1/Pa],-3.494e-12[1/Pa],1.2048e-11[1/Pa],-4.5312e-12[1/Pa],-4.5312e-12[1/Pa],1.5625e-11[1/Pa],0[1/Pa],0[1
```

Piezoelectric charge constants, d

```
dET(2,4) = dET(1,5);
dET(3,2) = dET(3,1);
dET
```

```
dET = 3×6
10^-9 ×
         0         0         0         0    0.6340         0
         0         0         0    0.6340         0         0
   -0.1310   -0.1310    0.2880         0         0         0
```

```
% for COMSOL Multiphysics
dET_C = strings(1,18);
k = 1;
```

```
for i=1:6
    for j=1:3
        dET_C(k) = strcat(num2str(dET(j,i)), "[C/N]");
        k = k + 1;
    end
end
dET_C = strjoin(dET_C,',')
```

```
dET_C =
"0[C/N],0[C/N],-1.31e-10[C/N],0[C/N],0[C/N],-1.31e-10[C/N],0[C/N],0[C/N],2.88e-10[C/N],0[C/N],6.34e-10[C/N],0[C/N],6
```

Stress-charge form

Stiffness matrix, c_{E}

```
cE = inv(sE)
```

```
cE = 6×6
10^11 ×
    1.1654    0.5220    0.4894         0         0         0
    0.5220    1.1654    0.4894         0         0         0
    0.4894    0.4894    0.9238         0         0         0
         0         0         0    0.2300         0         0
         0         0         0         0    0.2300         0
         0         0         0         0         0    0.3217
```

```
% for COMSOL Multiphysics
cE_C = strings(1,21);
k = 1;
for i=1:6
    for j=1:i
        cE_C(k) = strcat(num2str(cE(i,j)), "[Pa]");
        k = k + 1;
    end
end
cE_C = strjoin(cE_C,',')
```

```
cE_C =
"116543179979.4456[Pa],52202094708.1278[Pa],116543179979.4456[Pa],48936129659.3963[Pa],48936129659.3963[Pa],9238295
```

Piezoelectric stress constants, e

```
% eES = dET*cE
eES = dET/sE    % for better calculation method in MATLAB
```

```
eES = 3×6
         0         0         0         0   14.5820         0
         0         0         0   14.5820         0         0
   -8.0120   -8.0120   13.7850         0         0         0
```

```
% for COMSOL Multiphysics
eES_C = strings(1,18);
k = 1;
for i=1:6
    for j=1:3
```

```
        eES_C(k) = strcat(num2str(eES(j,i)), "[C/m^2]");
        k = k + 1;
    end
end
eES_C = strjoin(eES_C,',')
```

```
eES_C =
"0[C/m^2],0[C/m^2],-8.012[C/m^2],0[C/m^2],0[C/m^2],-8.012[C/m^2],0[C/m^2],0[C/m^2],13.785[C/m^2],0[C/m^2],14.582[C/m
```