

Tutorial Excel program for ANSYS piezoelectric simulation

(Extended program from S. Imaoka, Engineering consultant)

http://ansys.net/tips/Week13_TNT_Conversion_of_Piezoelectric_Material_Data.pdf

On the Input Sheet page, select the kind of ceramic by the rolling menu “material type” (red circle). Inform the material number of piezo element (blue circle). It is the only thing you need to do!

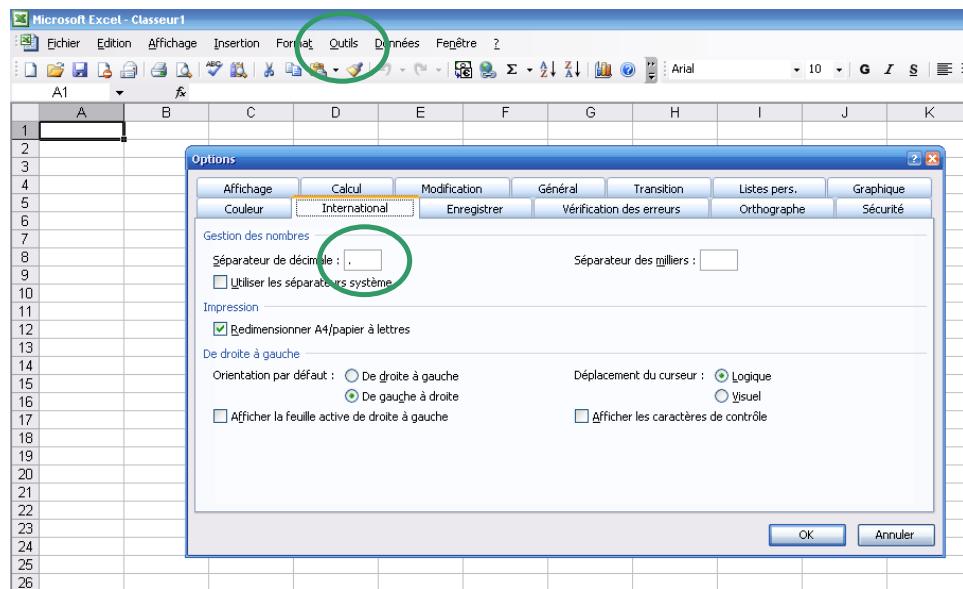
	A	B	C	D	E	F	G	H	I
1		Material type	Pz34						
2	p	Pz29					Pz21	Pz23	Pz25
3	d ₃₁	Pz34	/m ³				7.78E+03	7.70E+03	7.70E+03
4	d ₃₃	Pz35	/V				-2.59E-10	-1.28E-10	-5.80E-10
5	d ₁₅	Pz37	/V				6.40E-10	3.28E-10	1.48E-10
6	d ₁₅	Pz46	/V				6.16E-10	4.21E-10	1.51E-10
7	s ^E ₁₁	Pz52	/s ² /kg				1.82E-11	1.48E-11	1.05E-11
8	s ^E ₃₃	Pz54	/s ² /kg				1.80E-11	1.94E-11	1.36E-11
9	s ^E ₁₂	Pz26, FEM use	/s ² /kg				-7.76E-12	-5.84E-12	-3.13E-12
10	s ^E ₁₃		/s ² /kg				-6.85E-12	-7.12E-12	-4.77E-12
11	s ^E ₄₄		/s ² /kg				3.80E-11	3.90E-11	2.30E-11
12	s ^E ₆₆		/s ² /kg				5.20E-11	4.13E-11	2.72E-11
13	$\varepsilon_1/\varepsilon_0$		(unitless)				3.24E+03	1.37E+03	8.10E+02
14	$\varepsilon_3/\varepsilon_0$		(unitless)				3.98E+03	1.50E+03	4.25E+02
15	Material number		5						
16	ε_0		8.05E-12 F/m						
17									
18	E ₁		N/m ²						
19	E ₃		N/m ²						

The list of ceramic materials can be extended by fulfil the parameters in the next columns (column U to DD). The 3 next pages give the ANSYS program according to the polarized axis (X, Y or Z). Just copy the blue field and directly waste it in your ANSYS File.

1	/com	Pz34	Z-polarized
2			
3	/com	Stiffness	
4	TB,	ANEL,	5 , 1 , 0
5	TBDATA,	1,	1.4465E+11 , 3.2795E+10 , 1.3014E+10
6	TBDATA,	7,	1.4465E+11 , 1.3014E+10
7	TBDATA,	12,	1.3877E+11
8	TBDATA,	16,	5.5927E+10
9	TBDATA,	19,	5.8106E+10
10	TBDATA,	21,	5.8106E+10
11			
12	/com	Piezoelectric	
13	TB,	PIEZ,	5
14	TBDATA,	3,	-0.3471
15	TBDATA,	6,	-0.3471
16	TBDATA,	9,	6.2447
17	TBDATA,	14,	2.5170
18	TBDATA,	16,	2.5170
19			
20	/com	Permittivity	
21	EMUNIT	EPZRO,	8.85E-12
22	MP,	PERX,	5 , 224
23	MP,	PERY,	5 , 224
24	MP,	PERZ,	5 , 175
25	/com	Density	

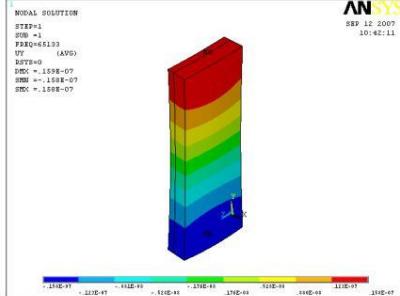
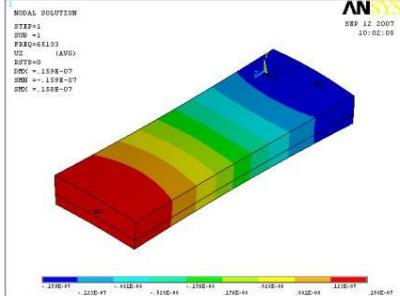
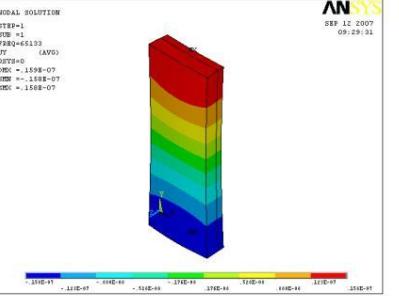
Other pages are the matrix shape fulfilled by the selected parameters (stiffness, piezoelectric, permittivity).

① Advertising: for French users, you must change the options of Excel software to have a point as decimal separation, in order to waste directly the lines code into the ansys file.
In the menu : « Outils/Options/International/Séparateur de décimale », select point.



Validation

The validation of matrix transformation has been performed with a bimorph bender in elongation mode.

X polarized	Y polarized	Z polarized
 <p>NODAL SOLUTION STEP=1 SUB =1 PRIM=65133 US RTF=0 (ANS) RDTF=0 DMC =-.1588E-07 DMR =-.1588E-07 SMDC =.1588E-07</p>	 <p>NODAL SOLUTION STEP=1 SUB =1 PRIM=65133 US RTF=0 (ANS) RDTF=0 DMC =-.1588E-07 DMR =-.1588E-07 SMDC =.1588E-07</p>	 <p>NODAL SOLUTION STEP=1 SUB =1 PRIM=65133 US RTF=0 (ANS) RDTF=0 DMC =-.1588E-07 DMR =-.1588E-07 SMDC =.1588E-07</p>

Results

Static analysis

Capacitance=2.715nF

Modal analysis

resonance freq=65.13kHz

anti-res freq.=64.416kHz

kinetic energy=0.3634e-4J

maximal displacement=0.391um

electrical charge=-0.6839e-7C

Results

Static analysis

Capacitance=2.715nF

Modal analysis

resonance freq=65.13kHz

anti-res freq.=64.415kHz

kinetic energy=0.3693e-4J

maximal displacement=0.395um

electrical charge=-0.6907e-7C

Results

Static analysis

Capacitance=2.715nF

Modal analysis

resonance freq=65.13kHz

anti-res freq.=64.415kHz

kinetic energy=0.3669e-4J

maximal displacement=0.393um

electrical charge=-0.687e-7C

The relative error between each configuration is negligible and essentially due to the meshing precision.

Following code is about the X polarized configuration:

First file: parameters	Second file: geometry, element type and meshing
<pre>***** ! geometrical parameters of piezo bender * ! (Francois Pigache 2007) * ***** /prep7 emunit,mks ***** ! isotropic material properties * ***** density_copper=8900 young_copper=96e9 poisson_copper=0.3 ***** ! Main dimensions * ***** th=2e-3 ! copper thickness length=25e-3 ! copper length width=10e-3 ! copper width th_cer=1e-3 ! ceramic thickness</pre>	<pre>***** ! design of the Bender polarized in X direction * ! (Francois Pigache 2007) * ***** /prep7 csys,0 BTOL,1e-6 !precision ***** ! design blocks * ***** wpoff,-th_cer,0,0 BLC4, 0,0, th_cer, length, width wpoff,th_cer,0,0 BLC4, 0,0, th, length, width vsel,all vglue,all ***** ! element type * ***** et,1,solid98,0 ! element 3D structural KEYOPT,1,3,1 et,2,solid92 allsel ***** ! Ceramic properties ***** /com Pz26 X-polarized /com Stiffness TB, ANEL, 1 , 1 , 0 TBDATA, 1, 1.2264E+11 , , 9.9905E+10 , 9.9905E+10 TBDATA, 7, 1.6800E+11 , , 1.1035E+11 TBDATA, 12, 1.6800E+11 TBDATA, 16, 3.0126E+10 TBDATA, 19, 2.8825E+10 TBDATA, 21, 3.0126E+10 /com Piezo matrix TB, PIEZ 1 TBDATA, 1, 14.6913 TBDATA, 4, -2.8012 TBDATA, 7, -2.8012 TBDATA, 11, 9.8568 TBDATA, 18, 9.8568 /com Permittivity EMUNIT, EPZRO, 8.85E-12 MP, PERX, 1 , 701 MP, PERY, 1 , 829 MP, PERZ, 1 , 829 /com Density MP, DENS, 1 , 7700 ***** ! isotropic material properties ***** mp,dens,2,density_copper mp,ex,2,young_copper mp,nuxy,2,poisson_copper ***** ! Material affiliation ***** VSEL,all VSEL,s,loc,x,-th_cer,0 !ceramic selection VATT,1,,1 ! material 1 attribution VSEL,all VSEL,s,loc,x,0,th !copper selection VATT,2,,1 ! material 2 attribution ***** ! MESHING ***** allsel esize,th_cer, vmesh,all</pre>

	allsel finish
Third file: static analysis	Fourth file: modal analysis (short-circuited ceramic)

```

!*****
Calculation of Capacitance
!*****


/PREP7
NSEL,S,LOC,x,0
cp,1,volt,all
*get,n_ground,node,0,num,min
                                         ! component n°1 ground

allsel
NSEL,S,LOC,x,-th_cer
cp,3,volt,all
electrode
*get,n_supply,node,0,num,min
allsel
                                         ! component n°2 top

!*****
!      Loads on electrodes
!*****


d,n_ground,volt,0      ! Apply 0 voltage to the ground electrode
d,n_supply,volt,1      ! Apply unit voltage to top electrode
allsel,all

fini

/solu
antype,static          ! Static analysis
solve
*get,Cp,node,n_supply,rf,amps ! use AMPS label with SOLIDS5
Cp = abs(Cp)           ! C = Q/V, where V = 1 Volt
ALLSEL
FINISH

!*****
Results
!*****


/com, -----
/com,     Equivalent parameter of the piezoelement
/com,
/com, Static primary capacitance Cp = %Cp% F

/PREP7
*ddele,all,volt        !delete loads
allsel,all
FINISH

```

```

!*****
! modal analysis with short-circuited ceramic
!*****


/PREP7
NSEL,S,LOC,x,0
cp,1,volt,all
*get,n_ground,node,0,num,min
                                         ! component n°1 ground

allsel
NSEL,S,LOC,x,-th_cer
cp,3,volt,all
electrode
*get,n_supply,node,0,num,min
allsel
                                         ! component n°2 top

!*****
!      Parameters of simulation
!*****


freqstart=60000
freqstop=80000
nbremode=5
                                         !*****

!      Loads on electrodes
!*****


allsel,all
d,n_ground,volt,0      ! Apply 0 voltage to the ground electrode
d,n_supply,volt,0      ! Apply 0 voltage to top electrode
ALLSEL
FINISH

/SOLU
ANTYPE,2
MSAVE,0
!*
MODOPT,LANB,nbremode
EQSLV,SPAR
MXPAND,nbremode, , ,1
LUMPM,0
PSTRES,0
!*
MODOPT,LANB,nbremode,freqstart,freqstop, ,ON

solve
finish

/POST1
SET,LIST
FINISH

```