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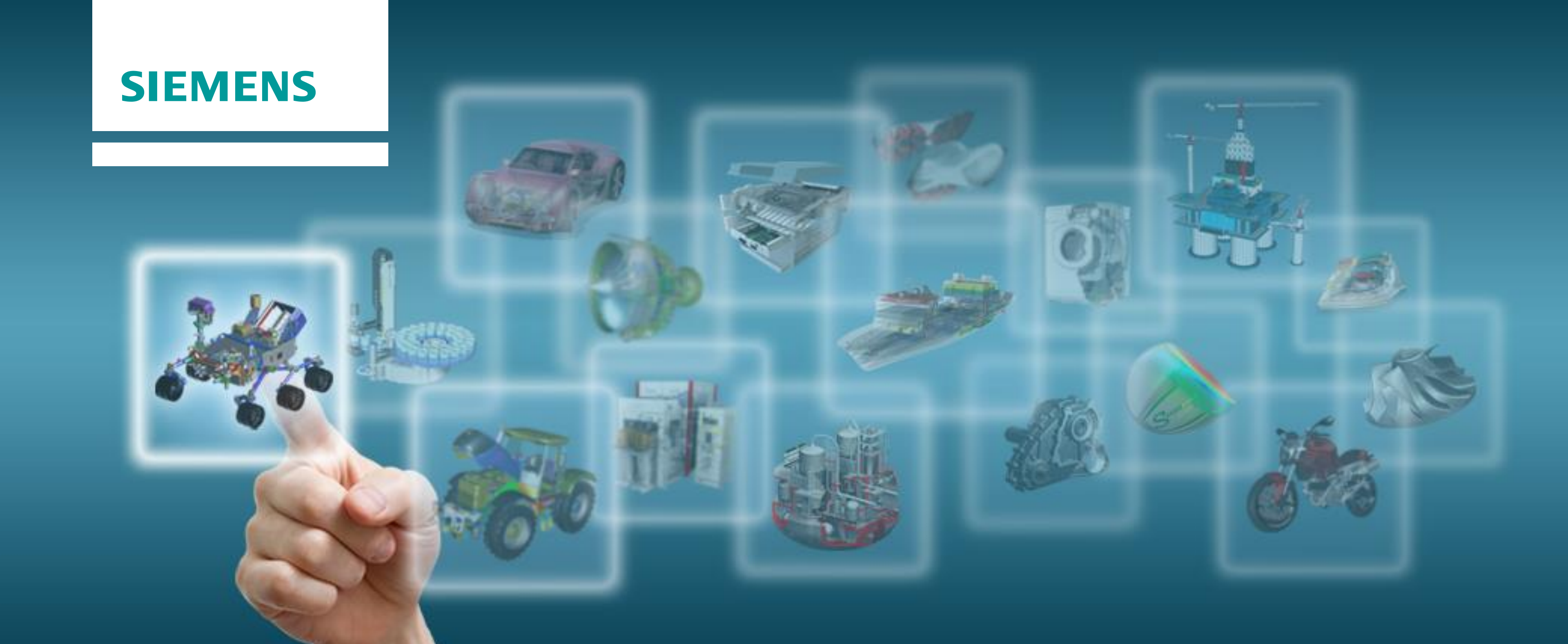

ARRAYCON - ESR1

Smart structures modelling and model order reduction techniques for feasible distributed active damping solutions

ZhongZhe DONG

Smarter decisions, better products.

Future activities and difficultes

PAPER SUMMARY:

1. Introduction
   Citing references and the description for the use of this method
2. Neutral surface location for a wafer bonded to a plate
   The arguments of the method to find the new neutral surface in the section of the structure, relation with the excisted method
3. Smart materials' strain variation analysis
   Focus on the bending moment, to show how to estimate the curvature and the strain
4. Results comparison and discussion
   some FEM simulation results compare with the analytical results
   comparison between the analytical results with the references results
5. Conclusion

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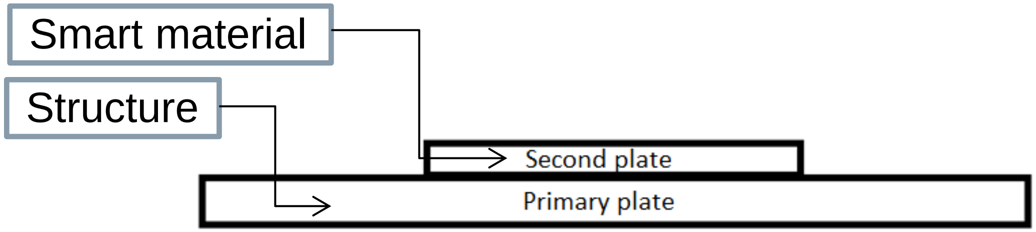
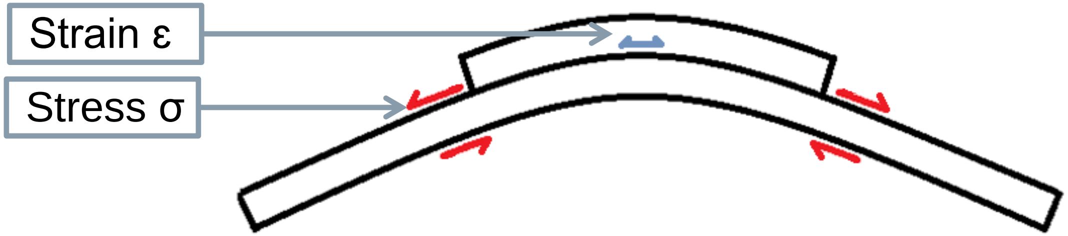
Recent work

DONE:

1. Mechanical coupling analysis between primary panel and smart material
2. Mechanical coupling simulations





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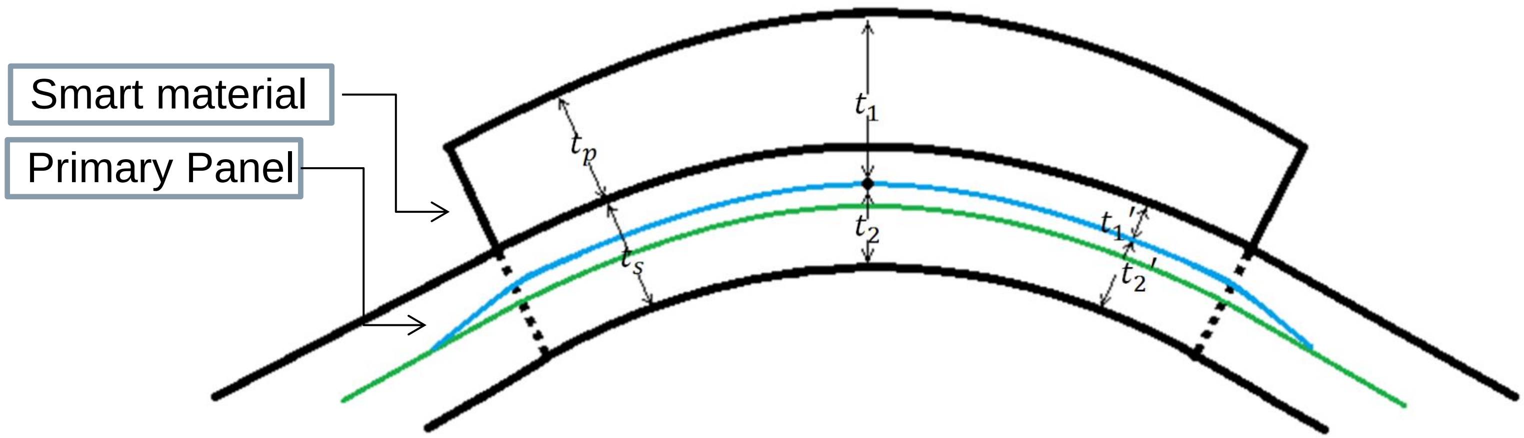
MECHANICAL ANALYSIS:

Kirchhoff's plate hypothesizes satisfied!!!



a) Existence of the neutral aix in the primary panel
b) Retention of the neutral axis in the primary panel section
c) Smart material in tension and bending
d) Exaltation of the neutral axis' location

Recent work

MECHANICAL ANALYSIS:

Determinate the neutral axis location

The normal efforts on the neutral axis = null

$$N_x = -\frac{E^+ {t_1'}^2}{2(1-(\vartheta^+)^2)}\left(\frac{\partial^2 w}{\partial x^2} + \vartheta^+ \frac{\partial^2 w}{\partial y^2}\right) - \frac{E_p[(t_1' + t_p)^2 - {t_1'}^2]}{2\left(1-(\vartheta_p)^2\right)}\left(\frac{\partial^2 w}{\partial x^2} + \nu_p \frac{\partial^2 w}{\partial y^2}\right) + \frac{E^- {t_2}^2}{2(1-(\vartheta^-)^2)}\left(\frac{\partial^2 w}{\partial x^2} + \vartheta^- \frac{\partial^2 w}{\partial y^2}\right) = 0$$

$$N_y = -\frac{E^+ {t_1'}^2}{2(1-(\vartheta^+)^2)}\left(\frac{\partial^2 w}{\partial y^2} + \vartheta^+ \frac{\partial^2 w}{\partial x^2}\right) - \frac{E_p[(t_1' + t_p)^2 - {t_1'}^2]}{2\left(1-(\vartheta_p)^2\right)}\left(\frac{\partial^2 w}{\partial y^2} + \nu_p \frac{\partial^2 w}{\partial x^2}\right) + \frac{E^- {t_2}^2}{2(1-(\vartheta^-)^2)}\left(\frac{\partial^2 w}{\partial y^2} + \vartheta^- \frac{\partial^2 w}{\partial x^2}\right) = 0$$

After the simplification

$$\frac{E_s({t_2}^2 - {t_1'}^2)}{2(1-\nu_s)} = \frac{E_p[(t_1' + t_p)^2 - {t_p}^2]}{2(1-\nu_p)}$$

with t= $t_p + t_s, = t_1 + t_2$ & $t_s = t_1' + t_2$

Finally

$$t_1' = \frac{\alpha {t_s}^2 - \beta {t_p}^2}{2(\beta t_p + \alpha t_s)},$$ which, $\alpha = \frac{1-\nu_p}{1-\nu_s}$ & $\beta = \frac{E_p}{E_s}$

So

$$t_1 = t_p + t_1' \;\&\; t_2 = t - t_1$$

Test case: $\alpha = \beta = 1$ (Isotropic homogenous materials): $t_1 = t_2 = \frac{t}{2}$

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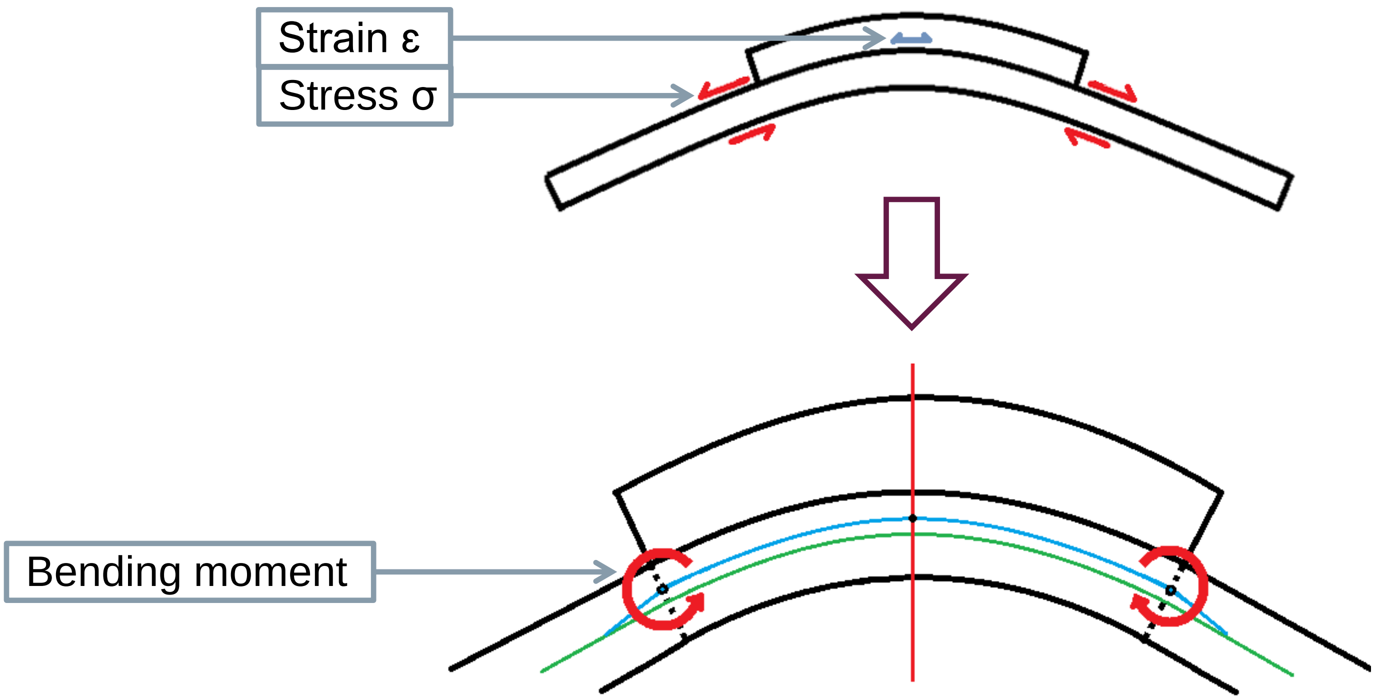
Mechanical analysis:

Determinate the strain in the smart material

Conservation of the moments in x and y directions



Recent work

MECHANICAL ANALYSIS:

$$M_x: -a\frac{E^+{t_1}^3}{3(1-(\vartheta^+)^2)}\left(\theta_x+\vartheta^+\theta_y\right)-a\frac{E^-{t_2}^3}{3(1-(\vartheta^-)^2)}\left(\theta_x+\vartheta^-\theta_y\right)-a'\frac{E_p\left[({t_1}'+t_p)^3-{t_1}'^3\right]}{3\left(1-(\nu_p)^2\right)}\left(\theta_x+\nu_p\theta_y\right)=-a\frac{E_s t^3}{12(1-\nu^2)}\left(\theta_x^s+\vartheta\theta_y^s\right)$$

$$M_y: -b\frac{E^+{t_1}^3}{3(1-(\vartheta^+)^2)}\left(\theta_y+\vartheta^+\theta_x\right)-b\frac{E^-{t_2}^3}{3(1-(\vartheta^-)^2)}\left(\theta_y+\vartheta^-\theta_x\right)-b'\frac{E_p[({t_1}'+t_p)^3-{t_1}'^3]}{3(1-(\nu_p)^2)}\left(\theta_y+\nu_p\theta_x\right)=-b\frac{E_s t^3}{12(1-\nu^2)}\left(\theta_y^s+\vartheta\theta_x^s\right)$$

$\theta_x=\frac{\partial^2 w}{\partial x^2}$ & $\theta_y=\frac{\partial^2 w}{\partial y^2}$: curvature of the neutral layer in x & y directions

With

$$\varepsilon_{xx}=-z\frac{\partial^2 w}{\partial x^2}=-z\theta_x$$

$$\varepsilon_{yy}=-z\frac{\partial^2 w}{\partial y^2}=-z\theta_y$$

Finally,

$$\varepsilon_{xx}=\frac{2z}{t_s}\left[\frac{\left[(aD\gamma_1-bD\gamma_3\nu_s){\varepsilon_{xx}}^s+(aD\gamma_2\nu_s-bD\gamma_3){\varepsilon_{yy}}^s\right]}{(\gamma_1\gamma_2-\gamma_3\gamma_4)}\right]$$

$$\varepsilon_{yy}=\frac{2z}{t_s}\left[\frac{\left[(aD\gamma_2-bD\gamma_1\nu_s){\varepsilon_{xx}}^s+(aD\gamma_4\nu_s-bD\gamma_1){\varepsilon_{yy}}^s\right]}{(\gamma_3\gamma_4-\gamma_1\gamma_2)}\right]$$

$\gamma_1, \gamma_2, \gamma_3, \gamma_4$: factors from the Moments equations

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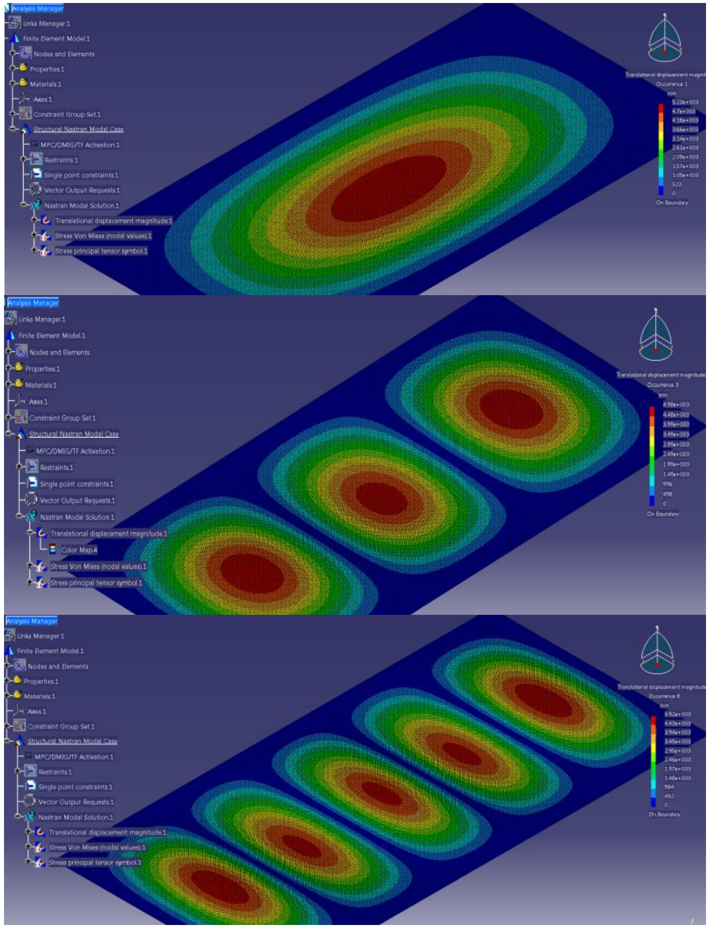
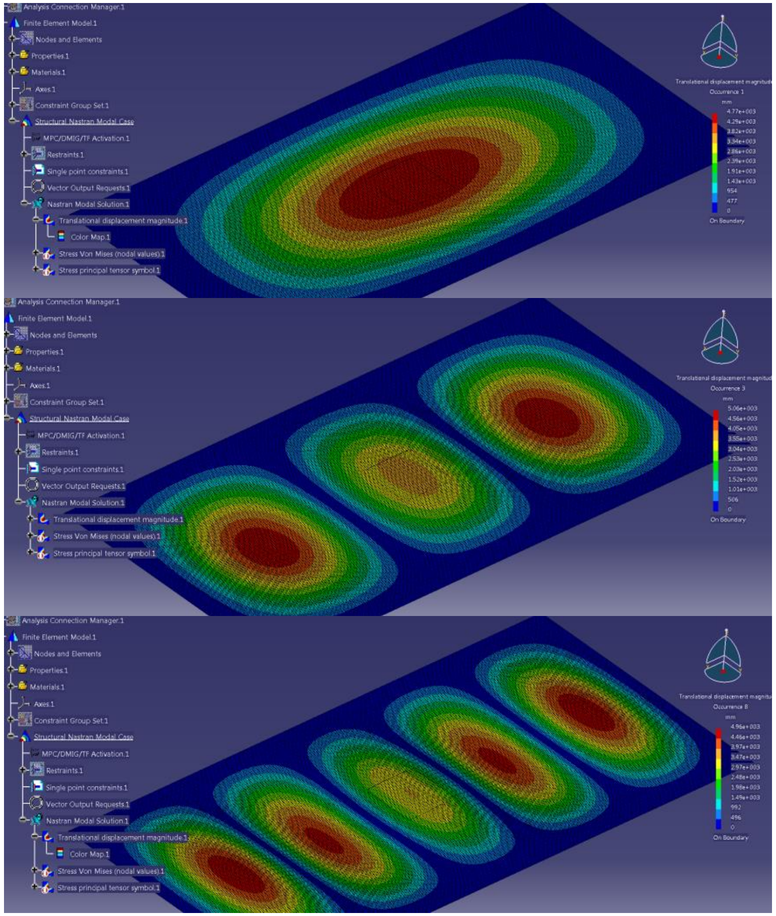
One smart material numerical simulations:





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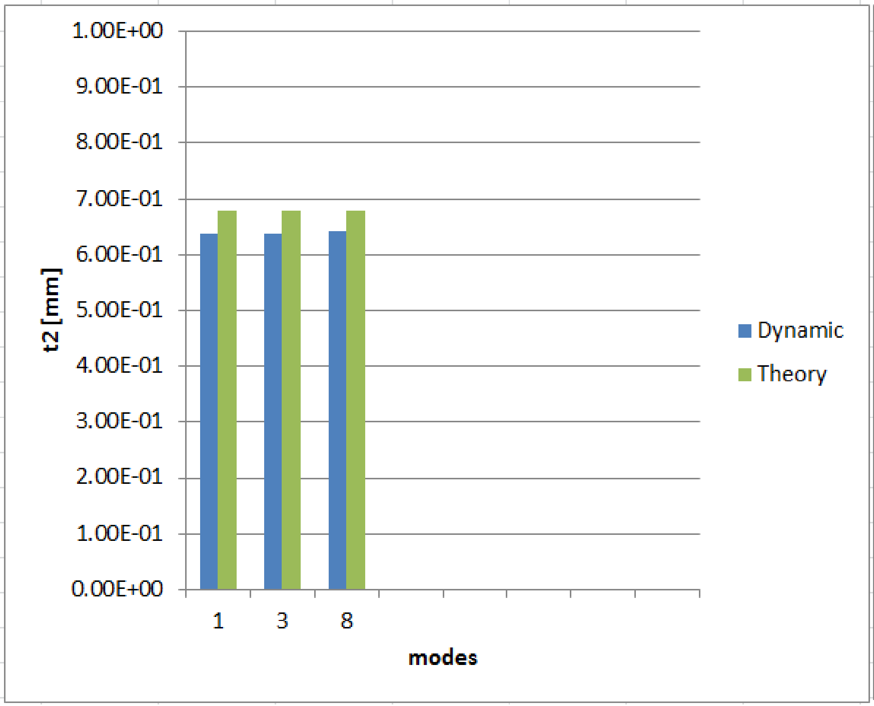
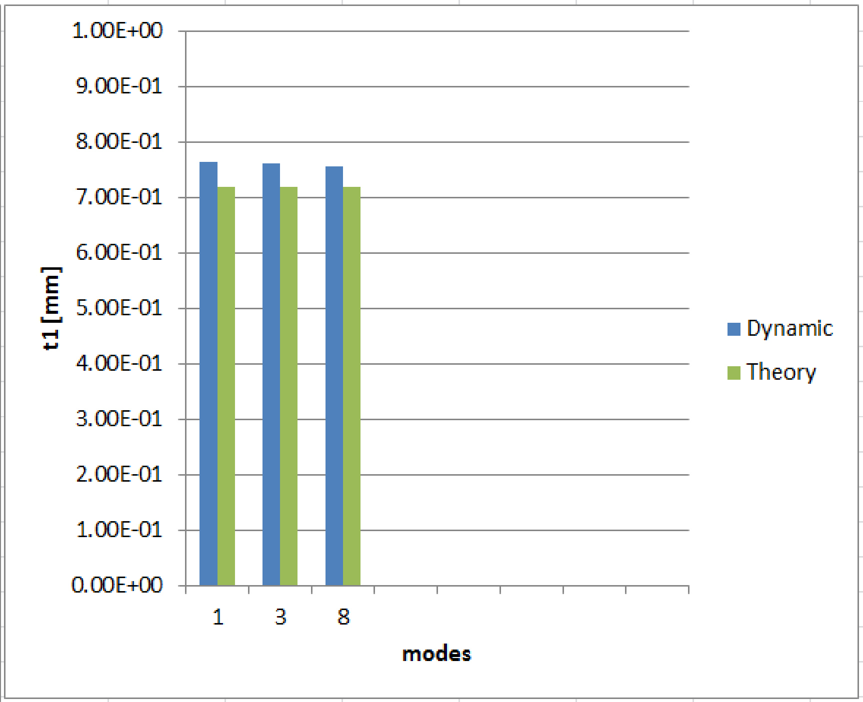
ONE SMART MATERIAL NUMERICAL SIMULATIONS :





Neutral axis position: Error between analytical solution and simulation: **5%**

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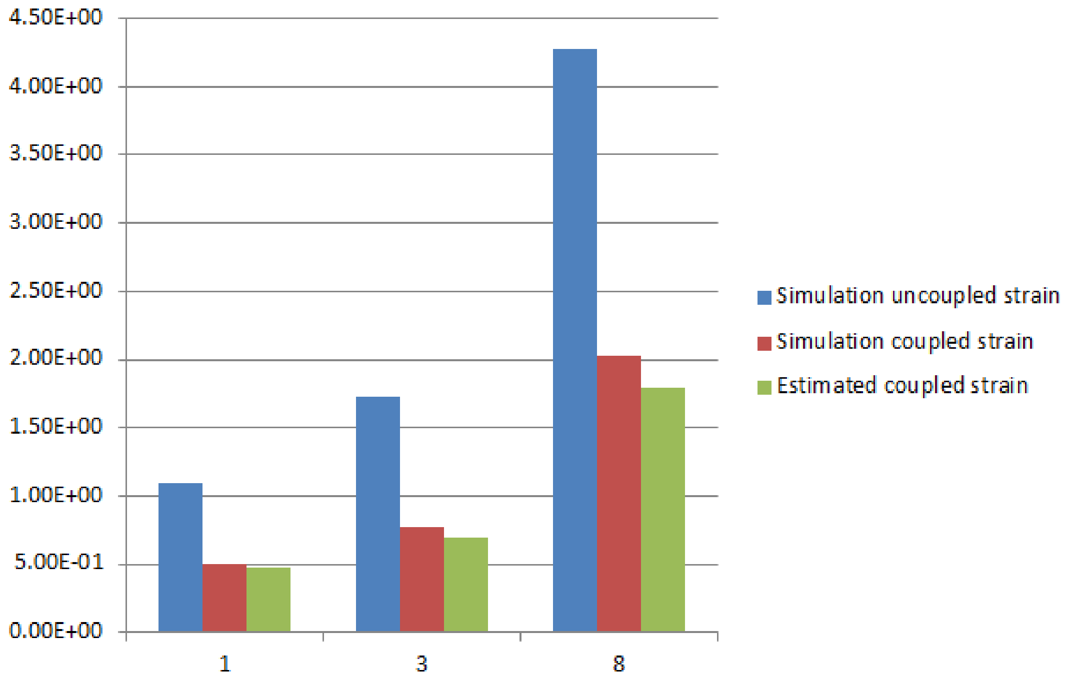
One smart material numerical simulations :



mode	Simulation uncoupled strain	Simulation coupled strain	Estimated coupled strain	relative error
1	1.10E+00	5.08E-01	4.72E-01	6%
3	1.73E+00	7.76E-01	6.97E-01	8%
8	4.27E+00	2.03E+00	1.80E+00	10%

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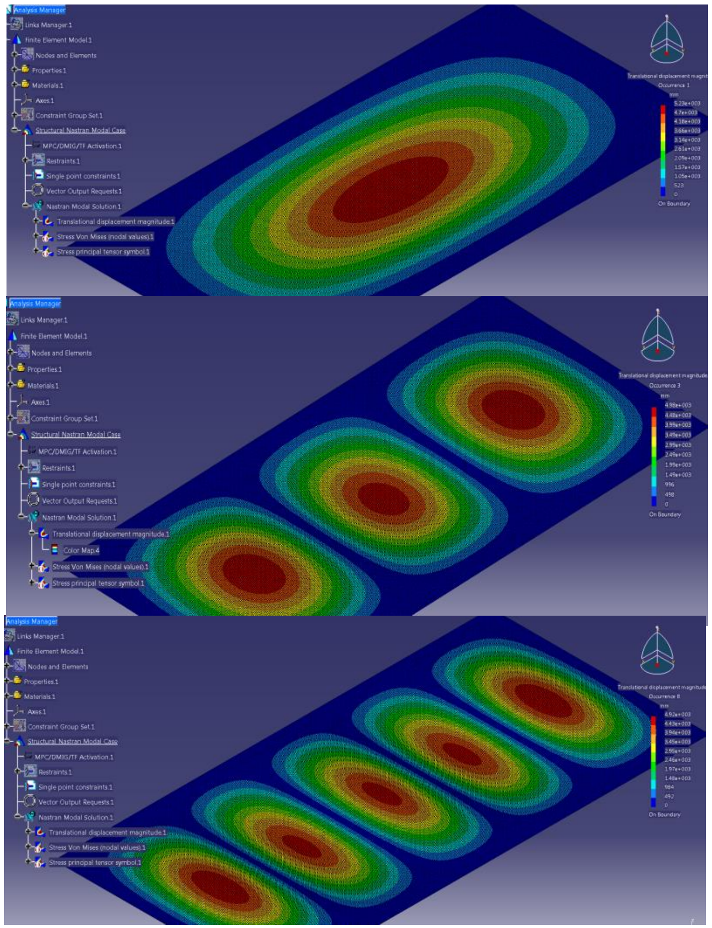
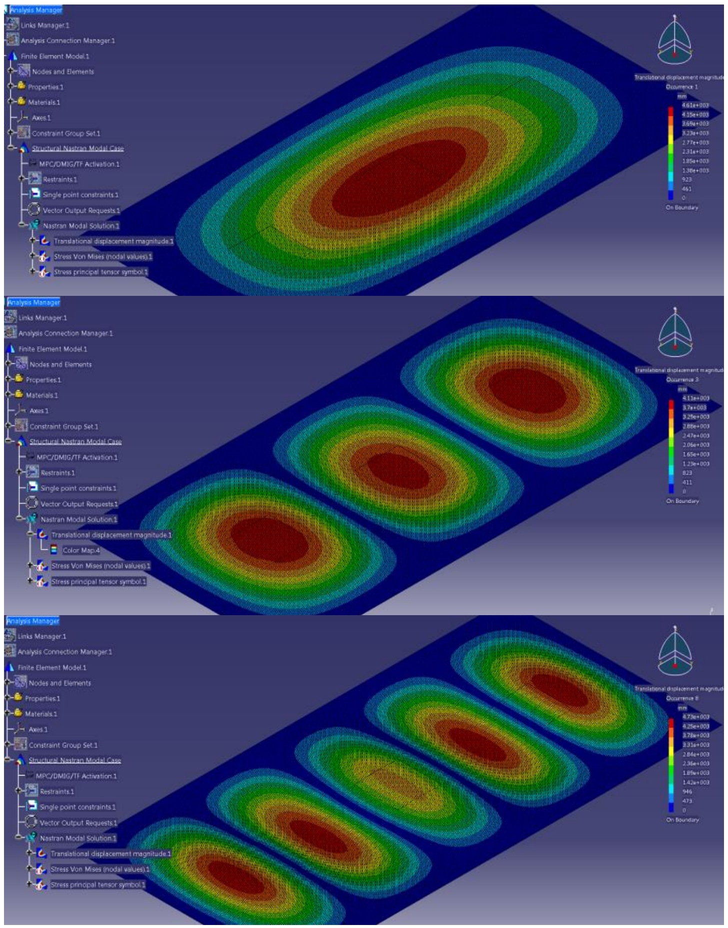
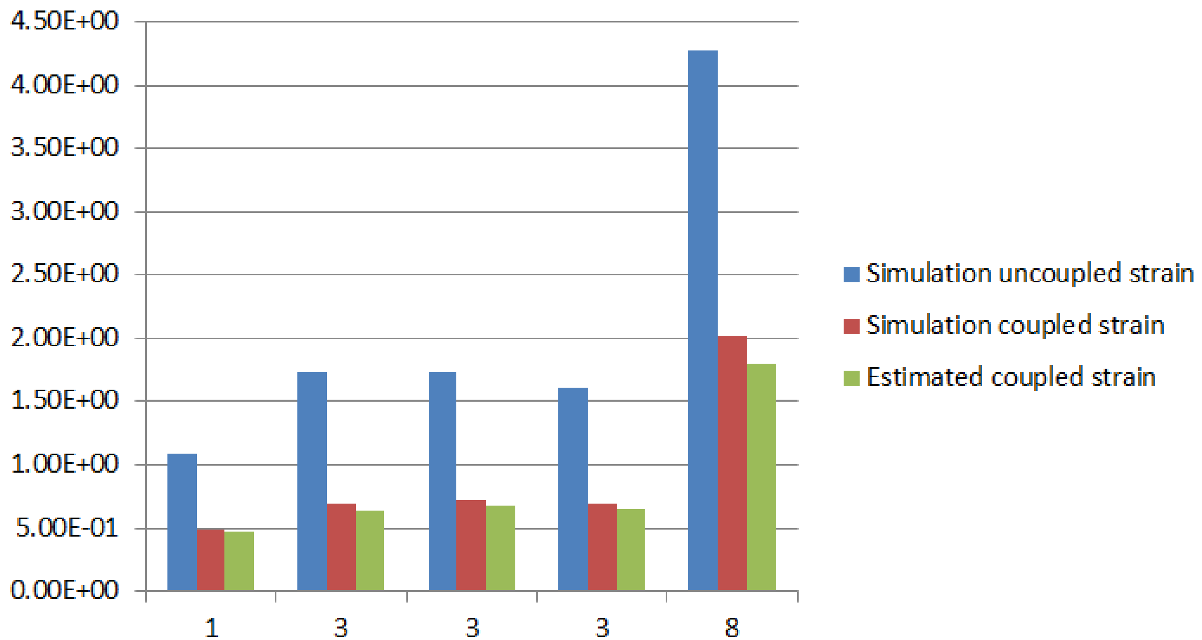
THREE SMART MATERIAL NUMERICAL SIMULATIONS :





Recent work

THREE SMART MATERIAL NUMERICAL SIMULATIONS :



mode	Simulation uncoupled strain	Simulation coupled strain	Estimated coupled strain	relative error
1	1.10E+00	4.93E-01	4.72E-01	3%
3	1.73E+00	6.90E-01	6.35E-01	5%
3	1.73E+00	7.21E-01	6.82E-01	4%
3	1.61E+00	6.90E-01	6.56E-01	4%
8	4.27E+00	2.02E+00	1.80E+00	10%

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Future activities and difficultes

WORK TO ACHIEVE:

1. Piezoelectric-mechanic relation of smart materials (literature search)
2. More detail FEM simulations
3. Results comparison with the literature references