



VALIDATION OF SIMULATION PLATFORM FOR MODELING OF RF MEMS CONTACTS

Fabienne PENNEC, David PEYROU, Patrick PONS,
Robert PLANA, [LAAS-CNRS](#)

Frédéric COURTADE, [CNES-FRANCE](#)

8th World Congress on
Computational
Mechanics
WCCM8

5th European Congress on
Computational Methods
in Applied Sciences and
Engineering **ECCOMAS 2008**

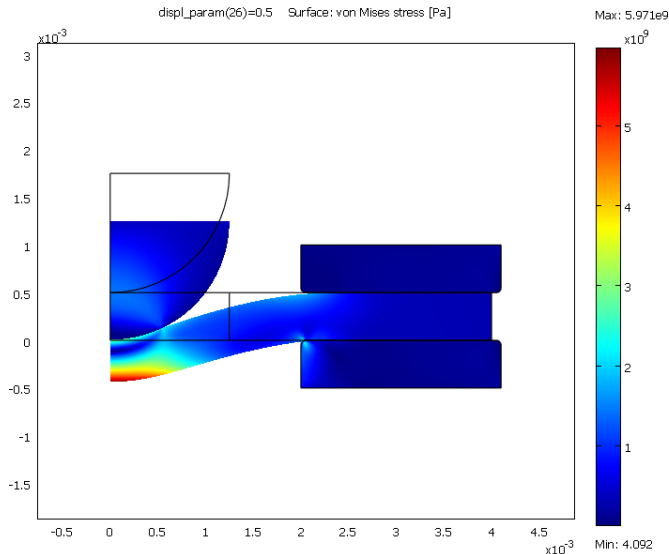
INTRODUCTION

- **GENERAL AIM:** find the best candidate to simulate many mechanical contact problems coupled with other physics, with a reduced time of calculation and good accuracy on the results
- **FINAL OBJECTIVE:** choose the most efficient commercial software for our application, that is finite element simulation of actual rough surfaces of electrical contact of RF MEMS micro-switches.

OUTLINE

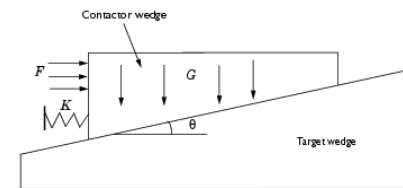
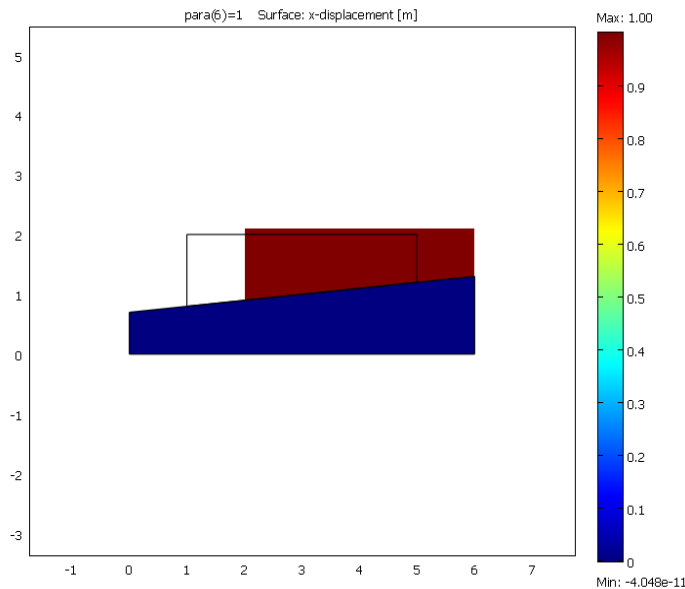
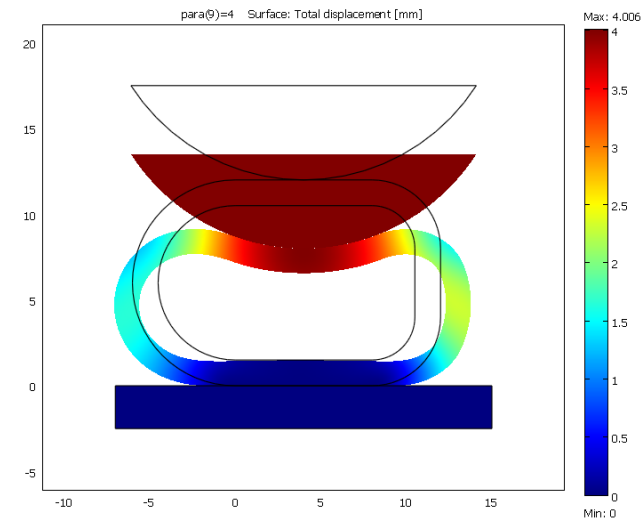
- Examples of contact problems in COMSOL & ANSYS
- Comparison study between ANSYS & COMSOL
- Originalities & drawbacks of both software
- Use of ANSYS to simulate electric contact resistance of actual rough surfaces of RF MEMS microswitches
- Conclusions

EXAMPLES OF CONTACT AND FRICTION MODELS IN COMSOL 3.4

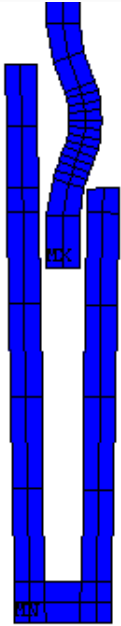


Typical model of process used for forming of sheet metal, demonstrating nonlinear structural analysis with contact, large deformation and the use of elasto-plastic material model

2D model of a car door seal using a Mooney Rivlin hyperelastic material model

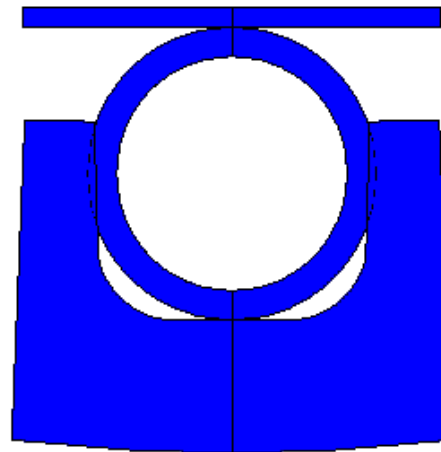
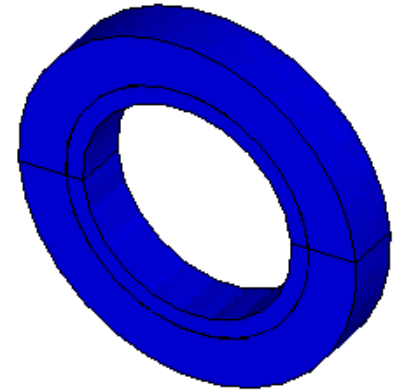


EXAMPLES OF CONTACT AND FRICTION MODELS IN ANSYS 11



2D large deflection and sliding contact analysis of a mechanical connector including contact and friction

3D contact analysis with cocentric cylinders including initial penetration and plasticity effects



2D flexible-flexible contact with an O ring using a Mooney Rivlin hyperelastic material model

OUTLINE

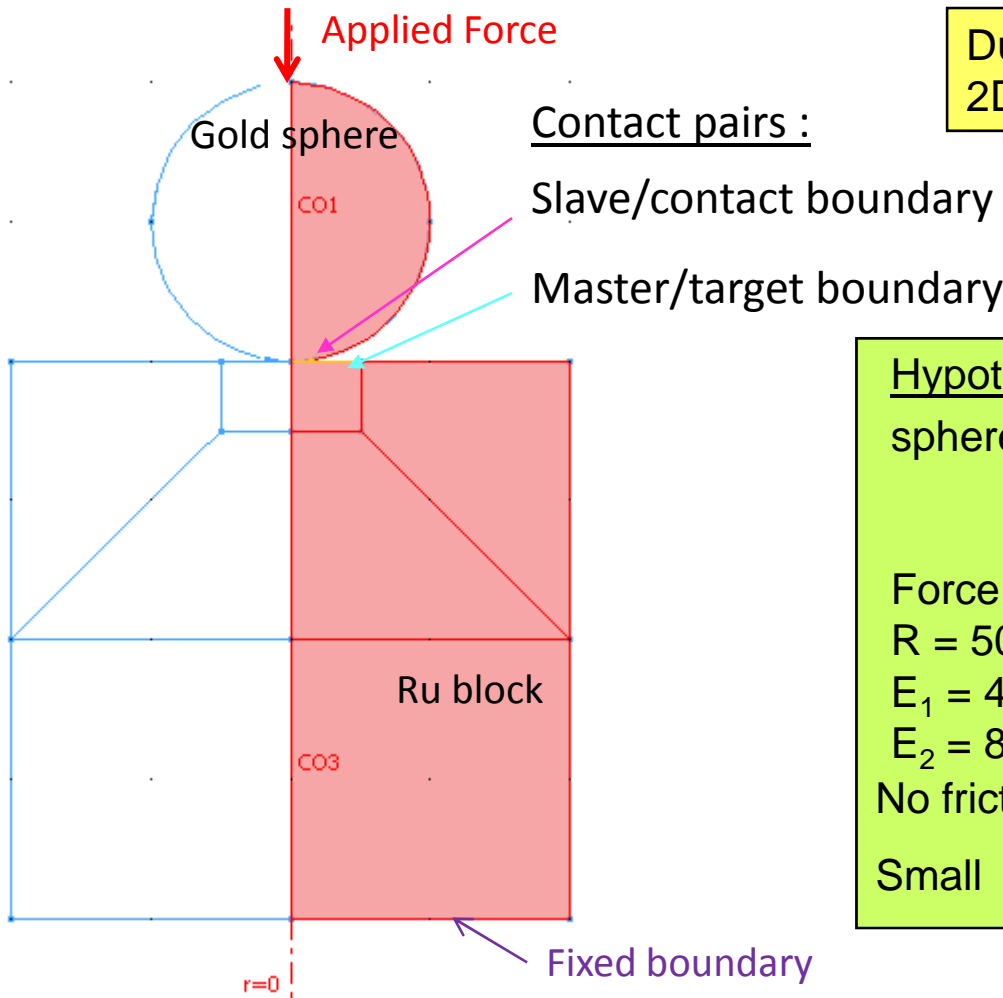
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Contact model between a cylinder and a sphere

A Static Hertz Contact Problem

objective : find for both software (COMSOL & ANSYS) the contact pressure distribution and the length of contact between the block and the sphere and compare with the analytical solution

Due to the axial symmetry of the problem:
2D axisymmetric model



Hypothesis:

sphere and block material : elastic
homogeneous
isotropic

Force = 50000 N

R = 50 mm

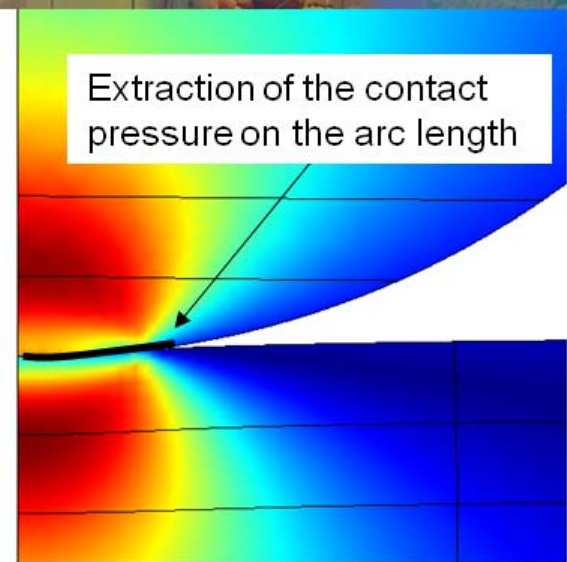
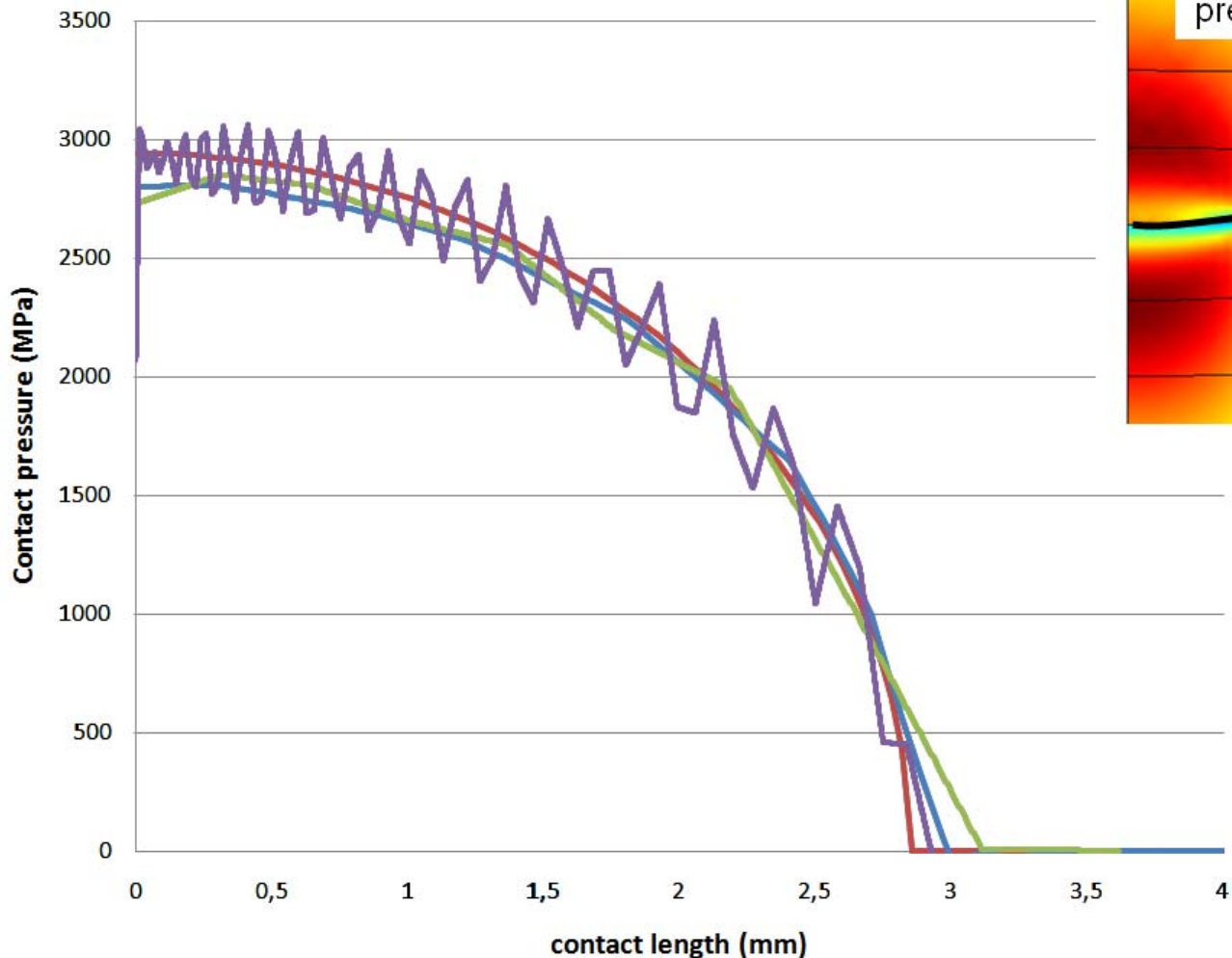
$E_1 = 443000 \text{ MPa}$ $\nu_1 = 0.3 \rightarrow$ Ru block

$E_2 = 80000 \text{ MPa}$ $\nu_2 = 0.42 \rightarrow$ Au sphere

No friction

Small deformations

Comparison between the analytical and simulated solutions



- analytical Hertz solution
- Computed COMSOL solution
- simulated ANSYS solution

Comparison between FEM (COMSOL) results, FEM (ANSYS) results and analytical results



	COMSOL	ANSYS	ANSYS – thin mesh
Maximal contact pressure	4.82 %	5.80%	0.14%
Contact radius	4.21%	10.88%	2.81%
Simulation time	2h30min	7 min	1h30min

Discrepancy between simulated results and Hertzian solution

- Simulated contact results in good agreement with analytical solution
- reduced calculation time with ANSYS 11

2D axisymmetric large deflection and contact analysis

I-model definition

Exemple of a model including geometric non linearities (large deformation) and contact non-linearities

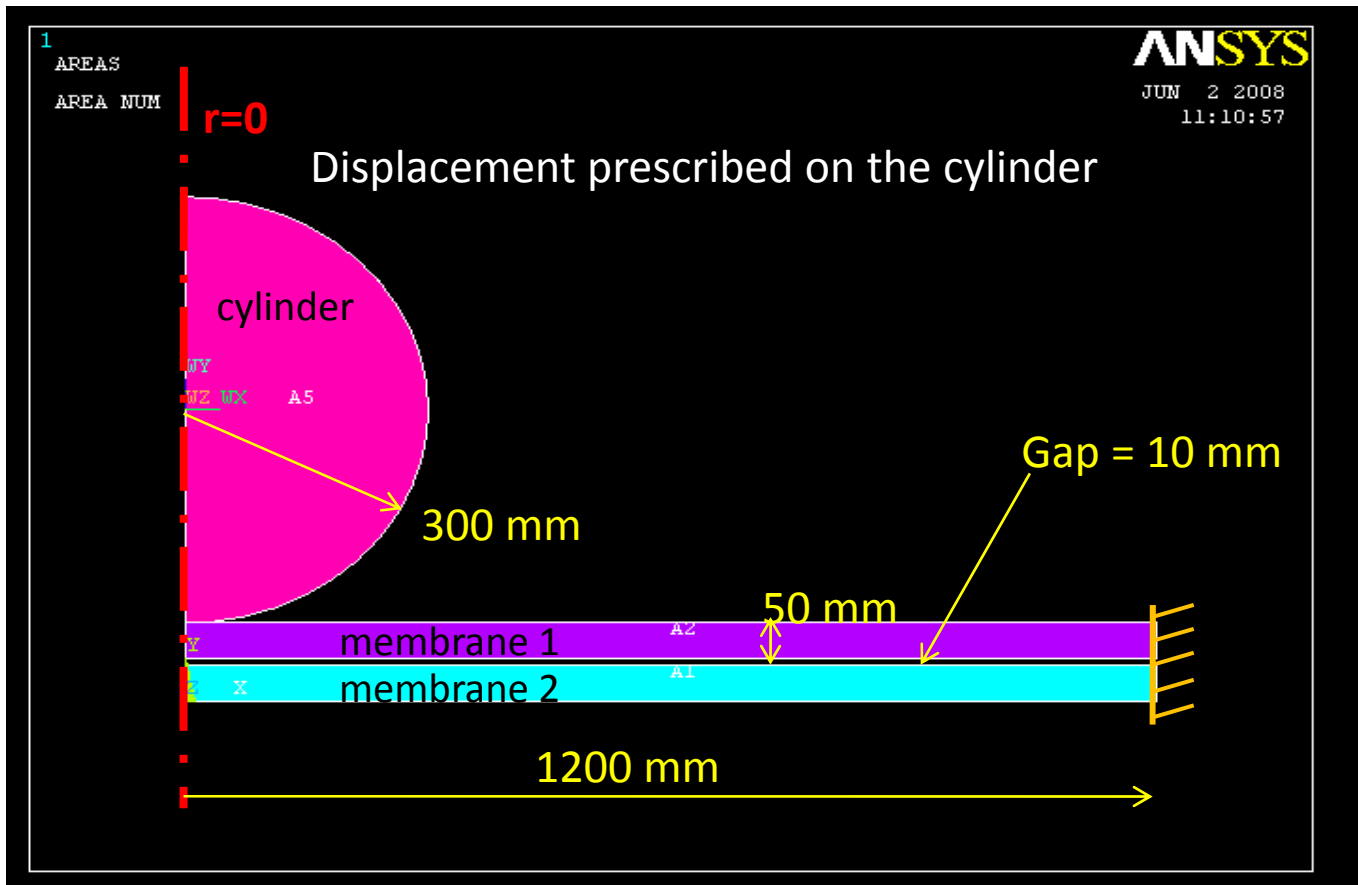
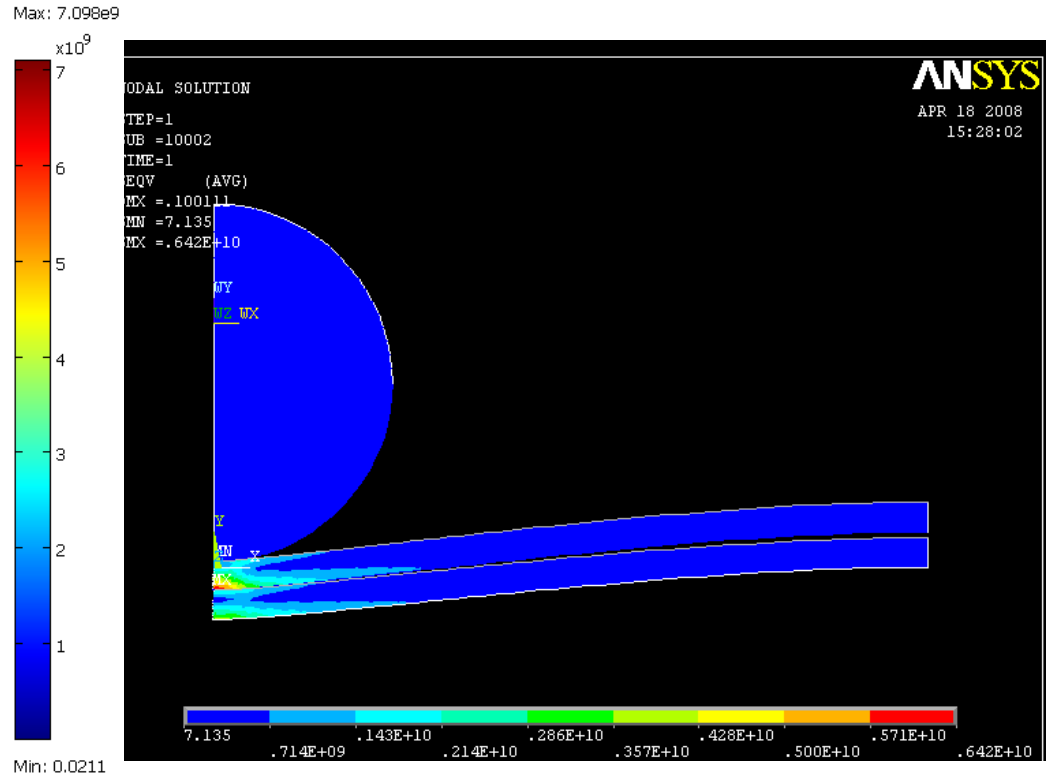
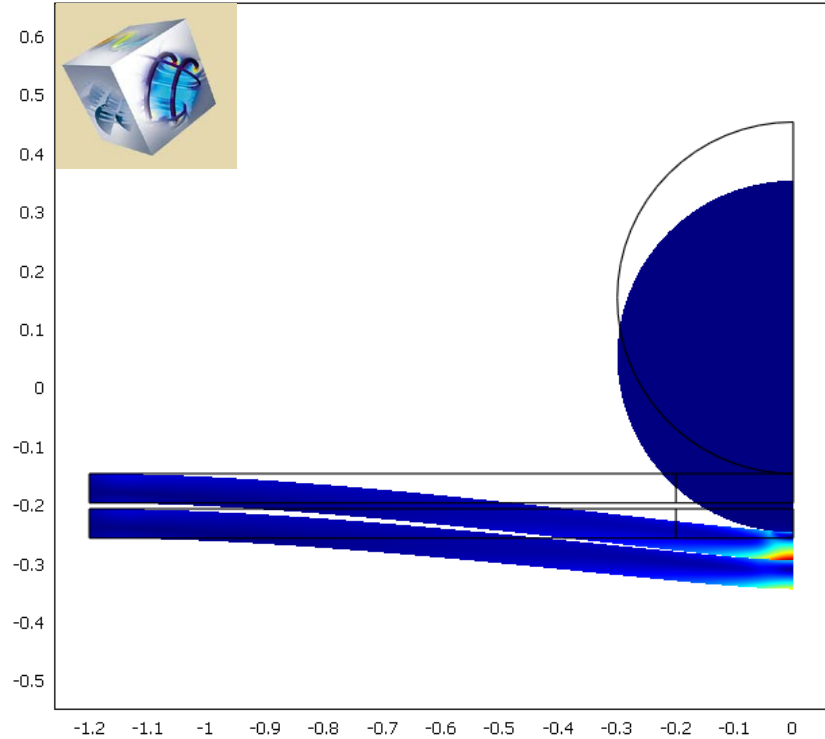


Illustration of Von Mises stresses distribution with membranes deformation

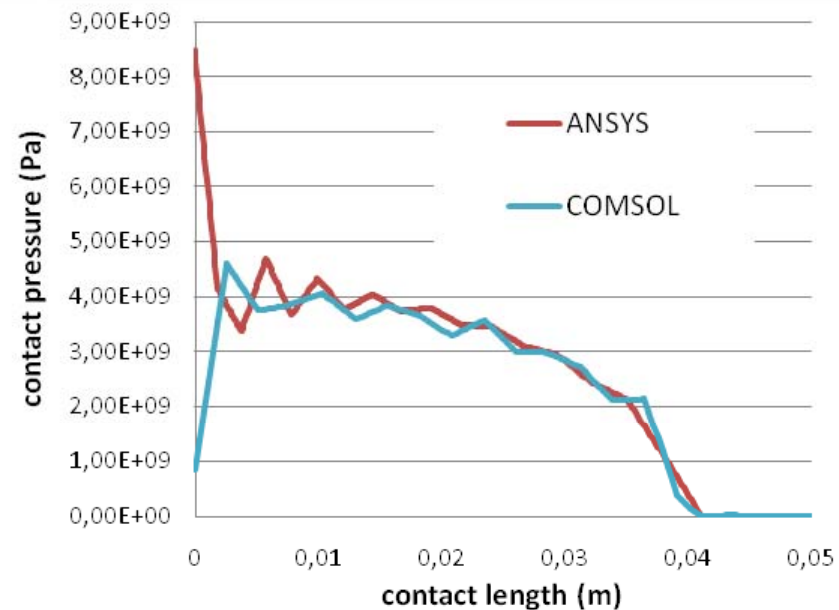
Prescribed displacement = 0.1m

d(212)=0.1 Surface: von Mises stress [Pa]

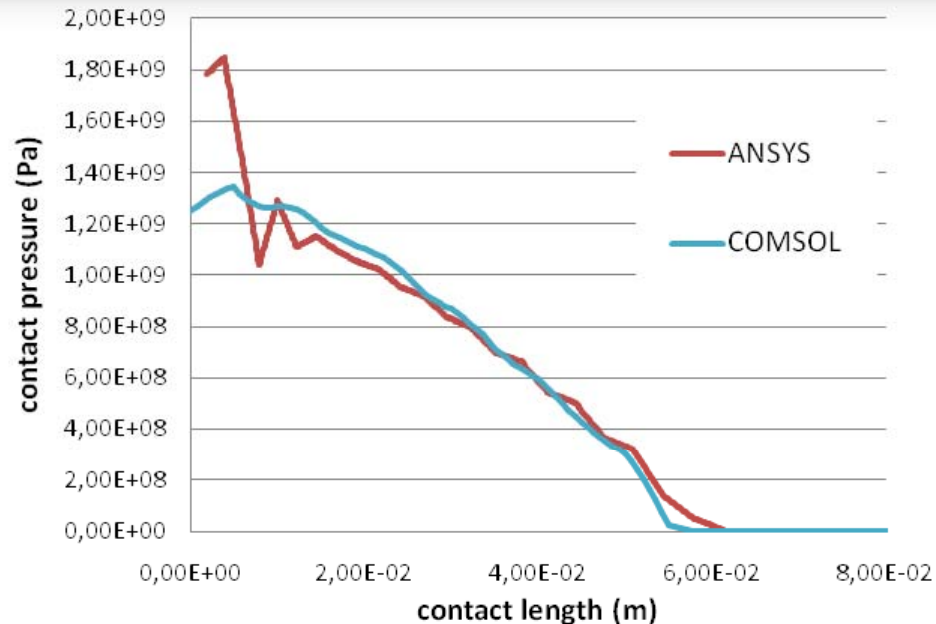


maximum Von Mises stress discrepancy between ANSYS & COMSOL = 11%

2D axisymmetric large deflection and contact analysis II- results



First contact between the cylinder and the membrane 1



Second contact between both membranes

- Despite the numerical aberrations, specially with ANSYS, the curves are well superposing, showing the capacity and accuracy of both finite element models to hold contact analysis with large deformation
- However, whereas the simulation time is very small with ANSYS (a few minutes), the calculation time with COMSOL can take many hours to succeed the convergence

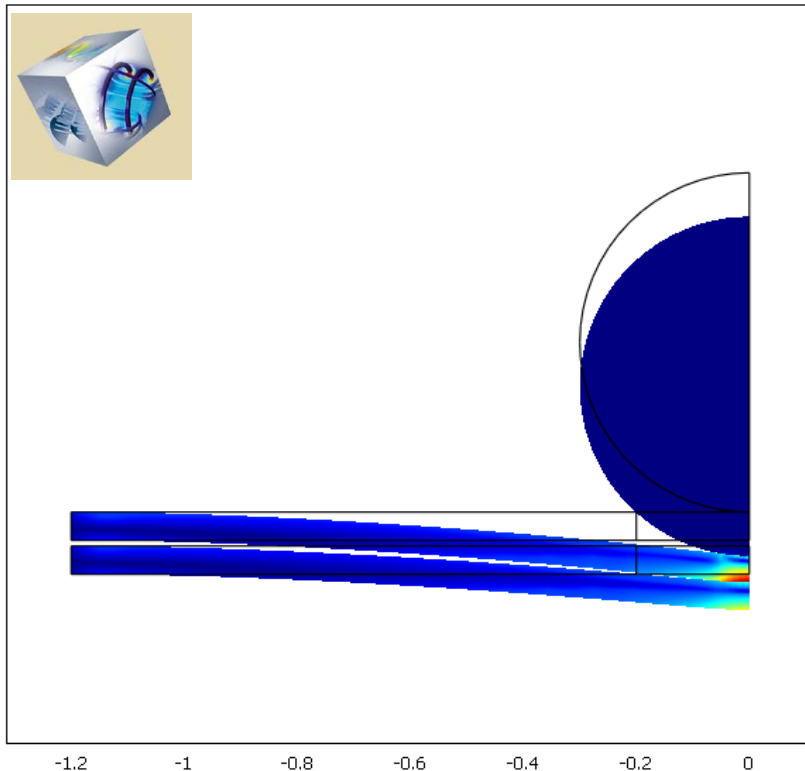
2D axisymmetric large deflection and contact analysis with elastoplastic material model

Prescribed displacement = 0.1m

Due to convergence difficulties in COMSOL 3.4, results will be given for a displacement of 0.0775m

Material properties		
Young modulus E	MPa	80000
Poisson ratio		0,3
Yield strength σ	MPa	300
Tangent modulus	MPa	10000

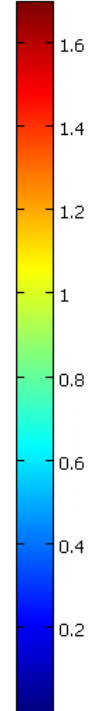
d(1)=0.0775 Surface: von Mises stress [Pa]



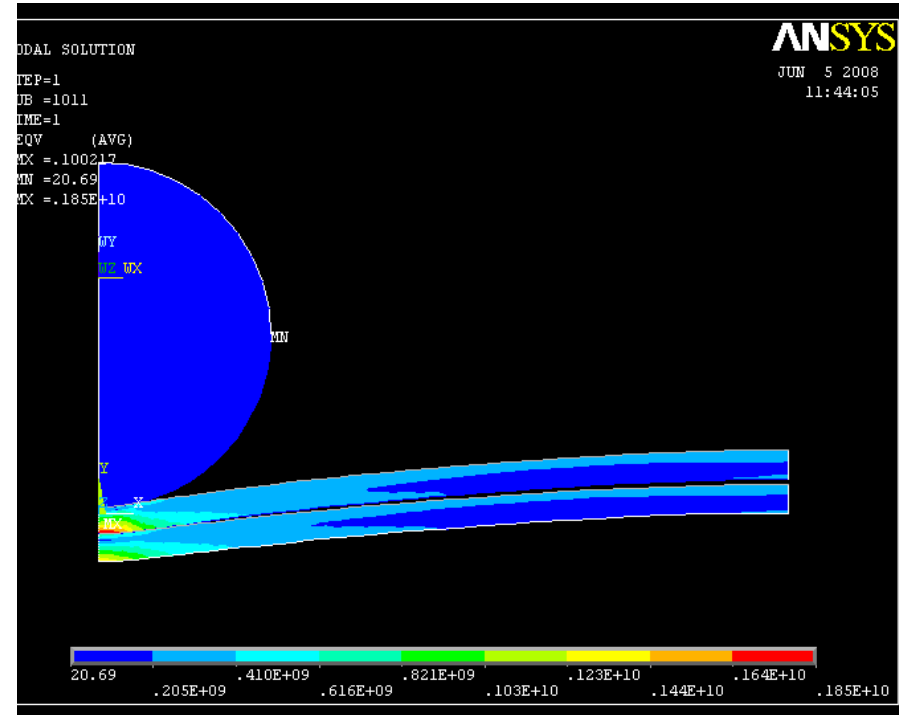
d=0.0775m

Max: 1.696e9

$\times 10^9$

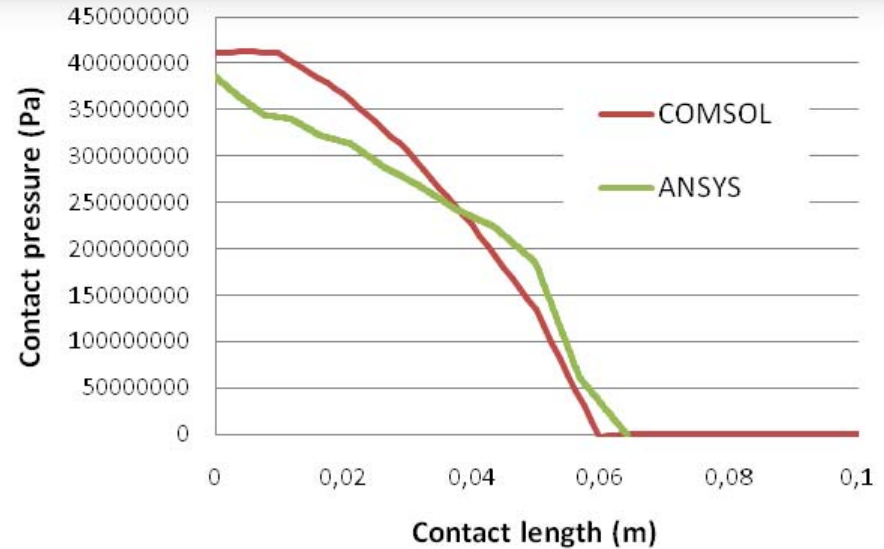
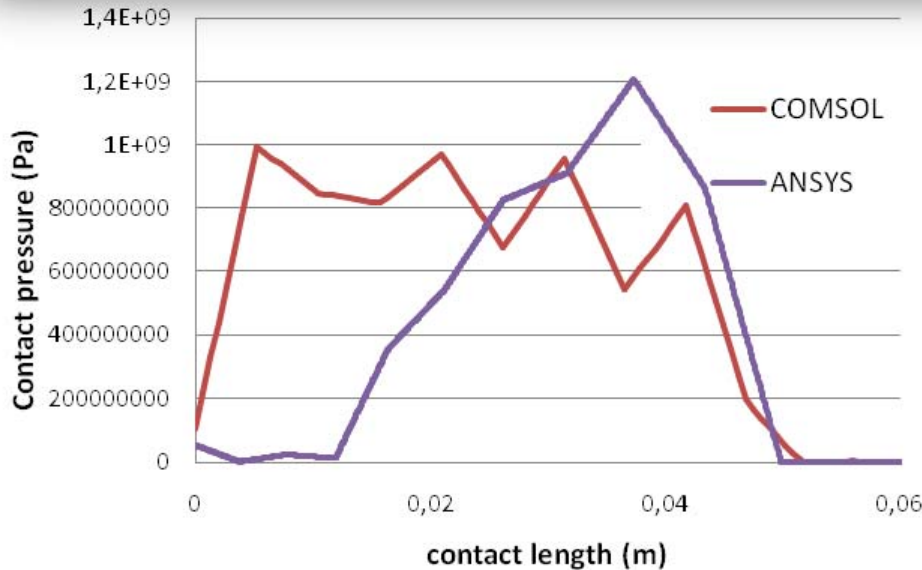


Min: 8.941



d=0.1m

2D axisymmetric large deflection, elastoplastic material model and contact analysis II- results



First contact between the cylinder and the membrane 1

Second contact between both membranes

rigid-flexible contact	max contact pressure	17,52%
	contact radius	4,23%
flexible-flexible contact	max contact pressure	6,07%
	contact radius	5,60%

Difference between numerical solutions (COMSOL & ANSYS)

- Severe discrepancies between ANSYS & COMSOL solutions
- Comsol fails to find a solution for too large deflection (displacement limitation = 0.0775m)
- Requires long time for the user to set up the parameters in COMSOL 3.4

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Comsol 3.4 software

- Originalities:
 - good interactive interface
 - Possibility to simulate mechanical contact problems coupled with other physics
- Drawbacks:
 - limitation in the memory, specially for 3D contact problems
 - Requires a certain amount of effort from the user to converge contact problems with geometric or material non linearities or complex geometries

ANSYS 11 software

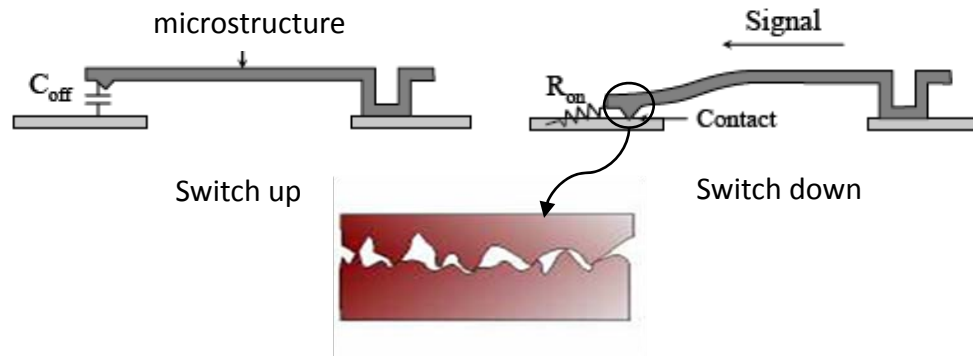
- Advantages:
 - Computationally efficient for any kind of contact models (3D, geometric, material nonlinearities)
 - Comfortable for the user to set contact parameters
 - Hold a high volume of elements
 - Possibility to run many simulations in batch and to stock only the pertinent results
- Drawbacks:
 - Difficulties to create the solid model with the interface graphic. Use APDL in preference to build the models

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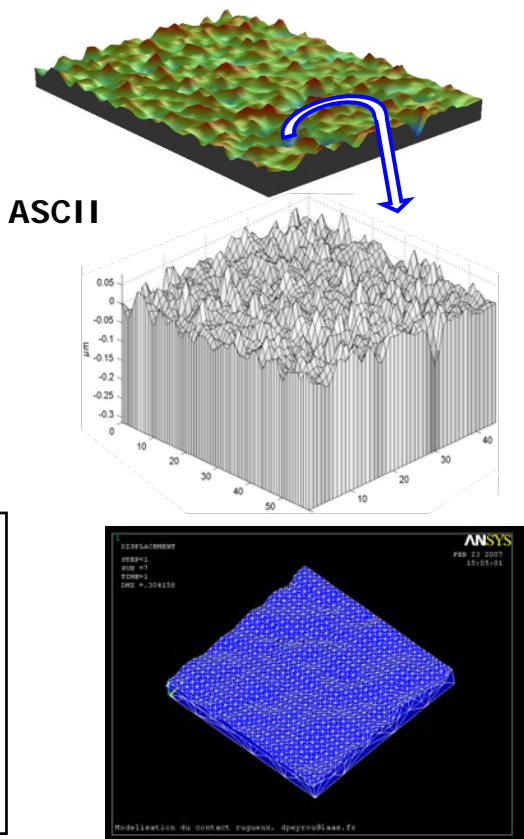
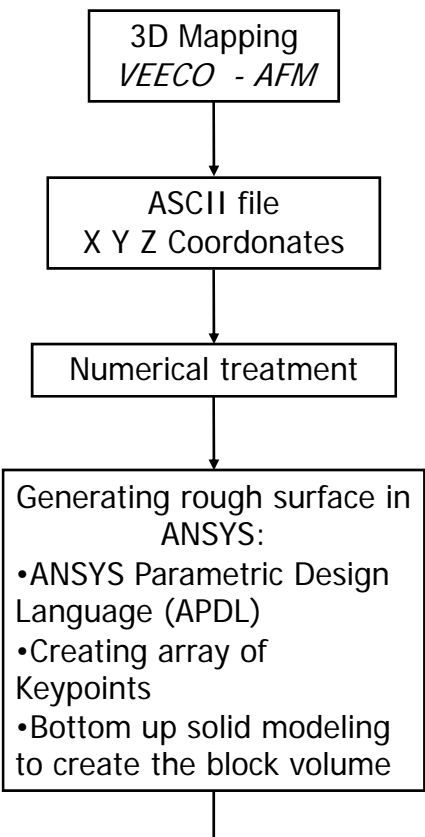
Requirement study

- Limitations of DC contact RF MEM switches:
 - Quality and repeatability of the contact that drive the RF performance
 - Reliability
 - Intense research effort to understand the failure mechanism at contact interface



- Need a software able to simulate the mechanical contact between surfaces with multiple asperities

REVERSE ENGINEERING METHODOLOGY



Contact Algorithms

- Penalty
- **Augmented Lagrangian**
- Lagrangian: zero penetration enforced
- Penalty/Lagrangian: zero penetration normal /penalty spring tangential

Non-linear solver

Convergence stack

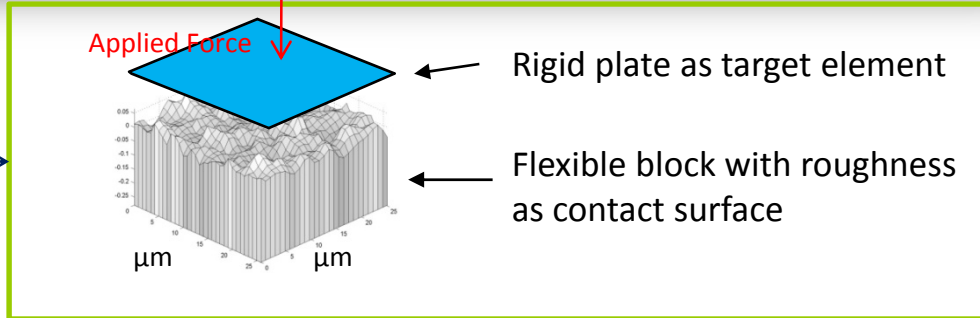
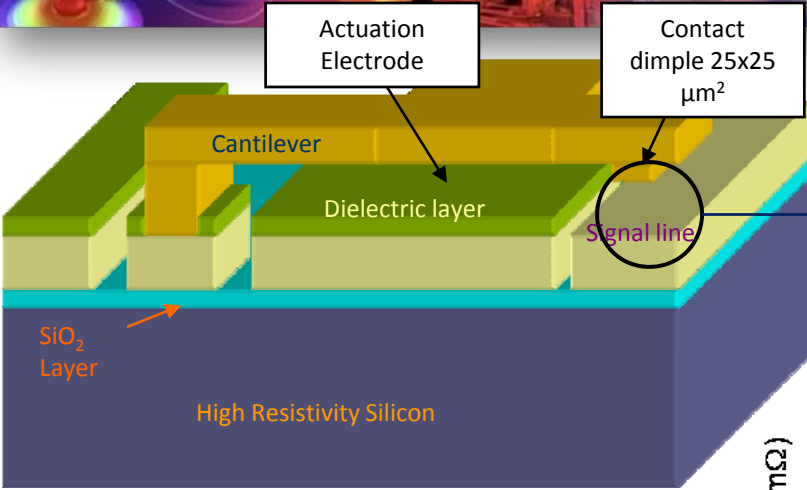
The plot shows a logarithmic scale for Absolute Convergence Norm (from 1.0E+00 to 1.0E+07) against Cumulative iterations (from 0 to 40). The curve shows oscillatory behavior that generally decreases over time, indicating convergence.

Results
Post-processing

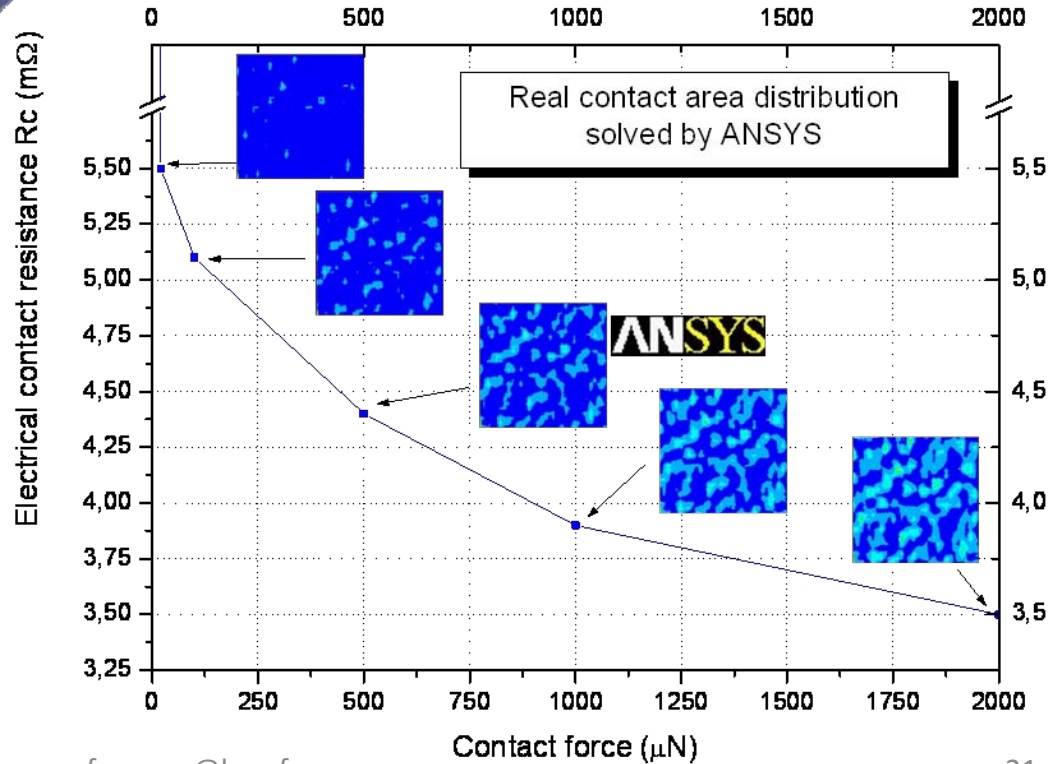
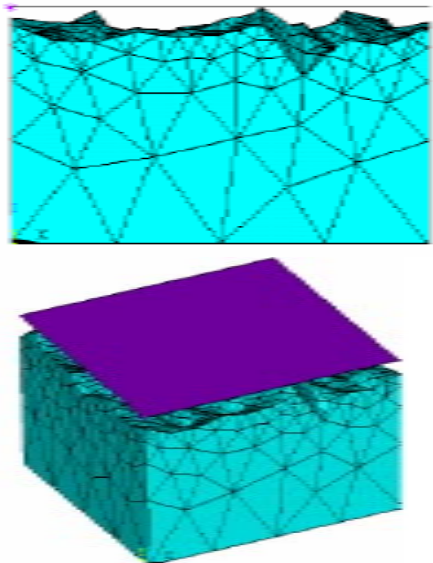
Contact pressure distribution

The ANSYS plot shows a 3D view of the contact surface with a color-coded pressure distribution. A legend at the bottom indicates pressure values from 0 to 7440.

APPLICATION



ANSYS contact model



CONCLUSIONS

1. Comparison study between two commercial finite element simulators: COMSOL & ANSYS
2. Limitations with COMSOL due to the time of calculation and lack of memory
3. Capabilities and accuracy of ANSYS validated for all kind of contact models and with a reduced calculation time and a minimum effort from the user
4. Especially, the real topography of the contact surfaces can be included in finite element simulations, allowing us to investigate the impact of roughness on the quality and the repeatability of the RF MEMS contact



THANK YOU !