Effects of Solvers on Finite Element Analysis in COMSOL MULTIPHYSICS®

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COMSOL CONFERENCE
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Excerpt from the Proceedings of the 2014 COMSOL Conference in Bangalore

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Outline

- Background
- Objective
- Methodology
- Simulation results and discussion
- Conclusion

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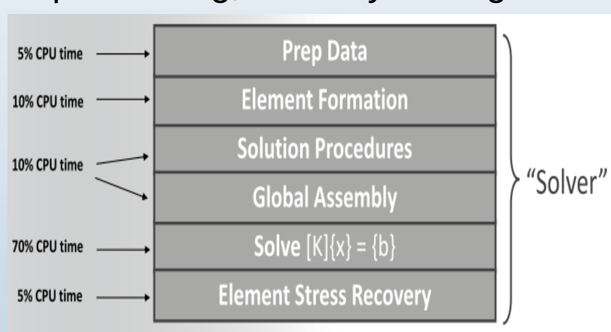
Finite element analysis

Preprocessing | Analysis | Post processing

Model:
Size/Number of DOF
Analysis Type

Solver type
Number of cores, RAM, Parallel processing, Memory setting



Graphical representation of the results

Scope for optimization

Objectives

1. To understand the various solvers available in COMSOL

2. To validate the adoptability of various solvers and solver settings

3. To capture the effect of the solvers on the solution in terms of
   a. Accuracy of results
   b. Memory consumed
   c. Computational time

4. To understand the need of changing the default solver settings

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Methodology

Solvers and its importance

↓

Understanding all the available solvers in COMSOL

↓

Selecting a problem for which solution is well known

↓

Simulating the model in COMSOL

↓

Changing the solver setting and estimating the results

↓

Comparison and conclusion

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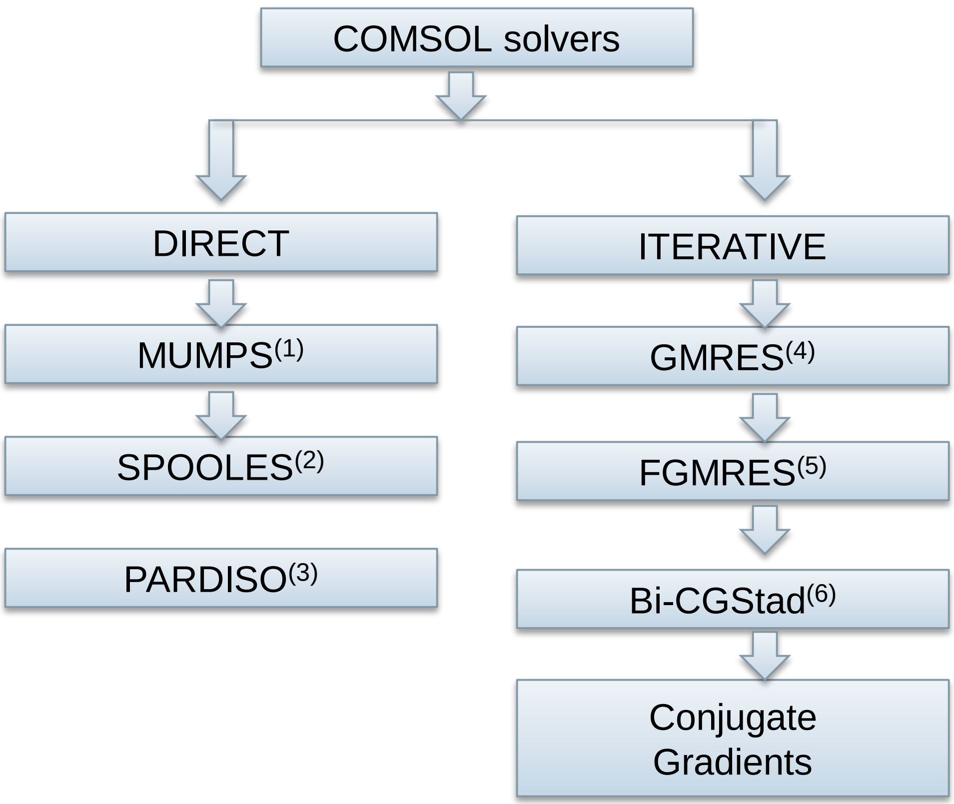
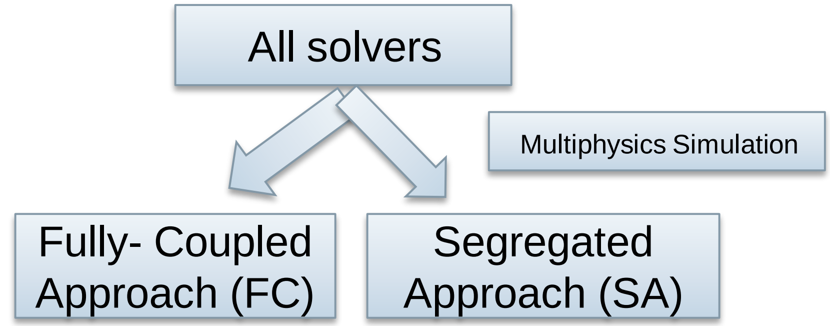
COMSOL and its solvers

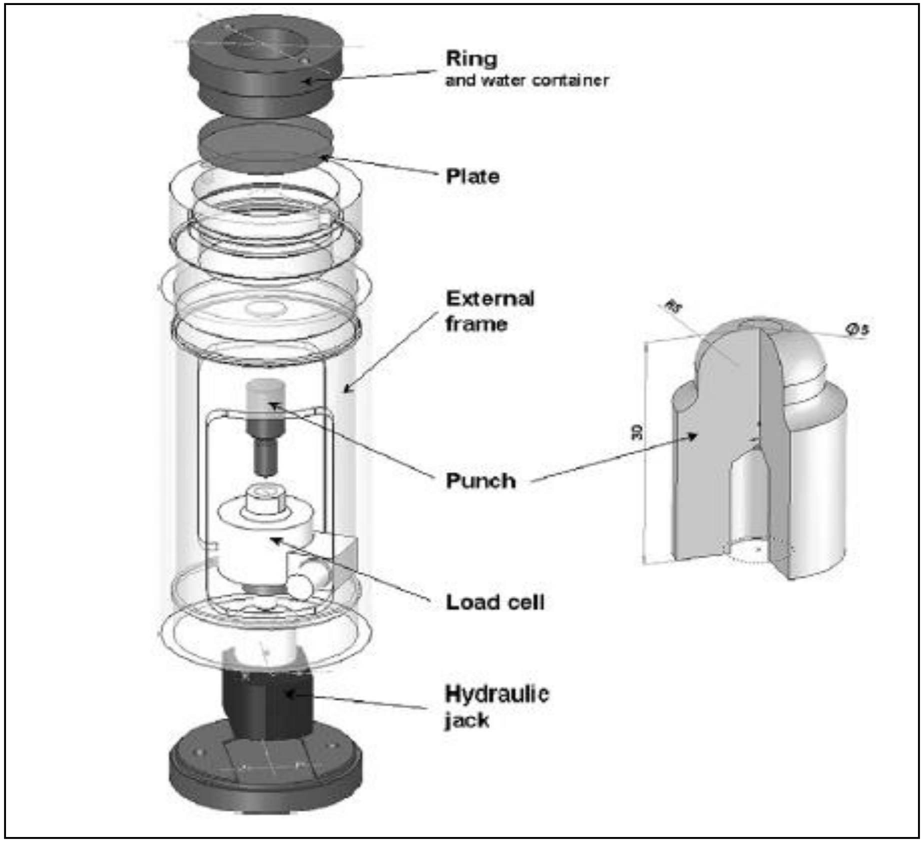




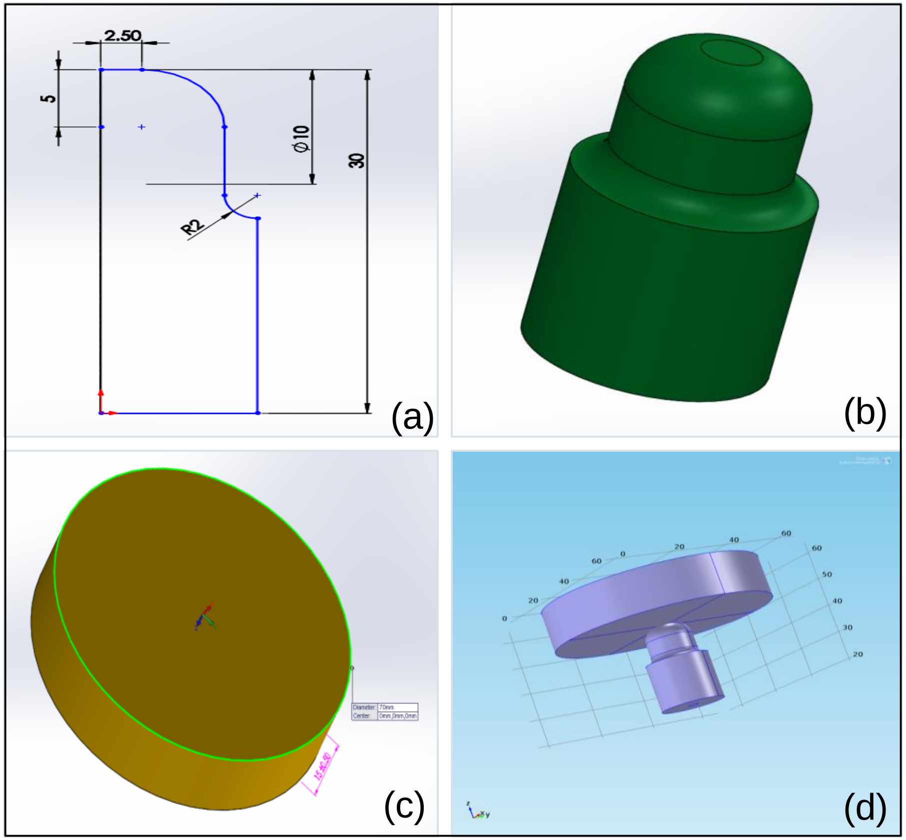
- FC - Solves the problem fully without dividing
- SA- Solves the problem by dividing it into sections and provides final solution to the complete problem
- Direct solver : Gauss elimination or LU factorization
- Iterative solver : Conjugate gradient methods

(1) Multi-frontal Massively Parallel Sparse Direct Solver
(2) Sparse Object Oriented Linear Equations Solver
(3) Parallel Sparse Direct Solver
(4) Generalized minimum residual iterative method
(5) Flexible generalized minimum residual method
(6) Bi conjugate gradient stabilized iterative method

Plate - Indenter Contact Assembly to Review Solver



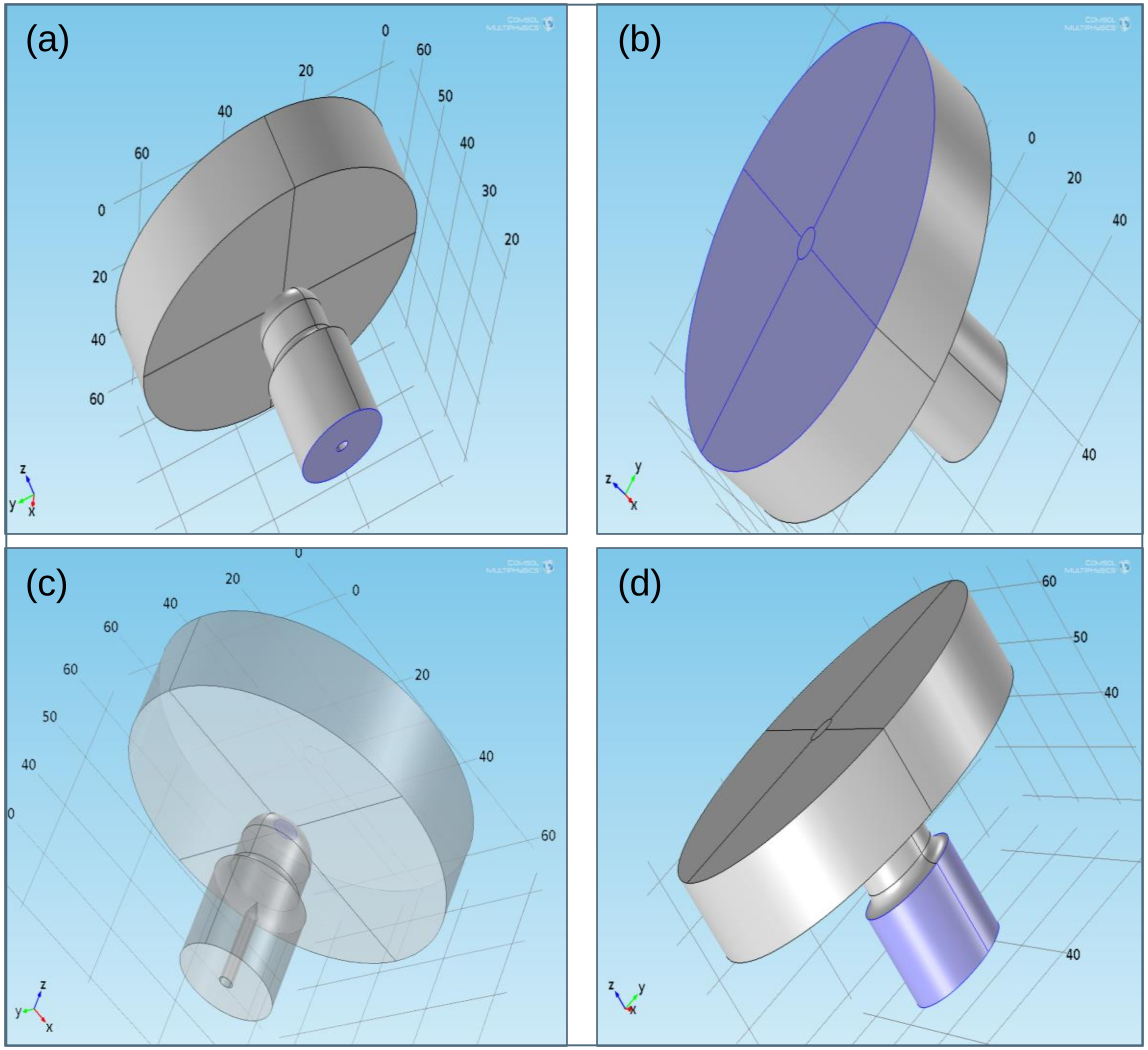
Experimental arrangement for the punch–plate contact



(a) Indenter dimensions (b) Indenter 3D model
(c) Plate model (d) Plate indenter assembly

Source: Massimiliano pau, and Antonio baldi, “Experimental analysis of contact for the indentation of a flat rounded punch”, International journal of solids and structures, Elsevier, volume No. 43, 2006, 7959-7965

Boundary conditions assigned in COMSOL



Boundary conditions assigned

Boundary conditions defined

(a) Boundary load of 12kN Fig.8(a)

(b) Fixed boundary Fig.8(b)

(c) Contact pair * Fig.8(c)

(d) x and y displacement are constrained Fig.8(d)

Material Properties for both indenter and plate:

Material: AISI 3140Steel

Young's modulus: 210X10^9 N/m^2

Poisson's Ratio: 0.3

Density: 7700 kg/m^3

* Augmented Lagrangian Method

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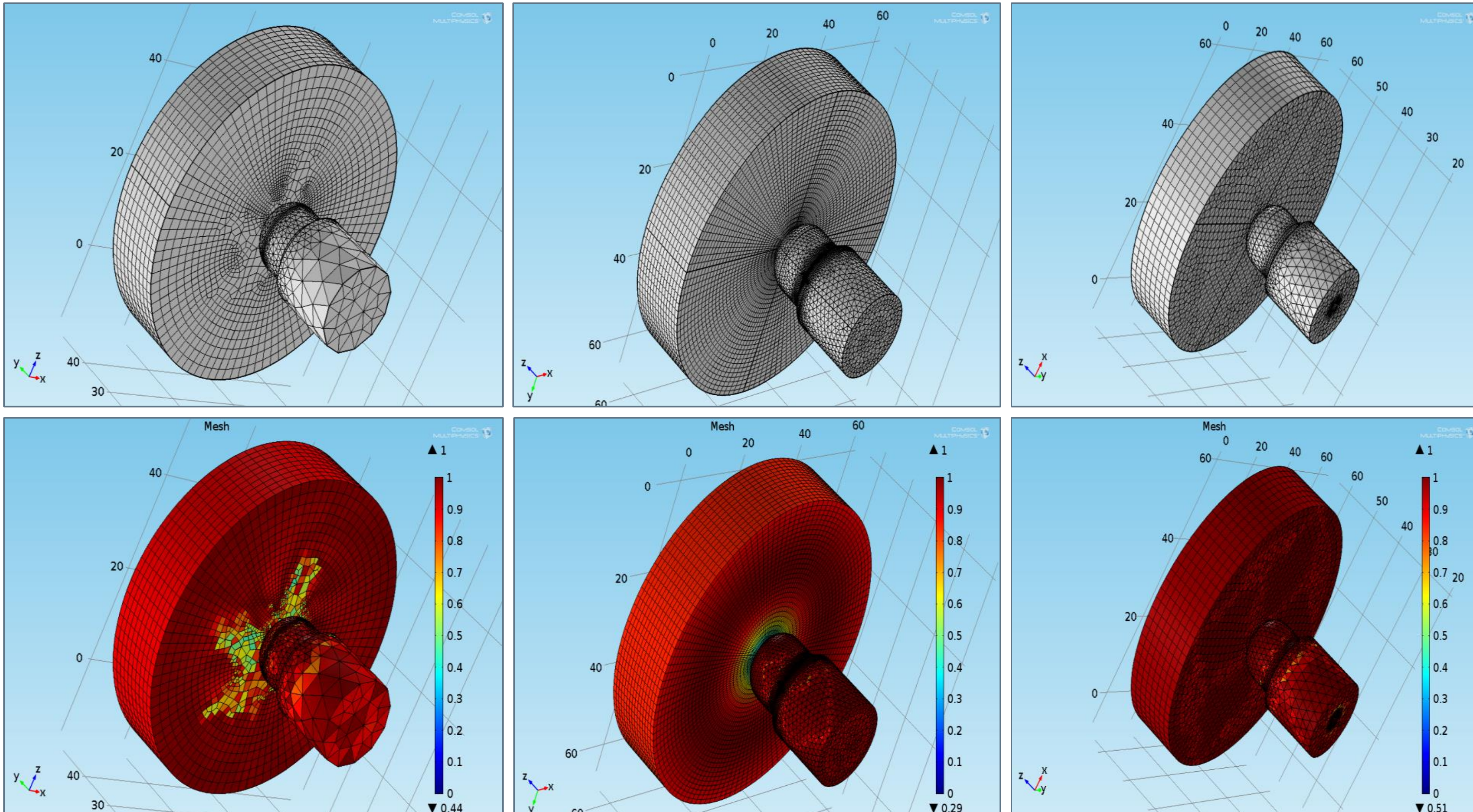
Discretized plate punch model



Discretized model and mesh quality plots

Results and discussion

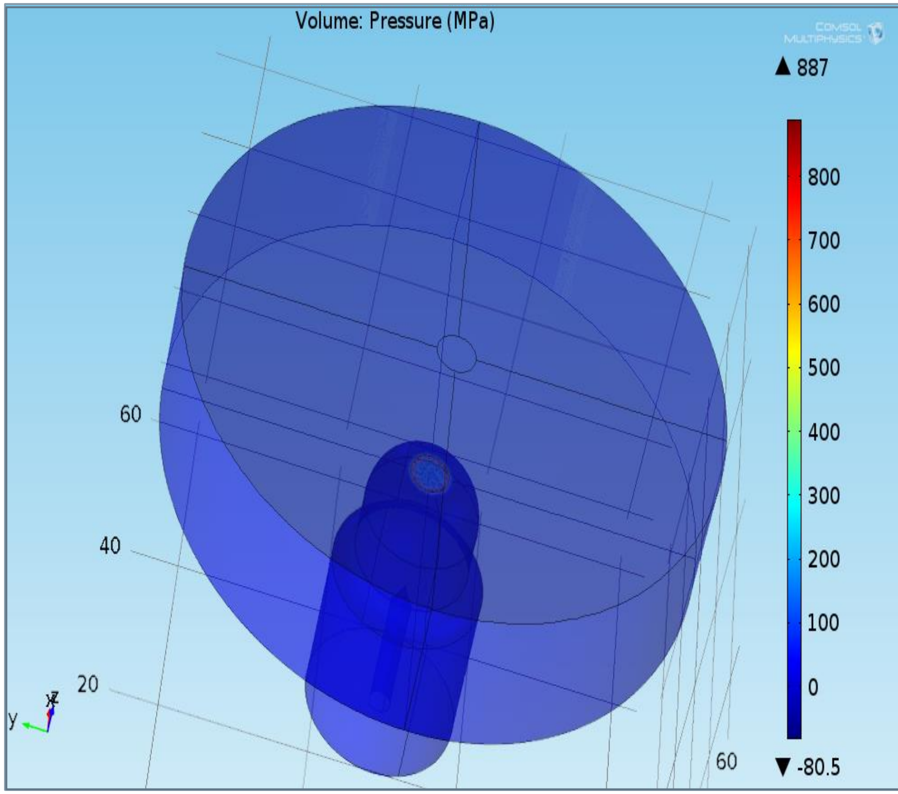


Fig.10 volume pressure plot

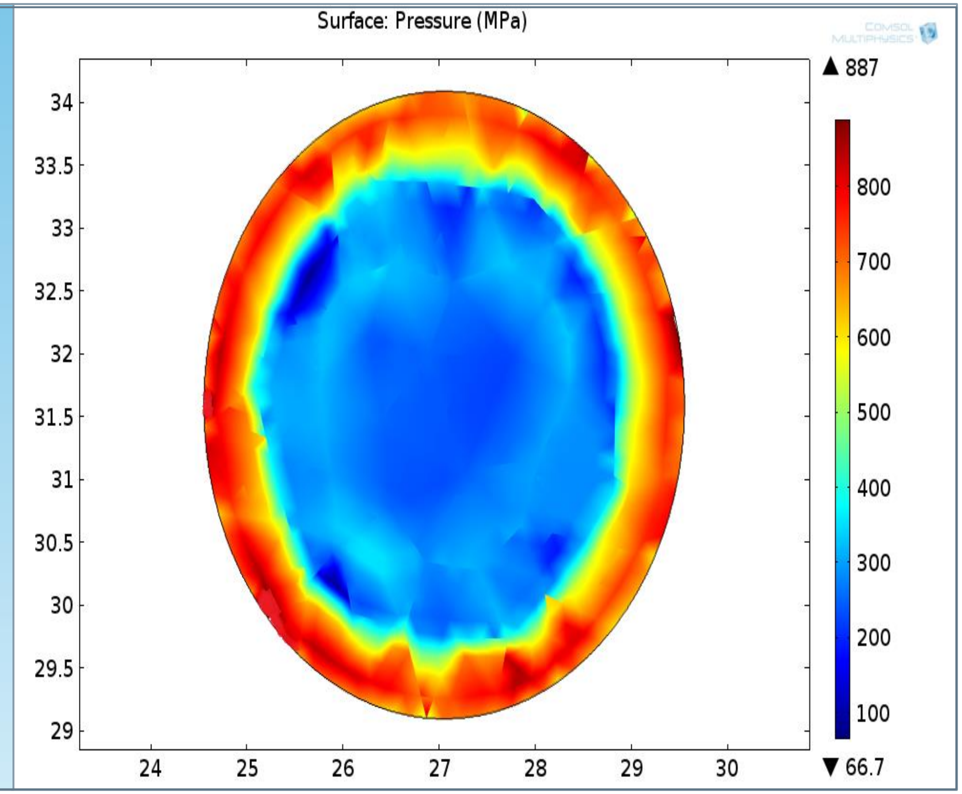


Fig.11 Surface contact pressure plot

Mesh statistics:

Total number of tetrahedral elements : 67868

Minimum element quality : 0.1802

Average element quality : 0.7718

Experimental contact pressure	**900MPa**
Simulated Contact pressure	**887MPa**

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Results from various solvers and its comparision

Solver	Approach	Sub category	Percentage Error	Time taken to solve	Memory consumed
Direct	Fully coupled	MUMPS	1.5%	23min	12GB
		PARDISO	1.47%	30min	12.6GB
		SPOOLES	1.48%	240min	18GB
Direct	Segregated	MUMPS	Same as above		
		PARDISO			
		SPOOLES			
Iterative [GMRES]	Segregated	Jacobi	14.15%	47min	3.06GB
		SOR	14.2%	15min	3.09GB
		Vanka	14.3%	16min	3.46GB
		SCGS	14.15%	51min	3.44GB
		SOR Line	14.18%	28min	3.54GB
		SOR Gauge	14.62%	34min	3.19GB
		SOR Vector	14.17%	18min	3.2GB
		Multigrid	14.12%	5min	3.29GB
		Domain Decomposition	14.56%	20min	10.52GB
		Incomplete LU	14.14%	60min	3.78GB

Conclusion

- Contact pressure is evaluated with the help of various solvers available
- Direct solver algorithms are always the best if problem size allows using this solver (DOFs depends on the analysis type)
- Direct solvers are resource intensive i.e. large memory requirements
- Method used in iterative solver reduces error through an iterative process and leads solution to convergence
- Iterative solvers requires less memory and best for well conditioned bigger problem
- Problems involving time dependent contact and more number DOF demands the change in default solver settings.

References

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Thanks for your attention!