T023: Solver Recommendations

Introduction

This document describes the different solvers used in DEFORM and gives recommendations for when to use each.

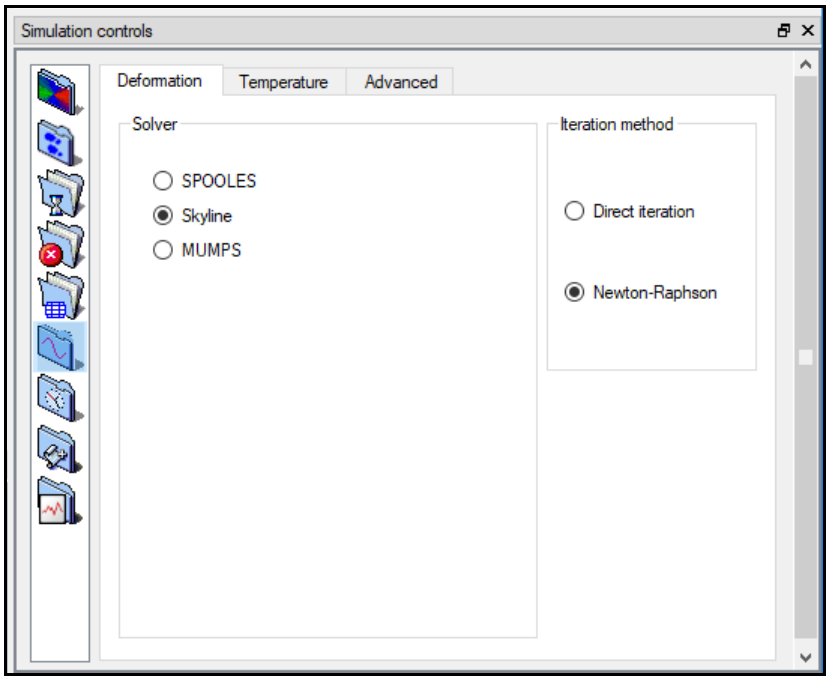
Solver Descriptions

The DEFORM system offers a range of available solvers. Through efforts to improve performance, the selection is constantly evolving as new solver technology is implemented. The optimal solver selection will be based on object type (plastic, elastic-plastic), movement control (velocity, force, sliding die), model dimension (2D vs 3D), and model size (with newer, special purpose solvers being available for model sizes approaching or exceeding 1 million elements).

***Note** - when selecting a "solver" is discussed, this actually consists of choosing a solver and the iteration method to be used.*

2D

The following options are available for 2D simulations.

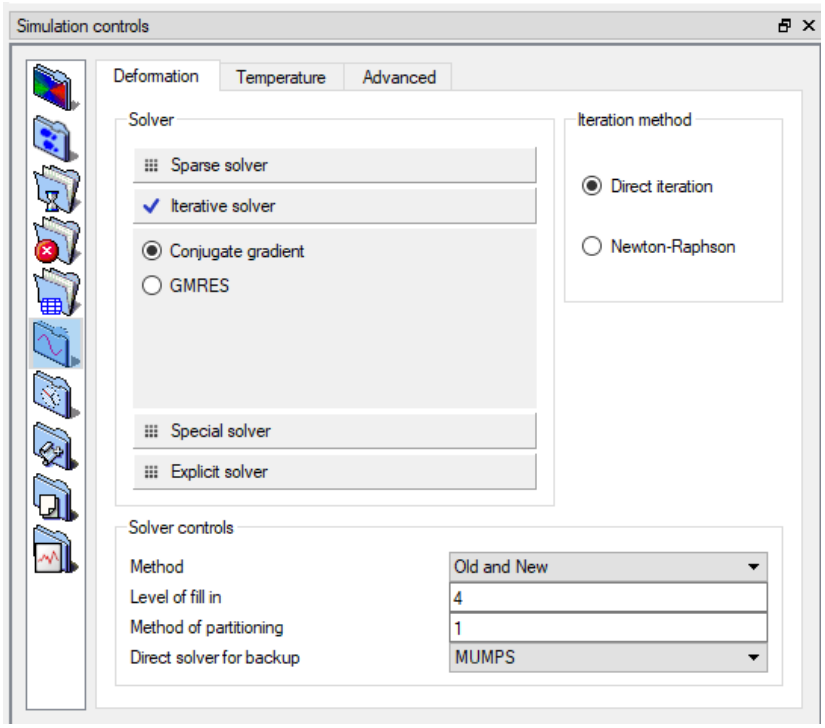


In V11.3, the default 2D setting is the Skyline solver with Newton-Raphson (NR) iteration method. The Skyline solver is a very basic matrix inversion solution and it was the original solver used in DEFORM. It is robust, but not necessarily efficient. The SPOOLES and MUMPS sparse matrix solvers are newer and more efficient, especially for larger problems.

In the upcoming V12.0, the MUMPS solver with Newton-Raphson iteration method with be the new default for all simulations (plastic, elastoplastic, force-controlled, etc.).

3D

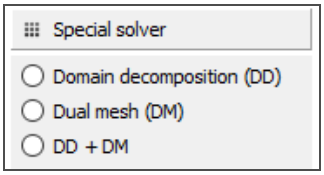
The following options are available for 3D simulations. You can see that there are quite a few additional options that are not available in 2D.



In V11.3, the default 3D solver for simulations with plastic objects is Conjugate gradient (CG) with direct iterations. Specifically, the 'Old and New' CG solver (Level of fill in = 4, Method of partitioning = 1) is the default with the MUMPS solver being the backup if needed for convergence.

Elasto-plastic (EP) simulations cannot use the direct iteration method, so the recommendation for EP is the MUMPS solver with Newton-Raphson iterations.

The Special solver category contains several newly developed options intended to speed up the solving of very large 3D simulations (millions of elements).



Domain decomposition (DD) splits the workpiece into several small sub-domains that can each be solved separately on different cores. Dual mesh (DM) simultaneously uses both a fine and coarse mesh on the workpiece, where the solution on the coarse mesh is used as the initial guess for the fine mesh. This can substantially improve the solving speed of the CG solver. If desired, both of these techniques can be used for the same simulation (DD + DM).

All the solvers that have been discussed thus far are called implicit solvers. These solvers calculate a series of iterations in order to establish equilibrium at each step.

An explicit solver is now available for 3D simulations. An explicit solver does not require any iterations and the nodal velocities are solved directly. Explicit solvers are typically used to simulate processes which have a very short time duration (such as automobile crashes). The time step in an explicit analysis must be very small - less than the time it takes a sound wave to travel across an element. Implicit simulations, on the other hand, do not have an inherent time step size limit, so implicit time steps are generally several orders of magnitude larger than explicit time steps. If the process being modeled is very short, or the time steps are required to be very small, the explicit solver might be a good fit. Contact DEFORM Technical Support if you would like to try the explicit solver.

Solver Recommendations

Now that the solvers for 2D and 3D have been described, it would be helpful to have a table detailing the recommended solvers for various model setups.

2D				
Workpiece Type	**Tool Type**	**Movement**	**Preferred Solver**	**Alternate solver**
All	All	All	MUMPS/NR	Skyline/NR

As the table shows, the MUMPS solver is recommended in all situations. For small problem sizes, all the solvers will have essentially the same speed. As the problem size increases, the MUMPS solver becomes the fastest option.

3D				
Workpiece Type	**Tool Type**	**Movement**	**Preferred Solver**	**Alternate solver**
Plastic (single)	Rigid	Velocity	CG/ MUMPS backup	MUMPS/NR
				Dual Mesh[1]
				Domain Decomposition[2]
Plastic (single)	Rigid	Force	MUMPS/NR	Domain Decomposition[2]
Plastic (single)	Rigid	Hydraulic Press	CG/ MUMPS backup	MUMPS/NR
				Dual Mesh[1]
Plastic (rotational symmetry)	Rigid	Velocity	CG/ MUMPS backup	MUMPS/NR[3]
Plastic	Elastic	Any	MUMPS/NR	CG will run, but is dramatically slower
Multiple Plastic	Any	Any	MUMPS/NR	None
Plastic (brick mesh)	Any	Any	MUMPS/NR	CG with reduced velocity and force error limits
Elasto-plastic	Rigid (no mesh)	Velocity	MUMPS/NR	Combined DM / DD for very large models
Elasto-plastic	Rigid (no mesh)	Force		Combined DM / DD for very large models
Elasto-plastic	None (WP - Mixed formulation tets)	Thermal Load		Combined DM / DD for very large models
Elasto-plastic	Elastic/ Rigid (w/ mesh)	Velocity		None
Elastic only	Rigid or Elastic	Velocity / None	CG/ MUMPS backup	MUMPS/NR[4]acceptable but generally slower
Elastic only	Rigid or Elastic	Force	MUMPS/NR[4]	
Porous	Rigid	Velocity	CG/ MUMPS backup	MUMPS/NR
Porous	Any combination other than Rigid tool / velocity control		MUMPS/NR	None
[1] *Dual Mesh must use tetrahedral mesh. DM may be faster for very large problems.*				
[2] *Domain Decomposition cannot have mesh on rigid tools, and FEM-based volume compensation cannot be used. DD may be faster for very large problems.*				
[3] Rotationally symmetric models with a brick mesh MUST use the MUMPS solver.				
[4] *If convergence is an issue, run with MUMPS/NR and "DEF_ELAON.DAT" in working directory (accepts a "close" solution, with a variation of around 10% in load and stress results).*				

Solver selection in 3D is less straightforward than 2D. Most 3D DEFORM simulations have one Plastic workpiece and velocity-controlled Rigid tools. These simulations should use the CG solver. Elasto-plastic simulations should use the MUMPS solver. The recommended solver for all other scenarios can be found in the above table.