



AD FALCON API Manual

IMEX Benchmark — 3D Fully Coupled Dynamic Column (Unsaturated)

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1 IMEX Benchmark — 3D Fully Coupled Dynamic Column (Unsaturated)

This example is a **3-D fully coupled** (`ThreeDFullyCoupled`) dynamic analysis intended to benchmark **IMEX** time integration for unsaturated soils (solid + PW + PA). The goal is to compare IMEX configurations that differ only in:

- **Mechanics mass solve** used by IMEX (`@@MassSolve: Diagonal, Direct, CG`)
- **Flow linear solver** (`@@SolverType: Direct` vs an iterative KSP solver)

See also: [Simulation Modes in Coupled & Fully-Coupled Analyses, Implicit Time Integration](#)

1.1 Problem definition

1.1.1 Geometry (as defined by the input)

A prismatic 3-D domain spanning approximately:

- $x \in [0.363, 1.777]$ ($\Delta x \approx 1.414$)
- $y \in [-6.574, -5.160]$ ($\Delta y \approx 1.414$)
- $z \in [0, 10]$ ($\Delta z = 10$)



1.1.2 Material and phases

Single material `Mat1` with:

- `@Mech: Elastic` (`YoungsModulus 2937600.0, PoissonRatio 0.3`)
- `@SWRC: BrooksAndCorey` (`psi_b 50, lambda 1.5`)
- `@EffectiveStress: GhorbaniKodikara` (`Beta1 1.0, Beta2 0.0`)
- `@Perm: BrooksCorey` (`k_sat 2.5e-12, lambda 1.5`)
- `@PhaseChar` specified for Solid/Liquid/Gas

1.1.3 Initial conditions

- `@Void` assigned uniformly: `0.3`
- `@PW` assigned uniformly: `-53.64` (pressure unit in the dataset: kPa)
- PA is not explicitly initialized in these files (it starts near zero in the reported outputs).

1.2 Boundary conditions and loading

1.2.1 Mechanical boundary conditions (roller + base support)

The inputs apply displacement constraints on the outer faces:

- `XMIN` and `XMAX`: `DisX = 0` (roller in the x-normal direction)
- `YMIN` and `YMAX`: `DisY = 0` (roller in the y-normal direction)
- `ZMIN` (base): `DisZ = 0` (vertical support at the bottom)

No PW / PA Dirichlet or flux boundary conditions are prescribed in these input files (i.e., hydraulics are “closed” in the sense of boundary conditions).

1.2.2 Applied load (surface pressure)

A small surface pressure is applied via the **Stress Boundary** block using repeated @Surface Pressure patches (normal pressure $-1e-3$, tangentials 0.0), with:

- LoadType Immediate Step 1
- Propagate: Yes

1.3 Time integration (IMEX) and solver variants

All variants use:

- @@SimMode: Dynamic
- @@TimeIntegration: Imex
- @@StepTime: 0.1 and @@NumberSteps: $100000 \Rightarrow dt = 1e-6$
- @@ModernAutoInc: No
- @@OutputTypes: None + a lightweight @DOFOutput

The “flow iterative” variant in this dataset uses:

```
@@SolverType: KSPBICG
@@PreconditionerType: PCILU
```

1.4 Input files (copied into this manual)

Each file below is a standalone fem_data.txt representing one IMEX configuration:

- IMEX diag(M), flow Direct: [Falcon_inputs/imex_3d_full_Top1_dt1e-6_diagonal_flow_direct.txt](#)
- IMEX diag(M), flow Iterative: [Falcon_inputs/imex_3d_full_Top1_dt1e-6_diagonal_flow_iter.txt](#)
- IMEX Mdd (Direct), flow Direct: [Falcon_inputs/imex_3d_full_Top1_dt1e-6_direct_flow_direct.txt](#)
- IMEX Mdd (Direct), flow Iterative: [Falcon_inputs/imex_3d_full_Top1_dt1e-6_direct_flow_iter.txt](#)
- IMEX Mdd (CG), flow Direct: [Falcon_inputs/imex_3d_full_Top1_dt1e-6_cg_flow_direct.txt](#)
- IMEX Mdd (CG), flow Iterative: [Falcon_inputs/imex_3d_full_Top1_dt1e-6_cg_flow_iter.txt](#)

1.5 Probes and outputs

1.5.1 DOF probes (DisZ + PW/PA)

The inputs write time histories at three probes:

```
% DOFOutput
@Nodes 36 1276 2460
@DOFs DisZ PW PA
@Every 10
@OutputFile dof_output.csv
```

probe	node_id	(x, y, z)
bottom	36	(1.19058, -5.6599974, 0.0)
mid	1276	(0.99900917, -5.9217444, 5.1525582)
top	2460	(1.19058, -5.6599974, 10.0)

1.6 Results

The plots below compare `@MassSolve = {Diagonal, Direct, CG}` while keeping **flow solve = Direct** (all generated from the corresponding `dof_output.csv` files in the dataset). The **flow Iterative** variants are not included in these figures because they use a different flow solver (`@SolverType: KSPBICG`), and this figure focuses on isolating `@MassSolve`.

Note: the reported PW/PA values in these `dof_output.csv` files are small transients about the initialized state (i.e., they do not include the initial `@PW` offset in the time history).

1.6.1 Displacement (DisZ)

1.6.2 Pore-water pressure (PW)

1.6.3 Pore-air pressure (PA)

1.7 Run time summary (dataset)

All runs in the dataset were executed with `OMP_NUM_THREADS=1` and completed the full Step 1 horizon ($T=0.1$, $dt=1e-6$) for the successful configurations:

run	@SolverType (flow)	@MassSolve	wall_s
IMEX diag(M), flow Direct	Direct	Diagonal	74979
IMEX diag(M), flow Iterative	KSPBICG + PCILU	Diagonal	74999
IMEX Mdd (Direct), flow Direct	Direct	Direct	75009
IMEX Mdd (Direct), flow Iterative	KSPBICG + PCILU	Direct	75219

run	@@SolverType (flow)	@@MassSolve	wall_s
IMEX Mdd (CG), flow Direct	Direct	CG	93836
IMEX Mdd (CG), flow Iterative	KSPBICG + PCILU	CG	93876

1.8 Notes

- Some mass-lumping strategies (e.g., row-sum lumping) can be problematic for certain element formulations/meshes; the inputs linked above keep only the stable IMEX configurations used for comparison.



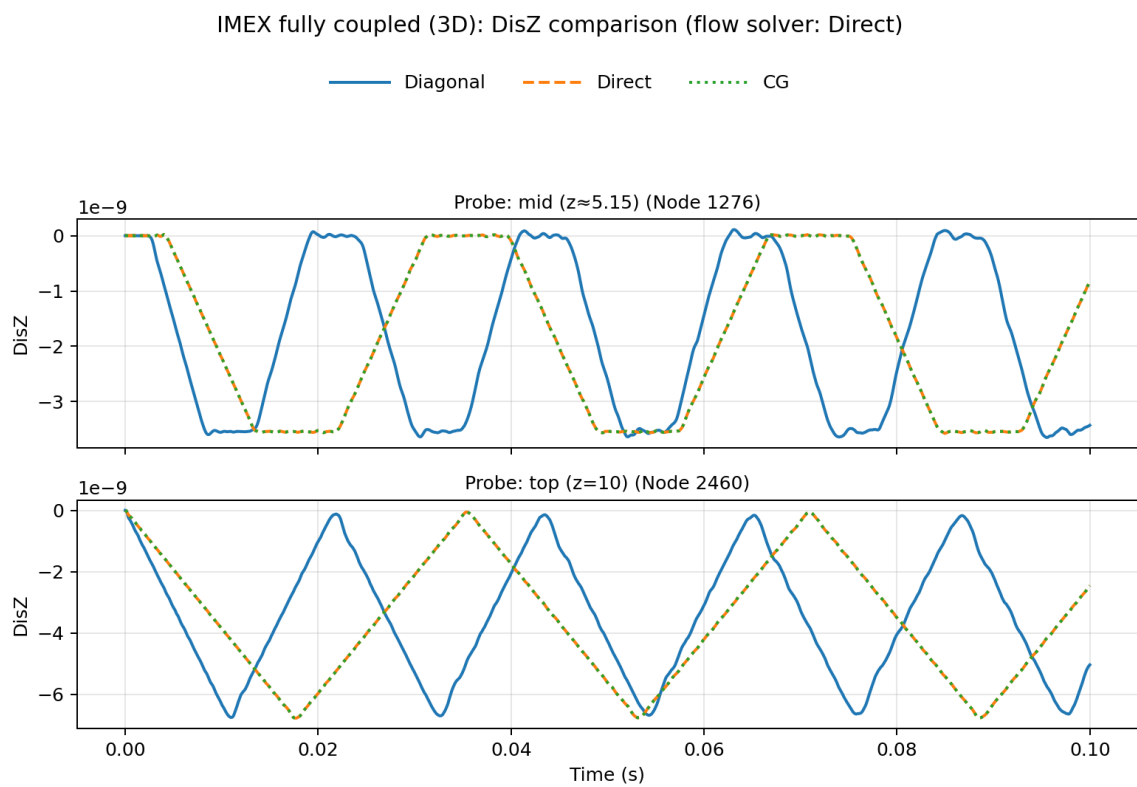


Figure 1: IMEX fully coupled 3D DisZ comparison

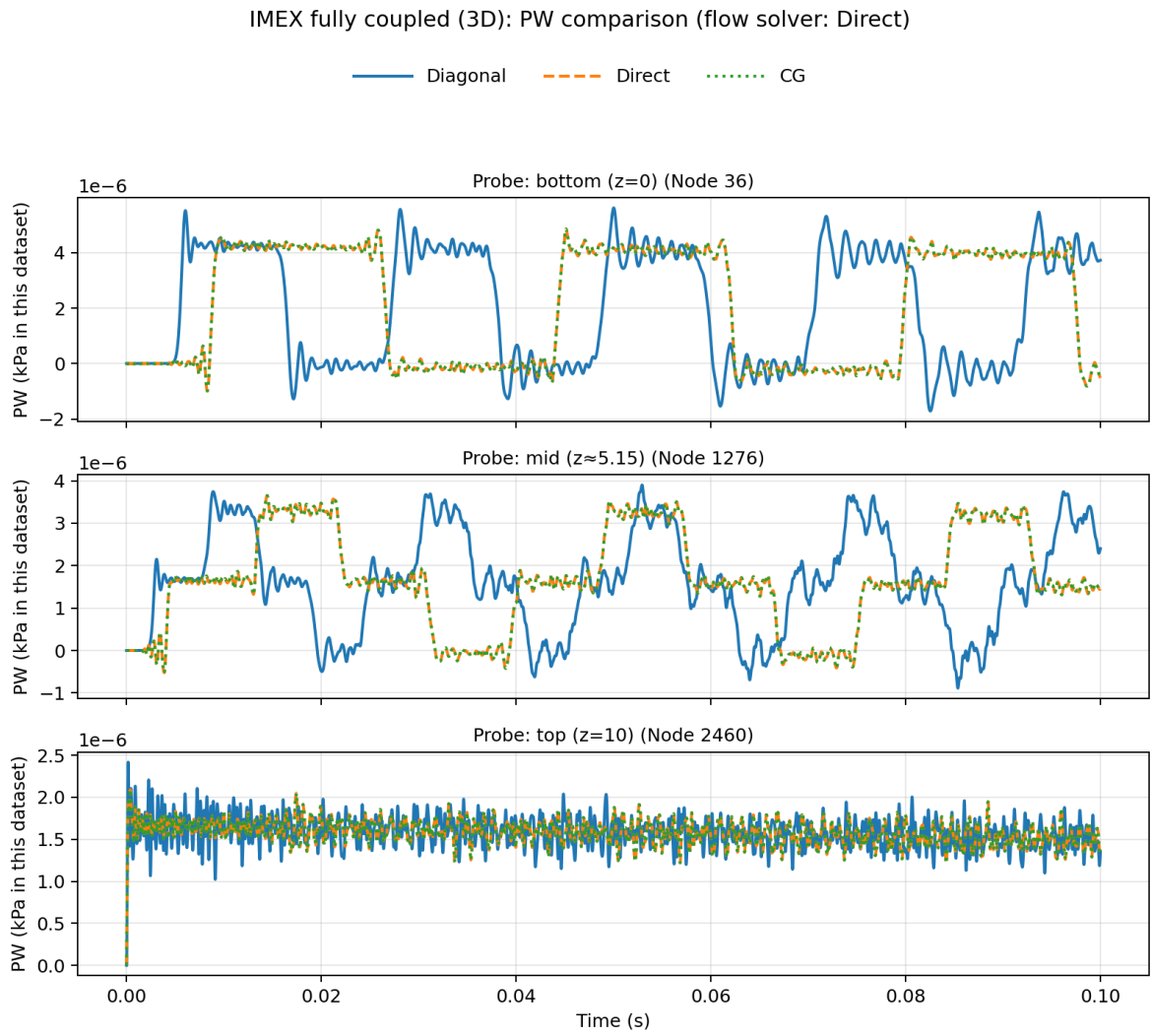


Figure 2: IMEX fully coupled 3D PW comparison

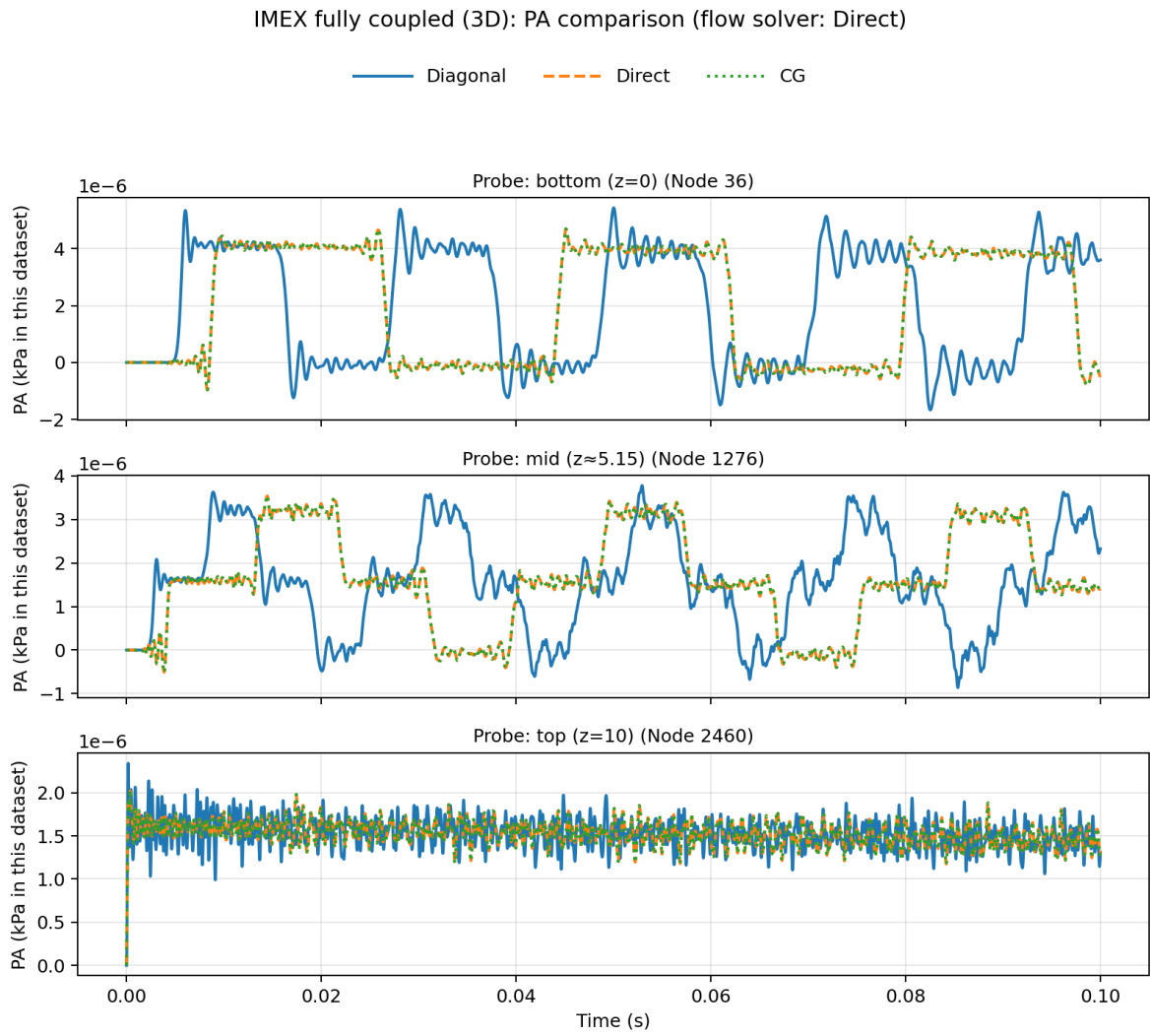


Figure 3: IMEX fully coupled 3D PA comparison