AD FALCON API Manual

Phase Properties

Javad Ghorbani

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Contents

1 Phase Properties

Phase properties define the physical characteristics of the solid, liquid, and gas phases in FALCON materials. They are required for all analysis types; liquid and gas phases become relevant in coupled and fully coupled analyses where multiple phases interact.

1.1 Overview

FALCON supports three phases: - **Solid**: The soil skeleton - **Liquid**: Water phase (for coupled and fully coupled analyses) - **Gas**: Air phase (for fully coupled analyses)

Each phase requires specific properties that define its density, bulk modulus, and viscosity (where applicable).

1.2 Syntax

Phase properties are specified using the `@PhaseChar:` directive in the `% Materials` section:

```
@PhaseChar: Solid rhos <density>
@PhaseChar: Liquid rhow <density> K_l <bulk_modulus> l_vicosity <viscosity>
@PhaseChar: Gas rhog <density> k_g <bulk_modulus> g_vicosity <viscosity>
```

1.2.1 Directive Format

- **Case-insensitive**: `@PhaseChar:`, `@phasechar:`, `@PHASECHAR:` are all equivalent
- **Colon spacing**: Both `@PhaseChar: Solid ...` and `@PhaseChar:Solid ...` are accepted
- **Parameters**: Space-separated `name value` pairs (not `name=value`)

1.3 Phase Definitions

1.3.1 Solid Phase

Format: `@PhaseChar: Solid rhos <density>`

Parameter	Description	Dimensions	Required
`rhos`	Solid density parameter	M/L^3	Yes

Example:

```
@PhaseChar: Solid rhos 2.7
```

Notes: - Required for all analysis types - In `*NonCoupled` / `*UnCoupled` analyses, FALCON uses `rhos` directly as the continuum density `rho` in inertia and body-force terms (i.e., `rho = rhos`) - In `*Coupled` and `*FullyCoupled` analyses, FALCON computes the bulk density `rho` from `rhos`, porosity (from void ratio), saturation, and (when present) `rhow` / `rhog` - Dimensions: M (mass), L (length)

1.3.2 Liquid Phase

Format: `@PhaseChar: Liquid rhow <density> K_l <bulk_modulus> l_vicosity <viscosity>`

Parameter	Description	Dimensions	Required
`rhow`	Liquid (water) density	M/L^3	Yes
`K_l`	Liquid bulk modulus	$M/(L \cdot T^2)$	Yes
`l_vicosity`	Liquid viscosity	$M/(L \cdot T)$	Yes

Example:

```
@PhaseChar: Liquid rhow 0.997 K_l 2.25e6 l_vicosity 1e-6
```

Notes: - Required for coupled (`*Coupled`) and fully coupled (`*FullyCoupled`) analyses - Used in pore pressure calculations and flow equations - Dimensions: M (mass), L (length), T (time)

1.3.3 Gas Phase

Format: `@PhaseChar: Gas rhog <density> k_g <bulk_modulus> g_vicosity <viscosity>`

Parameter	Description	Dimensions	Required
`rhog`	Gas (air) density	M/L^3	Yes
`k_g`	Gas bulk modulus	$M/(L \cdot T^2)$	Yes
`g_vicosity`	Gas viscosity	$M/(L \cdot T)$	Yes

Example:

```
@PhaseChar: Gas rhog 1.1e-3 k_g 1.01e2 g_vicosity 1.8e-5
```

Notes: - Required for fully coupled (`*FullyCoupled`) analyses only - Used in air pressure calculations and two-phase flow - Dimensions: M (mass), L (length), T (time)

1.4 Material Requirements by Analysis Type

Analysis Type	Required Phases
`*NonCoupled` / `*UnCoupled`	Solid only
`*Coupled`	Solid + Liquid
`*FullyCoupled`	Solid + Liquid + Gas

> **Important**: In fully coupled analyses, **all materials must include all three phases** (`@PhaseChar: Solid`, `@PhaseChar: Liquid`, `@PhaseChar: Gas`). Missing any phase property will result in an error.

1.5 Complete Material Example

1.5.1 Uncoupled Analysis

```
% Materials
Clay
@UMAT:/path/to/LinearElasticUMAT.cpp /path/to/LinearElasticUMAT.hpp
Mechanical YoungsModulus=2.0e8 PoissonsRatio=0.3
@PhaseChar: Solid rhos 2.7
%%%
```

1.5.2 Coupled Analysis

```
% Materials
Clay
@UMAT:/path/to/MohrCoulombUMAT.cpp /path/to/MohrCoulombUMAT.hpp Mechanical
Cohesion=10000 FrictionAngle=30
@Perm: Constant k_sat 1e-10
@PhaseChar: Solid rhos 2.7
@PhaseChar: Liquid rhow 0.997 K_l 2.25e6 l_vicosity 1e-6
%%%
```

1.5.3 Fully Coupled Analysis

```
% Materials
Clay
@UMAT:/path/to/GCCUMAT.cpp /path/to/GCCUMAT.hpp Mechanical lambda=0.2
kappa=0.05 M=1.25
```

```
@SWRC: Hysteretic alpha_1 0.5 n 1.4 m 0.5 omega_prime 0.1 alpha_2 0.2 bd
0.05 bw 0.05 SW_max 0.45 SW_min 0.05 b_s_c 0.01
@EffectiveStress: GhorbaniKodikara Beta1 0.55 Beta2 0.25
@Perm: Constant k_sat 1e-12
@PhaseChar: Solid rhos 2.7
@PhaseChar: Liquid rhow 0.997 K_l 2.25e6 l_vicosity 1e-6
@PhaseChar: Gas rhog 1.1e-3 k_g 1.01e2 g_vicosity 1.8e-5
%%%
```

1.6 Physical Significance

1.6.1 Density (`rhos`, `rhow`, `rhog`)

Densities determine the mass of each phase per unit volume. They are used in: - Mass balance equations - Inertial effects in dynamic analyses - Body force calculations

Dimensions: M/L^3 where M (mass), L (length)

1.6.2 Bulk Modulus (`K_l`, `k_g`)

Bulk moduli characterize the compressibility of fluids: - **Liquid bulk modulus (`K_l`)**: Controls liquid compressibility; typically much larger than gas bulk modulus, making liquids nearly incompressible - **Gas bulk modulus (`k_g`)**: Controls gas compressibility; typically much smaller than liquid bulk modulus, making gases highly compressible

These moduli are critical for: - Pore pressure calculations - Volume change predictions - Coupling between mechanical and hydraulic behavior

Dimensions: $M/(L \cdot T^2)$ where M (mass), L (length), T (time)

1.6.3 Viscosity (`l_vicosity`, `g_vicosity`)

Viscosities control the resistance to flow: - **Liquid viscosity (`l_vicosity`)**: Affects liquid flow through porous media (Darcy's law) - **Gas viscosity (`g_vicosity`)**: Affects gas flow in unsaturated soils

Viscosities are used in: - Permeability calculations - Flow rate predictions - Relative permeability models

Dimensions: $M/(L \cdot T)$ where M (mass), L (length), T (time)

1.7 Common Issues and Troubleshooting

1. **Missing phase properties**: Ensure all required phases are defined for your analysis type
2. **Dimensional consistency**: Verify that all input values use consistent dimensions (M, L, T, F) throughout the analysis
3. **Unrealistic values**: Check that density, bulk modulus, and viscosity values are physically reasonable relative to each other

4. **Temperature effects**: Note that viscosity and density can vary with temperature; use values appropriate for your simulation conditions

1.8 Related Documentation

- Materials - General material property definitions
- Input File Structure - Overall input file syntax
- Coupled Analysis Theory - Theory behind coupled analyses
- Fully Coupled Analysis Theory - Theory behind fully coupled analyses