PhiPsi Keywords Manual.

- This manual simply describes the usage of each keyword used in PhiPsi.
- Author: Fang Shi
- Website: www.phipsi.top
- Email: shifang@hyit.edu.cn / shifang@ustc.edu.cn
- Updated on March 9, 2024

Basic control keywords.

- ***Work_Dirctory** - File location of the input files of PhiPsi, i.e., the work directory.

  Keyword example:

  ```
  *Work_Directory
  X:\PhiPsi_Work\FEM
  ```

- ***Filename** - Filename of the input files of PhiPsi (all input files have the same filename).

  Keyword example:

  ```
  *Filename
  FEM
  ```

- ***Key_Unit_System** - Unit system.

  = 1, international system of units (default);

  = 2, mm-ton-s.

  Keyword example:

  ```
  *Key_Unit_System
  1     % SI.
  ```

- ***Key_Dimension** - The dimension of the problem.

  = 2, two-dimension (Plane stress or plane strain)

  = 3, three-dimension

  Keyword example:

  ```
  *Key_Dimension
  2     % 2D problem.
  ```

- ***Key_Type_2D** - Define plane stress or plane strain for 2D problems.

  = 1, plane stress;

= 2, plane strain (default).

Keyword example:

```
*Key_Type_2D
2     % plane strain.
```

- *__Key_Analysis_Type__ - Analysis type.

  = 1, quasi-static (default);

  = 2, implicit dynamic;

  = 3, hydraulic fracturing simulation;

  = 4, Hydraulic fracturing simulation with slick water;

  = 7, nonlinear problem (such as plastic deformation problem);

  = 15, field problem (such as heat transfer problem).

  Keyword example:

```
*Key_Analysis_Type
1     % quasi-static.
```

- *__Key_SIFs_Method__ - Method to calculate the stress intensity factors (SIFs).

  = 1, displacement interpolation method (DIM; default);

  = 2, the interaction integral method.

  Keyword example:

```
*Key_SIFs_Method
2     % the interaction integral method.
```

- *__Key_SIFs_DIM_Points__ - Number of points to calculate SIFs using DIM method (default to 2).

  Keyword example:

```
*Key_SIFs_DIM_Points
2
```

- *__Key_SIFs_DIM_Method__ - Model assumption of the DIM method.

  = 1, plane stress (default);

  = 2, plane strain.

  Keyword example:

```
*Key_SIFs_DIM_Method
2
```

- *__Key_Print_SIFs_to_Screen__ - Print SIFs to screen / terminal.

  = 0, do not print SIFs to screen / terminal (default);

  = 1, print SIFs to screen / terminal.

  Keyword example:

  ```
  *Key_Print_SIFs_to_Screen
  1
  ```

- ***Key_Contact** - Consider contact between crack surfaces or not.

  = 0, no (default);

  = 1, yes.

  Keyword example:

  ```
  *Key_Contact
  1     % Active contact between crack surfaces.
  ```

- ***Max_Contact_Iter** - The maximum number of contact iterations (default to 50).

  Keyword example:

  ```
  *Max_Contact_Iter
  10
  ```

- ***fric_mu_Cont** - Friction coefficient of crack surfaces (default to 0.3).

  Keyword example:

  ```
  *fric_mu_Cont
  0.4
  ```

- ***kn_Cont_Penalty** - Normal penalty stiffness of crack surfaces (default to 1.0e13).

  Keyword example:

  ```
  *kn_Cont_Penalty
  1.0e12
  ```

- ***kt_Cont_Penalty** - Tangential penalty stiffness of crack surfaces (default to 1.0e13).

  Keyword example:

```
*kt_Cont_Penalty
1.0e12
```

- *__Conve_Tol_Penalty__ - Convergence tolerance for the contact iteration (default to 1.0e-5).

  Keyword example:

  ```
  *Conve_Tol_Penalty
  1.0e-4
  ```

- *__Num_Substeps__ - Number of steps need to be performed.

  Keyword example:

  ```
  *Num_Substeps
  10
  ```

- *__CFCP__ - Criterion of crack propagation.

  = 1, maximum tensile circumferential stress criterion (default);

  = 2, maximum principal tensile stress criterion;

  = 3, Schollmann's criterion.

  Keyword example:

  ```
  *CFCP
  2      % Maximum principal tensile stress criterion.
  ```

- *__Key_CFCP_3_Type__ - Crack growth behavior for the Schollmann's criterion.

  = 1, crack grows only when the equivalent stress intensity factor is greater than the fracture toughness $K_I$$_c$ (default);

  = 2, crack grows when the equivalent stress intensity factor is greater than zero.

  Keyword example:

  ```
  *Key_CFCP_3_Type
  2
  ```

- *__Key_TipEnrich__ - Crack tip enrichment type.

  = 0, no crack tip enrichment, the crack tip is automatically adjusted to the element boundary;

  = 1, standard crack tip enrichment (4 items, F_1 to F_4; default).

  = 2, keep only the first item (F_1, this is recommended for dynamic analysis);

  = 3, not available yet;

= 4, Cohesive crack tip_cohesive crack (only 1 enrichment function item).

Keyword example:

```
*Key_TipEnrich
1
```

- *__Key_Fd_TipEnrich__ - Crack tip enrichment type for field problems.

  = 0, no crack tip enrichment, the crack tip is automatically adjusted to the element boundary;

  = 1, strong discontinuity crack tip enrichment (enrichment function is $sqrt(r) * sin(\theta/2)$; adiabatic crack for heat conduction problem; default);

  = 2, weak discontinuity crack tip enrichment (enrichment function is $sqrt(r) * cos(\theta/2)$; isothermal crack for heat conduction problem).

  Keyword example:

  ```
  *Key_Fd_TipEnrich
  1
  ```

- *__Key_InPlane_Growth__ - Plannar or nonplanar crack propagation.

  = 0, nonplanar crack propagation (default);

  = 1, planar crack propagation.

  Keyword example:

  ```
  *Key_InPlane_Growth
  1
  ```

- *__Key_Allow_3D_Outside_Crack__ - Allow the 3D cracks to be outside the model.

  = 0, does not allow the cracks to be outside the model (default);

  = 1, allow the cracks to be outside the model.

  Keyword example:

  ```
  *Key_Allow_3D_Outside_Crack
  1
  ```

- *__Key_Stop_Outside_Crack__ - Do not allow cracks to grow outside the model.

  = 0, allow cracks to grow outside the model (default);

  = 1, do not allow cracks to grow outside the model.

  Keyword example:

```
*Key_Stop_Outside_Crack
1
```

- *__Key_Denoise_Vertex_Value__ - Denoise vertex values for 3D cracks.

  = 0, no (default);

  = 1, yes.

  Keyword example:

  ```
  *Key_Denoise_Vertex_Value
  1
  ```

- *__Key_Smooth_Vertex_Value__ - Smooth vertex values for 3D cracks.

  = 0, no (default);

  = 1, yes.

  Keyword example:

  ```
  *Key_Smooth_Vertex_Value
  1
  ```

- *__Key_Smooth_GF_Value__ - Smooth the propagation for 3D cracks.

  = 0, no (default);

  = 1, yes.

  Keyword example:

  ```
  *Key_Smooth_GF_Value
  1
  ```

- *__Key_Smooth_Front__ - 3D crack propagation front vertex smoothing scheme.

  = 0, do not smooth crack front (default);

  = 1, Smooth the crack front edge according to the straight line equation;

  = 2, According to the equation of the circle;

  = 3, CSAPS cubic spline fitting;

  = 4, B-spline curve fitting;

  = 5, According to the equation of ellipse;

  = 6, Taubin smoothing algorithm.

  Keyword example:

```
*Key_Smooth_Front
6
```

- *__Key_Force_Control__ - The method to control the value of the applied force for each step.

  = 1, the force is applied all at once (default);

  = 2, the applied force increases linearly in each step;

  = 3, not available yet;

  = 4, special scheme for cohesive crack;

  = 5, make sure that only one crack grows in each step.

  Keyword example:

```
*Key_Force_Control
1
```

- *__Key_Initiation__ - Initiation of cracks.

  = 0, no new crack generated (default);

  = 1, new cracks are allowed to be generated.

  Keyword example:

```
% New cracks are allowed to be generated.
*Key_Initiation
1
```

- *__Key_Propagation__ - Propagation of cracks.

  = 0, cracks are not allowed to propagate;

  = 1, cracks are allowed to propagate (default).

  Keyword example:

```
% Cracks are allowed to propagate.
*Key_Propagation
1
```

- *__Cracks_Allow_Propa__ - Allow cracks 1 to n to propagate.

  = 0, does not allow cracks to propagate;

  = 1, allow cracks to propagate (default).

  Keyword example:

```
*Cracks_Allow_Propa
1,1,1,1,1,0,0,0,0,0     % Allow cracks 1 to 5 to propagate, and does nc
```

- *__Key_CS_Natural_Crack__ - Using penalty function method to simulate contact of natural cracks.

  = 0, no (default);

  = 1, yes.

  Keyword example:

  ```
  *Key_CS_Natural_Crack
  1
  ```

- *__Key_Check_and_Adjust_Cracks_3D__ - Check and adjust initial 3D cracks.

  = 0, no (default);

  = 1, yes.

  Keyword example:

  ```
  *Key_Check_and_Adjust_Cracks_3D
  1
  ```

- *__Factor_Propagation__ - Factor of propagation length of cracks, i.e., propagation length $\Delta l = *Factor_Propagation \times l_c$, where l_c represents the average size of enriched elements.

  Keyword example:

  ```
  *Factor_Propagation
  1.5
  ```

- *__Propagation_Length__ - Propagation length of cracks during a propagation step (Unit: m).

  Keyword example:

  ```
  *Propagation_Length
  0.010
  ```

- *__Key_Fracture_Zone__ - % Define propagation zone, i.e., cracks are allowed to propagate just inside the propagation zone.

  = 0, no propagation zone (default);

  = 1, define a propagation zone (default).

  Keyword example:

```
*Key_Fracture_Zone
1
```

- ***Frac_Zone_MinX** - % Minimum value of range x of the fracture zone.

  Keyword example:

  ```
  *Frac_Zone_MinX
  4.0e-3
  ```

- ***Frac_Zone_MinY** - % Minimum value of range y of the fracture zone.

  Keyword example:

  ```
  *Frac_Zone_MinY
  4.0e-3
  ```

- ***Frac_Zone_MinZ** - % Minimum value of range z of the fracture zone.

  Keyword example:

  ```
  *Frac_Zone_MinZ
  4.0e-3
  ```

- ***Frac_Zone_MaxX** - % Maximum value of range x of the fracture zone.

  Keyword example:

  ```
  *Frac_Zone_MaxX
  50.0e-3
  ```

- ***Frac_Zone_MaxY** - % Maximum value of range y of the fracture zone.

  Keyword example:

  ```
  *Frac_Zone_MaxY
  50.0e-3
  ```

- ***Frac_Zone_MaxZ** - % Maximum value of range z of the fracture zone.

  Keyword example:

  ```
  *Frac_Zone_MaxZ
  50.0e-3
  ```

- ***Key_InSitu_Strategy** - In-situ stress.

  = 0, does not consider initial stress issues;

= 1, the displacement field generated by in-situ stress is processed through linear superposition;

= 2, use the method proposed in the book 'The Finite Element Method: its Basis and Fundamentals';

= 3, shield the applied in-situ stress (only for hydraulic fracturing analysis);

= 4, specify the initial stress or read from the initial stress file.

Keyword example:

```
*Key_InSitu_Strategy
4     % Active gravity.
```

- ***InSitu_S1_3D** - In-situ stress S_1 when Key_InSitu_Strategy = 4. Keyword example:

```
*InSitu_S1_3D
0.0e6
```

- ***InSitu_S1_nv_3D** - Normal vector of In-situ stress S_1 when Key_InSitu_Strategy = 4. Keyword example:

```
*InSitu_S1_nv_3D
1.0,0.0,0.0
```

- ***InSitu_S2_3D** - In-situ stress S_2 when Key_InSitu_Strategy = 4. Keyword example:

```
*InSitu_S2_3D
0.0e6
```

- ***InSitu_S2_nv_3D** - Normal vector of In-situ stress S_2 when Key_InSitu_Strategy = 4. Keyword example:

```
*InSitu_S2_nv_3D
1.0,0.0,0.0
```

- ***InSitu_S3_3D** - In-situ stress S_3 when Key_InSitu_Strategy = 4. Keyword example:

```
*InSitu_S3_3D
0.0e6
```

- ***InSitu_S3_nv_3D** - Normal vector of In-situ stress S_3 when Key_InSitu_Strategy = 4. Keyword example:

```
*InSitu_S3_nv_3D
1.0,0.0,0.0
```

- *Key_Gravity - Gravity.

  = 0, no gravity (default);

  = 1, apply gravity to the whole model.

  Keyword example:

  ```
  *Key_Gravity
  1     % Active gravity.
  ```

- *g_X_Y_Z - Values of gravitational acceleration in x, y and z directions.

  1, gravitational acceleration in x direction;

  2, gravitational acceleration in y direction;

  3, gravitational acceleration in z directions.

  Keyword example:

  ```
  *g_X_Y_Z
  0,0,9.8      % Set gravitational acceleration in z direction.
  ```

- **KEY_RANDOM_SCHEME - Random generation.

  = 0, randomly generates, but the generated results remain unchanged;

  = 1, randomly generates and the generated results are different (default);

  = 2, randomly generates with a given seed.

  = 3, randomly generates with a seed, seed is randomly generated.

  Keyword example:

  ```
  *Key_Random
  2
  ```

- *Seed - Seed for random generation (when *Key_Random=4).

  Keyword example:

  ```
  *Key_Random
  2
  *Seed
  12345  % Can be arbitrary integer.
  ```

- *Key_Crack_Aperture_Method - Method to calculate crack aperture.

  = 1, equation (default);

  = 2, according to displacements of points on both sides of the fracture surface.

  Keyword example:

```
*Key_Crack_Aperture_Method
1
```

Linear solvers.

- *__Key_SLOE__ - Select the solver of linear system.

  = 1, the direct solver (finding the inverse matrix);

  = 2, Gaussian elimination;

  = 3, Pardiso (only available for Intel Fortran compiler ifort or ifx);

  = 4, ITPACK (no longer supported);

  = 5, LAPACK (default);

  = 6, MUMPS (no longer supported);

  = 7, UMFPACK;

  = 8, Lis;

  = 9, SuperLU;

  = 10, Y12m (no longer supported);

  = 11, EBE-PCG (Element by element, preconditioned conjugate gradient solver).

  Keyword example:

  ```
  *Key_SLOE
  11      % EBE-PCG solver.
  ```

- *__Key_EBE_Precondition__ - Preconditioner for EBE-PCG solver.

  = 0, no preconditoner.

  = 1, diagonalized preprocessor (default);

  = 2, HW preprocessor.

  Keyword example:

  ```
  *Key_EBE_Precondition
  1
  ```

Define initial cracks, voids (holes) and inclusions.

- *__num_Crack__ - Number of initial cracks.

  Keyword example:

```
*num_Crack
5
```

- *__num_Hole__ - Number of initial holes.

  Keyword example:

  ```
  *num_Hole
  3
  ```

- *__num_Circ_Hole__ - Number of initial circle holes.

  Keyword example:

  ```
  *num_Circ_Hole
  1
  ```

- *__num_Circ_Incl__ - Number of circular inclusions.

  Keyword example:

  ```
  *num_Circ_Incl
  5
  ```

- *__num_Poly_Incl__ - Number of polygonal inclusions.

  Keyword example:

  ```
  *num_Poly_Incl
  3
  ```

- *__CRACK_1 - CRACK_50__ - Define the coordinates of each initial cracks (line segments) for 2D problem (input format: $P1_x$, $P1_y$, $P2_x$, $P2_y$, $P3_x$, $P3_y$, ... , Pn_x, Pn_y).

  Keyword example:

  ```
  % Coordinates of 5 initial cracks.
  *CRACK_1
  0.0217,0.0229,0.0253,0.0247
  *CRACK_2
  0.0083,0.0193,0.0123,0.0283
  *CRACK_3
  0.0383,0.0283,0.0423,0.0193
  *CRACK_4
  0.0217,0.0397,0.0253,0.0379
  *CRACK_5
  0.0083,0.0343,0.0123,0.0433
  ```

- *__Crack3D_Coor_1 - Crack3D_Coor_50__ - Define the coordinates of each initial cracks (plane in 3D composed of four points) for 3D problem (input format: x_1, y_1, z_1, x_2, y_2, z_2, x_3, y_3, z_3, x_4, y_4, z_4).

  Keyword example:

  ```
  *Crack3D_Coor_1
  10.0,14.0,6.0,10.0,14.0,14.0,10.0,6.0,14.0,10.0,6.0,6.0
  *Crack3D_Coor_2
  14.0,10.0,6.0,14.0,10.0,14.0,6.00,10.0,14.0,6.0,10.0,6.0
  *Crack3D_Coor_3
  6.0,6.0,10.0,14.0,6.0,10.0,14.0,14.0,10.0,6.0,14.0,10.0
  ```

- *__Hole_Coor_1 - Hole_Coor_30__ - Define the coordinates of initial holes in 2D (input format: x, y, r).

  Keyword example:

  ```
  % Define initial holes.
  *Hole_Coor_1
  15.25e-3,7.75e-3,2.0e-3
  *Hole_Coor_2
  4.25e-3,7.75e-3,1.5e-3
  *Hole_Coor_3
  26.25e-3,7.75e-3,1.5e-3
  ```

- *__Circ_Inclu_Coor_1 - Circ_Inclu_Coor_30__ - Define the coordinates of initial circular inclusions in 2D (input format: x, y, r).

  Keyword example:

  ```
  % Define an initial inclusion.
  *Circ_Inclu_Coor_1
  13.5e-3,10.5e-3,3.0e-3
  ```

- *__Key_Random_NaCr__ - Randomly generate initial cracks or not.

  = 0, do not generate (default);

  = 1, randomly generates;

  = 2, read from FracMan file (*.fab);

  = 3, generates according to user-defined parameters.

  Keyword example:

  ```
  % Read initial cracks from FracMan file (*.fab).
  *Key_Random_NaCr
  2
  ```

- *__Key_NaCr_Active_Scheme_3D__ - Activation algorithm for 3D natural fractures.

= 1, all natural fractures are activated at the initial moment. After being activated by hydraulic fracture, the fractures will be filled with fracturing fluid (default);

= 2, natural fractures are activated after being communicated by hydraulic fracture. After being activated by hydraulic fracture, the fractures will be filled with fracturing fluid;

= 3, natural fractures are partially activated after being communicated by hydraulic fracture. After being activated by hydraulic fracture, only part of the crack open and expand along the surface where the natural cracks are located.

Keyword example:

```
% Partially enable natural crack when activated by hydraulic cracks.
*Key_NaCr_Active_Scheme_3D
3
```

- *__KIC_NACR__ - $K_I$$_c$ of initial natural cracks.

  Keyword example:

  ```
  *KIC_NACR
  10
  ```

- *__KIC_NA_Crack_1 - KIC_NA_Crack_30__ - $K_I$$_c$ of initial natural crack n.

  Keyword example:

  ```
  *KIC_NA_Crack_1
  0.1e6
  *KIC_NA_Crack_2
  0.2e6
  ```

- *__St_NACR__ - S_t of natural cracks.

  Keyword example:

  ```
  *St_NACR
  0.1e6
  ```

- **St_NA_Crack_1 - St_NA_Crack_30* - S_t of natural crack n.

  Keyword example:

  ```
  *St_NA_Crack_1
  0.1e6
  *St_NA_Crack_2
  0.5e6
  ```

- *__Key_NaCr_Cross__ - Allow the intersection of initially generated natural cracks.

  = 1, no (default);

= 2, yes;

Keyword example:

```
*Key_NaCr_Cross
1
```

- *__num_Rand_Na_Crack__ - Number of cracks need to be randomly generated.

  Keyword example:

```
*num_Rand_Na_Crack
10
```

- *__NaCr_Orientation__ - Average direction (in degrees) of the cracks need to be randomly generated for 2D problems.

  Keyword example:

```
*NaCr_Orientation
-60.0
```

- *__NaCr_3D_n_Vector__ - Average direction (normal vector) of cracks need to be randomly generated for 3D problems.

  Keyword example:

```
*NaCr_3D_n_Vector
1.0,0.0,1.0
```

- *__NaCr_Ori_Delta__ - Fluctuation range (+ or -) of the average direction (in degrees) for 2D problems.

  Keyword example:

```
*NaCr_Ori_Delta
10.0
```

- *__NaCr_3D_n_Vector_Delta__ - Amplitude of fluctuation of the normal direction (in degrees) for 3D problems.

  Keyword example:

```
*NaCr_3D_n_Vector_Delta
15.0
```

- *__NaCr_Length__ - Average length of the cracks need to be randomly generated for 2D problems.

  Keyword example:

```
*NaCr_Length
10.0
```

- *__NaCr_3D_Size__ - Average size of the cracks need to be randomly generated for 3D problems.

  Keyword example:

  ```
  *NaCr_3D_Size
  10.0
  ```

- *__NaCr_Len_Delta__ - Fluctuation range (+ or -) of the average length of natural cracks for 2D problems.

  Keyword example:

  ```
  *NaCr_Len_Delta
  2.0
  ```

- *__NaCr_3D_Sz_Delta__ - Fluctuation range (+ or -) of the average size of natural cracks for 3D problems.

  Keyword example:

  ```
  *NaCr_3D_Sz_Delta
  5.0
  ```

- *__num_Rand_Hole__ - Number of holes need to be randomly generated.

  Keyword example:

  ```
  *num_Rand_Hole
  6
  ```

- *__Rand_Hole_R__ - Size of initial generated holes.

  Keyword example:

  ```
  *Rand_Hole_R
  1.2e-2
  ```

- *__Rand_Hole_Delta_R__ - Fluctuation range (+ or -) of size of initial generated holes.

  Keyword example:

  ```
  *Rand_Hole_Delta_R
  0.3e-2
  ```

- *__Key_Hole_Crack_Generate__ - Allow cracks to emerge from the inner edge of the holes.

  = 0, no (default);

  = 1, yes.

  Keyword example:

  ```
  *Key_Hole_Crack_Generate
  1
  ```

- *__Key_Num_Cr_Hole_Generated__ - The maximum number of cracks emerged from the inner edge of the holes.

  Keyword example:

  ```
  *Key_Num_Cr_Hole_Generated
  2
  ```

- *__Key_NaCr_Type_3D__ - Shape of initially generated natural cracks for 3D problems.

  = 1, rectangle;

  = 2, circle;

  = 3, polygon.

  Keyword example:

  ```
  *Key_NaCr_Type_3D
  1
  ```

- *__Key_Rand_Circ_Incl__ - Randomly generate circular inclusions or not.

  = 0, do not generate (default);

  = 1, generates.

  Keyword example:

  ```
  *Key_Rand_Circ_Incl
  1
  ```

- *__num_Rand_Circ_Incl__ - Number of circular inclusions need to be randomly generated.

  Keyword example:

  ```
  *num_Rand_Circ_Incl
  10
  ```

- *__Rand_Circ_Incl_R__ - The average radius of the circular inclusions need to be randomly generated.

Keyword example:

```
*Rand_Circ_Incl_R
0.5e-3
```

- *__Rand_Circ_Inc_R_Delta__ - Fluctuation range (+ or -) of the average radius.

  Keyword example:

  ```
  *Rand_Circ_Inc_R_Delta
  0.1e-3
  ```

- *__Key_Rand_Poly_Incl__ - Randomly generate initial regular polygonal inclusions or not.

  = 0, do not generate (default);

  = 1, generates.

  Keyword example:

  ```
  *Key_Rand_Poly_Incl
  1
  ```

- *__num_Rand_Poly_Incl__ - Number of regular polygonal inclusions need to be randomly generated.

  Keyword example:

  ```
  *num_Rand_Poly_Incl
  10
  ```

- *__num_Vert_Poly_Incl__ - Number of edges of regular polygonal inclusions.

  Keyword example:

  ```
  *num_Vert_Poly_Incl
  5
  ```

- *__Rand_Poly_Incl_R__ - Average radius of circumcircle of regular polygonal inclusions.

  Keyword example:

  ```
  *Rand_Poly_Incl_R
  0.5e-3
  ```

- *__Rand_Poly_Inc_R_Delta__ - Fluctuation range (+ or -) of the average radius of circumcircle of regular polygonal inclusions.

  Keyword example:

```
*Rand_Poly_Inc_R_Delta
0.1e-3
```

Definition of material parameters.

- ***Material_Type_1 - Material_Type_70** - material type definition for each material.

  = 1, isotropic material;

  = 2, plastic material (Von Mises yield criterion);

  = 3, damage material;

  = 4, Mohr-Coulomb plastic;

  = 5, Composite (for 3D problems only);

  = 6, Drucker-Prager plastic.

  Keyword example:

  ```
  *MATERIAL_TYPE_1
  1
  *MATERIAL_TYPE_2
  1
  *MATERIAL_TYPE_3
  1
  ```

- ***Material_Para_1 - Material_Para_10** - 20 parameters possibly needed to be defined for each material.

  1, elasticity modulus, E;

  2, Poisson's ratio, ν;

  3, density, ρ;

  4, thickness for 2D plane stress model, t;

  5, tensile strength, σ_t;

  6, fracture toughness, $K_I$$_c$;

  7, compressive strength, σ_c;

  8, coefficient of thermal expansion, T_α;

  9, specific heat coefficient, c;

  10, conductivity coefficient, Kxx;

  11, conductivity coefficient, Kyy;

  12, Mises yield stress σ_y;

  13, Tangent modulus after yielding E_T;

14, Hardening parameter β;

15, Cohesive strength c;

16, Internal friction angle φ;

17, Initial damage strain for tension;

18, Ultimate damage strain for tension;

19, Initial damage strain for compression;

20, Ultimate damage strain for compression.

Keyword example:

```
% Parameters for material type 1.
*Material_Para_1
35.0e9,0.25,2000.0,1.0,2.0e6,1.0e6,100.0e6,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
% Parameters for material type 2.
*Material_Para_2
0.02e9,0.3,200.0,1.0,1000.0e6,2.0e6,100.0e6,0.0,0.0,0.0,0.0,0.0,0.0,0.0
```

Keywords related to hydraulic fracturing simulation.

- ***Num_Frac** - Number of steps of the hydraulic fracturing simulation.

  Keyword example:

  ```
  *Num_Frac
  10
  ```

- ***Key_Symm_HF** - Symmetric hydraulic fracturing model.

  = 0, no (full model);

  = 1, yes.

  Keyword example:

  ```
  *Key_Symm_HF
  0
  ```

- ***Cracks_HF_State** - Initial states of each crack (fluid driven or not).

  = 0, free crack without fluid;

  = 1, hydraulic fluid-driven crack.

  Keyword example:

```
*Cracks_HF_State
1
```

- ***Inject_Crack_Num** - For full model (Key_Symm_HF=0), define the crack which contains the injection point of fluid (For symmetric model, the injection point is just the mouth of the edge crack which is also crack number 1).

  Keyword example:

  ```
  *Cracks_HF_State
  1
  ```

- ***Inj_Point_Loc** - For full model, define the coordinates of the injection point (input format: x, y).

  Keyword example:

  ```
  *Inj_Point_Loc
  8.5, 8.5
  ```

- ***Inject_Q_Time** - Define the time instants of the data curve of injection rate of fracturing fluid (unit: s; 20 time instants at most).

  Keyword example:

  ```
  *Inject_Q_Time
  0,10000
  ```

- ***Inject_Q_Val** - Define the values of injection rate of the data curve of injection rate of fracturing fluid (unit: m^3/s).

  Keyword example:

  ```
  *Inject_Q_Val
  0.001,0.001
  ```

- ***Inject_c_Time** - Define the time instants of the data curve of volumetric concentration of injected proppant (unit: s; 20 time instants at most).

  Keyword example:

  ```
  *Inject_c_Time
  0,10000,20000
  ```

- ***Inject_c_Val** - Define the values of concentration of the data curve of volumetric concentration of injected proppant.

  Keyword example:

```
*Inject_c_Val
0,0.1,0.3
```

- *__Key_Visco_Type__ - Static viscosity or dynamic viscosity.

  = 1, static viscosity;

  = 2, dynamic viscosity.

  Keyword example:

  ```
  *Key_Visco_Type
  1
  ```

- *__Viscosity__ - The viscosity of fracturing fluid (unit: $Pa\cdot s$).

  Keyword example:

  ```
  *Viscosity
  0.01
  ```

- *__Viscosity_Par_m__ - Parameter m of dynamic viscosity (define when *Key_Visco_Type =2).

  Keyword example:

  ```
  *Viscosity_Par_m
  2
  ```

- *__Key_Proppant__ - Consider proppant or not.

  = 0, no (default);

  = 1, yes.

  Keyword example:

  ```
  *Key_Proppant
  1
  ```

- *__Key_Propp_Trans__ - Consider the transport of proppant or not.

  = 0, no (default);

  = 1, yes.

  Keyword example:

  ```
  *Key_Propp_Trans
  1
  ```

- *__Key_Leakoff__ - Consider the leak off of the fracturing fluid or not.

= 0, no (default);

= 1, yes.

Keyword example:

```
*Key_Leakoff
0
```

- *Coeff_Leak - Leak coefficient of the Carter model (define when *Key_Leakoff =1).

  Keyword example:

```
*Coeff_Leak
1.0d-5
```

- ***Key_Crack_Inner_Pressure** - Active initial fluid pressure of cracks.

  = 0, no (default);

  = 1, yes.

  Keyword example:

```
*Key_Crack_Inner_Pressure
1
```

- ***INI_CRACK_PRESSURE_1 - INI_CRACK_PRESSURE_50** - Initial fluid pressure of cracks.

  = 0, no (default);

  = 1, yes.

  Keyword example:

```
*INI_CRACK_PRESSURE_1
10.0e6
*INI_CRACK_PRESSURE_2
10.0e6
```

- ***Key_3D_HF_Time_Step_Method** - Method to solve the fluid-solid coupling problem for the 3D hydraulic fracturing simulation with slick water.

  = 1, Dual-layer Newton-Raphson iteration (default);

  = 2, bisection.

  Keyword example:

```
*Key_3D_HF_Time_Step_Method
1
```

- *__Key_3D_HF_SlipWater_fk_Type__ - Calculation method of the equivalent stress intensity factor crack propagation criterion for 3D hydraulic fracturing simulation with slick water.

  = 1, the maximum equivalent stress intensity factor;

  = 2, the avarage equivalent stress intensity factor;

  = 3, the minimum equivalent stress intensity factor.

  Keyword example:

  ```
  *Key_3D_HF_SlipWater_fk_Type
  3
  ```

- *__Key_HF_Multistage_3D__ - Active staged fracturing.

  = 0, no (default);

  = 1, yes.

  Keyword example:

  ```
  *Key_HF_Multistage_3D
  1
  ```

- *__num_Wellbore__ - Number of wellbores.

  Keyword example:

  ```
  *num_Wellbore
  1
  ```

- *__num_Points_WB_1 - num_Points_WB_10__ - Number of points to define wellbore n.

  Keyword example:

  ```
  *num_Points_WB_1
  2
  ```

- *__Wellbore_Coors_1_1 - Wellbore_Coors_10_6__ - Points to define wellbore n.

  Keyword example:

  ```
  % Point 1 to define wellbore 1.
  *Wellbore_Coors_1_1
  100.0,100.0,0.1
  % Point 2 to define wellbore 1.
  *Wellbore_Coors_1_2
  100.0,100.0,199.9
  ```

- *__WELLBORES_START_POINT_1 - WELLBORES_START_POINT_10__ - Start point for fracturing of wellbore n.

Keyword example:

```
*WELLBORES_START_POINT_1
100.0,100.0,90.0
```

- *__WELLBORES_END_POINT_1 - WELLBORES_END_POINT_10__ - End point for fracturing of wellbore n.

  Keyword example:

  ```
  *WELLBORES_END_POINT_1
  100.0,100.0,110.0
  ```

- *__num_Stages_Wellbores_1 - num_Stages_Wellbores_10__ - Number of stages of wellbore n.

  Keyword example:

  ```
  *num_Stages_Wellbores_1
  1
  ```

- *__NUM_CRS_STAGES_WELLBORES_1_1 - NUM_CRS_STAGES_WELLBORES_5_5__ - Number of clusters of a stage of wellbore n.

  Keyword example:

  ```
  % Number of clusters of stage 1 of wellbore 5.
  *NUM_CRS_STAGES_WELLBORES_5_1
  1
  ```

- *__Key_Gen_Ini_Crack_Wellbores__ - Shape of initial hydraulic fractures.

  = 1, rectangle;

  = 2, circle;

  = 3, polygon.

  Keyword example:

  ```
  % Generate circle initial fractures along the wellbore.
  *Key_Gen_Ini_Crack_Wellbores
  2
  ```

- *__Size_Ini_Crack_Wellbores__ - Size of initial hydraulic fractures, for circle or polygon cracks, size denotes diameter.

  Keyword example:

```
*Size_Ini_Crack_Wellbores
3.0
```

- ***INJECTION_Q_STAGES_WELLBORES_1_1 - INJECTION_Q_STAGES_WELLBORES_5_5** - Injection rate of a stage of wellbore 1 (unit: m^3/s).

  Keyword example:

  ```
  % Injection rate of stage 1 of wellbore 5.
  *INJECTION_Q_STAGES_WELLBORES_5_1
  0.01
  ```

- ***INJECTION_T_STAGES_WELLBORES_1_1 - INJECTION_T_STAGES_WELLBORES_5_5** - Injection time of a stage of wellbore 1 (unit: s).

  Keyword example:

  ```
  % Injection time of stage 1 of wellbore 5.
  *INJECTION_T_STAGES_WELLBORES_5_1
  1000
  ```

- ***Key_Get_Permeability** - Calculate the element equivalent permeability for 3D hydraulic fracturing simulation.

  = 0, no;

  = 1, yes.

  Keyword example:

  ```
  *Key_Get_Permeability
  1
  ```

Keywords related to nonlinear analysis.

- ***NL_ITRA** - Maximum number of Newton-Raphson iteration (default：30).

  Keyword example:

  ```
  *NL_ITRA
  40
  ```

- ***NL_ATOL** - Maximum Norm-2 value of the residual of Newton-Raphson iteration (default：1.0e8).

  Keyword example:

```
*NL_ATOL
2.0e8
```

- *__NL_NTOL__ - Maximum number of bisection of force for Newton-Raphson iteration (default：6).

  Keyword example:

  ```
  *NL_NTOL
  10
  ```

- *__NL_TOL__ - Convergence tolerance for Newton-Raphson iteration (default：1.0e-6).

  Keyword example:

  ```
  *NL_TOL
  1.0e6
  ```

- *__NL_TIMS_1 - NL_TIMS_30__ - Load step control, 5 parameters are needed for each load step:

  1, starting time for the current load step;

  2, ending time for the current load step;

  3, time increment for the current load step;

  4, starting force factor for the current load step;

  5, ending force factor for the current load step.

  Keyword example:

  ```
  *NL_TIMS_1
  0.0,0.4,0.1,0.0,0.5
  *NL_TIMS_2
  0.4,1.0,0.05,0.5,1.0
  ```

Keywords related to cohesive crack.

- *__Coh_Constitutive_type__ - Constitutive model of the cohesive crack:

  = 1, bilinear model, first rise and then fall (Define both *Coh_Width_Critical1 and *Coh_Width_Critical2);

  = 2, linear model (Define *Coh_Width_Critical2);

  = 3, constant model (Define *Coh_Width_Critical2).

  Keyword example:

```
*Coh_Constitutive_type
1
```

- ***Coh_Width_Critical1** - Normal width of crack at which the crack surface has the ultimate normal traction (needs to be defined only when *Coh_Constitutive_type =1).

  Keyword example:

  ```
  *Coh_Width_Critical1
  2.0e-4
  ```

- ***Coh_Width_Critical2** - Normal width of crack at which the crack surface has no normal traction.

  Keyword example:

  ```
  *Coh_Width_Critical2
  1.0e-5
  ```

- ***Coh_f_Ultimate** - The ultimate normal traction.

  Keyword example:

  ```
  *Coh_f_Ultimate
  3.0D5
  ```

- ***Coh_Tangential_Key** - Consider tangential traction or not.

  = 0, no (default);

  = 1, yes (Define *Coh_Width_Critical1_T, *Coh_Width_Critical2_T, *Coh_f_Ultimate_T).

  Keyword example:

  ```
  *Coh_Tangential_Key
  1
  ```

- ***Coh_Width_Critical1_T** - Tangential width of crack at which the crack surface has the ultimate tangential traction (needs to be defined only when *Coh_Constitutive_type =1 and * Coh_Tangential_Key =1).

  Keyword example:

  ```
  *Coh_Width_Critical1_T
  0.25D-3
  ```

- ***Coh_Width_Critical2_T** - Tangential width of crack at which the crack surface has no tangential traction.

  Keyword example:

```
*Coh_Width_Critical2_T
0.50D-3
```

- ***Coh_f_Ultimate_T** - The ultimate tangential traction

  Keyword example:

  ```
  *Coh_f_Ultimate_T
  5.0D6
  ```

Keywords related to implicit dynamic analysis.

- ***IDy_Num_Iteras** - Number of steps of the implicit dynamic analysis.

  Keyword example:

  ```
  *IDy_Num_Iteras
  200
  ```

- ***IDy_Num_force_Itr** - Number of steps with force applied (In other words, the applied force will be removed if the current step number is larger than *IDy_Num_force_Itr).

  Keyword example:

  ```
  *IDy_Num_force_Itr
  100
  ```

- ***Delt_Time_NewMark** - Time increment of the Newmark time integration algorithm (default to 1.0e-6).

  Keyword example:

  ```
  *Delt_Time_NewMark
  5.0e-6
  ```

- ***Factor_Prop_Dy** - Factor of dynamic propagation length of cracks (default to 1.63). Propagation length $\Delta l = *Factor_Prop_Dy \times l_c$, where l_c represents the average size of enriched elements.

  Keyword example:

  ```
  *Factor_Prop_Dy
  1.63
  ```

- ***Key_EQ**: Earthquake analysis.

  = 0, no (default);

  = 1, yes.

Keyword example:

```
*Key_EQ
1
```

- *__num_EQ_Ac_nodes__ - Number of the nodes with earthquake acceleration applied.

  Keyword example:

  ```
  *num_EQ_Ac_nodes
  31
  ```

- *__EQ_Ac_nodes__ - List of nodes with earthquake acceleration applied.

  Keyword example:

  ```
  *EQ_Ac_nodes
  187,188,189,190,191,192,193,194,195,196,197,198,199,200,201,202,203,204
  ```

- *__EQ_Ac_Time_Gap__ - Time interval of the earthquake acceleration data (define when *Key_EQ=1).

  Keyword example:

  ```
  *EQ_Ac_Time_Gap
  0.01
  ```

Coupling of degrees of freedom.

- *__num_CP_x_nodes__ - The total amount of nodes need to be coupled in x direction.

  Keyword example:

  ```
  *num_CP_x_nodes
  21
  ```

- *__CP_x_nodes__ - The nodes number of all the nodes need to be coupled in x direction.

  Keyword example:

  ```
  *CP_x_nodes
  2,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101
  ```

- *__num_CP_y_nodes__ - The total amount of nodes need to be coupled in y direction.

  Keyword example:

```
*num_CP_y_nodes
21
```

- *__CP_y_nodes__ - The nodes number of all the nodes need to be coupled in y direction.

  Keyword example:

```
*CP_y_nodes
2,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101
```

Deactivation elements.

- *__Key_EKILL__ - Deactivate elements during simulation.

  = 1, no (default);

  = 1, yes.

  Keyword example:

```
*Key_EKILL
1
```

- *__Ele_Killed_Each_Load_Step_02 - Ele_Killed_Each_Load_Step_40__ - Define element lists for load step n.

  Keyword example:

```
% Define elements to be killed at each step (from step 2 to step 5).
*Ele_Killed_Each_Load_Step_02
501,466
*Ele_Killed_Each_Load_Step_03
502,467
*Ele_Killed_Each_Load_Step_04
503,468
*Ele_Killed_Each_Load_Step_05
504,469
```

Surface load.

- *__Num_Surface_Loads__ - Number of applied surface load.

  Keyword example:

```
*Num_Surface_Loads
3
```

- *__File_Surface_Load_1 - File_Surface_Load_20__ - File suffix of surface load n.

Keyword example:

```
*File_Surface_Load_1
surf
*File_Surface_Load_2
top
*File_Surface_Load_3
inner
% Each line of the *.surf file stores surface element number, node 1, r
% 1415.    7789.    7828.    7790.    7829.   0.12500000E-06
% 1416.    7828.    7867.    7829.    7868.   0.12500000E-06
```

- ***Surface_Pressure_1 - Surface_Pressure_20** - Pressure value if surface load n.

  Keyword example:

  ```
  *Surface_Pressure_1
  -10.0e6
  ```

Control of the program.

- ***Key_Clear_All** - Clear all the results files in the current work directory before starting.

  = 0, disable;

  = 1, enable (default).

  Keyword example:

  ```
  *Key_Clear_All
  1
  ```

- ***Key_Close_Window** - Close the console window when calculation is finished.

  = 0, wait user to close (default);

  = 1, auto close.

  Keyword example:

  ```
  *Key_Close_Window
  0
  ```

- ***Key_Data_Format** - Save data in ASCII format or in binary format.

  = 1, ASCII format (default);

  = 2, binary format.

  Keyword example:

```
*Key_Data_Format
1
```

- *__Key_Num_Process__ - Set the number of threads of CPU for OpenMP (if taken as 99, then all threads are available, default to 1).

  Keyword example:

  ```
  *Key_Num_Process
  4     % Use 4 threads.
  ```

- *__Key_Save_vtk__ - Save the simulation results as vtk files for postprocessing using ParaView.

  = 0, do not save vtk file;

  = 1, save vtk file (default).

  Keyword example:

  ```
  *Key_Save_vtk
  1
  ```

- *__Key_Simple_Post__ - Save only necessary result files.

  = 0, save all result files (default);

  = 1, save only necessary result files.

  Keyword example:

  ```
  *Key_Simple_Post
  1
  ```