LMGC90 Post-Processing

User's guide - v3

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Credits

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Contains

Contains

Introduction

The LMGC90 post-processing tools allow to extract in independent files the evolution with respect to time of different quantities during a simulation or in some case using existing outputs (a.k.a post-mortem).

For example one can extract :

- evolution of the position of a single body ;
- evolution of the energy dissipated by the system ;
- convergence of the contact solver.

It relies on a set of commands given in the POSTPRO.DAT file located in the DATBOX directory.
This file might be generated by the preprocessor ; it can be modified directly but it is no recommended.

Introduction

The post-processing starts by an initialization phase performed with the command *OpenPostproFiles()*.
This command scans the POSTPRO.DAT file and initializes the post-processing data structures.

During the time evolution loop, the command *WritePostproFiles()* allows the treatment of post-processing commands.
Each command is executed during the simulation process according to its own execution frequency.
The resulting files are written in the POSTPRO directory.

All the files are closed by to the *ClosePostproFiles()* command.

Introduction

If a simulation has already run, it is possible to do a post-mortem analysis using the stored output files (Vloc_Rloc.OUT.XXX and DOF.OUT.XXX files for instance).

It means that the user does not need to run the simulation again.

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Command list

The available commands have been grouped in three sections :

- commands which could be used in both 2D and 3D simulations ;
- commands which could be used only in 2D simulations ;
- commands which could be used only in 3D simulations.

2-3D commands

AVERAGE VELOCITY EVOLUTION	BODY TRACKING	CLOUD ANALYSIS
CONTACT FORCE DISTRIBUTION	COORDINATION NUMBER	Dep EVOLUTION
DISPLAY TENSORS	DISSIPATED ENERGY	DOUBLET INTERACTIONS
DRY CONTACT NATURE	ELECTRO EVOLUTION	Fint EVOLUTION
HEAT BOUND PROFILE	KINETIC ENERGY	MAILx Dist
MP SNAPSHOT SAMPLE	MP VALUE TRACKING	NETWORK EVOLUTION
NEW BOUNDED SETS	NEW MECAx SETS	NEW RIGID SETS
NORMAL CONTACT DISTRIBUTION	QUASI SLIDING CONTACT	SNAPSHOT SAMPLE
SOLVER INFORMATIONS	SPECIES KINETIC ENERGY	THERMAL EVOLUTION
TORQUE EVOLUTION	VIOLATION EVOLUTION	WET CONTACT NATURE

2D commands

COMPACITY EVOLUTION	CREATE TEXT DATA	DENSE SAMPLE COMPACITY
PLPLx ANALYSIS		

3D commands

PRxxx DETECTION	PTPT3 ANALYSIS	TRIAXIAL COMPACITY
VISIBILITY STATE		

Contains

AVERAGE VELOCITY EVOLUTION

The command allows to determine the mean velocity of a set of particles at a given time step during the simulation process. Data are stored in the file AVERAGE_VELOCITY.DAT as :

2D	t	$\bar{\dot{\mathbf{q}}}_x$	$\bar{\dot{\mathbf{q}}}_y$	$\bar{\omega}_z$	$\|\bar{\dot{\mathbf{q}}}\|$				
3D	t	$\bar{\dot{\mathbf{q}}}_x$	$\bar{\dot{\mathbf{q}}}_y$	$\bar{\dot{\mathbf{q}}}_z$	$\bar{\omega}_\alpha$	$\bar{\omega}_\beta$	$\bar{\omega}_\gamma$	$\|\bar{\dot{\mathbf{q}}}\|$	

where t is the simulation time, $\bar{\dot{\mathbf{q}}}_i$ the mean velocity along the i direction, $\bar{\omega}_i$ the mean spin around the axe (G ;i) (i equal to Z in 2D and α,β or γ in 3D) and $\|\bar{\dot{\mathbf{q}}}\|$ the euclidean norm of the mean velocity.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
AVERAGE VELOCITY EVOLUTION
STEP N
COLOR
```

where **N** denotes the command period (*INTEGER*) and **COLOR** the color of particles for which the average is performed (*CHARACTER(LEN=5)*).

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BODY TRACKING

The command allows to track the evolution of both position and velocity of one or more selected bodies.
Different data are stored in files BODY_TRACKING_XXXXXXX.DAT as :

2D	t	$\mathbf{q}_x$	$\mathbf{q}_y$	θ_z	$\Delta\mathbf{q}_x$	$\Delta\mathbf{q}_y$	$\Delta\theta_z$	$\dot{\mathbf{q}}_x$	$\dot{\mathbf{q}}_y$	ω_z			
3D	t	$\mathbf{q}_x$	$\mathbf{q}_y$	$\mathbf{q}_z$	$\Delta\mathbf{q}_x$	$\Delta\mathbf{q}_y$	$\Delta\mathbf{q}_z$	$\dot{\mathbf{q}}_x$	$\dot{\mathbf{q}}_y$	$\dot{\mathbf{q}}_z$	ω_α	ω_β	ω_γ

where t is the simulation time, $\mathbf{q}_i$ the position along the i direction, $\Delta\mathbf{q}_i$ the displacement along the i direction, $\dot{\mathbf{q}}_i$ the velocity along the i direction and ω_i the spin around the axe (G ;i) (i equal to Z in 2D and α,β,γ in 3D).

The synopsis of the command in the POSTPRO.DAT file is the following :

BODY TRACKING
STEP **N**
nb
ID_1
...
ID_nb

where **N** denotes the command period, **nb** the number of tracked bodies and **ID_i** the index of the body in the RBDY2 or RBDY3 list.
There is **nb** files BODY_TRACKING_XXXXXXX.DAT created where each file is identified by the body index instead of the XXXXXXX characters.

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CLOUD ANALYSIS

The synopsis of the command in the POSTPRO.DAT file is the following :

```
CLOUD ANALYSIS
STEP N
```

where **N** denotes the command period.

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CONTACT FORCE DISTRIBUTION

This command allows to plot an histogram of the contact force repartition in a sample normalized by its mean value.

The histogram is created using both the euclidean norm of the contact force and its normal component only. The discretization is an input of the command.

Data are stored in the files CONTACT_FORCE_DISTRIBUTIONXXXX.DAT (the XXXX characters correspond to the time increment) as :

2D/3D	V_r	N_r	V_{r_n}	N_{r_n}

where for each interval V_r corresponds to the value on the normalized force, N_r to the number of contact corresponding to this value, V_{r_n} to the value on the normalized normal force and N_{r_n} to the number of contact corresponding to this value. The number of line is equal to the discretization level.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
CONTACT FORCE DISTRIBUTION
STEP N
sa
```

where **N** denotes the command frequency and **sa** the force scale discretization.

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COORDINATION NUMBER

This command allows to track the evolution of the mean coordination number (number of contacts per body) according to different definitions :

$$c_0 = \frac{n_p}{n_b} \quad c_+ = \frac{n_c}{n_b} \quad c_- = \frac{n_t}{n_b} \quad c = \frac{n_a}{n_b} \tag{1}$$

where n_p, n_c, n_t, n_a and n_b denote respectively the mean number of contacts, the mean number contacts in compression ($r_n > 0.$), the mean number contact in traction ($r_n < 0.$), the mean number of active contacts ($r_n \neq 0.$) and the number of bodies. Data are stored in files COORDINATION_NUMBER.DAT as :

2D/3D	t	c_0	c_+	c_-	c

where t is the simulation time.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
COORDINATION NUMBER
STEP N
```

where **N** denotes the command period.

Works for DISKx on RBDY2 !

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Dep EVOLUTION

The command allows to track the mean displacement and the mean velocity of a node set of a deformable body defined using the command NEW_MECAx_SETS. Data are stored in the file Dep_XXX.DAT as :

2D	t	u_x	u_y	v_x	v_y		
2D	t	u_x	u_y	u_z	v_x	v_y	v_z

where t is the simulation time, u_x and u_y the mean displacements along the X and Y axes and, v_x and v_y the mean velocities along the X and Y axes. The number of file Dep_XXX.DAT is equal to the number of mechanical set defined using the command NEW_MECAx_SETS. XXX characters are replaced by the index of the mechanical set in the global list.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
Dep EVOLUTION
STEP N
```

where **N** denotes the command period.

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DOUBLET INTERACTIONS

This command allows to track the evolution of a contact between two rigid bodies.
Data are stored in the file DOUBLET_INTERACTIONS.DAT as :

2D	t	g	r_n	r_t	v_n	v_t		
3D	t	g	r_n	r_t	r_s	v_n	v_t	v_s

where t is the simulation time, g the distance between particles, r_n, r_t and r_s the normal and tangential forces, v_n, v_t and v_s the normal and tangential relative velocities.

The synopsis of the command in the POSTPRO.DAT file is the following :

DOUBLET INTERACTIONS
STEP **N**
TYPE
ID1
ID2

where **N** denotes the command period, **TYPE** the nature of the contact (in the interaction list),**ID1** and **ID2** the two body identifiants.

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DRY CONTACT NATURE

This command allows to track the evolution of the number of contacts according to their status for dry contact law.
Data are stored in the file DRY_CONTACT_NATURE.DAT as :

2D/3D	t	N_{no}	N_{stick}	N_{Slide}

where t is the simulation time, N_{no} the number of non active contacts, N_{Slide} the number of sliding contact and N_{stick} the number of sticking contacts.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
DRY CONTACT NATURE
STEP N
```

where **N** denotes the command period.

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ELECTRO EVOLUTION

The command allows the storage of electrical output during the simulation process. Data are stored in the file ELECTRO_EVOLUTION.DAT as :

2D	t	it_L	ϵ	it_{NL}	C_m	Nb_O	Nb_{CO}	Nb_{S0}

where t is the simulation time, it_L the number of iterations for the resolution of the linear electrical problem, ϵ the error value, it_{NL} the number of iterations for the resolution of the nonlinear electrical problem, C_m the mean conductivity of the sample, Nb_O the number of oxided contacts ...

The synopsis of the command in the POSTPRO.DAT file is the following :

```
ELECTRO EVOLUTION
STEP N
```

where **N** denotes the command period.

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Fint EVOLUTION

The command allows to track the forces acting on a node set of a deformable body defined using the command NEW_MECAx_SETS. Data are stored in the file Fint_XXX.DAT as :

2D	t	Rc_x	Rc_y	$F_{int,x}$	$F_{int,y}$	$F_{iner,x}$	$F_{iner,y}$	R_x	R_y
3D	t	Rc_x	Rc_y	Rc_z	$F_{int,x}$	$F_{int,y}$	$F_{int,z}$		
	$F_{iner,x}$	$F_{iner,y}$	$F_{iner,z}$	R_x	R_y	R_z			

where t is the simulation time, Rc the contact forces, F_{int} the internal forces, F_{iner} the inertial forces and finally R the sum of all forces. The number of file Fint_XXX.DAT is equal to the number of mechanical set defined using the command NEW_MECAx_SETS. XXX characters are replaced by the index of the mechanical set in the global list.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
Fint EVOLUTION
STEP N
```

where **N** denotes the command period.

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KINETIC ENERGY

The command allows to compute the kinetic energy of a sample as well as the power and the variation of kinetic energy during the simulation process. The kinetic energy and the potential energy are defined as :

$$\mathcal{E}_c = \frac{1}{2}\sum_{i=1}^{n_b}\{m_i\dot{\mathbf{q}}_i^2 + I_i\omega_i^2\} \quad \mathcal{E}_p = \sum_{i=1}^{n_b} m_i\mathbf{g}.\mathbf{q} \tag{2}$$

where n_b denotes the number of bodies, m_i the mass of body i, $\dot{\mathbf{q}}_i$ its velocity, I_i its inertia momentum and ω_i its spin. $\mathbf{g}$ denotes the gravity acceleration and $\mathbf{q}$ the body position.

Data are stored in the file KINETIC_ENERGY.DAT as :

2D/3D	t	$\mathcal{E}_c$	$\mathcal{E}_p$	$\Delta\mathcal{E}$	$\mathcal{P}$

where t is the simulation time, $\mathcal{E}_c$ and $\mathcal{E}_p$ denote the kinetic and potential energy respectively, $\Delta\mathcal{E}$ the energy variation and $\mathcal{P}$ the power of the system.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
KINETIC ENERGY
STEP N
```

where **N** denotes the command period.

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MAILx Dist

To complete ...

The synopsis of the command in the POSTPRO.DAT file is the following :

```
MAILx Dist
STEP N
```

where **N** denotes the command period.

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MP SNAPSHOT SAMPLE

The command allows to make a snapshot of the thermal, electrical and mechanical sample. For each snapshot, data are stored in two files.
The file BODY_SNAPSHOTXXXXXX.DAT contains body information written as follow (n_b lines, where n_b is the number of bodies, 16 columns in 2D and 25 columns in 3D) :

2D	$\mathbf{q}_x$	$\mathbf{q}_y$	A	$\dot{\mathbf{q}}_x$	$\dot{\mathbf{q}}_y$	ω_z	σ_{xx}	σ_{xy}	σ_{yx}	σ_{yy}	c
	T	C_T	E	C_E	W_S						

3D	$\mathbf{q}_x$	$\mathbf{q}_y$	$\mathbf{q}_z$	V	$\dot{\mathbf{q}}_x$	$\dot{\mathbf{q}}_y$	$\dot{\mathbf{q}}_z$	ω_x	ω_y	ω_z
	σ_{xx}	σ_{xy}	σ_{xz}	σ_{yx}	σ_{yy}	σ_{yz}	σ_{zx}	σ_{zy}	σ_{zz}	c
	T	C_T	E	C_E	W_S					

where $\mathbf{q}_i$ denotes the body position, A (V) the body surface (volume), $\dot{\mathbf{q}}_i$ the component of the velocity along i, ω_i the spin around the (0; i) axe, $\sigma_i j$ the body stress tensor, c the coordination number, T the temperature, C_T the thermal conductivity, E the electrical potential, C_E the electrical conductivity and $\mathbb{W}_S$ the surface energy (i, j equal to x, y or z).

The file CONTACT_SNAPSHOTXXXXXX.DAT contains contact information written as follow (n_c lines , where n_c is the number of contacts, 13 columns in 2D and 15 columns in 3D) :

2D	*type*	*cd*	*an*	r_n	r_t	v_n	v_t			$internal(1:6)$
3D	*type*	*cd*	*an*	r_n	r_t	r_s	v_n	v_t	v_s	$internal(1:6)$

where *type* denotes the type of contact (DKDKx,PLPLx,...), *cd* and *an* the number of the candiate and the antagonist in the contactor list, *r* the contact force, *v* the contact relative velocity and *internal* some internal variables associate to the contact (see specific contact laws as CZM ones).

The synopsis of the command in the POSTPRO.DAT file is the following :

```
MP SNAPSHOT SAMPLE
STEP N
```

where **N** denotes the command period.

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NETWORK EVOLUTION

The command allows to track the number of changing contact status during the computation of contact forces. The global, weak and strong network are checked. Data are stored in the file NETWORK_EVOLUTION.DAT as :

2D/3D	t	N_G	N_W	N_S

where t is the simulation time, N_G,N_W and N_S respectively the number of contact for which the status change in the global, weak and strong network.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
NETWORK EVOLUTION
STEP N
```

where **N** denotes the command period.

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NEW BOUNDED SETS

The command allows the definition of new sets of rigid particles. The particles contained in a bounded set should have successive number in the body list. For each new set, different information are given in different files :

2D

EVOL_BOUNDED_SET_0000000.DAT									
t	$\mathbf{q}_x$	$\mathbf{q}_y$	$\mathbf{q}_z$	$\Delta\mathbf{q}_x$	$\Delta\mathbf{q}_y$	$\Delta\dot{\mathbf{q}}_y$	$\dot{\mathbf{q}}_x$	$\dot{\mathbf{q}}_y$	ω_z

REAC_BOUNDED_SET_0000000.DAT						
t	R_x	R_y	M_z	$Fext_x$	$Fext_y$	$Mext_z$

3D

EVOL_BOUNDED_SET_0000000.DAT												
t	$\mathbf{q}_x$	$\mathbf{q}_y$	$\mathbf{q}_z$	$\Delta\mathbf{q}_x$	$\Delta\mathbf{q}_y$	$\Delta\dot{\mathbf{q}}_y$	$\dot{\mathbf{q}}_x$	$\dot{\mathbf{q}}_y$	$\dot{\mathbf{q}}_z$	ω_x	ω_y	ω_z

REAC_BOUNDED_SET_0000000.DAT						
t	R_x	R_y	R_z	M_x	M_y	M_z

Fext_BOUNDED_SET_0000000.DAT						
t	$Fext_x$	$Fext_y$	$Fext_z$	$Mext_x$	$Mext_y$	$Mext_z$

Fine_BOUNDED_SET_0000000.DAT						
t	$Fine_x$	$Fine_y$	$Fine_z$	$Mine_x$	$Mine_y$	$Mine_z$

where t is the simulation time, $\mathbf{q}$ the position, $\Delta\mathbf{q}$ the displacement, $\dot{\mathbf{q}}$ the velocity and ω the splin. R and M are the resultant and the moment due to contact forces, *Fext* and *Mext* the sum of external forces and momentum, and *Fine* and *Mine* the inertia force and momemtum. All variables are indexed according to the different axes.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
NEW BOUNDED SETS
n
N1_1
N1_m1
...
Nn_1
Nn_mn
```

where **n** is the number of sets, **Ni_1** and **Ni_mi** the number of the first and last bodies which defined the set i. Remember that in a given set, all bodies have successive number.

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NEW MECAx SETS

The command allows the definition of node sets. The command must be used with the command Fint EVOLUTION and Dep EVOLUTION to obtain information. If the command is used alone, no information are obtained.

The synopsis of the command in the POSTPRO.DAT file is the following :

NEW MECAx SETS
n
id1 m1
N1_1
...
N1_m1
...
idn mn
Nn_1
...
Nn_mn

where **n** is the number of sets, **idi** and **mi** the type and the number of node of the set *i* and **Ni_1**,...,**Ni_mi** the list of nodes.

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NEW RIGID SETS

The command allows the definition of new sets of rigid particles. The particles contained in a rigid set do not have necessary successive number in the body list. For each new set, different information are given in different files :

2D

EVOL_RIGID_SET_0000000.DAT

t	$\mathbf{q}_x$	$\mathbf{q}_y$	$\mathbf{q}_z$	$\Delta\mathbf{q}_x$	$\Delta\mathbf{q}_y$	$\Delta\dot{\mathbf{q}}_y$	$\dot{\mathbf{q}}_x$	$\dot{\mathbf{q}}_y$	ω_z

REAC_RIGID_SET_0000000.DAT

t	R_x	R_y	M_z	$Fext_x$	$Fext_y$	$Mext_z$

3D

EVOL_RIGID_SET_0000000.DAT

t	$\mathbf{q}_x$	$\mathbf{q}_y$	$\mathbf{q}_z$	$\Delta\mathbf{q}_x$	$\Delta\mathbf{q}_y$	$\Delta\dot{\mathbf{q}}_y$	$\dot{\mathbf{q}}_x$	$\dot{\mathbf{q}}_y$	$\dot{\mathbf{q}}_z$	ω_x	ω_y	ω_z

REAC_RIGID_SET_0000000.DAT

t	R_x	R_y	R_z	M_x	M_y	M_z

Fext_RIGID_SET_0000000.DAT

t	$Fext_x$	$Fext_y$	$Fext_z$	$Mext_x$	$Mext_y$	$Mext_z$

Fine_RIGID_SET_0000000.DAT

t	$Fine_x$	$Fine_y$	$Fine_z$	$Mine_x$	$Mine_y$	$Mine_z$

where t is the simulation time, $\mathbf{q}$ the position, $\Delta\mathbf{q}$ the displacement, $\dot{\mathbf{q}}$ the velocity and ω the splin. R and M are the resultant and the moment due to contact forces, *Fext* and *Mext* the sum of external forces and momentum, and *Fine* and *Mine* the inertia force and momemtum. All variables are indexed according to the different axes.
The synopsis of the command in the POSTPRO.DAT file is the following :

```
NEW RIGID SETS
n
m1
N1_1
...
N1_m1
...
mn
Nn_1
...
Nn_mn
```

where **n** is the number of sets, **mi** the number of body in the set number *i* followed by the list of *mi* bodies **Ni_1**,...,**Ni_mi**.

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NORMAL CONTACT DISTRIBUTION

The command allows the representation of normal contact vector distribution between DISKx or POLYG. Three representations are available related to the global contact network, the weak contact network and the strong contact network. The difference between the strong and weak contact networks is made in regards of the mean value of the normal contact force $\bar{r_n}$ defined as :

$$\bar{r_n} = \frac{1}{n_a} \sum_{\alpha=1}^{n_a} r_n^{\alpha} \tag{3}$$

where n_a denotes the number of active contact (non nul) and r_n^{α} the normal force associated to contact α.

Data are stored in two files. The first file is the file NORMAL_CONTACT_DISTRIBUTION.DAT where the diagram data are stored as :

$$\textbf{2D} \mid X_G \quad Y_G \quad X_W \quad Y_W \quad X_S \quad Y_S$$

where indices G, W and S refer respectively to global, weak and strong contact network.

The second file is the file P2THETA.DAT where the histogram data are stored as :

$$\textbf{2D} \mid \theta_i \quad N_G \quad N_W \quad N_S$$

where θ_i is the sector value (in radian) ranging from $-\pi$ to π, N_G, N_W and N_S the percent of contact of the global, weak and strong contact network in the θ_i direction.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
NORMAL CONTACT DISTRIBUTION
STEP N
ns
```

where **N** denotes the command period, **nb** the number of angular sectors of the upper part.

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QUASI SLIDING CONTACT

The command computes the number of contacts for which the tangential force r_t is close to the sliding threshold μr_n. To be taken into account, the tangential force of a contact must satisfied :

$$(1 - \epsilon)\mu r_n < |r_t| \leq \mu r_n \qquad (4)$$

where ϵ is a small real value.

Data are stored in the file QUASI_SLIDING_CONTACT_EVOLUTION.DAT as :

2D/3D	t	N	p

where t is the simulation time, N the number of quasi sliding contacts and p the quasi sliding contacts percent.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
QUASI SLIDING CONTACT
STEP N
P
```

where **N** denotes the command period and **P** the part of the friction threshold in less (range from 0 to 1).

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SNAPSHOT SAMPLE

The command allows to make a snapshot of the thermal, electrical and mechanical sample. For each snapshot, data are stored in two files.
The file BODY_SNAPSHOTXXXXXX.DAT contains body information written as follow (n_b lines, where n_b is the number of bodies, 16 columns in 2D and 25 columns in 3D) :

2D	$\mathbf{q}_x$	$\mathbf{q}_y$	A	$\dot{\mathbf{q}}_x$	$\dot{\mathbf{q}}_y$	ω_z	σ_{xx}	σ_{xy}	σ_{yx}	σ_{yy}	c
3D	$\mathbf{q}_x$	$\mathbf{q}_y$	$\mathbf{q}_z$	V	$\dot{\mathbf{q}}_x$	$\dot{\mathbf{q}}_y$	$\dot{\mathbf{q}}_z$	ω_x	ω_y	ω_z	
	σ_{xx}	σ_{xy}	σ_{xz}	σ_{yx}	σ_{yy}	σ_{yz}	σ_{zx}	σ_{zy}	σ_{zz}	c	

where $\mathbf{q}_i$ denotes the body position, A (V) the body surface (volume), $\dot{\mathbf{q}}_i$ the component of the velocity along i, ω_i the spin around the (0; i) axe, $\sigma_i j$ the body stress tensor, c the coordination number (i, j equal to x, y or z).

The file CONTACT_SNAPSHOTXXXXXX.DAT contains contact information written as follow (n_c lines , where n_c is the number of contacts, 13 columns in 2D and 15 columns in 3D) :

2D	*type*	*cd*	*an*	r_n	r_t	v_n	v_t			*internal*(1 : 6)
3D	*type*	*cd*	*an*	r_n	r_t	r_s	v_n	v_t	v_s	*internal*(1 : 6)

where *type* denotes the type of contact (DKDKx,PLPLx,...), *cd* and *an* the number of the candiate and the antagonist in the contactor list, r the contact force, v the contact relative velocity and *internal* some internal variables associate to the contact (see specific contact laws as CZM ones).

The synopsis of the command in the POSTPRO.DAT file is the following :

```
SNAPSHOT SAMPLE
STEP N
```

where **N** denotes the command period.

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SOLVER INFORMATIONS

The command allows to track the evolution of the number of iterations, the last value of error criteria (after convergence or not) and the contact number. Data are stored in file SOLVER_INFORMATIONS.DAT as :

2D/3D	t	N_{it}	ϵ_1	ϵ_2	ϵ_3	n_C

where t is the simulation time, N_{it} the number of iterations, ϵ_i (i=1,2,3) the last values of error criteria and n_C the number of contacts.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
SOLVER INFORMATIONS
STEP N
```

where **N** denotes the command period.

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SPECIES KINETIC ENERGY

The command allows to compute the kinetic energy of different species of a sample as well as the power and the variation of kinetic energy during the simulation process. The kinetic energy is defined as it is for the KINETIC ENERGY command. Data are stored in the file XXXXX_KINETIC_ENERGY.DAT as :

2D/3D	t	$\mathcal{E}_c$	$\mathcal{E}_p$	$\Delta\mathcal{E}$	$\mathcal{P}$

where t is the simulation time, $\mathcal{E}_c$ and $\mathcal{E}_p$ denote the kinetic and potential energy respectively, $\Delta\mathcal{E}$ the energy variation and $\mathcal{P}$ the power of the system.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
KINETIC ENERGY
STEP N
ns
S_1
...
S_ns
```

where **N** denotes the command period, **ns** the number of species, **S_i** the different tracked species. There is **ns** files XXXXX_KINETIC_ENERGY.DAT created where each file is identified by the species name instead of the XXXXX characters.

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TORQUE EVOLUTION

The command allows to track the evolution of the torque of contact forces and external forces of different bodies. Data are stored in different files as :

2D

TORQUE_EVOLUTION_XXXXXXX.DAT						
t	R_x	R_y	M_z	$Fext_x$	$Fext_y$	$Mext_z$

3D

REAC_XXXXXXX.DAT						
t	R_x	R_y	R_z	M_x	M_y	M_z

Fext_XXXXXXX.DAT						
t	$Fext_x$	$Fext_y$	$Fext_z$	$Mext_x$	$Mext_y$	$Mext_z$

Fine_XXXXXXX.DAT						
t	$Fine_x$	$Fine_y$	$Fine_z$	$Mine_x$	$Mine_y$	$Mine_z$

where t is the simulation time, R and M the resultant and the moment due to contact forces, *Fext* and *Mext* the sum of external forces and momentum, and *Fine* and *Mine* the inertia force and momemtum, all indexed according to the different axes (x, y or z).

The synopsis of the command in the POSTPRO.DAT file is the following :

```
TORQUE EVOLUTION
STEP N
nb
ID_1
...
ID_nb
```

where **N** denotes the command period, **nb** the number of tracking bodies and **ID_i** the index of the body in the RBDY2 or RBDY3 list.
There is **nb** files TORQUE_EVOLUTION_XXXXX.DAT created where each file is identified by the body index instead of the XXXXXXX characters.

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VIOLATION EVOLUTION

The command compute the mean and maximal violation in a sample during the simulation process. The mean and maximal violation are defined as :

$$\left\{ \begin{array}{l} V_{mean} = \dfrac{1}{n_C} \sum_{\alpha} |\min(0, g_\alpha)| \\ V_{max} = \max_{\alpha} \{ |\min(0, g_\alpha)| \} \end{array} \right. \tag{5}$$

where n_C denotes the number of contacts and g_α the gap associated to contact α.

Data are stored in the file VIOLATION_EVOLUTION.DAT as :

2D/3D	t	V^0_{mean}	V_{mean}	V^0_{max}	V_{max}

where t is the simulation time, V^0_{mean} et V_{mean} the mean violations at the beginning and the end of a time step and V^0_{max} et V_{max} the maximal violations at the beginning and the end of a time step.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
VIOLATION EVOLUTION
STEP N
```

where **N** denotes the command period.

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WET CONTACT NATURE

The command allows to track the evolution of the number of contacts according to their status for cohesive contact law. Data are stored in the file WET_CONTACT_NATURE.DAT as :

2D/3D	t	N_{Stick}	N_{Slide}	N_{no}

where t is the simulation time, N_{Stick} the number of sticking contacts, N_{Slide} the number of sliding contac et N_{no} the number of non active contacts.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
WET CONTACT NATURE
STEP N
```

where **N** denotes the command period.

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Contains

COMPACITY EVOLUTION

Works only for deformable objects ! !

CREATE TEXT DATA

Bull shit !
To serialize the various results (usually stored in OUTBOX) in a text file for analysis.
The synopsis of the command in the POSTPRO.DAT file is the following :

```
CREATE TEXT DAT
STEP N
```

where **N** denotes the command period.

PLPLx ANALYSIS

The command determines the number of simple contacts and the number of double contacts in a polygon sample. Data are stored in the file PLPLx_ANALYSIS.DAT as :

$$\textbf{2D} \; \Big| \; t \quad N_s \quad N_d$$

where t is the simulation time, N_s the number of simple contacts and N_d the number of double contacts.

The synopsis of the command in the POSTPRO.DAT file is the following :

```
PLPLx ANALYSIS
STEP N
```

where **N** denotes the command period.

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PRxxx DETECTION

The synopsis of the command in the POSTPRO.DAT file is the following :

```
PRxxx DETECTION
STEP N
```

where **N** denotes the command period.

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TRIAXIAL COMPACITY

The synopsis of the command in the POSTPRO.DAT file is the following :

```
TRIAXIAL COMPACITY
STEP N
iXmin
iXmax
iYmin
iYmax
iZmin
iZmax
```

where **N** denotes the command period (*INTEGER*),**iXmin** and **iXmax** the number of PLANx bounding the set along the X direction, **iYmin** and **iYmax** the number of PLANx bounding the set along the Y direction. **iZmin** and **iZmax** the number of PLANx bounding the set along the Z direction.

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VISIBILITY STATE

The synopsis of the command in the POSTPRO.DAT file is the following :

```
VISIBILITY STATE
STEP N
```

where **N** denotes the command period.

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Contains

Postpro file example

```
#23456789012345678901234567890:
BODY TRACKING                 :
STEP 1                        :
1                             :
54                            :
TORQUE EVOLUTION              :
STEP 1                        :
1                             :
56                            :
SOLVER INFORMATIONS           :
STEP 1                        :
DISSIPATED ENERGY             :
STEP 1                        :
VIOLATION EVOLUTION           :
STEP 1                        :
END                           :
```