LMGC90v2

User's guide

2012

Outline

LMGC90 files - Introduction

A simulation is performed in a dedicated working directory, which contains various subdirectories :

- **DATBOX** (mandatory) which contains all data files.
- **OUTBOX** (mandatory) which contains all result files.
- **DISPLAY** (optional) which contains visualization files (`gmv` or `paraview`).
  It also contains a text file named `DISPLAYED_GMV`.
- **POSTPRO** (optional) which contains post-processing file created during the simulation process.

Data files may be generated using the *LMGC90 PRE*. Various examples are also given.
In this document we will explain the content of these files.

LMGC90 files - DATBOX

The different files necessary to describe the model are :

./DATBOX/BODIES.DAT	*sample description : geometry, models, etc.*
./DATBOX/BULK_BEHAV.DAT	*bulk behaviour parameters*
./DATBOX/TACT_BEHAV.DAT	*interaction law and visibilty rules*
./DATBOX/DRV_DOF.DAT	*forces and driven degrees of freedom*
./DATBOX/DOF.INI	*initial values of degrees of freedom of bodies*
./DATBOX/Vloc_Rloc.INI	*initial values of interactions*
./DATBOX/POSTPRO.DAT	*post-processing commands and parameters*

For sample with deformable bodies, the following files must be added :

./DATBOX/MODELS.DAT	*numerical models*
./DATBOX/GPV.INI	*initial values at gauss points*

A file containing simulation commands and parameters is also necessary :

./command.py	*ChiPy python instructions*

LMGC90 files - Output

The standard result files can be decomposed in 2 sets.

The first one came from the scanning of data files :

./OUTBOX/BODIES.OUT
./OUTBOX/BULK_BEHAV.OUT
./OUTBOX/TACT_BEHAV.OUT
./OUTBOX/MODELS.OUT
./OUTBOX/DRV_DOF.OUT
./OUTBOX/POSTPRO.OUT

This set of files is useful to check if data files have been read correctly.

The second one are database back-up files :

./OUTBOX/DOF.LAST
./OUTBOX/DOF.OUT.00p
./OUTBOX/GPV.LAST
./OUTBOX/GPV.OUT.00p

Using a set of these files, and copying it in the equivalent .INI files, allows to restart a simulation from an existing initial solution.

LMGC90 files - Output

The visualisation files for `gmv` are :

./DISPLAY/DISPLAYED_GMV	stores the rank of the last gmv file written
./DISPLAY/agmv.out.xxxx	asciii file
./DISPLAY/bgmv.out.xxxx	binary file

The visualisation files for `paraview` are :

./DISPLAY/a_rbdy3_xxxxxx.vtu	data stored/computed at centers of inertia of a RBDY3
./DISPLAY/a_mailx_xxxxxx.vtu	data stored/computed at nodes of MAILx
./DISPLAY/a_tact_xxxxxx.vtu	data stored/computed on contactor
./DISPLAY/a_inter_xxxxxx.vtu	data stored/computed at interaction

For post-processing files, the reader could refer to the specific documentation (Manuals/LMGC90_Postpro.pdf).

This text file gathers the description of rigid bodies or deformable bodies, together with their bulk properties, degrees of freedom and contactors.

The data are formatted and read as follows :

```
The symbol   '$'      preceeds a keyword used in scanning files.

The symbol   'bdyty'  stands for 'body type data'.
These data are distributed according to the following species.

The specy    'blmty'  stands for 'bulk element type data', i.e. part
or total bulk geometric description, and bulk behaviour laws;

The specy    'nodty'  stands for 'node type data',i.e. degrees of
freedom data;

The specy    'tacty'  stands for 'contactor type data';

The keyword  '$$$$$$' ends a body record.
```

The `BODIES.DAT` file is made of a collection of “cards” described as previously.

A line starting with # or ! is a comment.

DATBOX : : BODIES.DAT

To describe a 2D rigid body (RBDY2) with 2 boundaries :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$bdyty
 RBDY2      1
$blmty
 PLAIN      1  behav  PLEXx  avrd= 0.1600000D-02  gyrd= 0.1131200D-02
$nodty
 NO3xx      1                avrd= 0.5808000D-01  coo2= 0.4928000D-01  coo3= 0.0000000D+00
$tacty
 DISKx      1  color  BLEUx  byrd= 0.1600000D-02
 xKSID      2  color  REDxx  byrd= 0.1600000D-01
$$$$$$
```

- avrd and gyrd allow to compute the mass and inertia of the body, independantly of the shape of the contactors. If these parameters are set to 0, *LMGC90* try to compute them using the shapes of the contactors. In this last case *LMGC90* doesn't manage overlaps of contactors.
- usually contactors are described relatively to the center of inertia frame. If the nodal coordinates are set equal to 0, it means that the contactors are defined relatively to the global frame. In this case the center of inertia frame is rebuild. You may specify as many contactors as you want.

Available boundaries for RBDY2 are :

- DISKx, full disc :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 DISKx       1  color  BLEUx  byrd= 0.1600000D-02
```

- xKSID, hollow disc :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 xKSID       1  color  BLEUx  byrd= 0.1600000D-02
```

- DISPx, full pneumatic disc :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 DISPx       1  color  BLEUx  byrd= 0.1600000D-02
```

- xPSID, hollow pneumatic disc :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 xPSID       1  color  BLEUx  byrd= 0.1600000D-02
```

- DISKb, full excentred disc :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 DISKb       1  color  BLEUx  byrd= 0.1600000D-02
                              coo1= 0.9999582D+00  coo2=-0.0091384D+00
```

Available Boundaries for RBDY2 are :

- JONCx, full wall :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 JONCx      1  color  UPxxx  ax1 = 0.5000000D+02  ax2 = 0.1000000D+01
```

- POLYG, full polygon :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 POLYG      1  color  BLEUx  nb_vertex=    5      byrd= 0.7250500D+01
                             coo1=-0.3561507D+00  coo2= 0.5481881D-01
                             coo1=-0.3561979D+00  coo2= 0.6334220D-01
                             coo1=-0.3643187D+00  coo2= 0.6593115D-01
                             coo1=-0.3692904D+00  coo2= 0.5900783D-01
                             coo1=-0.3642423D+00  coo2= 0.5214002D-01
```

- PT2Dx, a point :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 PT2Dx      2  color  BLEUx  coo1= 0.0000000D+00  coo2= 0.0000000D+00
```

To describe a 3D rigid body (RBDY3) :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$bdyty
 RBDY3      1
$blmty
 PLAIN      1  behav  xxxxx  avrd= 0.2081680D-03
$nodty
 NO6xx      1                coo1=-0.2969270D-02  coo2=-0.2851180D-02  coo3= 0.3336920D-03
                             coo4= 0.0000000D+00  coo5= 0.0000000D+00  coo6= 0.0000000D+00
$tacty
 SPHER      1  color  bleu_  byrd= 0.2081680D-03
$$$$$$
```

DATBOX : : BODIES.DAT

Available Boundaries for RBDY3 are :

- SPHER, full sphere :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 SPHER      1  color  bleu_  byrd= 0.2081680D-03
```

- CYLND, full cylinder :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 CYLND      1  color  GREE1  High= 0.2000000D+02  byrd= 0.2000000D+01
```

- DNLYC, hollow cylinder :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 DNLYC      1  color  GREE1  High= 0.2000000D+02  byrd= 0.2000000D+01
```

DATBOX : : BODIES.DAT

Available Boundaries for RBDY3 are :

- cluster of spheres :

```
$bdyty
 RBDY3      1
$blmty
 PLAIN      1  behav  PLEX3  avrd= 0.0000000D+00
$nodty
 NO6xx      1                cool= 0.0000000D-01  coo2= 0.0000000D-01  coo3= 0.0000000D-01
                             coo4= 0.0000000D+00  coo5= 0.0000000D+00  coo6= 0.0000000D+00
$tacty
 SPHEb      1  color  BLEUx  byrd= 0.5000000D-02
                             cool= 0.2500000D-02  coo2= 0.4330127D-02  coo3= 0.5000000D-02
 SPHEb      1  color  BLEUx  byrd= 0.5000000D-02
                             cool=-0.5000000D-02  coo2= 0.0000000D-02  coo3= 0.5000000D-02
 SPHEb      1  color  BLEUx  byrd= 0.5000000D-02
                             cool= 0.2500000D-02  coo2=-0.4330127D-02  coo3= 0.5000000D-02
 SPHEb      1  color  BLEUx  byrd= 0.5000000D-02
                             cool= 0.0000000D-02  coo2= 0.0000000D-02  coo3= 1.3660254D-02
$$$$$$
```

DATBOX : : BODIES.DAT

Available Boundaries for RBDY3 are :

- POLYR, full polyedra :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 POLYR       1  color  BLEU1  nb_vertex=    8       nb_face=   12
                              coo1= 0.1000000D+01  coo2= 0.1000000D+01  coo3= 0.1000000D+01
                              coo1= 0.1000000D+01  coo2= 0.2000000D+01  coo3= 0.1000000D+01
                              coo1= 0.1000000D+01  coo2= 0.2000000D+01  coo3= 0.0000000D+00
                              coo1= 0.1000000D+01  coo2= 0.1000000D+01  coo3= 0.0000000D+00
                              coo1= 0.3000000D+01  coo2= 0.2000000D+01  coo3= 0.1000000D+01
                              coo1= 0.3000000D+01  coo2= 0.2000000D+01  coo3= 0.0000000D+00
                              coo1= 0.3000000D+01  coo2= 0.1000000D+01  coo3= 0.1000000D+01
                              coo1= 0.3000000D+01  coo2= 0.1000000D+01  coo3= 0.0000000D+00
                              ver1= 1              ver2= 2              ver3= 3
                              ver1= 1              ver2= 3              ver3= 4
                              ver1= 2              ver2= 5              ver3= 6
                              ver1= 2              ver2= 6              ver3= 3
                              ver1= 5              ver2= 7              ver3= 8
                              ver1= 5              ver2= 8              ver3= 6
                              ver1= 1              ver2= 4              ver3= 8
                              ver1= 1              ver2= 8              ver3= 7
                              ver1= 3              ver2= 6              ver3= 8
                              ver1= 3              ver2= 8              ver3= 4
                              ver1= 1              ver2= 2              ver3= 5
                              ver1= 1              ver2= 5              ver3= 7
```

- PLANx, plane :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 PLANx       1 color   VERTx  axe1= 0.0100000D+03  axe2= 0.0100000D+03  axe3= 0.0000100D+03
```

- PT3Dx, point :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 PT3Dx       2  color  TYTYx  coo1= 0.0000000D+00  coo2= 0.0000000D+00  coo3= 0.0000000D+00
```

To describe a 2D deformable body (MAILx) with a boundary :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$bdyty
 MAILx      1
$blmty
 Q4xxx      1  nodes      1      3      4      2
               model  M2DNL  behav  Steel
$nodty
 NO2xx      1              coo1= 0.0000000D+00  coo2= 0.0000000D+00
 NO2xx      2              coo1= 0.0000000D+00  coo2= 0.1000000D+01
 NO2xx      3              coo1= 0.1000000D+01  coo2= 0.0000000D+00
 NO2xx      4              coo1= 0.1000000D+01  coo2= 0.1000000D+01
$tacty
 ALpxx      1  color  REDxx  noda=    2  nodb=    4
$$$$$$

$bdyty
 MAILx      2
$blmty
 Q4xxx      1  nodes      1      3      4      2
               model  M2DNL  behav  Steel
$nodty
 NO2xx      1              coo1= 0.0000000D+00  coo2= 0.1000000D+01
 NO2xx      2              coo1= 0.0000000D+00  coo2= 0.2000000D+01
 NO2xx      3              coo1= 0.1000000D+01  coo2= 0.1000000D+01
 NO2xx      4              coo1= 0.1000000D+01  coo2= 0.2000000D+01
$tacty
 CLxxx      1  color  REDxx  noda=    3  nodb=    1  apab= 0.5000000D+00
$$$$$$
```

- you may define “continuous” line :

```
$tacty
 ALpxx      1  color  REDxx  noda=    2  nodb=    4
+ALpxx      1  color  REDxx  noda=    4  nodb=    5
+ALpxx      1  color  REDxx  noda=    5  nodb=    6
```

- the 2D boundaries must be defined clockwise

Available Boundaries for 2D MAILx are :

- CLxxx, candidate point on a line :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 CLxxx       1  color  REDxx  noda=     3  nodb=     1  apab= 0.5000000D+00
```

- ALpxx, antagoniste line :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 ALpxx       1  color  REDxx  noda=     2  nodb=     4
```

- PT2Dl, point on a line :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 PT2Dl       1  color  REDxx  noda=     3  nodb=     1  apab= 0.5000000D+00
```

- DISKL, full disc :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 DISKL       1  color  BLEUx  noda=     4  nodb=     3  apab= 0.5000000D+00  byrd= 0.1000000D+00
```

Available Boundaries for 3D MAILx are :

- CSxx3 and CSxx4 candidate point on a surface :

```
!23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 CSxx3      1  color  REDxx  noda=    3  nodb=    1  nodc=    2
                             w1  = 0.1000000D+00  w2  = 0.5000000D+00  w3  = 0.4000000D+00
!
 CSxx4      1  color  REDxx  noda=    3  nodb=    1  nodc=    2  nodd=    4
                             w1  = 0.2500000D+00  w2  = 0.2500000D+00  w3  = 0.2500000D+00
                             w4  = 0.2500000D+00
```

- ASpx3 and ASpx4 antagoniste surface :

```
!23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
 ASpx3      1  color  REDxx  noda=    3  nodb=    1  nodc=    2
!
 ASpx4      1  color  REDxx  noda=    3  nodb=    1  nodc=    2  nodd=    4
```

DATBOX : : TACT_BEHAV.DAT

This file contains two types of cards :

- some describing the interaction laws

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 iqsc0  IQS_CLB                        fric= 0.9500000D+00
```

- some describing the visibility tables :

```
!234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$seety
 cdbdy  cdtac  cdcol  behav  anbdy  antac  ancol        alert
 RBDY3  PT3Dx  TYTYx  BIOff  RBDY3  PT3Dx  TYTYx        0.5000000D+02
```

The list of all interaction law is the following :

Rigid/Rigid

IQS_CLB	IQS_DS_CLB	IQS_CLB_RGR
IQS_MOHR_DS_CLB	IQS_WET_DS_CLB	xQS_WET_DS_CLB
IQS_MAC_CZM	IQS_SGR_CLB_WEAR	
IQS_CLB_nosldt	IQS_CLB_noslds	
IQS_MAC_CZM_3D_nosldt	IQS_MAC_CZM_3D_noslds	IQS_MAC_CZM_3D
RST_CLB	RST_DS_CLB	
ELASTIC_WIRE	ELASTIC_ROD	
VOIGT_WIRE	VOIGT_ROD	
ELASTIC_REPELL_CLB	ELASTIC_REPELL_WET_CLB	CRITICAL_VOIGT_CLB
COUPLED_DOF	PLASTIC_COUPLED_DOF	NORMAL_COUPLED_DOF
TANGENTIAL_COUPLED_DOF	TEX_SOL_UNILAT	
MD_JKRs	DEM_Cohe_Hertz	
PERIO_DOF		

Rigid/Defo and Defo/Defo

GAP_SGR_CLB	GAP_SGR_DS_CLB	GAP_WET_DS_CLB
VEL_SGR_CLB	VEL_SGR_DS_CLB	
GAP_SGR_CLB_WEAR		
MAC_CZM	MAC_CZM_3D_nosldt	MAC_CZM_3D_noslds

DATBOX : : BULK_BEHAV.DAT

- This file contains values of some bulk parameters
- the fact you give some bulk parameters doesn't imply any thing on the way the computation run (see MODELS.DAT and command files)
- you have to give the gravity field :

```
$gravy
                   grv1=-0.0000000D+01  grv2= 0.0000000D+01  grv3=-0.9810000D+01
```

- then it works with filters which imply to define subset of parameters :

➡ rigid bulk parameters :

```
$behav  lawty
 tdurx  RIGID                                Umas= 0.2500000D+04
```

➡ elastic bulk parameters :

```
$behav  lawty
 Steel  ELAS                                 Umas= 0.7800000D-08
                                             elas: standard
                                             ani_: isotropic
                                             EYng= 0.2000000D+06  EPss= 0.3000000D+00
```

The known filters

- RIGID
- ELAS
- ELAS_DILA
- ELAS_PLAS
- VISCO_ELAS
- THERMO_ELAS
- THERMO_ELAS_VARIA
- THERMO_RIGID
- ELECTRO_RIGID
- THERMO_ELECTRO_RIGID

DATBOX : : MODELS.DAT

see zooef.pdf file.

DATBOX : : DRV_DOF.DAT

Contains the description of imposed (driven) degrees of freedom.

```
$bdyty
 RBDY2       1
$nodty
 NO3xx       1
$dofty         [CT......+......AMP..*..cos.(..OMEGA.*.time.+.PHI..)]...*...[RAMPI.....+.....RAMP.*.time]
 vlocy       1  0.1000000D+00  0.5460000D+00  0.3140000D+00  0.0000000D+00  0.5000000D+00  0.1000000D-01
 force       2 -0.6837000D+00  0.0000000D+00  0.0000000D+00  0.0000000D+00  0.1000000D+01  0.0000000D+00
 vlocy       3  0.0000000D+00  0.0000000D+00  0.0000000D+00  0.0000000D+00  0.1000000D+01  0.0000000D+00
$$$$$$

$bdyty
 RBDY2       3
$nodty
 NO3xx       1
$dofty         [CT......+......AMP..*..cos.(..OMEGA.*.time.+.PHI..)]...*...[RAMPI.....+.....RAMP.*.time]
 vlocy       1 evolution vx.dat
 vlocy       3  0.0000000D+00  0.0000000D+00  0.0000000D+00  0.0000000D+00  0.1000000D+01  0.0000000D+00
$$$$$$
```

Consider the 2D rigid body 1 (RBDY2) equipped with a 3 degrees of freedom node NO3xx.
The degrees of freedom number 1, 3 are submitted to imposed velocities, keyword vlocy.
The degree of freedom number 2 is submitted to an imposed force, keyword force.

The imposed velocities or forces are :

- described by a function :

$$V = (C + A * cos(\omega * (t + \phi)) * sign(ramp(t)) * min(1, \|ramp(t)\|),$$
$$C, A, \omega, \phi, \text{are scalar constants ,}$$
$$ramp(t) = RI + RP * t \text{ is an affine function,}$$
$$RI, RP, \text{are scalar constants.}$$

- described by an evolution file
  $t_0\ v(t_0)$
  $t_1\ v(t_1)$
  ...
  $t_n\ v(t_n)$

The INI files

- **DATBOX** : :DOF.INI
  It describes the displacements,
- **DATBOX** : :Vloc_Rloc.INI
- **DATBOX** : :GPV.INI

OUTBOX : : DOF.OUT

This text files contain the degrees of freedom results with the same format and meaning than `DOF.INI`. These files are written in the subdirectory `OUTBOX` as called by the following user commands :

- The user command WRITE LAST DOF writes the last computed record of X, V in the output file OUTBOX/DOF.LAST.
- The user command WRITE OUT DOF STEP p writes the computed record of X, V at step modulo p (some integer) in the output file OUTBOX/DOF.OUT.int(nstep/p), i.e. the files are numbered int(nstep/p) the integer part of the ratio nstep/p, where nstep is the current step number.

OUTBOX : : Vloc_Rloc.OUT

OUTBOX : : GPV.OUT

ChiPy

Have a look to Manuals/ChiPy.pdf and Docs/ChiPy.html

Restart

Visualisation

IQS_CLB

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 iqsc1  IQS_CLB                           fric= 0.5000000D+00
```

comments:

This contact law is used to describe an **I**nelastic **Q**uasi **S**hock law coupled with the Coulomb's friction law (**CLB**) . This inelastic shock law is appropriate to simulate large deformation problems of compact collections of rigid bodies. The normal part is describe by the classical linear complementarity problem (Signorini condition) :

$$g \geq 0 \quad R_N \geq 0 \quad g \cdot R_N = 0$$

and the tangential part by the classical Coulomb condition :

$$\|R_T\| \leq \mu R_N \;\; \textit{if} \; \|R_T\| = \mu R_N \; \textit{then} \; U_T = -\lambda \frac{R_T}{\|R_T\|} \; \textit{with} \; \lambda > 0 \; \textit{else} \; U_T = 0$$

The only coefficient defining this law is the friction coefficient μ (**fric**). Note that when contactors are approaching it allows a relative velocity to impose a null gap after the resolution. Otherwise a null relative velocity is imposed.

back to tact_behav list

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 irgr1   IQS_CLB_RGR                       T/H = 0.5000000D+00  gtol= 0.1000000D-04
                                           fric= 0.2000000D+00
```

comments:

This contact law is used to describe an **I**nelastic **Q**uasi **S**hock law coupled with the Coulomb's friction law (**CLB**) with an articial artifact allowing a mild gap violation restoring procedure so called **R**adjai **G**ap **R**escue. This law is defined through three coefficient : the friction coefficient μ (**fric**), a gap tolerance g_{tol}, and a articial damping parameter τ_h.

If the gap $g(t_i)$, resulting of the previous contact resolution is greater than the gap tolerance then the standard IQS_CLB law is applied. Otherwise an artificial repulsive force is applied to body in contact to retrieve a gap that respect the given gap tolerance :

$$R_N^* = -2\frac{\pi^2}{Wnn\tau_h^2}\frac{(g(t_i) - g_{tol})}{h}$$

back to tact_behav list

IQS_DS_CLB

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 idsc1  IQS_DS_CLB                     dyfr= 0.3000000D+00  stfr= 0.5000000D+00
```

comments:

This contact law is used to describe an **I**nelastic **Q**uasi **S**hock law coupled with a **D**ynamic/**S**tatic Coulomb's friction law (**CLB**) . The IQS_CLB formalism is used but the Coulomb's law is equipped with a static friction coefficient **stfr** when the status at the beginning of the time step is stick and a dynamical friction coefficient **dyfr** otherwise.

back to tact_behav list

TACT_BEHAV.DAT synopsis:

```
#234567890123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 gapc1   GAP_SGR_CLB                       fric= 0.5000000D+00
```

comments:

The Signorini condition involving the gap is used as a unilateral constraint, together with Coulomb's law. This Signorini condition is a complementary condition between the gap and the normal reaction impulse. The only coefficient defining this law is the friction coefficient **fric**.

This law may be used in quasi-static situations when one of the contactor is deformable. When dynamical problems between rigid bodies are under consideration, this law which has the property to correct penetrations within a single step introduces correcting impulses well up to cause artifact burst. This law is not recommended to deal with dynamical contact between rigid bodies.

back to tact_behav list

GAP_SGR_DS_CLB

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 gdsc1  GAP_SGR_DS_CLB                   dyfr= 0.3000000D+00  stfr= 0.5000000D+00
```

comments:

This contact law is an enrichment fo the law GAP_SGR_CLB except that static **stfr** and dynamic **dyfr** friction coefficients are considered. The Coulomb's law is equipped with the static coefficient when the status at the beginning of the time step is stick, otherwise the dynamical friction coefficient is used.

back to tact_behav list

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 velc1  VEL_SGR_CLB                      fric= 0.5000000D+00
```

comments:

When a contact is fore-casted, a complementary condition between the normal relative velocity and the normal reaction impulse is used, together with Coulomb's law. Such a law implies that unilateral constraints are satisfied (J.J. Moreau). The only coefficient defining this law is the friction coefficient **fric**.

This law may be used in quasi-static situations when one of the contactor is deformable. When dynamical problems between rigid bodies are under consideration, this law which has the property to correct penetrations within a single step introduces correcting impulses well up to cause artifact burst. This law is not recommended to deal with dynamical contact between rigid bodies. This laws is appropriate to deal with dynamical contacts between rigid or deformable contactors. It acts as an inelastic shock law.

back to tact_behav list

VEL_SGR_DS_CLB

TACT_BEHAV.DAT synopsis:

```
#234567890123456789012345678901234567890123456789012345678901234567890123456789012345678890
$behav  lawty
 vdsc1   VEL_SGR_DS_CLB                     dyfr= 0.5000000D+00  stfr= 0.6000000D+00
```

comments:

This contact law is an enrichment to VEL_SGR_CLB except that static **stfr** and dynamic **dyfr** friction coefficients are considered. The Coulomb's law is equipped with the static coefficient when the status at the beginning of the time step is stick, otherwise the dynamical friction coefficient is used.

back to tact_behav list

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 rstc1   RST_CLB                         rstn= 0.9000000D+00   rstt 0.5000000D+00
                                         fric= 0.0000000D+00
```

comments:

When a contact is fore-casted, a restitution shock law involving the relative velocity before the impact time (at the beginning of the time step) and after the impact time (at the end of the time step) is imposed. This law is a generalization by J.J. Moreau of the classical Newton restitution law. A normal restitution **rstn** and a tangential restitution coefficient **rstt** are used. This shock law is used together with Coulomb's law, with a friction coefficient **fric**.
This law may be used between impacting rigid bodies in granular flows. There are experimental results proving that this law is relevant for impacting spheres. Nevertheless, the concept of shock law, a limit law when waves propagation and complex local deformation phenomena occur is not ascertained. This simple shock law should not be used when the aspect ratio of contactors is high (...more than 5. or ?). Inelastic shock laws prove to be dissipative in any circumstances, which is not the case with this restitution law.

back to tact_behav list

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 rdsc1  RST_DS_CLB                      rstn= 0.9000000D+00  rstt= 0.5000000D+00
                                        dyfr= 0.3000000D+00  stfr= 0.5000000D+00
```

comments:

This contact law is an enrichment to RST_CLB except that static **stfr** and dynamic **dyfr** friction coefficients are considered. The Coulomb's law is equipped with the static coefficient when the status at the beginning of the time step is stick, otherwise the dynamical friction coefficient is used.

back to tact_behav list

IQS_MOHR_DS_CLB

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678890
$behav  lawty
 mohr1  IQS_MOHR_DS_CLB                    cohn= 0.9000000D+01  coht= 0.5000000D+00
                                           dyfr= 0.2500000D+00  stfr= 0.5500000D+00
```

comments:

This contact law is the Mohr Coulomb law when the status at the beginning of the time step is cohesive *statusBEGIN = Mstck*, otherwise the contact law is IQS_DS_CLB. The coefficients **cohn** and **coht** stand for normal and tangential cohesion thresholds, so that the Mohr-Coulomb cone has an opening angle ϕ, *tg*$\phi = \mathrm{coht}/\mathrm{cohn}$. Note that this law has been used formerly. It has to be checked again.

back to tact_behav list

TACT_BEHAV.DAT synopsis:

```
#234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 wet01  IQS_WET_DS_CLB                cohn= 0.2234379D+01  coht= 0.2234379D+01
                                      Wthk= 0.1000000D-02
                                      dyfr= 0.2500000D+00  stfr= 0.5500000D+00
```

comments:

This contact law takes into account cohesion between contactors, as a Lennard Jones law would do, but in the non smooth style. When the gap at the beginning of the time step is less than some given data, $gapBEGIN \leq$ **Wthk**, an cohesive law is applied. Otherwise a IQS_DS_CLB law is applied :

$$\begin{array}{c} If \quad gapBEGIN \geq Wthk \quad then \quad g \geq 0 \quad R_N \geq 0 \quad g \cdot R_N = 0 \\ else \quad (g) \geq 0 \quad (R_N + cohn) \geq 0 \quad g \cdot (R_N + cohn) = 0 \end{array}$$

The status resulting from the contact resolution could be *Wstck* (Wet sticking), *Wslfw* (Wet sliding forward), *Wslbw* (Wet sliding backward) or *Wnctc* (Wet no contact). For the next steps, cohesion is active as long as the gap remains less than the given value **Wthk**. When the detachment has occurred, $gap \geq$ **Wthk**, the adhesive status is lost and the law IQS_DS_CLB is applied. The adhesive process is active again if the gap appears to be less than **Wthk**. On the whole, the energy to separate the contactors is **cohn*Wthk**.
The coefficients **dyfr** and **stfr** stand for dynamic and static friction coefficient.

back to tact_behav list

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 wet01  xQS_WET_DS_CLB                    cohn= 0.2234379D+01  coht= 0.2234379D+01
                                          Wthk= 0.1000000D-02
                                          dyfr= 0.2500000D+00  stfr= 0.5500000D+00
```

comments:

This contact law takes into account adhesion between contactors, as a Lennard Jones law would do, but in the non smooth style. When the gap at the beginning of the time step is less than some given data, *gapBEGIN* $\leq$ **Wthk**, an cohesive law is applied. Otherwise a IQS_DS_CLB law is applied :

$$\begin{array}{l} If \quad gapBEGIN \geq Wthk \quad then \quad g \geq 0 \quad R_N \geq 0 \quad g \cdot R_N = 0 \\ else \quad (g) \geq 0 \quad (R_N + cohn) \geq 0 \quad g \cdot (R_N + cohn) = 0 \end{array}$$

The coefficients **dyfr** and **stfr** stand for dynamic and static friction coefficient. Contrary to the xQS_WET_DS_CL law, this one present an irreversible feature of cohesion. When the cohesive contact is broken, it could not be again cohesive adn the law acts as the IQS_DS_CLB law.

back to tact_behav list

GAP_WET_DS_CLB

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 wet01   GAP_WET_DS_CLB                    cohn= 0.2234379D+01  coht= 0.2234379D+01
                                           Wthk= 0.1000000D-02
                                           dyfr= 0.2500000D+00  stfr= 0.5500000D+00
```

comments: :

This contact law takes into account adhesion between contactors, as a Lennard Jones law would do, but in the non smooth style. When the gap at the beginning of the time step is less than some given data, $gapBEGIN \leq$ **Wthk**, an cohesive law is applied. Otherwise a GAP_DS_CLB law is applied.

This law may be used in quasi-static situations when one of the contactor is deformable. When dynamical problems between rigid bodies are under consideration, this law which has the property to correct penetrations within a single step introduces correcting impulses well up to cause artifact burst. This law is not recommended to deal with dynamical contact between rigid bodies.

back to tact_behav list

ELASTIC_REPELL_CLB

TACT_BEHAV.DAT synopsis:

```
#234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 erpcE  ELASTIC_REPELL_CLB              F/gp= 0.4000000D+05
                                        fric= 0.8391000D+00
```

comments:

This law describes a normal reaction force proportional to the gap (interpenetration), otherwise the reaction force vanishes when the contactors separate (positive gap). The friction law is Coulomb's law. Coulomb's law. The stiffness between contactors is described by the coefficient **F/gp** i.e. a force per unit length (of gap). The coefficient **fric** is the friction coefficient. This law is useful when there are physical reasons to take elasticity in consideration, for instance one of the contactor is soft. Be aware of the fact that dynamical effects (oscillations of the contactors) may occur if the time step is soft enough.

back to tact_behav list

ELASTIC_WIRE

TACT_BEHAV.DAT synopsis:

```
#234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 elawr  ELASTIC_WIRE                    F/st= 0.5000000D+01  prst=-0.5000000D-01
```

comments:

This law describes the behaviour of an elastic wire connecting two contactors, usually points PT2Dx, but actually any kind of contactors. The reaction force when the wire is under tension is proportional to the deformation, otherwise the wire does not present any compression and the reaction force vanishes.The reaction force writes,

$$RlocN = -F/st * strain,$$

with

$$strain = (gapTT - gapREF)/gapREF - prst,$$

where *gapREF* is the gap between contactors in the reference configuration, i.e. the configuration resulting of the combination of the BODIES.DAT and DOF.INI.

Remark : This law involving elasticity is treated as a so called *Derived Signorini Coulomb law* : auxiliary variables obtained by affine change of variables from standard reactions, gaps and relative velocities, must satisfy the standard Signorini Coulomb relations. The changes of variables done are relevant for $\theta = 1$. For $\theta \neq 1$ they should be revisited.

back to tact_behav list

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 elard  ELASTIC_ROD                    F/st= 0.1000000D+05  prst=-0.1000000D-03
```

comments:

This law describes the behaviour of an elastic rod connecting two contactors, usually points PT2Dx, but actually any kind of contactors. The reaction force is proportional to the deformation,

$$RlocN = -F/st * strain,$$

with

$$strain = (gapTT - gapREF)/gapREF - prst,$$

where *gapREF* is the gap between contactors in the reference configuration, i.e. the configuration resulting of the combination of the BODIES.DAT and DOF.INI. The data *gapREF* may be considered as an internal parameter and is now being carried on in Vloc_Rloc.INI, Vloc_Rloc.LAST files.

Remark : This law is treated as a so called *Derived Signorini Coulomb law*, i.e. auxiliary variables obtained by affine change of variables from standard reactions, gaps and relative velocities, must satisfy the standard Signorini Coulomb relations. The changes of variables done are relevant for $\theta = 1$. For $\theta \neq 1$ they should be revisited.

back to tact_behav list

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 vgtwr  VOIGT_WIRE                          F/st= 0.5000000D+01   prst=-0.5000000D-01
                                            F/sr= 0.5000000D-01
```

comments:

This law describes the behaviour of an visco-elastic wire connecting two contactors, usually points PT2Dx, but actually any kind of contactors. The reaction force when the wire is under tension is dependant of both deformation and deformation increment, otherwise the wire does not present any compression and the reaction force vanishes.The reaction force writes,

$$RlocN = -F/st * strain + F/sr * \dot{strain},$$

with

$$strain = (gapTT - gapREF)/gapREF - prst,$$

where *gapREF* is the gap between contactors in the reference configuration, i.e. the configuration resulting of the combination of the BODIES.DAT and DOF.INI.
Remark : This law involving visco-elasticity is treated as a so called *Derived Signorini Coulomb law* : auxiliary variables obtained by affine change of variables from standard reactions, gaps and relative velocities, must satisfy the standard Signorini Coulomb relations. The changes of variables done are relevant for $\theta = 1$. For $\theta \neq 1$ they should be revisited.

back to tact_behav list

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 vgtrd  VOIGT_ROD                      F/st= 0.5000000D+01  prst=-0.5000000D-01
                                       F/sr= 0.5000000D-01
```

comments:

This law describes the behaviour of an visco-elastic rod connecting two contactors, usually points PT2Dx, but actually any kind of contactors. The reaction force is proportional to the deformation,

$$RlocN = -F/st * strain + F/sr * \dot{strain},$$

with

$$strain = (gapTT - gapREF)/gapREF - prst,$$

where *gapREF* is the gap between contactors in the reference configuration, i.e. the configuration resulting of the combination of the BODIES.DAT and DOF.INI. The data *gapREF* may be considered as an internal parameter and is now being carried on in Vloc_Rloc.INI, Vloc_Rloc.LAST files.

Remark : This law involving visco-elasticity is treated as a so called *Derived Signorini Coulomb law* : auxiliary variables obtained by affine change of variables from standard reactions, gaps and relative velocities, must satisfy the standard Signorini Coulomb relations. The changes of variables done are relevant for $\theta = 1$. For $\theta \neq 1$ they should be revisited.

back to tact_behav list

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 elawr  ELASTIC_REPELL_WET_CLB         F/st= 0.5000000D+06
                                       cohn= 0.5000000D+00  Wthk= 0.5000000D-04
                                       fric= 0.5000000D+01
```

comments:

This law describes a normal reaction force proportional to the gap (interpenetration) combine with a cohesive force. The cohesive force acts according to an halo defined by the distance **Wthk**. For a gap larger than this value, the reaction force vanishes. The stiffness between contactors is described by the coefficient **F/st** and acts at the level of the cohesive force **cohn** :

$$RlocN = -F/st * gap - cohn,$$

The friction law associated is the Coulomb's law where **fric** is the friction coefficient.

back to tact_behav list

CRITICAL_VOIGT_CLB

TACT_BEHAV.DAT synopsis:

```
#234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 elawr  CRITICAL_VOIGT_CLB            T/H = 0.5000000D+01  v/cv=-0.5000000D-01
                                      fric= 0.5000000D+00
```

comments:

back to tact_behav list

TEX_SOL_UNILAT

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 txsol  TEX_SOL_UNILAT
```

comments:

back to tact_behav list

COUPLED_DOF

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 cpd01  COUPLED_DOF
```

comments:

back to tact_behav list

PLASTIC_COUPLED_DOF

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 pcpd1  PLASTIC_COUPLED_DOF
```

comments:

back to tact_behav list

NORMAL_COUPLED_DOF

TACT_BEHAV.DAT synopsis:

```
#234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 ncpd1  NORMAL_COUPLED_DOF
```

comments:

back to tact_behav list

TANGENTIAL_COUPLED_DOF

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 tcpd1  TANGENTIAL_COUPLED_DOF
```

comments:

back to tact_behav list

PERIO_DOF

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890123456789
$behav  lawty
 perd1  PERIO_DOF                       E_xx= 0.1000000D+05  E_yy=-0.1000000D-03  E_xy=-0.1000000D-03
```

comments:

back to tact_behav list

MD_JKRs

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678890
$behav  lawty
 jkrs1  MD_JKRs                         kn__= 0.1000000D+05  kt__= 0.1000000D+05
                                        damp= 0.1000000D+00  gamm= 0.1000000D+00
                                        fric= 0.8391000D+00
```

comments:

back to tact_behav list

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 dch01  DEM_Cohe_Hertz                    kn__= 0.1000000D+05  Weth= 0.1000000D+05
                                          damp= 0.1000000D+00  gamm= 0.1000000D+00
```

comments:

back to tact_behav list

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678901234567890
$behav  lawty
 mac01  IQS_MAC_CZM                  dfrc= 0.1150000D+01  sfrc= 0.1150000D+01
                                     cn   = 0.1000000D+08  ct   = 0.1000000D+06
                                     visc= 0.0000000D-00  dupr= 0.1000000D+06
```

comments:

This is a **C**ohesive **Z**one **M**odel interaction using the **M**oneri **A**cary **C**angemy model to describe the evolution of the damage variable β. The coefficients **dyfr** and **stfr** stand for dynamic and static friction coefficient. **cn** and **ct** are the normal and the tangential stiffnesses, **visc** a viscous parameter and **dupr** the energy dissipated when the interaction is broken.

back to tact_behav list

TACT_BEHAV.DAT synopsis:

```
#23456789012345678901234567890123456789012345678901234567890123456789012345678 90
$behav  lawty
 mal01   IQS_MAC_CZM                        dfrc= 0.1150000D+01  sfrc= 0.1150000D+01
                                            cn  = 0.1000000D+08  ct  = 0.1000000D+06
                                            sigc= 0.1000000D+07  dupr= 0.1000000D+06
```

comments:

This is a **C**ohesive **Z**one **M**odel interaction using the MAL model to describe the evolution of the damage variable β. The coefficients **dyfr** and **stfr** stand for dynamic and static friction coefficient. **cn** and **ct** are the normal and the tangential stiffnesses, **visc** a viscous parameter and **dupr** the energy dissipated when the interaction is broken.

back to tact_behav list

RIGID