# Note of use of the coupling enters *Code_Aster* and modulates it laws of behavior UMAT

**Summary:**

One describes the use of the coupling here enters *Code_Aster* and integration of laws of behavior UMAT, routine modulates it "user" whose arguments are specified by the Abaqus code.

Caution: the use of these laws of behavior "made-to-order" implies a specific validation for the study considered, because one places oneself out of field described as *Code_Aster*.

# Contents

# 1 Methods of use of the routines of the type UMAT

## 1.1 Description of routines UMAT

UMAT is a format of routine FORTRAN familiar of the users of the Abaqus code, being used to integrate their own laws of behavior. The contents of this routine are entirely free and with the load of the user, and must make it possible to integrate the law of behavior, i.e. in a point of integration, to calculate the tensor of the constraints, the variables internal, and the tangent operator (cf [D5.04.01] - To introduce a new behavior).

For more precise details on routines UMAT, to consult the documentation of the Abaqus code.

The heading of a routine UMAT is presented in the form of this:

```
SUBROUTINE UMAT (   STRESS, STATEV, DDSDDE, SE, SPD, SCD,
                 RPL, DDSDDT, DRPLDE, DRPLDT,
                    STRAN, DSTRAN, TIME, DTIME, TEMP, DTEMP, PREDEF, DPRED,
CMNAME,                        NDI, NSHR, NTENS, NSTATV, PROPS, NPROPS, COORDS,
DROT, PNEWDT,                        CONCEAL, DFGRD0, DFGRD1, CHRISTMAS, NPT,
TO BUSH-HAMMER, KSPT, KSTEP, KINC)
```

Briefly, the arguments as starter and at exit of a routine UMAT are the following:

### 1.1.1 Variables as starter

| Argument | Significance (Abaqus specification) | Values transmittedS by C*ode_hasster* |
|---|---|---|
| NDI | Component count of constraints (except shearing) at the current point of integration | 3 |
| NSHR | Component count of shear stresses at the current point of integration | 1 (D_PLAN, AXIS, C_PLAN) or 3 (in 3D) |
| NTENS | Full number of components of constraints and shearing | NTENS = NDI+NSHR |
| NPROPS | Many parameters materials | 50 (value fixes) |
| NSTATV | Many internal variables associated with the behavior. | NB_VARI under BEHAVIOR |
| CMNAME | Name of the behavior | UMAT |
| COORDS | Table containing the coordinates of the current point of integration | Coordinated point of current gauss if those are defined like variable of order in AFFE_MATERIAU. |
| PROPS (NPROPS) | Table of the parameters materials | DEFI_MATERIAU/UMAT/LISTE_COEF |
| TIME (1) | Time of the step at the beginning of the increment | $\Delta t = t_i - t_{i-1}$ |
| TIME (2) | Total time at the beginning of the increment | $t_{i-1}$ |
| DTIME | Increment of time | $\Delta t = t_i - t_{i-1}$ |

| | | |
|---|---|---|
| TEMP | Temperature at the beginning of the increment | $T(t_{i-1})$ |
| DTEMP | Increment of temperature | $T(t_i)-T(t_{i-1})$ |
| CONCEAL | Length characteristic of the element | *Nondefinite* |
| CHRISTMAS | Number of the element | Number of the element |
| NPT | Number of the point of integration | Number of the point of Gauss in the current element |
| TO BUSH-HAMMER | Number of the layer for the hulls (under-point of integration) | *Nondefinite* |
| KSPT | Number of the point of integration in the current underlayer | Number of under-point of integration |
| KSTEP | Number of the step | 2 (value fixes) |
| KINC | Number of the increment | Number of the iteration of Newton (KINC=0 in prediction) |
| DROT (3.3) | Matrix of increment of rotation, presents if the base for material turns with the element. | Calculated starting from the 3 nautical angles |
| DFGRD0 (3.3) | Table containing the gradient of transformation at the beginning of the increment | *Nondefinite* |
| DFGRD1 (3.3) | Table containing the gradient of transformation at the end of the increment | *Nondefinite* |
| STRAN (NTENS) | Total mechanical deformations at the beginning of the increment. (the thermal deformations are withdrawn). | $\varepsilon(t_{i-1})-\varepsilon^{th}(t_{i-1})$ |
| DSTRAN (NTENS) | Mechanical increments of deformations. The thermal deformations are withdrawn. | $\Delta\varepsilon(t_{i-1})-\Delta\varepsilon^{th}(t_{i-1})$ |
| PREDEF | Table of the interpolated values of the external fields imposed on the beginning of the increment | The provided values are: 'IRRA', 'SECH', 'HYDR', 'CORR', 'NEUT1', 'NEUT2', in this order. (the value is Not if the variable of order is not defined). |
| DPRED | Table of the increments of the external fields impose | Increments of variable of order in the same order as PREDEF. |

### 1.1.2 Produced or modified variables

| **Argument** | **Significance (Abaqus specification)** | **Values transmitted to *Code_Aster*** |
|---|---|---|
| STRESS (NTENS) | Tensor of the constraints of Cauchy at the | Stored in the field SIEF_ELGA, |

| | | |
|---|---|---|
| | beginning of the step of time. Must be modified to give the constraints at the end of the step of time. | used for the calculation of the internal forces (residue) |
| STATEV (NSTATV) | Table containing the internal variables of the law of behavior. | Stored in the field VARI_ELGA |
| DDSDDE (NTENS, NTENS) | Operator yourngent (symmetrical) model of behavior | Used for the calculation of the tangent matrix. |
| PNEWDT | Report of the new step of time suggested on the step of initial time | *Disconnected functionality* |
| SE, SPD, SCD | Elastic energy, of plastic dissipation and energy of creep. | Not used |

For the only coupled thermomechanical analyses:

| | | |
|---|---|---|
| RPL | Volumetric production of heat per unit of time at the end of the increment caused by mechanics. | Not used |
| DDSDDT (NTENS) | Variation of the increment of the constraints compared to the temperature | Not used |
| DRPLDE (NTENS) | Variation of the production of heat compared to the increments of deformation | Not used |
| DRPLDT | Variation of the production of heat compared to the temperature | Not used |

The current limitations of the interface Aster-Umat are:
- Only supported modelings are: 3D, AXIS, D_PLAN (and C_PLAN *via* DEBORST);
- Energies are not recovered by *Code_Aster* currently;
- Pas de thermomechanical coupling for the moment.

One can take into account the great deformations via DEFORMATION=' GDEF_LOG'.

## 1.2 Use of routines UMAT in a study

### 1.2.1 Creation of the dynamic library starting from a routine FORTRAN **umat.f**

The dynamic library containing the routine UMAT must be prepared before the execution of calculation. For that, the user has a simple way compile this library by using the utility as_run [U1.04.00], (with a version ofastk higher or equal to 1.8.3).

Operation is the following:
1) the user writes his routine of behavior umat.f (the names of the file and the routine are unspecified since they are recalled at the time of calculation);
2) Il product the dynamic library associated with this behavior in the following way:
   - Cd /chemin/fichiers/etude
   - as_run --make_shared - O libumat.so umat.f
3) for to launch the study, in astk, it indicates:
   - /chemin/fichiers/etude/libumat.so, **type= " name"**, UL=0, in Data (the file will be recopied in the repertoire of work without changing name)
   - in the command file, it indicates under BEHAVIOR :
     - RELATION=' UMAT' ,

- LIBRAIRIE=' libumat.so' ,
  (or in absolute way:
  LIBRAIRIE='/chemin/fichiers/etude/libumat.so')
- NOM_ROUTINE=' umat_ ' (one can omit the character "_")

By this mechanism, it is completely possible to have several different behaviors UMAT which cohabit (several routines in the same library or different libraries, to see for example the test umat002a).

### 1.2.2 Use in the command file

The UMAT-Code_Aster coupling is translated in the command file in the following way:

- The data necessary of the field material are provided in the operator DEFI_MATERIAU [U4.43.01], under the keyword UMAT/UMAT_FO.
- Under the keyword BEHAVIOR of STAT_NON_LINE, DYNA_NON_LINE or SIMU_POINT_MAT:
  - to specify RELATION=' UMAT' ;
  - under mot_clé NB_VARI, to specify the number of internal variables of the behavior;
  - the assumption of the plane constraints is taken into account by the method of Borst [R5.03.03] ;
  - to show the way towards the library under the keyword BOOKSTORE and the name of the routine contained in the library under the keyword NOM_ROUTINE, as described above.
- the keyword RESI_INTE_RELA, ITER_INTE_MAXI, ALGO_INTE, PARM_THETA, are not used, because the arguments of entry of UMAT do not make it possible to take them into account.

Examples: to see the tests umat001 (thermoelastic test with STAT_NON_LINE), umat002 (multidirectional analytical test with SIMU_POINT_MAT) or zzzz409a (thermomechanical test with a law of damage and in SIMU_POINT_MAT).