
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*.

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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, DDSDE, 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 Code_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_COEFF
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	$\Delta t = t_i - t_{i-1}$

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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	<i>Nondefinite</i>
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)	<i>Nondefinite</i>
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	<i>Nondefinite</i>
DFGRD1 (3.3)	Table containing the gradient of transformation at the end of the increment	<i>Nondefinite</i>
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,

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	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	<i>Disconnected functionality</i>
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;
- Thermomechanical Pas de 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 of astk 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`).