Operator POST_JMOD

Goal

This operator aims at calculating the modified *J* -integral in 3D ('3D' modeling) using the domain integral method based on the work Rice [1] (standard or without initial state) and Lei [2] (with initial state). The theoretical and numerical descriptions of this method are presented in the associated reference document [R7.02.22]. It works for:

- elastic and plastic materials;
- proportional/non-proportional and mixed-mode loads;
- initial strain associated with an equilibrium initial stress.

This operator is only available now for meshed crack (not yet for un-meshed "X-FEM" cracks).

Produces a *code_aster* concept of type table .

1 J. R. Rice, *J. Appl. Mech.* , vol. 35, no. 2, pp. 379–386, 1968.
2 Y. Lei, N. P. O'dowd, and G. A. Webster, *Int. J. Fract.* , vol. 106, no. 3, pp. 195–216, 2000.
Y. Lei, "Improvement of modified J evaluation using finite element method", *Br. Energy Eng.* , 2006.

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- Syntax

```
tj[table] = POST_JMOD     (

          ♦    FOND_FISS         =  fondfiss,              [fond_fiss]
          ♦    RESULTAT          =  resu,                / [evol_elas]
                                                         / [evol_noli]
          ◊    MODIFICATION      =  / 'NON',               [DEFAULT]
                                   =  / 'OUI',
          ◊    CONTOURS          =  / 4,                   [DEFAULT]
                                   =  / lcontour,            [I]
          ◊    ETAT_INIT         =  _F(EPSI = epsi0),    / [cham_elem]
                                                         / [cham_no]
          ◊    / GROUP_NO        =  lnodes,                [grno]
               / REDU_NODE       =  number_times,          [I]
          ◊    / INST            =  linst,                 [l_R]
                 ◊ PRECISION     =  / 1.E-06,              [DEFAULT]
                                   =  / coef_precis,         [R]
               / NUME_ORDRE      =  lordre,                [l_I]
          ◊    TITRE             =  / 'POST_JMOD',         [DEFAULT]
                                   =  / titre,               [l_Kn]

          )
```


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- Operands

3.1 Operand FOND_FISS

♦ FOND_FISS = fondfiss , [fond_fiss]

This operand allows providing the concept fond_fiss created by the command DEFI_FOND_FISS [U4.82.01] which contains necessary information for the automatic search of the crack front and one (symmetry problem) or two (non-symmetry problem) crack lips. The only requirement is that hexahedral elements must be used for elements which are used to perform contour integral. Also, it is recommended (not obligatory) that the planes passing through the crack tip nodes are planar within the contour integral zone.

N.B: There is not other restrictions on the mesh as long as it is obtained via the command DEFI_FOND_FISS . For verification purpose, the users are commended to first launch a study with CALC_G (without initial stress) to assure the quality of mesh and crack definition prior to launch POST_JMOD .

3.2 Operand RESULTAT

♦ RESULTAT = resu ,

resu is a concept of the types evol_elas or evol_noli . It is the result of STAT_NON_LINE or MECA_STATIQUE calculations that contain the displacement field for the entire model.

3.3 Operand MODIFICATION

• MODIFICATION = /'OUI', [DEFAULT]
/ 'NON'

For MODIFICATION = 'NON' , the J-integral valid under the conditions of initial strain and proportional loading is computed according to Equation (6) in the reference manual [R7.02.22].

For MODIFICATION = 'OUI' , the modified J-integral valid under the conditions of initial strain and non-proportional loading is computed. It is based on Lei's modification in [E/EAN/BBGB/0002/GEN/06 report] and is calculated according to the equation (10) in the reference manual [R7.02.22].

3.4 Operand CONTOURS

• CONTOURS = / 4, [DEFAULT]
/lcontour, [I]

lcontour is the number of contours around the crack tip on which the *J*- integral calculation using domain integral method is performed.

For the current version of *Code_Aster* , the macro-command POST_JMOD only works:

- if linear elements : CONTOURS < 20
- if quadratic elements : CONTOURS < 10

By default, CONTOURS = 4 .

NB: *Based on Lei's modifications in [E/EAN/BBGB/0002/GEN/06 report], when calculating J using a FE program, the J values obtained on the first 2 to 3 contours are generally dropped because of the inaccurate*

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stress, strain and displacement data at the vicinity of the crack tip. In order tominimize the effects of the inaccurate near-tip computational results a on the calculation of the correction part for the modified J , a very small area surrounding the crack tip is excluded from the integration area has been modified. That explains why the number of contours is assigned to be 4 by default.

3.5 Operand ETAT_INIT

- ETAT_IN IT = _F(EPSI = epsi0),

In the presence of initial strain, the *J* formulation according to the equations (6) and (13) of [R7.02.XX] will be used. The initial strain must be a deformation field defined by *Code_Aster* . That is TYPE_CHAM = 'XXXX_EPSI_R' . Here, XXXX can be ELGA or ELNO or NOEU . The initial strain must be self-equilibrium. Any type of initial strain that previously existed in structure prior to calling POST_JMOD is accepted.

NB: *If only the initial auto-equilibrium stress is available, an associated initial strain should be first obtained via the STAT_NON_LINE operator. It is very important to assure the auto-equilibrium of the initial state . Also, the user would need to employ the total initial strain.*

3.6 Operands

- OUP_NO = lnodes, [grno]
/ REDU_NODE = number_times, [I]

These operands allow reducing the number of nodes around the crack tip to compute J. By default, without this input, the calculation of *J* is performed for all nodes of the crack front. In order to save computing time, the user has the possibility to:

- select desired crack tip nodes by its names (keyword GROUP_NO);
- reduce the number of crack tip nodes of crack front to number_times times (keyword REDU_NODE). For example, if the front has 20 crack tip nodes and number_times = 4, the operator will perform the calculation on 20/4 = 5 nodes along the crack front (including the extreme points).

3.7 Operands INST, PRECISION, NUME_ORDRE

- / INST = linst, [l_R]
◊ PRECISION = / 1.E-06, [DEFAULT]
= / coef_precis, [R]

/ NUME_ORDRE = lordre, [l_I]

The keyword INST allows to access only the result of *J* corresponding to a list of instants linst [U4.71.00] . Because the instant values are usually real numbers, therefore, the keyword PRECISION allows to find the exact values of instants in the interval [inst- coef_precis, inst+coef_precis]. By default, PRECISION = 1.E-06 is set.

The keyword NUME_ORDRE allows to access only the result of *J* corresponding to a list of order numbers lordre [U4.34.02] [U4.71.00] .

If INST and NUME_ORDRE are not provided, *J* will be calculated and printed for all instants and all order numbers.

3.8 Operand TITRE

- TITRE = / 'POST_JMOD', [DEFAULT]

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/titre, [l_Kn]

This operand provides the title for the result table [U4.03.01].

- Current framework of application

The capabilities of POST_JMOD depend on the characteristics of the inputs such as modeling, mesh, element types and load. The current framework of applications of POST_JMOD is as following..

		J calculation by POST_JMOD
Modeling	'D_PLAN'	YES
	'C_PLAN'	
	'AXIS'	
	'3D'	
Mesh	MESHED CRACK	YES
	NON-MESHED CRACK	NO
Element types	2D and AXIS- ALL ELEMENT TYPES	YES
	3D HEXAHEDRAL ELEMENT	YES
	3D NON-HEXAHEDRAL ELEMENT	NON
Mechanical load	PROPORTIONAL LOAD	YES
	NON-PROPORTIONAL LOAD	
	MIXED-MODE LOAD	
Thermal load		NO
Mechanical load on the lips		NO

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- Example

Example can be found in the test cases for validations of Jmod3D development: forma07a, sslv134a, sslv154a, sslv116a, Jmod3D_t12, Jmod3D_z1, Jmod3D_cecc.

Example sslv116a: Circular crack in medium 3D with initial field.

'NFF3' is group of nodes of crack front (33 nodes):

```
MA=LIRE_MAILLAGE()

MA=DEFI_GROUP(reuse=MA,
MAILLAGE=MA,
CREA_GROUP_NO=_F(OPTION='NOEUD_ORDO',
NOM='NFF3',
GROUP_MA='LFF1',
GROUP_NO_ORIG='NFF1',
GROUP_NO_EXTR='NFF2',),)
```

Calculation using MECA_STATIQUE … and extract the initial strain field: EPSIELGA

'LEVSUP' and 'LEVINF' are the groups of upper and lower lips:

```
FISS=DEFI_FOND_FISS(MAILLAGE=MA,
FOND_FISS=_F(GROUP_NO='NFF3'),
LEVRE_SUP=_F(GROUP_MA='LEVSUP'),
LEVRE_INF=_F(GROUP_MA='LEVINF'),)

J5=POST_JMOD(FOND_FISS=FISS,
RESULTAT=RESUINI,
MODIFICATION='OUI',
CONTOURS=5,
ETAT_INIT=_F(EPSI=EPSIELGA),
REDU_NODE=6,
INST=3,
TITRE='POST_JMOD 5',)

IMPR_TABLE(TABLE=J5)
```

The obtained results are shown below:

```
#
#------------------------------------------------------------------------------
##POST_J 5
FOND_FISS NUME_FOND    INST         NUME_ORDRE   NOEUD_FOND NUM_PT       VOLUME       CONTOURS     J
 FISS               1  3.00000E+00           1   N49                 1  1.10718E-01           5  1.84063E+06
 FISS               1  3.00000E+00           1   N70                 7  1.10718E-01           5  1.87829E+06
 FISS               1  3.00000E+00           1   N91                13  1.10718E-01           5  1.89548E+06
 FISS               1  3.00000E+00           1   N202               19  1.10718E-01           5  1.89889E+06
 FISS               1  3.00000E+00           1   N1498              26  1.10718E-01           5  1.88280E+06
 FISS               1  3.00000E+00           1   N153               33  1.10718E-01           5  1.84063E+06
```


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