Operator TO SOLVE

1 Goal

To solve a system of linear equations (direct or iterative method)

Methods of resolutions established in Code_Aster and usable by this order are:

1) method MULT_FRONT (direct method),
2) method LDLT (direct method),
3) method MUMPS (direct method),
4) method GCPC (iterative method),
5) method PETSC (iterative method).

The effective choice of the method is done through the order TO FACTORIZE [U4.55.01].

For the direct methods, the matrix must be factorized beforehand by the order TO FACTORIZE [U4.55.01]. In the case of the iterative methods with prepacking, the matrix of pre conditioning is provided it-also by the operator TO FACTORIZE [U4.55.01].

The operator allows complex resolutions for the “direct” methods (not for the iterative methods).

Product a structure of data of the type cham_no.
2 Syntax

```plaintext
U [cham_no_∗] = TO SOLVE
(reuse = U,
MATR = With,
# If method LDLT, MULT_FRONT, MUMPS:
  / [matr_asse_DEPL_R]
  / [matr_asse_TEMP_R]
  / [matr_asse_TEMP_C]
  / [matr_asse_PRES_R]
  / [matr_asse_PRES_C]
# If method GCPC or PETSC:
  / [matr_asse_DEPL_R]
  / [matr_asse_TEMP_R]
  / [matr_asse_PRES_R]
◆ CHAM_NO = B, /
◆ CHAM_CINE = vcine, /
# if method PETSC :
◆ ALGORITHM = / 'GMRES', [DEFECT]
  / 'CG',
  / 'CR',
  / 'GCR',
# if method MUMPS, GCPC, PETSC :
◆ RESI_RELA = / 1.e-6, [DEFECT]
  / eps, [R]
# if method GCPC or PETSC :
◆ MATR_PREC = precond, /
  / [matr_asse_TEMP_R]
  / [matr_asse_PRES_R]
◆ NMAX_ITER = / niter, [I]
  / 0, [DEFECT]
# if method MUMPS :
◆ POSTTRAITEMENTS = ... (see keyword SOLVEUR [U4.50.01])
◆ TITLE = titr, [l_K80]
◆ INFORMATION = / 1 , [DEFECT]
  / 2 ,
)
```

If CHAM_NO:
```
[cham_no_DEPL_R] → DEPL_R
[cham_no_TEMP_R] → TEMP_R
[cham_no_PRES_C] → PRES_C
```
3 General information

This order makes it possible to solve:

• by a direct method, the linear system $AX = B$, where $A$ is a matrix “factorized beforehand” by the order \texttt{TO FACTORIZE [U4.51.01]},

• by an iterative method (\texttt{GCPC} or \texttt{PETSC}), the linear system $P^{-1}AX = P^{-1}B$, where $P^{-1}$ is a matrix of prepacking determined by the order \texttt{TO FACTORIZE [U4.51.01]} and $A$ the initial assembled matrix.

The resolution is possible for boundary conditions of Dirichlet (boundary conditions kinematics) dualized or eliminated [U2.01.02]. In this last case, if the loading $X = X_0$ on the “edge” $\Gamma_0$ is applied with a kinematic load (operator \texttt{AFFE_CHAR_CINE [U4.44.03]}) taken into account in the assembled matrix (operator \texttt{ASSE_MATRICE [U4.61.22]}), the “value” of this loading $X_0$, calculated by the operator \texttt{CALC_CHAR_CINE [U4.61.03]} must be provided by the keyword \texttt{CHAM_CINE}.

4 Operands

4.1 Operand \texttt{MATR}

\begin{itemize}
  \item MATR = With,
\end{itemize}

Name of the matrix of the system to be solved:

\begin{itemize}
  \item For the direct methods, one provides to \texttt{MATR} the concept modified by the operator \texttt{TO FACTORIZE}; this matrix can be real or complex, symmetrical or not.
  \item For the iterative methods, one provides to \texttt{MATR} the initial matrix. The matrix of prepacking is to be provided with the keyword \texttt{MATR_PREC}.
\end{itemize}

4.2 Operand \texttt{CHAM_NO}

\begin{itemize}
  \item CHAM_NO = B,
\end{itemize}

Name of the vector second member (in general obtained by the order \texttt{ASSE_VECTEUR}).

4.3 Operand \texttt{CHAM_CINE}

\begin{itemize}
  \item CHAM_CINE = vcine,
\end{itemize}

Name of the vector representing the “value” of the boundary conditions of Dirichlet eliminated (i.e. applied with one from the orders \texttt{AFFE_CHAR_CINE} or \texttt{AFFE_CHAR_CINE_F}).

\texttt{cham_no} comes from the execution of the operator \texttt{CALC_CHAR_CINE} on the list of \texttt{char_cine} (loadings kinematics) associated with the assembled matrix \texttt{With [U2.01.02]}.

4.4 Operand \texttt{ALGORITHM}

\begin{itemize}
  \item ALGORITHM =/'GMRES’ [DEFECT]/ 'CG'/ 'CR'/ 'GCR'
\end{itemize}
This keyword is used to choose the algorithm of the iterative method `PETSC`. The various algorithms available are documented in the keyword `SOLVEUR[U4.50.01].`  

### 4.5 Operand `MATR_PREC`

◊ `MATR_PREC = precond`

Matrix of prepacking, obtained by the operator `TO FACTORIZE [U4.55.01].` Prepacking is necessary in the iterative methods to obtain a good convergence with a minimum of iterations.

With the method `GCPC`, the matrix of prepacking is a matrix distinct from the matrix of the problem (keyword `MATR`). On the other hand, with the method `PETSC`, one uses the same matrix for `MATR_PREC` and `MATR`, which wants to say that the order `TO FACTORIZE` must be made “places from there” (with the keyword `reuse`). See example below.

### 4.6 Operand `RESI_RELA`

◊ `RESI_RELA = / 1.e-6, [DEFECT]
   / eps, [R]`

This keyword is described in `[U4.50.01]`

For the iterative methods `GCPC` and `PETSC`, it is the convergence criteria of the algorithm.

For the method `MUMPS`, this keyword makes it possible to check the quality of the solution.

### 4.7 Operand `NMAX_ITER`

◊ `NMAX_ITER = niter`

Maximum iteration count of the iterative algorithm.

If `niter = 0` then the algorithm chooses an iteration count by default.

### 4.8 Operand `TITLE`

◊ `TITLE = titr,`

Title which one wants to give to the produced result `[U4.03.01].`

### 4.9 Operand `INFORMATION`

◊ `INFORMATION =
  1: no impression.
  2: impressions`
5 Examples

5.1 Resolution by the direct method MULT_FRONT

- Constitution of the assembled matrix and the second member:

  The elementary terms before were calculated KEL, FEL.
  
  \[
  \text{NAKED} = \text{NUMÉRIQUE_DDL (MATR_RIGI=KEL)} \\
  K = \text{ASSE_MATRICE (MATR_ELEM=KEL, NUME_DDL=NU,)} \\
  F = \text{ASSE_VECTEUR (MATR_ELEM=FEL, NUME_DDL=NU,)}
  \]

- Factorization:

  \[
  K = \text{FACTORISER (reuse=K, MATR_ASSE=K, METHODE='MULT_FRONT',)}
  \]

- Resolution:

  \[
  U = \text{RESOUDRE (MATR=K, CHAM_NO=F,)}
  \]

- for the use of the loads kinematics (with elimination of the imposed degrees of freedom), to see the example set in the order AFFE_CHAR_CINE [U4.44.03].

5.2 Resolution by method MUMPS

\[
\text{NAKED} = \text{NUME_DDL (MATR_RIGI= KEL)} \\
K = \text{ASSE_MATRICE (MATR_ELEM= KEL, NAKED NUME_DDL=)} \\
F = \text{ASSE_VECTEUR (VECT_ELEM= FEL, NAKED NUME_DDL=)} \\
K = \text{TO FACTORIZE (reuse= K, MATR_ASSE= K, METHODE= 'MUMPS')} \\
\text{EPD.} = \text{TO SOLVE (CHAM_NO = F, MATR= K )}
\]

5.3 Resolution by the method of the conditioned pre combined gradient

\[
\text{NAKED} = \text{NUME_DDL (MATR_RIGI= KEL)} \\
K = \text{ASSE_MATRICE (MATR_ELEM= KEL, NAKED NUME_DDL=)} \\
F = \text{ASSE_VECTEUR (VECT_ELEM= FEL, NAKED NUME_DDL=)} \\
KPREC = \text{TO FACTORIZE (MATR_ASSE= K, METHODE= 'GCPC', PRE_COND='LDLT_INC')} \\
\text{EPD.} = \text{TO SOLVE (CHAM_NO = F, MATR= K, MATR_PREC= KPREC, NMAX_ITER= 1000 , RESI_RELA= 1e-07 )}
\]

5.4 Resolution by method PETSC

\[
\text{NAKED} = \text{NUME_DDL (MATR_RIGI= KEL)} \\
K = \text{ASSE_MATRICE (MATR_ELEM= KEL, NAKED NUME_DDL=)} \\
F = \text{ASSE_VECTEUR (VECT_ELEM= FEL, NAKED NUME_DDL=)} \\
K = \text{TO FACTORIZE (reuse=K, MATR_ASSE= K, METHODE= 'PETSC')} \\
\text{EPD.} = \text{TO SOLVE (CHAM_NO = F, MATR= K, MATR_PREC= K, ALGORITHME= 'GMRES', NMAX_ITER= 1000 , RESI_RELA= 1e-07 )}
\]