*ALE_STRUCTURED_FSI_{OPTION}

Purpose: Perform Fluid-Structure Interaction (FSI) between Lagrangian structures modeled by shell/solids and ALE multi-material fluids using a structured ALE mesh (*ALE_STRUCTURED_MESH).

Available options for *OPTION* include:

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TITLE

With the keyword option TITLE, you can set a coupling (card) ID number and title for each coupling card. If a title is not defined, LS-DYNA will automatically create an internal title for this coupling definition.

Comparison to *CONSTRAINED_LAGRANGE_IN_SOLID:

*ALE_STRUCTURED_FSI, as its name suggests, only works with the structured ALE solver. It mostly follows the format of *CONSTRAINED_LAGRANGE_IN_SOLID, but with a few exceptions:

- **Coupling Type.** Unlike *CONSTRAINED_LAGRANGE_IN_SOLID, *ALE_STRUCTURED_FSI only has one penalty formulation coupling method which is similar to a combination of CTYPE = 4 and 5 in *CONSTRAINED_LAGRANGE_IN_SOLID.
- **Number of Coupling Points.** For each Lagrangian segment, there are a certain number of coupling points, evenly distributed at the segment surface. Penalty springs are attached to those coupling points. When using *CONSTRAINED_LAGRANGE_IN_SOLID, you need to specify the number while with this keyword, you do not need to since LS-DYNA automatically determines the number of coupling points during the initialization phase.
- **Leakage Control.** Leakage control is automated when using *ALE_STRUCTURED_FSI. Fluid leakage is detected and cured automatically with no user intervention needed.
- **Normal Type.** Normal type selection is automated, based on the local geometry. Users do not need to choose between nodal/segment normal.
- **Edge Coupling.** Edge coupling is automatic. Shell segments are picked out and the exposed edges are coupled. *CONSTRAINED_LAGRANGE_IN_SOLID_EDGE is not needed.
- **Erosion Coupling.** Eroded solid elements will change the coupling segments. Segments belonging to eroded elements need to be deleted, and newly exposed segments need to be added. With *CONSTRAINED_LAGRANGE_IN_SOLID, CTYPE = 5 needs to be specified in order to activate this segments modification algorithm. In the new *ALE_STRUCTURED_FSI, this process is always on and no flag is needed.

Title Card. Additional card for the TITLE keyword option.

Card ID	1	2	3	4	5	6	7	8
Variable	COUPID	TITLE						
Type	I	A70						

Card 1	1	2	3	4	5	6	7	8
Variable	SLAVE	MASTER	SSTYP	MSTYP				MCOUP
Type	I	I	I	I				I
Default	none	none	0	0				0

Card 2	1	2	3	4	5	6	7	8
Variable	START	END	PFAC	FRIC		FLIP		
Type	F	F	F	F		I		
Default	0.0	10^{10}	0.1	0.0		0		

VARIABLE	DESCRIPTION
COUPID	Coupling (card) ID. If not defined, LS-DYNA will assign an internal coupling ID based on the order of appearance in the input deck.
TITLE	Description of this coupling definition (A70)
SLAVE	Set ID defining a part, part set, or segment set ID of the Lagrangian structure (see *PART, *SET_PART or *SET_SEGMENT).
MASTER	Master set ID defining a part or part set ID of the Structured ALE mesh (see *PART).

VARIABLE	DESCRIPTION
SSTYP	Set type of SLAVE: EQ.0: Part set ID (PSID) EQ.1: Part ID (PID) EQ.2: Segment set ID (SGSID)
MSTYP	Set type of MASTER: EQ.0: Part set ID (PSID) EQ.1: Part ID (PID)
MCOUP	Multi-material(s) to be coupled (see Remark 1): EQ.0: Couple with all multi-material groups. EQ.-N: -N is the ID of *SET_MULTI-MATERIAL_GROUP.
START	Start time for coupling
END	End time for coupling
PFAC	Penalty factor. PFAC is a scale factor for scaling the estimated stiffness of the interacting (coupling) system. It is used to compute the coupling forces to be distributed on the slave and master parts. GT.0: Fraction of estimated critical stiffness LT.0: PFAC must be an integer, and -PFAC is a load curve ID. The curve defines the coupling pressure on the y-axis as a function of the penetration along the x-axis.
FRIC	Friction coefficient. The friction force is evaluated as the normal force multiplied by the friction coefficient. GT.0: Constant friction coefficient EQ.-N: Variable friction coefficient defined by a table with ID N. The friction coefficient is a function of coupling pressure and relative velocity. The table uses the coupling pressure as the parameter values. See Examples.
FLIP	A Lagrangian segment will couple to fluid on only one side of the segment. The segment normal is assumed to point toward the fluids to which it is coupled. If that is not the case, set FLIP to 1. EQ.0: No action EQ.1: Flip the segment normal, so it points toward the fluids to which it

VARIABLE	DESCRIPTION
	is to be coupled.

Remarks:

1. **Multi-Material Coupling Option.** MCOUP is used to specify which ALE multi-materials are to be coupled. In a typical simulation we want to prevent some fluid(s) on one side of structure from penetrating through to the other side. In this case, we would pick the AMMGs on one side and list them under * SET_MULTI-MATERIAL_GROUP card.

   Coupling to all materials as activated by MCOUP = 0 is generally not recommended. LS-DYNA calculates the fluid coupling interface as the surface where the sum of coupled ALE materials occupies a volume fraction equal to 50%. Since MCOUP = 0 couples to all materials, the sum of all coupled ALE materials is, in this case, trivially 100%. Consequently, when MCOUP = 0, there will not be a fluid interface with which to track leakage.

Examples:

The following is a partial input deck that illustrates defining a variable friction table. Table 2 gives three coupling pressures that correspond to the three *DEFINE_CURVEs specified under the table definition (see *DEFINE_TABLE for details). Each curve specifies the relationship between relative velocity and friction coefficient for a given coupling pressure. For example, if the coupling pressure is 100, curve 4 is used. If coupling pressure = 50, both curves 3 and 4 are used. The friction coefficient is interpolated from the values given by the curves.

```
*ALE_STRUCTURED_FSI
$#   slave    master     sstyp     mstyp         -         -         -     mcoup
         1         1         0         1         0         0         0        -1
$#   start       end      pfac      fric         -      flip
                           0.1        -2         0         0
*DEFINE_TABLE
$     tbid       sfa      offa
          2
$                   p
                  0.0
                100.0
               1000.0
$---------------------------------------------------------------------------
*DEFINE_CURVE
$ curve for p = 0.0
$     lcid      sidr       sfa       sfo      offa      offo    dattyp     lcint
         3         0       1.0       1.0       0.0       0.0         0         0
$                vel1                 mu1
                  0.0                 0.6
    1.0000000000e+02                  0.5
*DEFINE_CURVE
```

```
$ curve for p = 100.0
$     lcid      sidr       sfa       sfo      offa      offo    dattyp     lcint
         4         0       1.0       1.0       0.0       0.0         0         0
$               vel2                 mu2
                 0.0                 0.5
    1.0000000000e+02                 0.4
*DEFINE_CURVE
$ curve for p = 1000.0
$     lcid      sidr       sfa       sfo      offa      offo    dattyp     lcint
         5         0       1.0       1.0       0.0       0.0         0         0
$               vel3                 mu3
                 0.0                 0.3
    1.0000000000e+02                 0.2
```