*CONTROL_ADAPTIVE

Purpose: Activate adaptive meshing. The parts which are adaptively meshed are defined by ADPOPT under *PART. Note that "sandwiched" part's adaptivity is available when the variable IFSAND is set to "1". Other related keywords include: *CONTROL_ADAPTIVE_-CURVE, *DEFINE_BOX_ADAPTIVE (moving adaptive box), and *DEFINE_CURVE_-BOX_ADAPTIVITY. This keword is applicable to neither hyperelastic materials nor any material model based on a Total Lagrangian formulation.

Card 1	1	2	3	4	5	6	7	8
Variable	ADPFREQ	ADPTOL	ADPOPT	MAXLVL	TBIRTH	TDEATH	LCADP	IOFLAG
Type	F	F	I	I	F	F	I	I
Default	none	10^{20}	1	3	0.0	10^{20}	0	0

Remaining cards are optional.†

Card 2	1	2	3	4	5	6	7	8
Variable	ADPSIZE	ADPASS	IREFLG	ADPENE	ADPTH	MEMORY	ORIENT	MAXEL
Type	F	I	I	F	F	I	I	I
Default		0	0	0.0	inactive	inactive	0	inactive

Card 3	1	2	3	4	5	6	7	8
Variable	IADPN90	IADPGH	NCFREQ	IADPCL	ADPCTL	CBIRTH	CDEATH	LCLVL
Type	I	I	I	I	F	F	F	F
Default	0	0	none	1	none	0.0	10^{20}	

Card 4	1	2	3	4	5	6	7	8
Variable	CNLA			MMM2D	ADPERR	D3TRACE		IFSAND
Type	F			I	I	I		I
Default	0			0	0	0		0

VARIABLE	DESCRIPTION
ADPFREQ	Time interval between adaptive refinements, see Figures 12-2 and 12-1.
ADPTOL	Adaptive error tolerance in degrees for ADPOPT set to 1 or 2 below. If ADPOPT is set to 8, ADPTOL is the characteristic element size.
ADPOPT	Adaptive options:

EQ.1: angle change in degrees per adaptive refinement relative to the surrounding shells for each shell to be refined.

EQ.2: total angle change in degrees relative to the surrounding shells for each shell to be refined. For example, if the adptol = 5 degrees, the shell will be refined to the second level when the total angle change reaches 5 degrees. When the angle change is 10 degrees the shell will be refined to the third level.

EQ.4: adapts when the shell error in the energy norm, Δe, exceeds ADPTOL/100 times the mean energy norm within the part, which is estimated as:

$$\Delta e = \left(\int_{\Omega_e} \frac{\|\Delta\sigma\|^2}{E} d\Omega \right)^{1/2}$$

where E is Young's modulus. The error of the stresses $\Delta\sigma$ is defined as the difference between the the recovered solution $\sigma^\star$ and the numerical solution, σ^h i.e. $\Delta\sigma \equiv \sigma^\star - \sigma^h$. Various recovery techniques for $\sigma^\star$ and error estimators for Δe are defined by ADPERR. This options works for shell types 2, 4, 16, 18, 20.

EQ.7: 3D r-adaptive remeshing for solid elements. Solid element type 13, a tetrahedron, and 3-D EFG type 41 and 42, are used in the adaptive remeshing process. A completely new mesh is generated which is initialized from the old mesh

VARIABLE	DESCRIPTION
	using a least squares approximation. The mesh size is currently based on the minimum and maximum edge lengths defined on the *CONTROL_REMESHING keyword input. This option remains under development, and, we are not sure of its reliability on complex geometries.
	EQ.8: 2D *r*-adaptive remeshing for axisymmetric and plane strain continuum elements. A completely new mesh is generated which is initialized from the old mesh using a least squares approximation. The mesh size is currently based on the value, ADPTOL, which gives the characteristic element size. This option is based on earlier work by Dick and Harris [1992]. If ADPOPT is negative, then self-contacting material will not be merged together. The self-merging is often preferred since it eliminates sharp folds in the boundary; however, if the sharp fold is being simulated unexpected results are generated.
MAXLVL	Maximum number of refinement levels. Values of 1, 2, 3, 4, … allow a maximum of 1, 4, 16, 64, … shells, respectively, to be created for each original shell. The refinement level can be overridden by *DEFINE_BOX_ADAPTIVE, or *DEFINE_SET_ADAPTIVE.
TBIRTH	Birth time at which the adaptive remeshing begins, see Figures 12-2 and 12-1.
TDEATH	Death time at which the adaptive remeshing ends, see Figures 12-2 and 12-1.
LCADP	Adaptive interval is changed as a function of time given by load curve ID, LCADP. If this option is nonzero, the ADPFREQ will be replaced by LCADP. The *x*-axis is time and the *y*-axis is the varied adaptive time interval.
IOFLAG	Flag to generate adaptive mesh at exit including *NODE, *ELEMENT_SHELL_THICKNESS, *BOUNDARY_option, and *CONSTRAINED_ADAPTIVITY, to be saved in the file, adapt.msh.
	EQ.1: generate *h*-adapted mesh.
ADPSIZE	Minimum shell size to be adapted based on element edge length. If undefined the edge length limit is ignored.
	LT.0: absolute value defines the minimum characteristic element length to be adapted based on square root of the element area, i.e., instead of comparing the shortest element edge

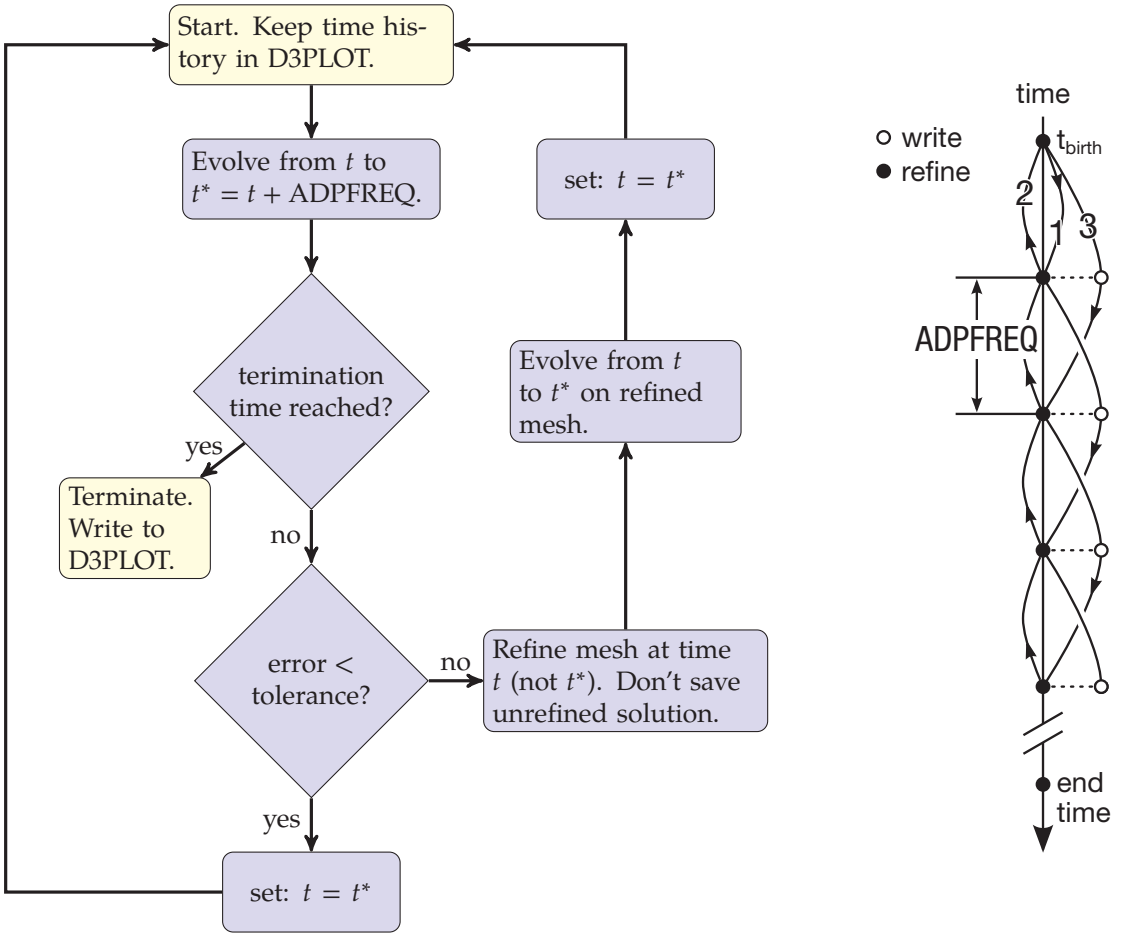

Figure 12-1. Flowchart for ADPASS = 0. While this option is *sometimes* more accurate, ADPASS = 1 is *much* less expensive and recommended when used *with* ADPENE.

VARIABLE	DESCRIPTION
	with ADPSIZE, it compares the square root of the element area with |ADPSIZE| whenever ADPSIZE is defined by a negative value.
ADPASS	One or two pass flag for *h*-adaptivity: EQ.0: two pass adaptivity as shown in Figure 12-2. EQ.1: one pass adaptivity as shown in Figure 12-1.
IREFLG	Uniform refinement level. A value of 1, 2, 3 … allow 4, 16, 64 … shells, respectively, to be created uniformly for each original shell. If negative, |IREFLG| is taken as a load curve ID. With the curve option, the abscissa values define the refinement time, and the ordinate values define the minimum element size. Only one refinement level is performed per time step. An advantage of the

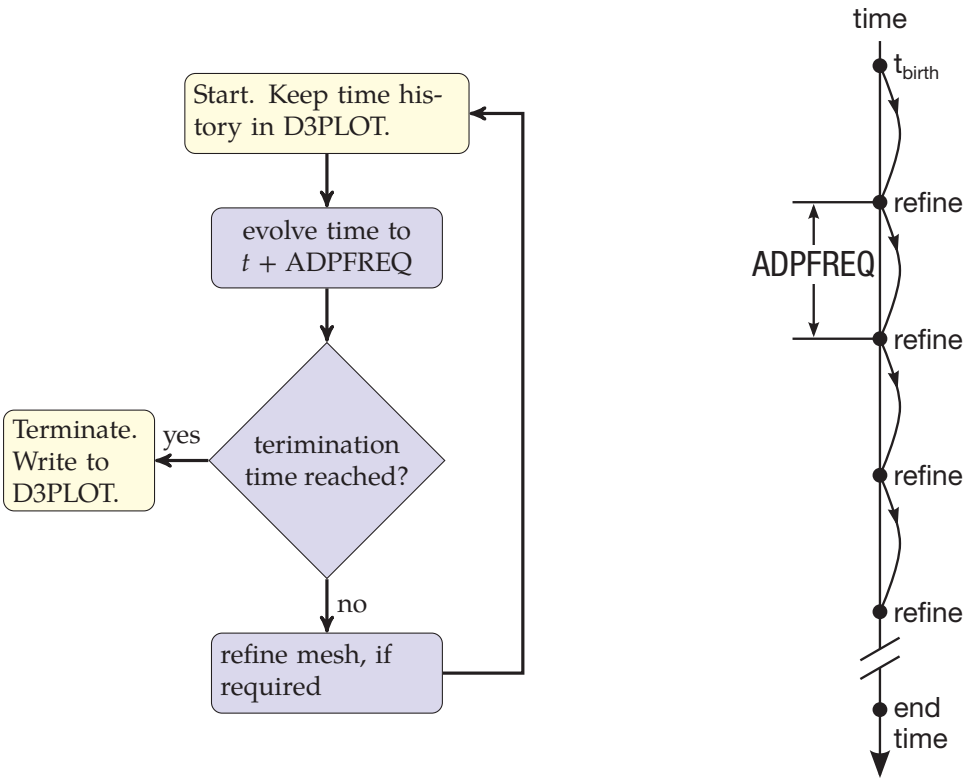

Figure 12-2. Flow chart for ADPASS = 1. This algorithm may be summarized as, "periodically refine" This method is recommended over ADPASS = 0 when used *with* ADPENE, which implements look ahead.

VARIABLE	DESCRIPTION
	load curve option is that the mesh is adapted to honor the minimum element size, but with the uniform option, IREFLG > 0, this is not possible. NOTE: If the element size defined with *DEFINE_CURVE is positive, the element size will override the element size defined with *CONTROL_ADAPTIVE and *DEFINE_SET_ADAPTIVE. Also, if the element size defined with *DEFINE_CURVE is negative the element size is used for refinement only.
ADPENE	For shell, *h*-adapt the mesh when the FORMING contact surfaces approach or penetrate the tooling surface depending on whether the value of ADPENE is positive (*approach*) or negative (*penetrates*), respectively. The tooling adaptive refinement is based on the curvature of the tooling. If ADPENE is positive the refinement generally occurs before contact takes place; consequently, it is possible that the parameter ADPASS can be set to 1 in invoke the one pass adaptivity. For three dimensions *r*-adaptive solid remeshing (ADPOPT = 2 in

VARIABLE	DESCRIPTION
	*PART), the mesh refinement is based on the curvature of the tooling when ADPENE is positive. See Remark 6.
ADPTH	EQ.0.0: This parameter is ignored GT.0.0: Absolute shell thickness level below which adaptive remeshing should began. LT.0.0: Element thickness ratio. If the ratio of the element thickness to the original element thickness is less than the absolute value of ADPTHK, the element will be refined. This option works only if ADPTOL is nonzero. If thickness based adaptive remeshing is desired without angle changes, then, set ADPTOL to a large angle.
MEMORY	This flag can have two meanings depending on whether the memory environmental variable is or is not set. The command "setenv LSTC_MEMORY auto" (or for bourne shell "export LSTC_MEMORY=auto") sets the memory environmental variable which causes LS-DYNA to expand memory automatically. Note that automatic memory expansion is not always 100% reliable depending on the machine and operating system level; consequently, it is not yet the default. To see if this is set on a particular machine type the command "env". If the environmental variable is not set then when memory usage reaches this percentage, MEMORY, further adaptivity is prevented to avoid exceeding the memory specified at execution time. Caution is necessary since memory usage is checked after each adaptive step, and, if the memory usage increases by more than the residual percentage, 100-PERCENT, the calculation will terminate. If the memory environmental variable is set then when the number of words of memory allocated reaches or exceeds this value, MEMORY, further adaptivity is stopped.
ORIENT	This option applies to the FORMING contact option only. If this flag is set to one (1), the user orientation for the contact interface is used. If this flag is set to zero (0), LS-DYNA sets the global orientation of the contact surface the first time a potential contact is observed after the birth time. If slave nodes are found on both sides of the contact surface, the orientation is set based on the principle of "majority rules". Experience has shown that this principle is not always reliable.
MAXEL	Adaptivity is stopped if this number of shells is exceeded.

VARIABLE	DESCRIPTION
IADPN90	Maximum number of shells covering 90 degree of radii. See Remark 5.
IADPGH	Fission flag for neighbor splitting. EQ.0: split all neighbor shells EQ.1: do not split neighbor shells
NCFREQ	Frequency of fission to fusion steps. For example, if NCFREQ = 4, then fusion will occur on the fourth, eighth, twelfth, etc., fission steps, respectively. If this option is used NCFREQ > 1 is recommended.
IADPCL	Fusion will not occur until the fission level reaches IADPCL. Therefore, if IADPCL = 2, MAXLVL = 5, any shell can be split into 256 shells. If the surface flattens out, the number of elements will be reduced if the fusion option is active, i.e., the 256 elements can be fused and reduced to 16.
ADPCTL	Adaptivity error tolerance in degrees for activating fusion. It follows the same rules as ADPOPT above.
CBIRTH	Birth time for adaptive fusion. If ADPENE > 0, look-ahead adaptivity is active. In this case, fission, based on local tool curvature, will occur while the blank is still relatively flat. The time value given for CBIRTH should be set to a time later in the simulation after the forming process is well underway.
CDEATH	Death time for adaptive fusion.
LCLVL	Load curve ID of a curve that defines the maximum refinement level as a function of time
CNLA	Limit angle for corner nodes. See Remark 7.
MMM2D	If non-zero, common boundaries of all adapted materials will be merged. Only for 2D r-adaptivity
ADPERR	3-digit number, as "*XYY*", where "*X*" and "*YY*" define the options for the recovery techniques and the error estimators, respectively, For *X*: EQ.0: superconvergent patch recovery (SPR) (default); EQ.1: the least square fit of the stress to the nodes (Global L2);

VARIABLE	DESCRIPTION
	EQ.2: error density SPR, as $\Delta\tilde{e} = \Delta e / \text{Area}_{\text{element}}$;
	EQ.3: self-weighted SPR, as $\Delta\mathring{e} = \sqrt{\Delta e \times e}$
	For YY:
	EQ.00: energy norm (default)
	EQ.01: Cauchy σ_x
	EQ.02: σ_y
	EQ.03: σ_z
	EQ.04: τ_{xy}
	EQ.05: τ_{yz}
	EQ.06: τ_{zx}
	EQ.07: effective plastic strain, ε_{ep}
	EQ.08: pressure
	EQ.09: von Mises
	EQ.10: principal deviator stress s11
	EQ.11: S_{22}
	EQ.12: S_{33}
	EQ.13: Tresca
	EQ.14: principal stress σ_{11}
	EQ.15: σ_{22}
	EQ.16: σ_{33}
	EQ.20: user subroutine "uadpval" to extract the numerical solutions for recovery, and "uadpnorm" to provide an error estimator.
D3TRACE	Flag that is either 0 or 1. If set to 1 then a d3plot state will be output just before and after an adaptive step even though it may not be requested. The reason for wanting to do this is to allow the LS-PrePost particle trace algorithm to work in the case of adaptivity.
IFSAND	Set this flag to "1" for sandwiched sheet forming, see **Remark**.

Remarks about 3D adaptivity:

1. **Restarting.** The d3dump and runrsf files contain all information necessary to restart an adaptive run. This did not work in version 936 of LS-DYNA.

2. **Related Field in *PART.** In order for this control card to work, the flag ADPOPT=1 must be set in the *PART definition. Otherwise, adaptivity will not function.

3. **Contact Types and Options.** In order for adaptivity to work optimally, the parameter SNLOG=1, must be set on Optional Control Card B in the *CONTACT Section. On disjoint tooling meshes the contact option *CONTACT_FORMING_… is recommended.

4. **Root ID (RID) File.** A file named "adapt.rid" is left on disk after the adaptive run is completed. This file contains the root ID of all elements that are created during the calculation, and it does not need to be kept if it is not used in post-processing.

5. **Note About IADPN90 Field.** For all metal forming simulation, IADPN90 should be set to -1.

6. **Contact and ADPENE.** In three dimensions when ADPENE>0 it is presumed that the solid part to be adapted is on the slave side of a contact, and the "tooling", consisting of a shell surface, is on the master side of that same contact. ADPENE>0 represents a distance from the tooling surface within which the adapted mesh refinement of the slave part is influenced by the radius of curvature of the tooling surface. This feature is currently *unavailable* in SMP and SOFT=2 in *CONTACT.

Remarks about 2D *r*-adaptivity:

7. **CNLA Field.** In two dimensions *r*-adaptive remeshing, the generated new mesh should have a node at each corner so that corners are not smoothed. By default, the mesher will assume a corner wherever the interior angel between adjacent edges is less than 110 degrees. Setting CNLA larger than 110 enables angles larger than 110 to be corners. Care should be taken to avoid an unnecessarily large value of CNLA as this may prevent the mesher from generating smooth meshes.

Remarks about mesh adaptivity for sandwiched parts (IFSAND):

8. Currently mesh adaptivity is available for sandwich parts, where one layer of solid elements (core) sandwiched by one layer of shell elements each on top and bottom surface of the solid elements, as shown in Figure 12-3. Common nodes are used for solid and shell interface. All solids and shell mesh will be adapted in-plane together.

Note sandwiched parts can be trimmed by setting ITYP = 1 in keyword *CONTROL_FORMING_TRIMMING and with keyword *DEFINE_CURVE_TRIM.

In a typical forming set up, the following cards need to be changed to activate the sandwiched part mesh adaptivity:

```
*CONTROL_ADAPTIVE
$# adpfreq    adptol    adpopt    maxlvl    tbirth    tdeath     lcadp    ioflag
   &adpfq 4.0000E+00         1         4     0.0001.0000E+20         0         0
$# adpsize    adpass    ireflg    adpene     adpth    memory    orient     maxel
   0.90000         1           10.00000     0.000         0         0         0
$# ladpn90    ladpgh    ncfred    ladpcl    adpctl    cbirth    cdeath     lclvl
        -1         0         0         1     0.000     0.0001.0000E+20         0
$                                                                        IFSAND
                                                                              1
*PART
Mid-core layer of solid elements
$      PID     SECID       MID     EOSID      HGID      GRAV    ADPOPT      TMID
         1         1         1                                       1
Top layer of shell elements
       100       100         1                                       1
Bottom layer of shell elements
       101       100         1                                       1
```

Note IFSAND in *CONTROL_ADAPTIVE is set to “1” to activate the sandwich part adaptivity; ADPOPT under *PART are all set to “1” to activate the adaptivity.

Revision Information:

9. IFSAND is available starting in Rev 104365 in both SMP and MPP versions. Later revisions may include improvements.

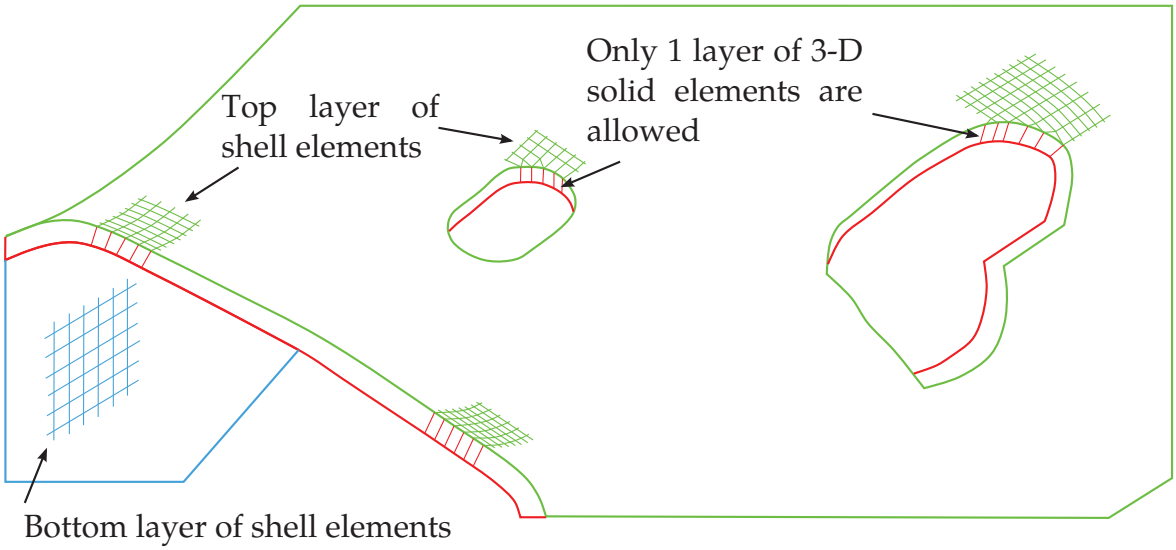

Figure 12-3. Mesh adaptivity of sandwiched parts (**IFSAND**).