*PERTURBATION

The keyword *PERTURBATION provides a means of defining deviations from the designed structure such as buckling imperfections. These perturbations can be viewed in LS-PrePost as user-defined fringe plots. Available options are:

*PERTURBATION_MAT

*PERTURBATION_NODE

*PERTURBATION_SHELL_THICKNESS

PERTURBATION_*OPTION

Available options are:

MAT

NODE

SHELL_THICKNESS

Purpose: Define a perturbation (stochastic field) over the whole model or a portion of the model, typically to trigger an instability. The NODE option modifies the three-dimensional coordinates for the whole model or a node set. For the SHELL_THICKNESS option, the shell thicknesses are perturbed for the whole model or a shell set. The MAT option perturbs a material parameter value for all the elements associated with that material.

Card Summary:

Card 1a. This card is included if and only if the MAT option is used.

TYPE	PID	SCL	CMP	ICOORD	CID		

Card 1b. This card is included if and only if the NODE option is used.

TYPE	NSID	SCL	CMP	ICOORD	CID		

Card 1c. This card is used if and only if the SHELL_THICKNESS option is used.

TYPE	EID	SCL	CMP	ICOORD	CID		

Card 2a. This card is included if and only if TYPE = 1.

AMPL	XWL	XOFF	YWL	YOFF	ZWL	ZOFF	

Card 2b. This card is included if and only if TYPE = 2.

FADE							

Card 2c. This card is included if and only if TYPE = 3.

FNAME							

Card 2d. This card is included if and only if TYPE = 4.

CSTYPE	ELLIP1	ELLIP2	RND				

Card 2d.1. Depending upon the value of CSTYPE, include one, two, or three cards of this format.

CFTYPE	CFC1	CFC2	CFC3				

Card 2e. This card is included if and only if TYPE = 8.

AMPL	DTYPE						

Data Card Definitions:

Material Perturbation Card. Card 1 for MAT keyword option. Perturb a material parameter.

Card 1a	1	2	3	4	5	6	7	8
Variable	TYPE	PID	SCL	CMP	ICOORD	CID		
Type	I	I	F	I	I	I		
Default	1	0	1.0	5	0	0		

VARIABLE	DESCRIPTION
TYPE	Type of perturbation: EQ.1: Harmonic Field (see Remark 3) EQ.3: Read perturbations from a file EQ.4: Spectral field
PID	Part ID
SCL	Scale factor
CMP	Component. See Remark 10 and *MAT_238.
ICOORD	Coordinate system to use (see Remarks 7, 8 and 9): EQ.0: Global Cartesian EQ.1: Cartesian EQ.2: Cylindrical (computed and applied) EQ.3: Spherical (computed and applied)

VARIABLE	DESCRIPTION
	EQ.-2: Computed in cartesian but applied in cylindrical
	EQ.-3: Computed in cartesian but applied in spherical
CID	Coordinate system ID; see *DEFINE_COORDINATE_NODES.

Node Perturbation Card. Card 1 for NODE keyword option. Perturb the coordinates of a node set (or all nodes).

Card 1b	1	2	3	4	5	6	7	8
Variable	TYPE	NSID	SCL	CMP	ICOORD	CID		
Type	I	I	F	I	I	I		
Default	1	{all}	1.0	7	0	0		

VARIABLE	DESCRIPTION
TYPE	Type of perturbation: EQ.1: Harmonic Field (see Remark 3) EQ.2: Fade out all perturbations at this node set (see Remark 4) EQ.3: Read perturbations from a file EQ.4: Spectral field EQ.8: Random value from uniform distribution
NSID	Node set ID. Specify 0 to perturb all the nodes in the model.
SCL	Scale factor
CMP	Component as given below: EQ.1: x coordinate EQ.2: y coordinate EQ.3: z coordinate EQ.4: x and y coordinates EQ.5: y and z coordinates EQ.6: z and x coordinates

VARIABLE	DESCRIPTION
	EQ.7: x, y, and z coordinates
ICOORD	Coordinate system to use (see Remarks 7, 8 and 9): EQ.0: Global Cartesian EQ.1: Cartesian EQ.2: Cylindrical (computed and applied) EQ.3: Spherical (computed and applied) EQ.-2: Computed in cartesian but applied in cylindrical EQ.-3: Computed in cartesian but applied in spherical
CID	Coordinate system ID; see *DEFINE_COORDINATE_NODES

Shell Thickness Card. Card 1 for SHELL_THICKNESS keyword option. Perturb the thickness of a set of shells (or all shells).

Card 1c	1	2	3	4	5	6	7	8
Variable	TYPE	EID	SCL	CMP	ICOORD	CID		
Type	I	I	F	I	I	I		
Default	1	{all}	1.0	none	0	0		

VARIABLE	DESCRIPTION
TYPE	Type of perturbation: EQ.1: Harmonic Field (see Remark 3) EQ.2: Fade out all perturbations at this element set (see Remark 4) EQ.3: Read perturbations from a file EQ.4: Spectral field EQ.8: Random value from uniform distribution
EID	Element set ID. Specify 0 to perturb all the elements in the model.
SCL	Scale factor

VARIABLE	DESCRIPTION
CMP	Component as given below: EQ.1: x coordinate EQ.2: y coordinate EQ.3: z coordinate EQ.4: x and y coordinates EQ.5: y and z coordinates EQ.6: z and x coordinates EQ.7: x, y, and z coordinates
ICOORD	Coordinate system to use (see Remarks 7, 8 and 9): EQ.0: Global Cartesian EQ.1: Cartesian EQ.2: Cylindrical (computed and applied) EQ.3: Spherical (computed and applied) EQ.-2: Computed in cartesian but applied in cylindrical EQ.-3: Computed in cartesian but applied in spherical
CID	Coordinate system ID; see *DEFINE_COORDINATE_NODES.

Harmonic Perturbation Cards (TYPE = 1). Card format 2 for TYPE = 1. Include as many cards of the following card as necessary. The input ends at the next keyword ("*") card.

Card 2a	1	2	3	4	5	6	7	8
Variable	AMPL	XWL	XOFF	YWL	YOFF	ZWL	ZOFF	
Type	F	F	F	F	F	F	F	
Default	1.0	0.0	0.0	0.0	0.0	0.0	0.0	

VARIABLE	DESCRIPTION
AMPL	Amplitude of the harmonic perturbation
XWL	x wavelength of the harmonic field

VARIABLE	DESCRIPTION
XOFF	x offset of harmonic field
YWL	y wavelength of the harmonic field
YOFF	y offset of harmonic field
ZWL	z wavelength of the harmonic field
ZOFF	z offset of harmonic field

Fade Field Perturbation Card (TYPE = 2). Card format 2 for TYPE = 2. See Remark 4.

Card 2b	1	2	3	4	5	6	7	8
Variable	FADE							
Type	F							
Default	1.0							

VARIABLE	DESCRIPTION
FADE	Parameter controlling the distance over which faded perturbations are faded (material perturbations are not faded).

Perturbation from File Card (TYPE = 3). Card format 2 for TYPE = 3.

Card 2c	1	2	3	4	5	6	7	8
Variable	FNAME							
Type	A							

VARIABLE	DESCRIPTION
FNAME	Name of file containing the perturbation definitions

Spectral Field Perturbation Card (TYPE = 4). Card format 2 for TYPE = 4 (fade field).

Card 2d	1	2	3	4	5	6	7	8
Variable	CSTYPE	ELLIP1	ELLIP2	RND				
Type	I	F	F	I				
Default	none	1.0	1.0	0				

VARIABLE	DESCRIPTION
CSTYPE	Correlation structure:

EQ.1: 3D isotropic. The x, y and z correlations are described using one correlation function. Define CFC1.

EQ.2: 3D product. The x, y and z correlations are described using a correlation function each. Define CFC1, CFC2 and CFC3.

EQ.3: 2D isotropic. A correlation function describes the x correlation while the yz isotropic relationship is described using another correlation function. Define CFC1 and CFC2.

EQ.4: 2D isotropic. The xz isotropic relationship is described using a correlation function, while another correlation function describes the y correlation while. Define CFC1 and CFC2.

EQ.5: 2D isotropic. The xy isotropic relationship is described using a correlation function, while another correlation function describes the z correlation while. Define CFC1 and CFC2.

EQ.6: 3D elliptic. Define CSE1, CSE2 and CFC1.

EQ.7: 2D elliptic. A correlation function describes the x correlation while the yz elliptic relationship is described using another correlation function. Define CSE1 and CFC1.

EQ.8: 2D elliptic. A correlation function describes the y correlation while the zx elliptic relationship is described using another correlation function. Define CSE1 and CFC1.

EQ.9: 2D elliptic. The xy elliptic relationship is described using a correlation function, while another correlation function describes the z correlation while. Define CSE1 and CFC1.

VARIABLE	DESCRIPTION
ELLIP1	Elliptic constant for 2D and 3D elliptic fields
ELLIP2	Elliptic constant for 3D elliptic field
RND	Seed for random number generator. EQ.0: LS-DYNA will generate a random seed. GT.0: Value to be used as seed

Spectral Perturbation Parameter Cards. Include one, two, or three cards of this format, depending on the value of CSTYPE.

Card 2d.1	1	2	3	4	5	6	7	8
Variable	CFTYPE	CFC1	CFC2	CFC3				
Type	I	F	F	F				
Default	none	1.0	1.0	1.0				

VARIABLE	DESCRIPTION
CFTYPE	Correlation function (see Remark 6) EQ.1: Gaussian EQ.2: Exponential EQ.3: Exponential Cosine EQ.4: Rational EQ.5: Linear
CFC*i*	Correlation function constant *i*

Random Value Perturbation Card (TYPE = 8). Card format 2 for TYPE = 8.

Card 2e	1	2	3	4	5	6	7	8
Variable	AMPL	DTYPE						
Type	F	F						
Default	1.0	0.0						

VARIABLE	DESCRIPTION
AMPL	Amplitude of the random perturbation
DTYPE	Distribution type: EQ.0.0: Uniform distribution between SCL × [0, AMPL] EQ.1.0: Uniform distribution between SCL × [−AMPL, AMPL]

Remarks:

1. **Postprocessing.** The perturbation can be viewed in LS-PrePost. For the NODE option, LS-DYNA creates files named pert_node_x/y/z/res, which can be viewed as user-defined fringe plots. For the SHELL_THICKNESS and MAT options, the files are named pert_shell_thickness and pert_mat respectively. If a coordinate system with a radial component is used, then the file pert_node_radial is also written.

2. **Linear Combinations and Maximum Amplitudes.** Perturbations specified using separate *PERTURBATION cards are created separately and then added together. This is true as well for special cases, such as CMP = 7 in which case the x, y and z fields are created separately and added together afterwards, which can result in an absolute amplitude greater than specified using AMPL or SCL.

3. **Harmonic Perturbations.** The harmonic perturbation is

$$p_{\mathrm{CMP}}(x,y,z) = \mathrm{SCL} \times \mathrm{AMPL} \times \left[\sin\left(2\pi \frac{x + \mathrm{XOFF}}{\mathrm{XWL}}\right) + \sin\left(2\pi \frac{y + \mathrm{YOFF}}{\mathrm{YWL}}\right) + \sin\left(2\pi \frac{z + \mathrm{ZOFF}}{\mathrm{ZWL}}\right)\right]$$

Note that the harmonic perturbations can sum to values greater than SCL × AMPL.

4. **Fade Perturbation.** The fade perturbation is

$$p'(x,y,z) = \mathrm{SCL} \times \left(1 - \frac{1}{e^{-\frac{\ln 0.05}{\mathrm{FADE}} \times x'}}\right) p(x,y,z)$$

where x' is the shortest distance to a node in the node set or element set specified, and FADE is the parameter controlling the sharpness of the fade perturbation.

5. **Keyword Format for FNAME Field.** The file FNAME must contain the perturbation in the LS-DYNA keyword format. This file can be created from the d3plot results using the LS-PrePost Output capability. The data must be arranged into two columns with the first column being the node ids. Lines starting with the character $ will be ignored.

6. **Correlation Functions.** The correlation functions are defined as follows:

   a) Gaussian: $B(t) = e^{-(at)^2}$

   b) Exponential: $B(t) = e^{-|at|^b}$

   c) Exponent and Cosine: $B(t) = e^{-|at|} \cos(bt)$

   d) Rational: $B(t) = (1 + |at|^b)^{-c}$

   e) Piecewise Linear: $B(t) = (1 - |at|)\chi(1 - |at|)$

   with χ the Heaviside step function and a, b and c corresponding to CFC1, CFC2 and CFC3, respectively.

7. **Cylindrical Coordinates.** For the cylindrical coordinate system option (ICOORD = 2), the default is to use the global coordinate system for the location of the cylindrical part, with the base of the cylinder located at the origin, and the global z-axis aligned with the cylinder axis. For cylindrical parts not located at the global origin, define a coordinate system (numbered CID) using *DEFINE_COORDINATE_NODES by selecting any three nodes on the base of the cylinder in a clockwise direction (resulting in the local z-axis to be aligned with the cylinder).

8. **Spherical Coordinates.** For the spherical coordinate system (ICOORD = 3), the coordinates are the radius, zenith angle $[0, \pi]$, and the azimuth angle $[0,2\pi]$. The default is to use the global coordinate system with the zenith measured from the z-axis and the azimuth measured from the x-axis in the xy-plane. For spherical parts not located at the global origin, define a coordinate system using *DEFINE_COORDINATE_NODES by selecting any three nodes as follows: the first node is the center of the sphere, the second specifies the x-axis of the coordinate

system, while the third point specifies the plane containing the new y-axis. The z-axis will be normal to this plane.

9. **Computed in Cartesian Applied to Cylindrical or Spherical.** It is possible to compute the perturbations in a Cartesian coordinate system, but to apply them in a cylindrical or spherical coordinate system (ICOORD = -2, -3). This is the natural method of doing say a radial perturbation of a sphere using a spectral perturbation field. We expect that computing the perturbation in the spherical coordinate system should be rare (ICOORD = 3). Computing a perturbation in a cylindrical coordinate system should be common though; for example, a circumferential harmonic perturbation.

10. **Material Perturbation Feature.** Only *MAT_238 (*MAT_PERT_PIECEWISE_-LINEAR_PLASTICITY) and solid elements in an explicit analysis can be perturbed using *PERTURBATION_MAT. See the documentation of this material for allowable components. Only one part per model can be perturbed. For some perturbed quantity c, the material perturbation is applied on an element-by-element basis as

$$c_{\text{new}} = (1 + p)c_{\text{base}}$$

where p is a random number, which is written to the pert_mat file during the calculation. Values of p less than -1 are not allowed because the material behavior is not defined.

Completely independent of *PERTURBATION_MAT, see *DEFINE_STOCHASTIC_VARIATION for a way to define a stochastic variation of yield stress and/or failure strain in material models 10, 15, 24, 81, and 98 and the shell version of material 123.