DAMPING_FREQUENCY_RANGE_*{OPTION}

Purpose: This feature provides approximately constant damping (that is, frequency-independent) over a range of frequencies. It applies to explicit analysis and to time-integrated implicit dynamic analysis (IMASS = 1 on *CONTROL_IMPLICIT_DYNAMICS) but not to any of the implicit analysis types that use modal superposition or those that work in the frequency domain.

Available OPTIONS are:

<BLANK>	Applies damping to global motion
DEFORM	Applies damping to element deformation

Card 1	1	2	3	4	5	6	7	8
Variable	CDAMP	FLOW	FHIGH	PSID		PIDREL	IFLG	ICARD2
Type	F	F	F	I		I	I	I
Default	0.0	0.0	0.0	0		0	0	0

This card is included only if ICARD2=1 and *OPTION* is DEFORM.

Card 2	1	2	3	4	5	6	7	8
Variable	CDAMPV	IPWP						
Type	F	I						
Default	=CDAMP	1						

VARIABLE	DESCRIPTION
CDAMP	Damping in fraction of critical. Accurate application of this damping depends on the time step being small compared to the period of interest.
FLOW	Lowest frequency in range of interest (cycles per unit time, such as Hz if time unit is seconds)

VARIABLE	DESCRIPTION
FHIGH	Highest frequency in range of interest (cycles per unit time, such as Hz if time unit is seconds).
PSID	Part set ID. The requested damping is applied only to the parts in the set. If PSID = 0, the damping is applied to all parts except those referred to by other *DAMPING_FREQUENCY_RANGE cards.
PIDREL	Optional part ID of rigid body. Damping is then applied to the motion relative to the rigid body motion. This input does not apply to the DEFORM option.
IFLG	Method used for internal calculation of damping constants: EQ.0: Iterative (more accurate). See Iterative Method. EQ.1: Approximate (same as R9 and previous versions)
CDAMPV	Damping in fraction of critical applied to pressure/volume response of solid elements.
IPWP	Flag to determine whether damping is applied to excess pore pressure in Parts referenced by *BOUNDARY_PORE_FLUID, see Remarks: EQ.0: Same as EQ.1 EQ.1: Excess pore pressure is subjected to damping ratio CDAMPV EQ.2: Damping is not applied to pore pressure, only to the effective stress.

Remarks:

This feature provides approximately constant damping (frequency-independent) over a range of frequencies. $F_{\mathrm{low}} < F < F_{\mathrm{high}}$. It is intended for small damping ratios (< 0.05) and frequency ranges such that $F_{\mathrm{high}}/F_{\mathrm{low}}$ is in the range 10 to 300. The drawback to this method of damping without the DEFORM keyword option is that it reduces the dynamic stiffness of the model, especially at low frequencies.

Where the model contains, for example, a rigid foundation or base, the effects of this stiffness reduction can be ameliorated by using PIDREL. In this case, the damping forces resist motion relative to the base and are reacted onto the rigid part PIDREL. "Relative motion" here means the difference between the velocity of the node being damped, and the velocity of a point rigidly connected to PIDREL at the same coordinates as the node being damped.

This undesirable effect of *DAMPING_FREQUENCY_RANGE on dynamic stiffness is somewhat predictable. As an example, when the DEFORM keyword option is not used, the natural frequencies of modes close to F_{low} are reduced by 3% for a damping ratio of 0.01 and $F_{\mathrm{high}}/F_{\mathrm{low}}$ in the range 10-30. Near F_{high} the error is between zero and one third of the error at F_{low}. Estimated frequency errors are shown in the following table. The tabulated values indicate the percent reduction in frequency at FLOW. The error at FHIGH is much less.

Damping Ratio	% error in frequency for F_{high}/F_{low} =		
	3 to 30	30 to 300	300 to 3000
0.01	3%	4.5%	6%
0.02	6%	9%	12%
0.04	12%	18%	24%

We recommend that the elastic stiffnesses in the model be increased slightly to account for this effect; for example, for 1% damping across a frequency range of 30 to 600 Hz, the average error across the frequency range is about 2%. It would therefore be appropriate to increase the stiffness by $(1.02)^2$, that is, by 4%.

Keyword Option DEFORM:

The DEFORM option applies damping to the element responses (unlike the standard *DAMPING_FREQUENCY_RANGE which damps the global motion of the nodes). Therefore, rigid body motion is not damped when the DEFORM keyword option is used. For this reason, DEFORM is recommended over the standard option. The damping is adjusted based on current tangent stiffness; this is believed to be more appropriate for a nonlinear analysis, which could be over-damped if a strain-rate-proportional or viscous damping scheme were used.

The DEFORM keyword option works with the following element formulations:

- Solids – types -1, -2, 1, 2, 3, 4, 9, 10, 13, 15, 16, 17, 99
- Beams – types 1, 2, 3, 4, 5, 9 (note: not type 6)
- Shells – types 1-5, 7-17, 20, 21, 23-27, 99
- Thick Shells – all types
- Discrete elements

The DEFORM option differs from the standard option in several ways:

Standard Damping vs. Deformation Damping

Characteristic Property	Keyword Option	
	<BLANK>	DEFORM
Damping on	Node velocities	Element responses
Rigid body motion	Can be damped	Never damped
Natural frequencies	Reduced (by percentages shown in the above table)	Increased (percentages shown in the above table)
Recommended compensation	Increase elastic stiffness	Reduce elastic stiffness
Effect on time step	None	Small reduction applied automatically, same percentage as in the frequency change
Element types damped	All	See list above
Damping energy output	Included in “system damping energy”	Included in Internal Energy only if RYLEN = 2 on *CONTROL_ENERGY

The effect of the DEFORM option on frequency is to increase the frequency, which is opposite the effect when the DEFORM option is not used. Furthermore, when the DEFORM option is invoked, the percent error in frequency shown in the first table above occurs at FHIGH and the error at FLOW is much less.

Iterative Method:

Starting with version R10, the internal calculation of the damping constants uses an iterative method by default (see input variable IFLG). This iterative method is available both with and without the DEFORM keyword option. The iterative method results in the actual damping matching the user-input damping ratio CDAMP more closely across the frequency range FLOW to FHIGH. As an example, for CDAMP = 0.01, FLOW = 1 Hz and FHIGH = 30 Hz, the actual damping achieved by the previous approximate method varied between 0.008 and 0.012 (different values at different frequencies), that is, there were errors of up to 20% of the target CDAMP. With the iterative algorithm, the errors are reduced to 1% of the target CDAMP.

CDAMPV:

CDAMPV applies only to solid elements, see *ELEMENT_SOLID. By default, the same damping ratio CDAMP is applied to all stress components of solid elements. If CDAMPV is defined as non-zero, it applies to the volumetric response of solid elements while CDAMP applies only to the deviatoric response.

Damping of Parts with pore pressure:

This remark, and the input parameter IPWP, are relevant only to models containing *CONTROL_PORE_FLUID and when the damping card references a Part containing pore pressure (i.e., a Part that is referenced by *BOUNDARY_PORE_FLUID). The terminology used in this remark is explained in the Remarks under *CONTROL_PORE_FLUID. In LS-DYNA versions up to and including R14, *DAMPING_FREQUENCY_RANGE_DEFORM was ineffective when applied to Parts containing pore pressure – not even the shear response was subjected to damping. Starting from R15, the default is for damping ratio CDAMP to be applied to both the excess pore pressure and the effective stress. If CDAMPV is defined as non-zero, it is applied to the excess pore pressure and the effective pressure, while CDAMP is applied to the deviatoric response. If IPWP is set to 2, this switches off damping of the pore pressure, leaving only the effective stress being subjected to damping.