OptiStruct – Direct Nonlinear Transient Analysis Setup

Product: OptiStruct
Product Version: OptiStruct 2021.2 or above

Topic Objective

Direct Nonlinear Transient Analysis Setup

Topic Detail

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1. Analysis Types

OptiStruct 2021.2 supports several types of finite element analysis. The following chart can be used to determine which type of analysis is best fit for analysts' use cases.

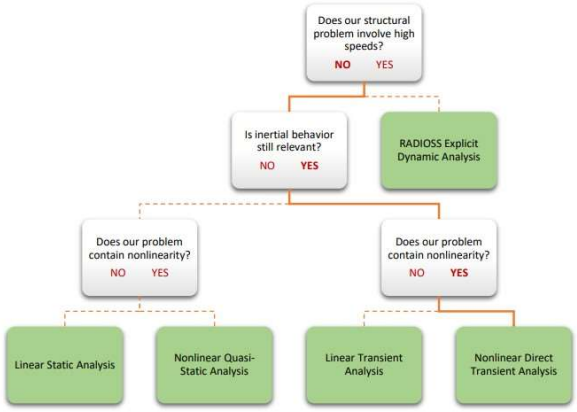

Figure1: Chart of Analysis Types

2. Direct Nonlinear Transient Analysis Setup

For direct nonlinear transient analysis setup, the process of setting up transient analysis model is mostly similar to the setup in other analysis, except for the load definition.

2.1. Loading Setup

This section would go through some of the most common loads or dynamic excitations setup of transient analysis. Typical transient dynamic loads/excitations were defined with TLOADi cards. The most used format was TLOAD1 which was shown in Figure 2. For detail information about TLOADi cards, please refer to OptiStruct help, reference guide manual.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
TLOAD1	*SID*	*EXCITEID*	*DELAY*	*TYPE*	*TID*				
	"EXTN"	*TSTIME*							

Figure 2: Input format for TLOAD1

The TID was referring to that time history curves that defined the dynamic excitation. Typical time history curves were defined with TABLEDi cards. The most used format was TABLED1 which was shown below. For detail information about TABLEDi cards, please refer to OptiStruct help, reference guide manual.

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(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
TABLED1	*TID*	*XAXIS*	*YAXIS*	*FLAT*					
	x1	*y1*	*x2*	*y2*	*x3*	*y3*	*x4*	*y4*	
	x5	*y5*	etc.	etc.	etc.	etc.	etc.	etc.	

Figure 3: Input format for TABLED1

Users could either use unit dynamic excitation load and defined the magnitude in time history curves or defined the magnitude in dynamic excitation and used unit time history curves.

The following figures showed the TLOAD1 definition examples in HyperWorks 2021.2

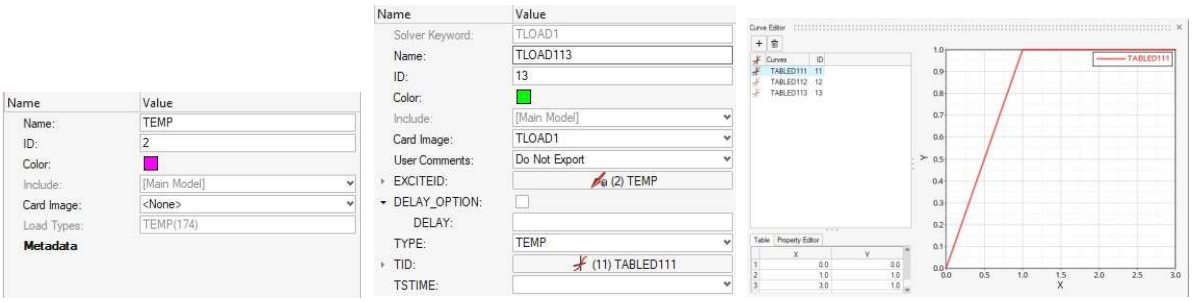

Figure 4: TLOAD1 example 1

In example 1, the dynamic excitation was enforced temperature with corresponding TEMP TYPE in TLOAD1 setup. Unit time history curve was used with magnitude defined in dynamic excitation setup.

The dynamic excitation was unit force in example 2 (see Figure 5). TYPE was left blank to use the default LOAD type in TLOAD1 setup. The excitation magnitude was defined in time history curve.

In the above example, the dynamic excitation was applied with 1.0 second delay. The delay was defined using the time history curve. Another way to apply the delay was to specify the delay in DELAY field of TLOAD1 as shown in Figure 6. Note that the time history curve should shift to the left accordingly.

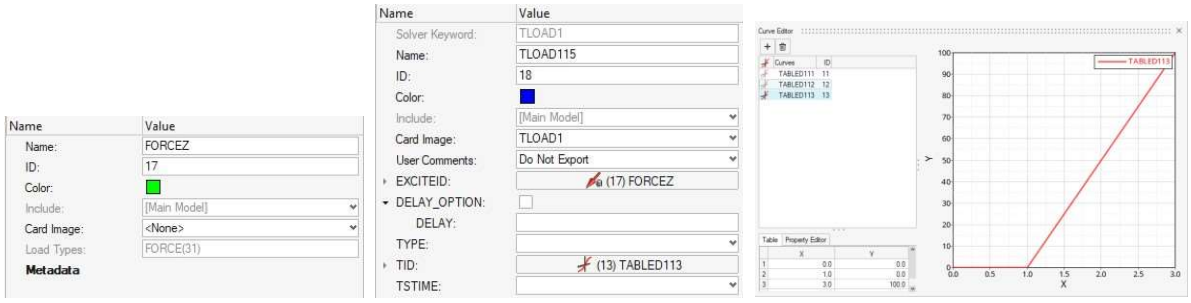

Figure 5: TLOAD1 example 2

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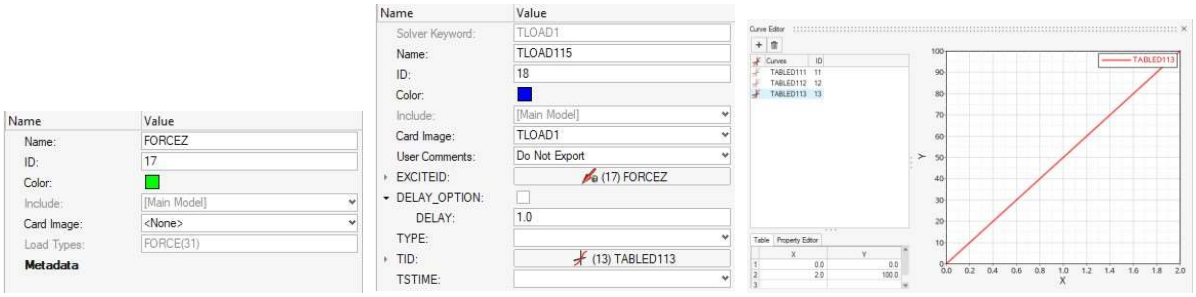

Figure 6: TLOAD1 example 3

The transient analysis modeling allowed definitions of multiple dynamic excitations. These dynamic excitations could be combined linearly to define complex transient event. In OptiStruct, the linear combination of these dynamic excitations was defined using DLOAD and the DLOAD was then referred by a subcase to complete the dynamic load definition. The input format of DLOAD was shown as below. For detail information about DLOAD card, please refer to OptiStruct help, reference guide manual.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
DLOAD	*SID*	*S*	*S1*	*L1*	*S2*	*L2*	*S3*	*L3*	
	S4	*L4*	etc	etc	etc	etc	etc	etc	

Figure 7: Input format of DLOAD

The S and Si fields in DLOAD provided another option to scale the magnitude of dynamic excitation. An example of DLOAD definition was shown in the following figure:

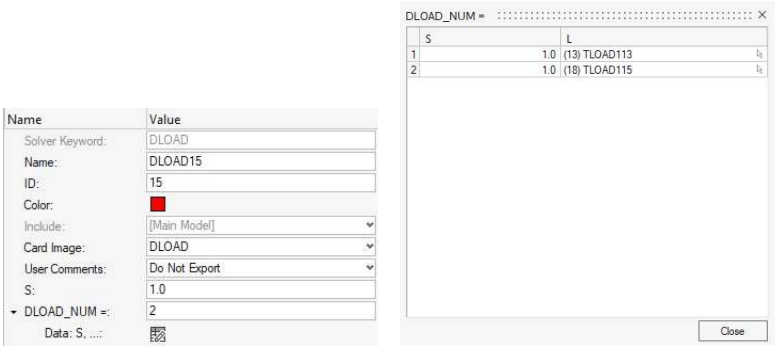

Figure 8: DLOAD example

2.2. Time Step Setup

In transient analysis modeling, users were required to setup the time step control parameter. In OptiStruct, this was defined using TSTEP card. The input format of TSTEP was shown below. For detail information about TSTEP card, please refer to OptiStruct help, reference guide manual.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
TSTEP	SID	N1	DT1	NO1	W3,1	W4,1			
		N2	DT2	NO2	W3,2	W4,2			
		etc.							
	TMTD	TC1	TC2	TC3	TC4	Alpha	Beta		
	MREF	TOL	TN1	TN2					

Figure 9: Input format of TSTEP

The number of time steps and time increment, Ni and DTi fields, were the minimum required definitions for TSTEP. Together, the two fields defined the total time duration of the transient event. An example of TSTEP definition was shown in Figure 10.

The general guideline on the time increment was it should be small enough to capture the highest frequency of interested responses. For example, if this value was 100 Hz, then each time period is 0.01s (10ms). The common practice was to have at least 5 increments per period to capture the interested response, i.e., DT = 0.002s (2ms). The preferred minimum number was 10 steps per period, i.e., DT = 0.001s (1ms).

By default, OptiStruct used the values in N and DT to determine end time and increments during nonlinear transient analysis,

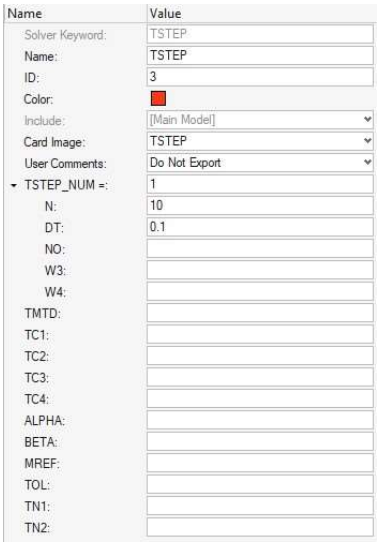

Figure 10: TSTEP example

By default, the Generalized Alpha Time Integration method was used (TMTD field left blank as shown in the above example) in the transient analysis. If users were having solution convergence issue, user could try setting TMTD to 2, changing the method to Backward Euler method for the analysis.

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2.3. Nonlinear Parameter Setup

When nonlinearities, such as nonlinear material, large deflection, or nonlinear contact, were present in the model, users were required to define the control parameters for the nonlinear analysis. In OptiStruct, these control parameters were defined in NLPARM card. The input format of NLPARM was shown below. For detail information about NLPARM card, please refer to OptiStruct help, reference guide manual.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
NLPARM	ID	NINC	DT			MAXITER	CONV		
	EPSU	EPSP	EPSW			MAXLS		LSTOL	
		TTERM							

Figure 11: Input format of NLPARM

The time steps and time increment, NINC and DT fields, work the same way as N and DT fields in TSTEP. However, the definitions in NLPARM will overwrite the ones in TSTEP when both were defined. An example of NLPARM definition was shown in Figure 12.

Name	Value
Solver Keyword:	Nonlinear Parameters
Name:	NLPARM1
ID:	20
Include:	[Main Model]
Config type:	Nonlinear Parameters
Type:	NLPARM
NINC:	10
DT:	0.1
KSTEP:	
MAXITER:	
CONV:	
EPSU:	
EPSP:	
EPSW:	
MAXLS:	
LSTOL:	
TTERM:	
OPTIONS:	NONE

Figure 12: NLPARM example 1

Name	Value
Solver Keyword:	Nonlinear Parameters
Name:	NLPARM2
ID:	21
Include:	[Main Model]
Config type:	Nonlinear Parameters
Type:	NLPARM
NINC:	
DT:	0.1
KSTEP:	
MAXITER:	
CONV:	
EPSU:	
EPSP:	
EPSW:	
MAXLS:	
LSTOL:	
TTERM:	2.0
OPTIONS:	NONE

Figure 13: NLPARM example 2

There was an alternative way of defining the time steps and increments in NLPARM. That was to define DT and TTERM, termination time of subcase. When NINC, DT and TTERM were defined, DT and TTERM values would overwrite the NINC values. An example of NLPARM alternative definition was shown in Figure 13. Note that the TTERM was termination time of subcase not the total time of dynamic event.

The values in NINC and DT were used as initial time steps and increments during nonlinear transient analysis, and then activated the automatic time-stepping. This was similar to the definition of the TSTEP. When automatic time stepping was activated, OptiStruct automatically increase or decrease the time increments to optimize the nonlinear transient solution convergence stability and speed. As a result, sometimes users might end up with less time step or larger time increments that were desired. The NLADAPT and NLOUT entities discussed in the subsequence sections could be defined to further control the time steps.

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2.4. Nonlinear Time Step and Convergence Parameter Setup

In OptiStruct, the nonlinear parameter could be further refined with NLADAPT. An example of NLADAPT definition was shown in the following figure. For detail information about NLADAPT card, please refer to OptiStruct help, reference guide manual.

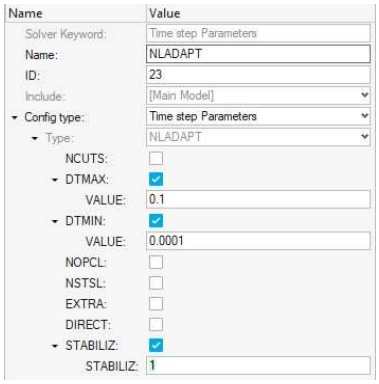

Figure 14: NLADAPT example 1

The default nonlinear parameters values in general worked relatively well. However, sometimes users needed more controls on the time step and convergence stability. NLADAPT provided these controls to the users. Some of the most common adjustments were shown in the above example. For example, the maximum time increment was defined to prevent increment increases above users' desired increment. The minimum time increment definition helped stop the analysis if there were error in the solution, i.e., elements become distorted. If the nonlinear analysis was having trouble converging, i.e., post buckling load case, additional numerical damping could be introduced by increasing the STABILIZ values (The default value is 1.0).

2.5. Nonlinear Output Setup

By default, OptiStruct output the results based on number of times in the nonlinear analysis. NLOUT could be used to request results at specific time step and hence forced analysis be performed at requested time step. The input format of NLOUT was shown as below. For detail information about NLOUT card, please refer to OptiStruct help, reference guide manual.

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
NLOUT	*ID*	*PARAM1*	*VALUE1*	*PARAM2*	*VALUE2*				

Figure 15: Input format of NLOUT

Examples of NLOUT setup in HyperWorks 2021.2 was shown in the following figures.

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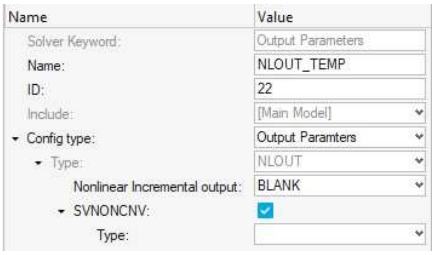

Figure 16: NLOUT example

In the above example, the nonlinear increment output was left blank. By default, OptiStruct output the results based on number of times in the nonlinear analysis. The SVNONCNV flag was checked to output nonconvergent solution for the purpose of debugging in case the analysis failed to converge.

Figure 17: Input format of NLPARM

In the above example, the nonlinear increment output was referring to a SET_TIME definition. A SET_TIME was a set used to define the time step users would like OptiStruct to output results.

2.6. Nonlinear Transient Analysis Subcase Setup

In this section, an example was used to illustrate how entities introduced in the above sections work together to define a nonlinear transient analysis subcase. The example was assumed to be combined transient thermal and forces nonlinear analysis. In the event, the transient thermal load was first applied, then followed by the transient loads. It was assumed that the applied temperature was first brought to the desired level and held steady (as shown in time history curve in Figure 4). Then, the transient loads were applied (as shown history curve in Figure 5). A DLOAD (as shown in Figure 8) was used to combine all the applied loads. In this example, separate loadcases were created for the transient thermal segment and combined transient thermal and applied loads segment. The loadcase setup in HyperWorks 2021.2 was shown in the following figures.

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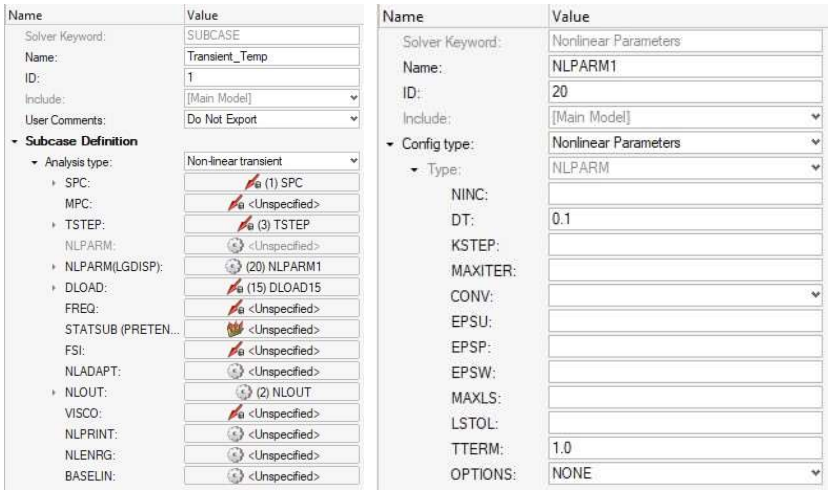

Figure 18: Loadcase Setup Example for Transient Thermal Loads

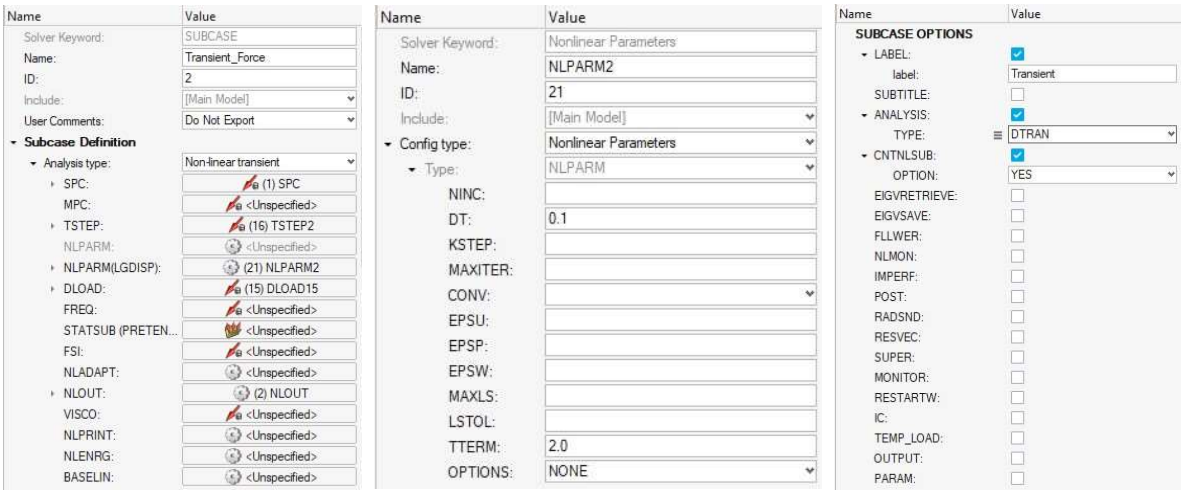

Figure 19: Loadcase Setup Example for Combined Transient Thermal and Applied Loads

In the above two loadcases, same DLOAD was used for both subcases. However, different time durations were specified in TSTEP and NLPARM to control what loadings were applied in each subcase. Since the time step and increment in NLPARM overwrote the ones in TSTEP, only NLPARM definitions are shown in the example. The DT and TTERM method of definition are used. Note that the TTERM is subcase termination time. In Figure 18, TTERM = 1.0 sec. During that time period (time history curve in Figure 5 and 6), applied temperature rose to a constant level and dynamic load remained zero. As a result, subcase in Figure 18 only had transient thermal loads.

In Figure 19, the CNTNUSUB option = YES indicated this subcase would restart from previous subcase. The TTERM is set to 2.0 sec which specified that this subcase would continue to run for 2 seconds after the initial first second from first subcase. This made the total time of the dynamic loading event equal to 3 seconds.

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From the time history curve in Figure 5 and 6, the transient load was introduced after 1 second and the temperature was held steady. Therefore, the subcase in Figure 19 consisted of combined transient thermal and applied load. Note that the total event time in the time history curve was consistent with the sum of subcases termination time.

3. Damping Setup

For direct transient analysis, structural damping was defined in the form of equivalent viscous damping. The viscous damping could come from direct definition of viscous damping elements, such as CVISC, overall structural damping coefficient via PARAM, G and element damping coefficient defined in material cards (MATi). While using PARAM, G, PARAM, W3 needed to be defined. Similarly, if damping was defined via GE in the material card, PARAM, W4 was needed. Both W3 and W4 were frequency of interest in radians per unit time (2π x number of Hz). Their relation to G and GE were shown below.

$$\mathbf{C} = \mathbf{C}_1 + \frac{G}{\omega_3}\mathbf{K} + \frac{1}{\omega_4}\mathbf{C}_{GE}$$

C = total damping
C_1 = damping from viscous damper elements
G = overall structural damping
C_{GE} = damping from element damping coefficient GE
ω_3 = Frequency of interest for converting over structural damping into viscous damping
ω_4 = Frequency of interest for converting element damping coefficient into viscous damping

4. References

[1] Altair OptiStruct 2021.2 Help, Altair Engineering Inc, Troy MI USA

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