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MD NASTRAN 2010 THERMAL ENHANCEMENT

Daniel Chu

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Glendale, CA

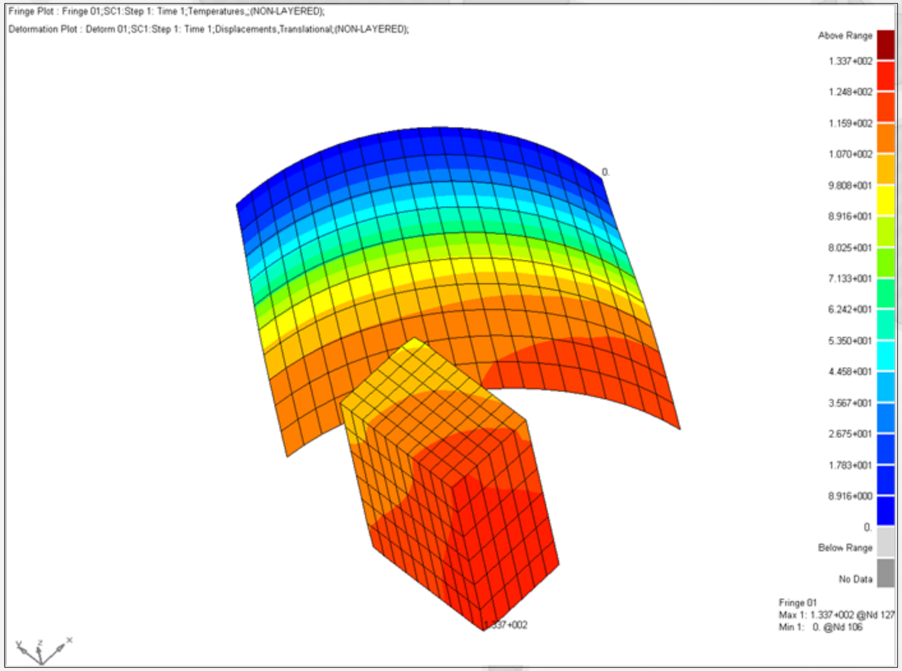
MD2010 thermal capabilities

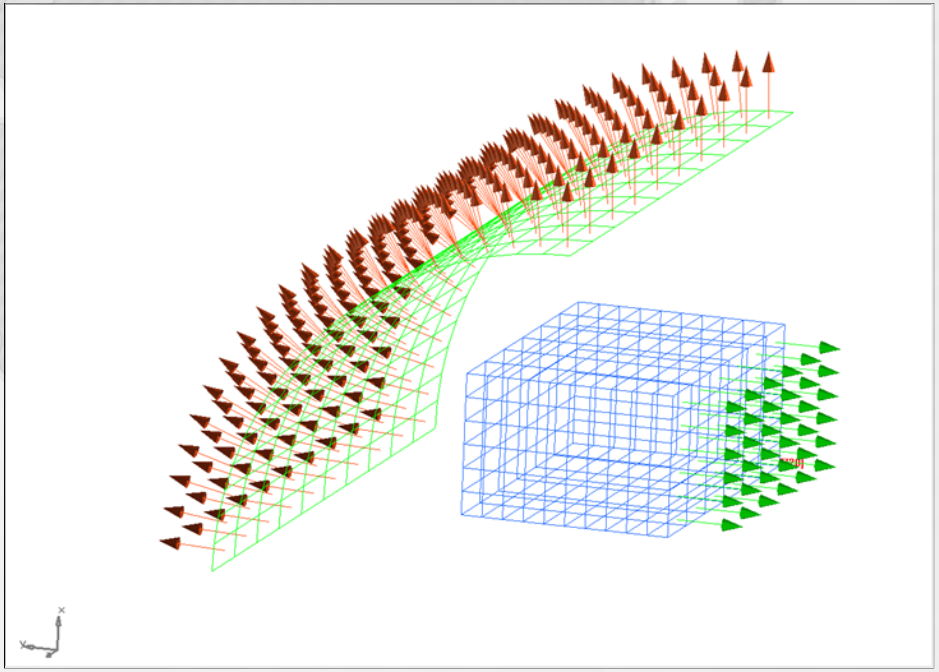
	HEMI-CUBE View factor	Composite 2D and 3D heat transfer	Thermal Contact with BCTABLE	Linear and quadratic thermal gradient through shell	Reflection Matrix in Radiation matrix decomposition	Adaptive time stepping using NLSTEP
MDR3	Yes	Yes			Yes	
MD2010			Yes	Yes		Yes

	Mesh-Mapping from different thermal and structure mesh	Multi-physics thermal structure interaction	21 new advanced element types	Axi-symmetric CQUADX and CTRIAX on the x-y plane		
MDR3			Yes			
MD2010	Yes	Yes		Yes		

What is new in MD2010 thermal capability

1. **Added true thermal contact , near contact , and radiation across gap using the entries BCTABLE and BCBODY.**





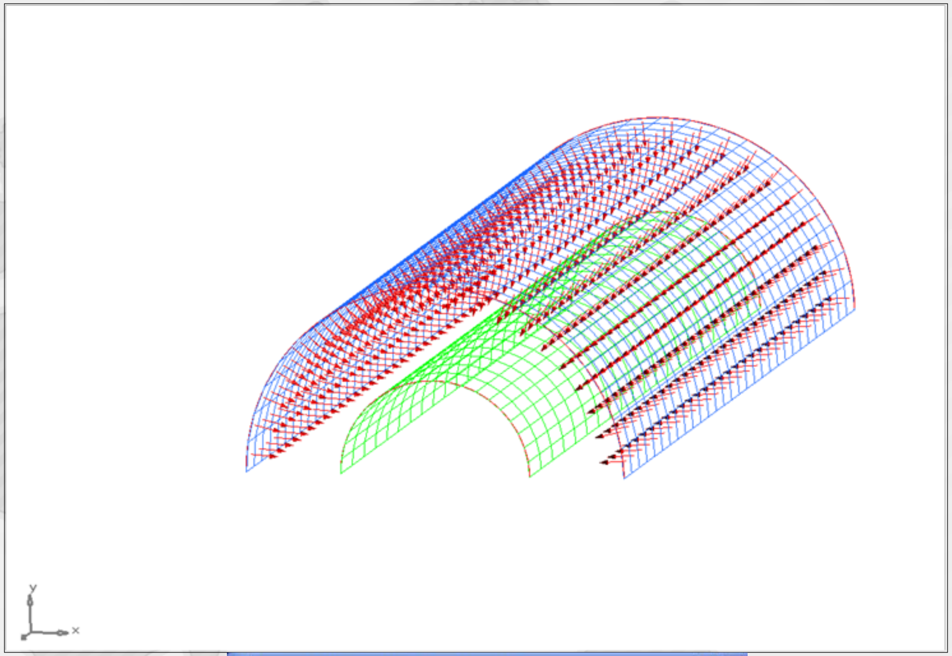
Shell with temperature with linear or quadratic temp distribution

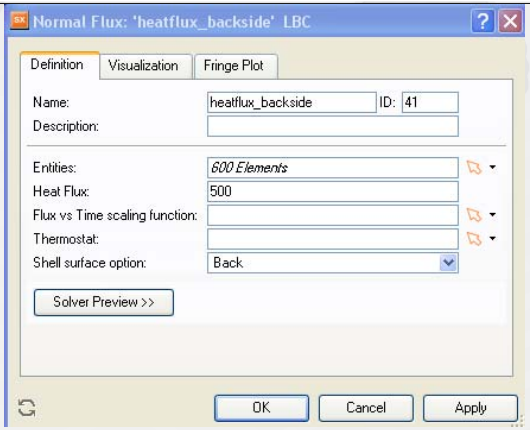
- **NLMOPTS,TEMPP,LINE or QUAD**
- **PSHELL 1 2 0.1 2 2**
- **pshln1,1,2,,,ish**
- **Thermal boundary conditions can be applied on the top or bottom of shell elements by the use of CHBDYE bulk data entries.**
- **Example:**

  CHBDYE,3001,401,6

  QBDY3,6,500.0,,3001

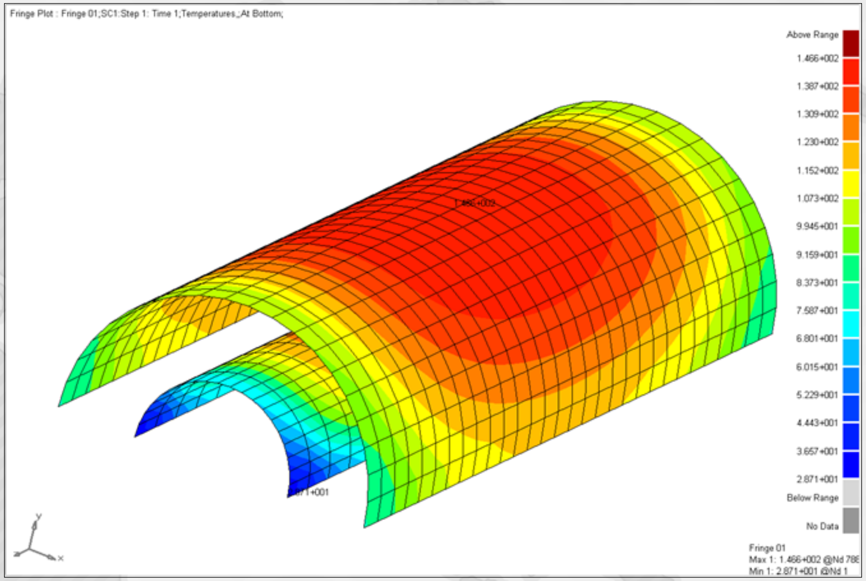
- **This CHBDYE element is referenced by CQUAD4 Element 401 with SIDE ID=6 that is the Bottom side of the element**
- **A heat flux and convection can then be applied to this CHBDYE surface. Since grids had only a single degree of freedom previously, it did not matter where the heat flux was applied. However now that, MD2010 has multiple degrees of freedom per grid, the effect of thermal gradients can be captured.**





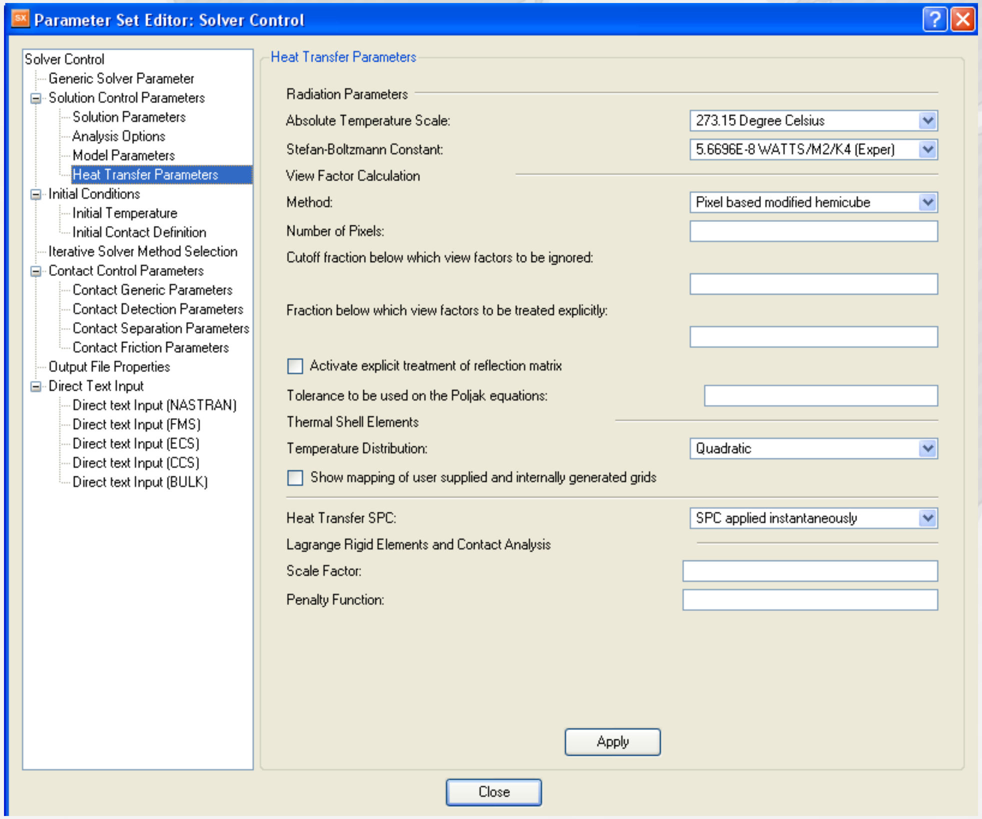
Shell temp with temperature gradients

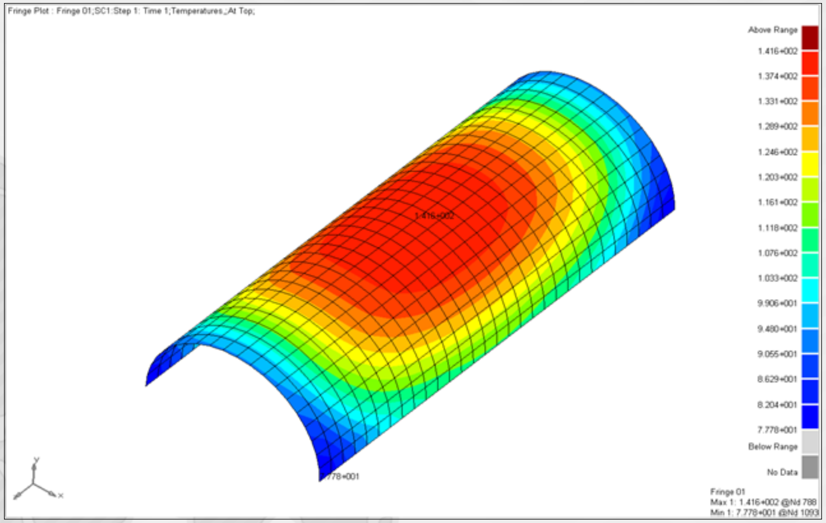
- **Boundary conditions:**
  - Heat flux, (500 watt/m^2)is applied on the entire outer cylinder.
  - Enclosure radiation is exchanged from the inner cylinder to the outer cylinder.
  - Radiation loss goes space at negative 273.15°C
  - Sigma is $5.67e^{-8}$ watt/m^2K^4
  - Offset temperature is 273.15°C, the input temperature is in Celsius.

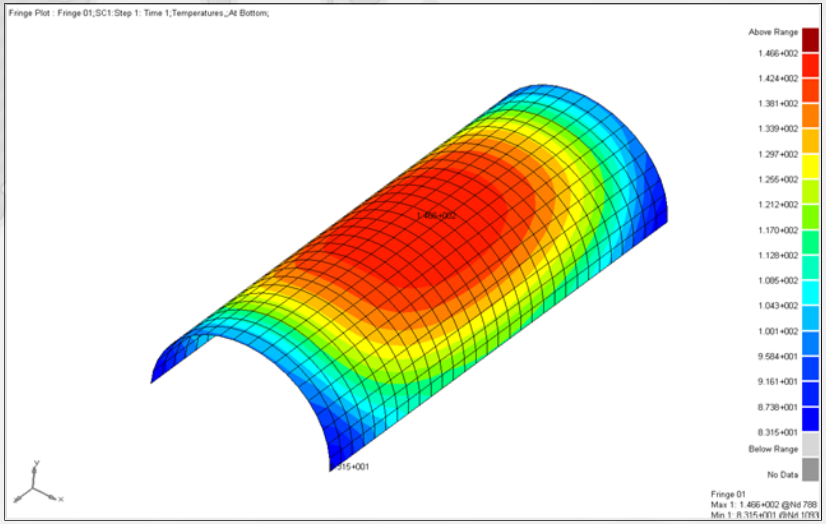


Shell with temp gradients

Outer cylinder	Top	Middle	Bottom
Temp(max)	141.6	144.1	146.6
Temp(min)	77.78	80.56	83.15

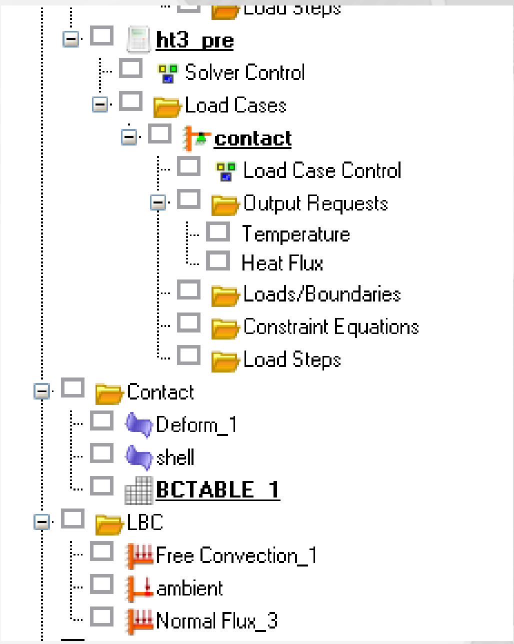




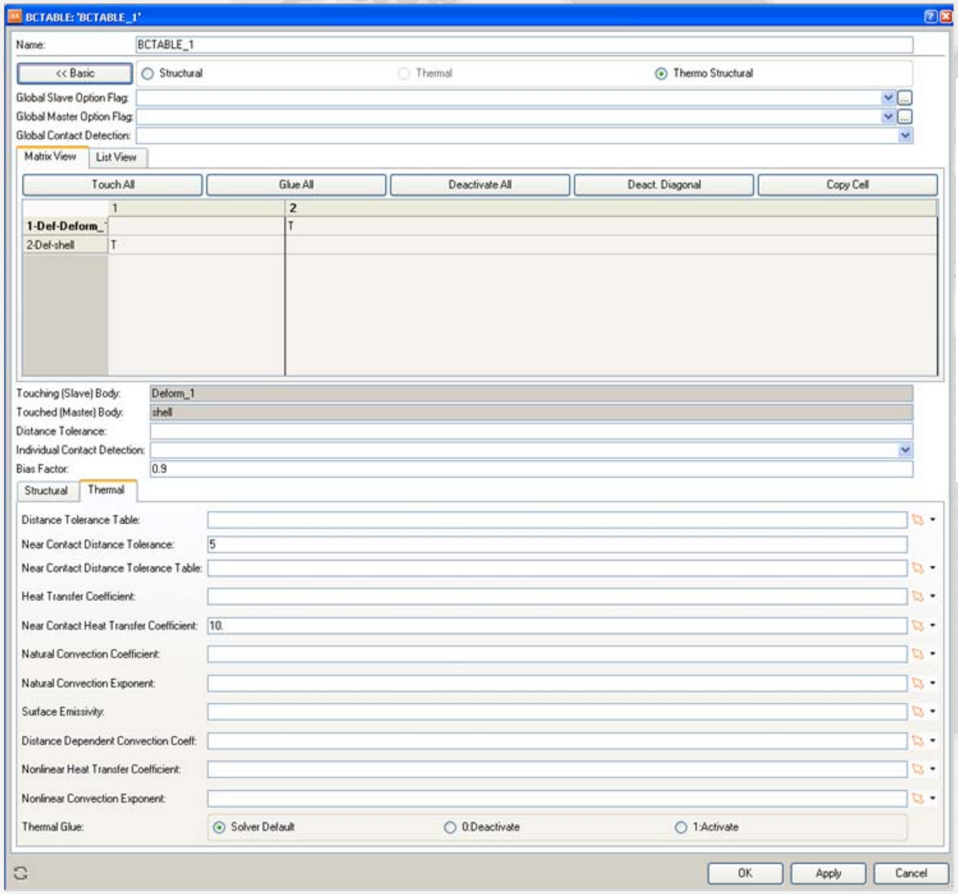


SIMX – Heat Transfer GUI

SIMX – Model Browser



Thermal contact GUI



27. For hard contact, with HGLUE=0:

    The convective heat flow per unit area over the two interfaces is given by:

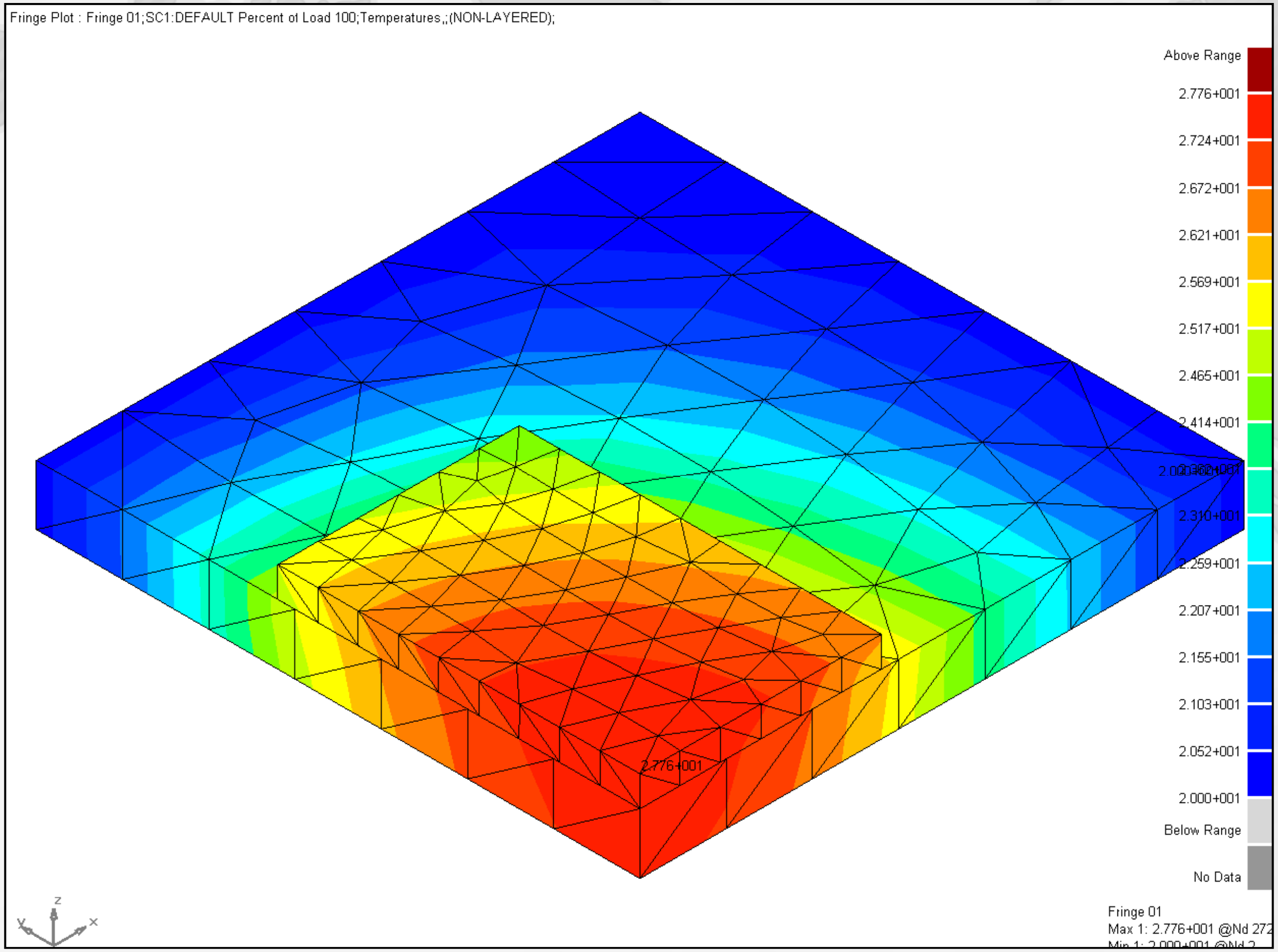
    $$q = HCT \cdot (T_A - T_B)$$

    where T_A is the contacting grid temperature and T_B is the face temperature in the contact point in case of a meshed body or the T_{BODY} temperature in case of a rigid geometry.

28. For near contact:

$$\begin{aligned} q = {} & HCV \cdot (T_A - T_B) + \\ & HNC \cdot (T_A - T_B)^{BNC} + \\ & HNL \cdot (T_A^{BNL} - T_B^{BNL}) + \\ & \sigma \cdot EMISS \cdot (T_A^4 - T_B^4) + \\ & \left[HCT \cdot \left(1 - \frac{dist}{DQNEAR}\right) + HBL \cdot \frac{dist}{DQNEAR}\right] \cdot (T_A \cdot T_B) \end{aligned}$$

Thermal contact with glue options



Temperatures are continues across the interface due to contact.

Set thermal glue=1

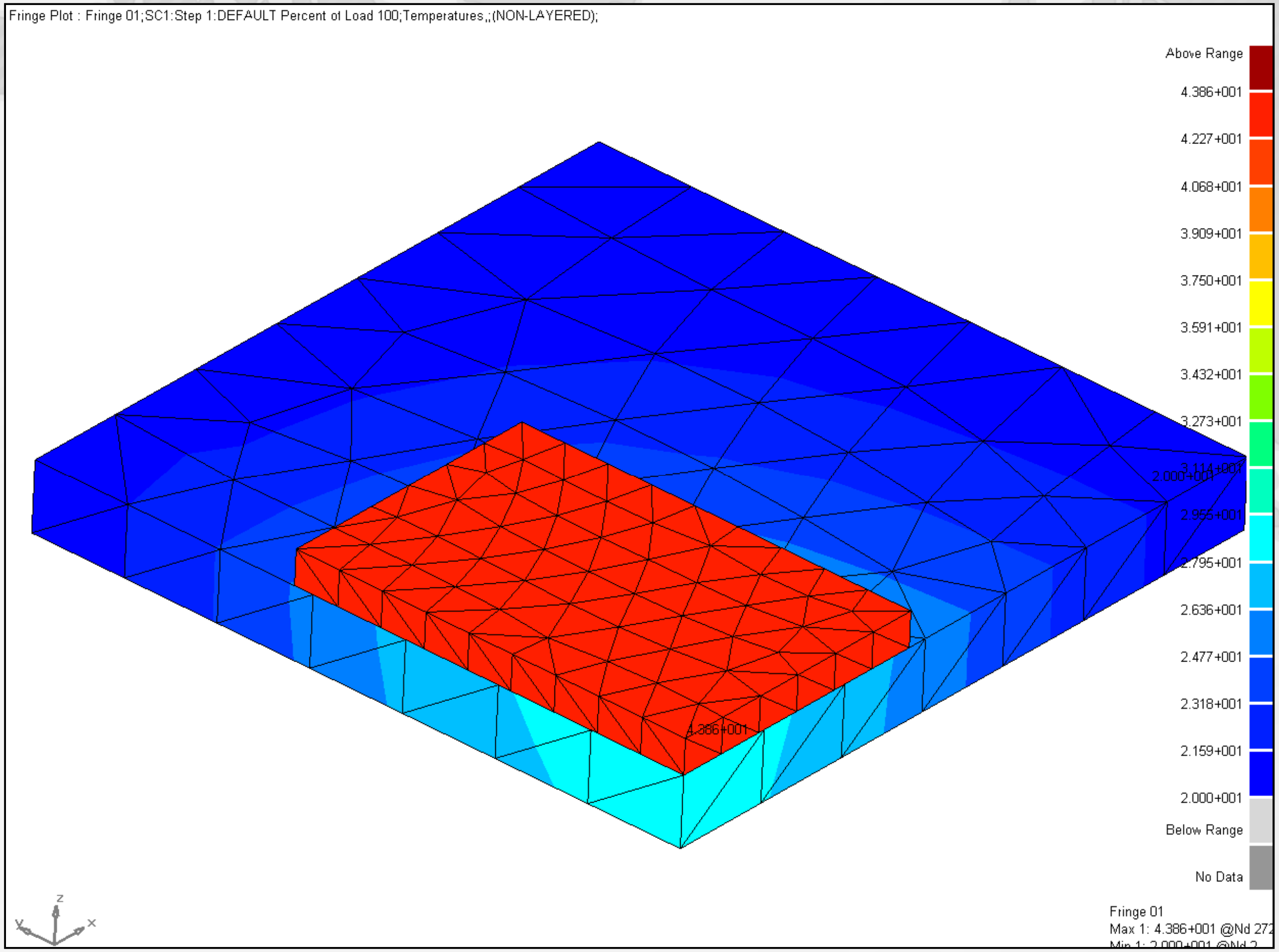
- **The HGLUE field on Field 6 behind the keyword HHHB can be set to 1. This will glue two parts with dissimilar mesh together with no temperature drop between the two parts.**

```
NASTRAN test deck: gap_glue.dat
BCTABLE  9                       1
         SLAVE   111     0.      0.      0.      0.      0
                 0       0       0       0       20.0    0
                 FBSH           .9
                 HHHB    0.0     0.      0.      0.      0.      0.
                                         1
         MASTERS 112
```

SOL 400 thermal contact

```
SOL 400
CEND
ANALYSIS = HSTAT
TITLE = MSC.Nastran job created on 28-Sep-05 at 16:03:52
ECHO = NONE
TEMPERATURE(INITIAL) = 1
 SUBCASE 1
 BCONTACT=9
   NLPARM = 1
   SPC = 1
   LOAD = 2
   THERMAL(SORT1,PRINT)=ALL
   FLUX(SORT1,PRINT)=ALL
BEGIN BULK
bsurf, 101, 314,thru,639
bsurf, 102, 1,thru,313
bcbody, 111, , heat, 101
,
, heat, 0., 0., 0., 0., 0., 0., 4
,     , 0., 0., 0.
bcbody, 112, , heat, 102
,
, heat, 0., 0., 0., 0., 0., 0., 4
,     , 0., 0., 0.
BCTABLE  9                      1
         SLAVE   111     0.      0.      0.      0.      0
                 0       0       0       0       20.0    0
                 FBSH           .9
                 HHHB    0.0     0.      0.      0.      0.      0.
                                         1
         MASTERS 112
```

Touched contact (contact resistance)



HTC=1.2

There is a temperature drop between the two parts

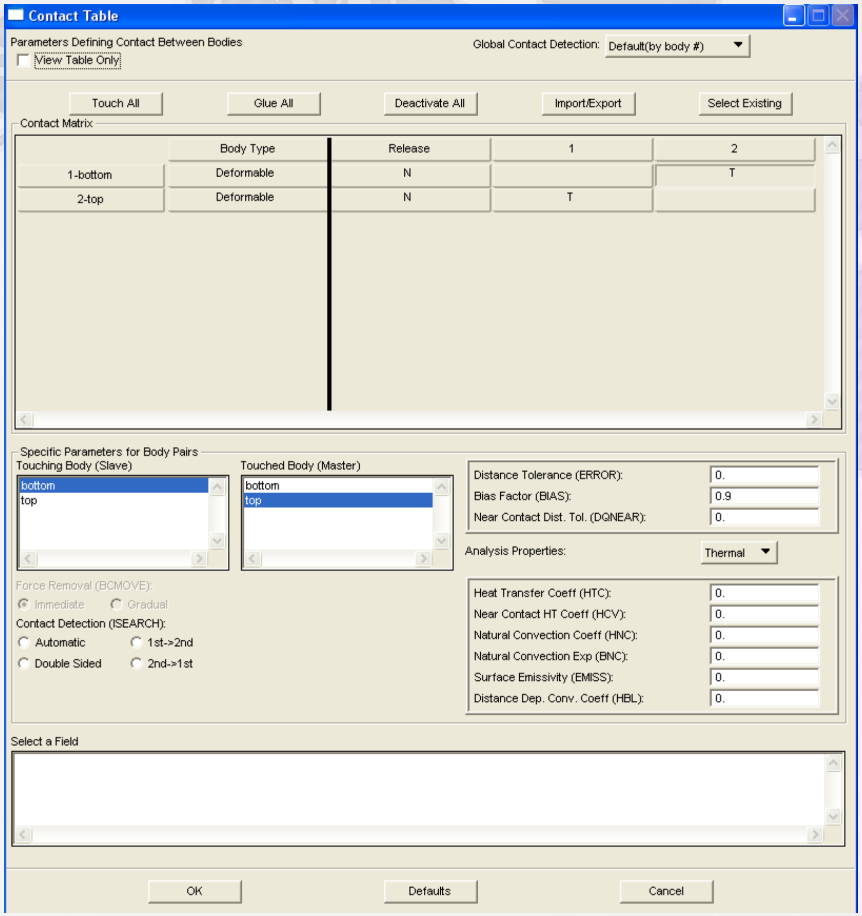
This option is used to simulate grease or contact resistance between two parts

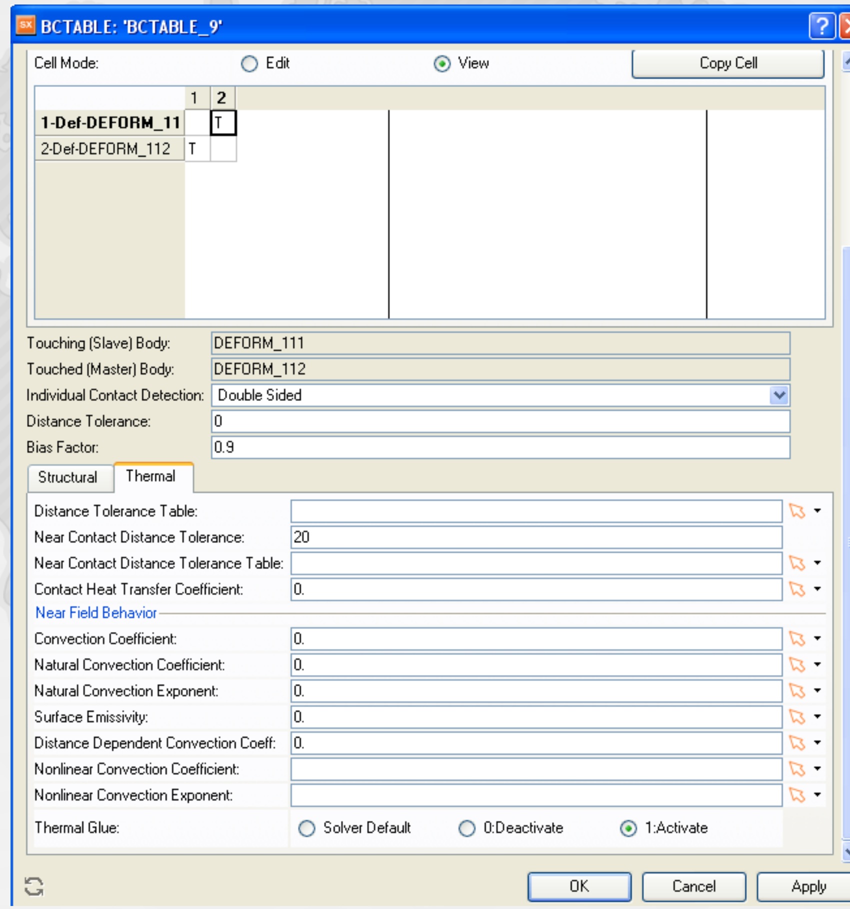
Touched contact

- We have a value of 1.2 in the field HTC that connect the two parts.

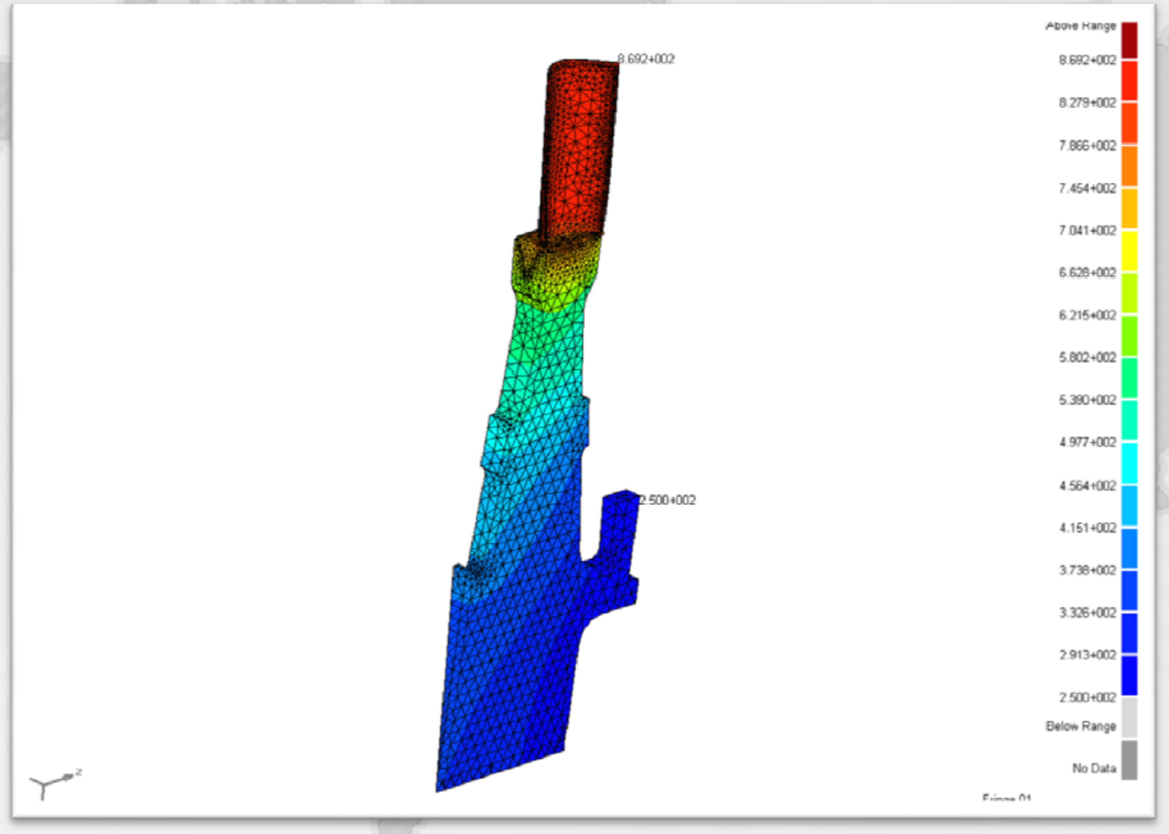
```
BCTABLE  9                    1
         SLAVE   111     0.      0.      0.      0.      0
                 0       0       0       0       20.0    0
                 FBSH           .9
                 HHHB    1.2     0.      0.      0.      0.      0.
         MASTERS 112
```

Thermal contact GUI (PATRAN and SIMX)

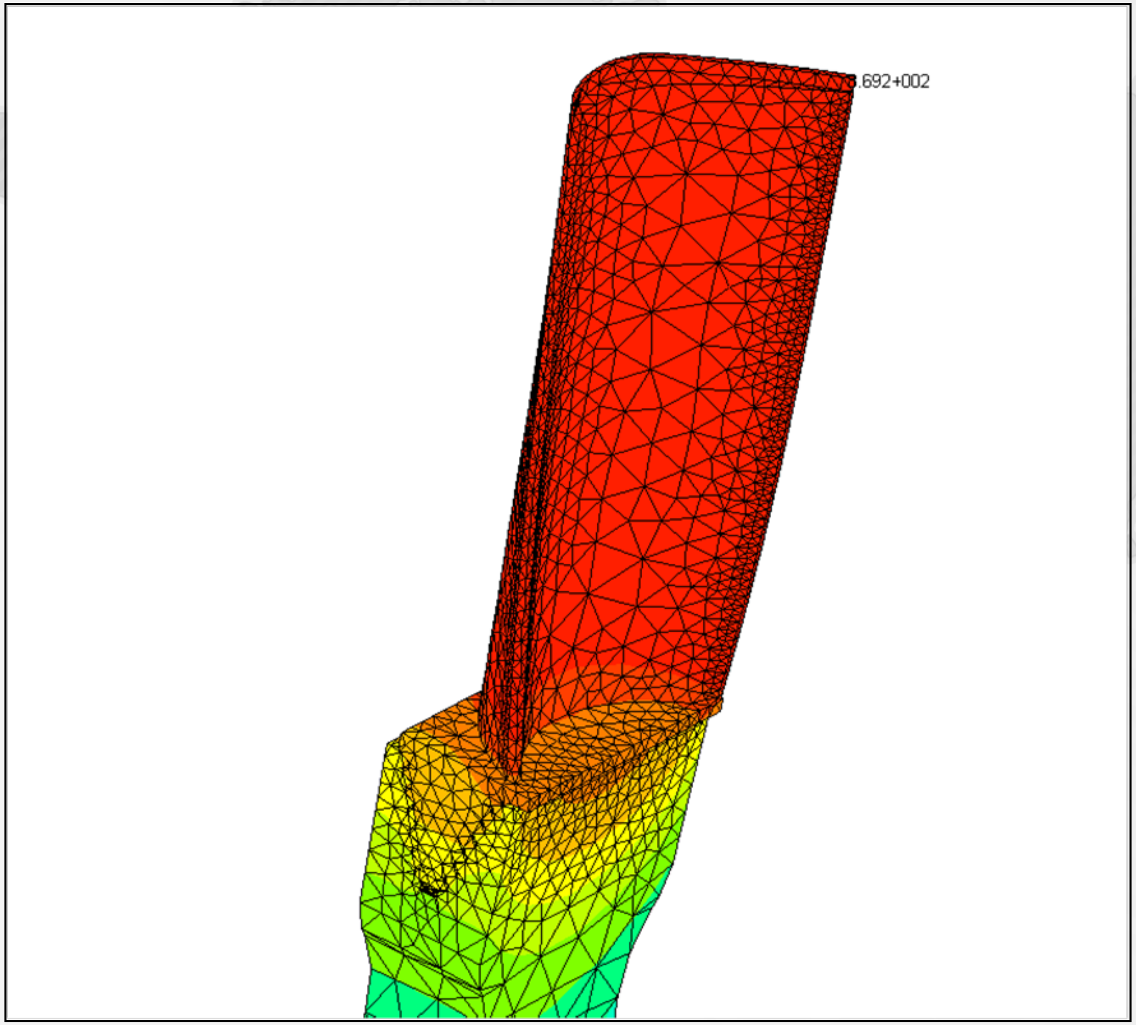




Thermal contact for turbine blade –disc interface



Detailed view of the contact surface



Non-matching mesh between the blade and the disc

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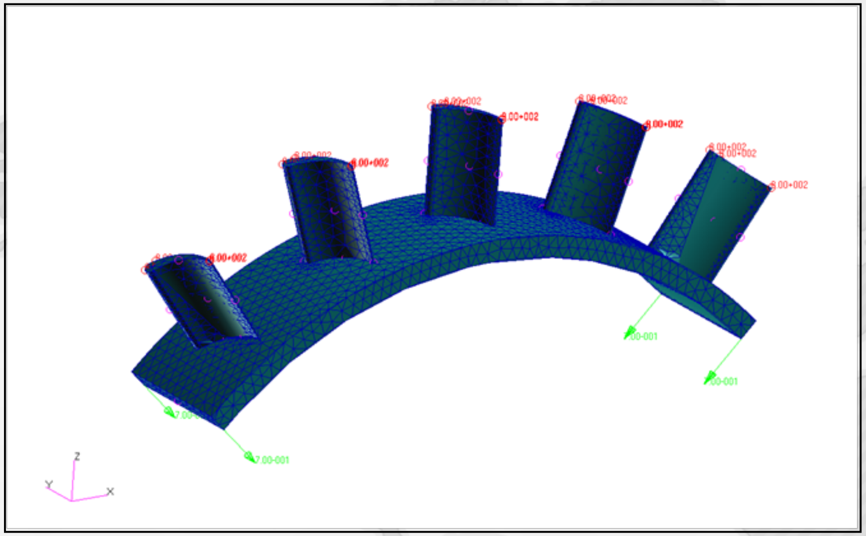
Thermal contact with multiple parts

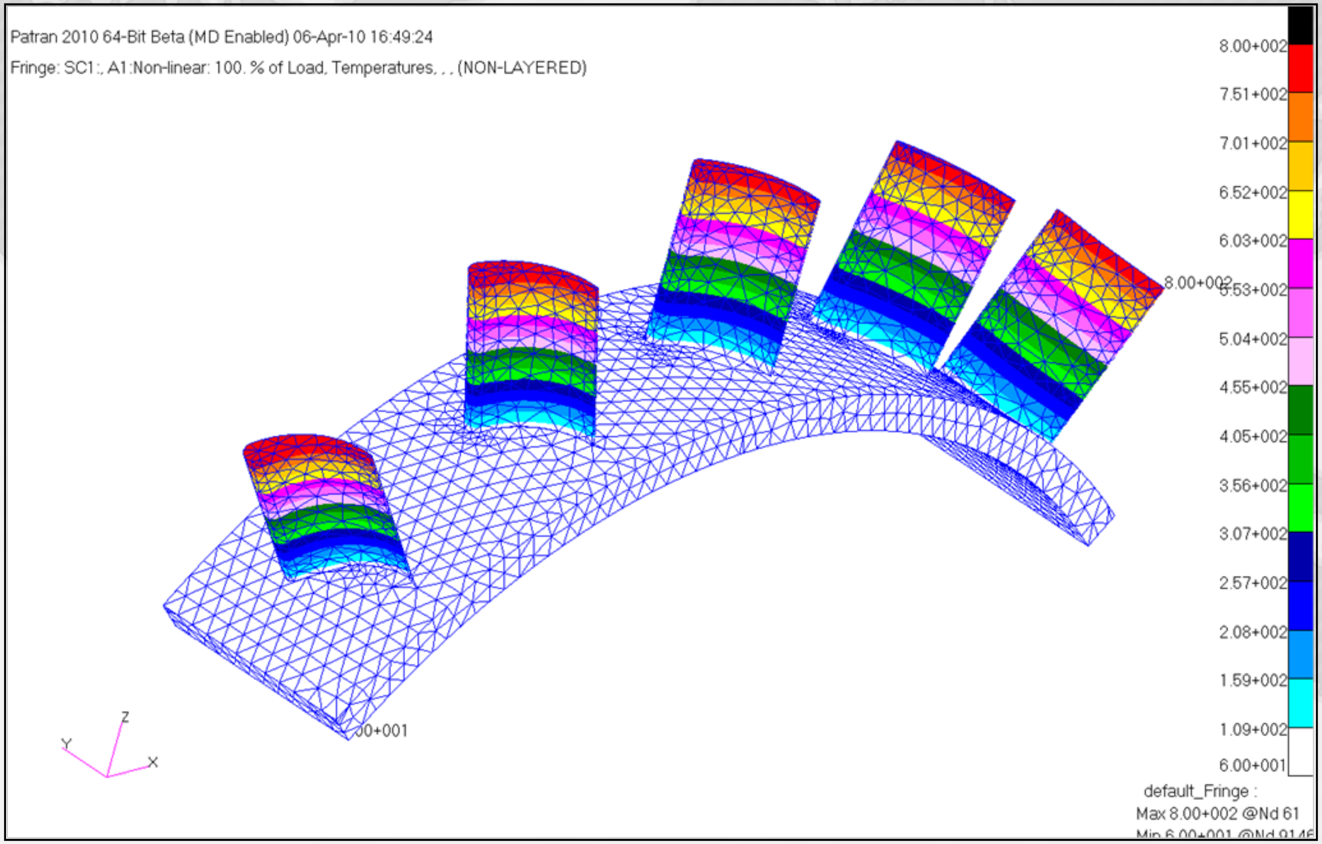


- **Tet10 mesh for blades and base.**
- **Blades and base are meshed individually. The mesh is not congruent at the interface.**
- **Thermal contact using glued thermal contact option-perfect contact.**
- **Enforced temperature of 800°F on top of the blades.**
- **Convection to ambient at 60°F with h = 0.1**

```
BCTABLE  1                          1
         SLAVE   1                                        0
                 0       0       0               .5
                 HHHB   .0
                                          1
         MASTERS 2
```

Thermal contact with multiple parts

NASTRAN test deck: large_contact1_glue.dat



Restart from thermal NASTRAN database into a fine structure mesh model

MDR4 SOL400 now has the capability to interpolate temperature from a coarse mesh thermal model into a fine mesh structure model using a restart from heat transfer run into a structure run.

The procedure is:

1. Start with two Nastran Decks. The deck is the thermal model. The second model is the structural model.
2. Run the thermal model, and save the NASTRAN database by specifying SCR=NO in the run.
3. The structural model is then run using a restart pointing to the same NASTRAN database that will interpolate the temperature in the fine mesh model .
4. The Case Control Command temp(load,hsubcase=1)= 9 will then use the thermal run from the Subcase 1 as the temperature load for a thermal stress analysis.

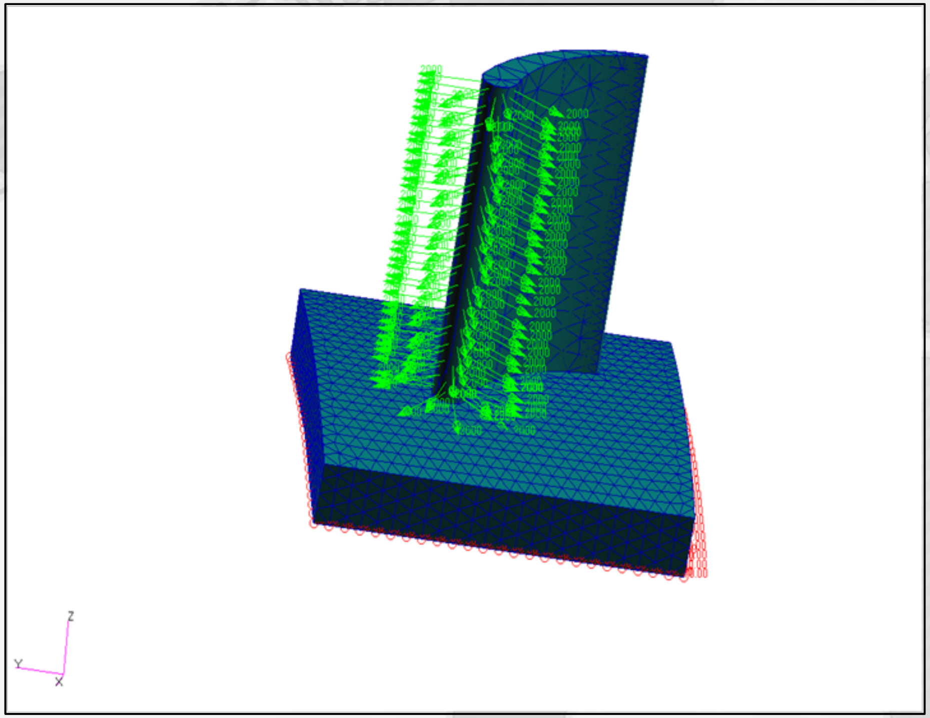
Example decks:

- NASTRAN thermal model: map_heat1_m.dat
- NASTRAN structure model: map_structure1b_m.dat

SEE URL example:

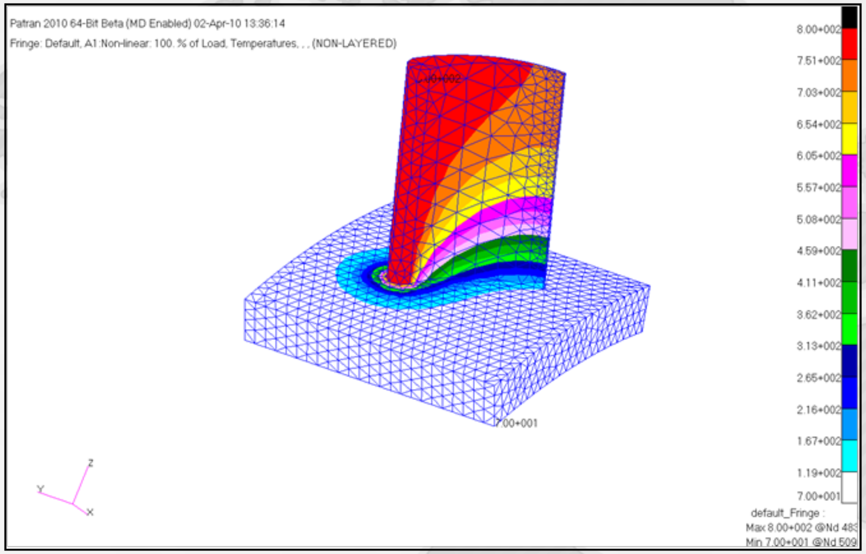
http://www.si.mscsoftware.com/nsp/SampleProb/heat/prob238/matching_mesh_thermal4.htm

Thermal mesh mapping examples



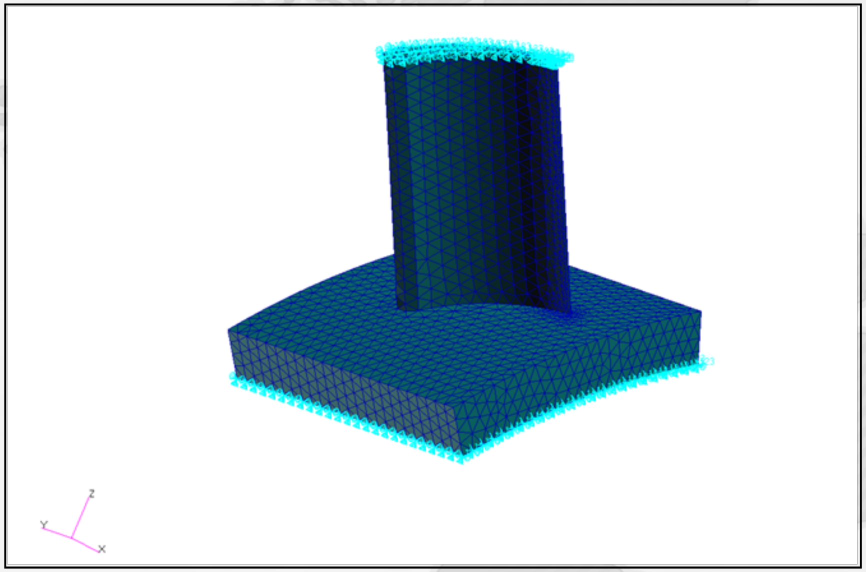
- **Thermal Boundary conditions:**
  - Convection exposed to hot gas at 800°F with h=0.2 Btu/sec-in^2·°F along the edge of the turbine blade.
  - Boundary condition on the bottom of base of 70°F.
  - Start off as the coarse mesh for thermal model.

Map meshing – Thermal run



- **NASTRAN test deck: map_heat1_m.dat**
- **Since the temperature gradients across the blade is significant we would like to re-mesh the blades to capture this temperature for thermal stress calculations.**

Map meshing – structure model(Restart)

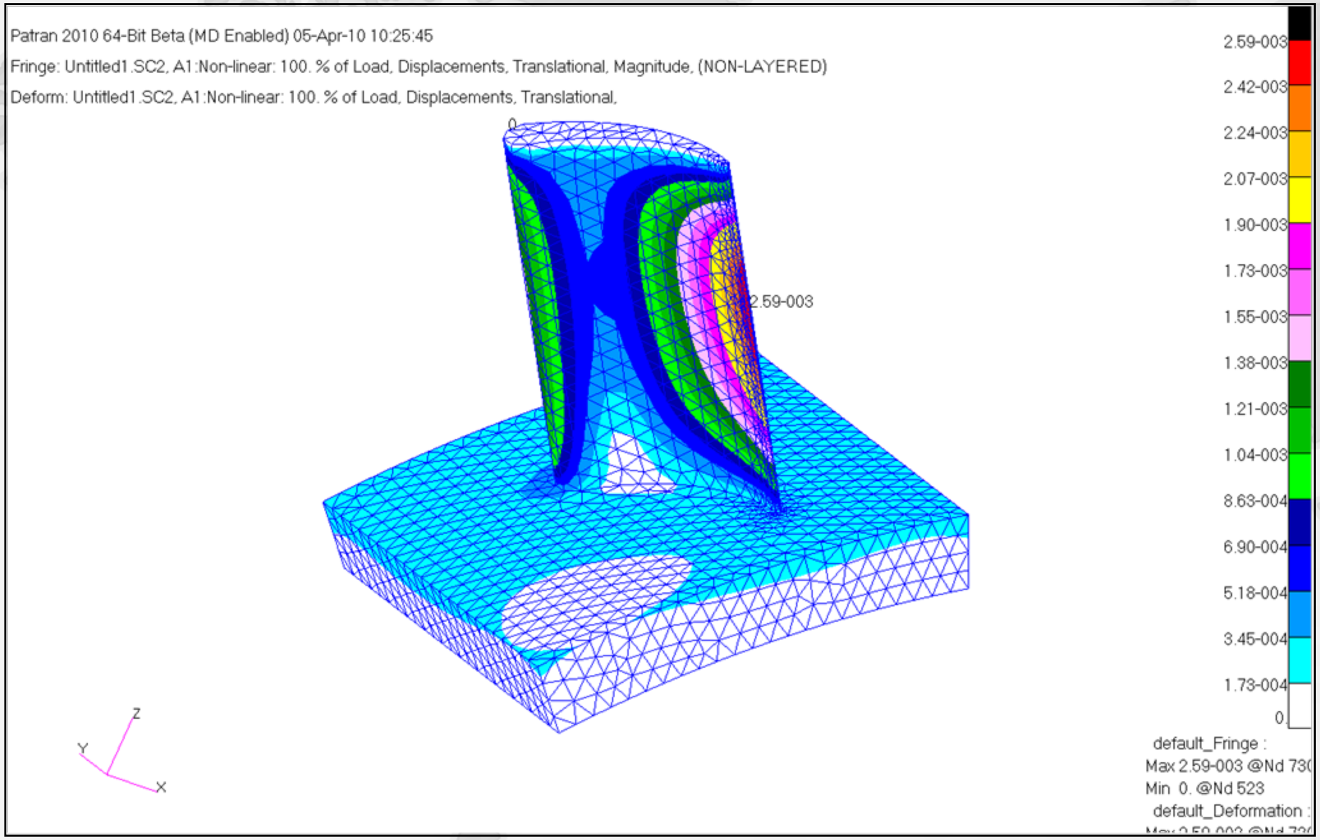


- **Structural model boundary conditions:**
  - Fixed on top of the blade
  - Fixed on the bottom of the base
  - Restart commands:

```
assign hrun='map_heat1.MASTER'
dbloc datablk=(heatdb) logi=hrun
```

- **Please note that for mesh mapping there is a parameter that you can control the interpolation between the coarse and fine mesh. In this case the default for NLMOPTS,MAPTOL is 0.2:**
-
- **This means that the box for the thermal mesh and structure mesh are within 20 percent.**
- **In this case, the MAPTOL tolerance is adjusted to 0.5, and then the interpolating from the coarse thermal - mesh temperature is now able to map to the fined structure mesh.**
- **nlmopts,maptol,0.5**

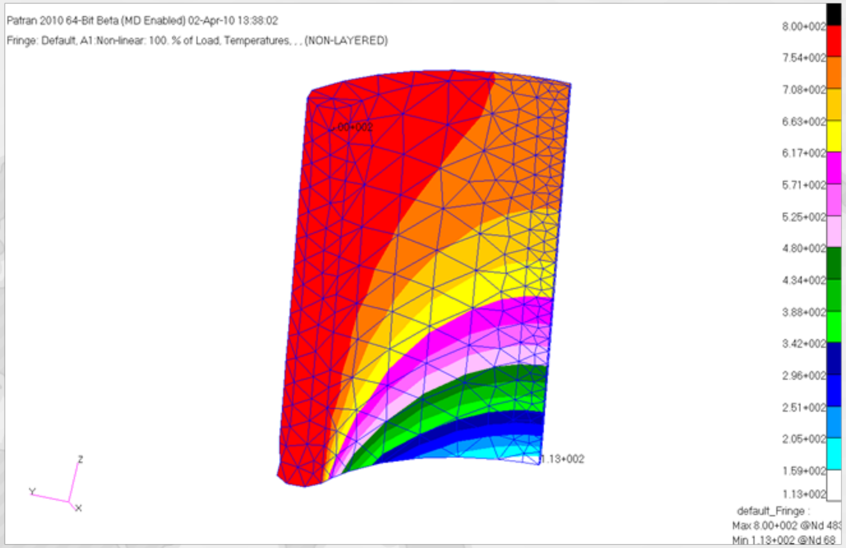
Mesh Mapping – Structure result



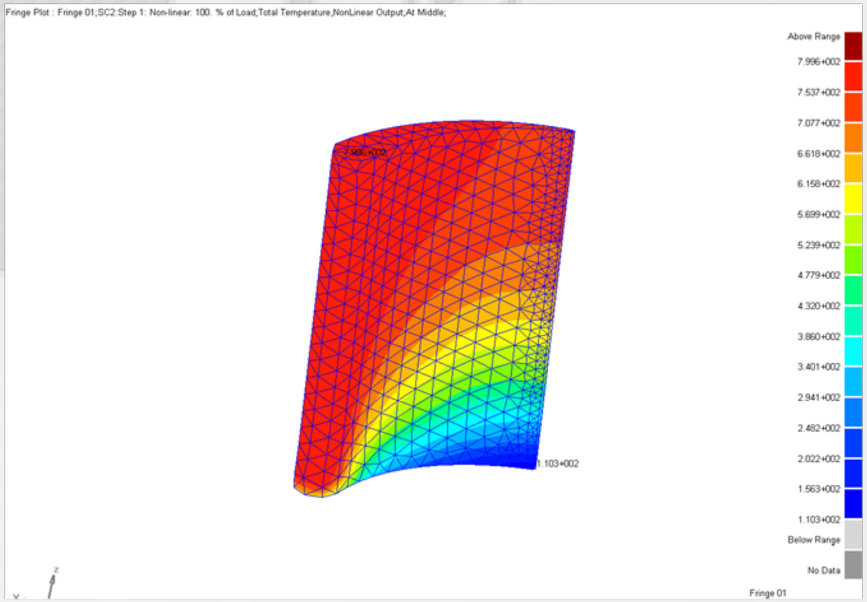
NASTRAN test deck:

Map_structure1b_m.dat

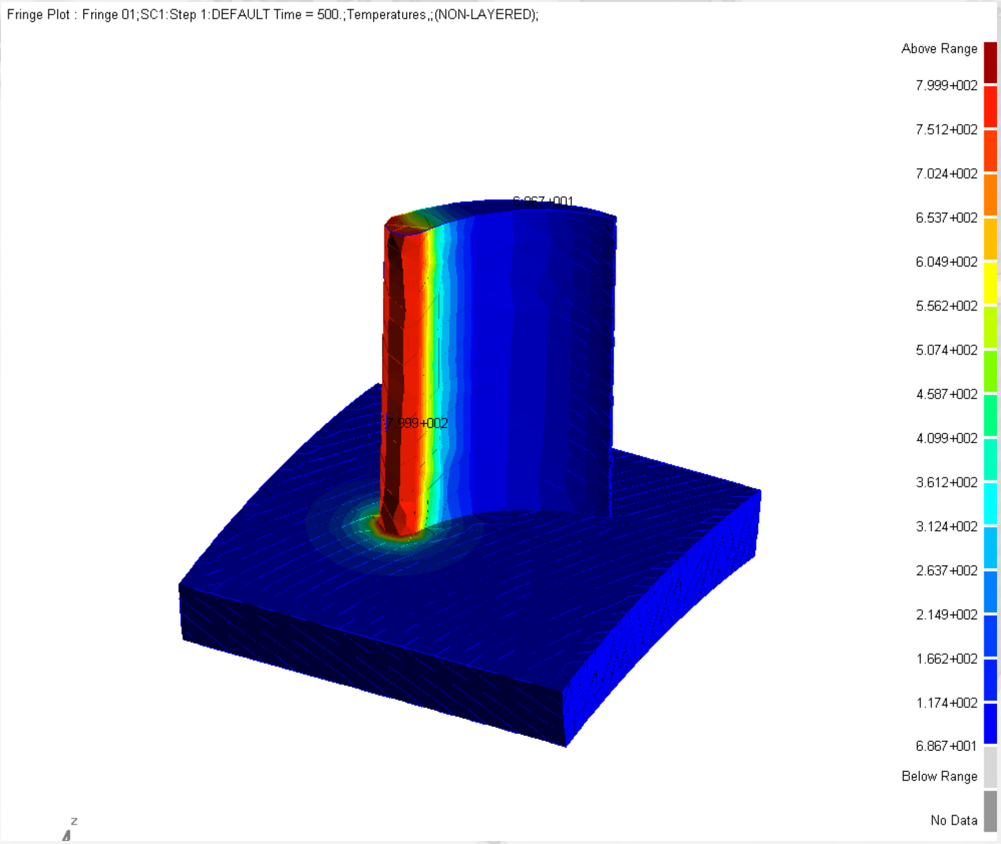
Mesh mapping – see the temperature on the interpolated mesh

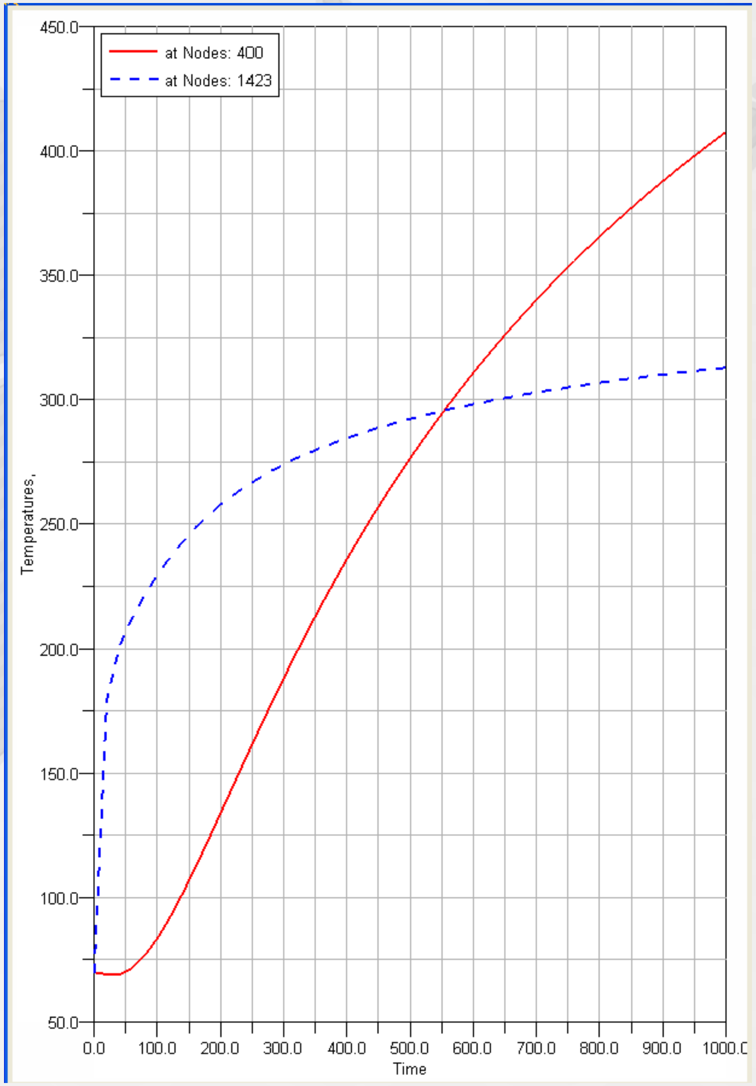


- Currently if you want to see the map temperature on the refine mesh , then we have to used the advance nonlinear element:
- PSOLID 1 1 0
- psldn1,1,1,,,ish
-
- Also we need to put
-
- nlstress(nlout=12)=all
- BEGIN BULK
- nlout,12,tottemp
-
- This will allow integration point temperatures to be available in the structural run also and can be post-processed. This capability is only available for advance nonlinear elements.



Mesh mapping in transient thermal analysis





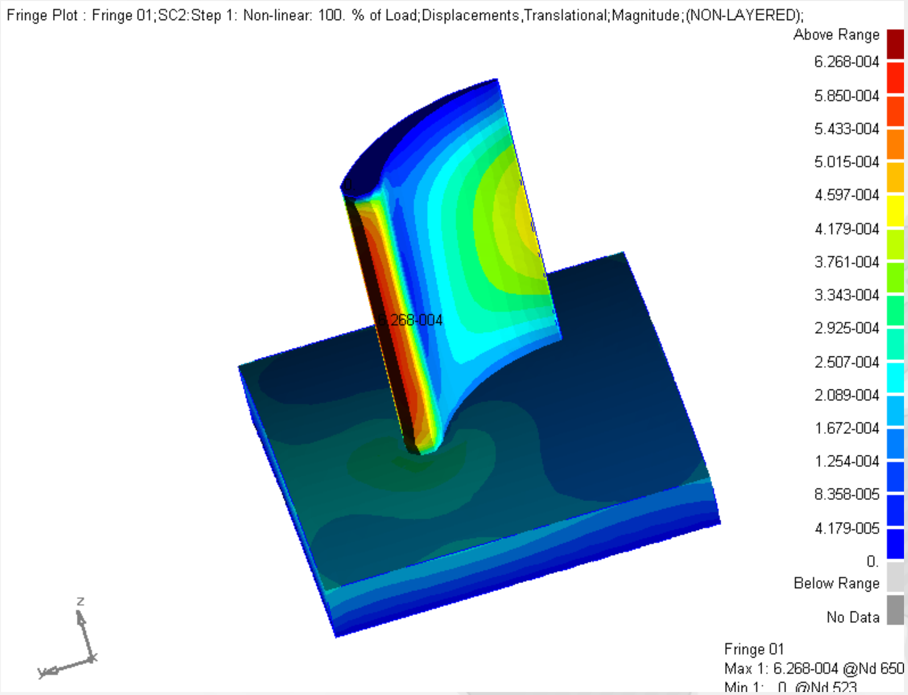
Tranheat.dat

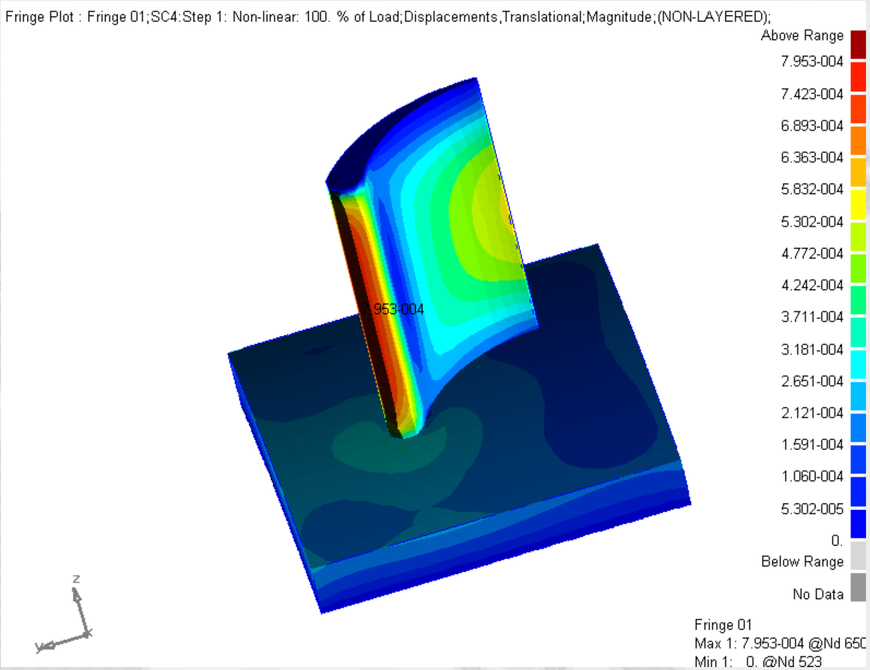
Mesh mapping in transient thermal run

```
assign hrun='tranheat.MASTER'
dbloc datablk=(heatdb) logi=hrun
NASTRAN system(316)=7
SOL 400
CEND
$ Direct Text Input for Global Case Control Data
TITLE = MD Nastran job created on 02-Apr-10 at 13:30:31
ECHO = NONE
SUBCASE 2
ANALYSIS=NLSTAT
  TITLE=This is a default subcase.
temp(load,hsub=1,htime=200.0)=9
  NLPARM = 1
  SPC = 2
DISPLACEMENT(SORT1,REAL)=ALL
  SPCFORCES(SORT1,REAL)=ALL
  STRESS(SORT1,REAL,VONMISES,BILIN)=ALL
nlstress(nlout=12)=all
SUBCASE 3
ANALYSIS=NLSTAT
  TITLE=This is a default subcase.
temp(load,hsub=1,htime=500.0)=11
  NLPARM = 1
  SPC = 2
  DISPLACEMENT(SORT1,REAL)=ALL
  SPCFORCES(SORT1,REAL)=ALL
  STRESS(SORT1,REAL,VONMISES,BILIN)=ALL
SUBCASE 4
ANALYSIS=NLSTAT
  TITLE=This is a default subcase.
temp(load,hsub=1,htime=610.0)=12
  NLPARM = 1
  SPC = 2
  DISPLACEMENT(SORT1,REAL)=ALL
  SPCFORCES(SORT1,REAL)=ALL
  STRESS(SORT1,REAL,VONMISES,BILIN)=ALL
nlstress(nlout=12)=all
$ Direct Text Input for this Subcase
BEGIN BULK
nlout,12,tottemp
nlmopts,maptol,0.5
```

WE want to run the thermal stress at time equals to 200,500, and 610 sec

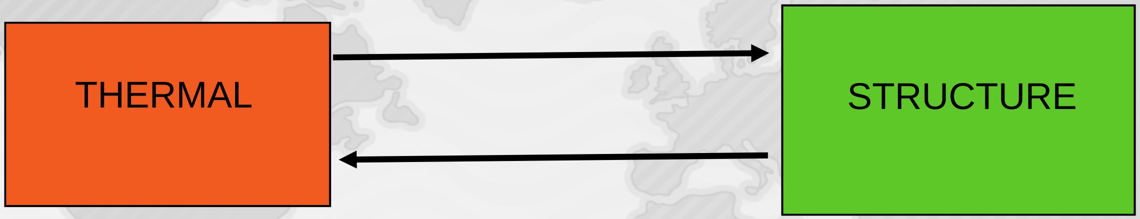
Displacement





Thermal displacement at time equals to 200 sec(left) and at time equals to 610 sec

Multi-Physics coupling



Bi-directional coupled thermal-mechanical analysis uses an increment-level staggered approach.

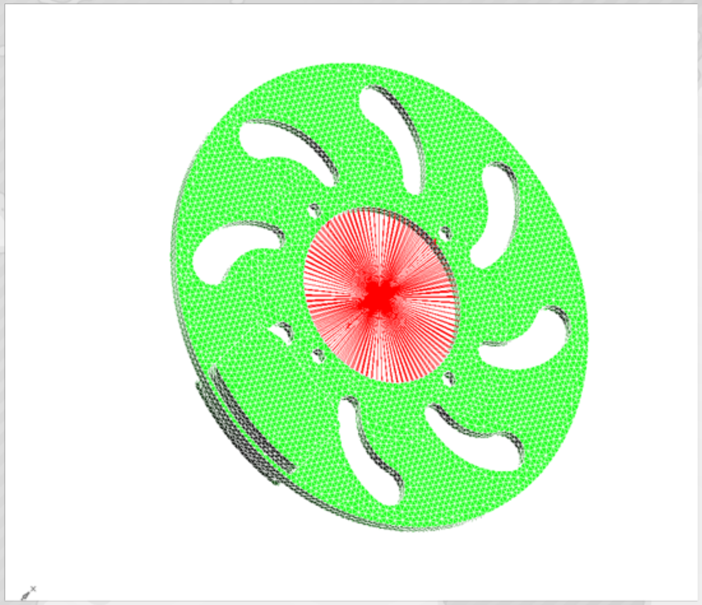
When the solution procedure moves on to a new sub-increment, relevant information from sub-increments (temperature, displacement, generated heat) is passed in. Regular Newton-Raphson iteration are conducted within each sub-increment until convergence is achieved.

Type of problems:

- 1) Thermal strains
- 2) Structure properties as a function of temperature
- 3)Thermal problems to be solved on updated geometry
- 4)Thermal loads due to plastic work
- 5) Thermal loads due to friction

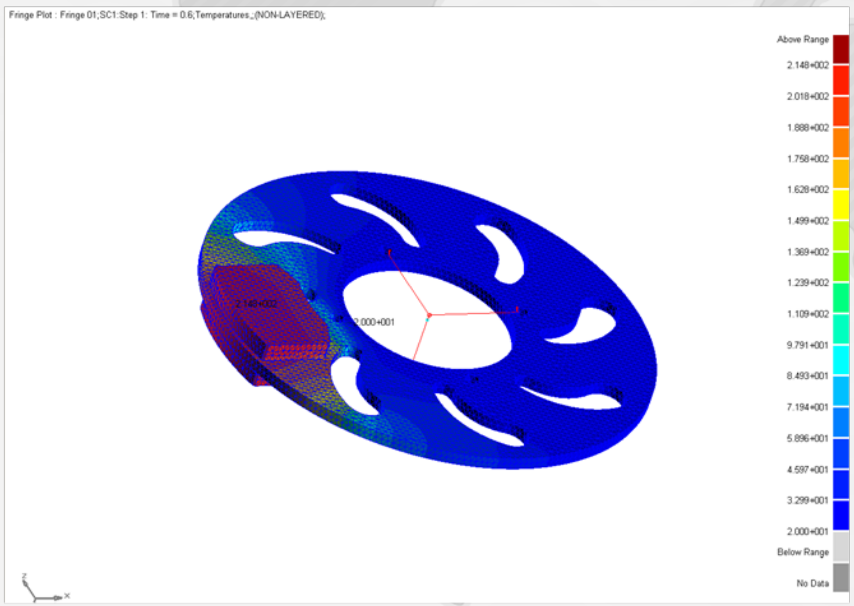
Coupled thermal and structure boundary conditions

- Enforced displacement on the disc in the z component at – 1.1 inch
- Rigid element at the center of disc
- Volumetric heating on the brake pad at 0.8 watt/inch**3
- Thermal structure contact between the 2 pad ,2 plate and the disc
- Enforced temperature of 20 degree C along the perimeter at the inner radius

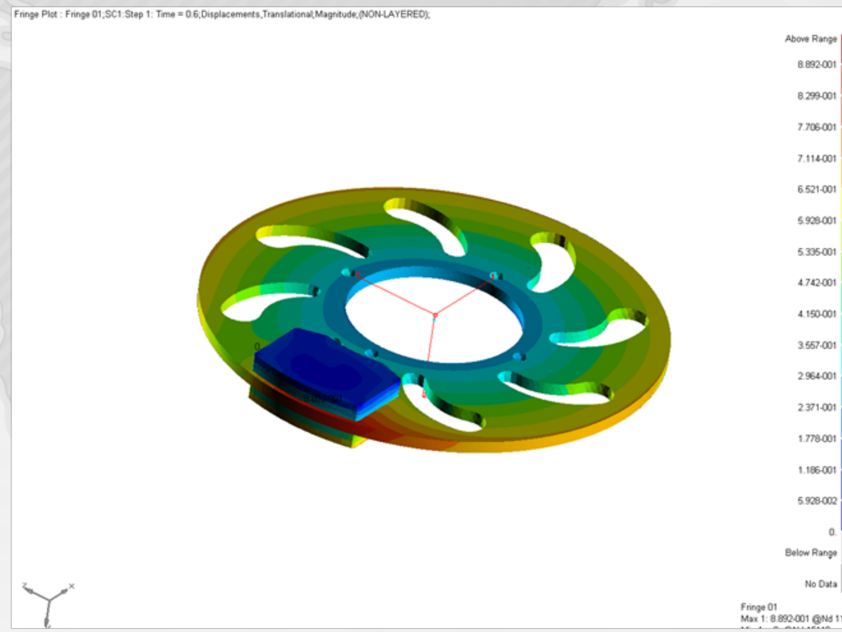


Coupled thermal structure analysis

Temperature contour



Displacement contour



Use of substeps for multi-physics

```
SOL 400
 CEND
ECHO = NONE
TEMP(INIT)=1
SUBCASE 1
STEP 1
NLSTEP=6
SUBSTEP 1
ANALYSIS=hstat
thermal=all
load=6
BCONTACT= 2
spc=8
SUBSTEP 2
ANALYSIS=nlstat
disp=all
spcf=all
spc=9
BCONTACT= 2
BEGIN BULK
NLSTEP,6,1.0
,GENERAL,10,1,10
,fixed,20,1
,HEAT,U,1.0E-2,1.0E-2,1.0E-2,AUTO
tempd,1,300.0
```

Analysis Type	Thermal	Structure
	HSTAT	NLSTAT
	HTRAN	NLTRAN

Typically the analysis is from nonlinear steady state thermal into nonlinear structure analysis or nonlinear transient thermal analysis into nonlinear structure analysis

NASTRAN test deck: brake2_mp1.dat

NLSTEP – ADAPT approach

1	2	3	4	5	6	7	8	9	10
NLSTEP	ID	TOTTIME							
	"GENERAL"	MAXITER	MINITER	MAXBIS	CREEP				
	"FIXED"	NINC	NO						
	"ADAPT"	DTINITF	DTMINF	DTMAXF	NDESIR	SFACT	INTOUT	NSMAX	
		IDAMP	DAMP	CRITTID	IPHYS	LIMTAR	RSMALL	RBIG	
		ADJUST	MSTEP	RB	UTOL				
	"ARCLN"	TYPE	DTINITFA	MINALR	MAXALR	SCALEA	NDESIR	NSMAXA	
	"HEAT"	CONVH	EPSUH	EPSPH	EPSWH	KMETHODH	KSTEPH		
		MAXQNH	MAXLSH	LSTOLH					

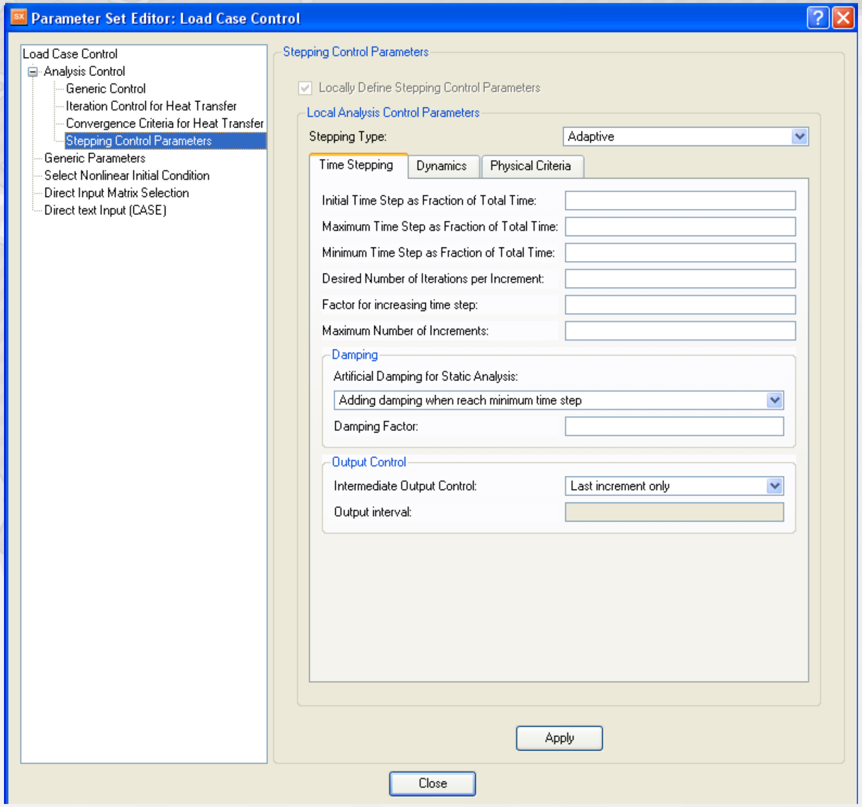
```
NLSTEP,6,1200.0
,GENERAL,10,1,10
,ADAPT,0.001,1.0E-5,0.5
,HEAT,U,1.0E-2,1.0E-2,1.0E-2,AUTO
```

NLSTEP advantage over the TSTEPNL

- **The adaptive approach in nonlinear transient thermal analysis can have an effect on runtimes by using 20x fewer iterations to reach end time.**
- **The user specifies Total time.**
  - For example if to run a transient thermal analysis to 1200 sec.

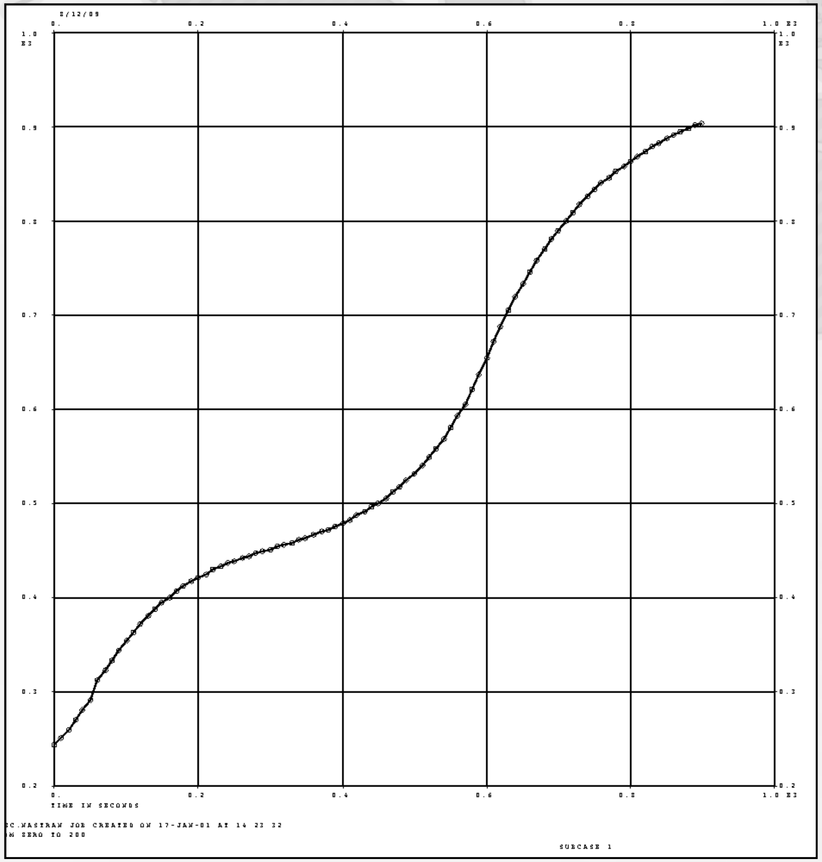
    NLSTEP,1,1200.0

    ,FIXED,50,1
  - The current technique is using 50 increments with fixed time step approach. Using ADAPT approach can be a significant benefit for large transient thermal analysis



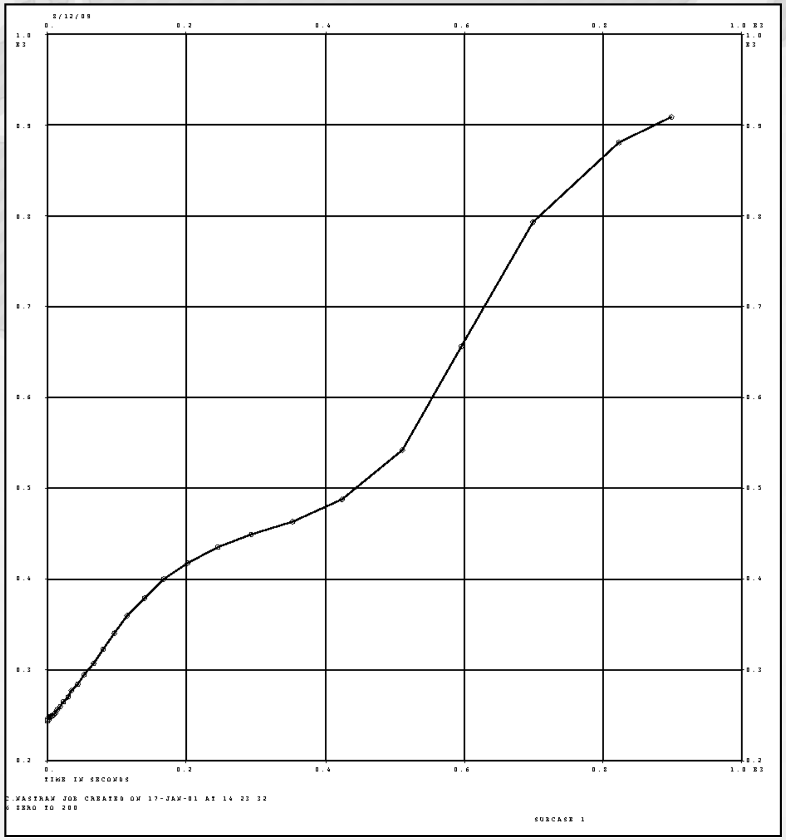
Number of steps is significantly reduced using the NLSTEP with ADAPT

TSTEPNL with ADAPT



1219 iterations

NLSTEP with ADAPT



63 iterations

NLSTEP bulk data entry

1	2	3	4	5	6	7	8	9	10
NLSTEP	ID	TOTTIME							
	"GENERAL"	MAXITER	MINITER	MAXBIS	CREEP				
	"FIXED"	NINC	NO						
	"ADAPT"	DTINITF	DTMINF	DTMAXF	NDESIR	SFACT	INTOUT	NSMAX	
		IDAMP	DAMP	CRITTID	IPHYS	LIMTAR	RSMALL	RBIG	
		ADJUST	MSTEP	RB	UTOL				
	"ARCLN"	TYPE	DTINITFA	MINALR	MAXALR	SCALEA	NDESIR	NSMAXA	
	"HEAT"	CONVH	EPSUH	EPSPH	EPSWH	KMETHODH	KSTEPH		
		MAXQNH	MAXLSH	LSTOLH					
	"MECH"	CONV	EPSU	EPSP	EPSW	KMETHOD	KSTEP	MRCONV	
		MAXQN	MAXLS	LSTOL	FSTRESS				

NLSTEP,6,1200.0

,GENERAL,10,1,10

,ADAPT,0.001,1.0E-5,0.5

,HEAT,U,1.0E-2,1.0E-2,1.0E-2,AUTO

NLSTEP,6,1200.0

,GENERAL,10,1,10

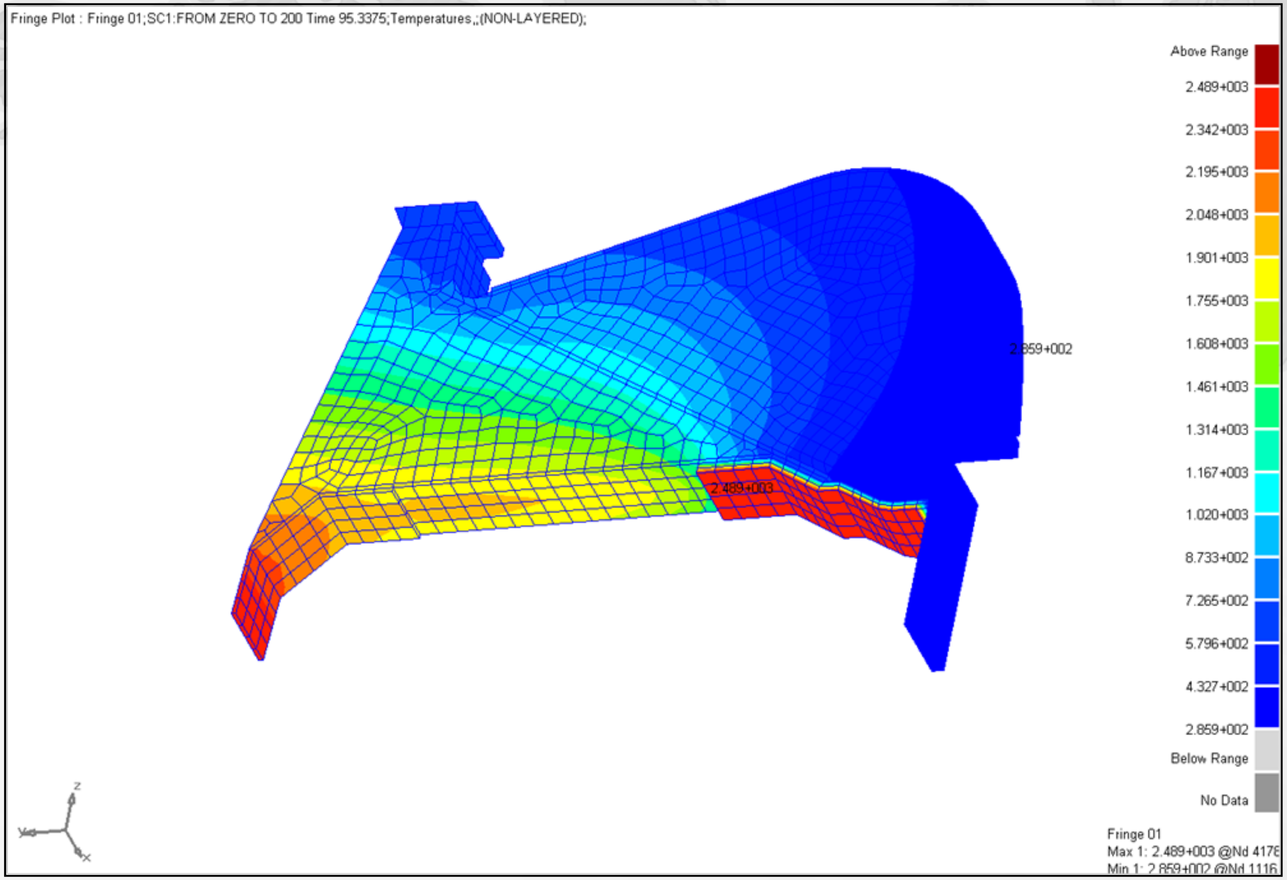
,ADAPT,0.001,1.0E-5,0.5, , ,12

,HEAT,U,1.0E-2,1.0E-2,1.0E-2,AUTO

The output will be at 1200 sec/ 12 = 100 sec

0,100,200,300 … 1200

Nonlinear transient thermal analysis of aircraft part subject to radiation thermal load



Thermal boundary conditions:

Fire source temperature: 2550°F

H(time) and heat sink is also a function of time.

Radiation to space from the part that exchange heat with ambient hot temperature .

Initial temperature is at 245°F.

Total analysis time is 900 sec.

NLSTEP test deck: flight_spcd_nlstep_900.dat

H(time)

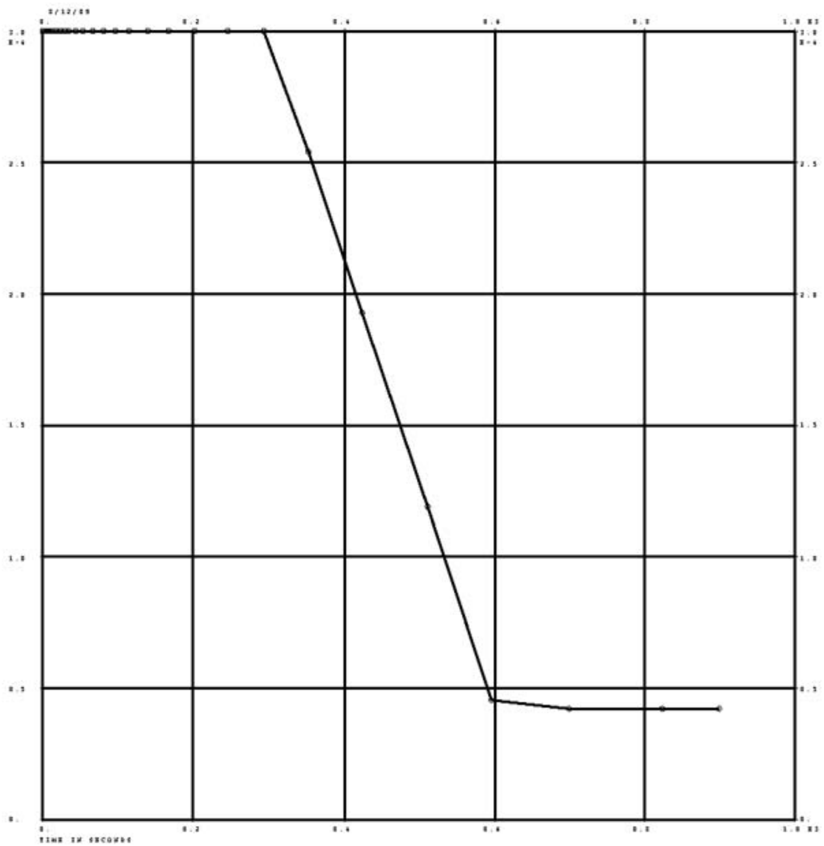


Figure 5: Convection coefficient as a function of time (NLSTEP)

As you can see that the adaptive scheme actually captured the variation very accurately.

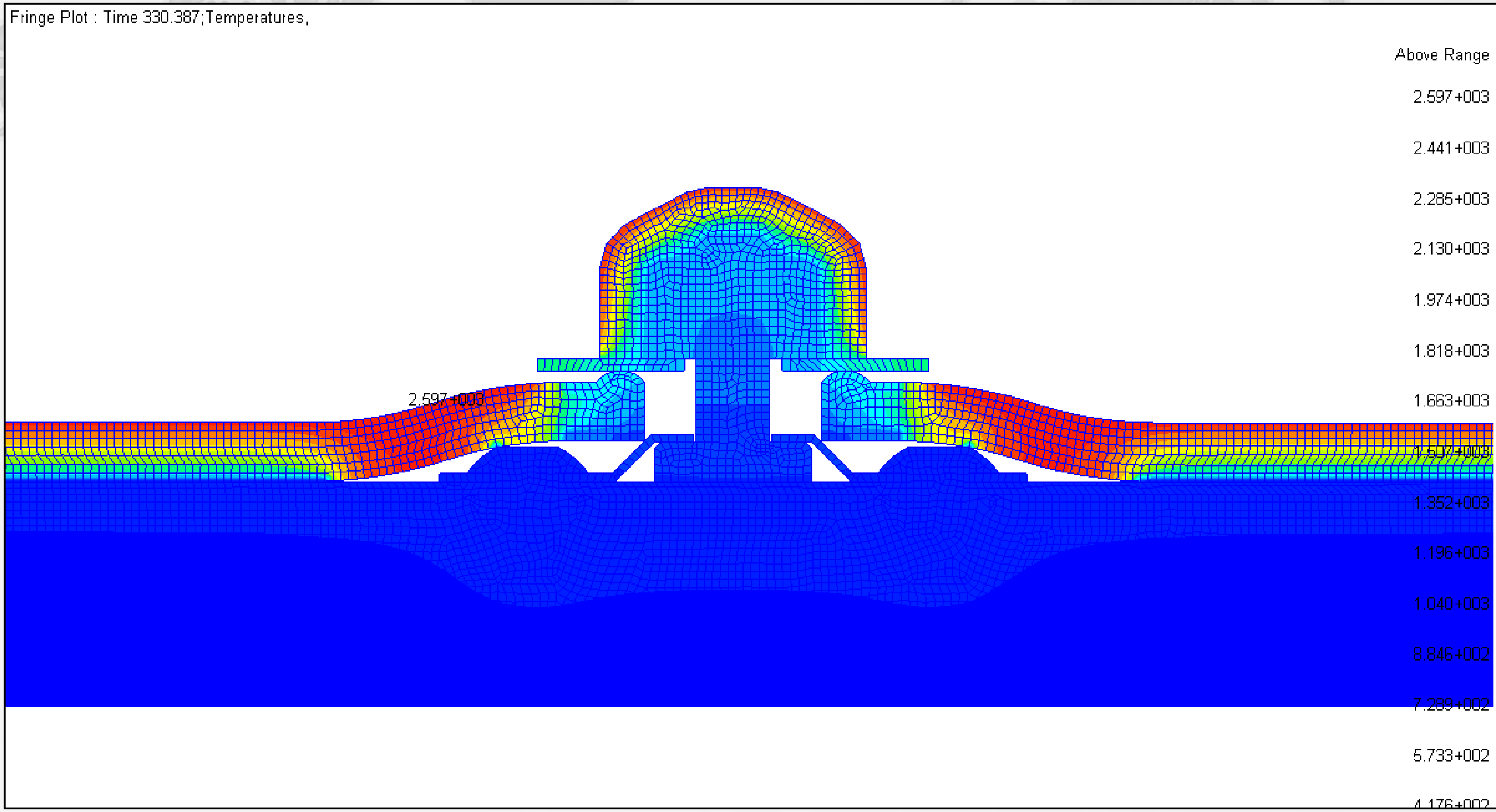
TABLED1 8

0. 3.-4 300. 3.-4 600. 4.24-5 900. 4.24-5

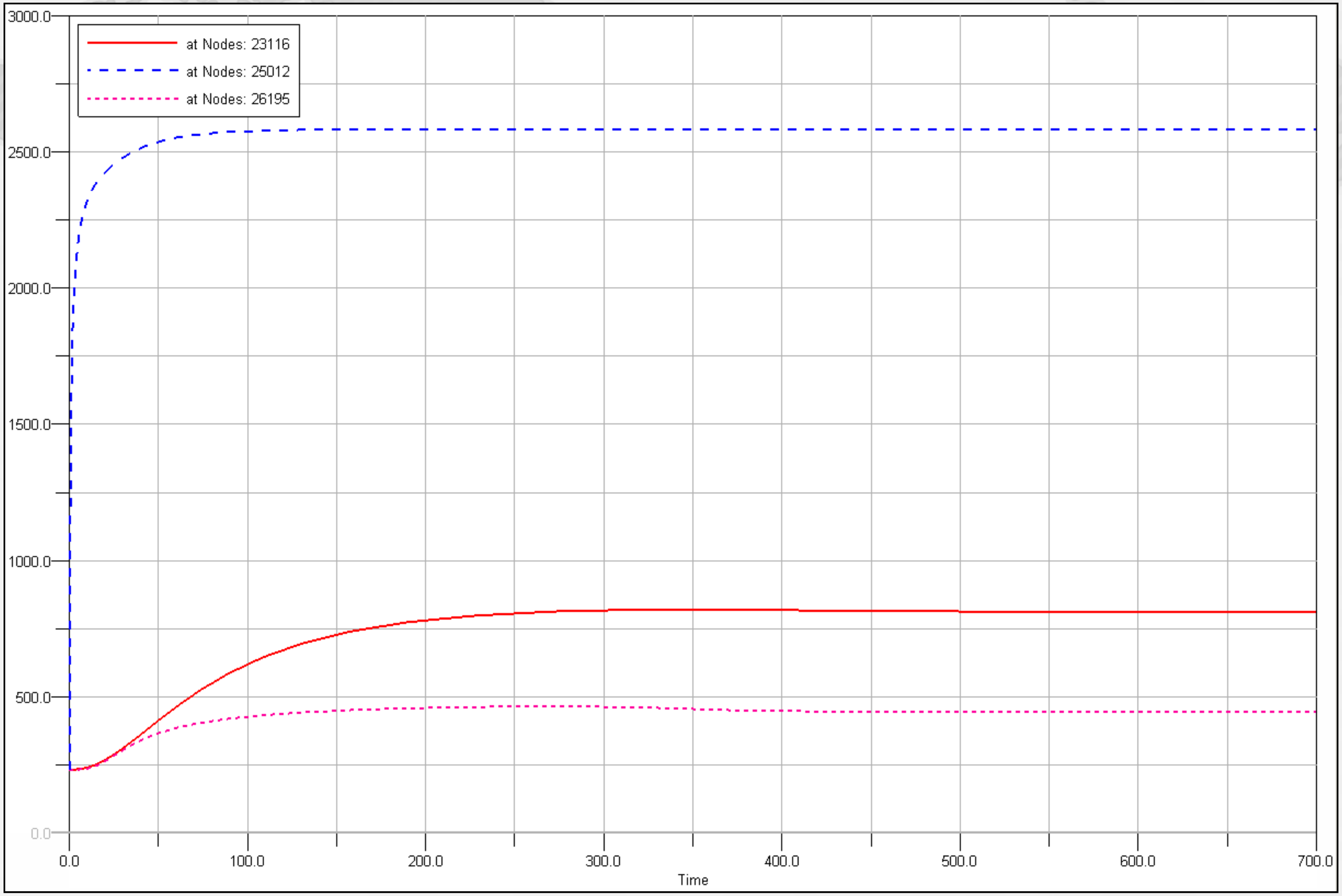
ENDT

The time stepping occurs on 293.6 and at 596.5 sec where in fact it is at 300.0 and 600 sec that we specified the change.

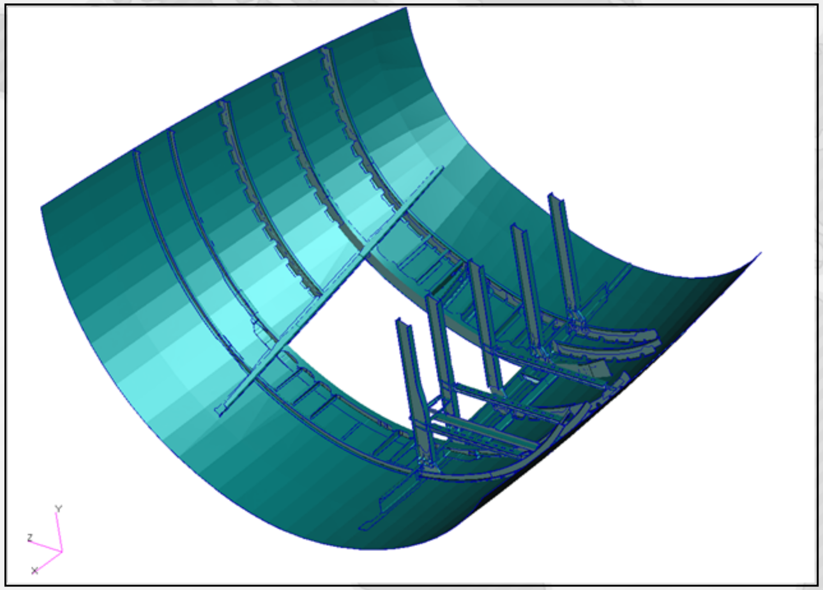
Transient thermal analysis



Temp versus time plot



NLSTEP with ADAPT option



This type of model required the use of radiation to space to a time varying temperature boundary conditions, thermal contact, convection coefficient as a function of time, ambient temperature as a function of time, and temperature dependent thermal conductivity.

The client is currently using SOL 159 for this type analysis. Recently the sent in this model, which was then run using SOL 400 using analysis=HTRAN

	Cpu time	Speed gain
SOL 159	1.622 hours	1.0
SOL 400	0.8 hours	2.0 times faster

NLSTEP,6,1200.0

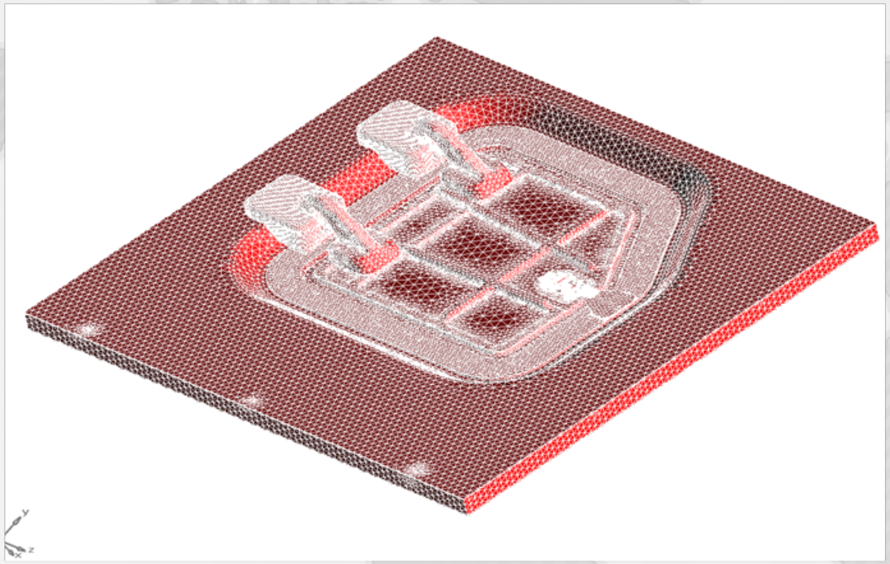
,ADAPT,0.001,1.0E-5,0.5

,HEAT,U,1.0E-2,1.0E-2,1.0E-2,AUTO

Reflection method

- **Let us define the radiation matrix in the thermal user guide App F 6-29:**
  - R=sigma*{A*eps-A*alpha*[A-F*(I-alpha)]$^{-1}$*F*eps}
- **The reflection matrix is**
  - [A-F*(I-alpha)]$^{-1}$
- **This reflection matrix is costly since it involves the factorization of a dense matrix.**
- **In MDR3 version of SOL 400, we can set the 8th field on the NLMOPTS to 1 to activate the explicit treatment of reflection matrix.**
- **In this procedure, the radiation exchange matrix constructed to be:**
  - R=sigma*{A*eps-A*alpha*F*eps}
- **Note that the expensive reflection term is absent. This reduced form of the radiation exchange matrix is added to the stiffness matrix. Since the reflection matrix is never calculated and factorized , the calculation of the radiation exchange matrix is significantly cheaper.**

Reflection matrix example

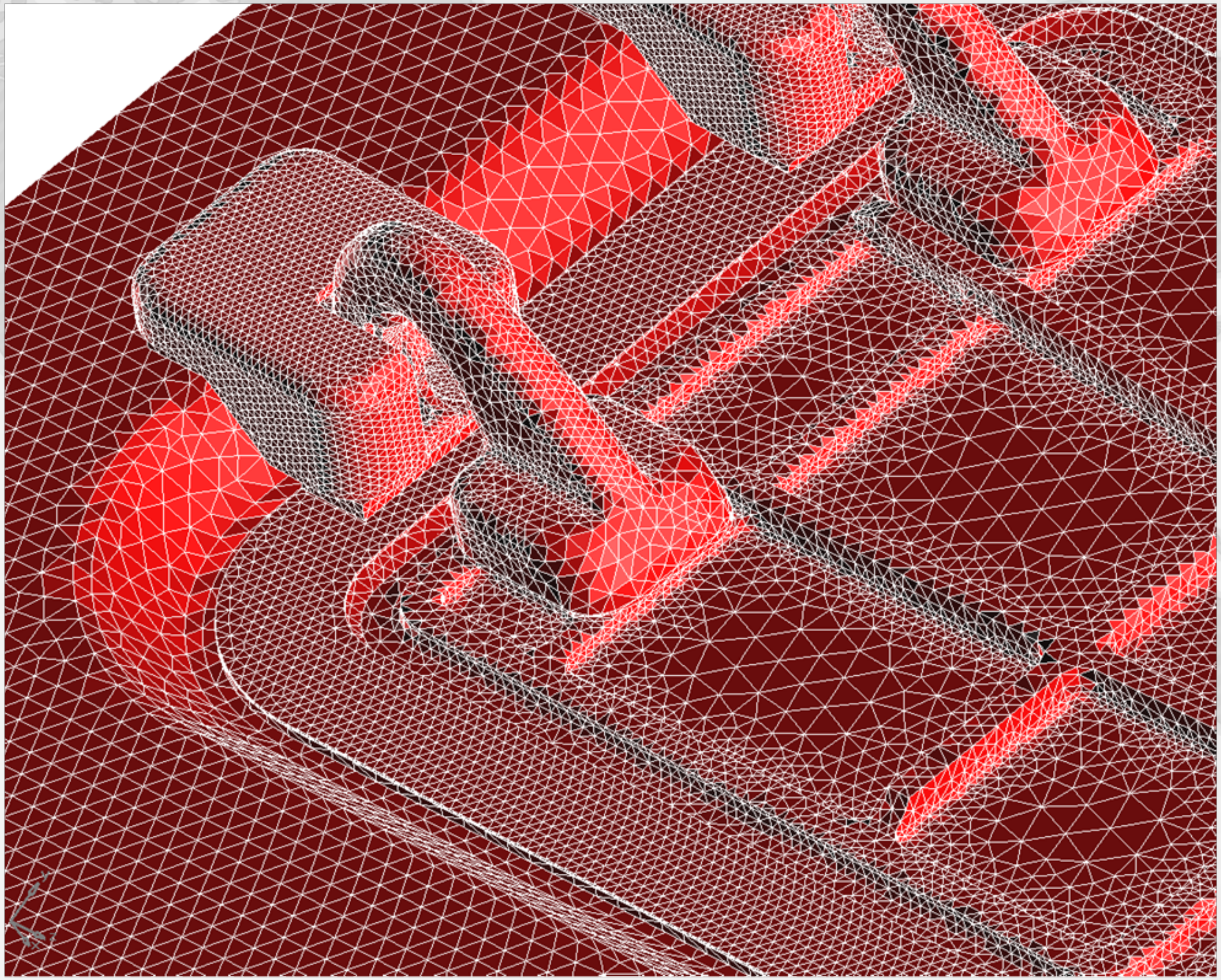


For the flux calculation, an iterative procedure is used based on iterating simultaneously satisfying both Poljak equations in the *MSC Nastran Ther* 6-11 and 6-12, respectively.

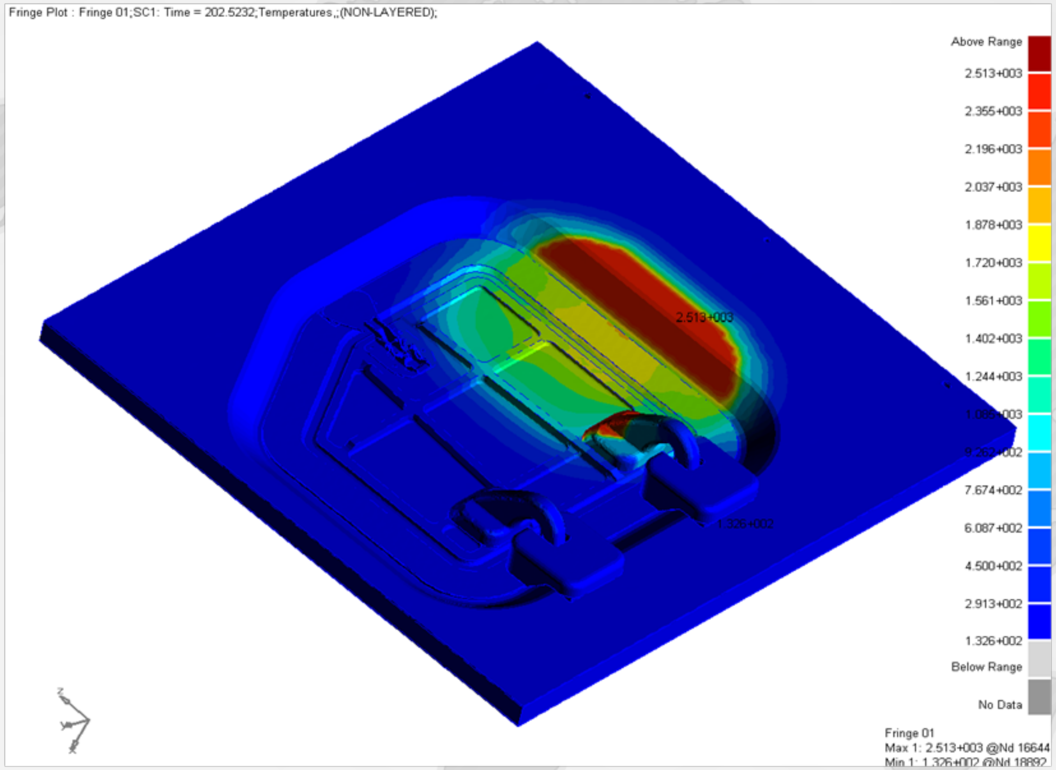
$$A\{q\}_e^{IN} = [F]\{q\}_e^{OUT}$$

$$\{q\}_e^{OUT} = \sigma[\varepsilon]\{u_e\}^4 + [I - \varepsilon]\{q\}_e^{IN}$$

Reflection example



Reflection example

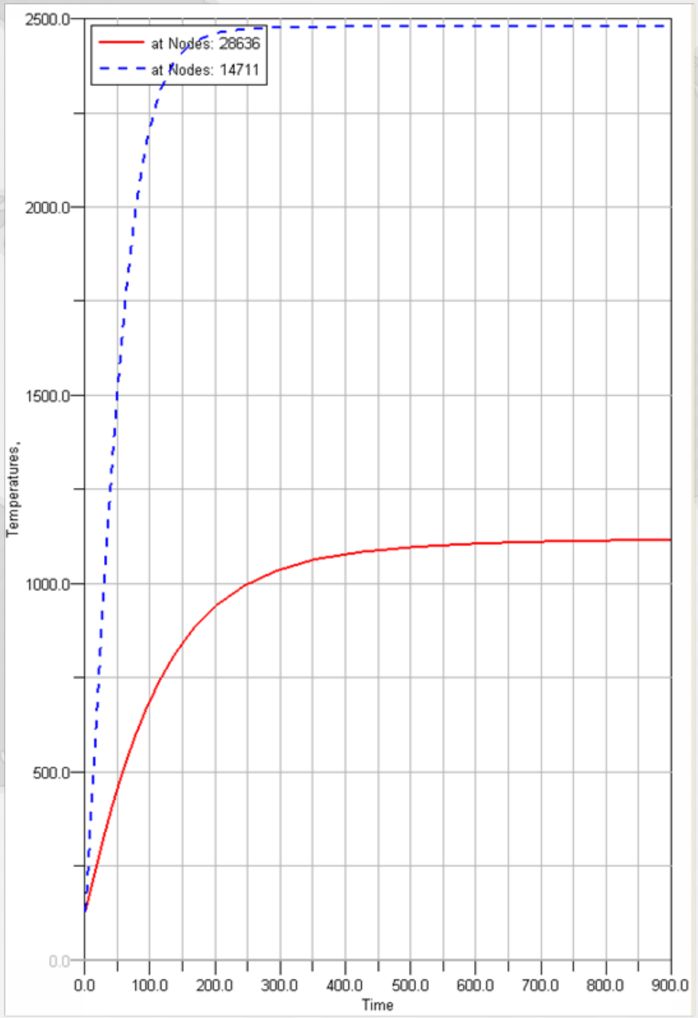


155158:CHBDYG
48:CHBDYP 162585:CONV
69:CROD 400845:CTETRA
113969:GRID

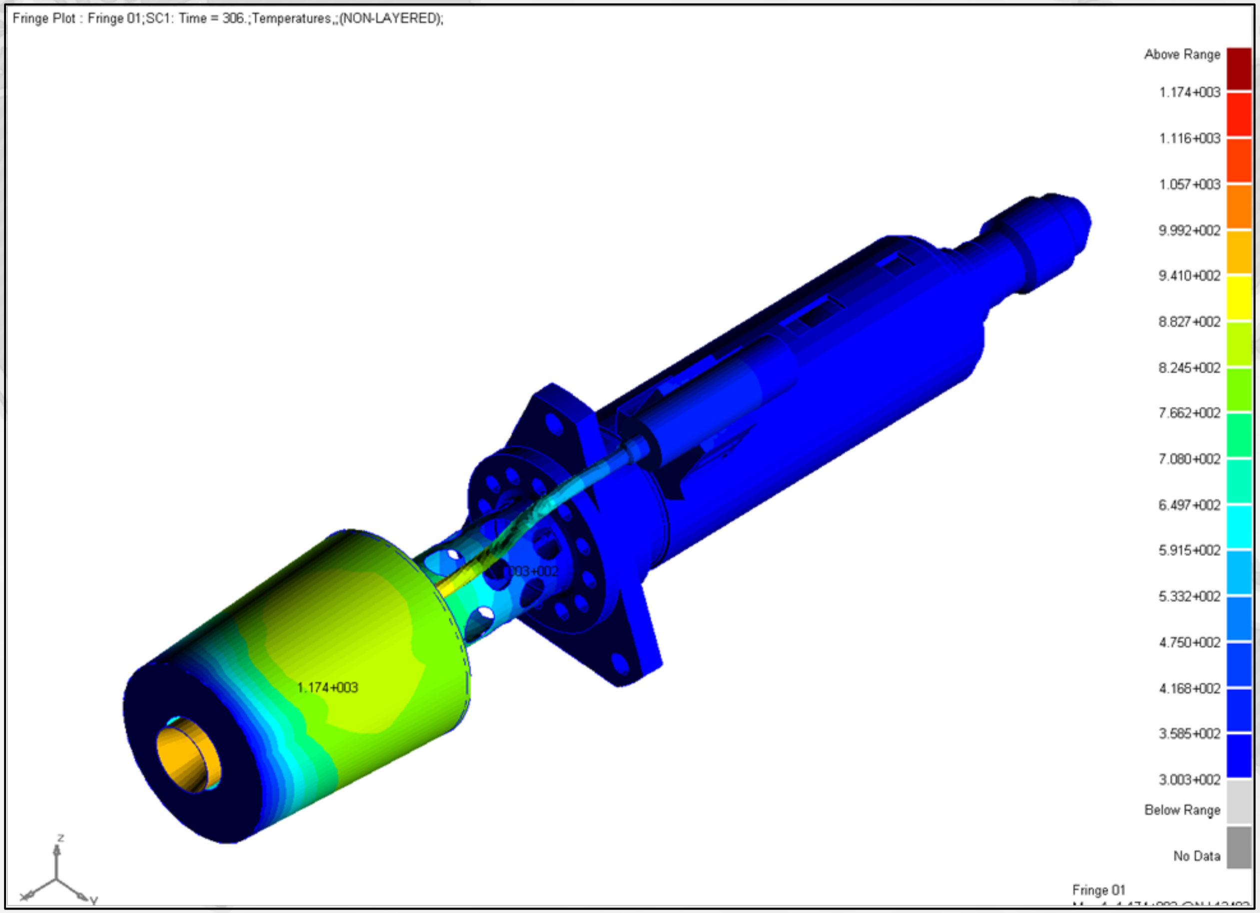
* 16:MAT4
10:MATT4 1:NLMOPTS
70947:RADBC
2:RADCAV 4:RADM

Test deck	Reflection	No reflection	Performance gain
Otad_400.dat	3200 sec	32446 sec	10 times

Reflection transient thermal run



Large nonlinear transient thermal run

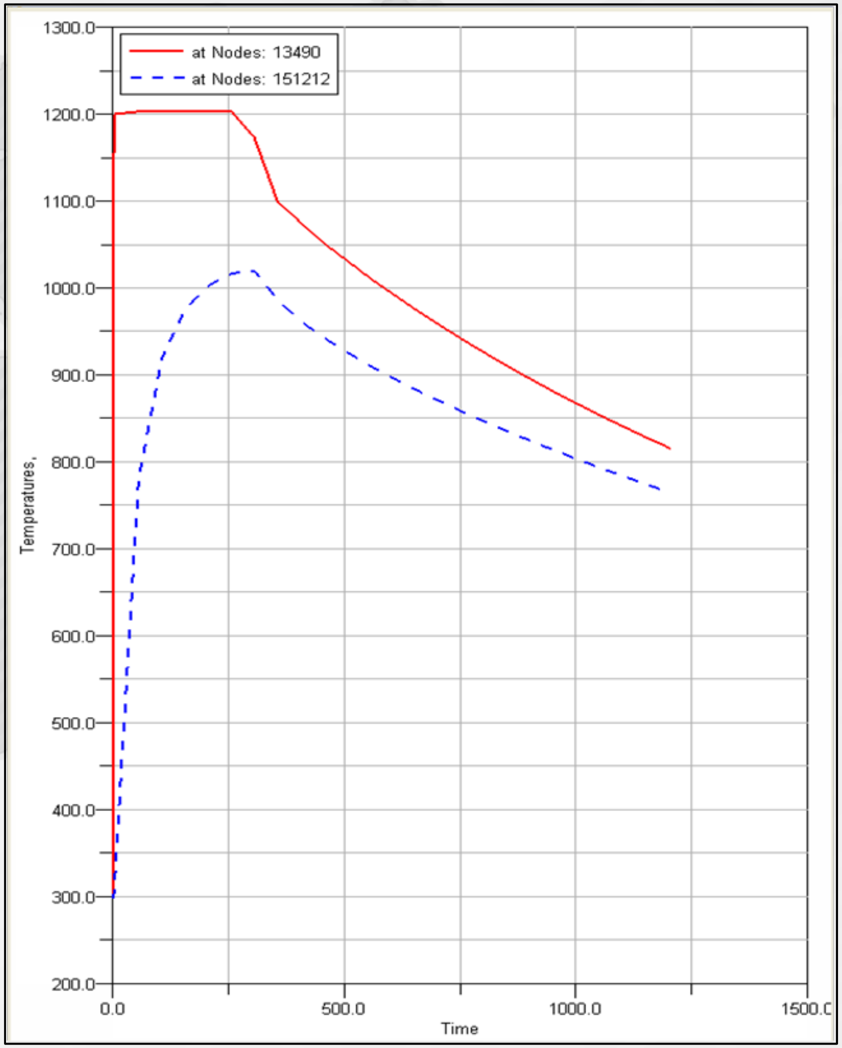


Thermal boundary conditions:

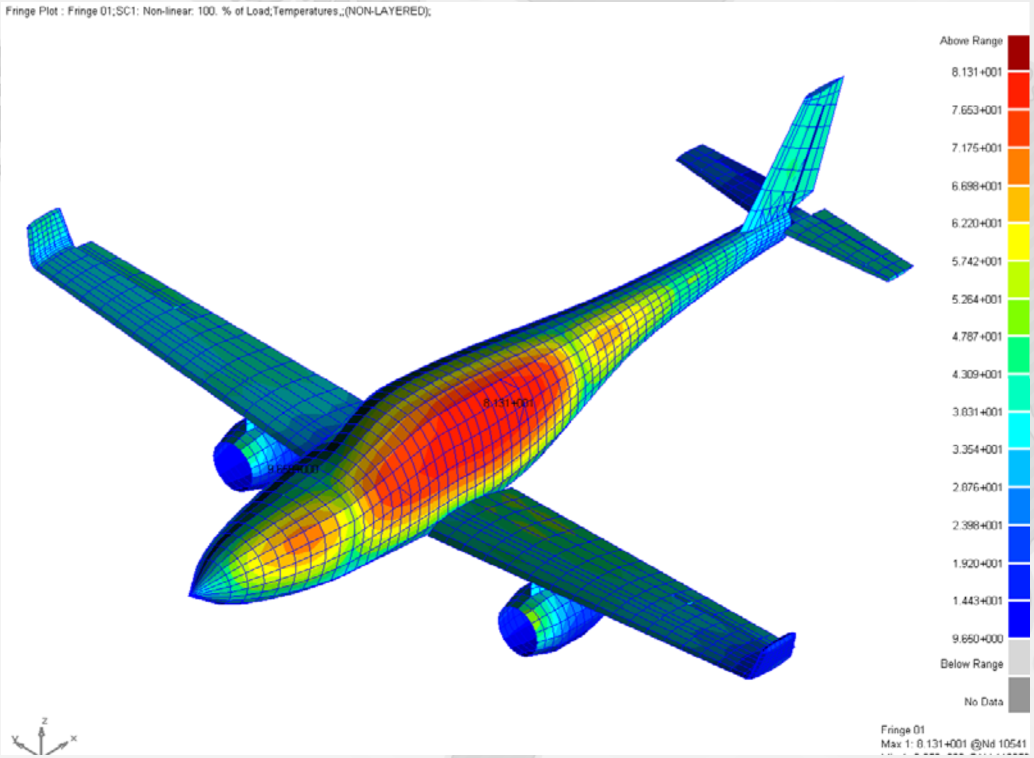
The next model is a large transient thermal model that consist of plate, solid, and rod elements.

Thermal boundary conditions:

- Mass flow rate in the tube as a function of time.
- Volumetric heat generation of heaters.
- Radiation to space at 298K.
- Coupled convection between parts.
- Convection to a hot source at 1220K from time zero to 300 sec.

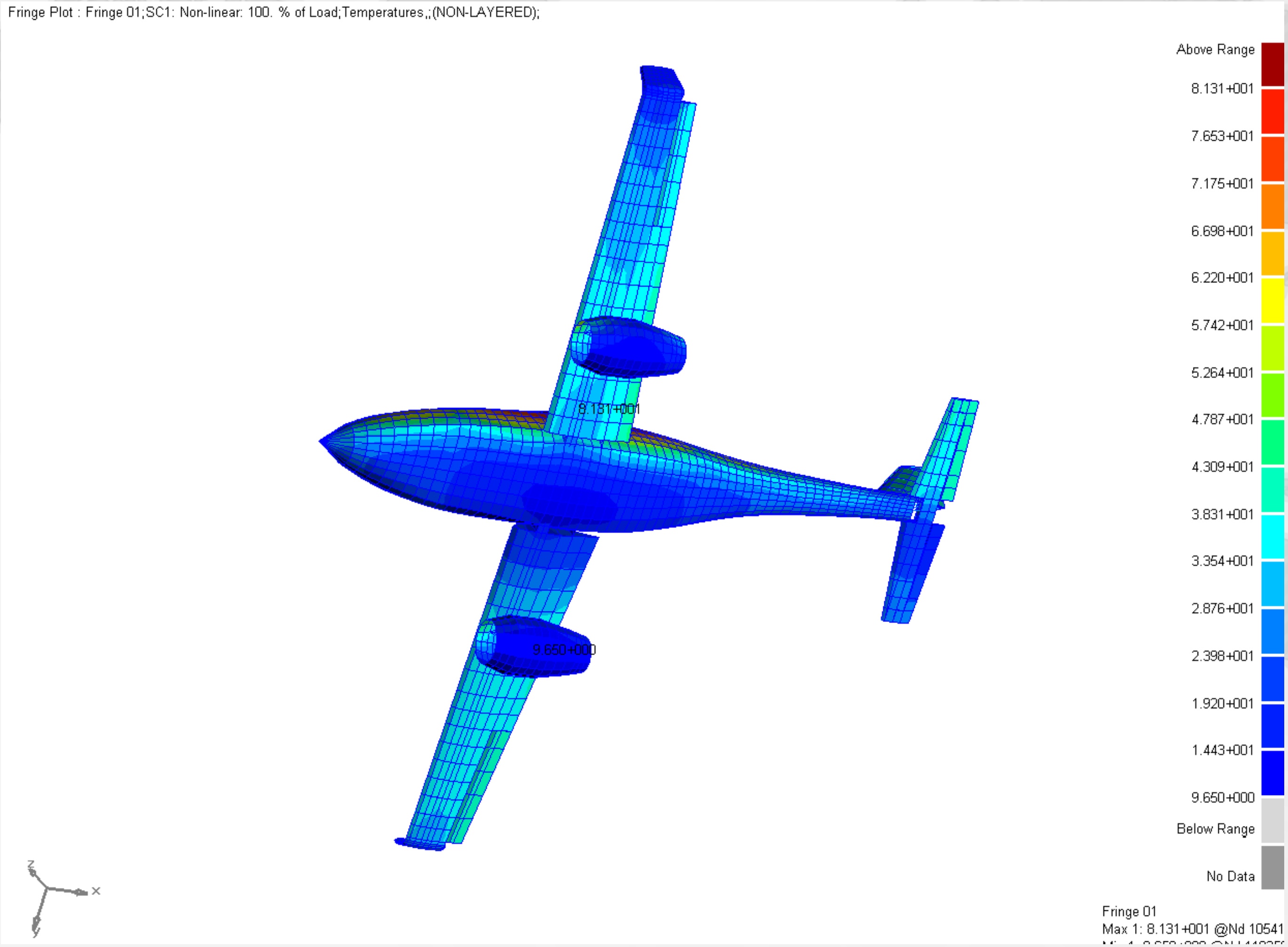


Solar heating on the aircraft

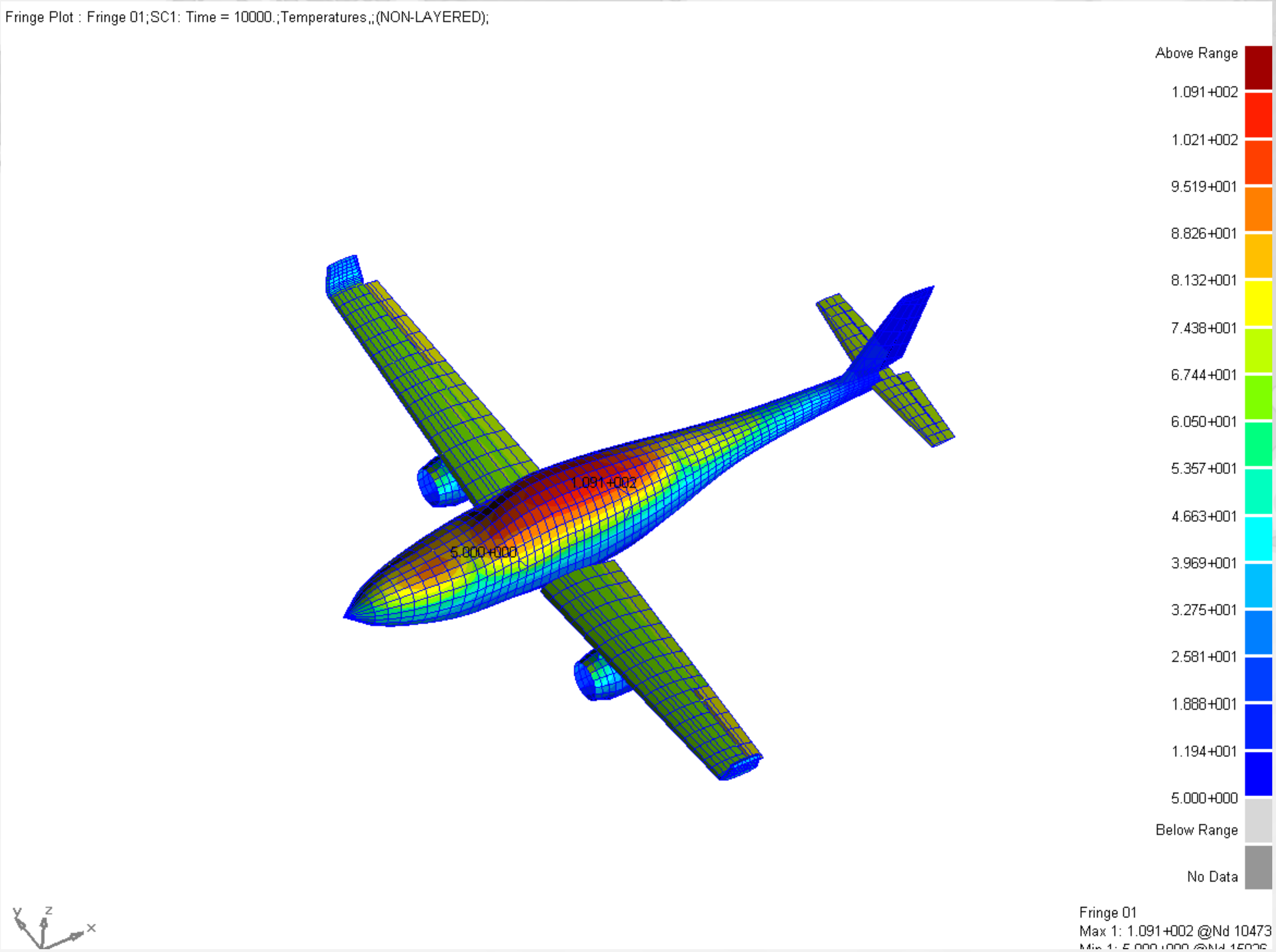


- NASTRAN test deck:air_45c.dat
- Directional heat load comes at 45 degree (0,1,-1) with solar flux equals to 0.48387 watt/in2
- View factor for all the exposed surfaces ,and the lost radiation goes to 5 degree C ambient

Solar heat load on aircraft

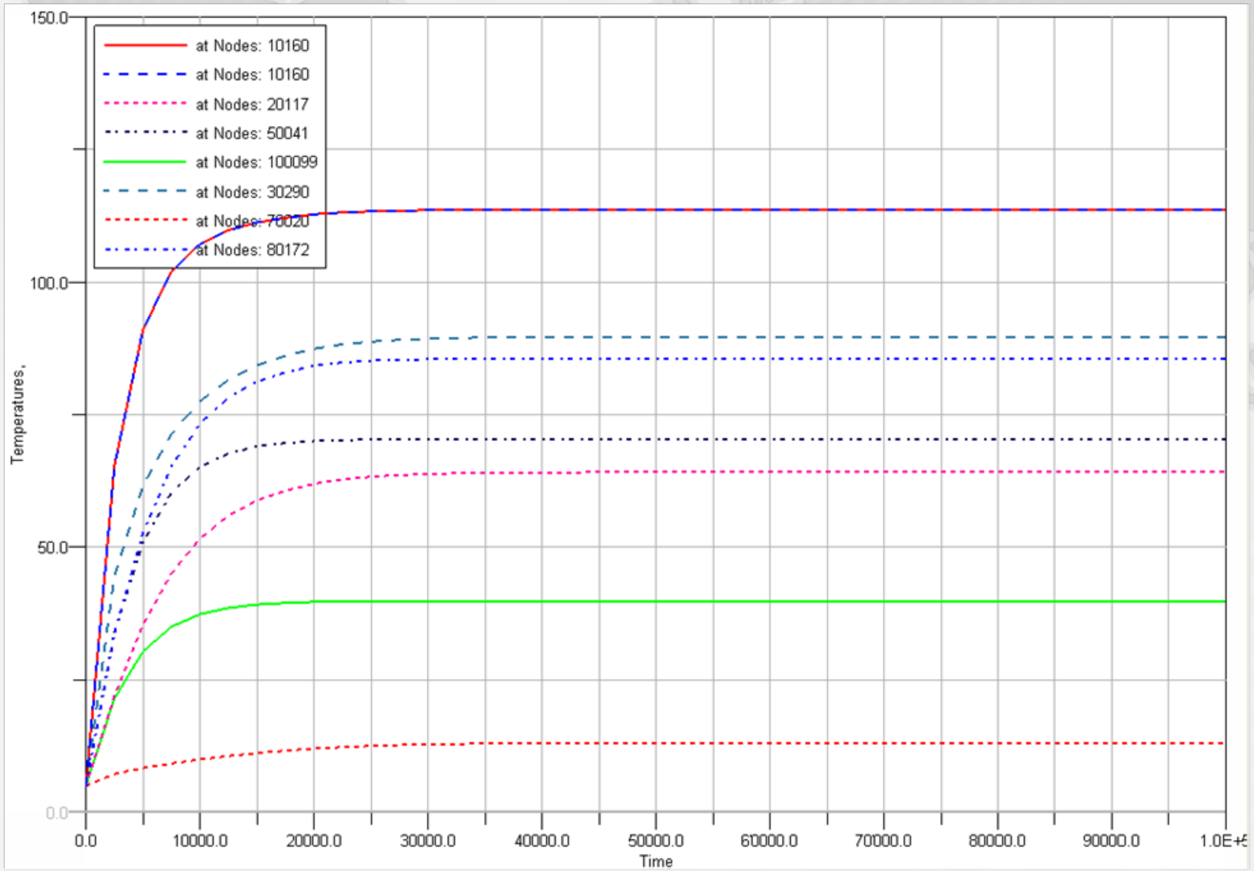


Transient thermal with solar heating on aircraft



Thermal boundary conditions

- Solar heating with 0.48387 watt/in2 coming in the –z direction
- Radiation to space to 5 degree C with view factor equals to 0.5



Performance improvement of MD2010 in SOL 400

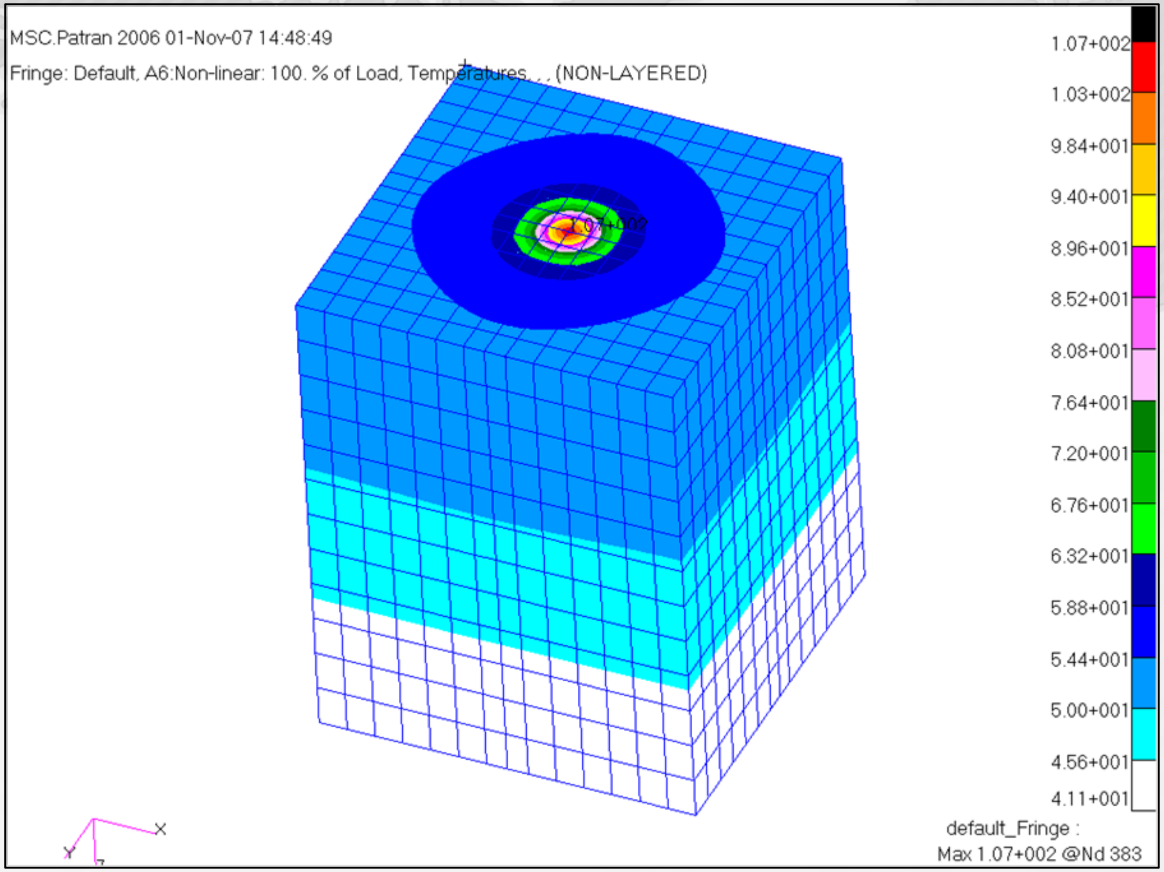
- **Client sees the benefit of CPU performance:**
  - NLSTEP with ADAPT – speed increase by a factor of 2.(example 1)
  - Reflection matrix in radiation decomposition – factor of 10 (example 2)
  - Hemi-cube view factor calculations – 10 to 30 times faster as compared with Gaussian integration method

Ease of Use:

- **Ease of use:**
  1. Thermal contact to join dissimilar mesh
  2. NLSTEP with ADAPT option – the initial time step was critical to reached convergence in nonlinear thermal analysis, In SOL 159 many nonlinear problem had to use the fix time steps. The adaptive time steps removed the guessing game of what is the best time step to used in my problem. Additionally the adaptive approach reduced the total solution time, and it offer an option to output even intervals in time.
  3. The multi-physics run from analysis=HTRAN into analysis=NLSTAT allows the user to compute the thermal stress at every time increment as specified by the NLSTEP option. The user no longer had to save the punched temperature output and manually do the temp(load)=x for every time increment.
     - This is a time saving feature
  4. Mapping from coarse thermal mesh into fine structure mesh using restart or vice versa. Previously in PATRAN once has to create a field that represent the temperature and then extrapolate this field to a different mesh model.(very tedious and time consuming)

3D composite heat transfer element

Test deck:
bench_3d_layer_176.dat



composite group number 1

number of layers 12

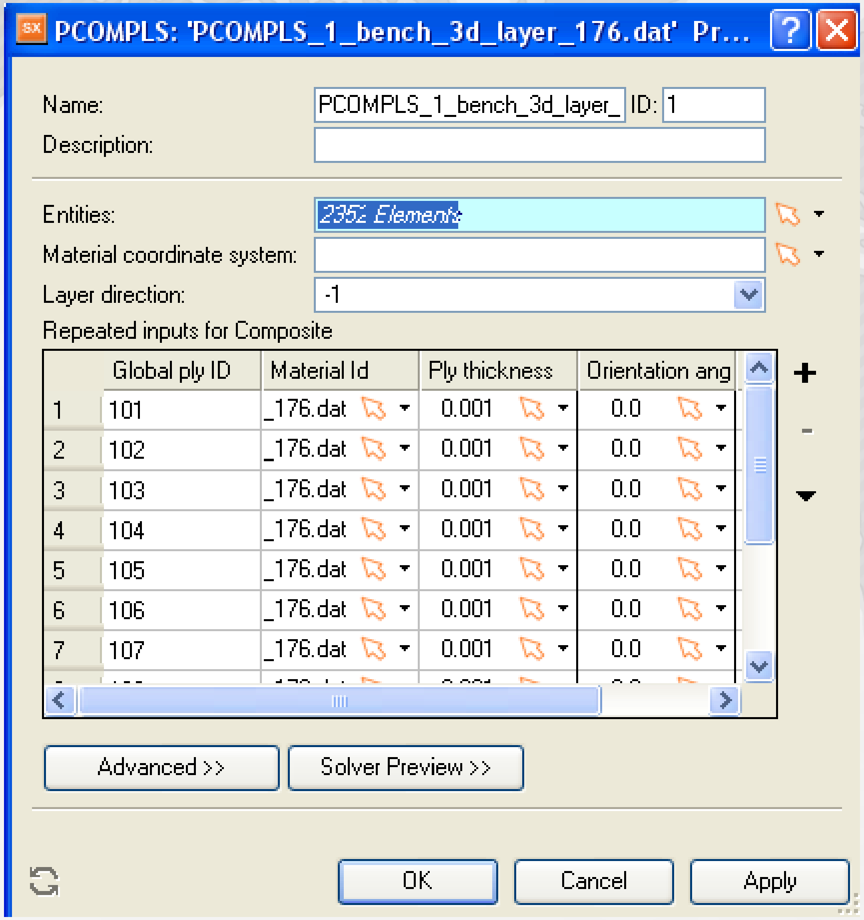
solid composite layer direction -1

allowable interlaminar bond shear stress 0.0000

actual layer thickness is given below

layer	layer id	mat id	thickness	ply angle
1	112	1	1.000E-03	0.000E+00
2	111	1	1.000E-03	0.000E+00
3	110	1	1.000E-03	0.000E+00
4	109	1	1.000E-03	0.000E+00
5	108	1	1.000E-03	0.000E+00
6	107	1	1.000E-03	0.000E+00
7	106	1	1.000E-03	0.000E+00
8	105	1	1.000E-03	0.000E+00
9	104	1	1.000E-03	0.000E+00
10	103	1	1.000E-03	0.000E+00
11	102	1	1.000E-03	0.000E+00
12	101	1	1.000E-03	0.000E+00

3D composite solid(Solid composite)



pcompls,1,-1,,,ih

,c20,,,slco,q

,101,1,0.001

,102,1,0.001

,103,1,0.001

,104,1,0.001

,105,1,0.001

,106,1,0.001

,107,1,0.001

,108,1,0.001

,109,1,0.001

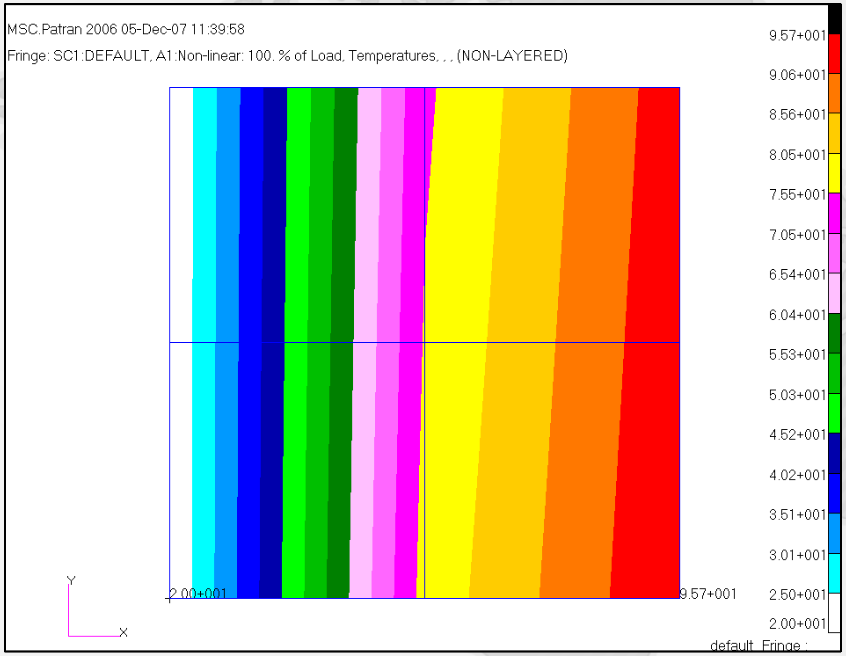
,110,1,0.001

,111,1,0.001

,112,1,0.001

2D composite heat transfer

2d_composite_web_rev.bdf



Boundary conditions:

Heat flux of 50 Btu/hr/inch^2 impose on the top surface.

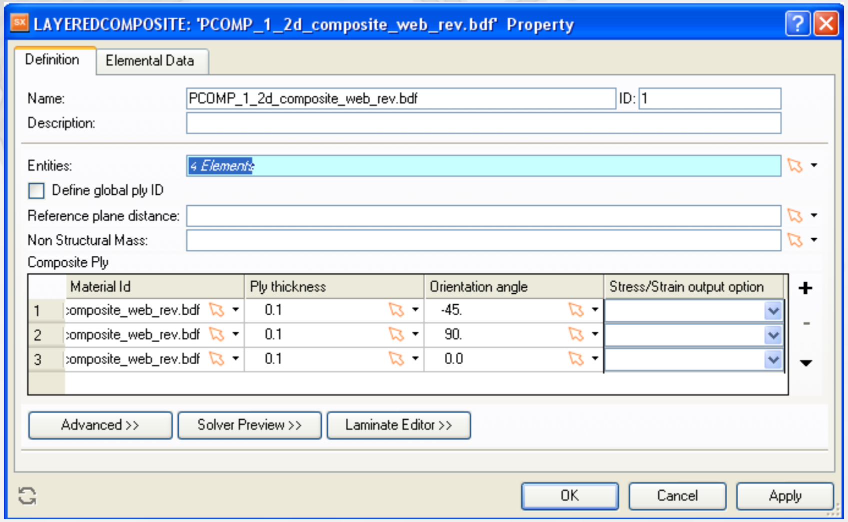
Edge is held at 20°F.

pshln1,1,1,,,ih

PCOMP,1

,1,0.1,-45.0,,2,0.1,90.0

,2,0.1,0.0



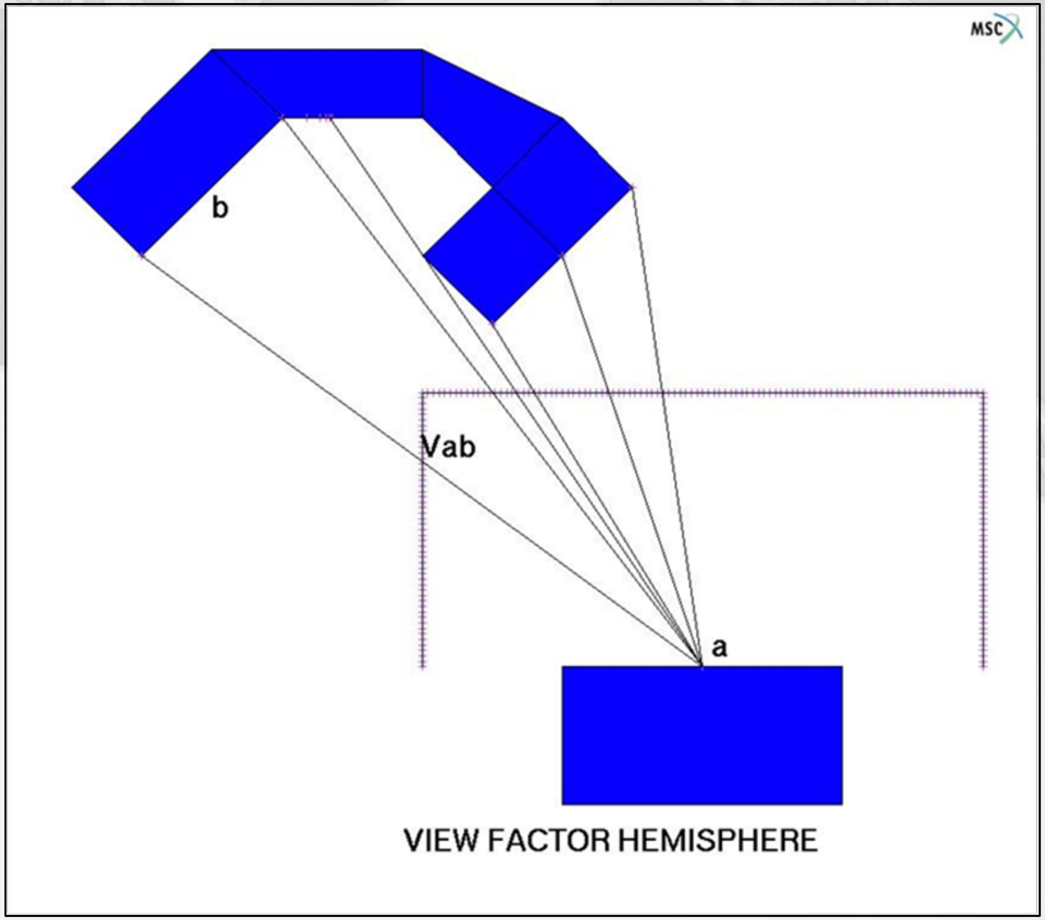
2D composite output (F06)

NLSTRESS=ALL to request this output

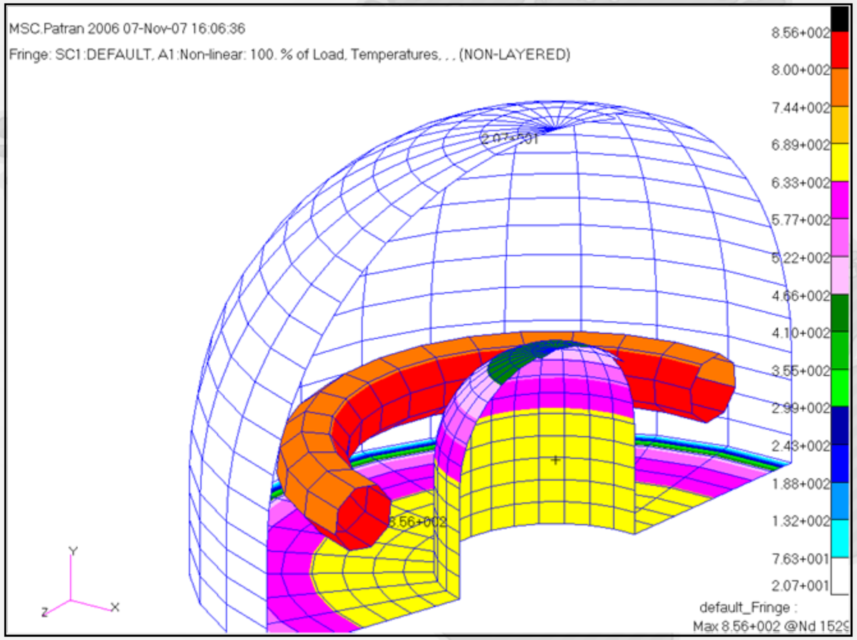
```
0                                                       SUBCASE 1        STEP 1
   LOAD STEP =  1.00000E+00

 G R A D I E N T S   A N D   F L U X E S   F O R   L A Y E R E D   C O M P O S I T E   E L E M E N T
S

 ELEMENT         INTEG.  -------G R A D I E N T S---------------F L U X E S---------------T E M P-
    ID    PLY ID POINT ID     T-X        T-Y        T-Z        F-X        F-Y        F-Z         T
     1       4       1 -8.574E-16 -6.128E+00  0.000E+00  1.286E-13  9.192E+02  0.000E+00  2.934E+01
                     2 -8.574E-16 -6.128E+00  0.000E+00  1.286E-13  9.192E+02  0.000E+00  2.934E+01
                     3 -1.391E-15 -6.128E+00  0.000E+00  2.087E-13  9.192E+02  0.000E+00  2.581E+01
                     4 -1.391E-15 -6.128E+00  0.000E+00  2.087E-13  9.192E+02  0.000E+00  2.581E+01
             3       1 -8.574E-16 -6.128E+00  0.000E+00  4.287E-14  3.064E+02  0.000E+00  2.934E+01
                     2 -8.574E-16 -6.128E+00  0.000E+00  4.287E-14  3.064E+02  0.000E+00  2.934E+01
                     3 -1.391E-15 -6.128E+00  0.000E+00  6.956E-14  3.064E+02  0.000E+00  2.581E+01
                     4 -1.391E-15 -6.128E+00  0.000E+00  6.956E-14  3.064E+02  0.000E+00  2.581E+01
```

Test deck: htshell1.dat

Hemi-Cube pixel based view calculation method



Radiation analysis using hemi-cube



- **NASTRAN test deck:quartz_lamp_hemi.dat**
- **CPU performance:**

Number of CHBDYG elements	Hemicube	Gaussian
1440	48.3 sec	182.6 sec
72643	4851.9 sec	259251 sec

The performance for the large model is 50 times faster using the hemicube method

How to activate the hemi-cube viewfactor analysis

```
SOL 400
CEND
ANALYSIS = HSTAT
TITLE = MSC/NASTRAN job created on 29-Oct-98 at 16:46:24
ECHO = NONE
MAXLINES = 999999999
TEMPERATURE(INITIAL) = 1
$ Direct Text Input for Global Case Control Data
SUBCASE 1
$ Subcase name : Default
   SUBTITLE=Default
   NLPARM = 5
   SPC = 1
   LOAD = 2
   THERMAL(SORT1,PRINT)=ALL
   FLUX(SORT1,PRINT)=ALL
$ Direct Text Input for this Subcase
BEGIN BULK
nlmopts,hemi,1
```

The Hemi-Cube option is also available for SOL 153 and SOL 159

```
SOL 153
CEND
ANALYSIS = HEAT
TITLE = MD Nastran job created on 07-May-07 at 15:18:11
ECHO = NONE
TEMPERATURE(INITIAL) = 1
SUBCASE 1
  TITLE=This is a default subcase.
  NLPARM = 1
  SPC = 1
  LOAD = 2
  THERMAL(SORT1,PRINT)=ALL
  FLUX(SORT1,PRINT)=ALL
BEGIN BULK
PARAM    POST    0
PARAM    TABS    273.15
PARAM    SIGMA   5.6696-8
NLPARM   1       1               FNT     1       25      PW      NO
 1.0e-6 .001    1.-7
$ Direct Text Input for Bulk Data
$ Elements and Element Properties for region : plate
nlmopts,hemi,1
```

NLMOPTS

NLMOPTS - SOL400 nonlinear heat transfer view factor method selection

nlmopts	**hemi**	**1**	**Npixel**	**Ndiv**	**Cutoff**	**Fraction**	**Faccnt**	**factol**
nlmopts	**hemi**	**1**			**0.0**	**0.01**	**1**	

Field 2: HEMICUBE keyword
Field 3 :
VMETHOD= 0 Default. Use Nastran finite difference, contour integration, or Gaussian integration method.
VFMETHOD = 1 (HEMI) Use pixel based modified hemi-cube method.

Field 4
NPIXEL = 500
Enter the number of pixels (default is 500).
Field 5
NDIVISION=36
For axisymmetric cavities, enter the number of divisions around circumference. Default is 36.
Field 6
CUTOFF = 0.0
Factor below which view factor will be set to zero.
Field 7
Fraction=0.01
Factor below which radiation exchange matrix terms are not added to the stiffness matrix.
Field 8
Faccnt=set to 1 to activate explicit treatment of reflection matrix.
Field 9
Factol = tolerance on the iterative procedure on the Poljak equation
Please note that the field 8 and 9 only pertains to SOL 400 thermal analysis. The explicit treatment is not in SOL 153 or SOL 159.

Reduced view factor output (Hemi-Cube or Gaussian method)

- **RADCAV,ICAVITY,ELEAMB,SHADOW,SCALE,PRTPCH**
  - The PRTPCH field by default is set to blank.
  - A blank PRTPCH means that there is no view factor print out in the F06 files

Value	Printout in .f06 file	Printout in .pch file
Blank	NO	YES
0	FULL PRINT	YES
1	NO	YES
2	FULL PRINT	NO
3	NO	NO
4	SUMMARY PRINT	YES
5	SUMMARY PRINT	NO

Summary output for VIEW3D

Radcav,1, , , ,4

*** VIEW FACTOR MODULE *** OUTPUT DATA *** CAVITY ID = 10 ***

ELEMENT TO ELEMENT VIEW FACTORS C*

PARTIAL

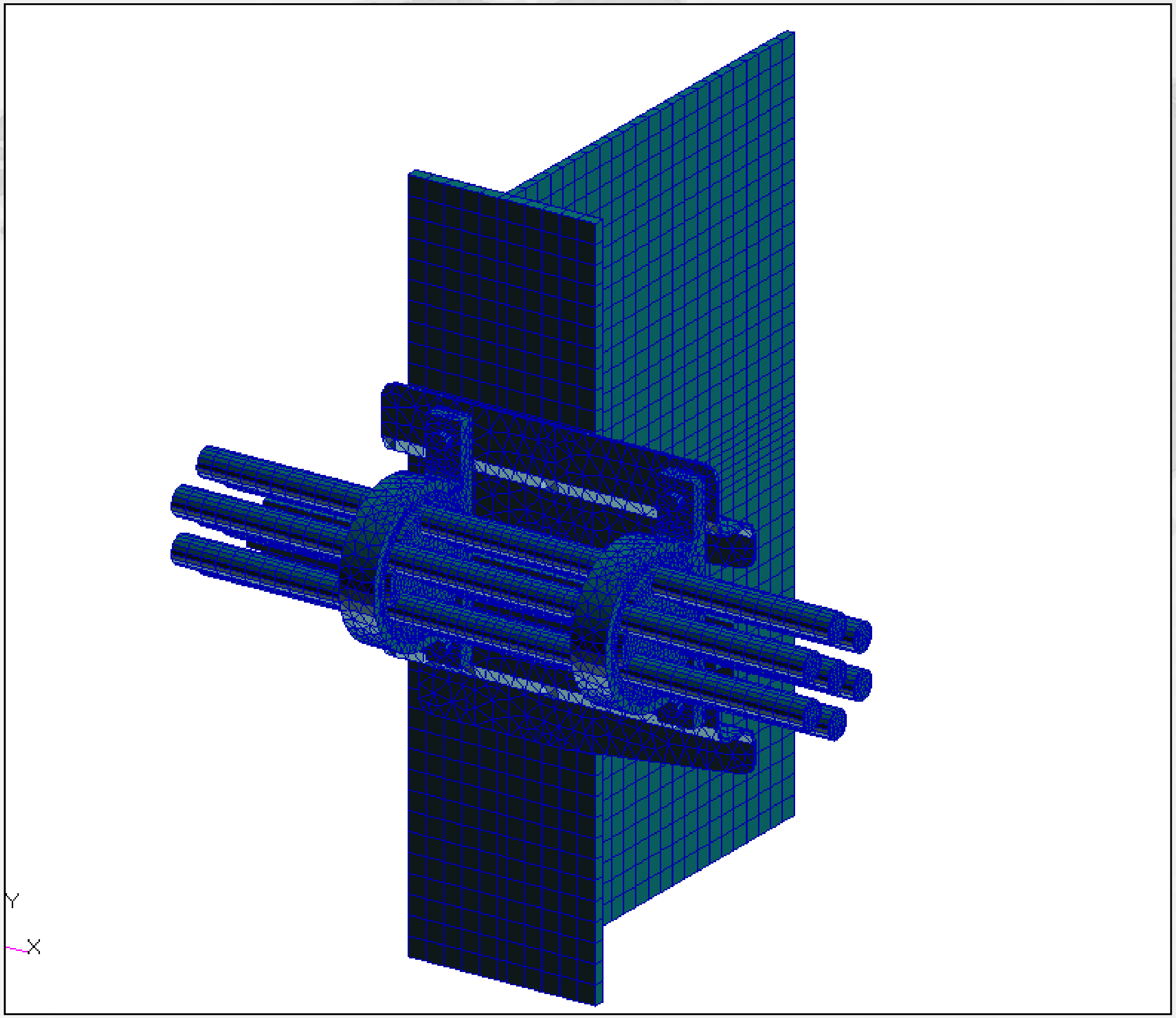
SURF-I	SURF-J	AREA-I	AI*FIJ	FIJ	ERROR	SHADING
100001	-SUM OF		3.89031E+00	9.92530E-01		
100002	-SUM OF		3.94100E+00	1.00546E+00		
100003	-SUM OF		3.94826E+00	1.00732E+00		
100004	-SUM OF		3.96734E+00	1.01218E+00		
100005	-SUM OF		3.89080E+00	9.92532E-01		
100006	-SUM OF		3.94149E+00	1.00546E+00		
100007	-SUM OF		3.94876E+00	1.00732E+00		
100008	-SUM OF		3.96788E+00	1.01220E+00		
100009	-SUM OF		3.89051E+00	9.92526E-01		
100010	-SUM OF		3.94120E+00	1.00546E+00		
100011	-SUM OF		3.94848E+00	1.00732E+00		

It is recommended that for the large radiation problem, set the prtpch field to 4 or 5 to see the summarized view factor output. For the complete enclosure, the FIJ should be close to 1.0.

FULL PRINT – option 0

```
1    MSC/NASTRAN JOB CREATED ON 29-OCT-98 AT 16:46:24
DECEMBER   6, 2007   MD NASTRAN 12/ 5/07   PAGE    19


0


          *** VIEW FACTOR MODULE *** OUTPUT DATA *** CAVITY ID =      10 ***


                     ELEMENT TO ELEMENT VIEW FACTORS
  SURF-I     SURF-J      AREA-I      AI*FIJ        FIJ        SCALE


   100001 -    100001   3.9196E+00  0.00000E+00  0.00000E+00  1.0000E+00
   100001 -    100002   3.9196E+00  0.00000E+00  0.00000E+00  1.0000E+00
   100001 -    100003   3.9196E+00  0.00000E+00  0.00000E+00  1.0000E+00
   100001 -    100004   3.9196E+00  0.00000E+00  0.00000E+00  1.0000E+00
   100001 -    100005   3.9196E+00  5.20687E-03  1.32842E-03  1.0000E+00
   100001 -    100006   3.9196E+00  3.60373E-03  9.19414E-04  1.0000E+00
   100001 -    100007   3.9196E+00  1.68619E-03  4.30195E-04  1.0000E+00
   100001 -    100008   3.9196E+00  7.66245E-04  1.95491E-04  1.0000E+00
   100001 -    100009   3.9196E+00  5.62728E-03  1.43568E-03  1.0000E+00
```

View factor for 19594 CHBDYG elements

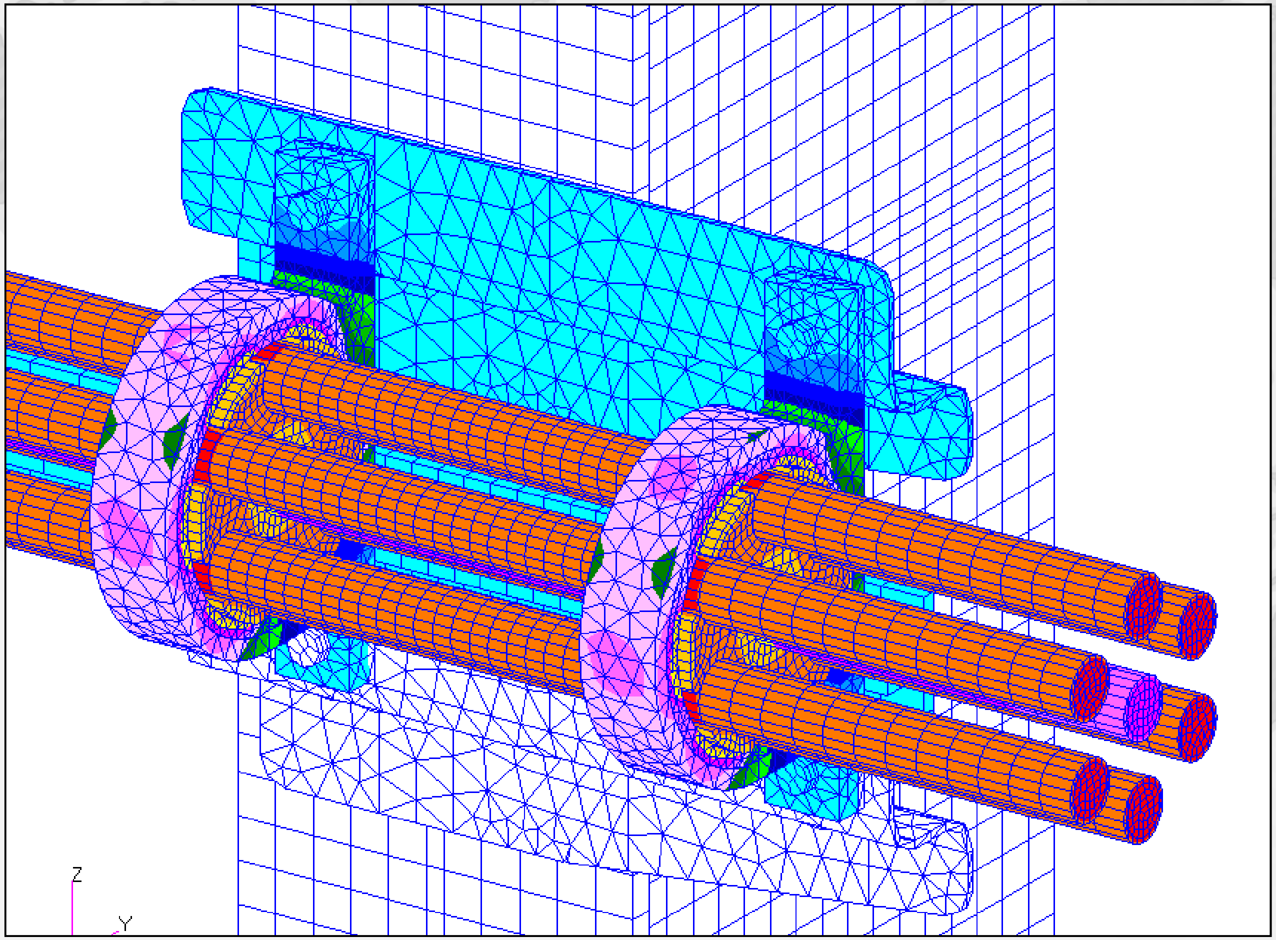


Hemicube: 321.3 cpu sec

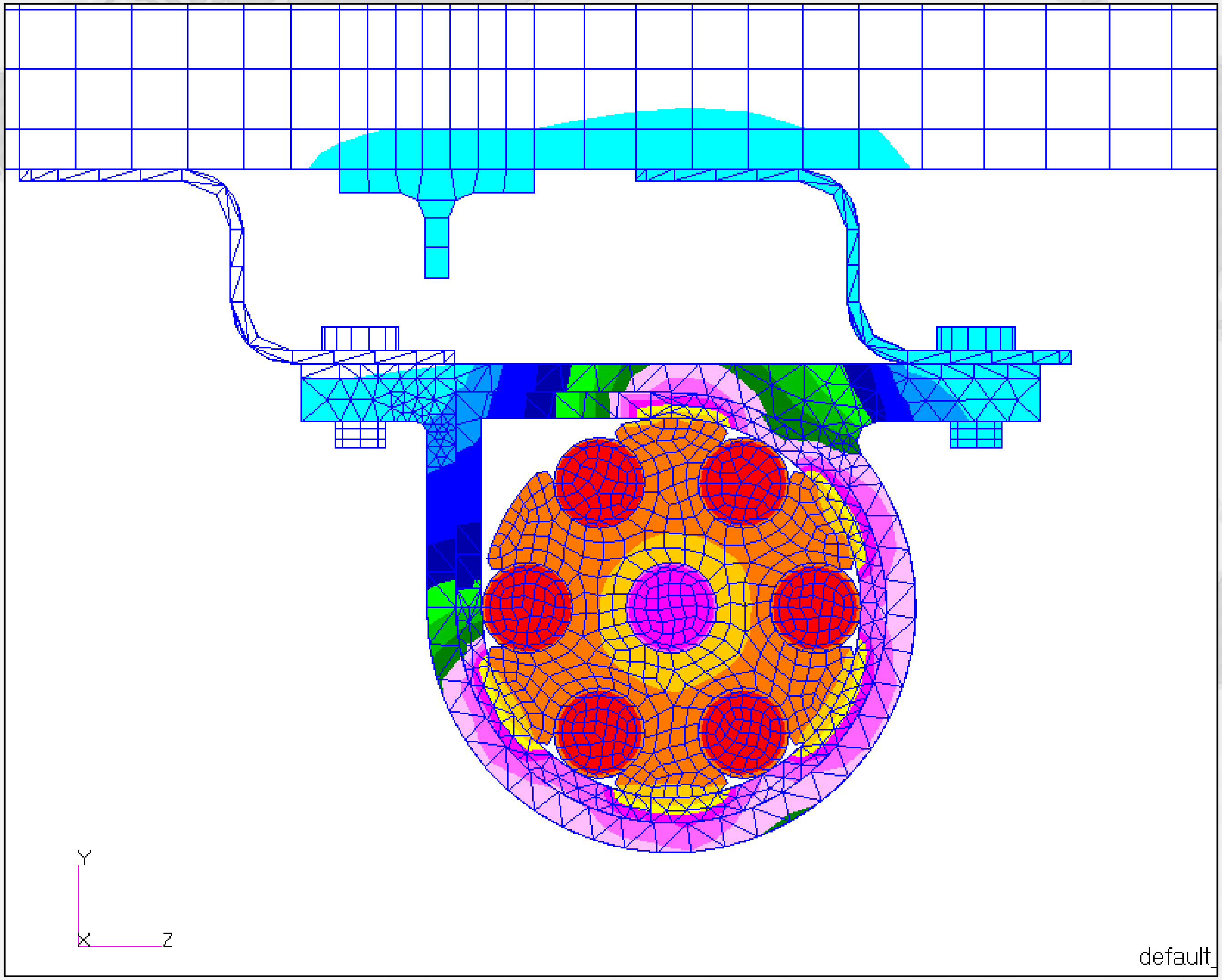
Gaussian (VIEW3D): 10751.9 cpu sec

A speed up of 33 times

Temperature Contour Plot

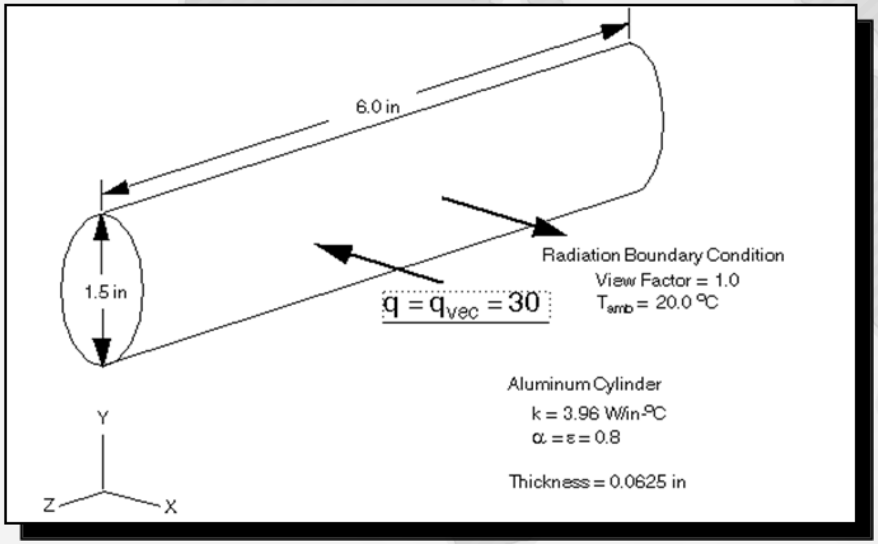


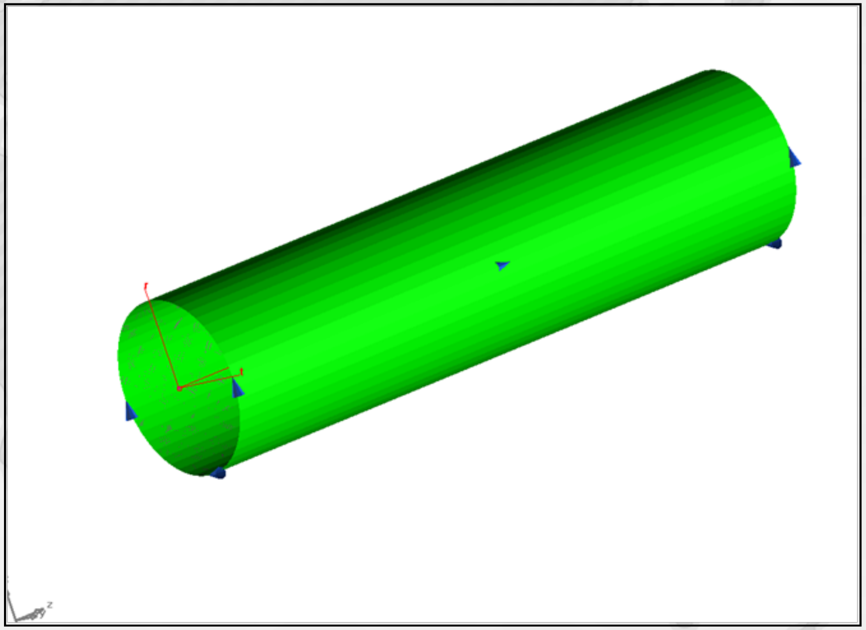
Temperature Contour Plot, (Cont.)



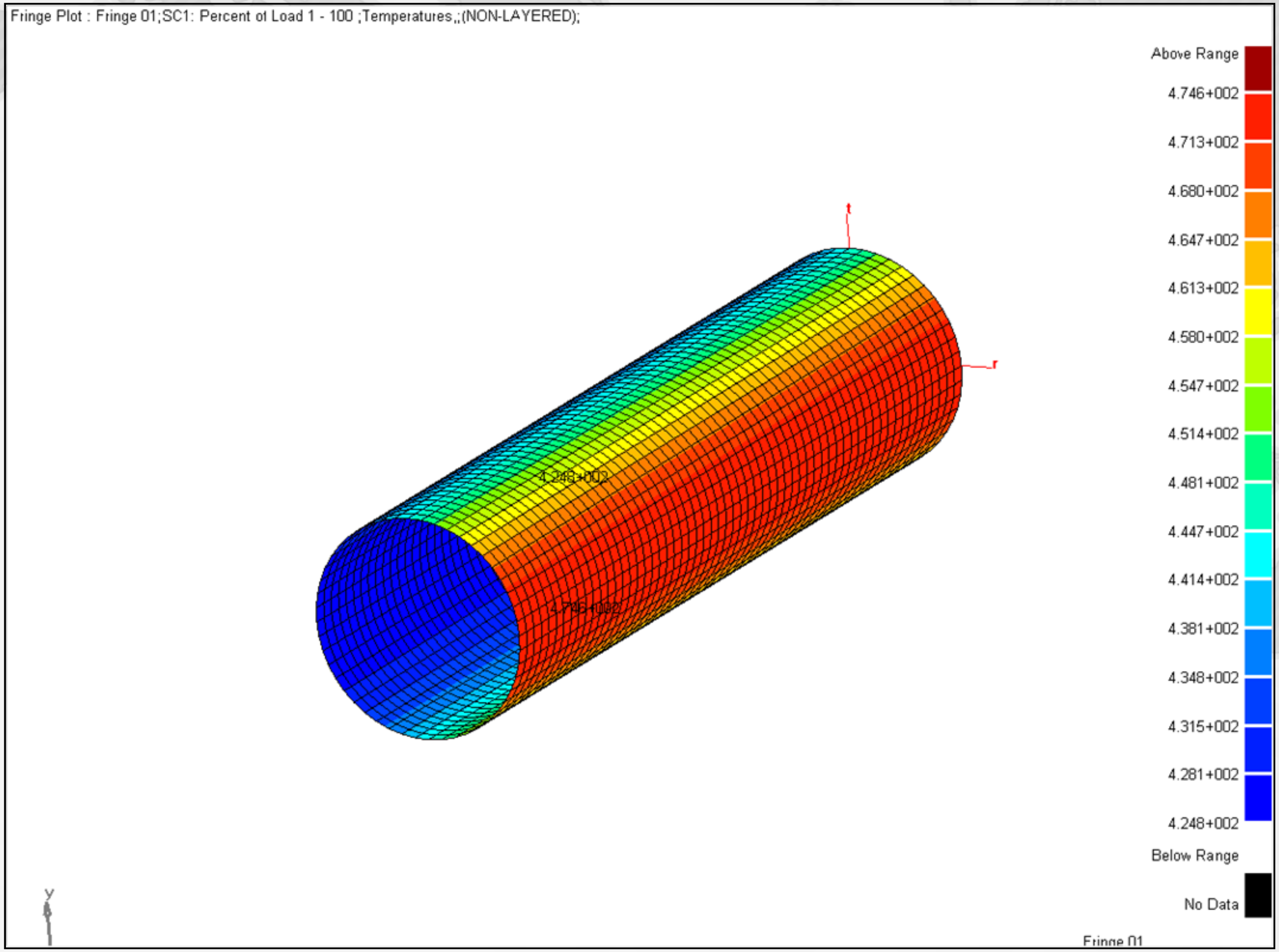
Directional heat load coupled thermal stress analysis

NASTRAN test deck: dirheat_simx1.dat
(problem 223)

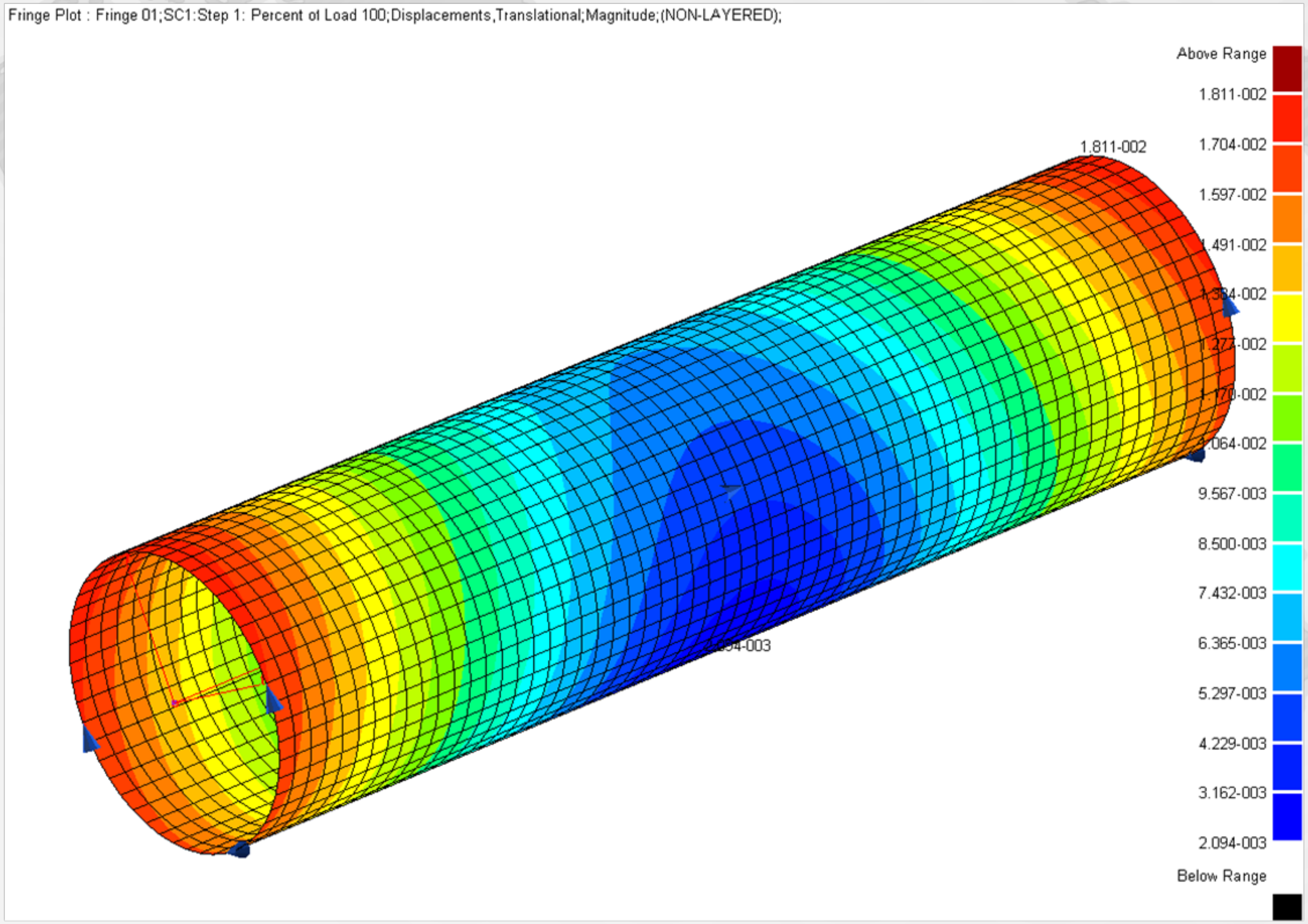




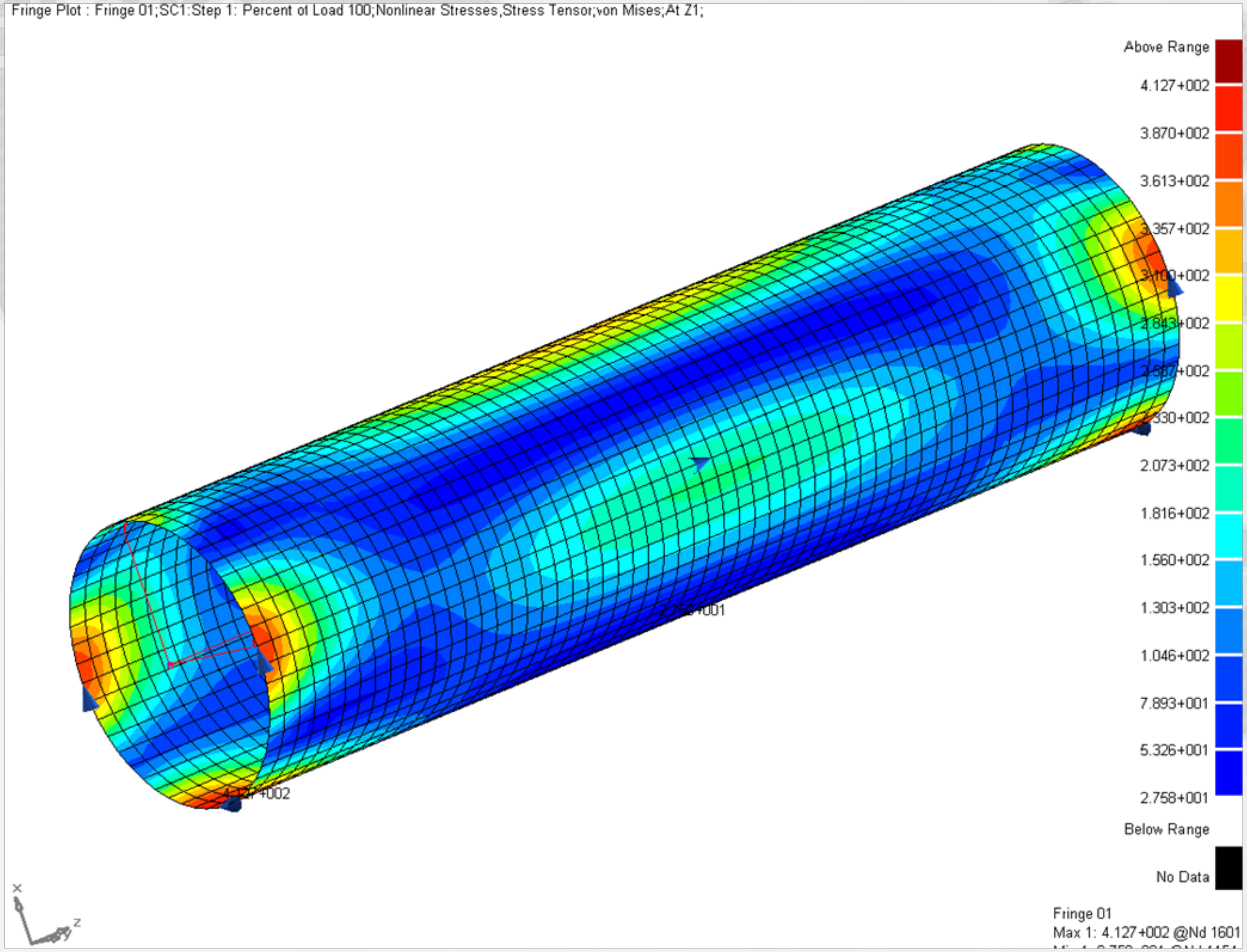
Calculated temperature of the cylinder:



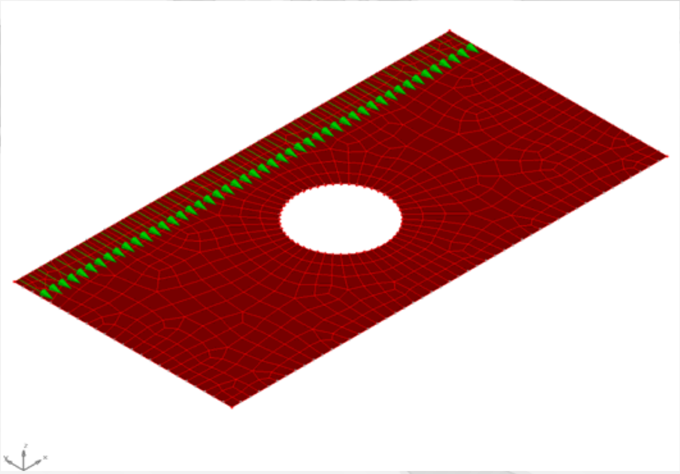
Thermal stress analysis

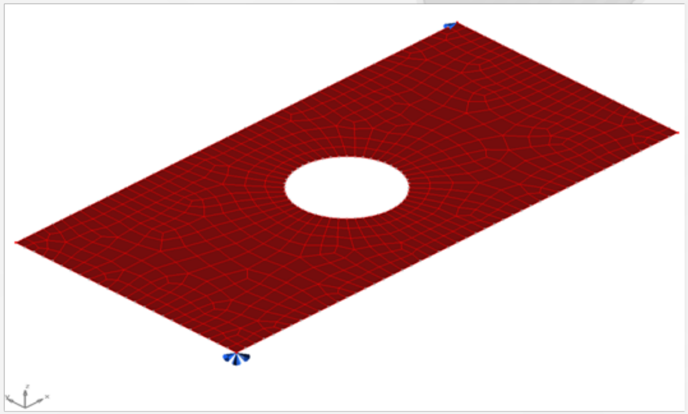


VonMises stress



Thermal and structure boundary conditions for multi-physics runs for the heat flow around the hole





NASTRAN test deck: hole_mp.bdf
SIMX file: cquad4_flux_mp.Simxpert
The plate is 10 inch by 5 inch, with hole diameter equals to 2 in
Thermal Boundary conditions:
•Heat flux of 200 watt/in2
•Temp held constant at 20 C at hole circumference.

In order to constraint the free-body moment of a plate:

The plate is bounded on lower left vertex(grid 599), upper right corner (grid 696)

spc1,2,123,599

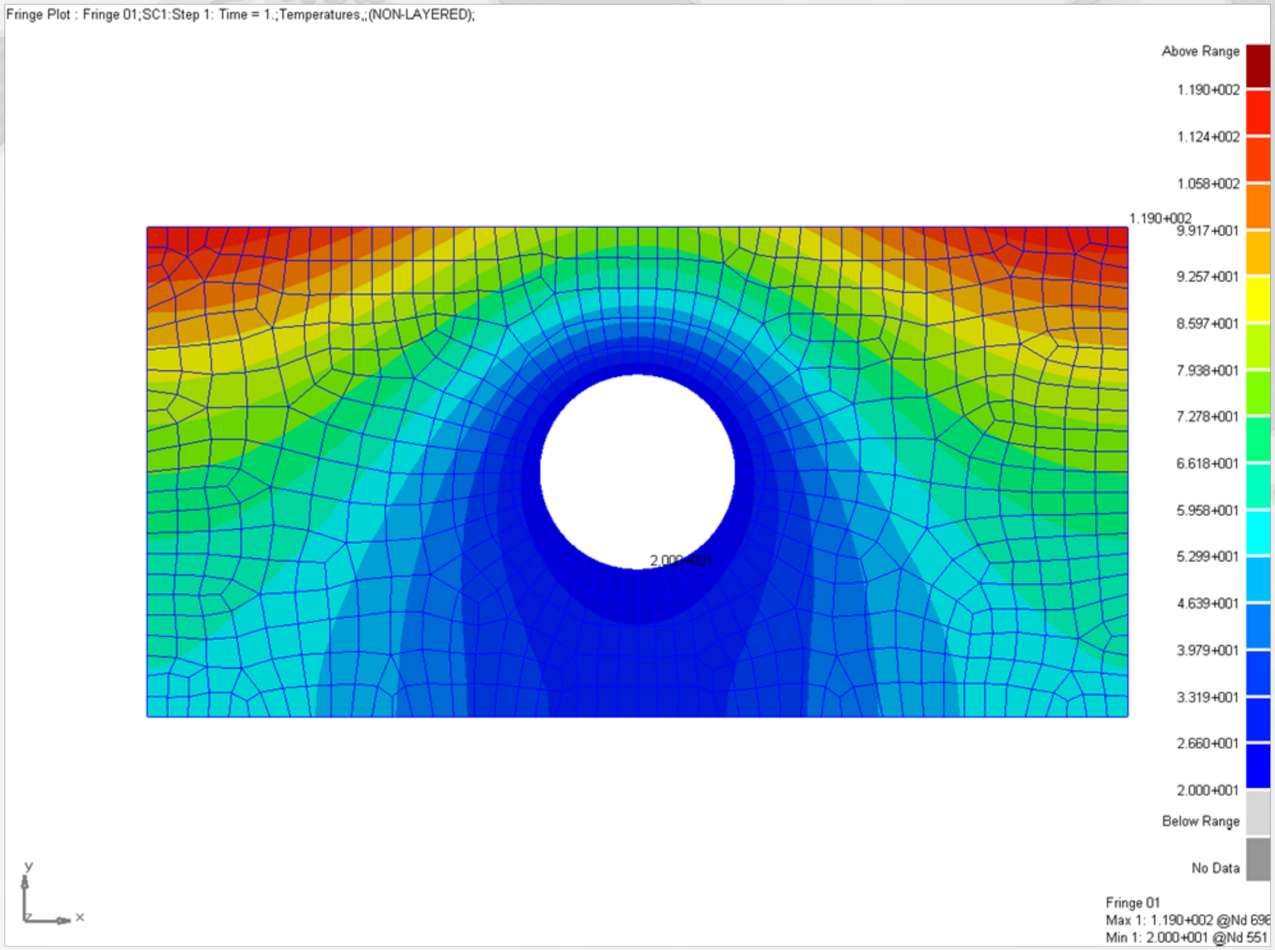
spc1,2,13,696

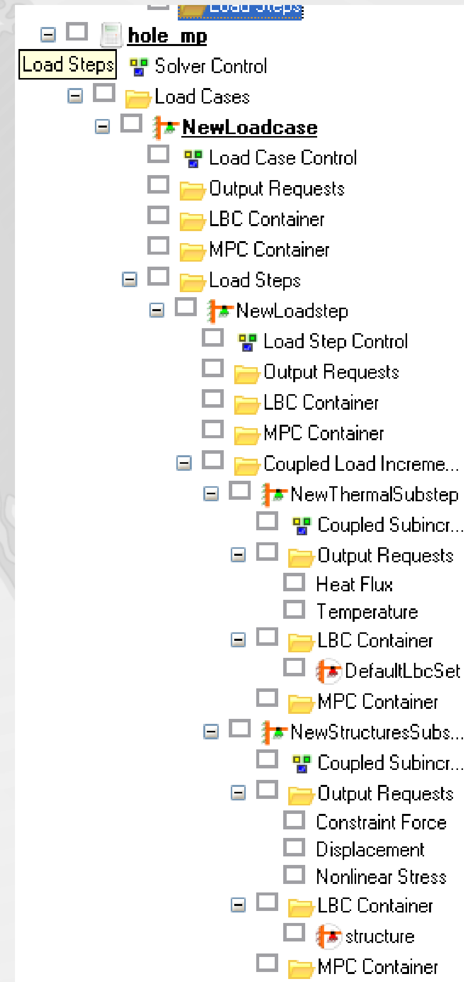
we need to fix the rotation in z direction, x on grid 599 and x on the grid 696 will take care the rotation in z.

The z at grid 599 and x at grid 696 will take care the rotation in x.

the y at grid 599 and z at grid 696 will take care the rotation in y.

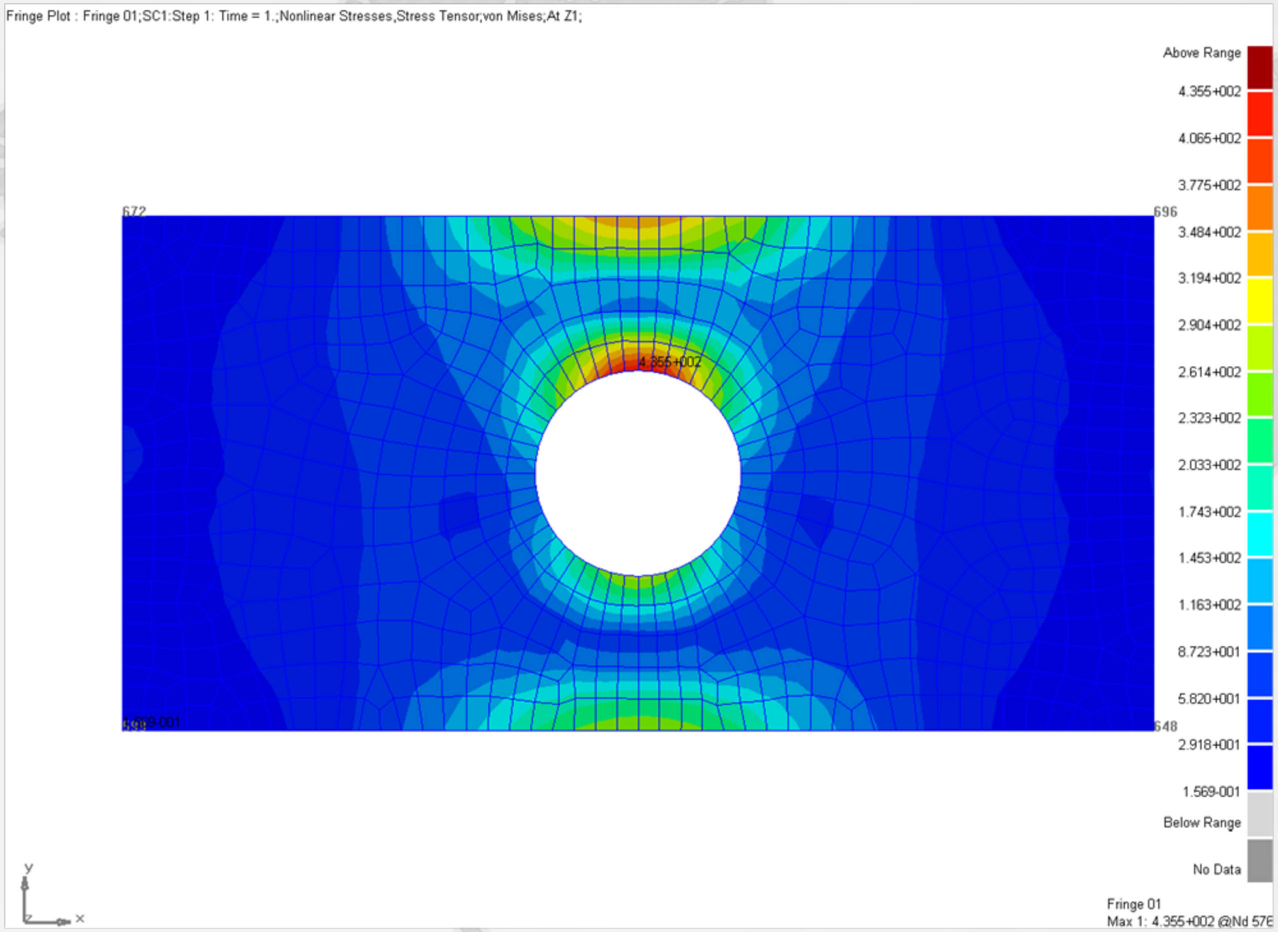
Multi-physics job set up using SIMX





Cquad4_flux_mp.Simxpert

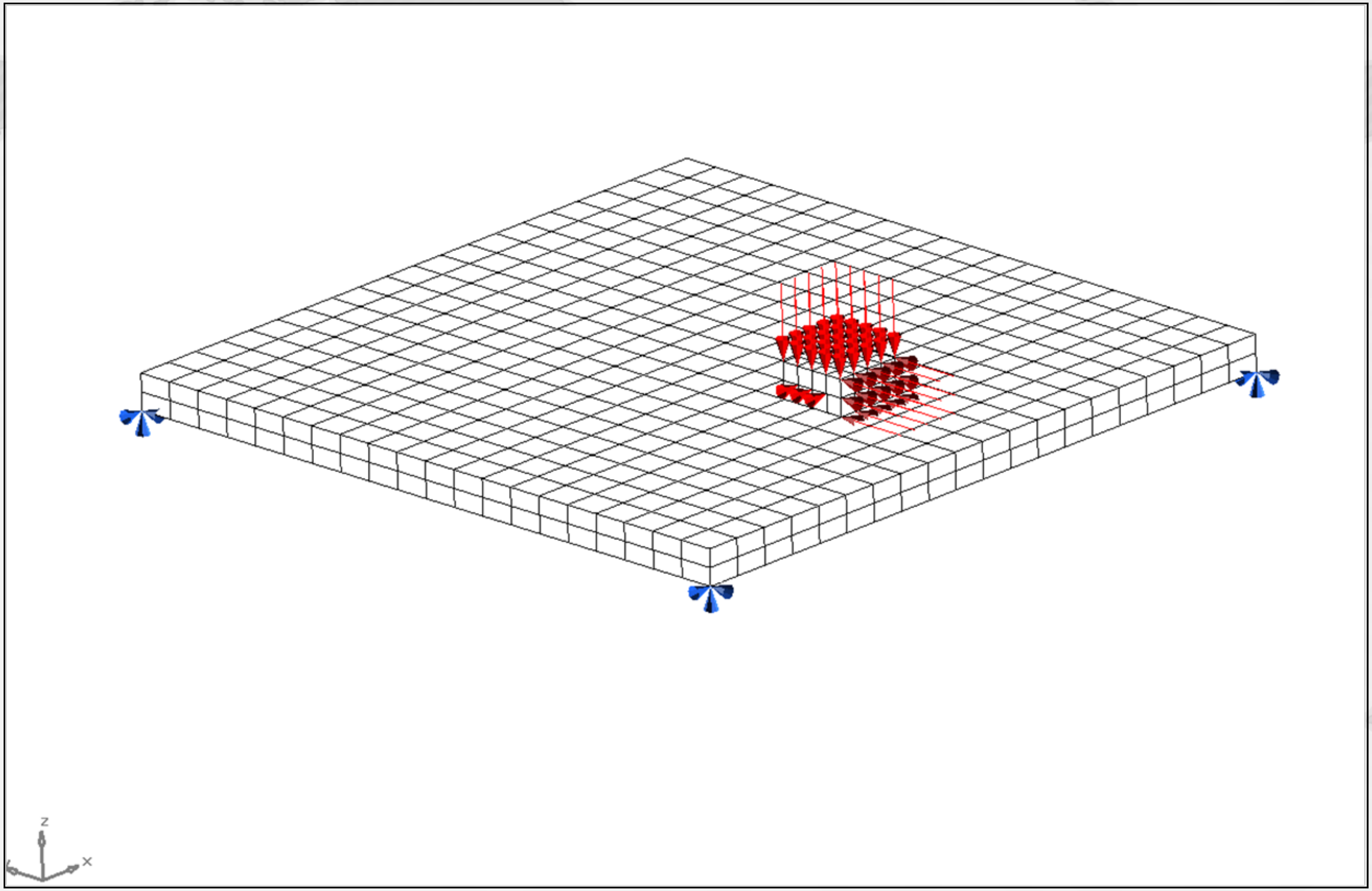
Multi-physic – heat flow around a hole



Thermal stress contour

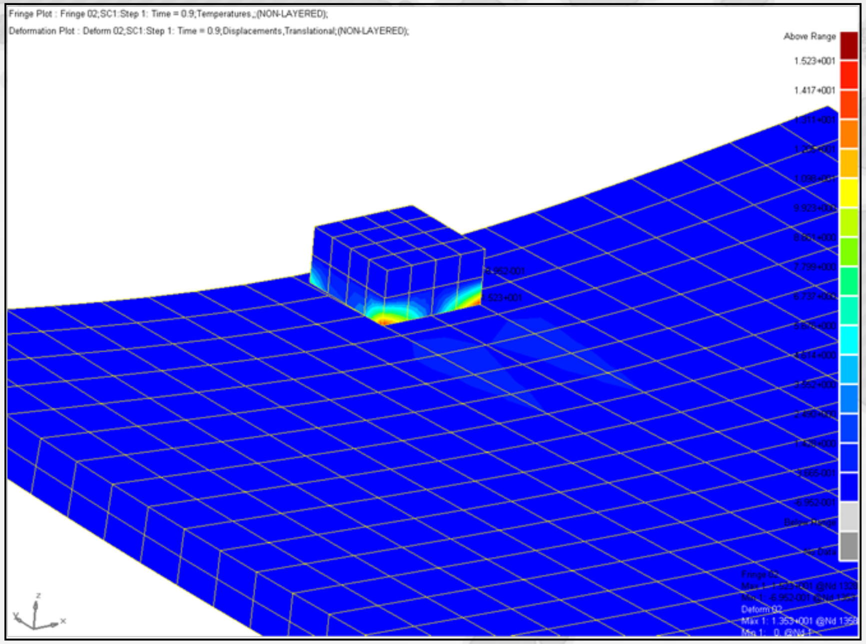
NASTRAN test deck: hole_mp.bdf

Friction heating example



Friction heating

NASTRAN test deck: spcd6.dat



- **The plate is 20 by 20 inch with thickness equal to 1 inch:**
- **The small block has a dimension of 2 by 2 inch with 1 inch thick.**

- **Structure boundary conditions:**
  - Enforce displacement of 15 in y direction along the right face of the top solid
  - Enforced displacement of 1 in negative z direction on the top face of the top solid.
  - Fix on three grids in x displacement
  - Pin condition along the four corners.
  - Structure contact between the small box and the surface
  - Frictional coefficient=0.1
  - HGENFRIC=0.1, conversion factor for heat generated due to friction
  - Scenario: analysis=HTRAN into analysis=NLSTAT
  - Bilinear coulomb friction
  - Initially the temperature is zero degree.

SOL 400 uses the SPCD and SPC1 instead of TEMPBC,TRAN option

- **Whenever you have a time–varying temperature boundary conditions, convection coefficient as a function of time, view factor as a function of time, NASTRAN previous in SOL 159 will write out a TEMPBC,TRAN for the control node.**
- **This type of input using TEMPBC,TRAN has been replaced with different type of input through SPCD and SPC1 bulk data entries in SOL 400.**

Converting from SOL 159 into SOL 400

```
ID MSC-NASTRAN V68
SOL 159
TIME 10
CEND
TITLE = EXAMPLE 7B
ANALYSIS = HEAT
THERMAL = ALL
FLUX = ALL
SPCF = ALL
OLOAD = ALL
IC = 20
TSTEPNL  = 100
DLOAD = 200
BEGIN BULK
TSTEPNL,100,7500,1.0,1,,,,U
$
```

```
ID MSC-NASTRAN V68
SOL 400
TIME 10
CEND
TITLE = EXAMPLE 7B
ANALYSIS = HTRAN
THERMAL = ALL
FLUX = ALL
SPCF = ALL
OLOAD = ALL
IC = 20
TSTEPNL  = 100
DLOAD = 200
BEGIN BULK
TSTEPNL,100,7500,1.0,1,,,,U
```

Example 7d: SOL 159 input

```
ID MSC-NASTRAN V68
SOL 159
TIME 10
CEND
TITLE = EXAMPLE 7D
ANALYSIS = HEAT
THERMAL = ALL
FLUX = ALL
SPCF = ALL
OLOAD = ALL
SPC = 10
IC = 20
TSTEPNL  = 100
DLOAD = 200
OUTPUT(XYPLOT)
XTITLE = TIME, SECONDS
YTITLE = GRID 1 TEMPERATURE DEGREES CELSIUS
TCURVE = GRID 1 TEMPERATURE VS. TIME
XYPLOT TEMP/1(T1)
XTITLE = TIME, SECONDS
YTITLE = GRID 50 TEMPERATURE DEGREES CELSIUS
TCURVE = GRID 50 TEMPERATURE VS. TIME
XYPLOT TEMP/50(T1)
BEGIN BULK
TSTEPNL,100,490,10.0,1
$
GRID,1,,0.0,0.0,0.0
GRID,2,,0.0,0.0,1.0
GRID,3,,1.0,0.0,1.0
GRID,4,,1.0,0.0,0.0
GRID,5,,0.0,1.0,0.0
GRID,6,,0.0,1.0,1.0
GRID,7,,1.0,1.0,1.0
GRID,8,,1.0,1.0,0.0
GRID,50,,50.0,50.0,50.0
GRID,99,,99.0,99.0,99.0
$
CHEXA,1,5,1,2,3,4,5,6,+CHX1
+CHX1,7,8
PSOLID,5,15
MAT4,15,204.0,896.0,2707.0,1000.0
$
CHBDYE,10,1,1
CHBDYE,20,1,2
CHBDYE,30,1,3
CHBDYE,40,1,4
CHBDYE,50,1,5
CHBDYE,60,1,6
$
CONV,10,35,,50,99
CONV,20,35,,50,99
CONV,30,35,,50,99
CONV,40,35,,50,99
CONV,50,35,,50,99
CONV,60,35,,50,99
PCONV,35,15,0,0.0
$
DLOAD,200,1.0,1.0,300,1.0,400
$
TLOAD1,300,500,,,700
TABLED1,700,,,,,,,,+TBD700
+TBD700,0.0,1.0,1000.0,1.0,ENDT
QBDY3,500,50000.0,,10,THRU,60,BY,10
$
TLOAD1,400,600,,,800
TABLED1,800,,,,,,,,+TBD800
+TBD800,0.0,0.0,1000.0,0.0,2000.0,1.0,5000.0,1.0,+TBD801
+TBD801,ENDT
TEMPBC,600,TRAN,1.0,50
SPC,10,99,,0.0
TEMP,20,99,0.0
TEMPD,20,0.0
$
ENDDATA
```

Example 7d using SOL 400

```
SOL 400
CEND
TITLE = EXAMPLE 7D
ANALYSIS = HTRAN
THERMAL = ALL
FLUX = ALL
SPCF = ALL
OLOAD = ALL
SPC = 10
IC = 20
TSTEPNL  = 100
DLOAD = 200
OUTPUT(XYPLOT)
XTITLE = TIME, SECONDS
YTITLE = GRID 1 TEMPERATURE DEGREES CELSIUS
TCURVE = GRID 1 TEMPERATURE VS. TIME
XYPLOT TEMP/1(T1)
XTITLE = TIME, SECONDS
YTITLE = GRID 50 TEMPERATURE DEGREES CELSIUS
TCURVE = GRID 50 TEMPERATURE VS. TIME
XYPLOT TEMP/50(T1)
BEGIN BULK
TSTEPNL,100,490,10.0,1
$
GRID,1,,0.0,0.0,0.0
GRID,2,,0.0,0.0,1.0
GRID,3,,1.0,0.0,1.0
GRID,4,,1.0,0.0,0.0
GRID,5,,0.0,1.0,0.0
GRID,6,,0.0,1.0,1.0
GRID,7,,1.0,1.0,1.0
GRID,8,,1.0,1.0,0.0
GRID,50,,50.0,50.0,50.0
GRID,99,,99.0,99.0,99.0
$
CHEXA,1,5,1,2,3,4,5,6,+CHX1
+CHX1,7,8
PSOLID,5,15
MAT4,15,204.0,896.0,2707.0,1000.0
$
CHBDYE,10,1,1
CHBDYE,20,1,2
CHBDYE,30,1,3
CHBDYE,40,1,4
CHBDYE,50,1,5
CHBDYE,60,1,6
$
CONV,10,35,,50,99
CONV,20,35,,50,99
CONV,30,35,,50,99
CONV,40,35,,50,99
CONV,50,35,,50,99
CONV,60,35,,50,99
PCONV,35,15,0,0.0
$
DLOAD,200,1.0,1.0,300,1.0,400
$
TLOAD1,300,500,,,700
TABLED1,700,,,,,,,,+TBD700
+TBD700,0.0,1.0,1000.0,1.0,ENDT
QBDY3,500,50000.0,,10,THRU,60,BY,10
$
SPC1,10,,50
SPCD,600,50,,1.0
TLOAD1,400,600,,1,800
TABLED1,800,,,,,,,,+TBD800
+TBD800,0.0,0.0,1000.0,0.0,2000.0,1.0,5000.0,1.0,+TBD801
+TBD801,ENDT
$TEMPBC,600,TRAN,1.0,50
SPC,10,99,,0.0
TEMP,20,99,0.0
TEMPD,20,0.0
$
ENDDATA
```

Using the SPCD to enforced temperature as a function of time

```
DLOAD,200,1.0,1.0,300,1.0,400
$
TLOAD1,300,500,,,700
TABLED1,700,,,,,,,,+TBD700
+TBD700,0.0,1.0,1000.0,1.0,ENDT
QBDY3,500,50000.0,,10,THRU,60,BY,10
$
TLOAD1,400,600,,,800
TABLED1,800,,,,,,,,+
+,0.0,0.0,1000.0,0.0,2000.0,1.0,5000.0,1.0,+
+,ENDT
TEMPBC,600,TRAN,1.0,50
SPC,10,99,,0.0
TEMP,20,99,0.0
TEMPD,20,0.0
```

Please note that a type 1 is required in field 5 on either the TLOAD1 or TLOAD2 card in a SOL 400 run

```
DLOAD,200,1.0,1.0,300,1.0,400
$
TLOAD1,300,500,,,700
TABLED1,700,,,,,,,,+TBD700
+TBD700,0.0,1.0,1000.0,1.0,ENDT
QBDY3,500,50000.0,,10,THRU,60,BY,10
$
SPC1,10,,50
SPCD,600,50,,1.0
TLOAD1,400,600,,1,800
TABLED1,800,,,,,,,,+
+,0.0,0.0,1000.0,0.0,2000.0,1.0,5000.0,1.0,+
+,ENDT
$TEMPBC,600,TRAN,1.0,50
SPC,10,99,,0.0
TEMP,20,99,0.0
TEMPD,20,0.0
$
```

Convert SOL159 into SOL400 when there is TEMPBC in the bulk data section

To Convert SOL 159 Models to SOL 400 Models

1. Executive Control Section - change SOL 159 to SOL 400.
2. Case Control Section - replace ANALYSIS=HEAT by ANALYSIS=HTRAN, also add SPC if all temperature boundary conditions are transient (case 3b below).
3. Bulk Data Section - replace the "TRAN" type TEMPBC by SPC1 and SPCD. The details are explained below.
   a. If all temperature boundary conditions are constant, no changes are required.
   b. If all temperature boundary conditions are transient, replace TEMPBC by SPC1 and SPCD and modify TLOAD1.

   For example, replace the following entries of SOL 159 model:

   TLOAD1,40,400,,,4000
   TEMPBC,400,TRAN,300.0,99

   by

   SPC = 111 (Case CC)
   :
   TLOAD1,40,400,,**1**,4000
   SPCD,400,99,,300.0
   SPC1,111,,99

Convert Sol 159 into SOL 400:

c. If a model has both constant and transient temperature boundary conditions, all boundary conditions must be converted into SPC1 and SPCD.

For example, replace the following entries of SOL 159 model:

```
DLOAD,222,1.0,1,0,30,1.0,40
TLOAD1,40,400,,,4000
TEMPBC,400,TRAN,300.0,99
 SPC,111,98,,20.0
```

by

```
DLOAD,222,1.0,1,0,30,1.0,40, 1.0,50
TLOAD1,40,400,,1,4000
SPCD,400,99,,300.0
SPC1,111,,99
TLOAD1,50,500,,1,5000
SPCD,500,98,,20.0
SPC1,111,,98
TABLED1,5000,,,,,,,,
,0.0,1.0,1000.0,1.0,ENDT
```

Convert from SOL 153 into SOL 400

```
SOL 153
$ Direct Text Input for Executive Control
CEND
ANALYSIS = HEAT
TITLE =  workshop 1
ECHO = NONE
TEMPERATURE(INITIAL) = 1
Data
SUBCASE 1
$ Subcase name : Default
   SUBTITLE=Default
   NLPARM = 1
   SPC = 1
   LOAD = 2
   THERMAL(SORT1,PRINT)=ALL
   FLUX(SORT1,PRINT)=ALL
   OLOAD(SORT1,PRINT)=ALL
   SPCFORCES(SORT1,PRINT)=ALL
$ Direct Text Input for this Subcase
BEGIN BULK
```

```
SOL 400
$ Direct Text Input for Executive Control
CEND
ANALYSIS = HSTAT
TITLE =  workshop 1
ECHO = NONE
TEMPERATURE(INITIAL) = 1
SUBCASE 1
$ Subcase name : Default
   SUBTITLE=Default
   NLPARM = 1
   SPC = 1
   LOAD = 2
   THERMAL(SORT1,PRINT)=ALL
   FLUX(SORT1,PRINT)=ALL
   OLOAD(SORT1,PRINT)=ALL
   SPCFORCES(SORT1,PRINT)=ALL
$ Direct Text Input for this Subcase
BEGIN BULK
```

End of presentation

Thank you

New nonlinear elements (1D and 2D)

Nast Type	N ID	REq nodes	Type Code	INT CODE	MARC ID	NL_PROP
ROD	1	2	ROD	L	36	PRODN1
Shell (3D)						
CQUAD4	33	4	DCT	L	85	PSHLN1
CQUAD8	64	8	DCT	Q	86	PSHLN1
CTRIA3	74	3	DCT	L	50	PSHLN1
Planar(2D)						
CQUAD4	139	4	PLST	L	39	PSHLN2
CTRIA3	162	3	PLST	L	37	PSHLN2
CQUAD8	164	8	PLST	Q	41	PSHLN2
CTRIA6	167	6	PLST	Q	131	PSHLN2
Planar Composite elements						
CQUAD4	139	4	COMP	L	177	PLCOMP
CQUAD8	164	8	COMP	Q	179	PLCOMP
Membrane elements						
CQUAD4	33	4	MB	L	198	PSHLN1
CTRIA3	74	3	MB	L	196	PSHLN1
CQUAD8	64	8	MB	Q	199	PSHLN1
CTRIA6	75	6	MB	Q	197	PSHLN1

New nonlinear elements (Solid)

Nast Type	N ID	REq nodes	Type Code	INT CODE	MARC ID	NL_PROP
Solid elements						
CHEXA	67	8	SOLI	L	43	PSLDN1
	67	20	SOLI	Q	44	PSLDN1
CTETRA	39	4	SOLI	L	135	PSLDN1
	39	10	SOLI	Q	133	PSLDN1
CPENTA	68	6	SOLI	L	137	PSLDN1
Solid composite elements						
CHEXA	67	8	SLCO	L	175	PCOMPLS
		20	SLCO	Q	176	PCOMPLS

PSHLN1 – Nonlinear property extension for PSHELL or PCOMPG entry

PSHLN1 – Nonlinear property extension for PSHELL or PCOMPG entry

PSHLN1	PID	MID1	MID2		ANALY			
	C3	BEH3	INT3	BEH3H	INT3H			TDIST
	C4	BEH4	INT4	BEH4H	INT4H			TDIST
	C6	BEH6	INT6	BEH6H	INT6H			
	C8	BEH8	INT8	BEH8H	INT8H			TDIST

ANALY is on the field 6:
Where ANALY =
IS (default) –and NASTRAN heat transfer element
IH – NASTRAN structure element NASTRAN structure element and MARC heat transfer element

TDIST , Field 9: Temperature distribution for the thick shell element

In the MDR3 version only constant will be supported.

Temperature distribution: 0=constant, 1=linear, 2=quadratic,

3=piecewise quadratic if not composite; default=0}

BEHi: default: DCT

DCT points to the 3D SHELL elements,

MB points to the membrane heat transfer elements

PSHLN2 – Nonlinear property extension for a PLPLANE entry

PSHLN2 – Nonlinear property extension for a PLPLANE entry
Descriptions: Specifies nonlinear properties for plane strain, plane stress, or axisymmetric elements

PSHLN2	PID	MID	DIRECT	T	ANALY		
	C3	BEH3	INT3	BEH3H	INT3H		
	C4	BEH4	INT4	BEH4H	INT4H		
	C6	BEH6	INT6	BEH6H	INT6H		
	C8	BEH8	INT8	BEH8H	INT8H		

Field
BEHi: default: PLST
PLST points to plane strain heat transfer element
AXSO points to the axisymmetric heat transfer element

PSLDN1– Nonlinear property extension for a PSOLID

PSLDN1– Nonlinear property extension for a PSOLID
Descriptions: Specifies nonlinear properties for solid elements

PSLDN1	PID	MID	DIRECT		ANALY		
	C4	BEH4	INT4	BEH4H	INT4H		
	C6	BEH6	INT6	BEH6H	INT6H		
	C8	BEH8	INT8	BEH8H	INT8H		
	C10	BEH10	INT10	BEH10H	INT10H		
	C20	BEH20	INT20	BEH20H	INT20H		

Field
BEHi: default: SOLI
SOLI points to solid heat transfer elements
COMPS points to solid composite heat transfer elements

3D composite heat transfer element

The composite heat transfer elements points to the PCOMPLS, and it can points to MAT4 or MAT5 heat transfer material cards.

PCOMPLS	PID	DIRECT	CORDM	SB	ANALY		
	C8	BEH8	INT8	BEH8H	INT8H		
	C20	BEH20	INT20	BEH20H	INT20H		
	ID1	MID1	T1	THETA1			
	ID1	MID2	T2	THETA2			

```
pcompls,1,-1,,,ih
,c8,
,c20,
,1,1,0.01
,2,2,0.02
```

How do I call out these new nonlinear formulations?

```
psldn1,1,1,,,ih
PSOLID   1      1      0
$ Pset: "pcb" will be imported as: "psolid.1"
CHEXA    5958   1      391    3742   3743   422    7355   7358
         7357   7356

PSHELL   1      1      1.
pshln1,1,1,,,ih
$ Pset: "plate" will be imported as: "pshell.1"
CQUAD4   1      1      1      2      5      4
```