Finite element numerical simulation of a TIG welding test

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Foreward

- This is a preliminary analysis about finite element simulation of a TIG welding test of two plates in AISI 316 LN stainless steel.
- Two uncoupled steps of analysis are executed: thermal and then mechanical one.
- The main strategy adopted is the “birth and death” technique.
- The analysis is carried out with Ansys rel.10

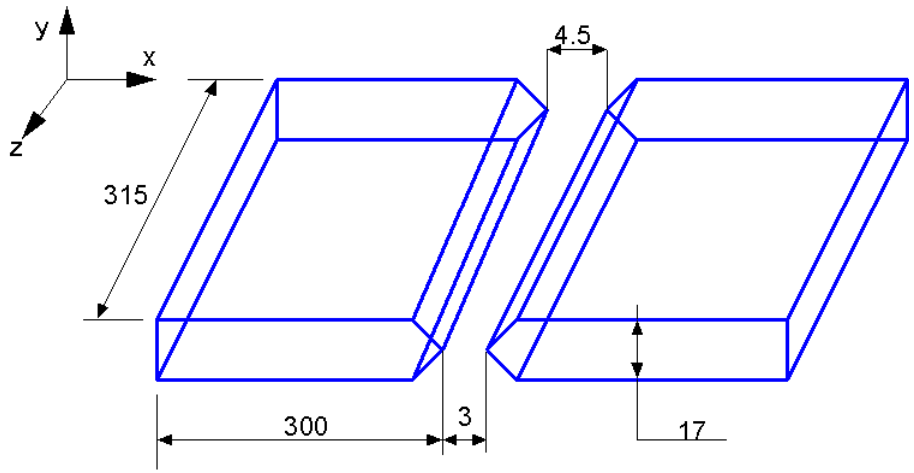
Main general analysis's aims

- Thermal shrinkage calculation
- Residual stress field calculation
- Restraints' choice and placement
- Best sequence's specifications
- Study of the effect of material property changes

Special aims of this analysis

- To build a simplified fem model in order to evaluate the feasibility of developing a larger fem model that can simulate a real TIG welding test
- To know the CPU time and the amount of Hard Disk demand for the simplified model (on a office PC) to assess the real request for the complete model on a faster machine
- Check if the final global strain of the first model is correctly foreseen

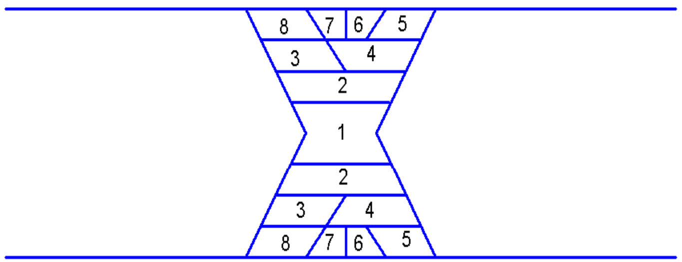
Geometry



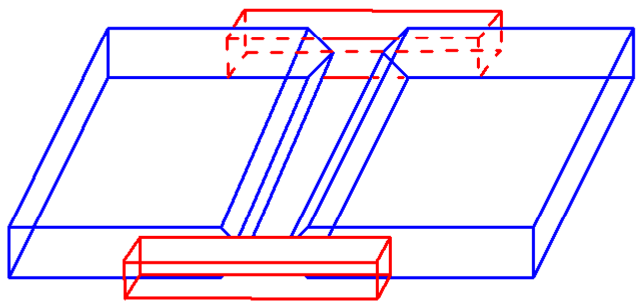
The geometrical model has the length that is one third of the real longitudinal dimension (z)

The width of the single plate is chosen to have a acceptable total node number

The caulker has a variable gap

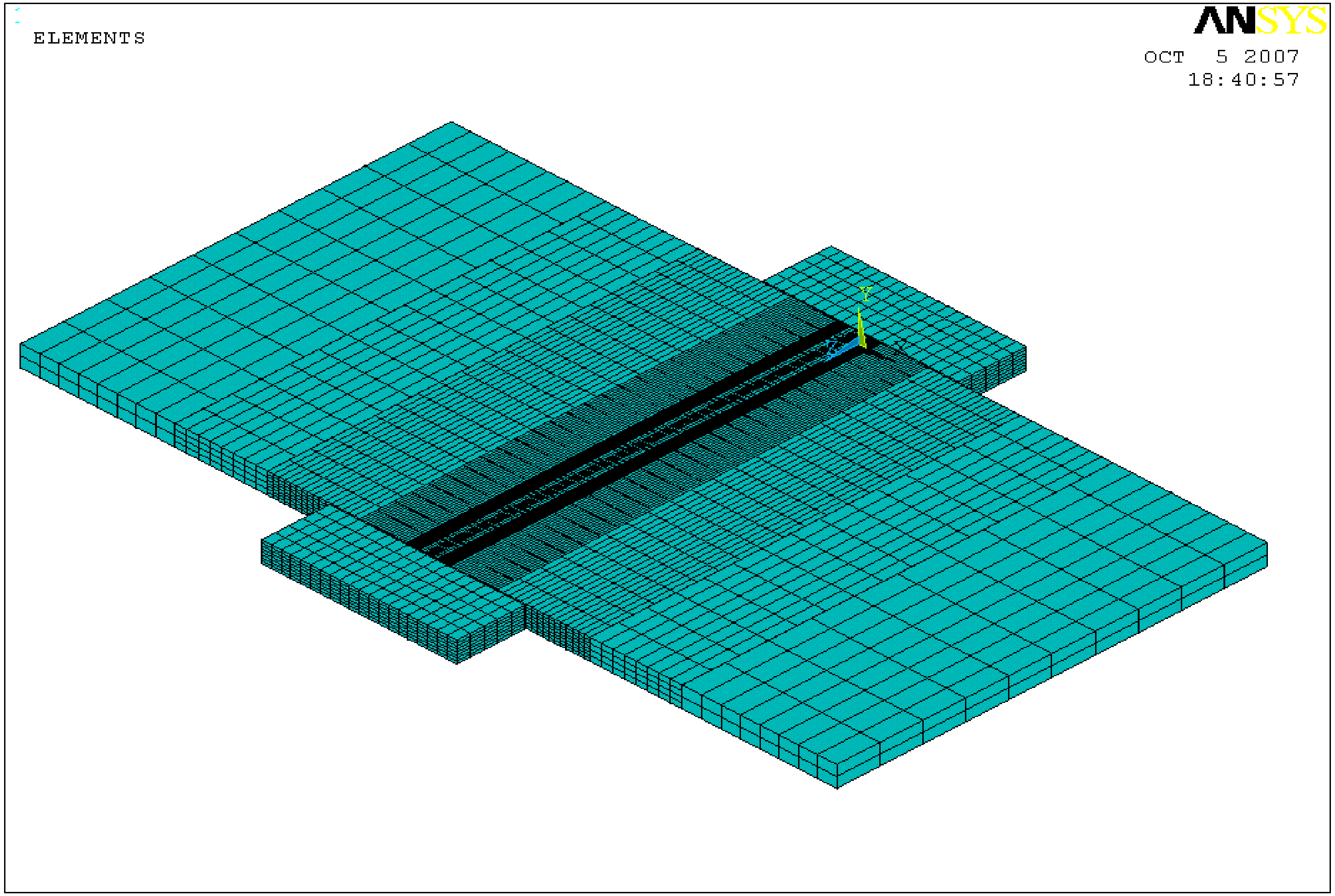


Scheme for subsequent passes



Lateral restraints position

FEM MODEL

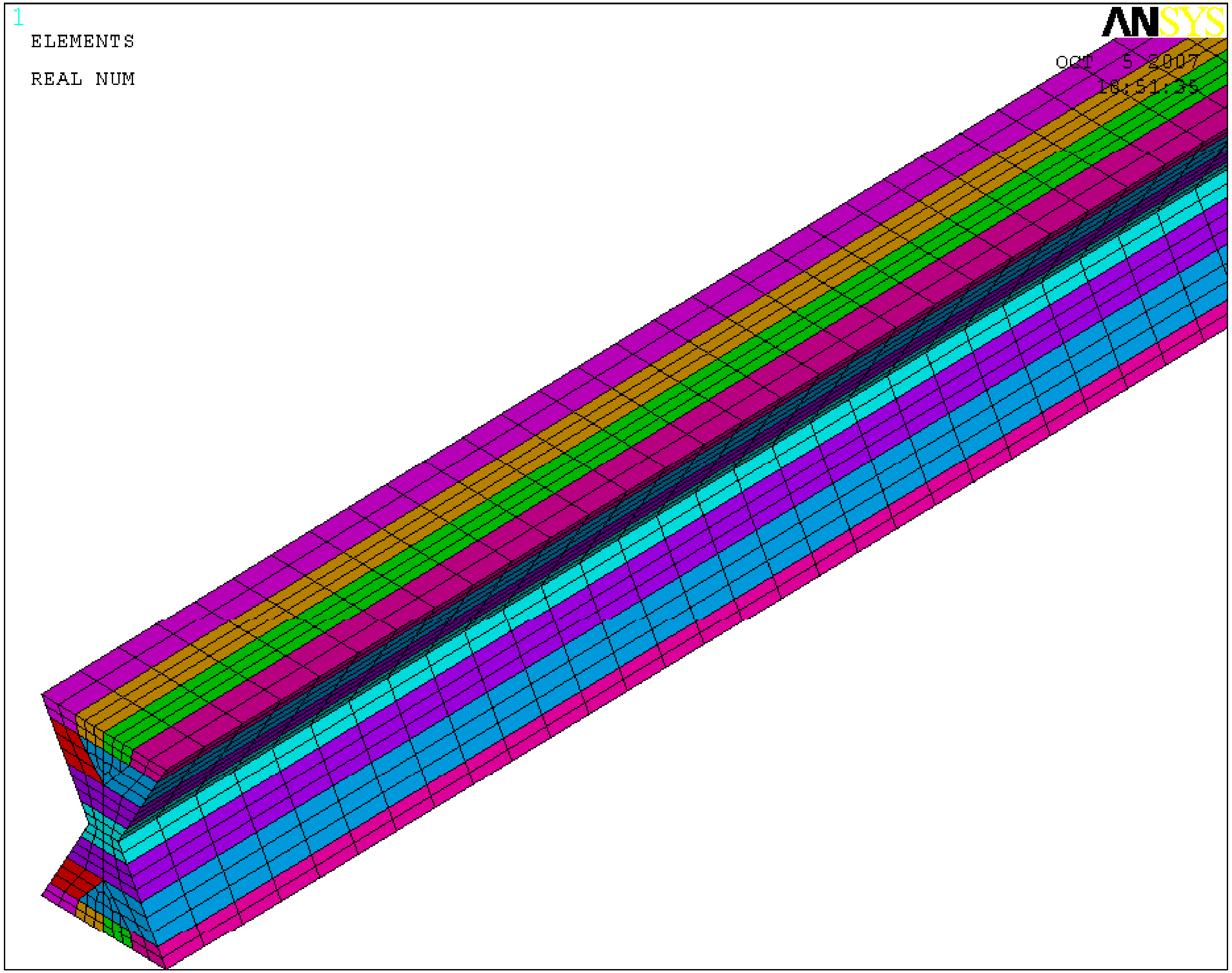


The connection between rigions with different mesh density is obtained with contact element with the “multi-point-constraint” option.

The connection between the plates and the edge restraints is made with coupling nodes DOF.

The model has about 91000 elements and 82000 nodes.

Caulker's elements

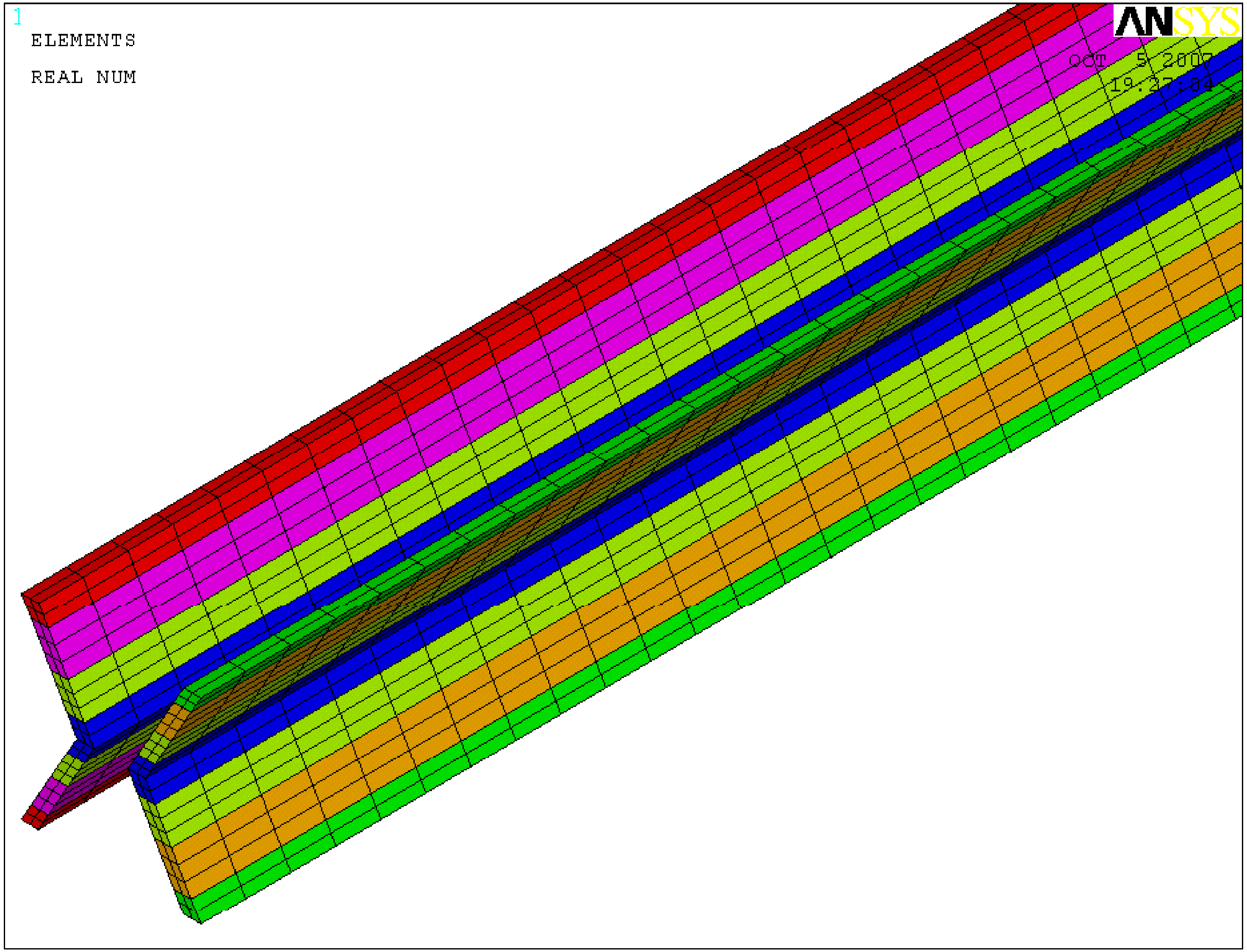


The elements that simulate the filling material are collected in groups that represent the different passes.

These elements are subjected to "birth" technique: they are killed at the beginning of the analysis and then reactivated at the proper time when the heat source passes.

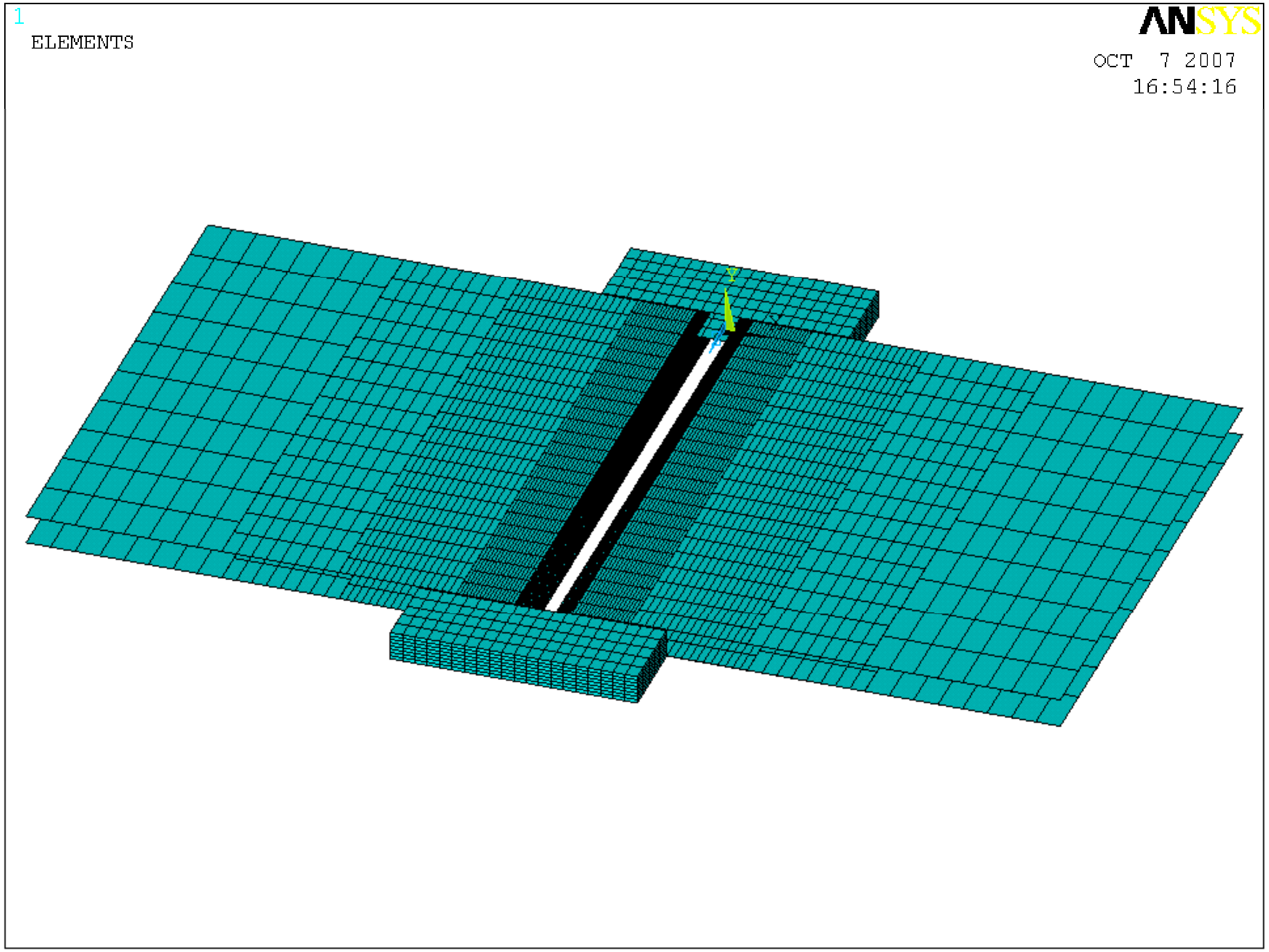
There are 80 elements in axial direction whose length is about 4 mm.

Heat Affected Zone elements



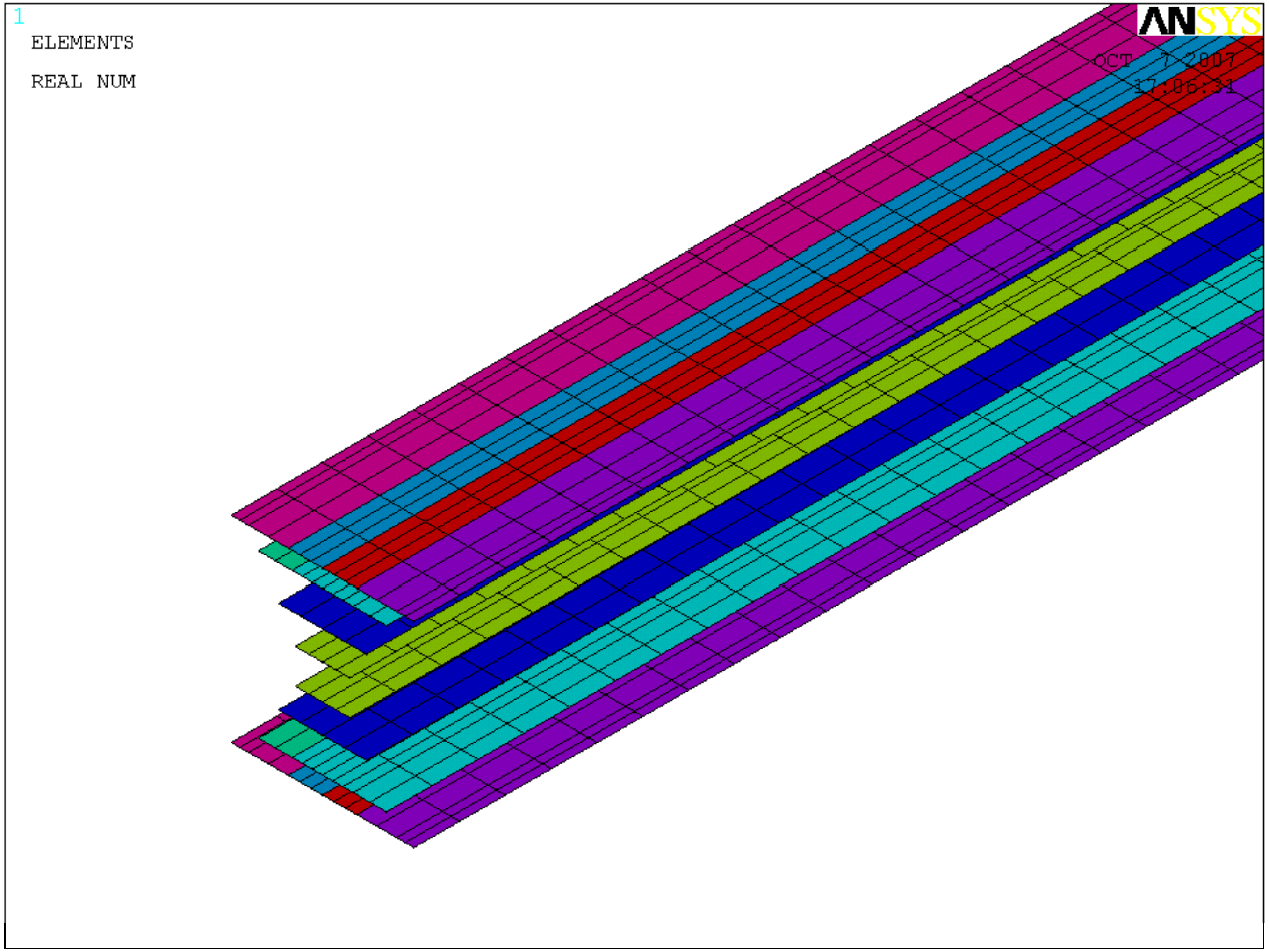
These elements represent the mushy zone whose final temperatures are checked to find out if the basic material is molten during welding. These region have the same mesh density of filling material.

Convection elements



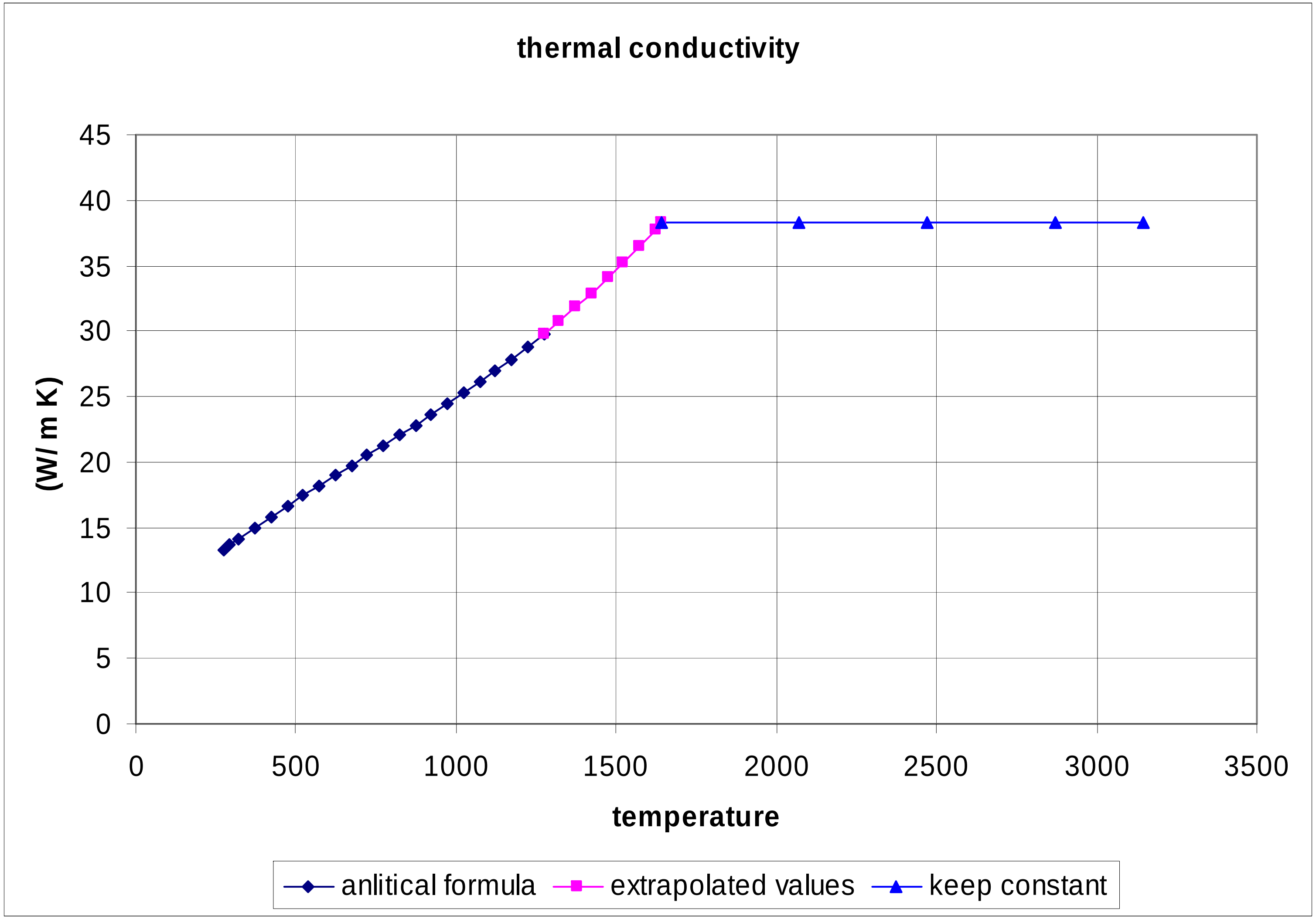
These elements overlay brick elements all over the plates. We can choose the film coefficient and the bulk temperature

Radiative elements



These elements overlay the elements describing filling material. They are killed at the beginning of the analysis and then reactivated one by one at the same time of the underlying brick element to simulatate the radiative heat loss of the molten metal drop.

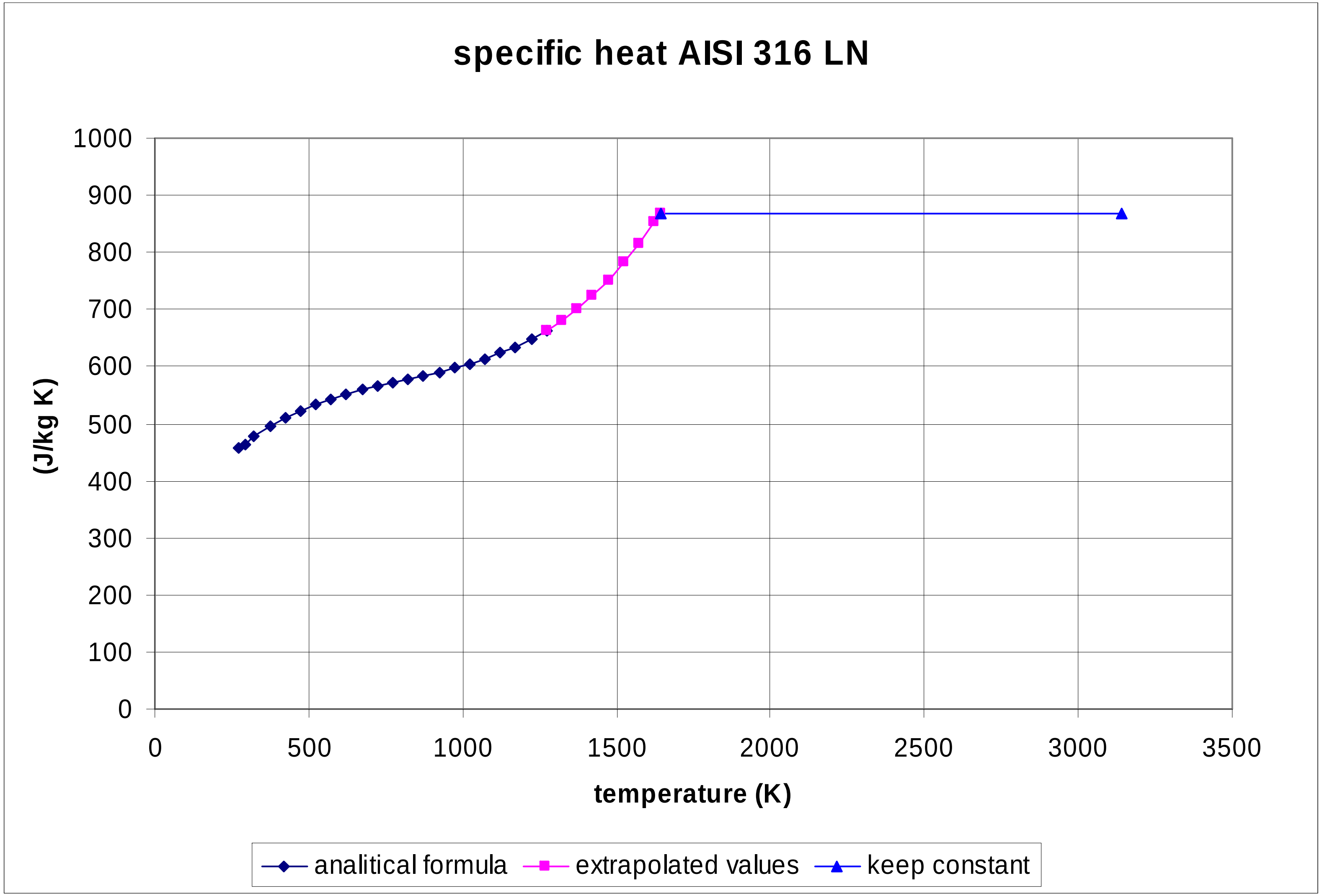
AISI 316 Material Property



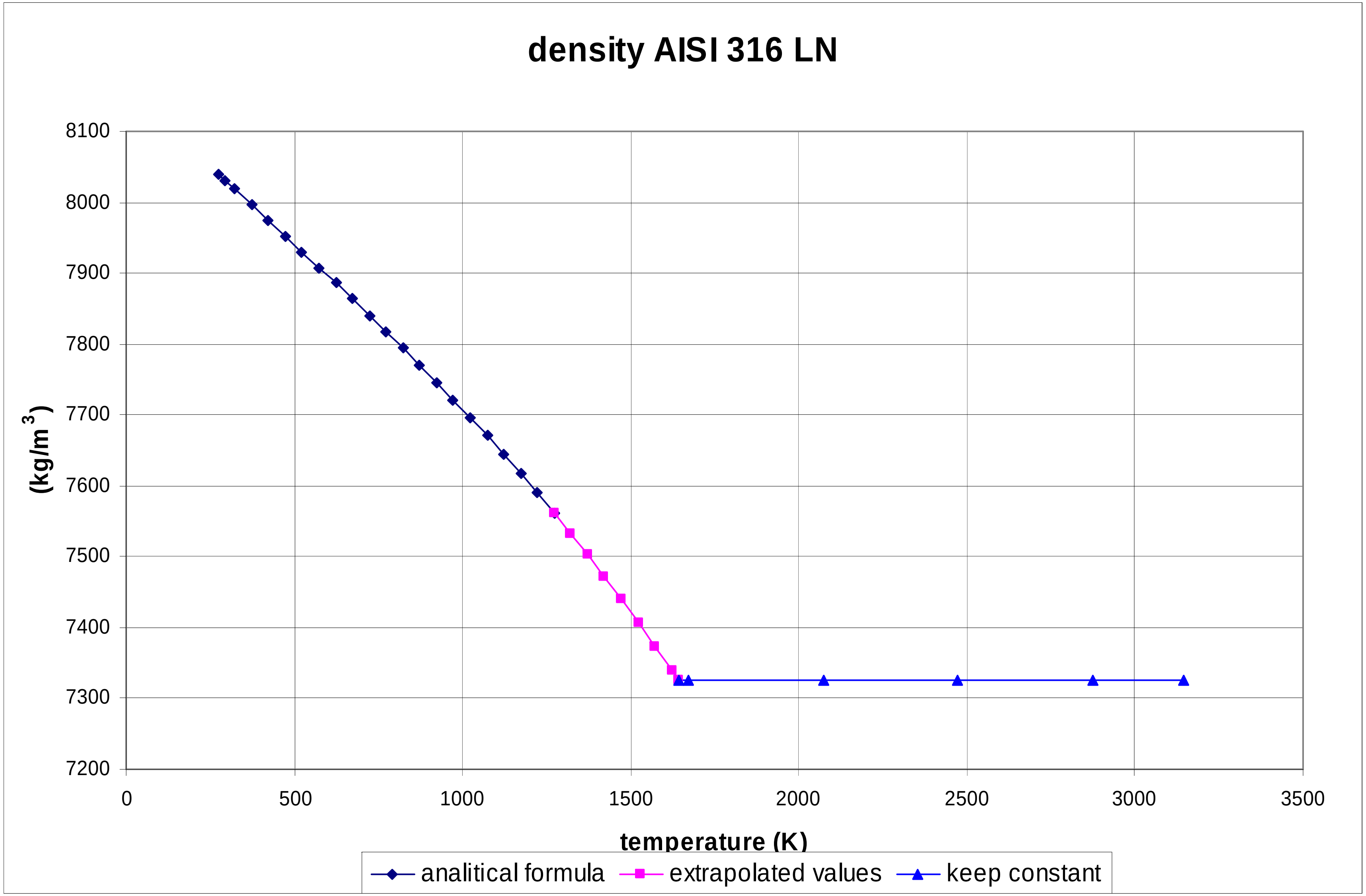
$T_{solidus}$ = 1370 °C = 1643 K

$T_{liquidus}$ = 1400 °C = 1673 K

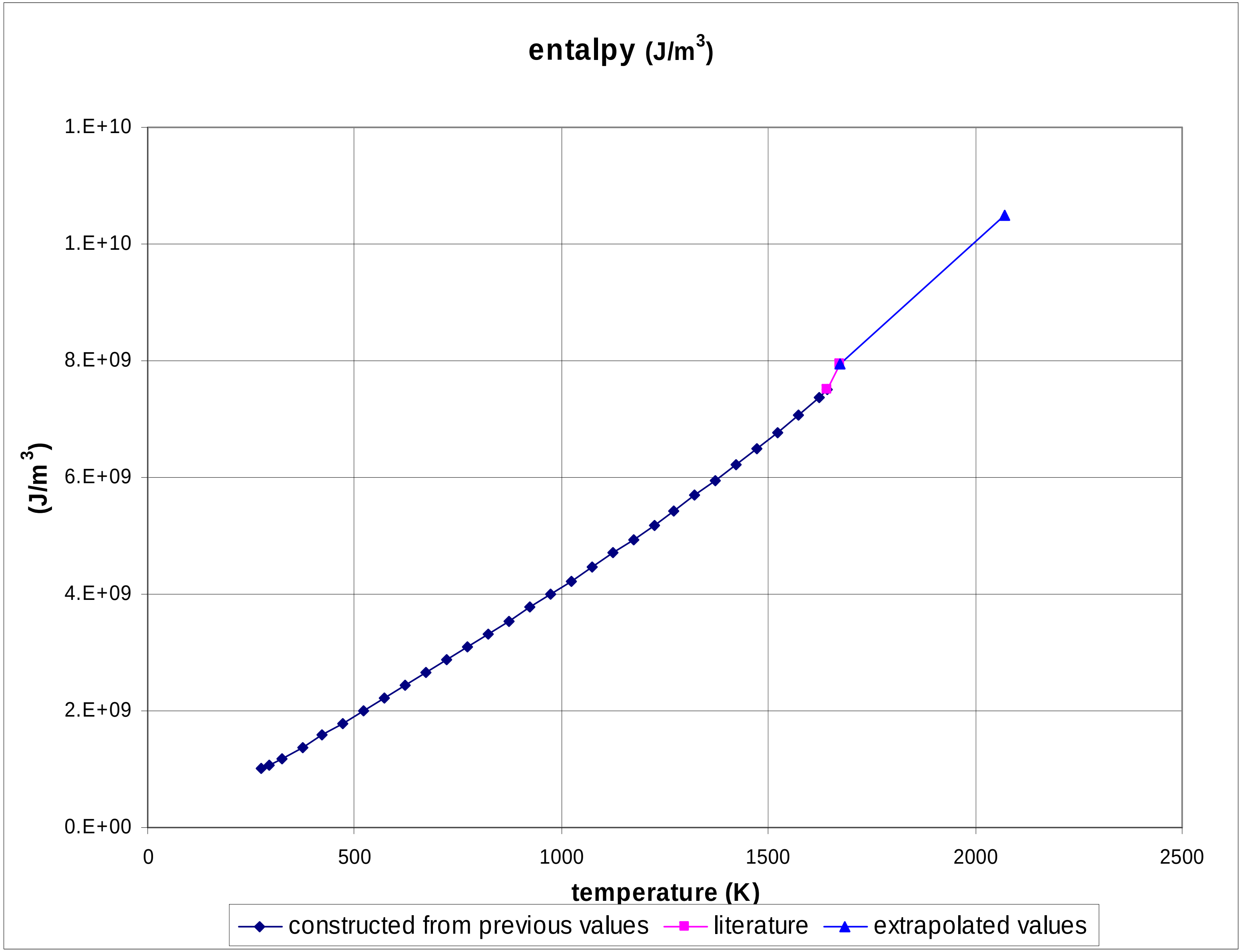
$$\lambda = 13.285 + 1.756 \cdot 10^{-2} T - 5.378 \cdot 10^{-6} T^{2} + 4.292 \cdot 10^{-9} T^{3}$$



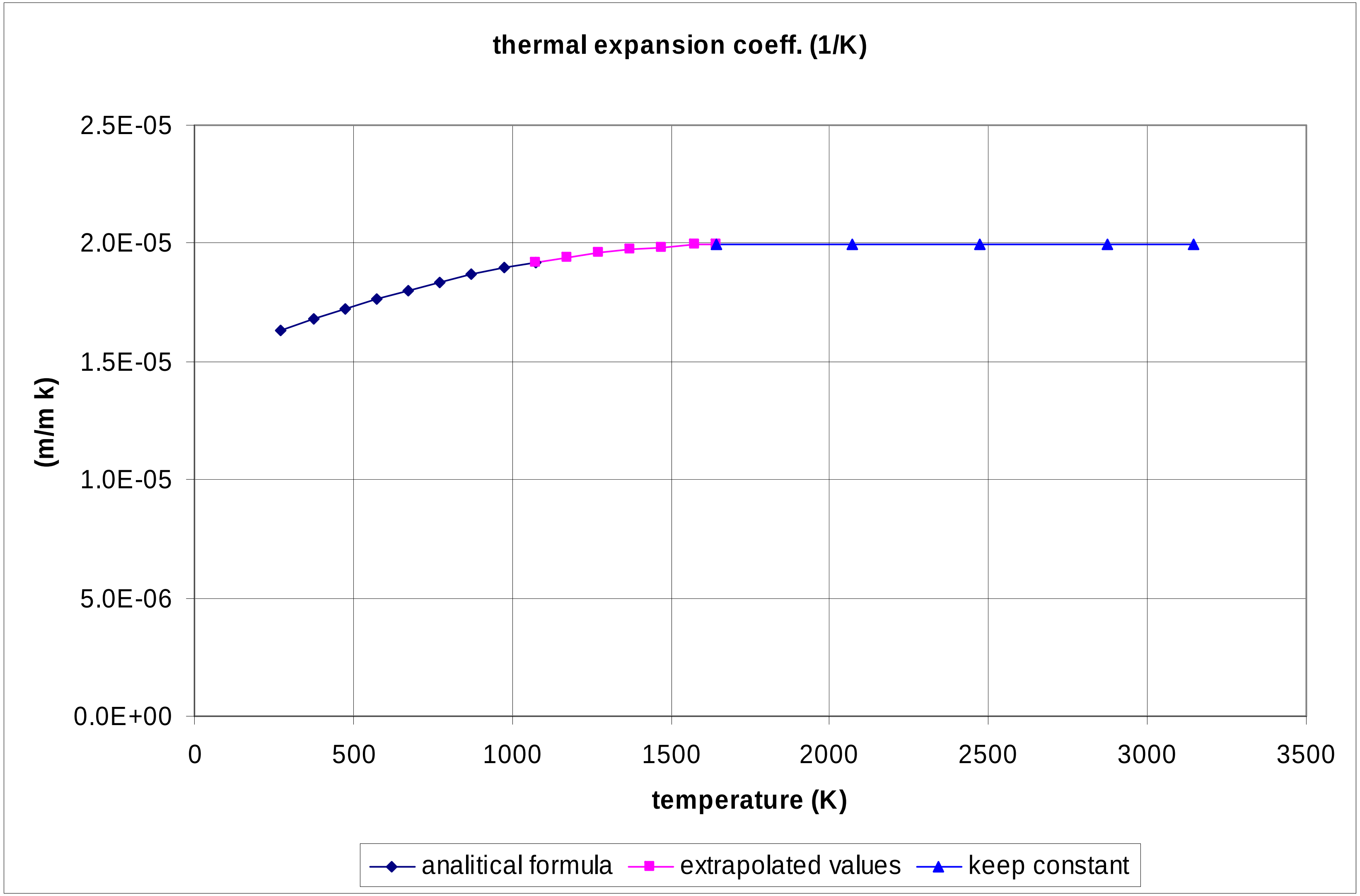
$$C_p = 456.28 + 0.43 \cdot T - 5.77 \cdot 10^{-4} T^2 + 3.50 \cdot 10^{-7} T^3$$



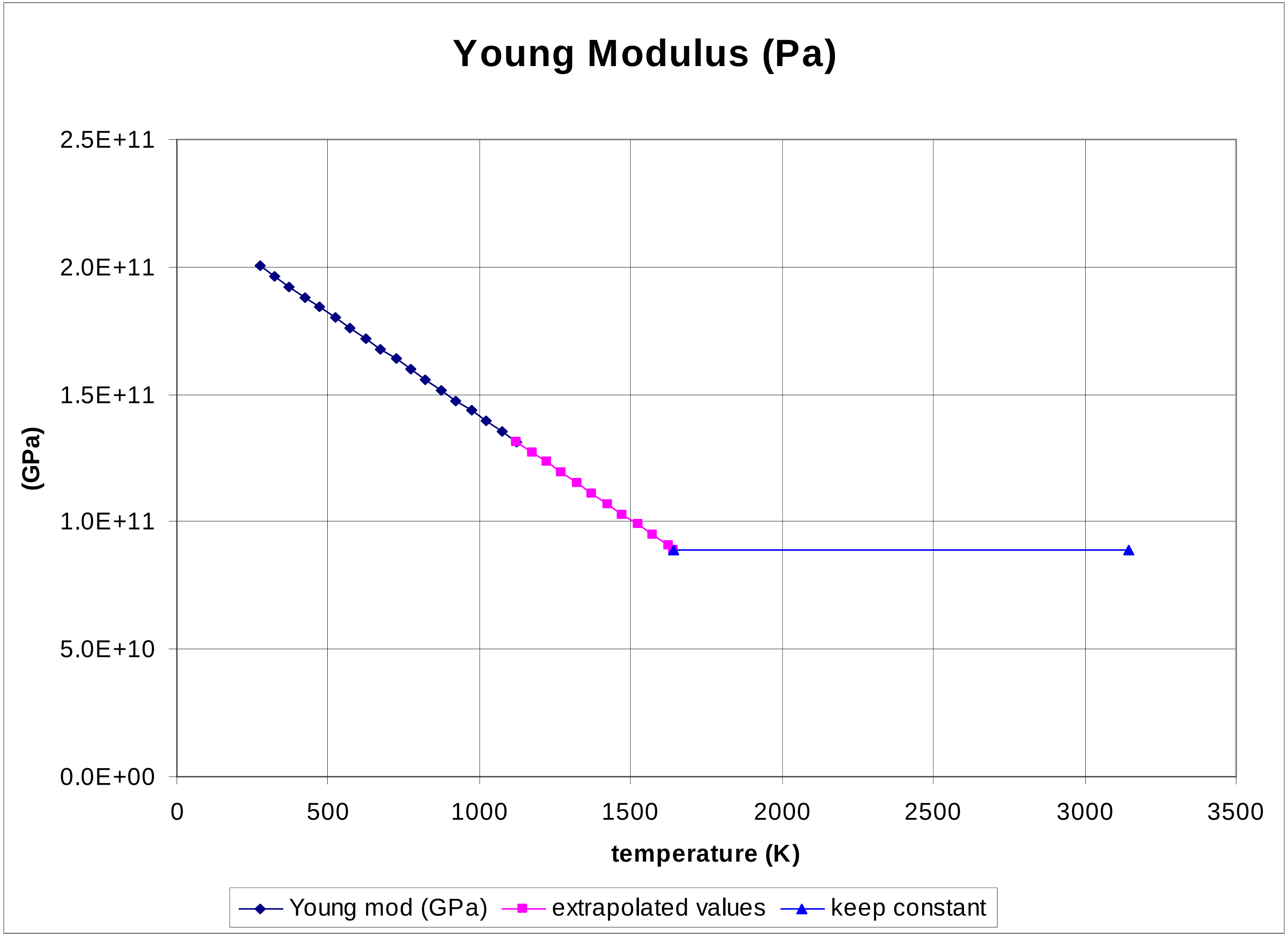
$$\rho = 8.038 - 4.103 \cdot 10^{-4} T - 6.488 \cdot 10^{-8} T^{2}$$



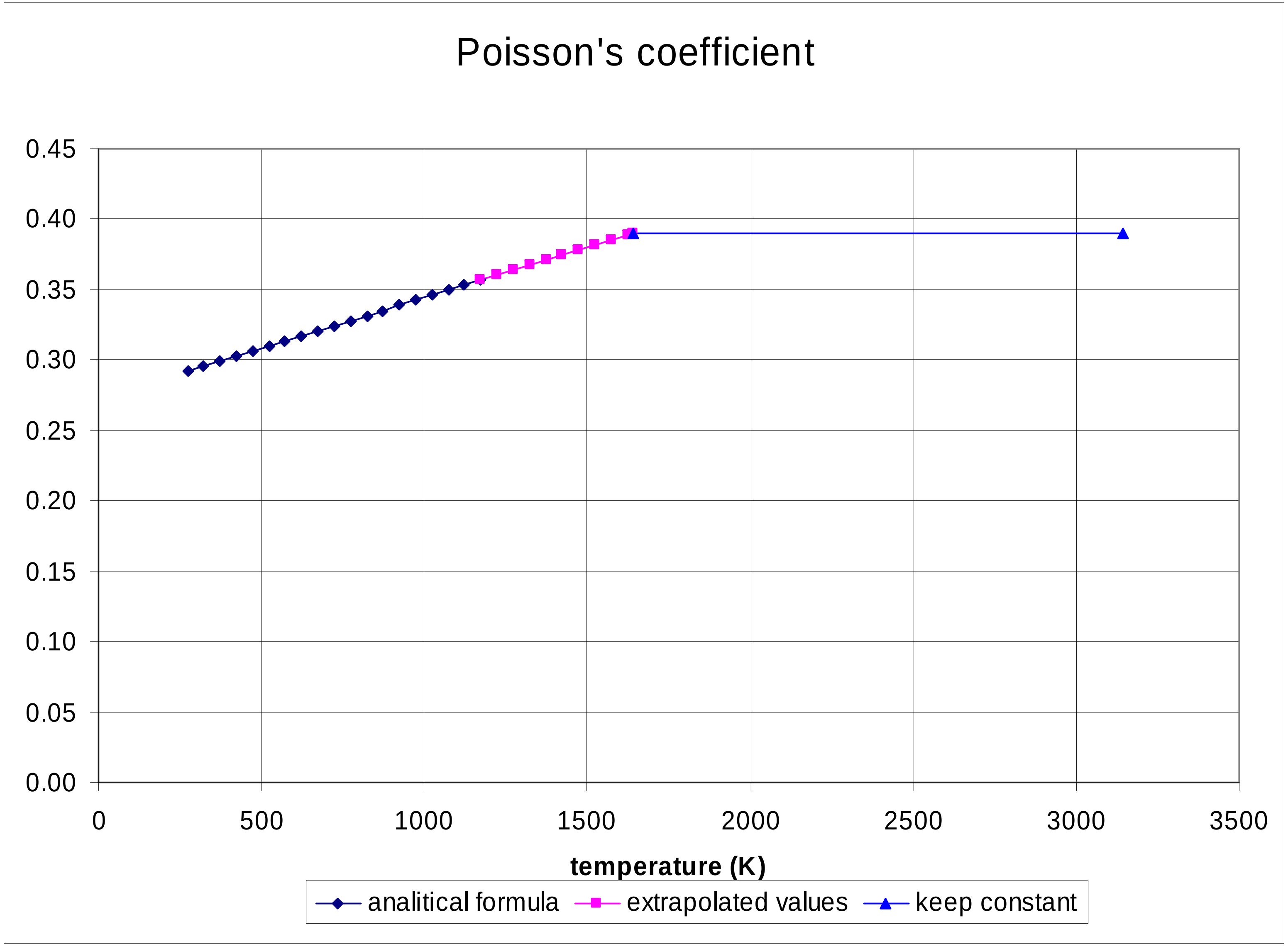
entalpy (J/m3)
1.E+10
1.E+10
8.E+09
6.E+09
4.E+09
2.E+09
0.E+00
(J/m3)
0
500
1000
1500
2000
2500
temperature (K)
constructed from previous values
literature
extrapolated values



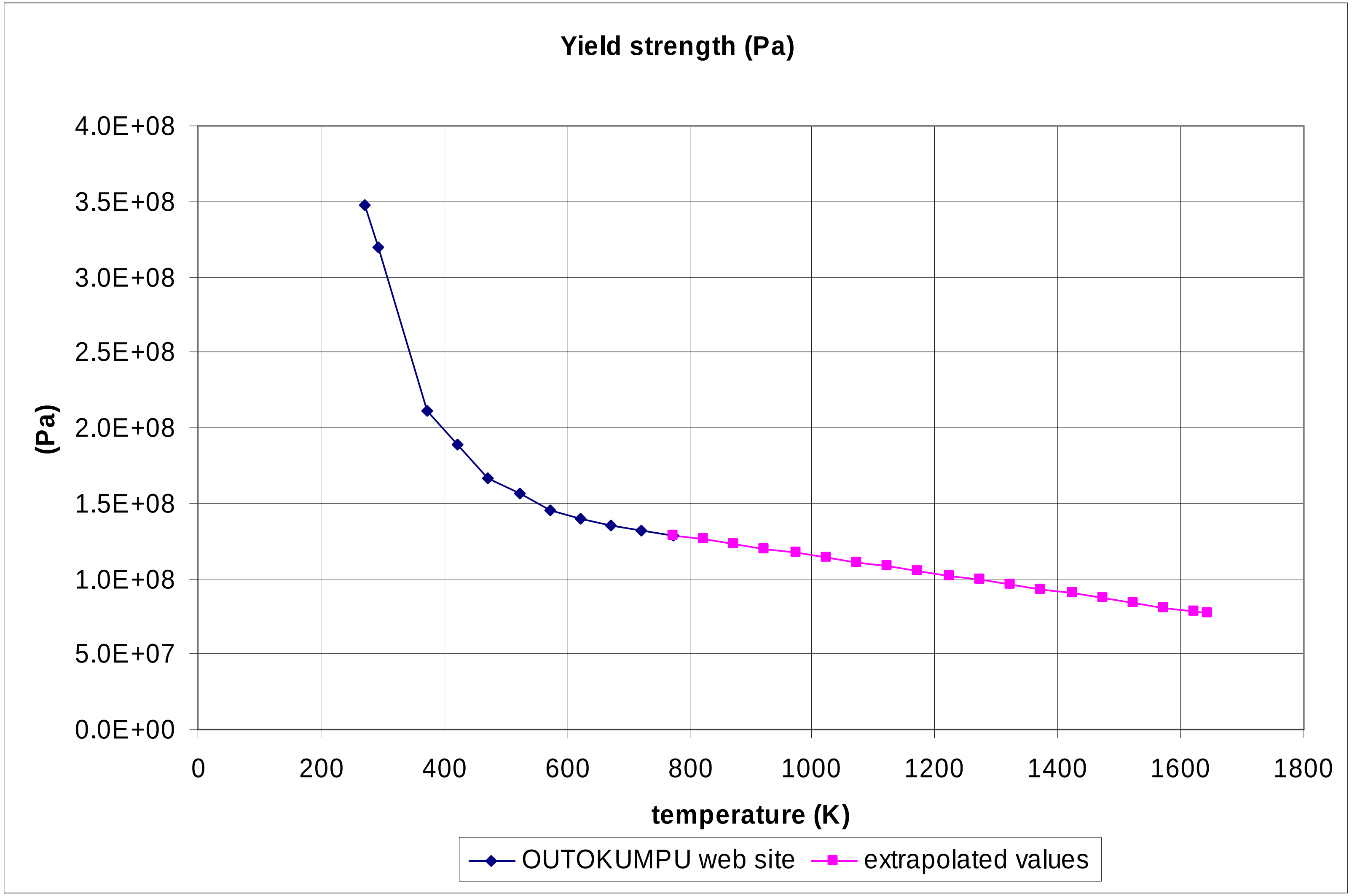
$$\alpha_m = 16.3153 + 4.9348 \cdot 10^{-3} T - 1.6585 \cdot 10^{-6} T^2$$

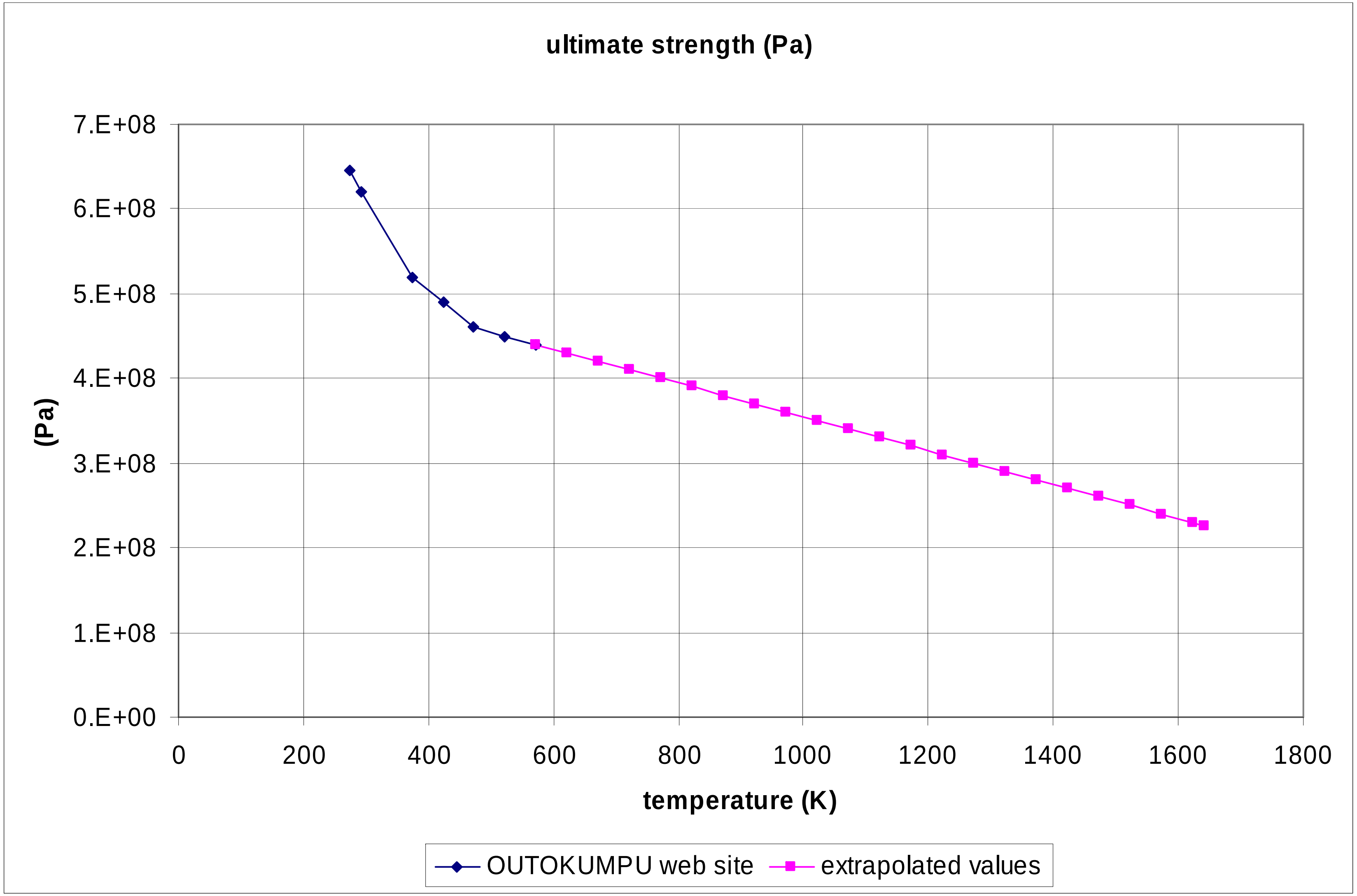


$$E = 200.3795 - 8.1221 \cdot 10^{-2} T$$



$$\nu = 0.2921 + 7.169 \cdot 10^{-5} T$$


Yield strength (Pa)
4.0E+08
3.5E+08
3.0E+08
2.5E+08
2.0E+08
1.5E+08
1.0E+08
5.0E+07
0.0E+00
(Pa)
0
200
400
600
800
1000
1200
1400
1600
1800
temperature (K)
OUTOKUMPU web site
extrapolated values


ultimate strength (Pa)
7.E+08
6.E+08
5.E+08
4.E+08
3.E+08
2.E+08
1.E+08
0.E+00
(Pa)
0
200
400
600
800
1000
1200
1400
1600
1800
temperature (K)
OUTOKUMPU web site
extrapolated values

Thermal analysis

•The axial length of model is 315 mm

•There are 80 elements in axial direction whose length is about 4 mm.

•Every pass is constituted by 80 load step plus 3 for cooling.

•The welding speed chosen is 0.25 mm/s.

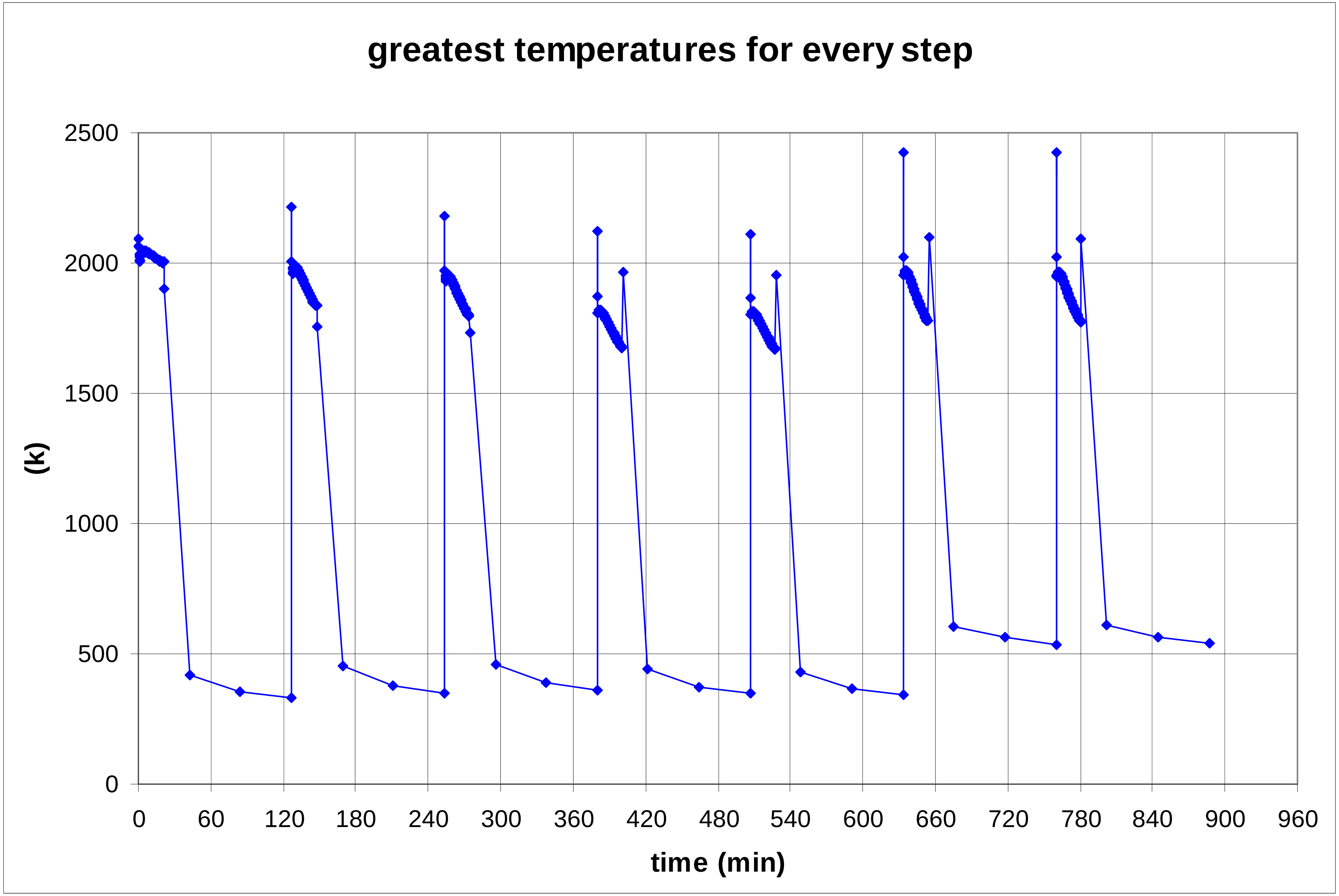
•The total time for a single pass is about 1265 s (~21 min)

•The cooling total time between each pass is 5 times the single pass welding time

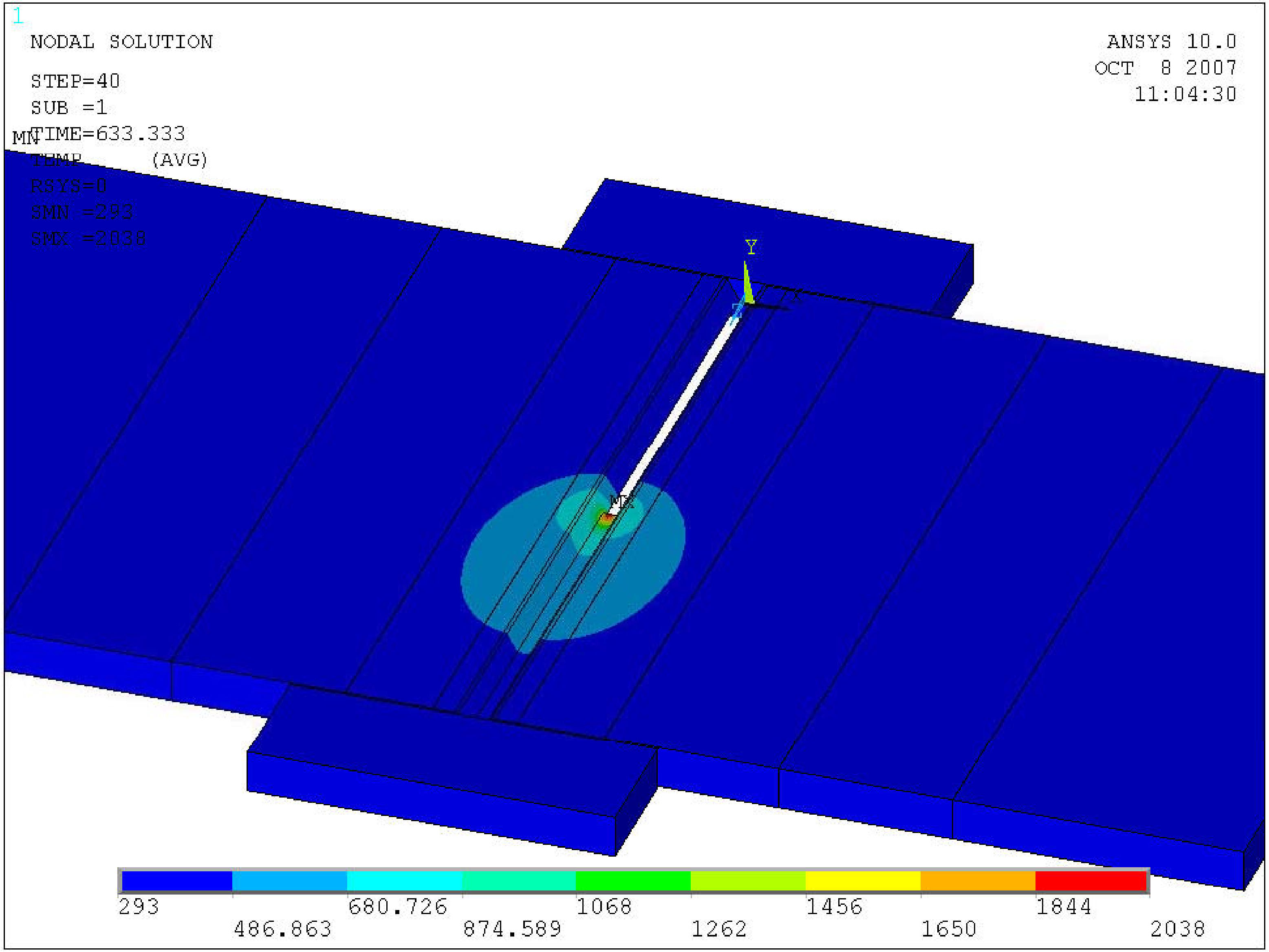
•The thermal analysis is concerned till the forth pass (up and down side)

•The CPU time is about 11 hours [Pentiun 4 (R) 3.2 GHz - 2Gb Ram]

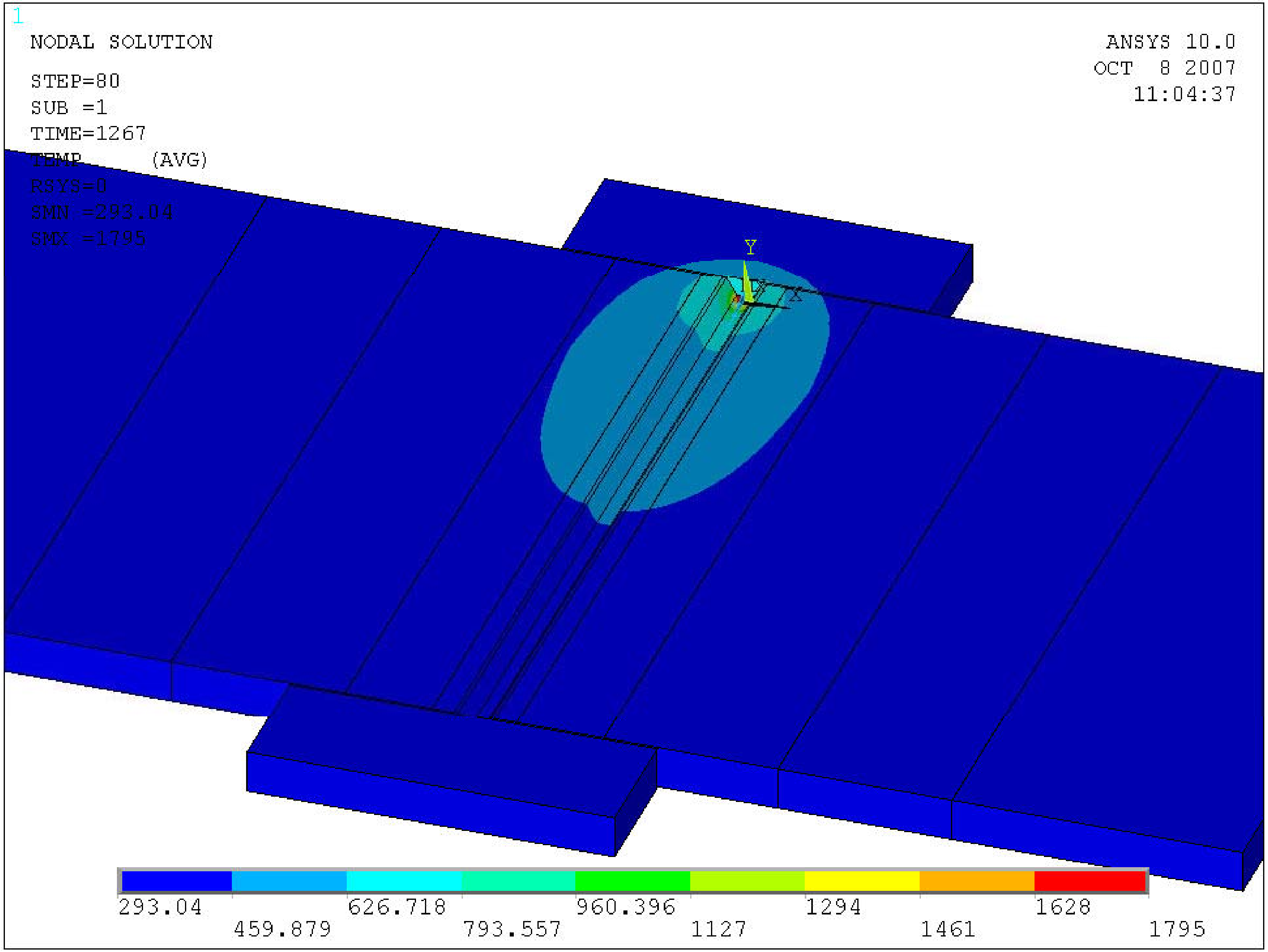
•The Hard Disk space is about 40 Gb


greatest temperatures for every step
(k)
2500
2000
1500
1000
500
0
0
60
120
180
240
300
360
420
480
540
600
660
720
780
840
900
960
time (min)

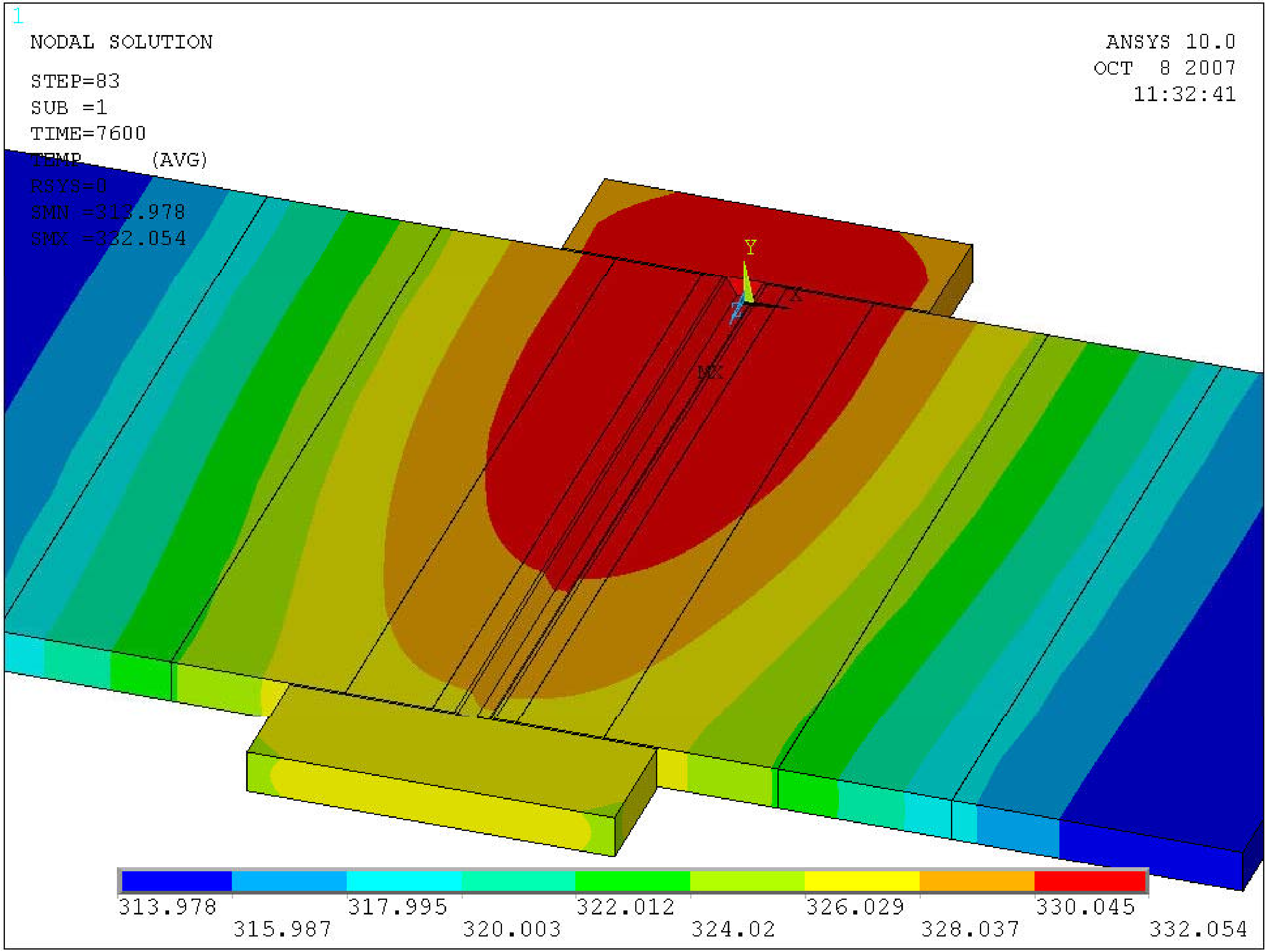
1st pass: step n. 40



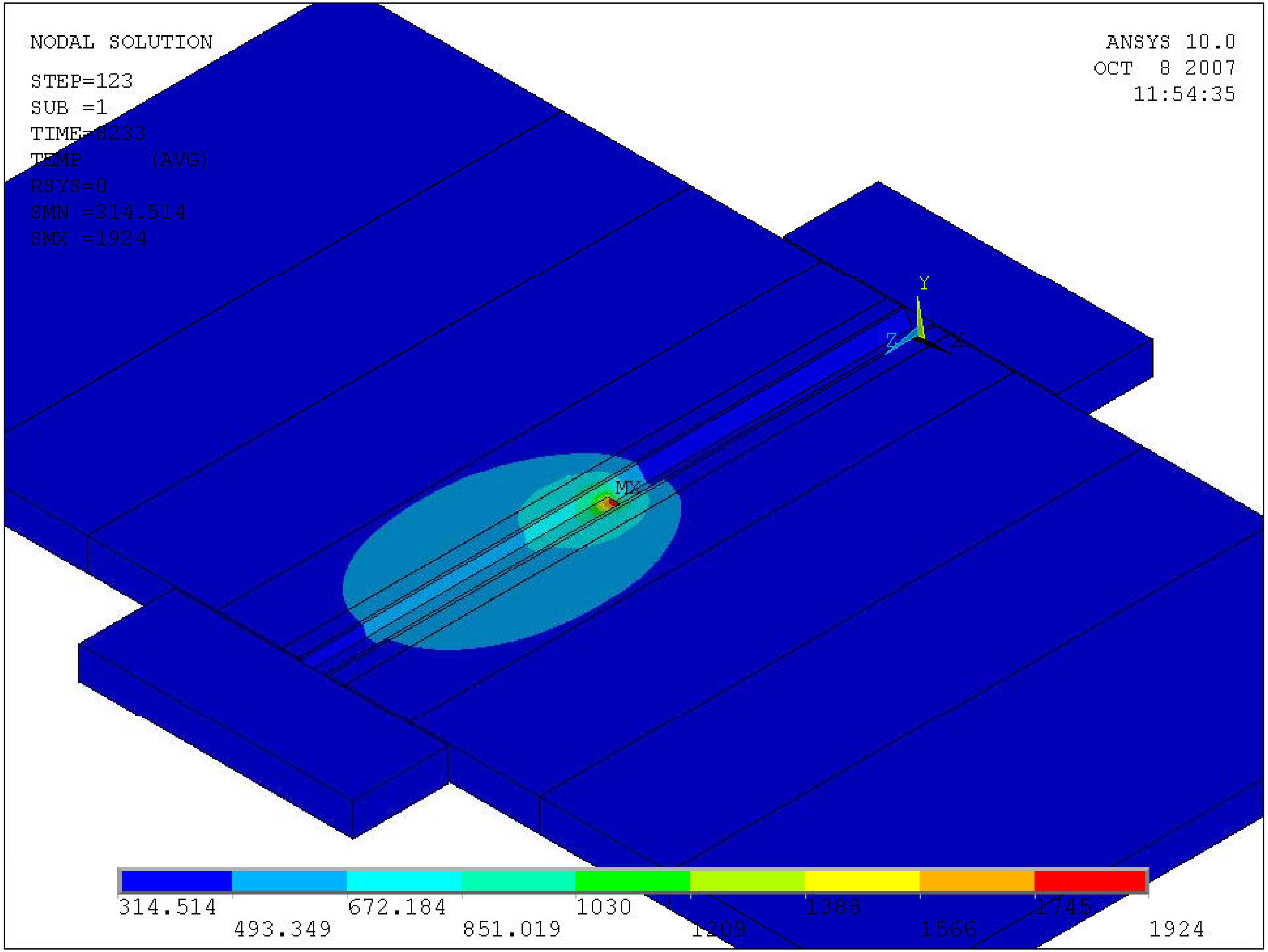
1st pass: step n. 80



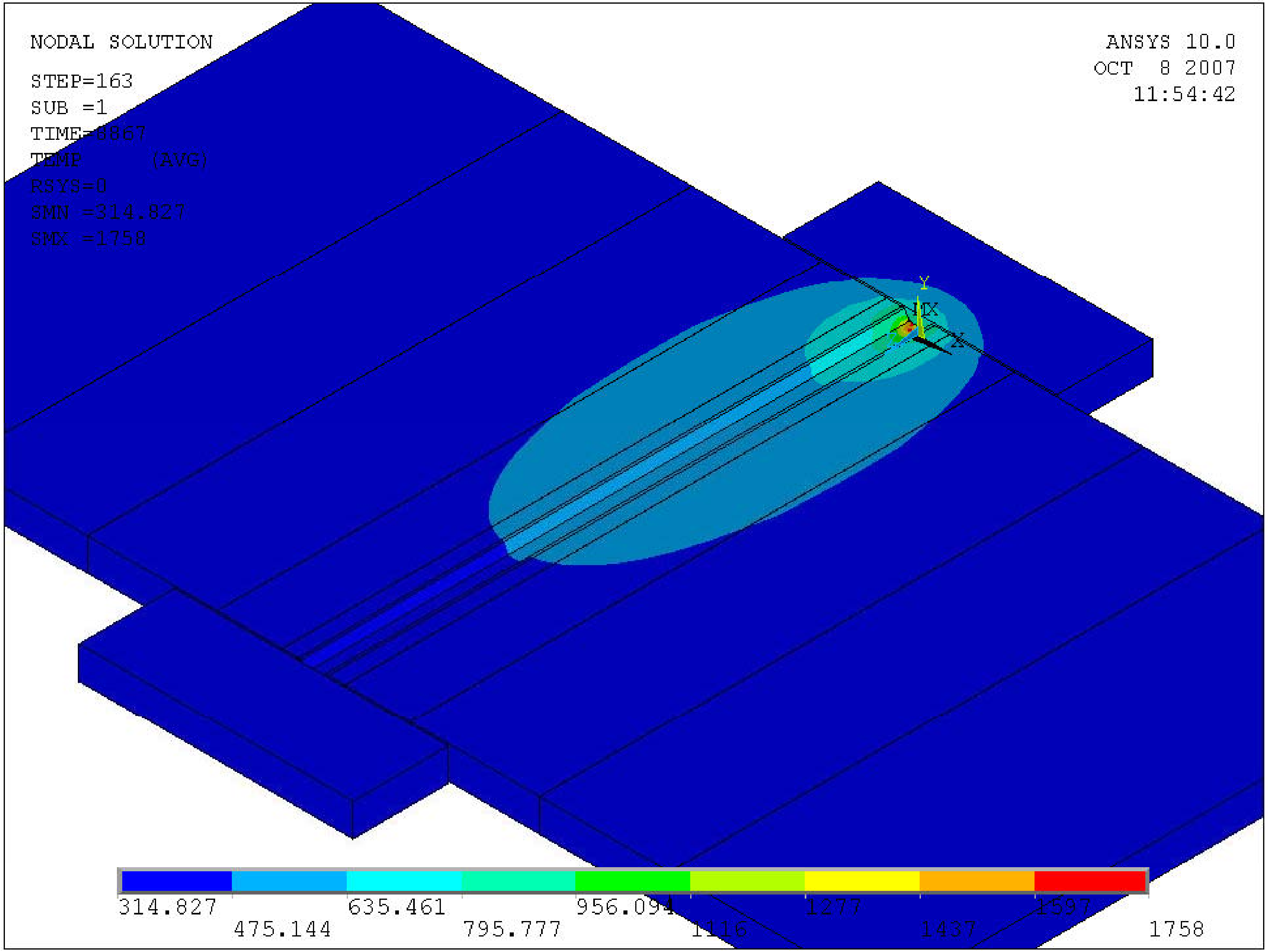
1st pass: final cooling step



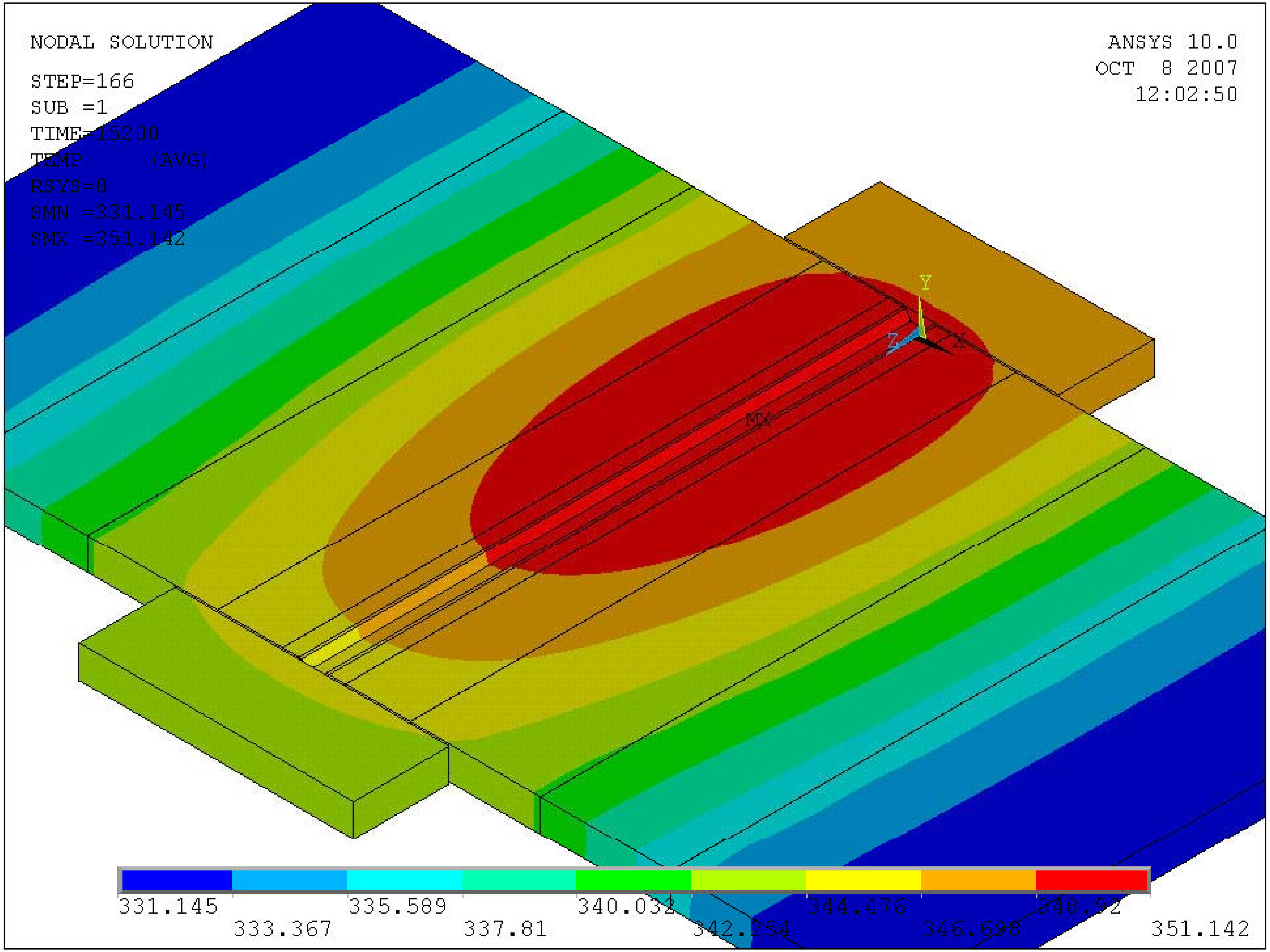
2nd upside pass: step n. 40



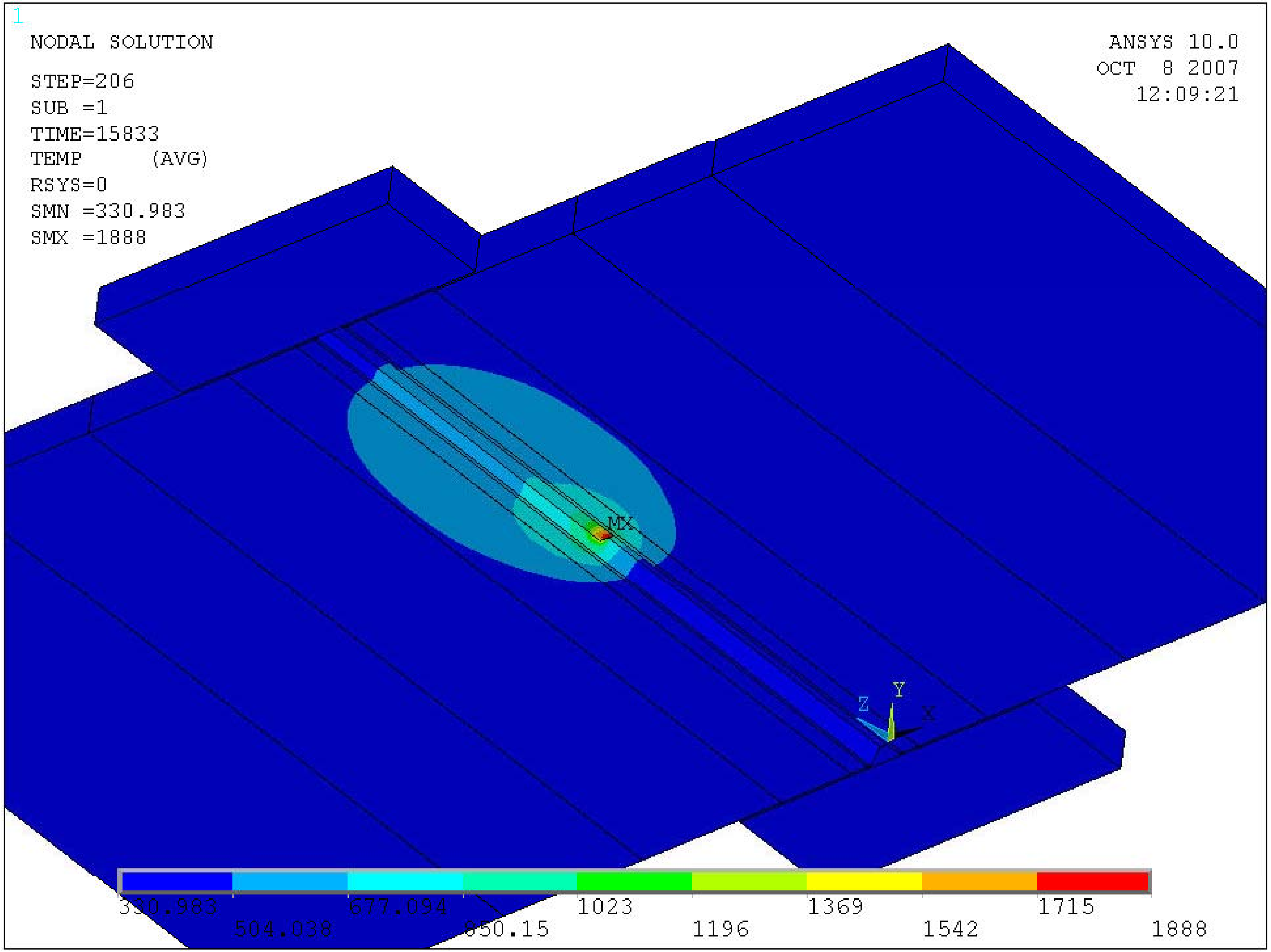
2nd upside pass: step n. 80



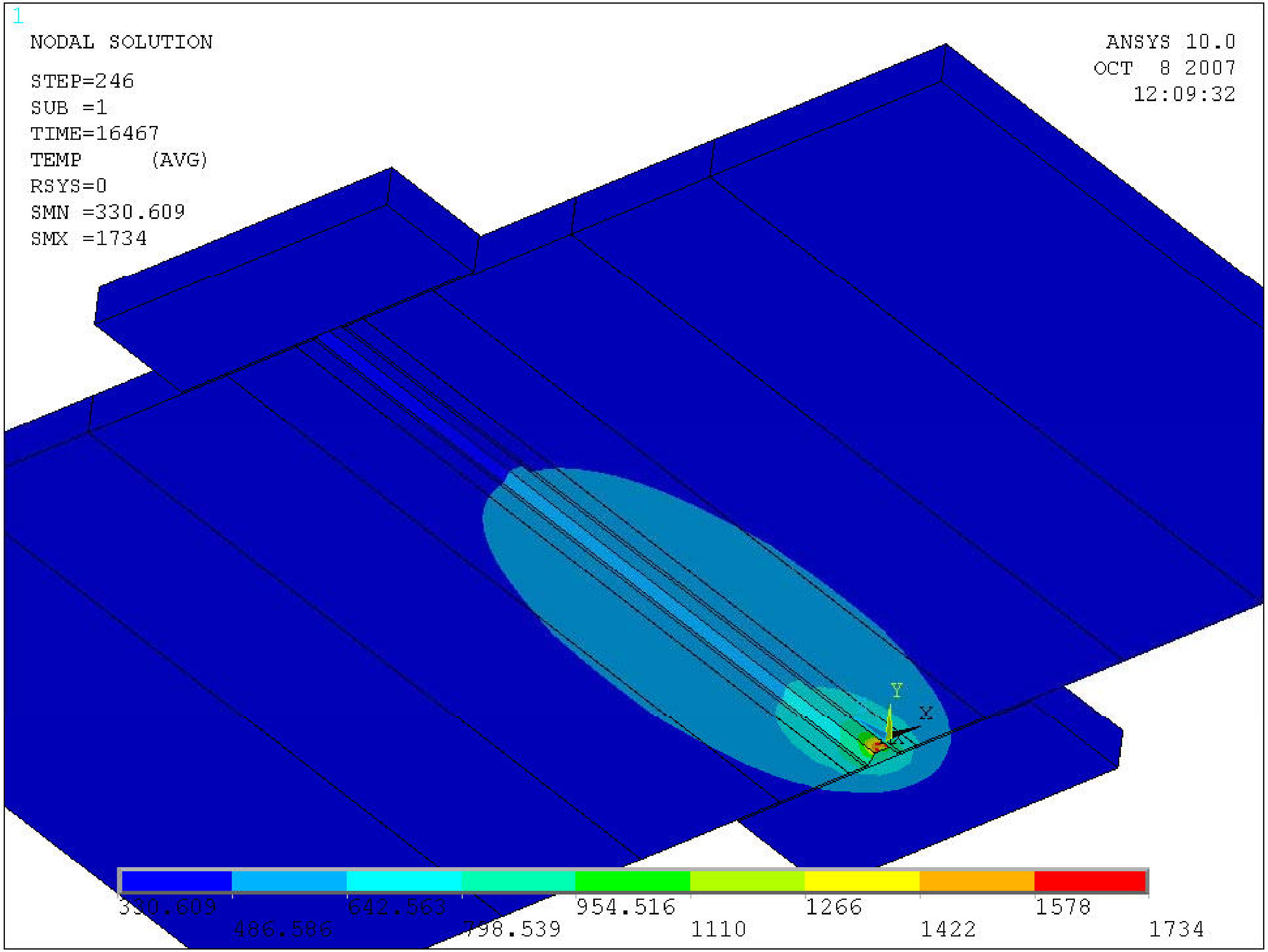
2nd upside pass: final cooling step



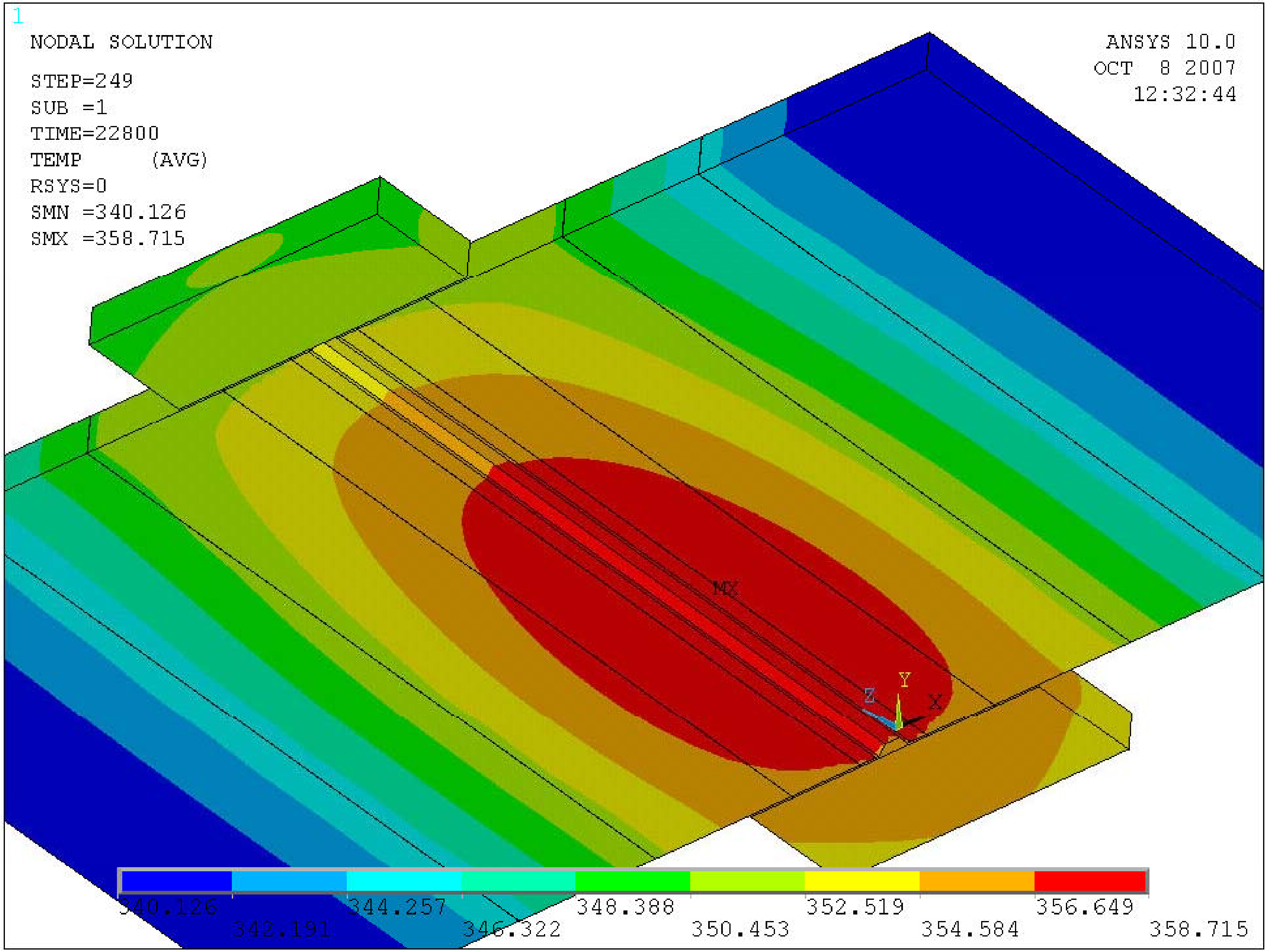
2nd downside pass: step n. 40



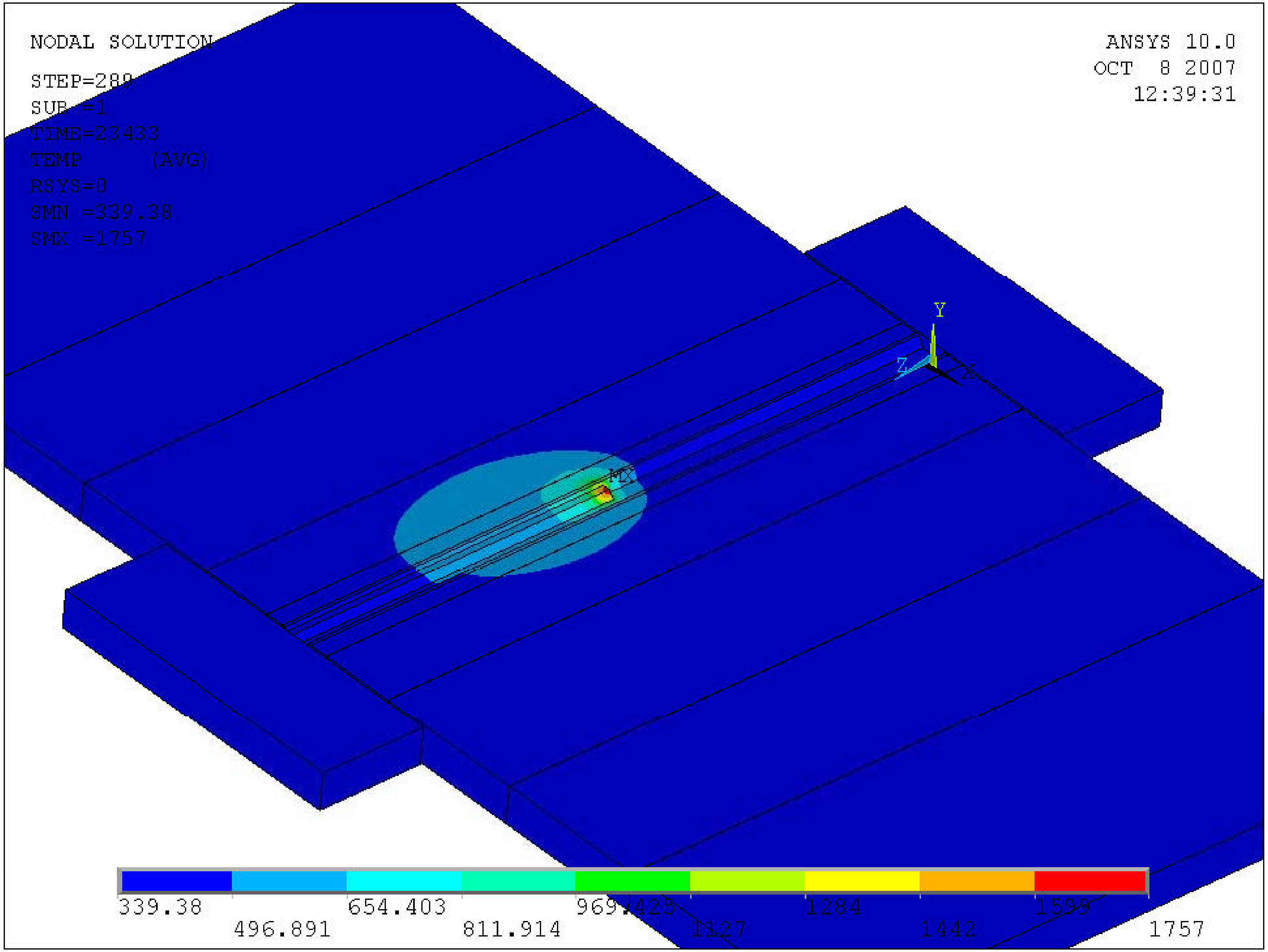
2nd downside pass: step n. 80



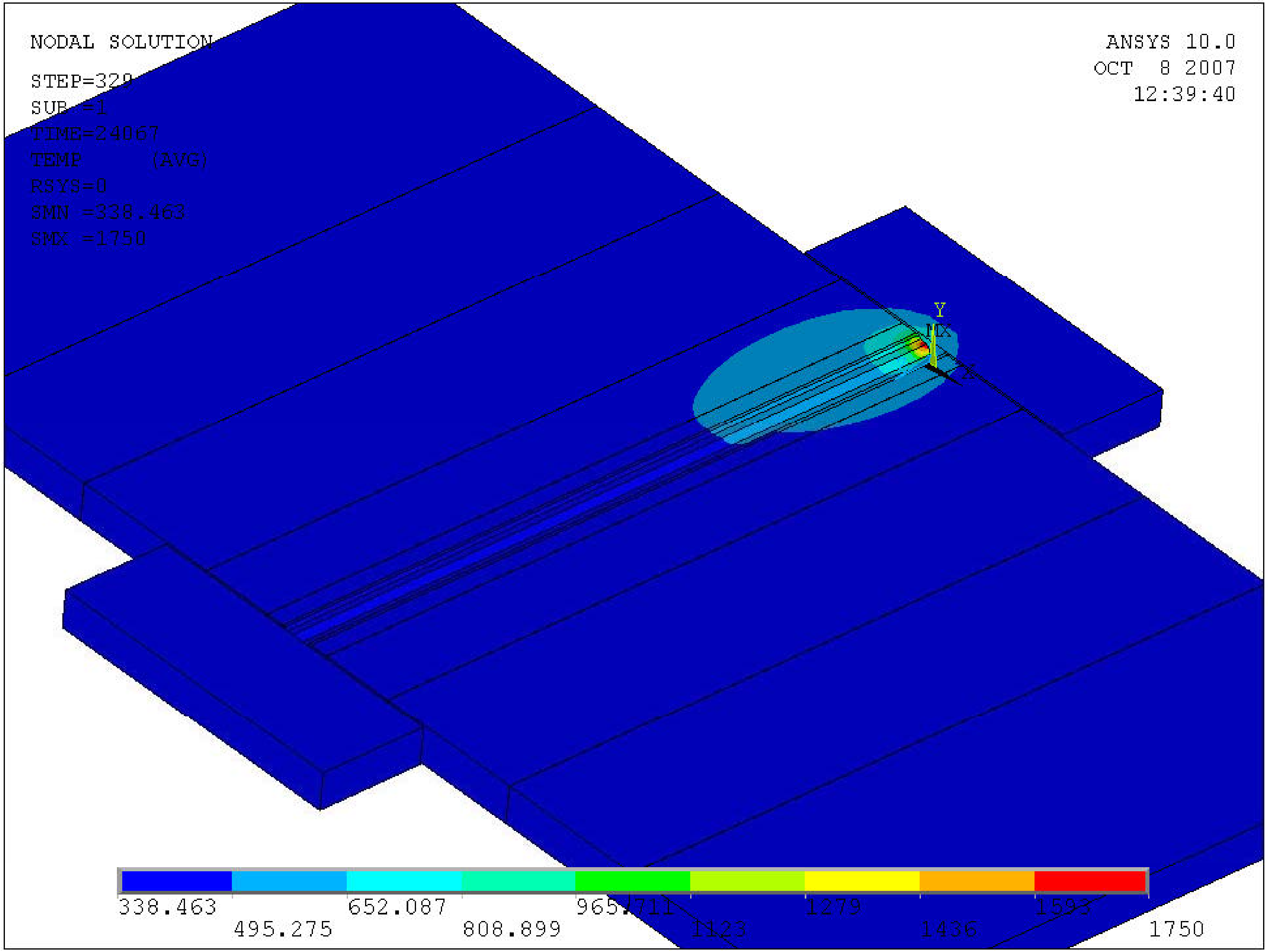
2nd downside pass: final cooling step



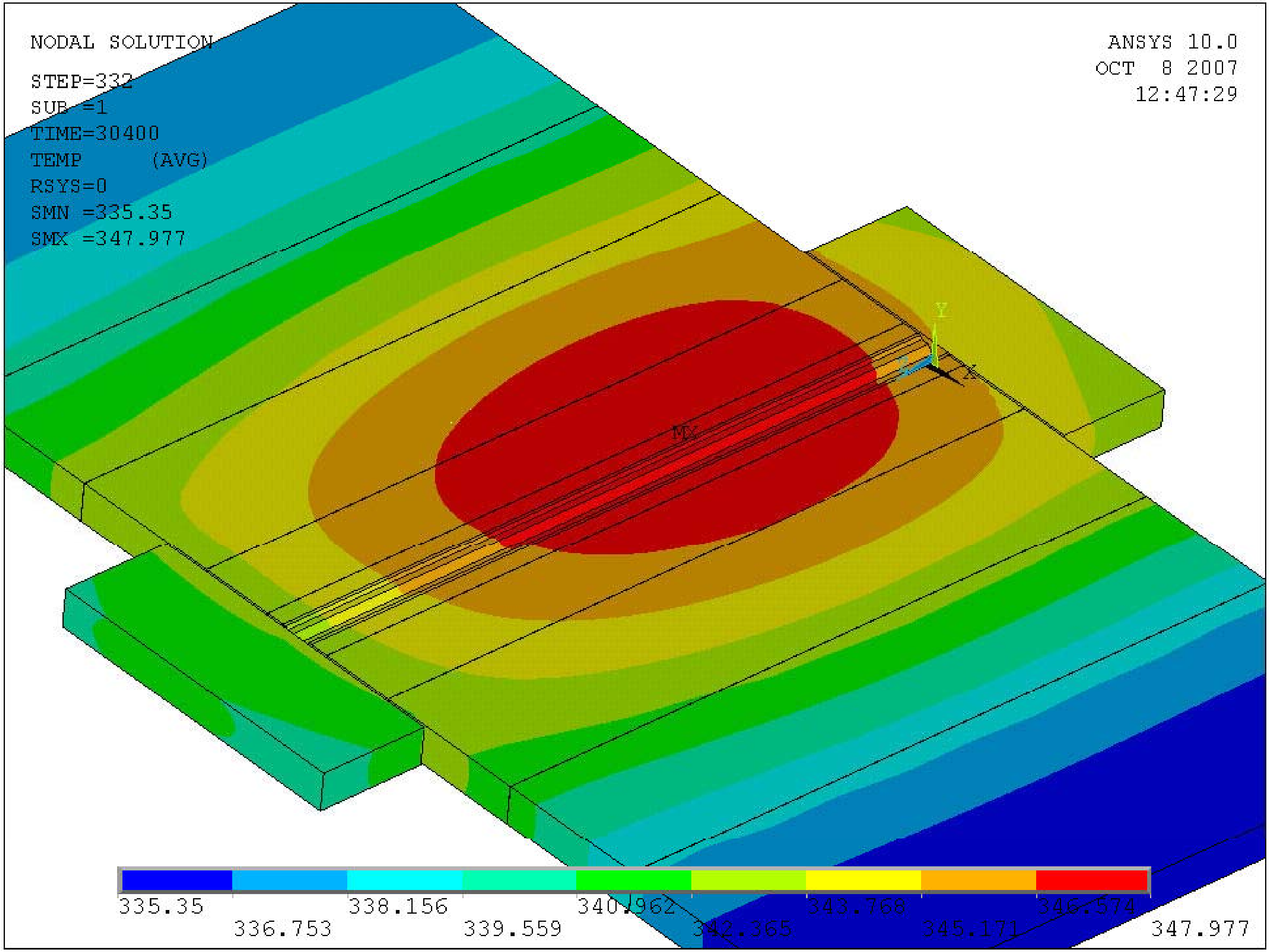
3rd upside pass: step n. 40



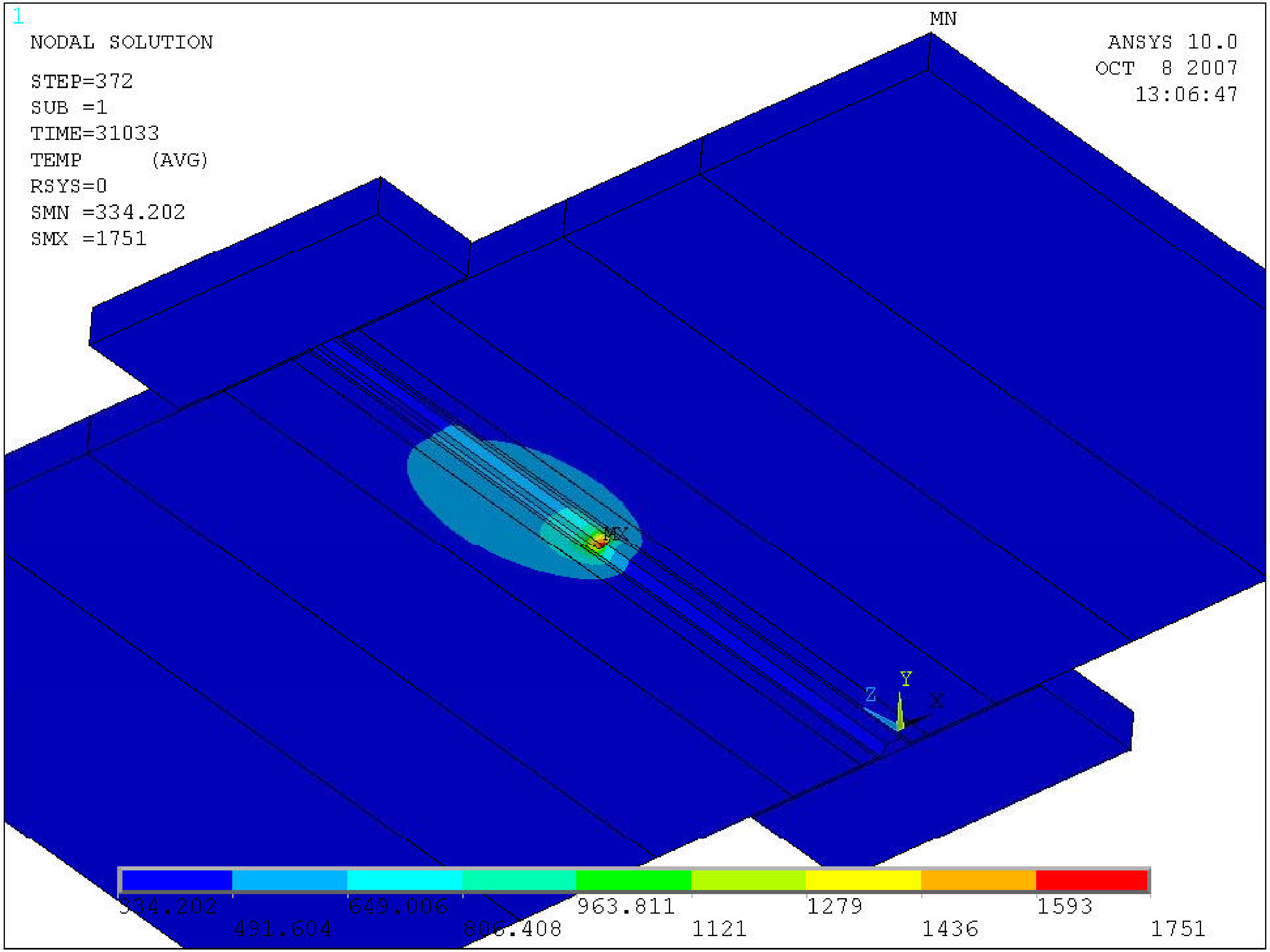
3rd upside pass: step n. 80



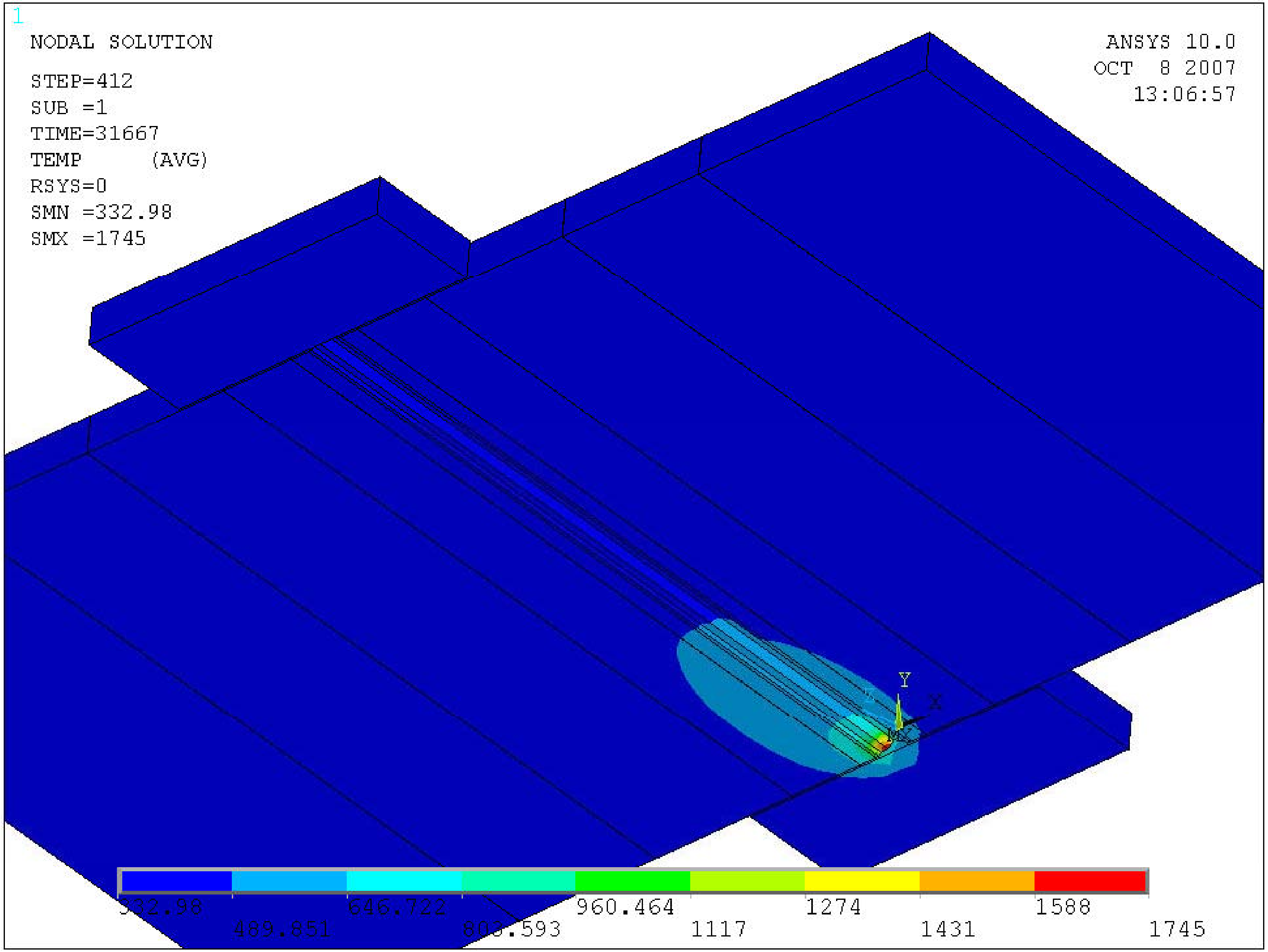
3rd upside pass: final cooling step



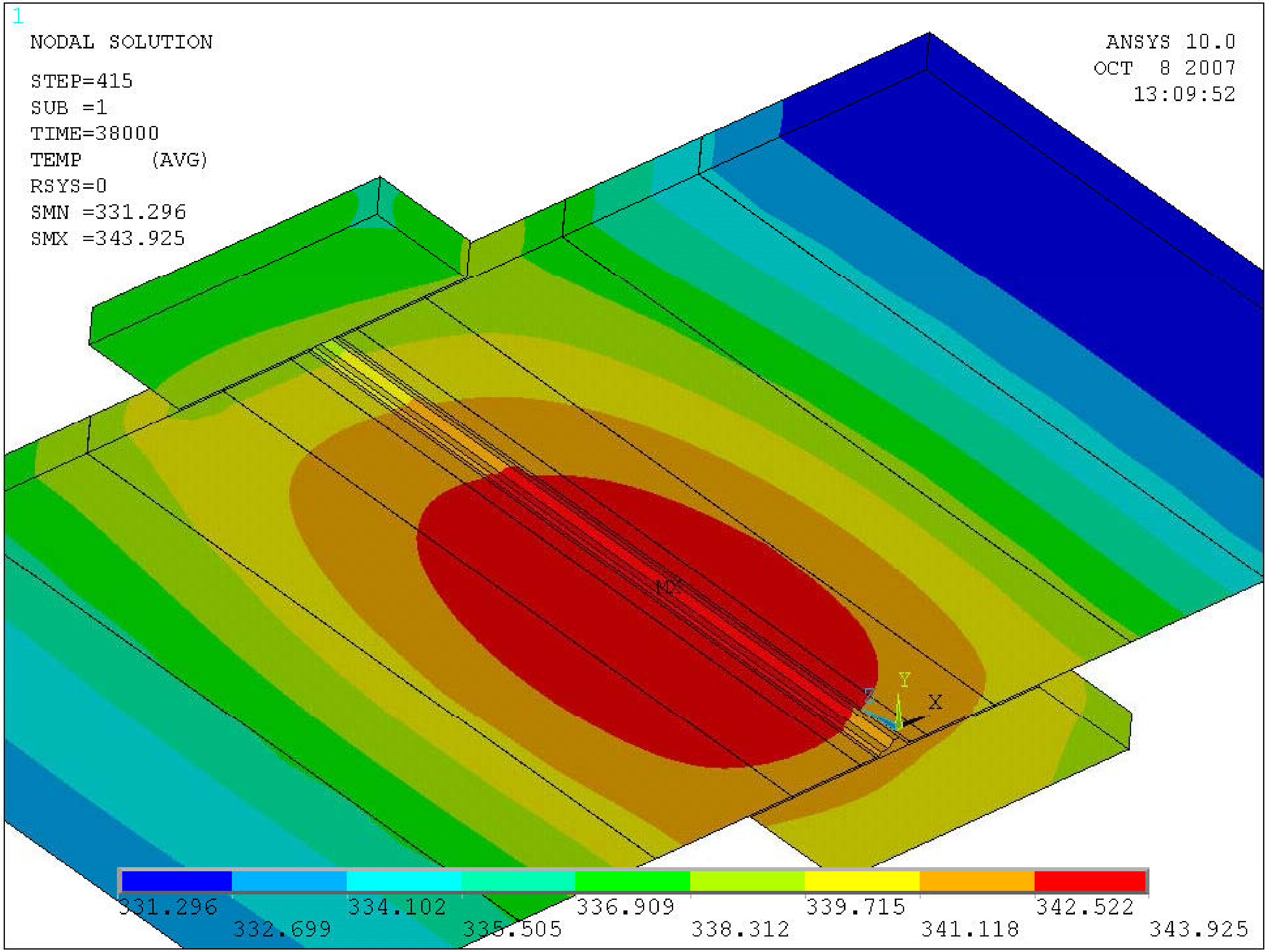
3rd downside pass: step n. 40



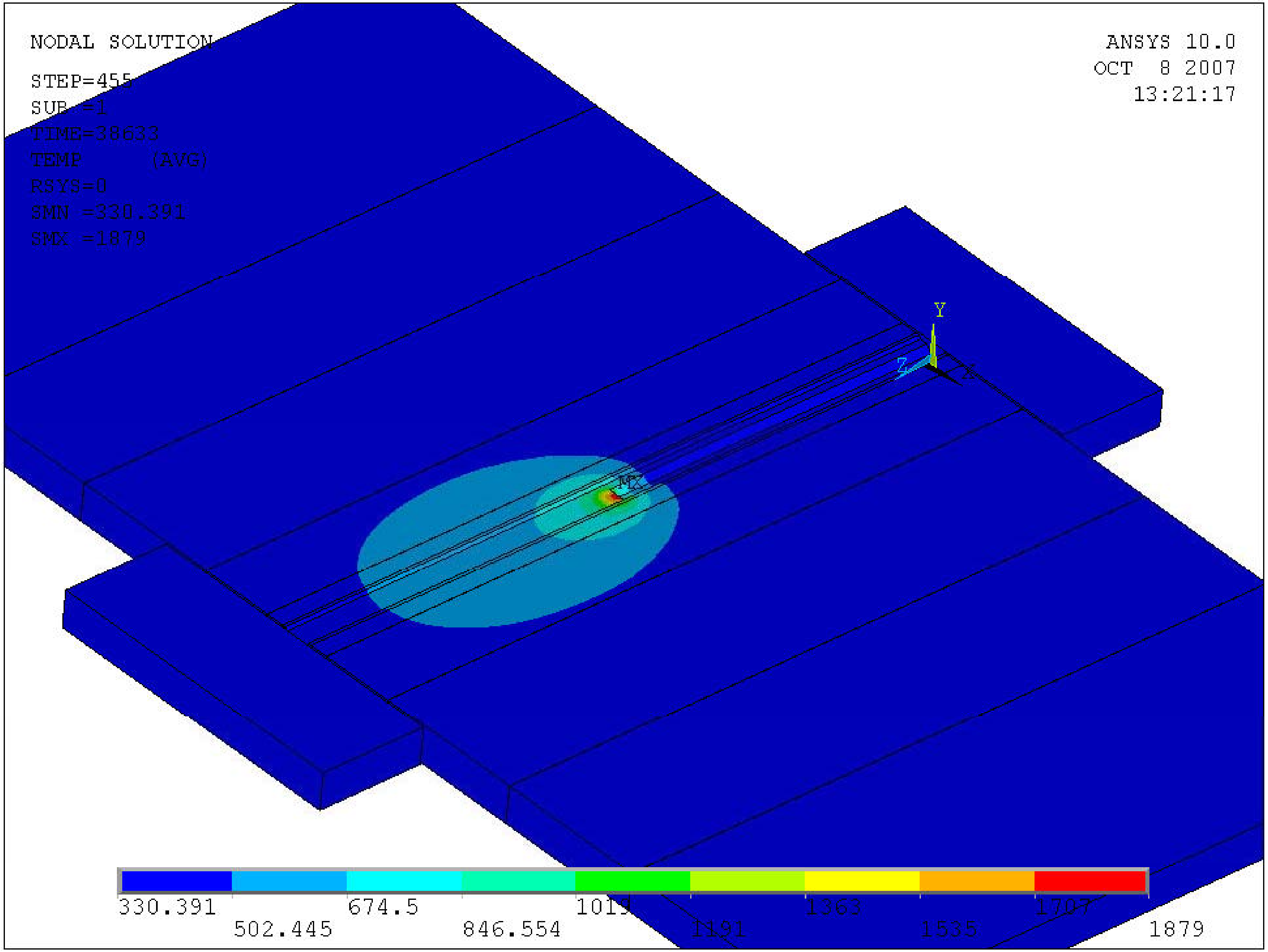
3rd downside pass: step n. 80



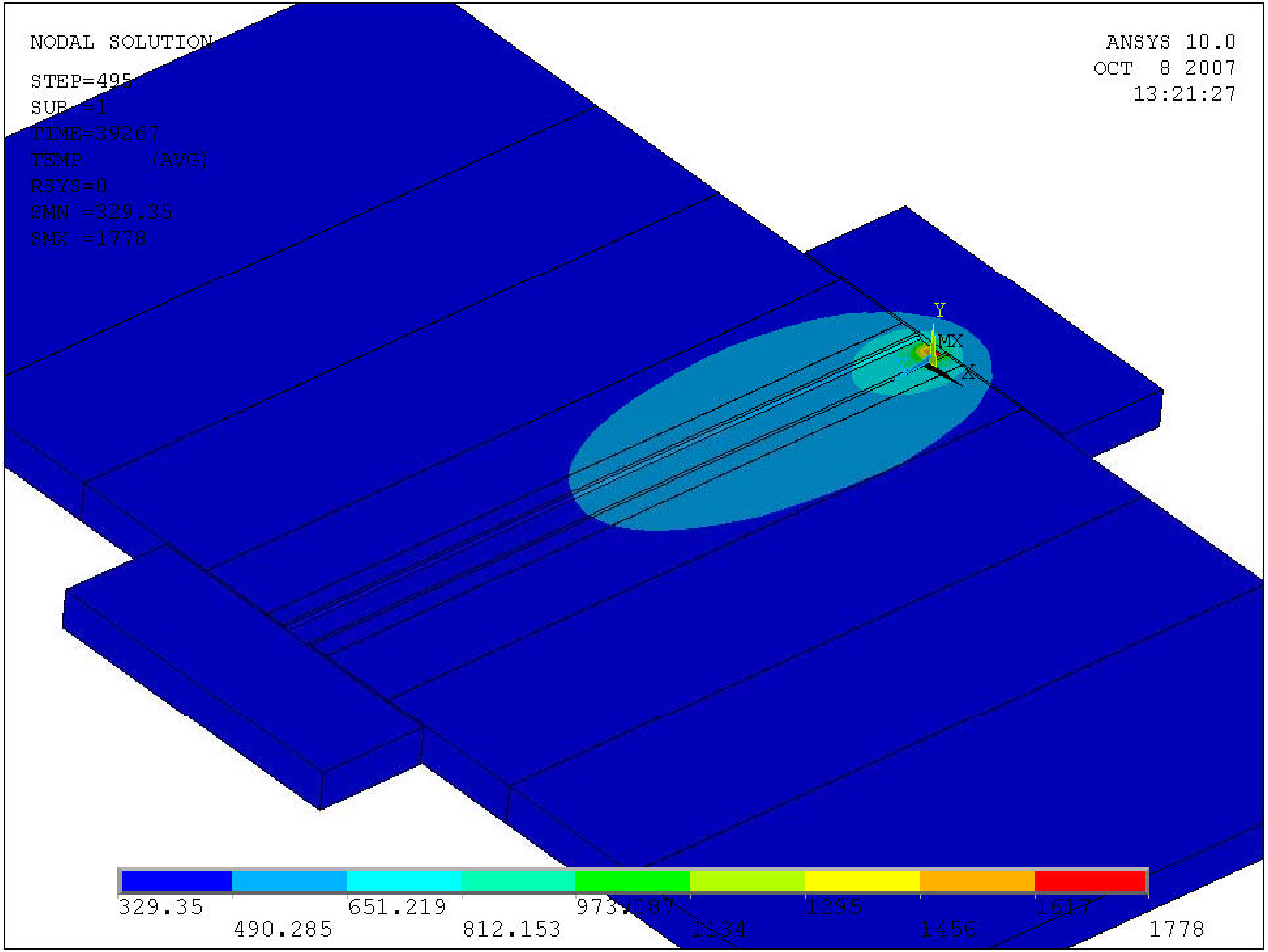
3rd downside pass: final cooling step



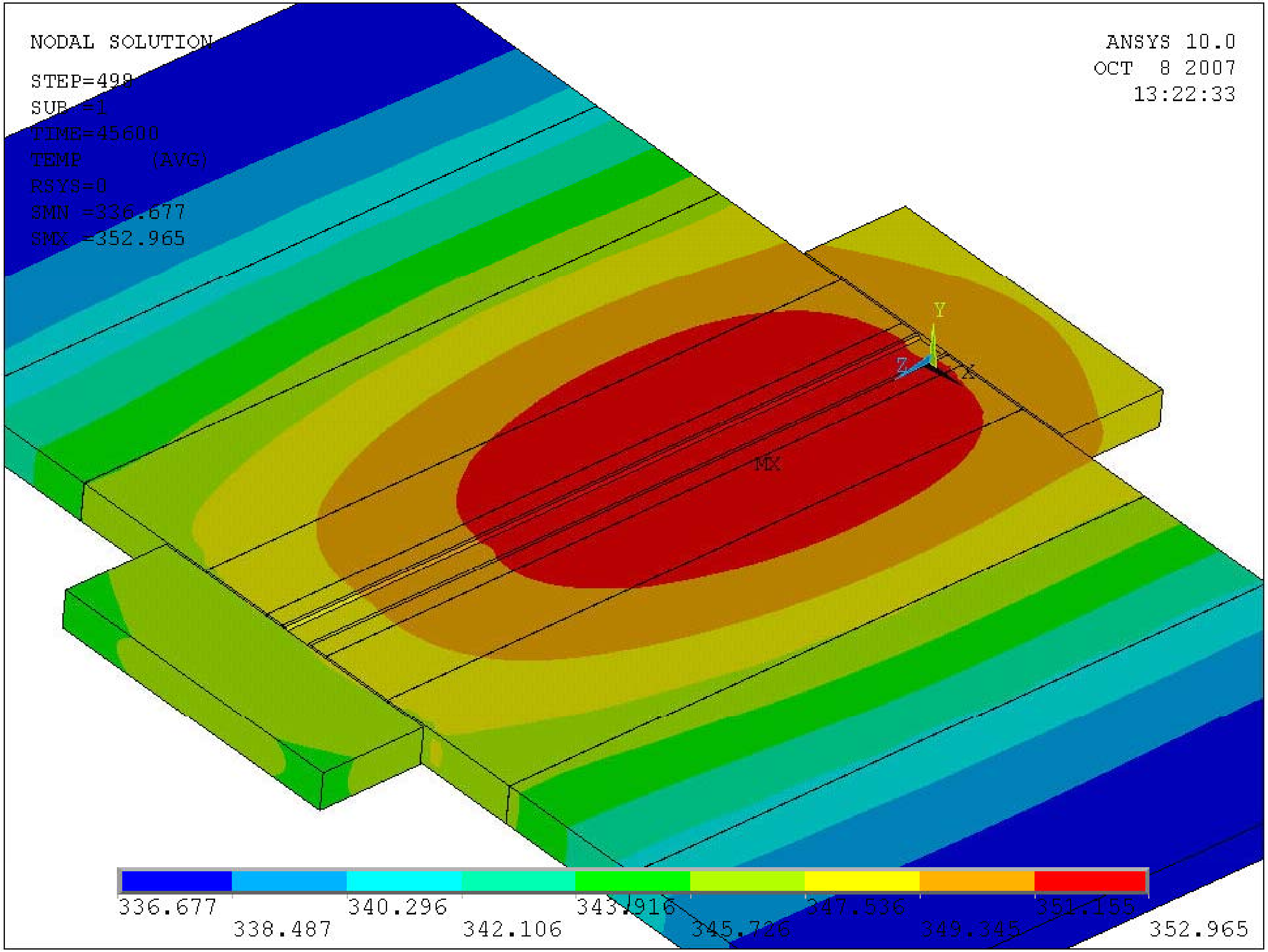
4th upside pass: step n. 40



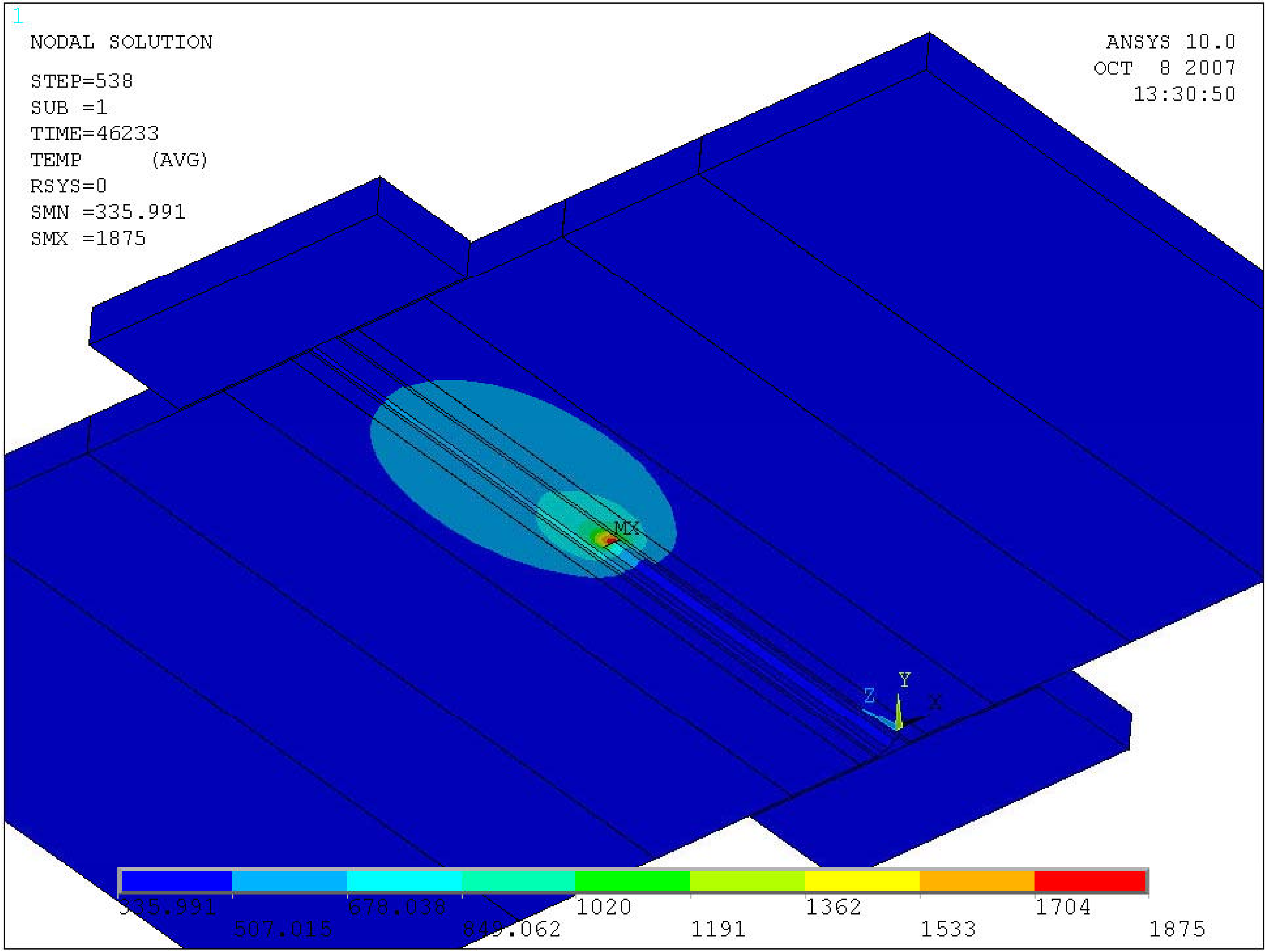
4th upside pass: step n. 80



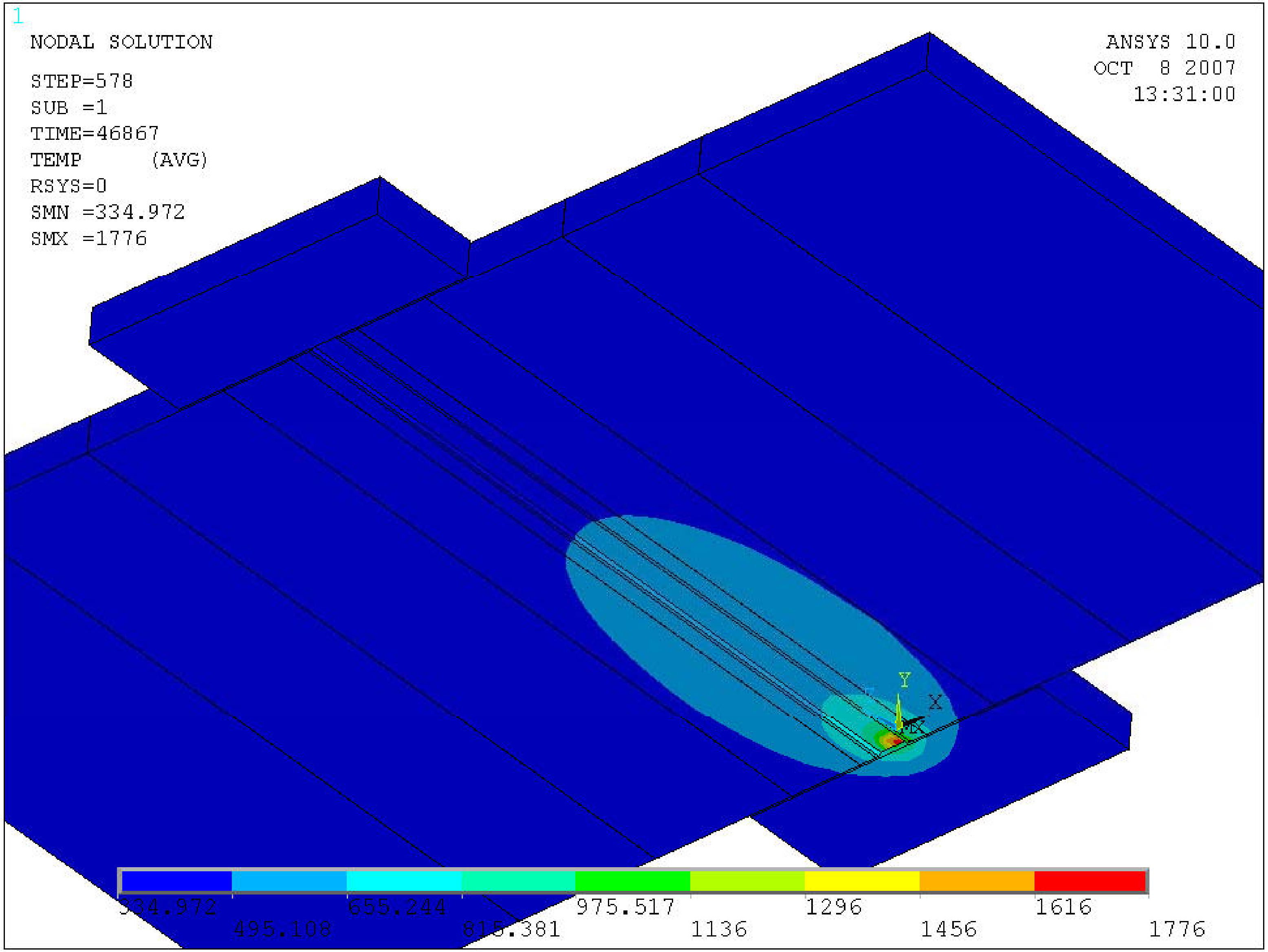
4th upside pass: final cooling step



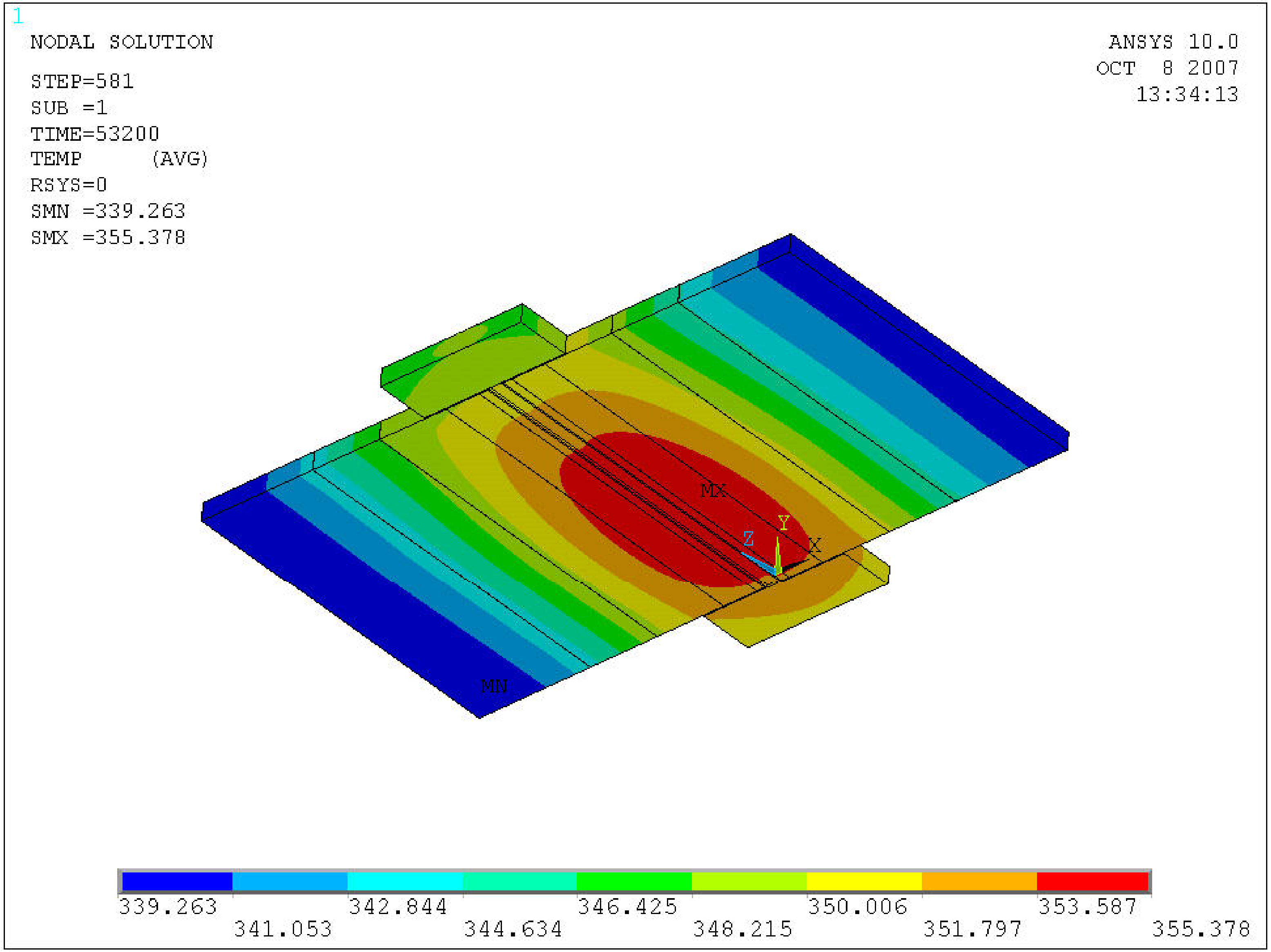
4th downside pass: step n. 40



4th downside pass: step n. 80



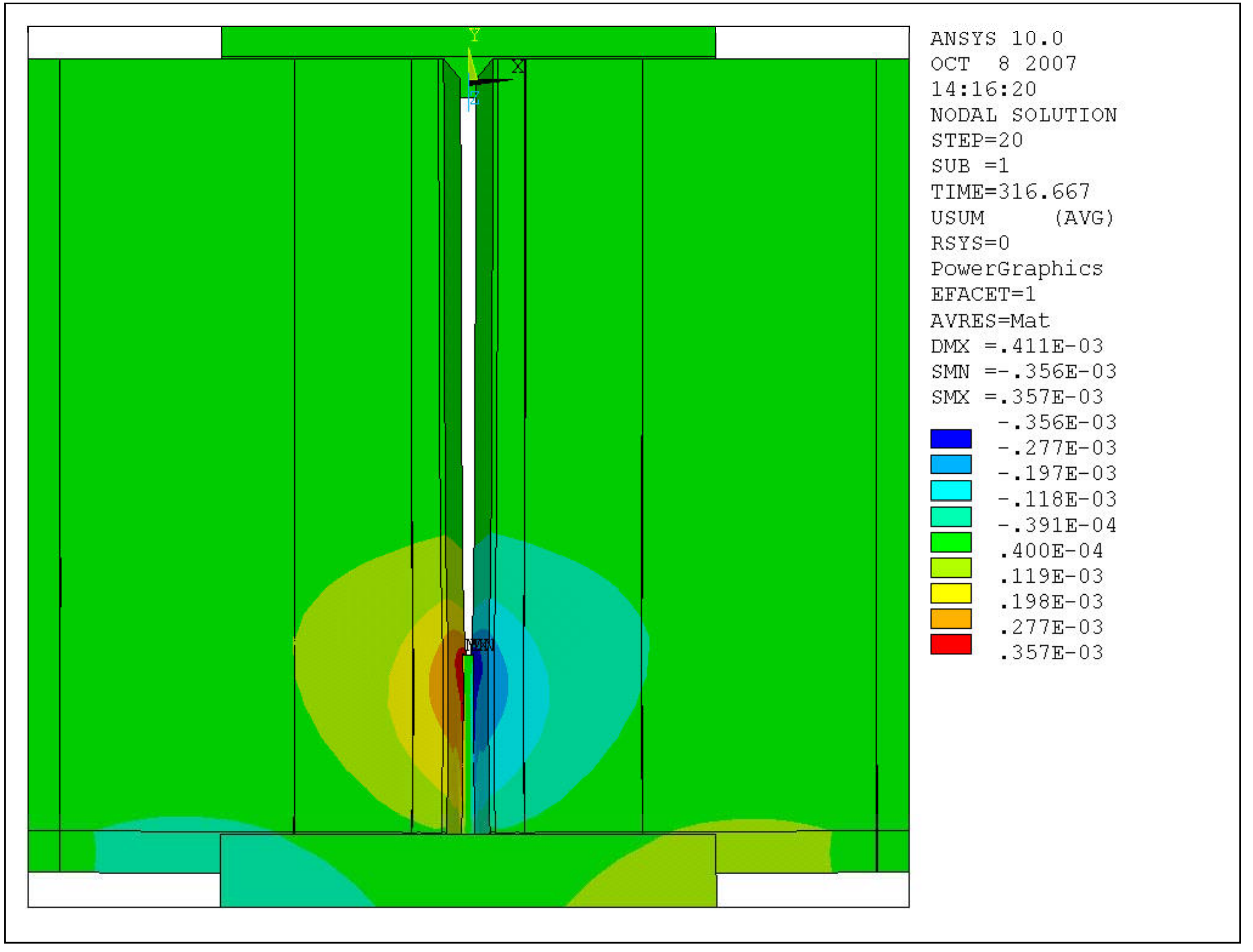
4th downside pass: final cooling step

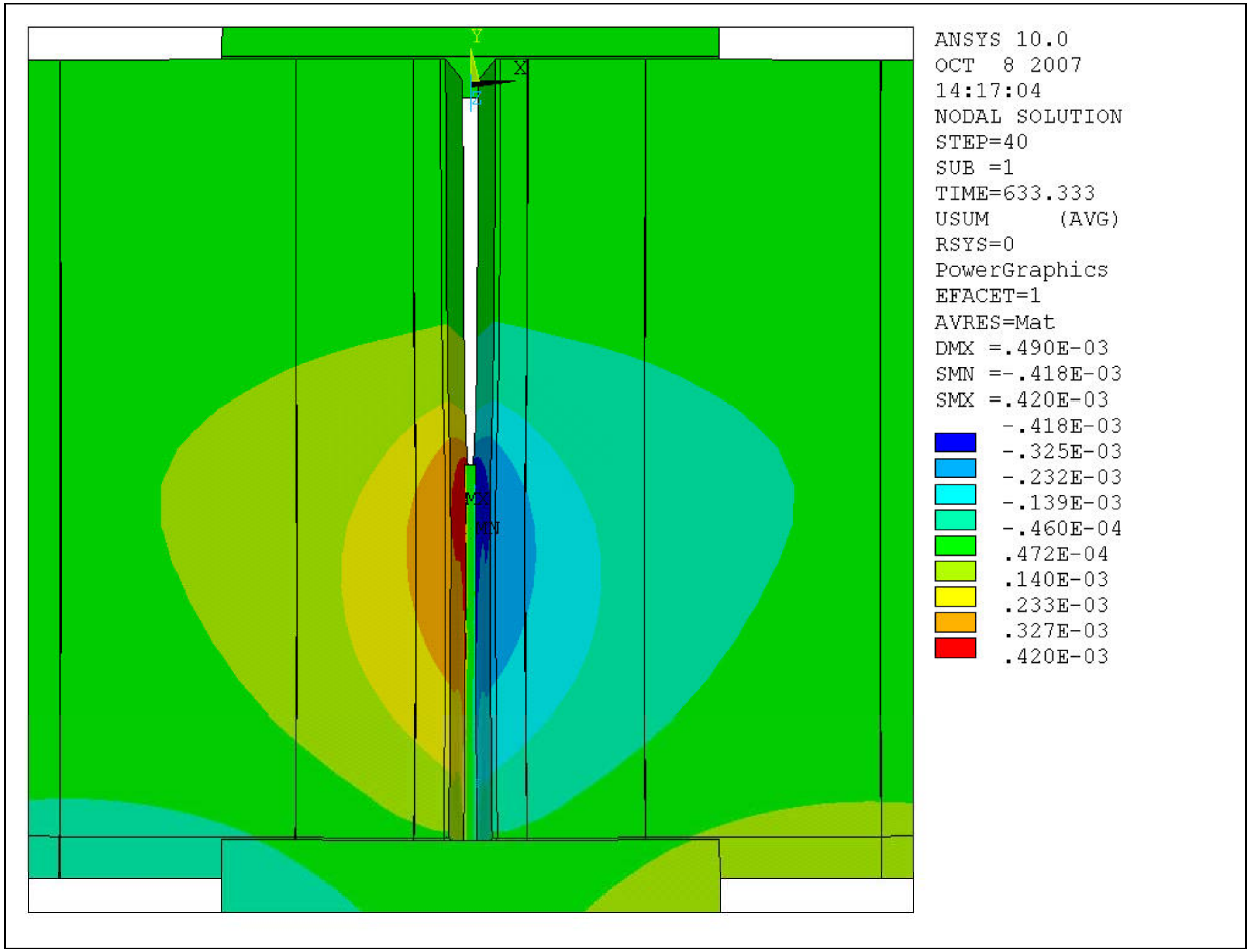


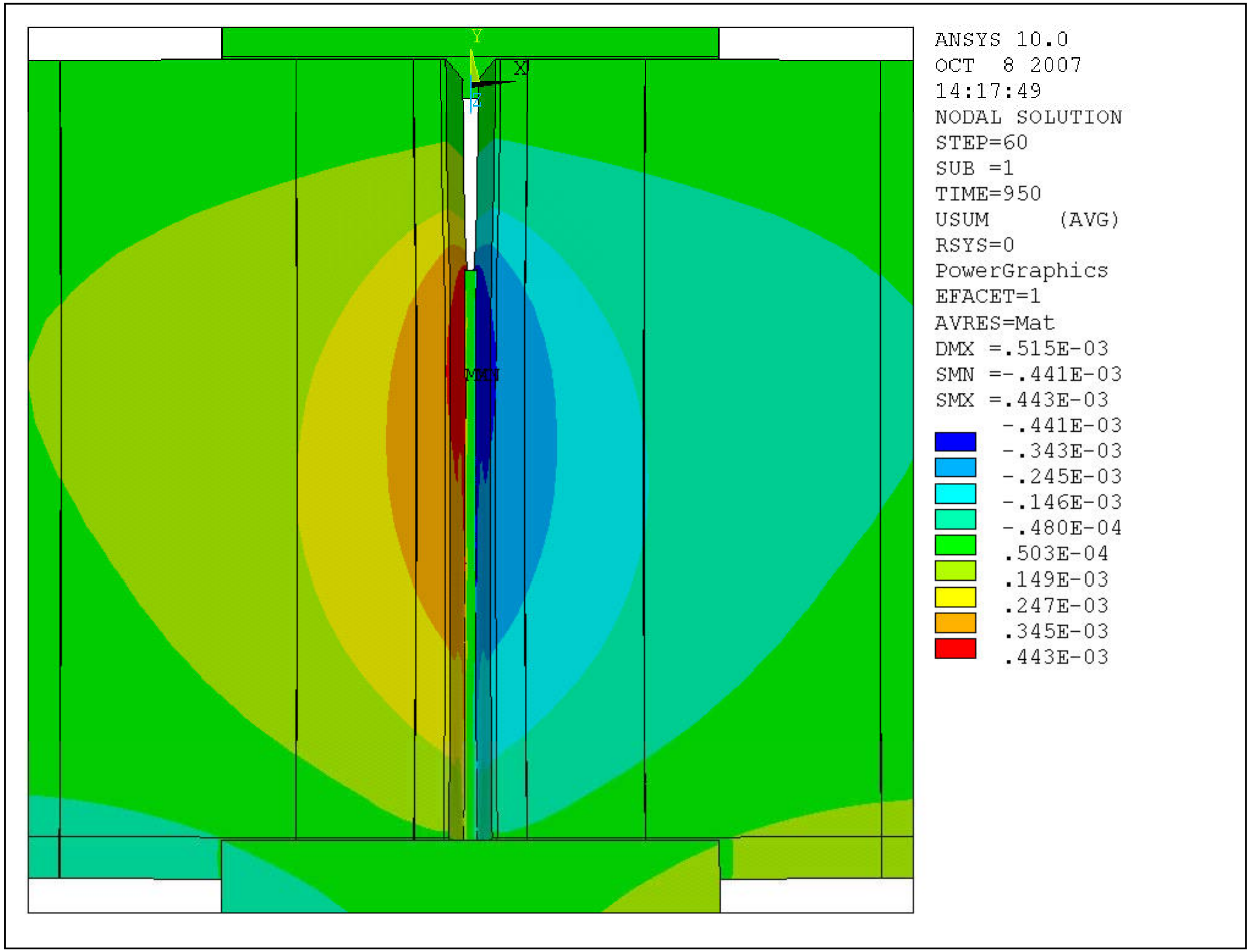
Structural analysis

Only the first pass has been executed.

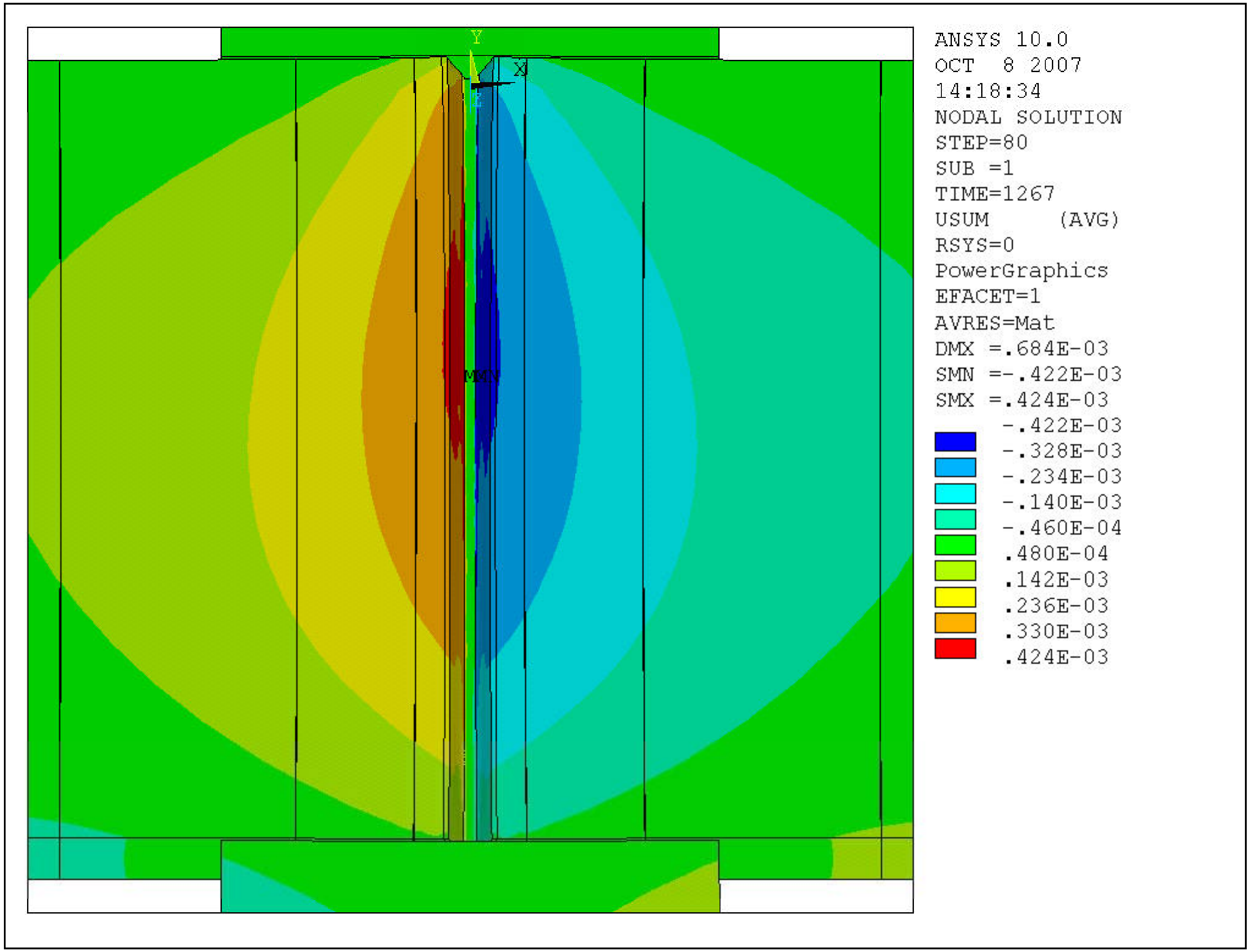
The need of CPU time is 3 days, and the Hard Disk space is about 21 Gb




ANSYS 10.0
OCT 8 2007
14:17:04
NODAL SOLUTION
STEP=40
SUB =1
TIME=633.333
USUM (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.490E-03
SMN =-.418E-03
SMX =.420E-03
-.418E-03
-.325E-03
-.232E-03
-.139E-03
-.460E-04
.472E-04
.140E-03
.233E-03
.327E-03
.420E-03
Y
X
MX
MN



ANSYS 10.0
OCT 8 2007
14:17:49
NODAL SOLUTION
STEP=60
SUB =1
TIME=950
USUM (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.515E-03
SMN =-.441E-03
SMX =.443E-03
-.441E-03
-.343E-03
-.245E-03
-.146E-03
-.480E-04
.503E-04
.149E-03
.247E-03
.345E-03
.443E-03


ANSYS 10.0
OCT 8 2007
14:18:34
NODAL SOLUTION
STEP=80
SUB =1
TIME=1267
USUM (AVG)
RSYS=0
PowerGraphics
EFACET=1
AVRES=Mat
DMX =.684E-03
SMN =-.422E-03
SMX =.424E-03
-.422E-03
-.328E-03
-.234E-03
-.140E-03
-.460E-04
.480E-04
.142E-03
.236E-03
.330E-03
.424E-03
Y
X
MN
MX