

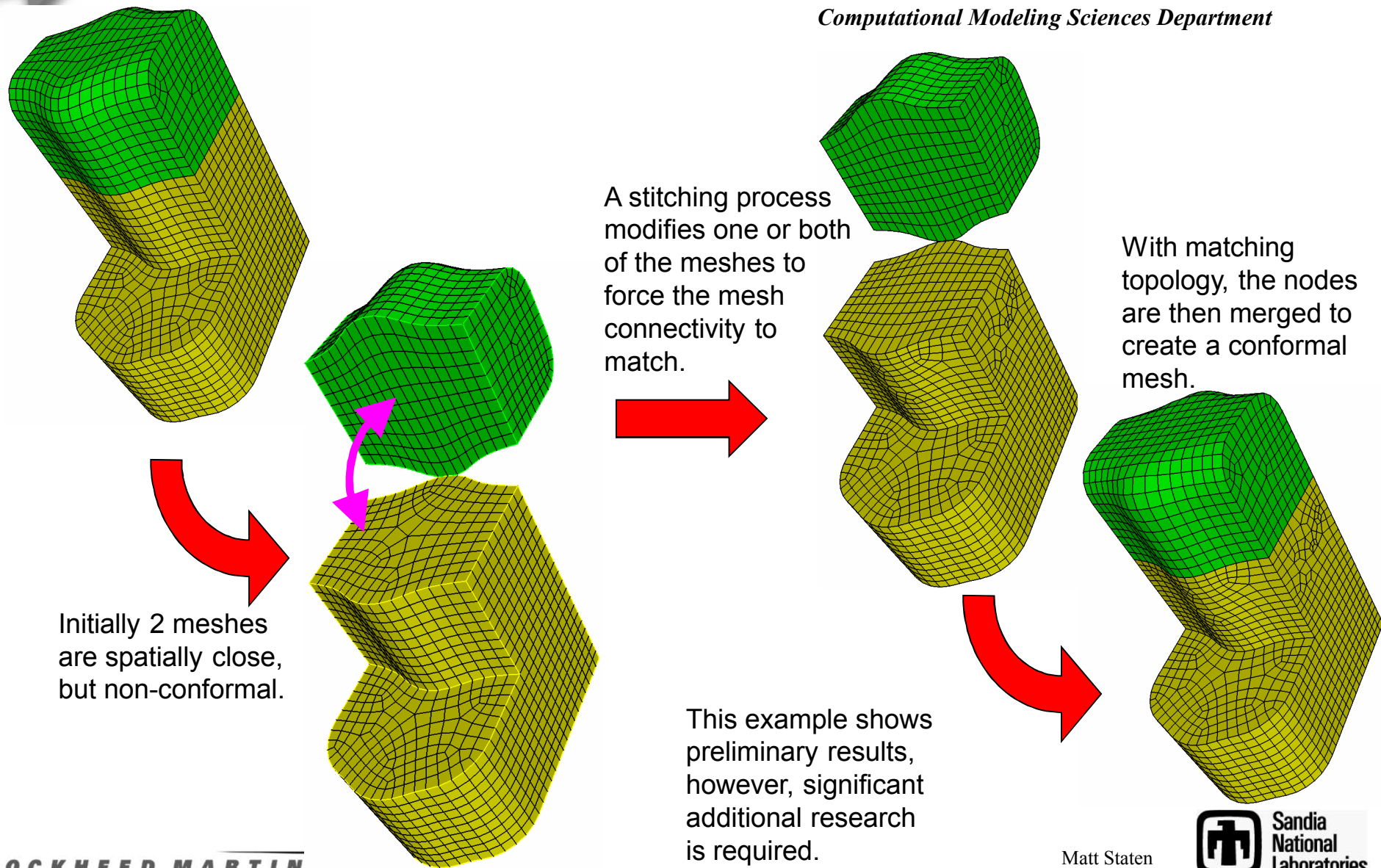
Sheet Based Mesh Manipulation Of Hexahedral Finite Element Meshes in Cubit

July 12, 2007

Matt Staten

Mesh Matching

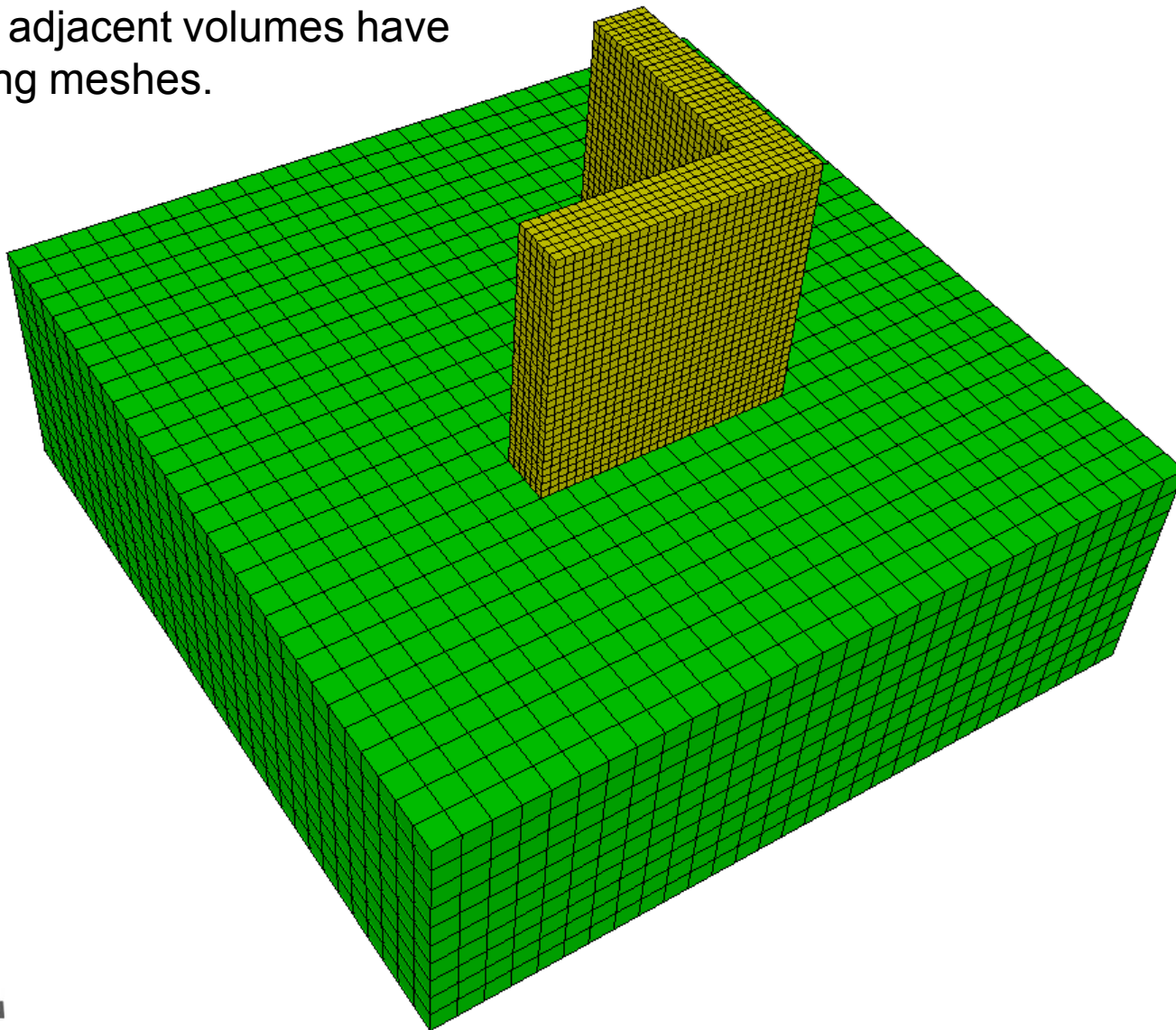
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Mesh Stitching/Matching Example

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Initially, two adjacent volumes have non-matching meshes.

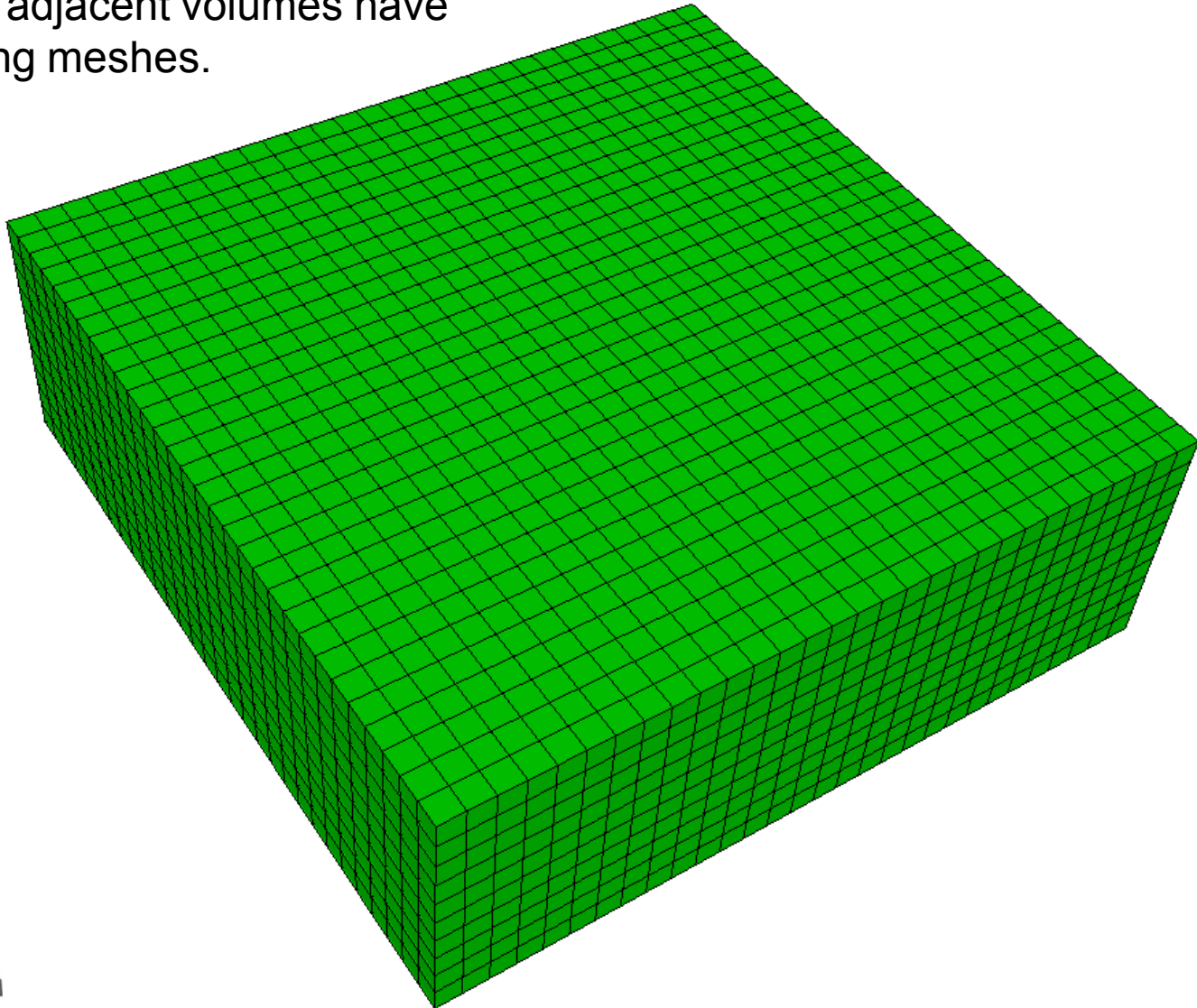




Mesh Stitching/Matching Example

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Initially, two adjacent volumes have non-matching meshes.

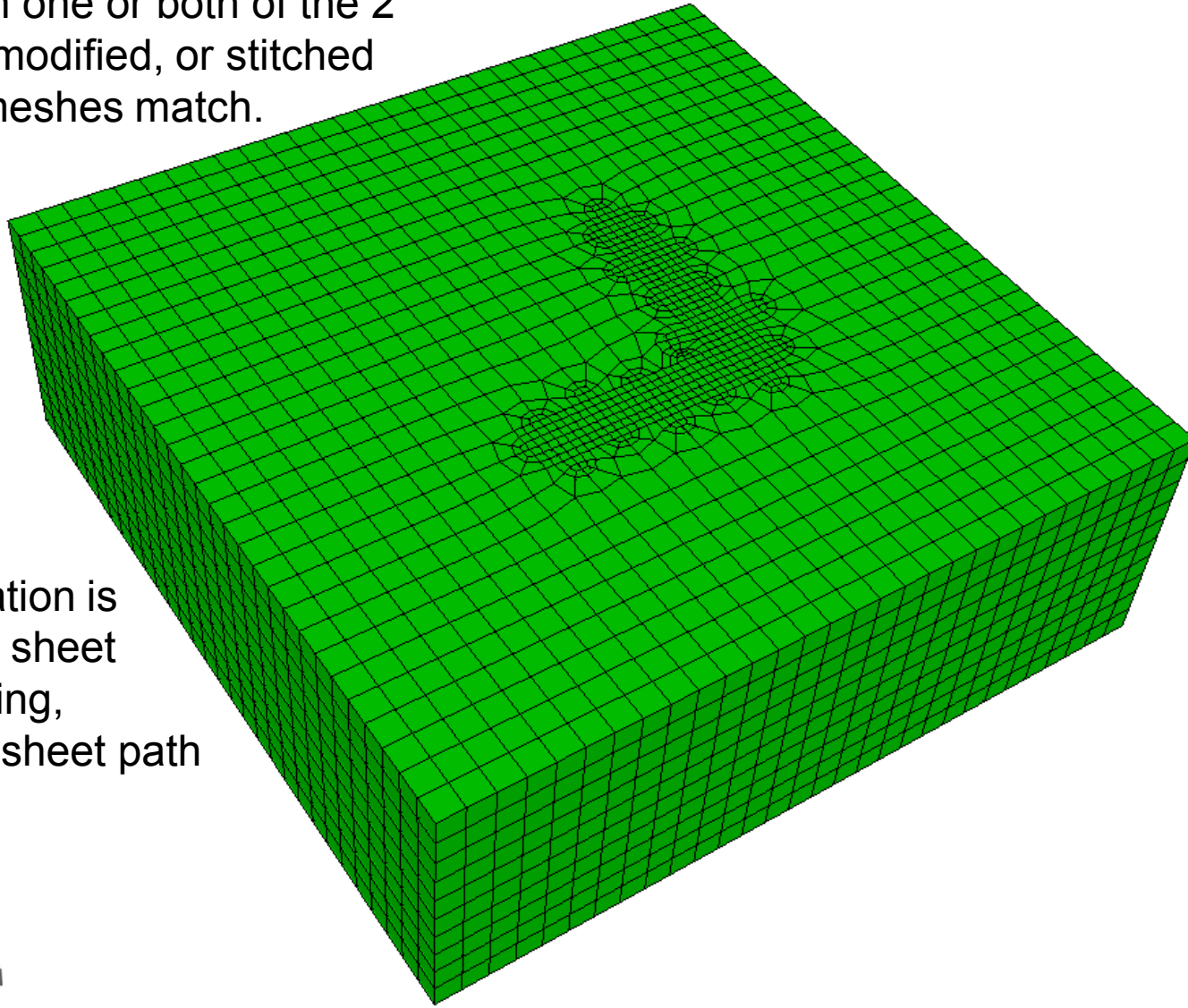




Mesh Stitching/Matching Example

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The mesh in one or both of the 2 volumes is modified, or stitched until the 2 meshes match.

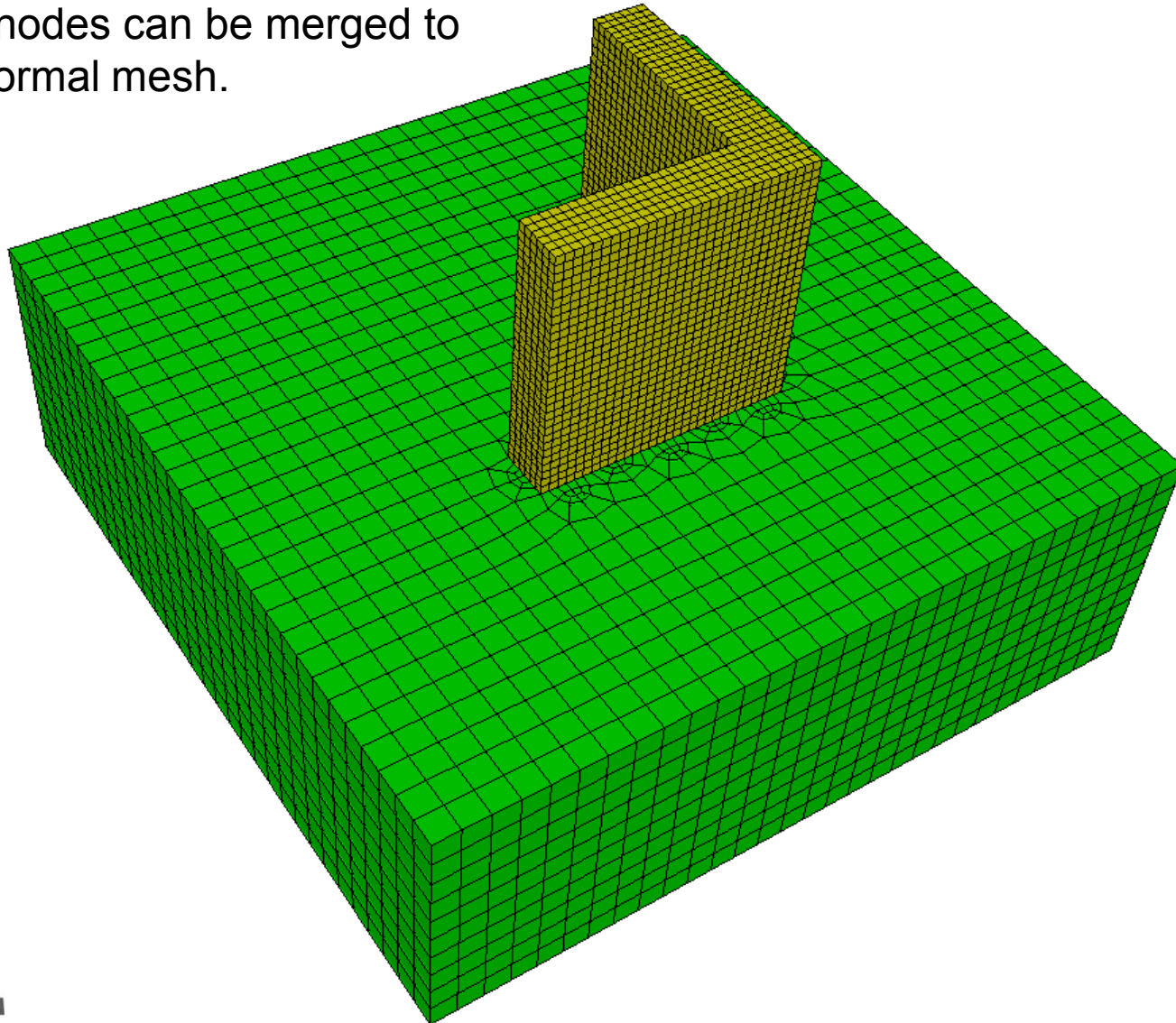


Mesh modification is based on dual sheet extraction, dicing, pillowing, and sheet path redirection.

Mesh Stitching/Matching Example

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Finally, the nodes can be merged to form a conformal mesh.



Mesh Matching

• Interactive Demo of Cubit Commands

```
## C:/Program Files/Cubit Beta/bin/ciarox.exe
## Cubit Version 11.0b
## Cubit Build 950
## Revised 06/29/2007 16:13:18 MST
## Running 07/02/2007 10:12:22 AM
## Command Options:
## -warning = On
## -information = On
reset
import mesh geometry
"C:\dev\demo\match_mesh3.exo" block all use
nodeset sideset feature_angle 135 linear merge
From 37.141857 51.436722 36.888494
At 5.000000 7.500000 -10.000000
Up -0.366868 0.790961 -0.489682
set developer on
```

```
vol 1 vis off
disp
group "hex1" add hex in node in surface 3
group "hex1" add hex in node in hex in hex1
group "hex1" add hex in node in hex in hex1
highlight hex in hex1
```

```
pillow hex in hex1 through surf all no_smooth
smooth curve all
smooth surface all
smooth volume all
draw sheet Edge 5311 182 mesh add
```

```
column face 2667 collapse node 7647
smooth surface all
smooth volume all
draw sheet edge 503 mesh add
```

```
extract sheet edge 503
disp
smooth curve all
smooth surface all
smooth volume all
group "hex1" add hex in node in hex in hex1
highlight hex in hex1
```

```
pillow hex in hex1 through surface all no_smooth
smooth surface all
smooth curve all
smooth surface all
smooth volume all
draw sheet Edge 5410 5411 mesh add
```

```
column face 2781 collapse node 7579
smooth surface all
smooth volume all
draw sheet edge 5226 mesh add
```

```
extract sheet edge 5226
disp
smooth curve all
smooth surface all
smooth volume all
group "hex2" add hex in node in curve 1
group "hex2" add hex in node in hex in hex2
group "hex2" add hex in node in hex in hex2
highlight hex in hex2
```

```
pillow hex in hex2 through surface all no_smooth
disp
smooth curve all
smooth surface all
smooth volume all
group "hex2" add hex in node in curve 11
group "hex3" add hex in node in hex in hex3
highlight hex in hex3
```

```
pillow hex in hex3 through surface all no_smooth
disp
smooth curve all
smooth surface all
delete hex3
group "hex3" add hex in node in curve 11
group "hex3" add hex in node in hex in hex3
group "hex3" add hex in node in hex in hex3
highlight hex in hex3
```

```
pillow hex in hex3 through surface all no_smooth
disp
smooth curve all
smooth surface all
smooth volume all
```

```
delete hex1 hex2 hex3
group "hex1" add hex in node in surface 3
group "hex1" add hex in node in hex in hex1
group "hex1" add hex in node in hex in hex1
group "hex1" add hex in node in hex in hex1
highlight hex in hex1
```

```
pillow hex in hex1 through surface all no_smooth
column face 2979 collapse node 7902
smooth curve all
smooth surface all
smooth volume all
draw sheet edge 318 mesh add
```

```
extract sheet edge 318
disp
smooth curve all
smooth surface all
volume all smooth scheme mean ratio
smooth volume all
```

```
group "hex2" add hex in node in surface 3
pillow hex in hex2 through surface all no_smooth
group "hex2" add hex in node in surface 3
pillow hex in hex2 through surface all no_smooth
smooth surface all
smooth curve all
smooth surface all
```

```
column face 2849 collapse node 7870
draw sheet edge 5486 mesh add
extract sheet edge 5486
disp
smooth curve all
smooth surf all
draw sheet Edge 5405 5406 mesh add
```

```
column face 2715 collapse node 7809
disp
smooth curve all
smooth surf all
draw sheet edge 5404 mesh add
```

```
extract sheet edge 5404
disp
smooth curve all
smooth surf all
vol all smooth scheme condi
vol all smooth scheme mean ratio
smooth vol all
draw sheet Edge 232 4869 mesh add
```

```
column Face 2440 collapse node 2439
smooth surf all
draw sheet edge 4882 mesh add
extract sheet edge 4882
disp
smooth curve all
smooth surf all
smooth vol all
```

```
column face 2749 collapse node 7689
smooth surf all
extract sheet edge 5319
smooth curve all
smooth surf all
smooth vol all
draw sheet edge 5282 mesh add
column face 155 collapse node 7543
disp
smooth surf all
smooth vol all
extract sheet edge 5143
smooth surf all
smooth vol all
qual vol all scal
draw sheet Edge 129 130 mesh add
draw Edge 4969 mesh color green add
draw sheet Edge 4969 mesh color green add
column face 2591 collapse node 6996
extract sheet edge 4968
```

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```
smooth surf all
smooth vol all
delete hex1
delete hex2
####delete hex3
group 'hex1' add hex in node in surf 3
pillow hex in hex1 through surf all no_smooth
group 'hex1' add hex in node in surf 3
pillow hex in hex1 through surf all no_smooth
smooth curve all
smooth surf all
smooth vol all
column face 2723 collapse node 7577
extract sheet edge 5256
smooth surf all
smooth vol all
vol all smooth scheme condi
smooth vol all
vol all smooth scheme condi beta 1.8
smooth vol 2
vol all smooth scheme condi beta 1.6
smooth vol 2
vol all smooth scheme mean ratio
disp
group 'hex4' add Hex 6055 6079 6099 6096 6095
6094 6093 6092 6091 6069 6039
draw hex4
group 'hex4' add hex in node in hex in hex4
disp
highlight hex4
group 'hex4' add hex in node in hex in hex4
highlight hex4
pillow hex in hex4 through surf all no_smooth
smooth curve all
smooth surf all
smooth vol all
qual vol all scal
group 'hex7' add hex 6046 6239 6402 6106 6093
6102 6392 6226 6063 6033
group 'hex7' add hex in node in hex in hex7
highlight hex7
group 'hex7' add hex in node in hex in hex7
highlight hex7
pillow hex in hex7 through surf all no_smooth
disp
smooth curve all
smooth surf all
smooth vol all

highlight hex7
group 'hex7' add hex in node in hex in hex7
highlight hex7
pillow hex in hex7 through surf all no_smooth
smooth curve all
smooth surf all
```

```
delete hex1 hex4 hex7
group 'hex1' add hex in node in Curve 6
highlight hex1
group 'hex1' add hex in node in hex in hex1
```

```
highlight hex1
pillow hex in hex1 through surf all no_smooth
smooth curve all
smooth surf all
smooth vol all

vol all vis on
vol 2 smooth scheme condi beta 1.8
smooth vol 2
vol 2 smooth scheme condi beta 1.7
smooth vol 2
qual vol all scal
```

Matt Staten

Mesh Matching

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• Interactive Demo of Cubit Commands

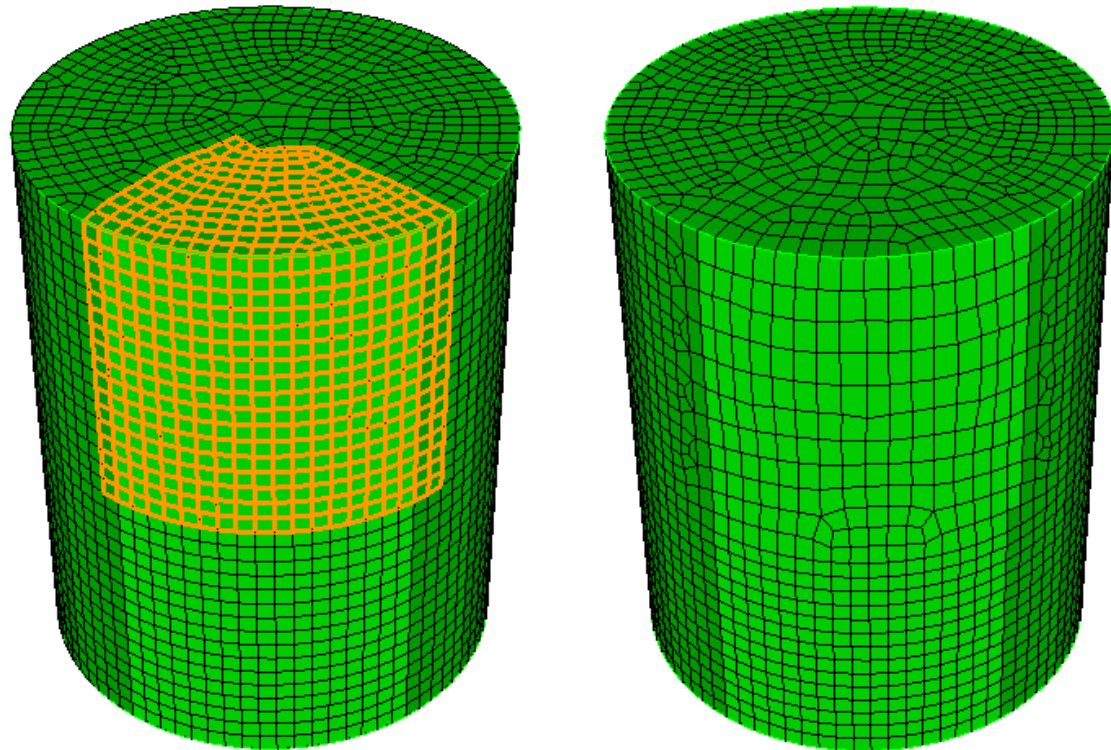
```
reset
import mesh geometry "C:/temp/match_mesh4.exo" block all use nodeset sideset feature_angle 135.00 linear merge
set deve on
pillow Hex 2 4 6 8 10 12 14 16 18 20 21 19 17 15 13 11 9 7 5 3 239 238 218 219 890 891 through surf all no_smooth
pillow Hex 18796 18777 18801 18802 18795 18778 18779 18794 18793 18780 18781 18792 18791 18782 18783 18790 18789 18784 18785 18788 18787
18786 18797 18800 18799 18798 through surf all no_smooth
pillow Hex 37 29 28 36 35 27 26 34 33 25 24 32 31 23 22 30 18737 18739 18847 18880 18879 18845 18741 447 427 426 446 18743 18843 18878 18877
18841 57 56 55 54 through surf all no_smooth
pillow Hex 18995 18996 18994 18993 18961 18962 18963 18964 18965 18966 18968 18967 18969 18970 18972 18971 18973 18974 18976 18975 18977
18978 18992 18979 18991 18980 18990 18981 18989 18982 18988 18983 18987 18984 18985 18986 through surf all no_smooth
pillow Hex 18885 19007 19077 19078 19009 18887 247 465 464 18891 19013 19080 19079 19011 18889 246 through surf all no_smooth
pillow Hex 19152 19153 19154 19145 19146 19147 19148 19149 19150 19151 19160 19159 19158 19157 19156 19155 through surf all no_smooth
pillow Hex 18893 18899 19019 19015 19081 19083 19084 19082 19017 18895 18897 19021 462 244 245 463 481 480 224 225 through surf all no_smooth
pillow Hex 19273 19274 19269 19272 19257 19258 19259 19260 19261 19262 19263 19264 19265 19268 19267 19266 19271 19270 19275 19276 through
surf all no_smooth
pillow Hex 461 460 18907 18901 19023 19027 19087 19085 19086 19088 19029 19025 18903 18905 242 243 through surf all no_smooth
pillow Hex 19377 19378 19379 19380 19381 19382 19383 19384 19385 19386 19387 19388 19389 19390 19391 19392 through surf all no_smooth
pillow Hex 459 458 18915 18909 19031 19035 19091 19089 19090 19092 19037 19033 18911 18913 240 241 221 220 201 200 477 476 through surf all
no_smooth
pillow Hex 19513 19514 19494 19493 19496 19495 19498 19497 19500 19499 19502 19501 19504 19503 19506 19505 19508 19507 19510 19509 19511
19512 through surf all no_smooth
pillow Hex 19518 19521 19447 19490 18733 18735 18839 18876 18875 18837 18745 445 444 18747 18835 18874 18873 18833 through surf all no_smooth
pillow Hex 19637 19636 19635 19638 19639 19634 19633 19640 19641 19632 19631 19642 19629 19628 19627 19630 19625 19626 through surf all
no_smooth
pillow Hex 423 422 442 443 18749 18751 18827 18829 18871 18870 18869 18872 18831 18825 18729 18731 494 512 through surf all no_smooth
pillow Hex 19742 19741 19744 19743 19746 19745 19748 19747 19750 19749 19752 19751 19754 19753 19756 19757 19758 19755 through surf all
no_smooth
pillow Hex 441 440 18755 18753 18821 18819 18866 18867 18868 18865 18817 18823 18727 18725 548 530 531 549 through surf all no_smooth
pillow Hex 19858 19857 19860 19859 19862 19861 19864 19863 19866 19865 19868 19867 19870 19869 19872 19871 19874 19873 through surf all
no_smooth
pillow Hex 419 418 438 439 18813 18759 18757 18803 18859 18863 18864 18860 18805 18815 18723 18721 584 566 through surf all no_smooth
pillow Hex 19974 19973 19976 19975 19978 19979 19977 19980 19981 19982 19983 19984 19985 19986 19987 19988 19989 19990 through surf all
no_smooth

smooth curve all
smooth surf all
vol 1 smooth scheme laplac
smooth vol 1
vol 1 smooth scheme mean ratio
smooth vol 1
vol 1 smooth scheme condition
qual vol 1 scaled
```

Hex Mesh Coarsening - Research

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- All-Hex conformal coarsening
- Localized to coarsening region
- 2567 elements selected for coarsening
- $2567 - 994 = 62\%$ coarsening



Hex Coarsening

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• Interactive Demo of Cubit Commands

```
reset
set dev on
color line black
create Cylinder height 10 radius 4
from 10.113971 -23.261030 17.811800
At 0.000000 0.000000 0.000000
Up -0.226036 0.528374 0.818370
vol all size 0.3
mesh vol all
```

```
group "coarsening_region" add Hex 10081 to 10100, 10165 to 10182, 10242 to
10258, 10313 to 10328, 10382 to 10384, 10423 to 10438, 10451 to 10463, 10508 to
10519, 10557, 10568 to 10578, 10618 to 10626, 10641 to 10646, 10661 to 10669,
10711 to 10730, 10795 to 10812, 10872 to 10888, 10943 to 10958, 11012 to 11014,
11053 to 11068, 11081 to 11093, 11138 to 11149, 11187, 11198 to 11208, 11248 to
11256, 11271 to 11276, 11291 to 11299, 11341 to 11360, 11425 to 11442, 11502 to
11518, 11573 to 11588, 11642 to 11644, 11683 to 11698, 11711 to 11723, 11768 to
11779, 11817, 11828 to 11838, 11878 to 11886, 11901 to 11906, 11921 to 11929,
11971 to 11990, 12055 to 12072, 12132 to 12148, 12203 to 12218, 12272 to 12274,
12313 to 12328, 12341 to 12353, 12398 to 12409, 12447, 12458 to 12468, 12508 to
12516, 12531 to 12536, 12551 to 12559, 12601 to 12620, 12685 to 12702, 12762 to
12778, 12833 to 12848, 12902 to 12904, 12943 to 12958, 12971 to 12983, 13028 to
13039, 13077, 13088 to 13098, 13138 to 13146, 13161 to 13166, 13181 to 13189,
13231 to 13250, 13315 to 13332, 13392 to 13408, 13463 to 13478, 13532 to 13534,
13573 to 13588, 13601 to 13613, 13658 to 13669, 13707, 13718 to 13728, 13768 to
13776, 13791 to 13796, 13811 to 13819, 13861 to 13880, 13945 to 13962, 14022 to
14038, 14093 to 14108, 14162 to 14164, 14203 to 14218, 14231 to 14243, 14288 to
14299, 14337, 14348 to 14358, 14398 to 14406, 14421 to 14426, 14441 to 14449,
14491 to 14510, 14575 to 14592, 14652 to 14668, 14723 to 14738, 14792 to 14794,
14833 to 14848, 14861 to 14873, 14918 to 14929, 14967, 14978 to 14988, 15028 to
15036, 15051 to 15056, 15071 to 15079, 15121 to 15140, 15205 to 15222, 15282 to
15298, 15353 to 15368, 15422 to 15424, 15463 to 15478, 15491 to 15503, 15548 to
15559, 15597, 15608 to 15618, 15658 to 15666, 15681 to 15686, 15701 to 15709,
15751 to 15770, 15835 to 15852, 15912 to 15928, 15983 to 15998, 16052 to 16054,
16093 to 16108, 16121 to 16133, 16178 to 16189, 16227, 16238 to 16248, 16288 to
16296, 16311 to 16316, 16331 to 16339, 16381 to 16400, 16465 to 16482, 16542 to
16558, 16613 to 16628, 16682 to 16684, 16723 to 16738, 16751 to 16763, 16808 to
16819, 16857, 16868 to 16878, 16918 to 16926, 16941 to 16946, 16961 to 16969,
17011 to 17030, 17095 to 17112, 17172 to 17188, 17243 to 17258, 17312 to 17314,
17353 to 17368, 17381 to 17393, 17438 to 17449, 17487, 17498 to 17508, 17548 to
17556, 17571 to 17576, 17591 to 17599, 17641 to 17660, 17725 to 17742, 17802 to
17818, 17873 to 17888, 17942 to 17944, 17983 to 17998, 18011 to 18023, 18068 to
18079, 18117, 18128 to 18138, 18178 to 18186, 18201 to 18206, 18221 to 18229,
18271 to 18290, 18355 to 18372, 18432 to 18448, 18503 to 18518, 18572 to 18574,
18613 to 18628, 18641 to 18653, 18698 to 18709, 18747, 18758 to 18768, 18808 to
18816, 18831 to 18836, 18851 to 18859, 18901 to 18920, 18985 to 19002, 19062 to
19078, 19133 to 19148, 19202 to 19204, 19243 to 19258, 19271 to 19283, 19328 to
19339, 19377, 19388 to 19398, 19438 to 19446, 19461 to 19466, 19481 to 19489,
19531 to 19550, 19615 to 19632, 19692 to 19708, 19763 to 19778, 19832 to 19834,
19873 to 19888, 19901 to 19913, 19958 to 19969, 20007, 20018 to 20028, 20068 to
20076, 20091 to 20096, 20111 to 20119, 20161 to 20180, 20245 to 20262, 20322 to
20338, 20393 to 20408, 20462 to 20464, 20503 to 20518, 20531 to 20543, 20588 to
20599, 20637, 20648 to 20658, 20698 to 20706, 20721 to 20726, 20741 to 20749
```

```
group "all_hexes" add hex all
```

```
group "non_coarsening_region" subtract group 2 from group 3
highlight hex in coarsening_region
```

```
#####
```

```
pillow Hex in coarsening_region through surf all no_smooth
```

```
draw sheet edge 8207 mesh add
```

```
#####
```

```
column Hex 20975 20973 collapse Node 23474
column Hex 20420 20418 collapse Node 23445
column Hex 20446 20448 collapse Node 23405
column Hex 20474 20471 collapse Node 23373
column Hex 20502 20499 collapse Node 23290
column Hex 20527 20530 collapse Node 23261
column Hex 20558 20555 collapse Node 23135
column Hex 20583 20586 collapse Node 23106
draw sheet Edge 2616 2612 2604 2596 2588 mesh
draw curve all add
disp
draw sheet Edge 2616 2612 2604 2596 2588 mesh add
#####
```

```
disp
extract sheet Edge 2552
disp
extract sheet Edge 2559
disp
extract sheet Edge 2442
disp
extract sheet Edge 2343
disp
extract sheet Edge 2244
disp
group "all_hexes" add hex all
group "coarsening_region" subtract group 4 from group 3
highlight hex in coarsening_region
pillow Hex in coarsening_region through surf all no_smooth
disp
draw sheet edge 7874 mesh add
#####
```

```
column Hex 20001 20003 collapse Node 21798
column Hex 19761 19486 collapse Node 22209
column Hex 19716 19459 collapse Node 22166
column Hex 19665 19426 collapse Node 22123
```

```
draw sheet Edge 7415 7172 6668 mesh
draw curve all add
```

```
#####
```

```
extract sheet Edge 7413
disp
extract sheet Edge 7172
disp
extract sheet Edge 6668
```

```
disp
```

```
group "all_hexes" add hex all
group "coarsening_region" subtract group 4 from group 3
highlight hex in coarsening_region
```

```
pillow Hex in coarsening_region through surf all no_smooth
```

```
dis
```

```
#####
```

```
column Hex 19924 19798 collapse Node 21882
column Hex 19428 19308 collapse Node 21858
```

```
draw sheet Edge 7211 7207 mesh
```

```
#####
```

```
dis
extract sheet Edge 7211
disp
extract sheet Edge 7166
disp
group "all_hexes" add hex all
group "coarsening_region" subtract group 4 from group 3
partition create curve 2 Node 735 677
composite create curve 3 2
smooth curve 5
partition delete curve all
surf all smooth scheme centro
smooth face in node in hex in coarsening_region
vol all smooth scheme condition number
smooth hex in coarsening_region
qual vol all scaled
# 2567 to 994 elements
# 61 % removed
#####
```

