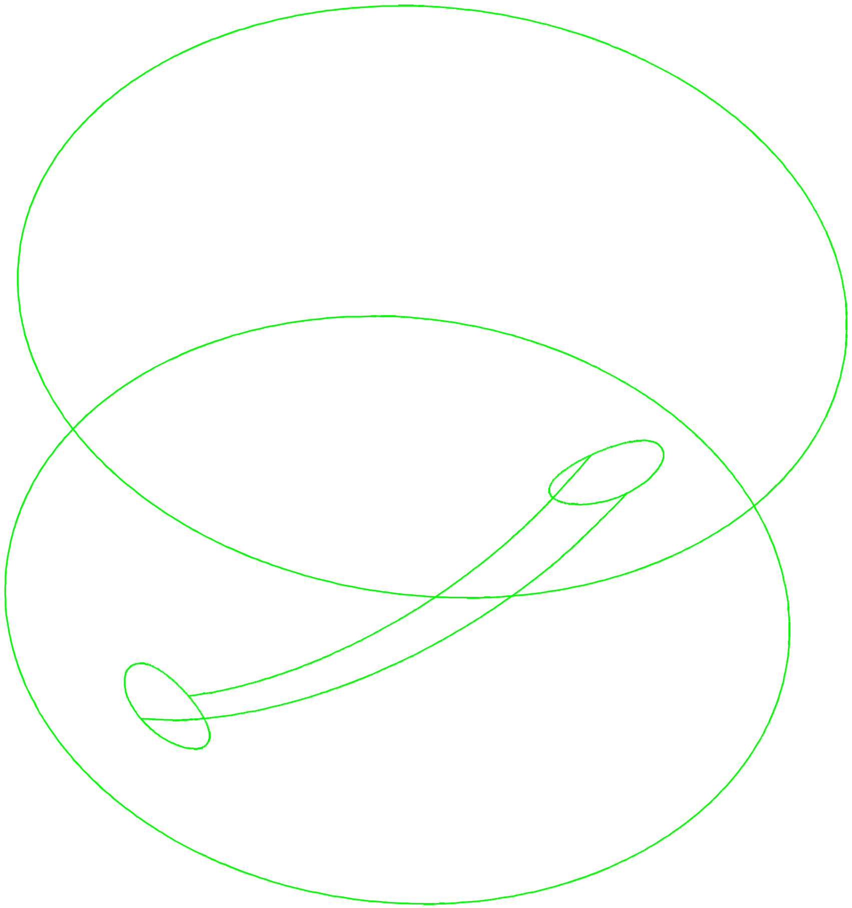
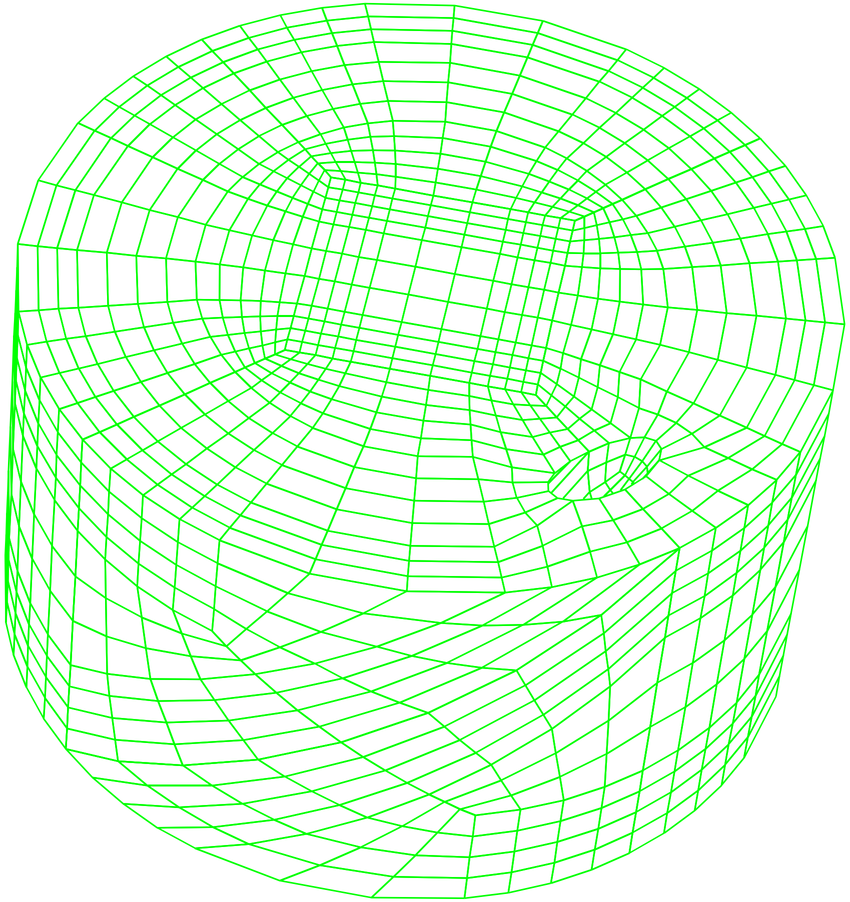
TrueGrid® Advanced Training Manual





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IGES Surface Extraction

IGES surfaces read in from IGES files can be reduced to only those groups of surfaces needed. The following operations demonstrates the method to reduce the surfaces of an entire femur to only the inner surface (sd 1) and outer surface (sd 2) of the central section. The conventions are that red designates a command and blue designates on environment window mouse pick with the left mouse button.

1.) get the geometry

 getol 20
 iges femur.igs 1 1;
 dasd
 pick surface
 display list (highlight surfaces to be removed)
 remove

2.) select surfaces to be combined into one

 lasd
 sd 1 sds (copy the list here) ;

3.) select outer surfaces

 dsd # (one of the outer surfaces)
 ansd .1 10 4
 lasd
 sd 2 sds (copy the list here) ;

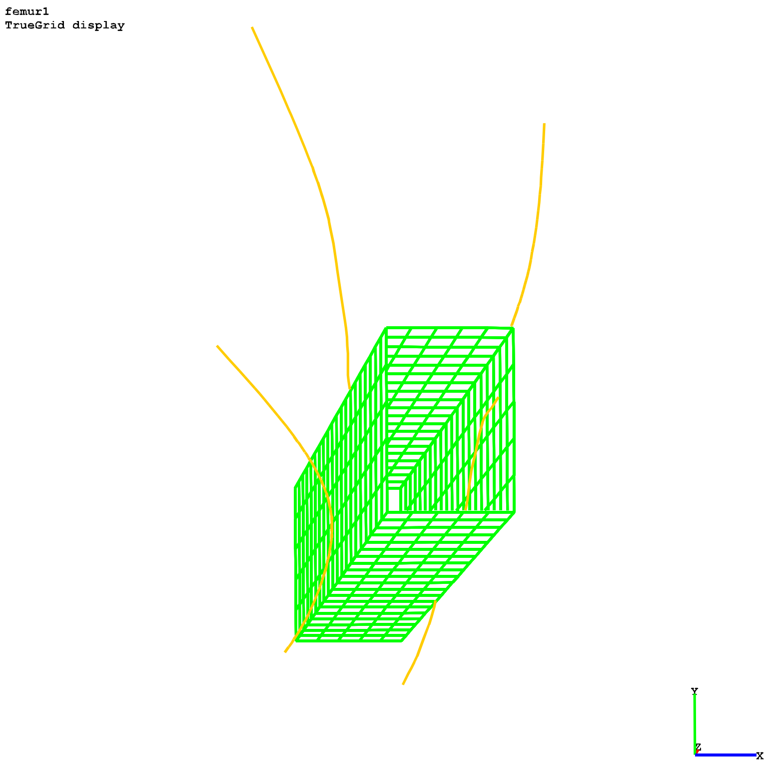
4.) select inner surfaces

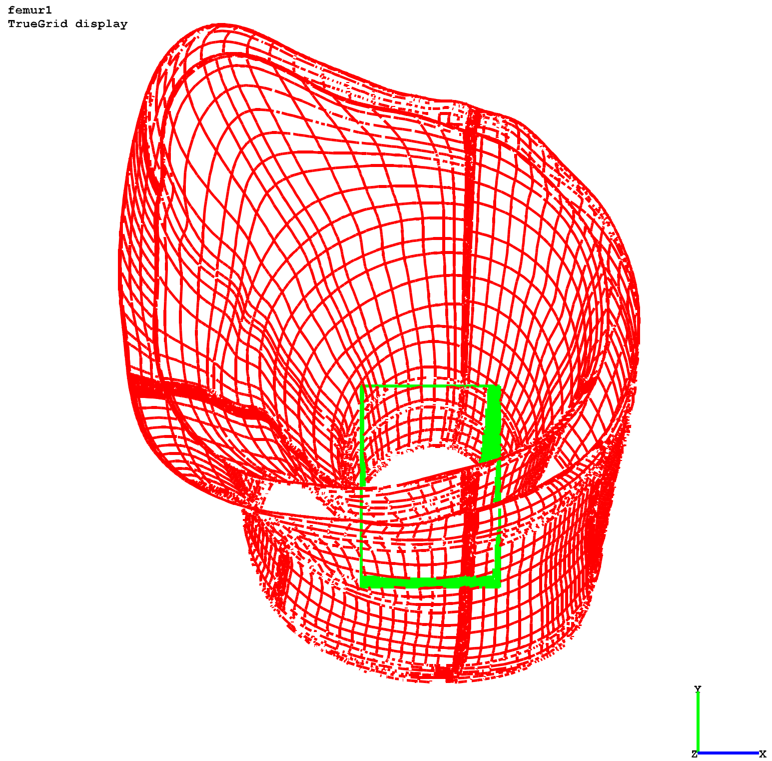
 dsd 1
 rsd 2
 lasd
 sd 3 sds (copy the list here) ;

Femur using butterfly technic

(femur1.tg) This example creates a solid mesh of a portion of a femur. This is done in the following steps:

1. The butterfly block with the i and j outer faces collapsed onto the core.





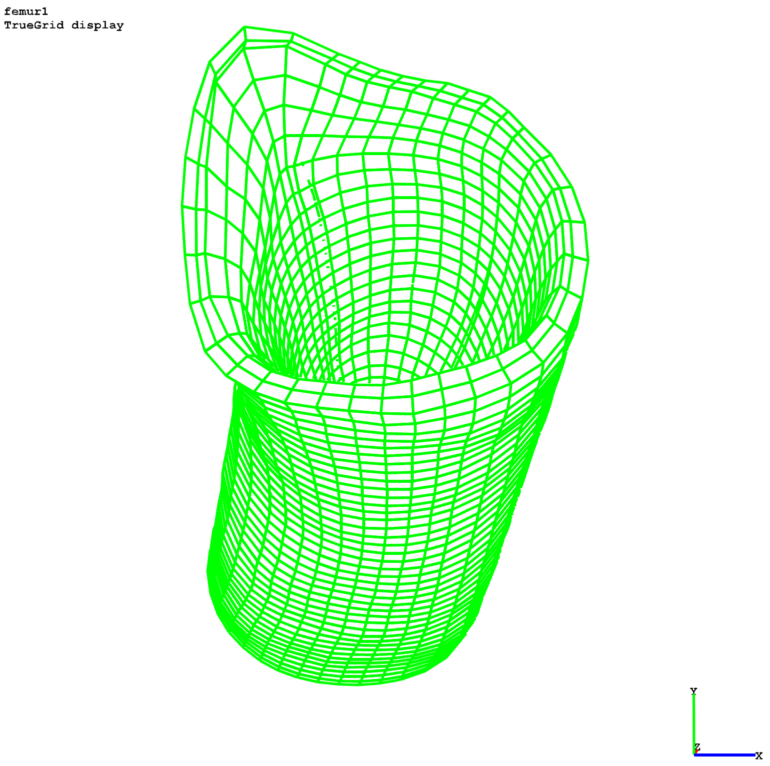
2. Curves are created near the core edges in the k-direction. Two curves are created using the twsurf curd command with the intersection of the inner bone surface and a plane through the center. Two other curves are created on the inner surface with the spline curve interactive window.

3. The tree edges at each of the deleted corners are attached to the corresponding curves.

4. The core faces are projected onto the inner surfaces and the outer faces are projected onto the outer surfaces.

5. The bottom of the mesh (minimum k) is projected to a plane. The top edges are attached to the curves of the upper edges of the inner and outer surfaces.

6. The mesh density is increased.



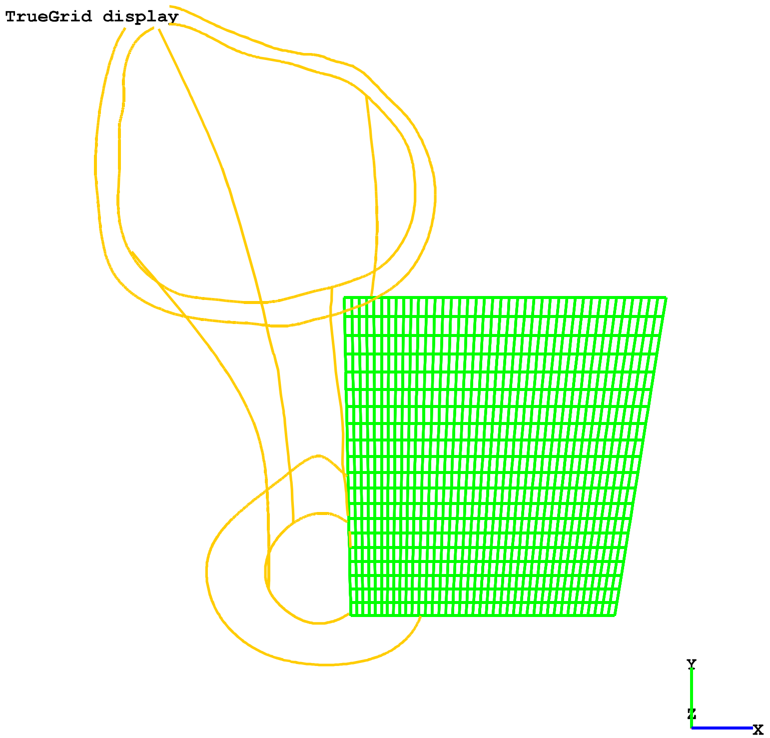
```
title femur1
lsdyna keyword
lsdyopts endtim .003  d3plot dtcycl .0001;;
lsdymats 1 3 rho 7.83e-3 e 2.07e11 pr .3
sigy 1.e8 etan 1.e6 ;
lsdymats 2 3 rho 7.83e-3 e 2.07e11 pr .3
sigy 1.e8 etan 1.e6 ;
getol 40
c useiges femur.bin
iges femur.igs 1 1;
  saveiges femur.bin
sd 1 sds 12 13 14 15 16 17 18;
sd 2 sds 19 20 21 22;
sd 3 pl3 rt -15.388713 9.2535696 358.58014
 rt -9.4950867 -.76184726 230.14107
 rt 3.3898385 20.136335 309.03134;
sd 4 pl3 rt -7.48591 9.8779745 205.24182
 rt -14.812638 31.227793 361.00757
 rt 1.2524102 -2.3078241 222.46727;
sd 5 plane 0 0 200 0 0 1
partmode i
block 2 5 2;2 5 2;20;
   -10 -10 1 1 1 1 17 17 200 385
dei 1 2 0 3 4;1 2 0 3 4;1 2; dei 2 3;2 3;;
curd 1 csp3 00
 -11.141433 -2.0192346e-01 1.9999309e+02
 -1.0269877e+01 2.4560499 2.5843872e+02
 -1.0655787e+01 6.0020523 2.9372382e+02
 -1.4612284e+01 9.5600433 3.3272491e+02
 -24.729206 1.5301673e+01 3.8196521e+02;;;
curd 2 csp3 00
 2.6108928 7.1842389e+00 1.9999939e+02
 2.9840410 1.0360577e+01 2.5279504e+02
 2.5904424 1.5411216e+01 2.9001147e+02
 4.8308396 2.4333895e+01 3.3467816e+02
 3.6252921 3.4585773e+01 3.8249869e+02 ;;;
```

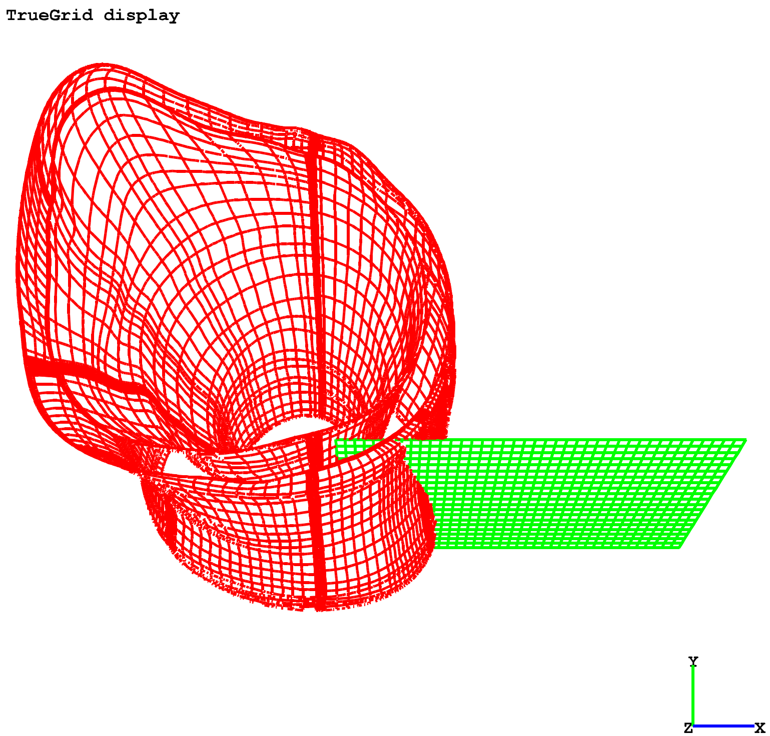
```
curd 3 twsurf 4 2
 -2.0682047e+01 4.3278934e+01 3.8230463e+02
 -1.1452212e+01 2.8495272e+01 3.4765891e+02
 -9.0711517 1.8374887e+01 2.9658469e+02
 -7.5674562 1.1862322e+01 2.3338618e+02
 -7.5713220 9.6519279e+00 2.0000885e+02;;;
curd 4 twsurf 4 2
 -4.4554377e-01 1.0822775e+01 3.8248468e+02
 5.1829863e-01 6.3018990e+00 3.3556650e+02
 7.5705409e-01 3.3452423e+00 2.8705746e+02
 1.1699607 -3.6472533 1.9999200e+02;;;
curs 3 2 1 3 2 2 4 curs 3 1 1 3 1 2 4
curs 4 2 1 4 2 2 4 curs 4 3 1 4 3 2 2
curs 3 3 1 3 3 2 2 curs 3 4 1 3 4 2 2
curs 2 4 1 2 4 2 3 curs 2 3 1 2 3 2 3
curs 1 3 1 1 3 2 3 curs 1 2 1 1 2 2 1
curs 2 2 1 2 2 2 1 curs 2 1 1 2 1 2 1
curd 5 se 16.1 se 12.1 se 15.1 se 14.1
 se 13.1 se 18.1 se 17.1
curd 6 se 12.3 se 16.3 se 16.4 se 16.5
 se 17.3 se 18.3 se 13.4 se 13.3 se 14.3
 se 15.3
curd 7 se 20.10 se 20.11 se 20.1 se 19.1
 se 19.2 se 19.3 se 21.1 se 22.3 se 22.2
 se 22.1
curd 8 se 21.3 se 19.5 se 20.3 se 20.4
 se 20.5 se 20.6 se 20.7 se 20.8 se 22.5
curs 2 2 2 2 3 2 8 curs 2 2 2 3 2 2 8
curs 3 2 2 3 3 2 8 curs 2 3 2 3 3 2 8
curs 1 2 2 1 3 2 5 curs 2 1 2 3 1 2 5
curs 4 2 2 4 3 2 5 curs 2 4 2 3 4 2 5
sfi -2 -3; -2 -3; 1 2;sd 1
sfi -1 -4; -1 -4;;sd 2 sfi ;; -1;sd 5
mseq i 0 4 0 mseq j 0 4 0 mseq k 20
mate 1
endpart
```

Femur using wrap around technic

(femur2.tg) The second approach to meshing the femur starts by wrapping the mesh around the surfaces.

1. Create a part with 4 blocks in the x-direction and one block in the other directions. The y-coordinate, which is the thickness direction, is collapsed so that a sheet is created.



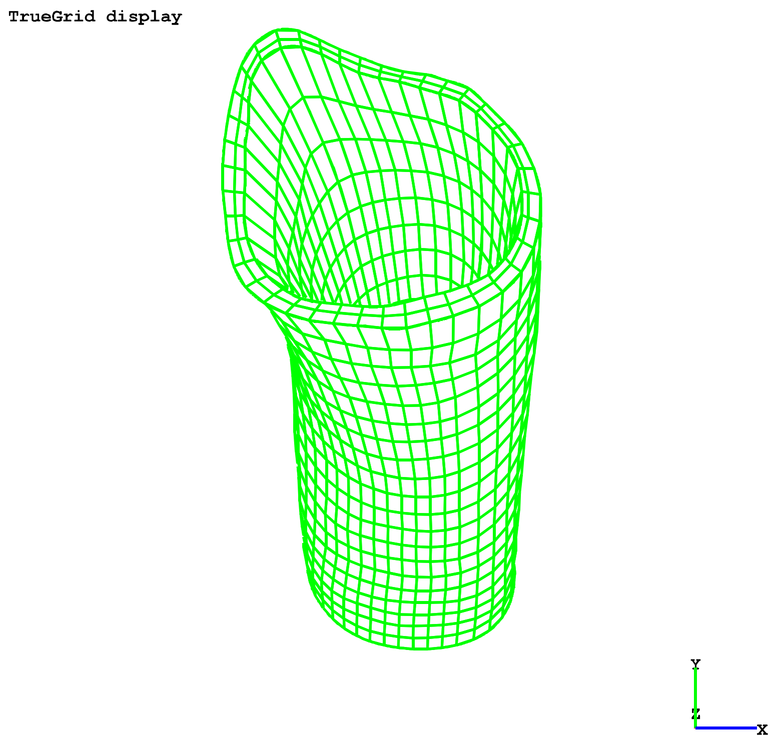


2. The 5 partitions (10 edges in the z-direction) are attached to each of the 4 curves (see the butterfly femur example) around the circumference of the inner surface of the bone.

3. The minimum j face is projected on the inner surface and the maximum j face is projected to the outer surface.

4. Project the minimum k face onto a plane. Attach the top edges to the curves at the top edges of the surfaces.

NOTE: The entire input file for this example is not included here because the geometry (i.e. IGES, surface, and curve generation) is the same geometry used in the previous example and is not repeated here.

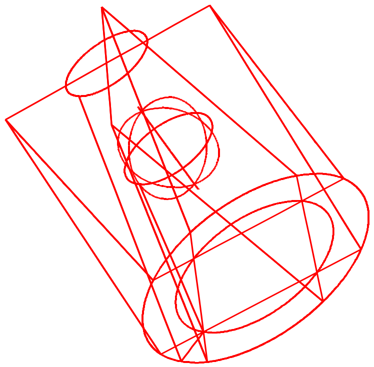


```
block 10 10 10 10; 2; 20;
1 10 20 30 40 10 10 200 385
pb 1 1 1 1 2 1 xyz
  2.6108928 7.1842389 199.99939
pb 2 1 1 2 2 1 xyz
  -7.5593119 9.647542 200.00896
pb 3 1 1 3 2 1 xyz
  -11.141433 -0.2019235 199.99309
pb 4 1 1 4 2 1 xyz
  1.1369659 -3.6014256 199.99998
pb 5 1 1 5 2 1 xyz
  2.6108928 7.1842389 199.99939
pb 1 1 2 1 2 2 xyz
  3.6252921 34.585773 382.49869
pb 2 1 2 2 2 2 xyz
  -21.603516 42.957771 382.164
pb 3 1 2 3 2 2 xyz
  -24.729206 15.301673 381.96521
pb 4 1 2 4 2 2 xyz
  -0.4844943 10.804322 382.48602
pb 5 1 2 5 2 2 xyz
  3.6252921 34.585773 382.49869
curs 2 1 1 2 1 2 3
curs 2 2 1 2 2 2 3
curs 1 2 1 1 2 2 2
curs 1 1 1 1 1 2 2
curs 3 2 1 3 2 2 1
curs 3 1 1 3 1 2 1
curs 4 2 1 4 2 2 4
curs 4 1 1 4 1 2 4
curs 5 2 1 5 2 2 2
curs 5 1 1 5 1 2 2
curs 1 2 2 5 2 2 5
curs 1 1 2 5 1 2 8
sfi 1 5; -1; 1 2;sd 1
sfi 1 5; -2; 1 2;sd 2
sfi 1 5; 1 2; -1;sd 5
mate 1
endpart
merge
```

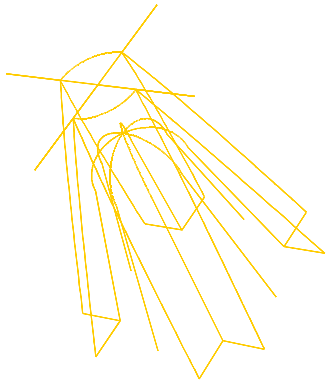
Keystone Topology

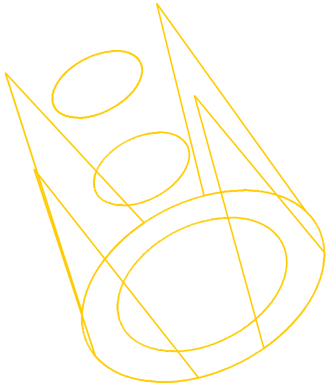
(keystone.tg) This example emphasizes the 3 basic steps that take a problem from geometry to final mesh. Finding the keystone part unravels the topology for the entire model. This keystone is built first and the rest of the model hangs off of it. The procedure is: 1. understand the geometry, 2. map the topology, and 3. generate the parts.

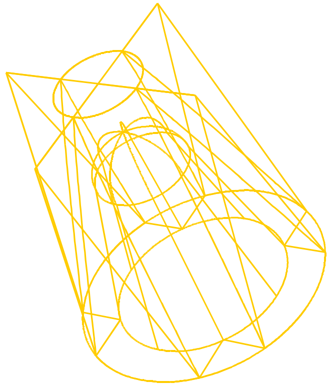
Geometry: Often you are given a set of surfaces and curves which may or may not communicate sufficient information.



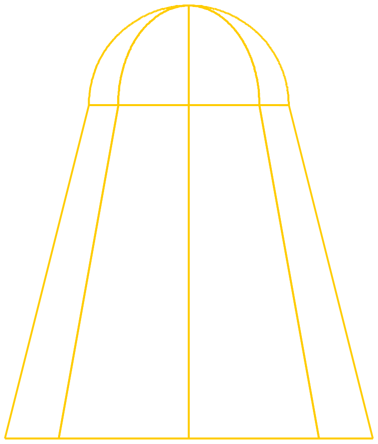
Additional 3D curves help understand the hidden features in the geometry. Use the cubic spline, coedge, lp3, and cpcd options of the curd command to interactively construct these curves.

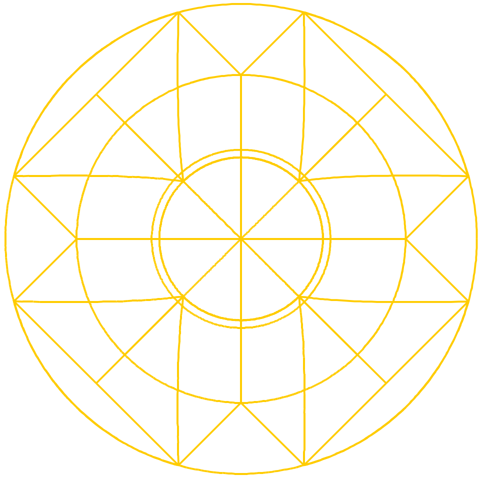


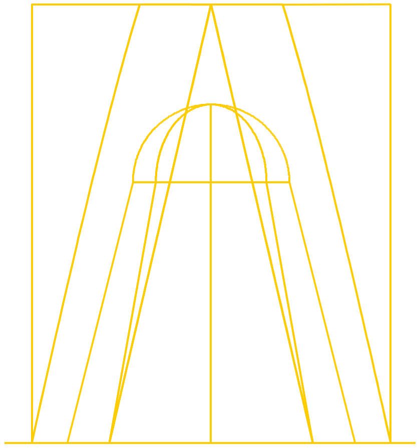


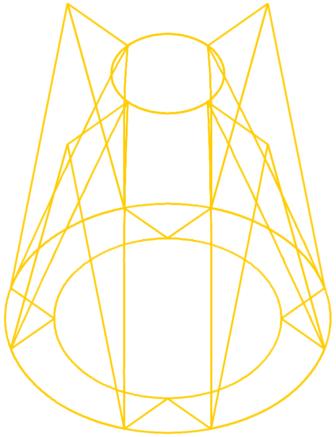


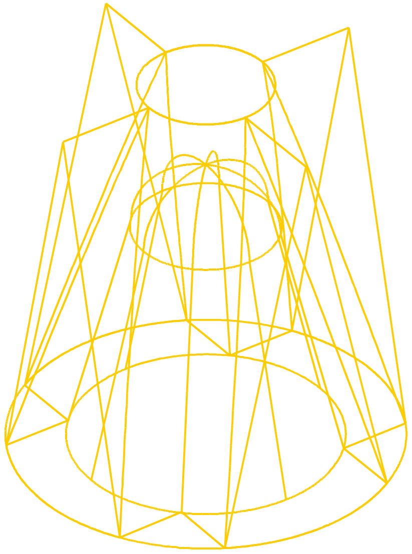
Topology: Using prints of the surface outlines and 3D curves, you should experiment with topologies. Symmetries are exploited to simplify the topology and reduce the effort in generating the parts.

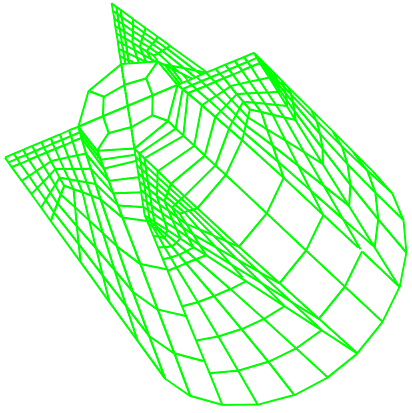




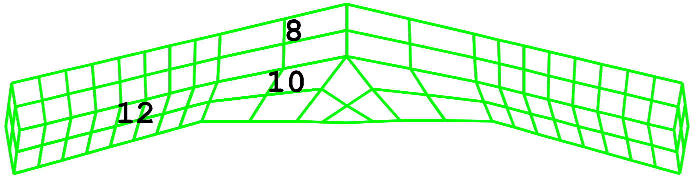


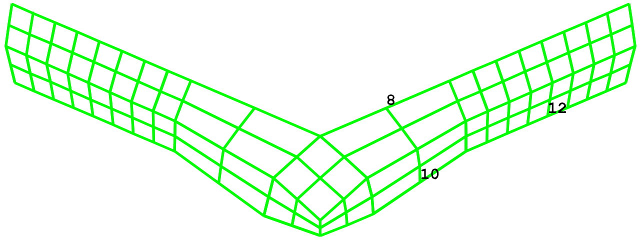




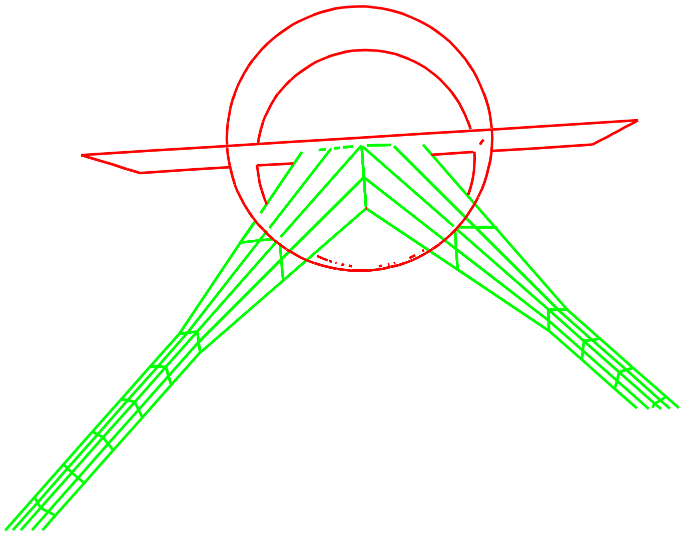


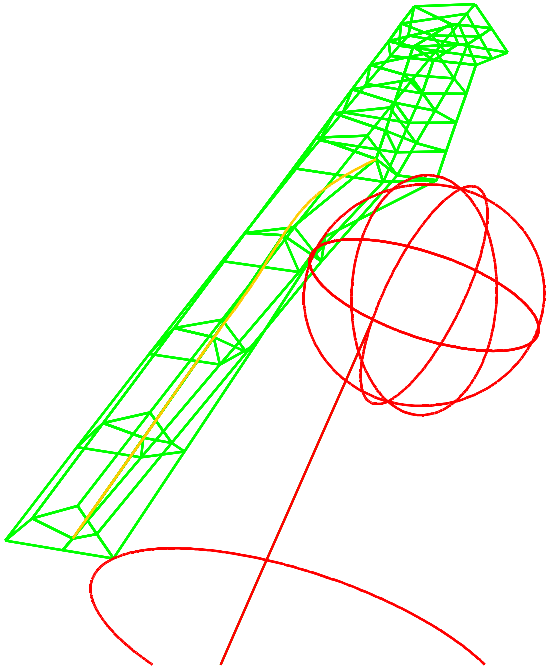
Generating parts: Once the topology is chosen, generating the parts is simply a mechanical step to completion.





The insure symmetry in this part, the intra-block boundary command is required. Each face on one side is glued to the appropriate face on the other side by applying a transformation in the bb command. When this part is replicated, the two halves will meet perfectly.





User defined surfaces are used to enforce the symmetry and to simplify the placement of some of the key vertices of the part. It is often necessary to attached an interior edge of the mesh to a shaping curve. Although these geometric entities are not directly tied to the model's geometry, they are needed to shape the interior of the mesh.

```
block 1 9 11 13;1 9 11 13;1 3;
  -1 -1 -1 1;-1 -1 -1 1; 0 1
dei 1 3; 1 3;;
tr 1 1 1 4 4 2 rz -135 ;
pb 1 3 1 1 3 1 xyz 3.548 3.548 0
pb 1 3 2 1 3 2 xyz 3.467 3.629 4.965185e-01
pb 1 4 1 1 4 1 xyz 3.629 3.467 4.965185e-01
pb 1 4 2 1 4 2 xyz 3.547 3.548 1
pb 2 3 1 2 3 1 xyz 1.41615 1.4122 0
pb 2 3 2 2 3 2 xyz 1.439433 1.60155 .501754
pb 2 4 1 2 4 1 xyz 1.601556 1.43943 .501754
pb 2 4 2 2 4 2 xyz 1.62227 1.61928 .9557584
pb 3 1 1 3 1 1 xyz -3.548 3.548 0
pb 3 1 2 3 1 2 xyz -3.467 3.629141 .4965185
pb 3 2 1 3 2 1 xyz -1.41225 1.41615 0
pb 3 2 2 3 2 2 xyz -1.439433 1.6015 .501754
pb 3 3 1 3 3 1 xyz 0 0 0
pb 3 3 2 3 3 2 xyz 0 .5 4.958810e-01
pb 3 4 1 3 4 1 xyz .5 0 4.958810e-01
pb 3 4 2 3 4 2 xyz .616027 .577715 1.23624
pb 4 1 1 4 1 1 xyz -3.62914 3.467 .496518
pb 4 1 2 4 1 2 xyz -3.548452 3.547698 1
pb 4 2 1 4 2 1 xyz -1.60155 1.43943 .501754
pb 4 2 2 4 2 2 xyz -1.61928 1.6222 .9557584
pb 4 3 1 4 3 1 xyz -.5 0 4.958810e-01
pb 4 3 2 4 3 2 xyz -.577715 .616027 1.23624
pb 4 4 1 4 4 1 xyz 0 0 1
pb 4 4 2 4 4 2 xyz 0 .301914 1.34359
sfi 1 2; -3; 1 2;sd 4
sfi -1; 3 4; 1 2;sd 10
sfi -2;;;sd 1
sfi 3 4; 3 4; -1;sd 102;
sfi -4; -3; -1;sd 101
sfi -3; -4; -1;sd 101
sfi 3 4; -2; 1 2; sd 1
sfi -2; 3 4; 1 2;sd 1
bb 4 3 1 4 4 2 1;
bb 3 3 2 4 4 2 2;
bb 3 4 1 4 4 2 3;
bb 3 2 1 3 3 2 8;
bb 2 3 1 3 3 2 9;
bb 3 2 2 4 3 2 10;
bb 2 3 2 3 4 2 11;
bb 2 3 2 3 4 2 10 ryz;
bb 2 3 1 3 3 2 8 ryz;
bb 2 4 1 3 4 2 10 rz 90;
bb 4 2 1 4 3 2 10 ryz rz 90;
bb 2 3 1 3 4 1 8 rz 90;
bb 3 2 1 4 3 1 8 ryz rz 90;
bb 3 1 2 4 2 2 12;
bb 1 3 2 2 4 2 12 ryz;
bb 1 4 1 2 4 2 12 rz 90;
bb 4 1 1 4 2 2 12 ryz rz 90;
lct 1 rxz ;lrep 0 1;
endpart
block 1 3 5;1 3 5; 1 5;-1 0 1;0 0 1;1 3
dei 2 3; 2 3; 1 2;
pb 1 1 2 1 1 2 xyz .5 0 2.87
pb 1 2 2 1 2 2 xyz 0 0 2.812352
pb 1 3 2 1 3 2 xyz -.5 0 2.870257
pb 2 1 2 2 1 2 xyz .3647126 .34203 2.87
pb 2 2 2 2 2 2 xyz 0 .1637298 2.818488
pb 2 3 2 2 3 2 xyz -.3420303 .3647126 2.87
pb 3 1 2 3 1 2 xyz 0 .5 2.87
pb 3 2 2 3 2 2 xyz -.34203 .3647126 2.87
pb 1 1 1 1 1 1 xyz .5 0 .495881
pb 1 2 1 1 2 1 xyz 0 0 1
pb 1 3 1 1 3 1 xyz -.49999 0 .495881
pb 2 1 1 2 1 1 xyz .616027 .577715 1.23624
pb 2 2 1 2 2 1 xyz 0 .245293 1.34359
pb 2 3 1 2 3 1 xyz -.577715 .616027 1.23624
pb 3 1 1 3 1 1 xyz 0 .680399 .495881
pb 3 2 1 3 2 1 xyz -.577715 .616027 1.23624
sfi ;; -2;sd 14
```

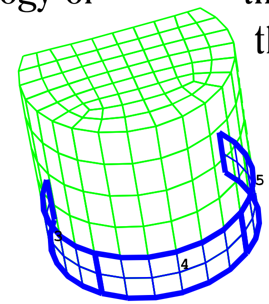
```
bb 1 2 1 2 3 1 1;
bb 1 1 1 2 1 2 4;
bb 2 1 1 3 1 2 5;
bb 3 1 1 3 2 2 6;
bb 1 3 1 2 3 2 7;
lct 1 rxz ;lrep 0 1;
endpart
block 1 2 3;1 2 3;1 3 7 11;
 0 1.25 2;0 1.25 2; 0 1 3.2 12.3
dei 2 3; 2 3; 1 4;
tr 1 1 1 3 3 4 rz 45;
pb 1 1 1 1 1 1 xyz 0 0 0
pb 1 1 2 1 1 2 xyz 0 .5 .495881
pb 1 1 3 1 1 3 xyz 0 .5 2.870257
pb 1 1 4 1 1 4 xyz 0 4.025 12.33
pb 1 2 1 1 2 1 xyz -.7061257 .708 0
pb 1 2 2 1 2 2 xyz -7.197165e-01
1.050773e+00 4.988176e-01
pb 1 2 3 1 2 3 xyz -3.688451e-01
1.252049e+00 3.244400e+00
pb 1 2 4 1 2 4 xyz -7.205829e-01
4.746858e+00 1.233000e+01
pb 1 3 2 1 3 2 xyz -1.439433e+00
1.601556e+00 5.017541e-01
pb 1 3 1 1 3 1 xyz -1.412251e+00
1.416150e+00 0.000000e+00
pb 1 3 2 1 3 2 xyz -1.439433e+00
1.601556e+00 5.017541e-01
pb 1 3 3 1 3 3 xyz -1.519183e+00
2.595096e+00 3.294861e+00
pb 1 3 4 1 3 4 xyz -1.534603e+00
5.560864e+00 1.232998e+01
pb 2 1 1 2 1 1 xyz 7.080752e-01
7.061256e-01 0.000000e+00
pb 2 1 2 2 1 2 xyz 7.197165e-01
1.050773e+00 4.988176e-01
pb 2 1 3 2 1 3 xyz 3.688451e-01
1.252049e+00 3.038060e+00
pb 2 1 4 2 1 4 xyz 7.205829e-01
4.746858e+00 1.233000e+01
pb 2 2 1 2 2 1 xyz 0.000000e+00
1.227280e+00 0.000000e+00
pb 2 2 2 2 2 2 xyz 0.000000e+00
1.767767e+00 7.173570e-01
pb 2 2 3 2 2 3 xyz 4.477141e-04
1.732667e+00 3.014205e+00
pb 2 2 4 2 2 4 xyz -3.095077e-03
4.896914e+00 1.233000e+01
pb 2 3 1 2 3 1 xyz 6.350810e-07
2.000000e+00 0.000000e+00
pb 2 3 2 2 3 2 xyz -1.759177e-09
2.254791e+00 8.335602e-01
pb 2 3 3 2 3 3 xyz 8.954281e-04
2.965335e+00 3.158152e+00
pb 2 3 4 2 3 4 xyz -6.190153e-03
5.768826e+00 1.233000e+01
pb 3 1 1 3 1 1 xyz 1.416150e+00
1.412251e+00 0.000000e+00
pb 3 1 2 3 1 2 xyz 1.439433e+00
1.601556e+00 5.017541e-01
pb 3 1 3 3 1 3 xyz 1.518879e+00
2.587570e+00 3.273117e+00
pb 3 1 4 3 1 4 xyz 1.534981e+00
5.560760e+00 1.232998e+01
pb 3 2 1 3 2 1 xyz 6.350810e-07
2.000000e+00 0.000000e+00
pb 3 2 2 3 2 2 xyz -1.759177e-09
2.254791e+00 8.335602e-01
pb 3 2 3 3 2 3 xyz 8.954281e-04
2.965335e+00 3.158152e+00
pb 3 2 4 3 2 4 xyz -6.190153e-03
5.768826e+00 1.233000e+01
curs 1 1 3 1 1 4 112
curs 2 2 3 2 2 4 121
```

```
curs 1 2 3 1 2 4 122
curs 2 1 3 2 1 4 123
bb 1 1 1 1 3 2 8;
bb 1 1 1 3 1 2 9;
bb 1 1 2 3 1 4 14;
bb 1 1 2 1 3 4 15;
bb 2 2 1 3 2 4 101;
bb 2 2 1 2 3 4 101;
sfi -3; 1 2; 1 4;sd 1
sfi 1 2; -3; 1 4;sd 1
sfi ;; -1;sd 12
sfi 2 3; -1; 1 4;sd 4
sfi -1; 2 3; 1 4;sd 6
sfi ;; -4;sd 7
sfi -1; -1; 3 4;sd 103;
lct 3 rz  90 ; rz 180 ; rz -90 ;lrep 0:3;
endpart
block 1 3 7 11; 1 3 5; 1 5 9;
0 1.4161503 2.48114
3.5480771 ;-1 0 1;.5 3.3 12.33;
dei 3 4; 1 3; 2 3;
tri ;;;rz 45;
pb 1 1 1 1 1 1 xyz 4.999909e-01
-2.185530e-08 4.958810e-01
pb 1 1 2 1 1 2 xyz 5.000003e-01 0 2.870257
pb 1 1 3 1 1 3 xyz 4.025000 0 1.233000e+01
pb 1 2 1 1 2 1 xyz .616027 .577715 1.23624
pb 1 2 2 1 2 2 xyz .364712 .34203 2.87
pb 1 2 3 1 2 3 xyz 2.846105 2.846105 12.33
pb 1 3 1 1 3 1 xyz 0 .5 4.958810e-01
pb 1 3 2 1 3 2 xyz 0 5.000003e-01 2.870257
pb 1 3 3 1 3 3 xyz 0 4.025 1.233000e+01
pb 2 1 1 2 1 1 xyz 1.60155 1.43943 .501754
pb 2 1 2 2 1 2 xyz 2.595 1.519183 3.294861
pb 2 1 3 2 1 3 xyz 5.560872 1.5346 1.23299
pb 2 2 1 2 2 1 xyz 1.622275 1.619285
9.557584e-01
pb 2 2 2 2 2 2 xyz 1.81442 1.85425 3.32158
pb 2 2 3 2 2 3 xyz 4.135019 4.02258 12.33
pb 2 3 1 2 3 1 xyz 1.439433 1.60155 .501754
pb 2 3 2 2 3 2 xyz 1.51887 2.58757 3.273117
pb 2 3 3 2 3 3 xyz 1.53498 5.56076 12.32999
pb 3 1 1 3 1 1 xyz 2.615752 2.452817 .5
pb 3 1 2 3 1 2 xyz 3.01589 2.31871 2.135218
pb 3 1 3 3 1 3 xyz 4.095335 3 3.352194
pb 3 2 1 3 2 1 xyz 2.584987 2.58386 .977879
pb 3 2 2 3 2 2 xyz 2.6274 2.707136 2.031164
pb 3 2 3 3 2 3 xyz 3.58339 3.58568 3.25158
pb 3 3 1 3 3 1 xyz 2.452822 2.615747 .499
pb 3 3 2 3 3 2 xyz 2.31469 3.01991 2.159914
pb 3 3 3 3 3 3 xyz 3 4.095315 3.352199
pb 4 1 1 4 1 1 xyz 3.62913 3.46701 .4965199
pb 4 1 2 4 1 2 xyz 4.095335 3 3.352194
pb 4 2 1 4 2 1 xyz 3.55111 3.55187 .999953
pb 4 2 2 4 2 2 xyz 3.58339 3.58568 3.251586
pb 4 3 1 4 3 1 xyz 3.467 3.629131 .4965221
pb 4 3 2 4 3 2 xyz 3 4.095315 3.352199
bb 1 1 1 1 2 2 6 rz 90;
bb 1 2 1 1 3 2 7 rz 90;
bb 1 3 1 2 3 3 14;
bb 1 1 1 2 1 3 15 rz 90;
bb 3 1 2 3 3 3 102;
bb 3 1 2 4 3 2 102;
sfi -4; 1 3; 1 2;sd 10
sfi 2 3; 1 3; -3;sd 10
sfi 2 4; -1; 1 3;sd 3
sfi 2 4; -3; 1 3;sd 4
sfi 1 2; 1 3; -3;sd 7
lrep 0:3;
endpart
```

Block boundaries and transition elements

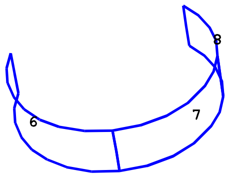
Transitions (peg.tg)

Sometimes the master block boundaries are in segments which do not match the topology of the slave side. A ghost part is created with material 0 to transform the block boundaries into segments that match the topology of the slave side.

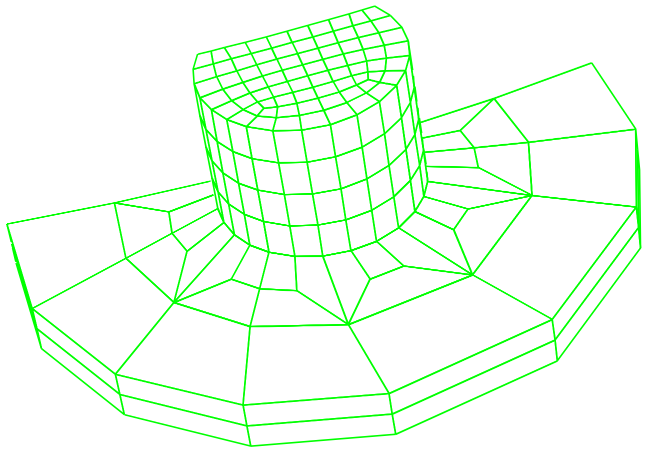


The first part is a peg which forms the master side of the interface.

The second part is a ghost part with material set to 0 where the 3 interfaces with 6 elements each are transformed to 8, 6, and 4 elements respectively. This problem is common when using the Transition Block Boundary interface.



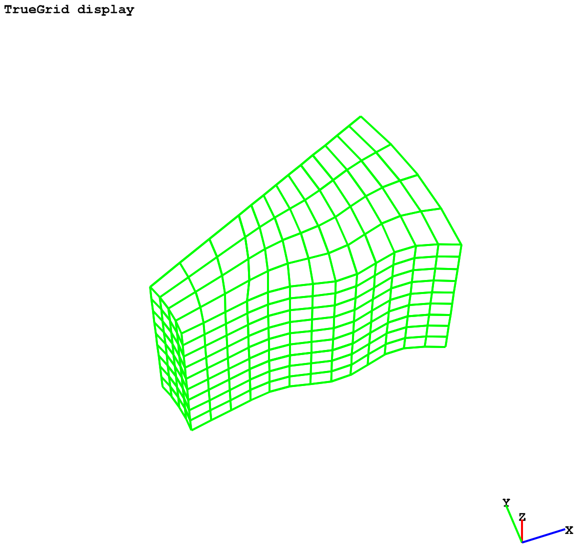
The third part has the slave faces forming transitions.

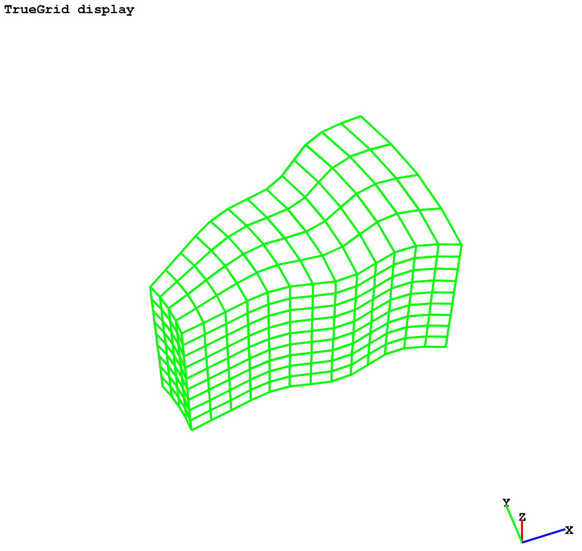


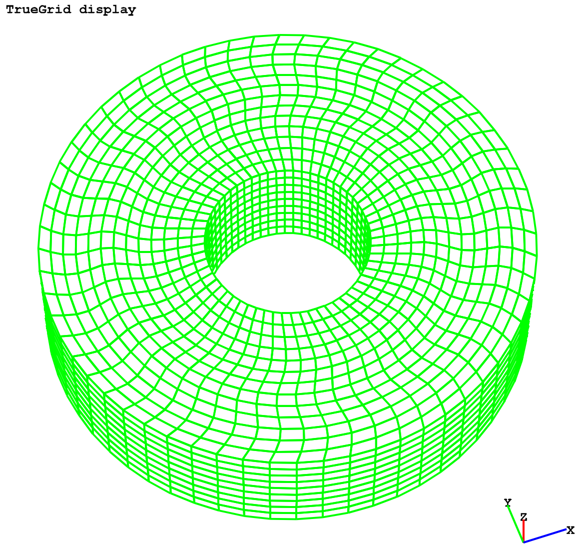
REMINDER: This is also a good example of transition block boundaries. The **trbb** command automatically transitions between parts when the ratio is either 2-to-4 or 1-to-3.

Intra-Part BB w/offset

(cyl.tg) The complex frot face of a wedge section is replicated on the back face with a transformed block boundary. The section is then replicated circumferentially to create a complete cylinder.



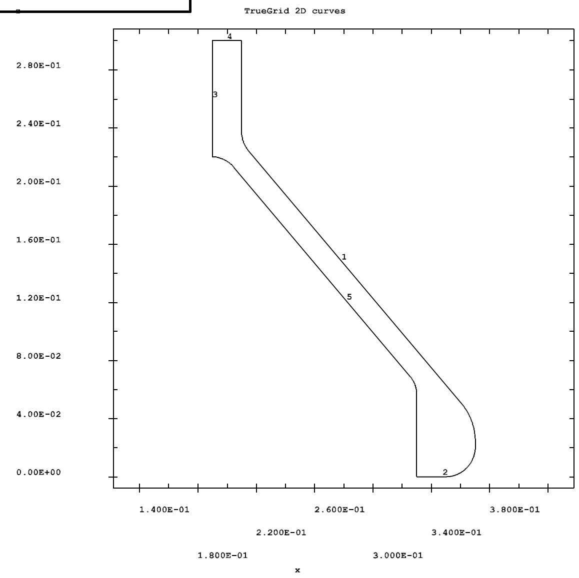





```
partmode i
cylinder 3 10;4 ;3 6;40 60 120 0 24 0 20 60
mbi -2; -2; 1 3; x 12.5869
curd 1 csp3 00
 40 0 60
 53.521618 2.2601 59.99865
 71.2369 3.64166 59.99865
 87.12854 69.698966 59.99865
 103.80174 4.0837345 59.99865
 120 0 60;;;
curd 2 cpcds 1;mz -60 ;
```

```
sd 1 rule3d 1 2 ; ;
sfi 1 3; -1; 1 3;sd 1
bb 1 1 1 3 1 3 1 rz 24;
bb 1 2 1 3 2 3 1;
lct 14 rz 24;repe 14; lrep 0:14;
mate 1
endpart
merge
stp .001
```

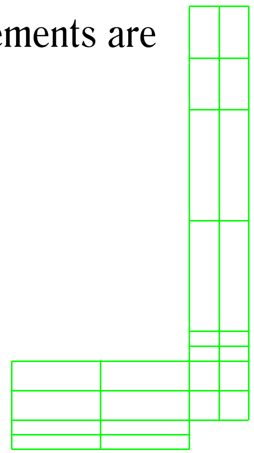
Advanced uses of the BLOCK command

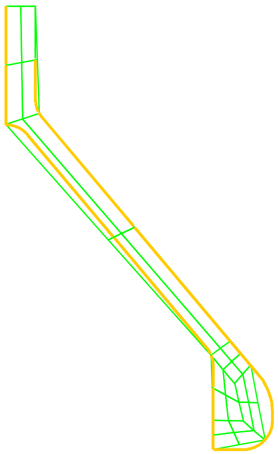


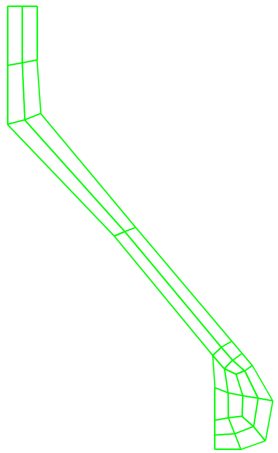
Create a 2D cross section and add the third dimension. (flange1.tg & flange2.tg)

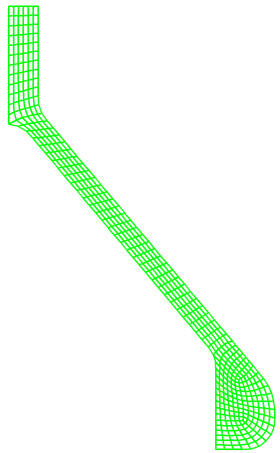
A 2D cross section is rotated. The cross section is defined with 2D curves. Take care to define different curves to form corners. It will be desirable to constrain an edge of the mesh along the intersection of 2 surfaces where the two surfaces form a corner. Plan ahead with fillets. An edge of the mesh will likely be constrained where the two fillet portions meet. These choices can be overcome later by combining surfaces with the SDS option of the SD command.

A block part is constructed with the j-index a constant (shells). The 2D curves are used to form 3D curves to help shape the part. Then the 2D curves form surfaces of projections. The mesh is also smoothed. Elements are added.









```
para r1 .19 r2 .21 r3 .37 r4 .33 r5 .02
  r6 .02 r7 .04 h1 .19 h2 .07 h3 .3
  h4 .2 th .015;
c  create the 2D curves
ld 1 lp2 %r2 %h3;
   lfil 90 [%r2+%h3*cos(50)]
    [%h3*(1-sin(50))-%h2] -50 %r6
   lfil -50 %r3 0 90 %r7
   lp2 %r3 %r6;
   lad [%r3-%r6] %r6 -45;
ld 2 lp2 %r4 0 [%r3-%r6] 0;
     lad [%r3-%r6] %r6 45;
ld 3 lp2 %r1 %h3 %r1 [%h3-%h2-%h4+%h1];
ld 4 lp2 %r1 %h3 %r2 %h3;
ld 5 lp2 %r1 [%h3-%h2-%h4+%h1];
  lfil 0 [%r2-%th*cos(40)+%h3*cos(50)]
  [%h3-%h2-%th*sin(40)-%h3*sin(50)] -50 %r5
  lfil -50 %r4 [%h3-%h2-%h4] 90 %r6
  lp2 %r4 0;
c  convert the 2D curves to 3D curves
curd 1 ld2d3d 1 rt y 0 0;
curd 2 ld2d3d 2 rt y 0 0;
curd 3 ld2d3d 3 rt y 0 0;
curd 4 ld2d3d 4 rt y 0 0;
curd 5 ld2d3d 5 rt y 0 0;
c  convert 2D curves to surface
sd 1 crz 1 sd 2 crz 2 sd 3 crz 3
sd 4 crz 4 sd 5 crz 5
c  create a block part of j-shells
block 1 3 5;-1;1 3 5 7 9 11;
 .21 .33 .37;0;0 .02 .06 .08 .23 .3;
c  remove corners
dei 1 2;-1;3 6; dei 2 3;-1;1 2;
c  position along the curves
pb 2 1 6 2 1 6 xyz 1.9e-01 0 3.0e-01
pb 2 1 5 2 1 5 xyz 1.9e-01 0 2.2e-01
pb 3 1 6 3 1 6 xyz 2.1e-01 0 3.0e-01
pb 3 1 5 3 1 5 xyz 2.125e-01 0 2.275e-01
pb 3 1 4 3 1 4 xyz 3.413e-01 0 7.349e-02
pb 3 1 3 3 1 3 xyz 3.551e-01 0 5.696e-02
pb 3 1 2 3 1 2 xyz 3.648e-01 0 6.617e-03
pb 2 1 1 2 1 1 xyz 3.648e-01 0 6.617e-03
pb 1 1 1 1 1 1 xyz 3.3e-01 0 0
pb 1 1 2 1 1 2 xyz 3.3e-01 0 1.978e-02
pb 1 1 3 1 1 3 xyz 3.284e-01 0 6.4e-02
pb 2 1 4 2 1 4 xyz 3.284e-01 0 6.4e-02
pb 2 1 3 2 1 3 xyz 0.344 0 0.446e-01
pb 2 1 2 2 1 2 xyz 0.350 0 0.192e-01
c  glue the internal edges
bb 2 1 1 2 1 2 1;bb 2 1 2 3 1 2 1;
bb 2 1 3 2 1 4 2;bb 1 1 3 2 1 3 2;
c  project to surfaces
sfi -3;-1;2 6;sd 1 sfi 1 2;-1;-1;sd 2
sfi -3;-1;-2; sd 2 sfi -2;-1;-1;sd 1
sfi -1;-1;1 3;sd 5 sfi -2;-1;4 5;sd 5
sfi -2;-1;5 6;sd 3 sfi 2 3;-1;-6;sd 4
c  smooth the face
unifm 2 1 2 3 1 6 & 1 1 1 2 1 3 20 0 1 ;
c  add elements
mseq i 4 4 mseq k 4 8 4 30 10
c  move vertices for the best mesh
pb 3 1 3 3 1 3 xyz 3.586e-01 0 5.285e-02
pb 3 1 4 3 1 4 xyz 3.391e-01 0 7.603e-02
pb 3 1 4 3 1 4 xyz 3.364e-01 0 7.93e-02
pb 3 1 5 3 1 5 xyz 2.104e-01 0 2.329e-01
```

The 2D shell mesh can easily be transformed into a 3D solid of revolution by following these steps:

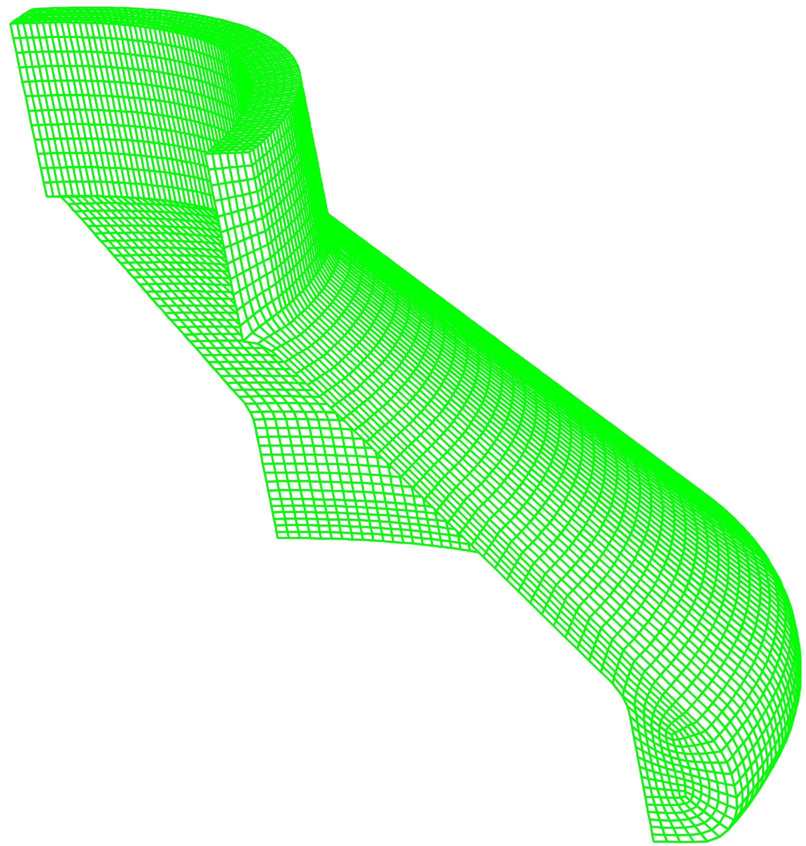
1. Switch from block to cylinder and add angular thickness in the j-direction

2. Remove the 3D curves

3. Remove the y-character from the placement commands and remove the y-coordinate from the coordinate list,

4. If a command has a region, change the second j-index to 0. If a command has an index progression, remove the -1.

5. The smoothing on the face needs to be applied to both j-faces.



```
para r1 .19 r2 .21 r3 .37 r4 .33 r5 .02
  r6 .02 r7 .04 h1 .19 h2 .07 h3 .3
  h4 .2 th .015 ;
ld 1 lp2 %r2 %h3;
  lfil 90 [%r2+%h3*cos(50)]
   [%h3*(1-sin(50))-%h2] -50 %r6
  lfil -50 %r3 0 90 %r7
  lp2 %r3 %r6;
  lad [%r3-%r6] %r6 -45 ;
ld 2 lp2 %r4 0 [%r3-%r6] 0;
  lad [%r3-%r6] %r6 45 ;
ld 3 lp2 %r1 %h3 %r1 [%h3-%h2-%h4+%h1];
ld 4 lp2 %r1 %h3 %r2 %h3;
ld 5 lp2 %r1 [%h3-%h2-%h4+%h1];
  lfil 0 [%r2-%th*cos(40)+%h3*cos(50)]
  [%h3-%h2-%th*sin(40)-%h3*sin(50)] -50 %r5
  lfil -50 %r4 [%h3-%h2-%h4] 90 %r6
  lp2 %r4 0;
sd 1 crz 1 sd 2 crz 2 sd 3 crz 3
sd 4 crz 4 sd 5 crz 5
c  convert the block to a cylinder
c  add thickness in the j-direction
cylinder 1 3 5;1 91;1 3 5 7 9 11;
  .21 .33 .37;0 90;0 .02 .06 .08 .23 .3;
c  remove the -1 in the j-direction
dei 1 2;;3 6;dei 2 3;;1 2;
c  remove the y character from the symbol
c  remove the y-coordinate
c  change the second j-index of 1 to 0
pb 2 1 6 2 0 6 xz 1.9e-01 3.0e-01
pb 2 1 5 2 0 5 xz 1.9e-01 2.2e-01
pb 3 1 6 3 0 6 xz 2.1e-01 3.0e-01
pb 3 1 5 3 0 5 xz 2.125e-01 2.275e-01
pb 3 1 4 3 0 4 xz 3.413e-01 7.349e-02
pb 3 1 3 3 0 3 xz 3.551e-01 5.696e-02
pb 3 1 2 3 0 2 xz 3.648e-01 6.617e-03
pb 2 1 1 2 0 1 xz 3.648e-01 6.617e-03
pb 1 1 1 1 0 1 xz 3.3e-01 0
pb 1 1 2 1 0 2 xz 3.3e-01 1.978e-02
pb 1 1 3 1 0 3 xz 3.284e-01 6.4e-02
pb 2 1 4 2 0 4 xz 3.284e-01 6.4e-02
pb 2 1 3 2 0 3 xz 0.344 0.446e-01
pb 2 1 2 2 0 2 xz 0.35 0.192e-01
c  change the second j-index of 1 to 0
bb 2 1 1 2 0 2 1;bb 2 1 2 3 0 2 1;
bb 2 1 3 2 0 4 2;bb 1 1 3 2 0 3 2;
c  remove the -1 in the j-direction
sfi -3;;2 6;sd 1 sfi 1 2;;-1;sd 2
sfi -3;;-2;sd 2 sfi -2;;-1;sd 1
sfi -1;;1 3;sd 5 sfi -2;;4 5;sd 5
sfi -2;;5 6;sd 3 sfi 2 3;;-6;sd 4
c  copy the unifm command and the j-index
unifm 2 1 2 3 1 6 & 1 1 1 2 1 3 20 0 1;
unifm 2 2 2 3 2 6 & 1 2 1 2 2 3 20 0 1;
mseq i 4 4 mseq k 4 8 4 30 10
c  remove the y character from the symbol
c  remove the 0 y-coordinate
c  change the second j-index of 1 to 0
pb 3 1 3 3 0 3 xz 3.586e-01 5.285e-02
pb 3 1 4 3 0 4 xz 3.391e-01 7.6e-02
pb 3 1 4 3 0 4 xz 3.364e-01 7.93e-02
pb 3 1 5 3 0 5 xz 2.104e-01 2.329e-01
```

Features of the History Table

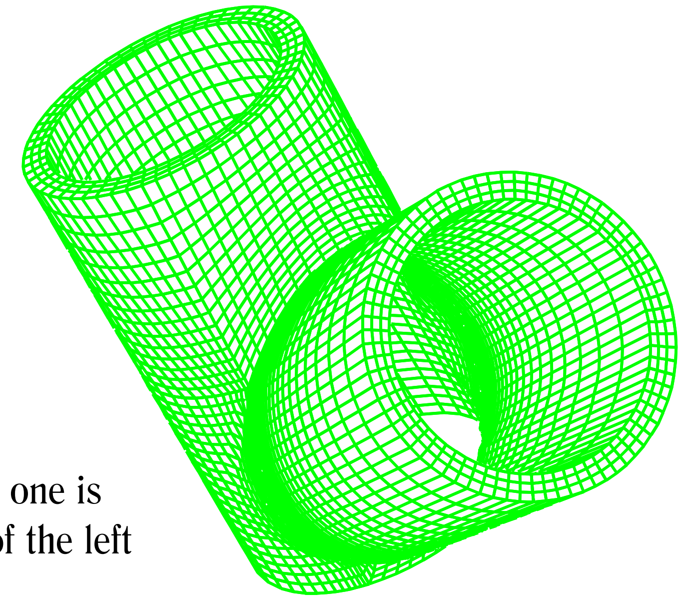
The history table can be a very powerful debugging tool. You can easily find mistakes by reviewing only the commands related to a specific region.

1. List of Features

(1) View Menu
(a) Status of commands (Activated or deactivated), command name or description, etc.
(b) Full or reduced indices
(c) Sort commands by sequence or by hierarchy
(d) Show all commands or only for the highlighted region
(2) List of surface, curve, edge or bb

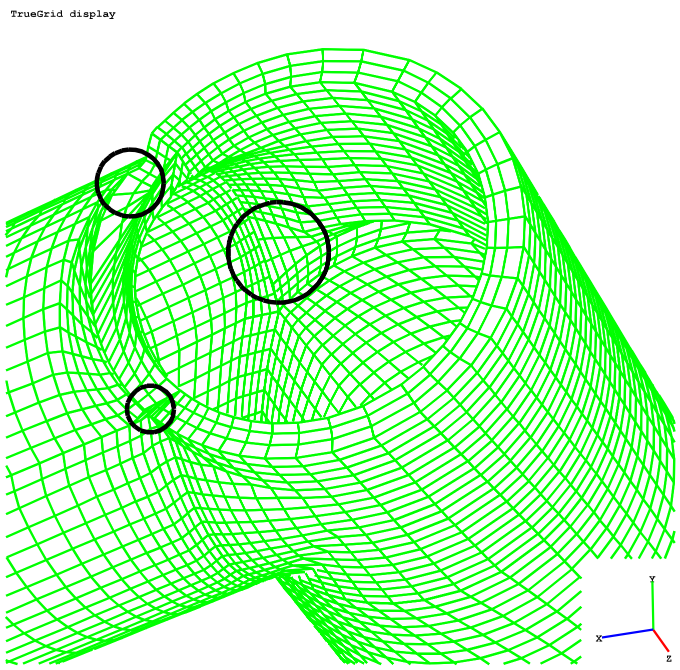
2. Exercise

(kpipe.tg) Try to find and fix three mistakes in the model using the history table. The three mistakes occurred while doing initialization, one is around the junction of the pipes the other two are in the inner wall of the left pipe.



Finished mesh with no error

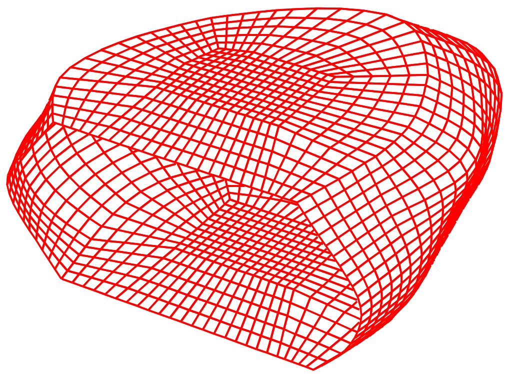
(1) Run the file kpipe.tg - all commands have been deactivated.
(2) Open history table To open the history table, press F3 of keyboard or click "HISTORY" button on environment window or type "history" command on text window.
(3) Check the block topology activate the deleted command by clicking middle or right mouse button on the column "Act/Deact"
(4) Try to find the errors while activating the other commands one by one. If a certain region is suspicious, you can get the commands specific to that region by choosing "Show Only" option under "View" menu after highlight the region. If you found an error, you can retrieve the dialog box for that command by selecting from any column except "Act/Deact" and "Region/Progression" or press the "Dialog" button in the bottom of history table after positioning the red box on the command.
(5) If you do not find the errors after activating all commands, try selecting one of the bad vertices and doing a history.



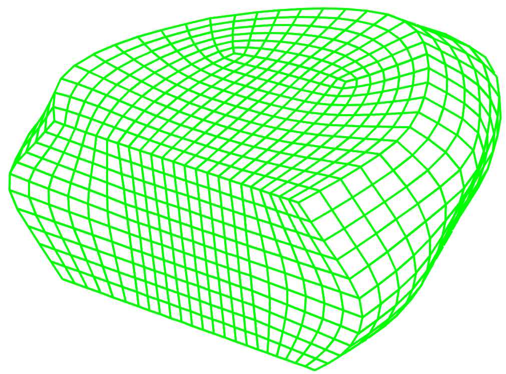
```
useiges kpipe.bin
iges kpipe.igs 1 1;
c saveiges kpipe.bin
sd 1 sds 5 7; sd 2 sds 6 8;
sd 3 plan 0 0 0 0 0 1
sd 10 pl3 rt 2.1219358 -2.1206756 0
 rt 2.0155716 -2.2220318 5.1153660
 rt 2.121935 2.120676 0
sd 12 plan 9.5 2.8 5.3 2 0 1
sd 13 plan 0 0 10 0 0 1
sd 14 pl3 rt 1.7809463 1.7554842 .75460356
 rt 1.7741714 -1.7612828 .75214648
 rt 1.8560611 -1.6723335 4.8598013
block 1 2 5 6 9;1 2 5 6;1 2 5 6 9;
 -2 -2 2 2 10 -2 -2 2 2 0 0 5 5 10
dei 4 5;;4 5;
dei 2 3;2 3;;
dei 2 5;2 3;2 3;
dei 1 2 0 3 4;1 2 0 3 4;;
dei ;1 2 0 3 4;1 2 0 3 4;
dei 1 2 0 3 4;2 3;1 2 0 3 4;
tr 5 1 1 5 4 4 mx -3 ry -30 mx 3;
tr 1 1 3 2 2 4 rz 7.5;
tr 1 3 3 2 4 4 rz -7.5;
tr 1 3 2 2 4 2 rz -15;
tr 1 1 2 2 2 2 rz 15;
sfi 4 5;-1 -4;-1 -4;sd 1
sfi 2 3;-1 -4;;sd 1
sfi -1;;;sd 1
sfi -4;2 3;4 5;sd 1
sfi -2 -3;-2 -3;;sd 2
sfi 4 5;-2 -3;-2 -3;sd 2
sfi -3 0 -4;-1 0 -4;2 3;sd 10
sfi -3;-1 0 -4;-4;sd 10
sfi -4;-2 0 -3;-4;sd 10
sfi -3 0 -4;-2 0 -3;2 3;sd 14
sfi -3;-2 0 -3;-4;sd 14
sfi 1 4;;-1;sd 3
sfi -5;;;sd 12 sfi ;;-5;sd 13
mseq i 2 7 2 8 mseq j 2 7 2 mseq k 2 8 2 7
insprt 1 2 4 1
tf 4 2 1 6 3 1
tf 4 2 4 6 3 4
tfi 4 6;2 3;-3;
tfi 4 6;-1 0 -4;2 3;
edge 5 2 2 5 3 2 6.1
edge 4 2 1 4 3 1 7.8
edge 4 2 4 4 3 4 5.2
edge 3 4 4 3 4 4 5.2
edge 3 1 4 3 1 4 5.2
edge 4 4 3 4 4 3 5.2
edge 4 1 3 4 1 3 5.2
edge 3 2 4 3 3 4 6.2
edge 3 3 3 3 3 3 6.2
edge 3 2 3 3 2 3 6.2
edge 4 2 3 4 3 3 6.2
edge 3 1 3 3 1 3 5.2
edge 3 4 3 3 4 3 5.2
edge 4 2 1 4 3 1 7.8
edge 3 4 2 3 4 2 7.8
edge 3 1 2 3 1 2 7.8
mseq i 0 4 0 4 5
mseq j 0 6 0
mseq k 0 10 0 5
res 2 1 2 3 4 3 i .85
res 5 1 1 6 4 5 i [1/.85]
res 2 1 4 3 4 4 i .85
res 1 1 4 4 4 5 k 1.05
lct 1 rxy;lrep 0 1;
```

Partition Insertion Technics

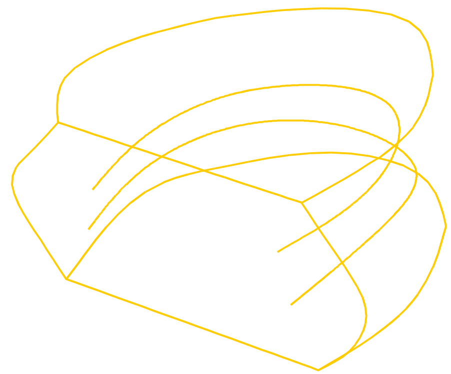
(kid.tg) This example demonstrates the use of the partition insertion to simplify the topology and initialization of the mesh. Additionally, the uniform smoothing is used to construct interior curves.



Geometry



Initial mesh

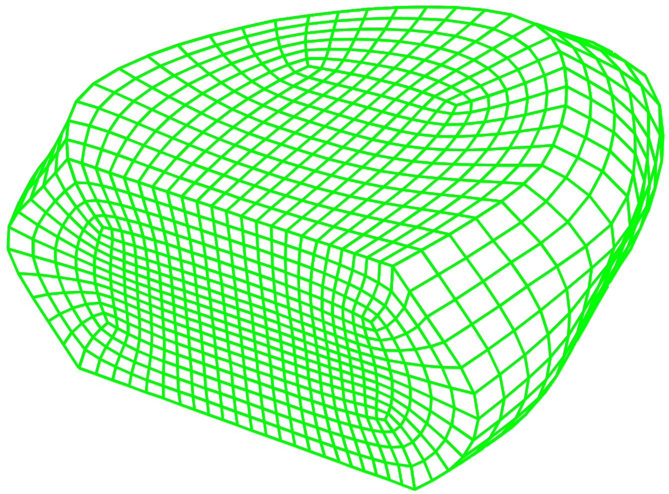


3D curves

Procedure:

1. Create curves from the surface
2. Create the initial butterfly part
3. Attach to curves and project to the surface
4. Glue the butterfly faces together

5. Smooth the faces and interior with uniform
6. Insert partitions in the k-direction for the second butterfly
7. Using only the k-partitions 1 and 2, create a 3D cubic spline curve for the interior butterfly edges
8. Do step 7 using k-partitions 3 and 4
9. Once the curves built, then deactivate the smoothing, the BB commands, and curve attachment commands because the scope of these commands include regions that will be deleted for the second butterfly.
10. Add partitions in the i and j-directions for the second butterfly
11. Move the corners of the butterfly regions to the same location as the corners of the regions that will soon be deleted
12. Delete the corner (collapsed regions) not needed in the second butterfly
13. Attach to curves
14. Glue all butterfly faces using the BB command
15. Smooth the mesh on faces and the interior
16. A elements where needed to improve the mesh quality

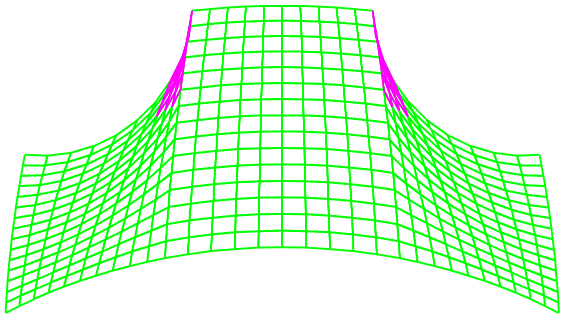
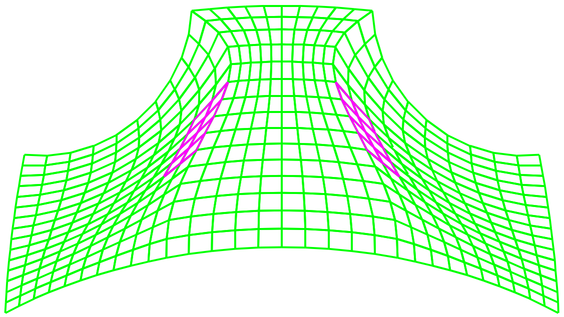
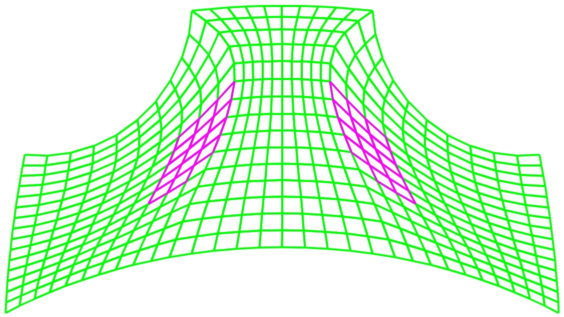


```
fetol 155 vpsd 1 kid.cor kid.ele;
curd 1 se 1.4 curd 2 se 1.2 curd 3 se 1.1
c  initial butterfly part
block 1 2 3 4;1 2 3;1 2;
.87542778 2.5178947 5.4706445 6.7993808;
0 3.9688373 6.0726705;1 5;
pb 4 2 1 4 2 2 xy 6.799381 6.07267
pb 3 3 1 3 3 2 xy 6.799381 6.07267
pb 1 2 1 1 2 2 xy .8754278 6.07267
pb 2 3 1 2 3 2 xy .8754278 6.07267
dei 1 2 0 3 4; 2 3;;
sfi -1 -4; 1 -3;;sd 1
mseq i 5 10 5 mseq j 10 5 mseq k 10
curs 1 1 2 1 2 2 1
curs 2 3 2 3 3 2 1
curs 4 1 2 4 2 2 1
curs 1 1 1 1 2 1 2
curs 2 3 1 3 3 1 2
curs 4 1 1 4 2 1 2
c  smooth the mesh
bb 3 2 1 3 3 2 1;
bb 3 2 1 4 2 2 1;
bb 2 2 1 2 3 2 2;
bb 1 2 1 2 2 2 2;
unifm 1 1 1 1 2 2 & 2 3 1 3 3 2
    & 4 1 1 4 2 2 30 0 1 ;
unifm 1 1 2 4 2 2 & 2 2 2 3 3 2 30 0 1 ;
unifm 1 1 1 4 2 1 & 2 2 1 3 3 1 30 0 1 ;
c  add some of the partitions for the
second butterfly
insprt 1 6 1 4
insprt 1 6 2 3
c  smooth the interior to create good
interior faces
unifm 1 1 1 4 2 4 & 2 2 1 3 3 4 40 0 1 ;
c  from each interior face, build a 3D
curve for the butterfly
curd 4 csp3 00
 1.2963876 6.5290876e-02 2.4657044
 1.0377349 2.7791026 2.4774117
 1.9579376 4.6815815 2.5110531
 4.0501380 5.6482730 2.4875875
 5.9825716 5.0090752 2.4885929
 6.5133886 2.7001033 2.4948130
 6.2986546 1.9135284e-08 2.4120665 ;;;
curd 5 csp3 00
 1.603484 3.3156187e-08 3.5868988
 1.3045115 2.1597354 3.5087986
 2.1357510 4.4463463 3.5185001
 4.8707495 5.5809669 3.5152369
 6.4055862 3.1606848 3.5554178
 6.0363846 .071375147 3.5482473 ;;;
c move vertices so edges can be unattached
pb 4 2 4 4 2 4 xyz 6.133368 5.575917 5
pb 1 2 4 1 2 4 xyz 1.805919 5.0098 5
pb 2 3 4 2 3 4 xyz 1.805919 5.0098 5
pb 3 3 4 3 3 4 xyz 6.133368 5.575917 5
pb 4 1 4 4 1 4 xyz 6.783649 4.306118e-03 5
pb 1 1 4 1 1 4 xyz .9107484 3.020810e-02 5
pb 4 1 1 4 1 1 xyz 6.82025 0 1
pb 4 2 1 4 2 1 xyz 6.217452 5.592057 1
pb 3 3 1 3 3 1 xyz 6.217452 5.592057 1
pb 1 2 1 1 2 1 xyz 1.548482 5.437421 1
pb 2 3 1 2 3 1 xyz 1.548482 5.437421 1
c  deactivate interpolation commands
decmd 8 decmd 9 decmd 10 decmd 11 decmd 12
decmd 13 decmd 14 decmd 15 decmd 16
decmd 17 decmd 18 decmd 19 decmd 20
decmd 43
c  add the remaining partitions for
c  the second butterfly
mseq i 4 0 4 mseq j 0 4
insprt 1 2 1 4
insprt 1 1 5 4
```

```
insprt 1 3 3 4
c  move vertices to corners
pb 5 1 4 5 1 4 xyz 6.783649 4.306118e-03 5
pb 6 1 3 6 1 3 xyz 6.783649 4.306118e-03 5
pb 5 1 1 5 1 1 xyz 6.82025 0 1
pb 6 1 2 6 1 2 xyz 6.820250 0 1
pb 2 1 4 2 1 4 xyz .9107484 3.020810e-02 5
pb 1 1 3 1 1 3 xyz .9107484 3.020810e-02 5
pb 2 1 1 2 1 1 xyz 8.754278e-01 0 1
pb 1 1 2 1 1 2 xyz 8.754278e-01 0 1
pb 6 2 3 6 2 3 xyz 6.133368 5.575917 5
pb 5 2 4 5 2 4 xyz 6.133368 5.575917 5
pb 4 3 4 4 3 4 xyz 6.133368 5.575917 5
pb 1 2 3 1 2 3 xyz 1.805919 5.0098 5
pb 2 2 4 2 2 4 xyz 1.805919 5.0098 5
pb 3 3 4 3 3 4 xyz 1.805919 5.0098 5
pb 4 4 3 4 4 3 xyz 6.133368 5.575917 5
pb 3 4 3 3 4 3 xyz 1.805919 5.0098 5
pb 1 2 2 1 2 2 xyz 1.548482 5.437421 1
pb 3 4 2 3 4 2 xyz 1.548482 5.437421 1
pb 2 2 1 2 2 1 xyz 1.548482 5.437421 1
pb 3 3 1 3 3 1 xyz 1.548482 5.437421 1
pb 5 2 1 5 2 1 xyz 6.217452 5.592057 1
pb 4 3 1 4 3 1 xyz 6.217452 5.592057 1
pb 6 2 2 6 2 2 xyz 6.217452 5.592057 1
pb 4 4 2 4 4 2 xyz 6.217452 5.592057 1
pb 1 1 1 1 1 1 xyz 5.631940e-01 0 1
pb 2 1 1 2 1 1 xyz 5.631940e-01 0 1
pb 1 1 2 1 1 2 xyz 5.631940e-01 0 1
pb 5 1 2 5 1 2 xyz 6.298655 0 2.412066
pb 2 1 2 2 1 2 xyz 1.2964 .065291 2.465704
pb 5 1 3 5 1 3 xyz 6.03638 .071375 3.548247
pb 2 1 3 2 1 3 xyz 1.603484 0 3.586899
c  delete the corner blocks
dei 1 2 0 5 6; 1 2; 1 2 0 3 4;
dei 3 4; 3 4; 1 2 0 3 4;
c  attach edges to the curves
curs 1 1 2 1 1 3 3 curs 6 1 2 6 1 3 3
curs 2 1 1 5 1 1 3 curs 2 1 4 5 1 4 3
curs 5 1 1 5 2 1 2 curs 6 1 2 6 2 2 2
curs 3 3 1 4 3 1 2 curs 3 4 2 4 4 2 2
curs 2 1 1 2 2 1 2 curs 1 1 2 1 2 2 2
curs 2 1 4 2 2 4 1 curs 1 1 3 1 2 3 1
curs 5 1 4 5 2 4 1 curs 6 1 3 6 2 3 1
curs 3 3 4 4 3 4 1 curs 3 4 3 4 4 3 1
curs 3 3 2 4 3 2 4 curs 5 1 2 5 2 2 4
curs 2 1 2 2 2 2 4 curs 2 1 3 2 2 3 5
curs 5 1 3 5 2 3 5 curs 3 3 3 4 3 3 5
c  glue the faces together for smoothing
bb 3 2 1 3 3 4 1; bb 2 2 1 3 2 4 1;
bb 3 3 2 3 4 3 2; bb 1 2 2 2 2 3 2;
bb 4 2 1 4 3 4 3; bb 4 2 1 5 2 4 3;
bb 4 3 2 4 4 3 4; bb 5 2 2 6 2 3 4;
bb 2 1 3 2 2 4 5; bb 1 1 3 2 2 3 5;
bb 3 3 3 4 3 4 6; bb 3 3 3 4 4 3 6;
bb 5 1 3 5 2 4 7; bb 5 1 3 6 2 3 7;
bb 2 1 1 2 2 2 8; bb 1 1 2 2 2 2 8;
bb 3 3 1 4 3 2 9; bb 3 3 2 4 4 2 9;
bb 5 1 1 5 2 2 10; bb 5 1 2 6 2 2 10;
c  smooth the mesh
unifm 1 1 2 6 1 3 & 2 1 3 5 1 4 & 2 1 1 5 1
2 20 0 1 ;
unifm 2 1 1 5 2 1 & 3 2 1 4 3 1 20 0 1 ;
unifm 2 1 4 5 2 4 & 3 2 4 4 3 4 20 0 1 ;
unifm 2 1 1 5 2 4 & 3 2 1 4 3 4
    & 5 1 2 6 2 3 & 3 3 2 4 4 3
    & 1 1 2 2 2 3 30 0 1 ;
unifm 3 4 2 4 4 3 20 0 1 ;
c  add elements to improve angle quality
mseq k 0 8 0
```

Improving Mesh Quality

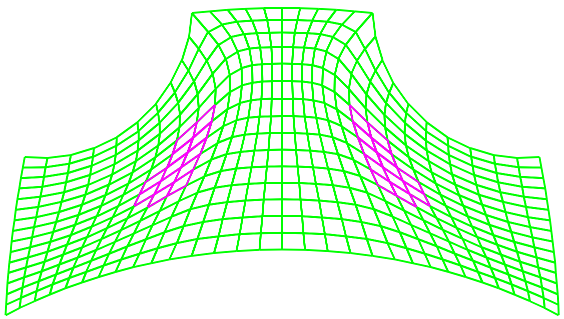
Improve the mesh quality in a local region without using a complicated topology (tooth.tg).

Initial mesh	With 3D curves	Modified 3D curves
		
orthogonal measure	orthogonal measure	orthogonal measure
-89.60042 to 88.14523	-71.30621 to 73.44894	-60.80908 to 63.15427
aspect measure	aspect measure	aspect measure
1.081062 to 2.625498	1.080100 to 3.127486	1.092917 to 3.128418
Jacobian measure	Jacobian measure	Jacobian measure
.0171947 to 1.004573	.2955195 to 1.044357	.4463104 to 1.044590

The quality of the mesh can be improved in small steps. A 3D curve can be used to shape an interior edge and get a better mesh than any interpolation. Small differences in the shape can make a difference. In the above, the modified curves improve the mesh by 10 degrees in orthogonality.

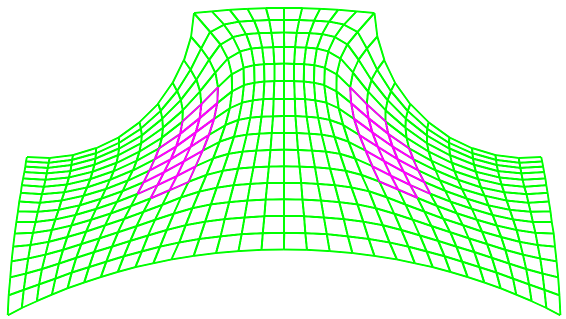
If the mesh is then smoothed with an iterative smoother like relax, it can take the edge of the interior mesh lines and improve the quality. In this example, 10 iterations were used but the step size was reduced to .25 so that in any iteration there is no big change. The antithesis is to let the smoother converge. This would produce a bad mesh and it would destroy any advantage that the 3D curves produced. The middle elements are skewed and by clustering the boundary nodes upward, the skewness is decreased. Finally, by clustering the nodes in the interior towards the bottom, the skewness is also decreased. In the process, the aspect ratio is sacrificed.

Smoothed



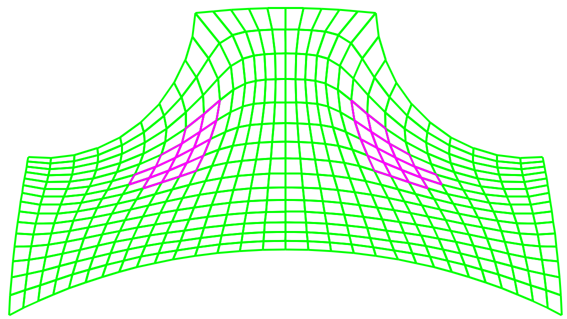
orthogonal measure
-58.83805 to 60.81065
aspect measure
1.057873 to 3.085737
Jacobian measure
.4672903 to 1.042871

Boundary clustering



orthogonal measure
-54.36819 to 56.89636
aspect measure
1.057966 to 5.582620
Jacobian measure
.5018687 to 1.042915

Interior clustering

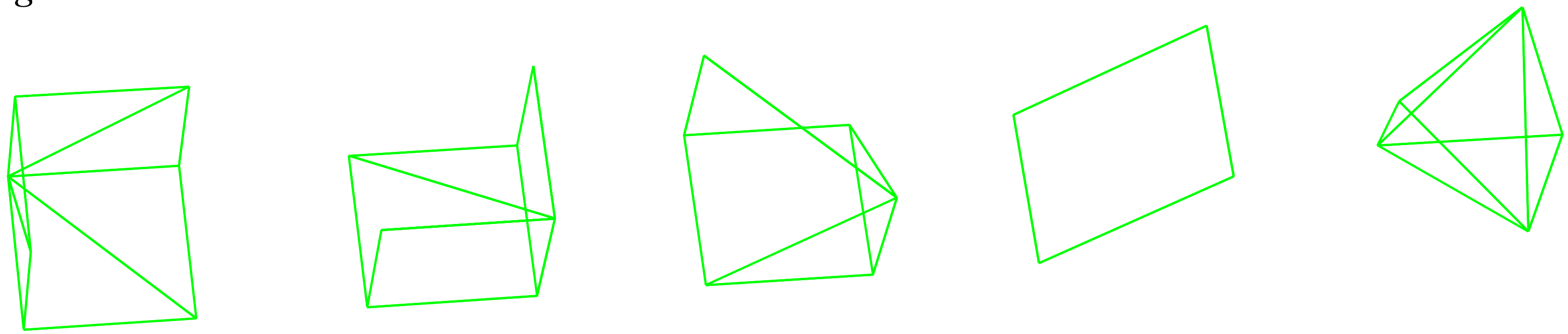


orthogonal measure
-51.89042 to 54.60112
aspect measure
1.063846 to 5.660308
Jacobian measure
.5144231 to 1.033201

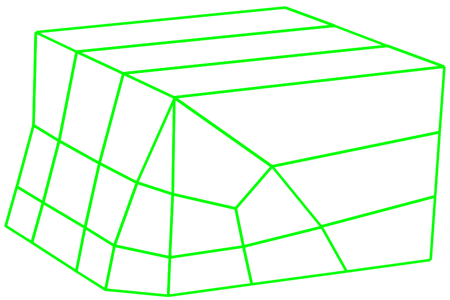
```
sd 1 sp 0 0 0 5
sd 2 cy -2 2 0 0 0 1 1.25
sd 3 cy 2 2 0 0 0 1 1.25
sd 4 cy 0 -5 0 0 0 1 5
sd 5 cy 0 -5 0 0 0 1 7
block 1 11 21 31;1 16;-1;-3 -1 1 3 0 3 5
pb 4 2 1 4 2 1 xy 2.5 0.5
pb 1 2 1 1 2 1 xy -2.5 0.5
sfi ;; -1; sd 1
sfi 2 3; -2; -1; sd 5
sfi 1 2; -2; -1; sd 2
sfi 3 4; -2; -1; sd 3
sfi ; -1; -1; sd 4
interrupt c First set of curves
curd 1 csp3 00
-7.5065166e-01 1.9596350e+00 4.5383205
-4.7419575e-01 1.7274317e+00 4.6680956
-9.3289751e-01 3.2772014e-01 4.9012551
-9.6252507e-01 -9.3520083e-02 4.9055886 ;;;
curd 2 csp3 00
 7.5065166e-01 1.9596350e+00 4.5383205
 4.7419563e-01 1.7274318e+00 4.6680956
 9.3289751e-01 3.2772014e-01 4.9012551
 9.6252507e-01 -9.3520083e-02 4.9055886 ;;;
curs 2 1 1 2 2 1 1
curs 3 1 1 3 2 1 2
interrupt c Second set of curves
curd 2 csp3 00
7.5065166e-01 1.9596350e+00 4.5383205
4.7419563e-01 1.7274318e+00 4.6680956
7.8869891e-01 3.5273141e-01 4.9250817e
9.6252507e-01 -9.3520083e-02 4.9055886 ;;;
curd 1 csp3 00
 -7.5065166e-01 1.9596350e+00 4.5383205
 -4.7419575e-01 1.7274317e+00 4.6680956
-7.9038078e-01 3.4637147e-01 4.9238572
-9.6252507e-01 -9.3520083e-02 4.9055886 ;;;
interrupt c Smoothing
relax 1 1 1 4 2 1 10 0 .25
interrupt c Boundary clustering
res 4 1 1 4 2 1 j .9
res 1 1 1 1 2 1 j .9
interrupt c Interior clustering
res 2 1 1 3 2 1 j 1.1
```

Nobody's Perfect Diagnostic Tools: Measure and Labels

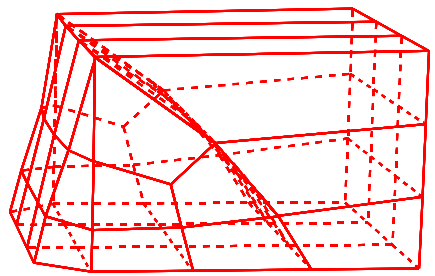
Some illegal elements:



(diagn.tg) This is a simple example with bad elements that are not easily seem. They are best detected in the merge phase. The diagnostics will detect bad shapes before the nodes are merged, but the special features to detect illegal elements cannot be effective until the nodes have been merge. In this example, everything is a free face.

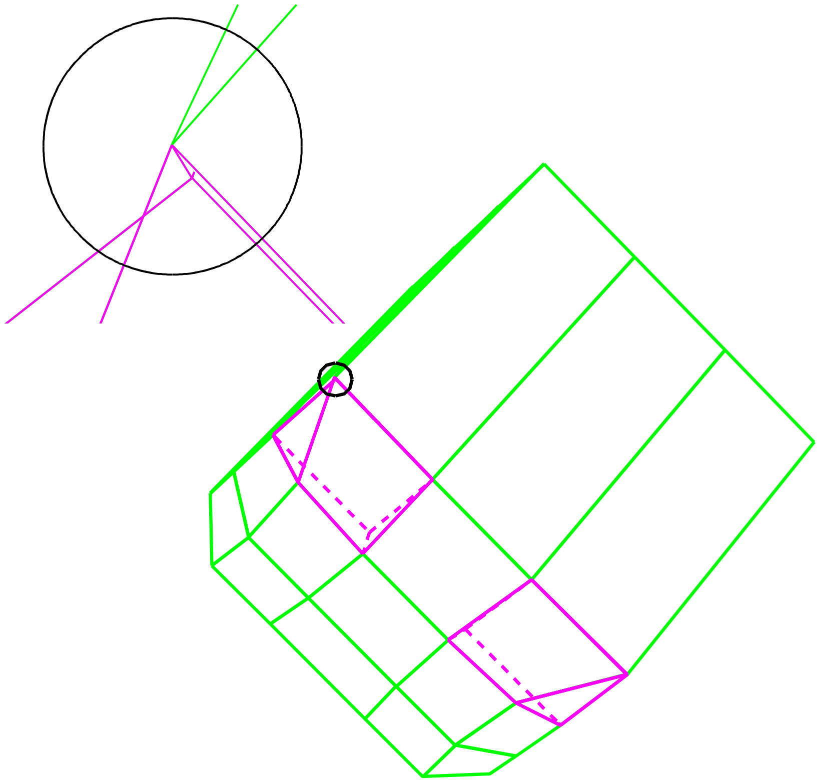


2 part model

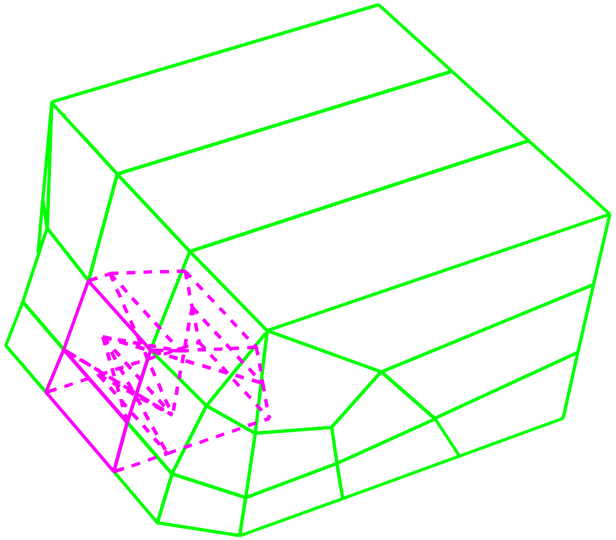


labels fraces (free faces)

```
errmod 2
curd 1 lp3 -1 4 2.93 -1.030909 3 2.93
  -1.030909 2 2.93 -1 1 2.93;;
curd 2 lp3 -1 4 1 -1.4686 3.614756 1
 -1.4686 2.9114861 1 -1.4686 2.0885112
  1 -1.4686 1.3852442 1 -1 1 1;;
sd 1 cy -3.2093 4 -1.376221 0 1 0 4.833687
sd 2 rule3d 1 2  ; ;
block 1 2; 1 2 3 4;1 4;1 2; 1 2 3 4;1 3;
pb 1 1 2 1 4 2 x -1
pb 1 1 2 1 1 2 xyz -1.00728 1.02942 2.92720
pb  1 2 2 1 2 2 xyz -1.02989 2 2.93792
pb 1 3 2 1 3 2 xyz -1.02996 2.99979 2.93792
pb 1 4 2 1 4 2 xyz -1.00157 4.00000 2.91874
sfi -1; 1 4; 1 2;sd 1
res 1 1 1 1 1 2 k 1.5
res 1 4 1 1 4 2 k 1.5
endpart
block 1 2 3 4;1 2 3 4; 1 2 3 4;
  -2 -1 0 1;1 2 3 4;1 1.666 2.3333 3;
dei  3 4;; 3 4;
pb 2 1 1 2 4 1 xz -1 1
pb 2 1 2 2 4 2 xz -1 1.37963
pb 2 1 3 2 4 3 xz -1 2
pb 2 1 4 2 4 4 xz -1.030909 2.938775
pb 3 1 1 3 4 1 xz -8.388881e-02 1
pb 3 1 2 3 4 2 xz -1.988184e-01 1.395386
pb 3 1 3 3 4 3 xz -3.081551e-01 1.789148
pb 3 1 4 3 4 4 xz 8.844042e-02 2.15783
pb 4 1 1 4 4 1 xz 1 1
pb 4 1 2 4 4 2 xz .6785097 1.495984
pb 4 1 3 4 4 3 xz 8.844042e-02 2.15783
pb 2 1 4 2 1 4 xyz -1.00728 1.02942 2.92720
pb 1 2 4 1 2 4 xyz -1.02989 2.00018 2.93792
pb 1 3 4 1 3 4 xyz -1.02996 2.99979 2.93792
pb 1 4 4 1 4 4 xyz -.9994967 4 2.922773
pb 2 4 4 2 4 4 xyz -1.005882 3.989 2.926049
pb 3 1 4 3 1 4 xyz .085 1.0154471 2.161031
pb 4 1 3 4 1 3 xyz .085 1.0154471 2.161031
pb 2 2 2 2 2 2 y 3
pb 2 3 2 2 3 2 y 2
res 1 4 1 1 4 4 k 1.5
res 1 1 1 1 1 4 k 1.5
tfi -1; 1 4; 1 4;
sfi -4; 1 4; 1 3;sd 1
sfi 1 3; 1 4; -4;sd 1
sfi -1; 1 4; 1 4;sd 2
endpart
merge
stp .001
measure triangle
measure orthogon
measure jacobian
labels fraces
labels cracks 5
labels tol 1 2
labels ijk2
```

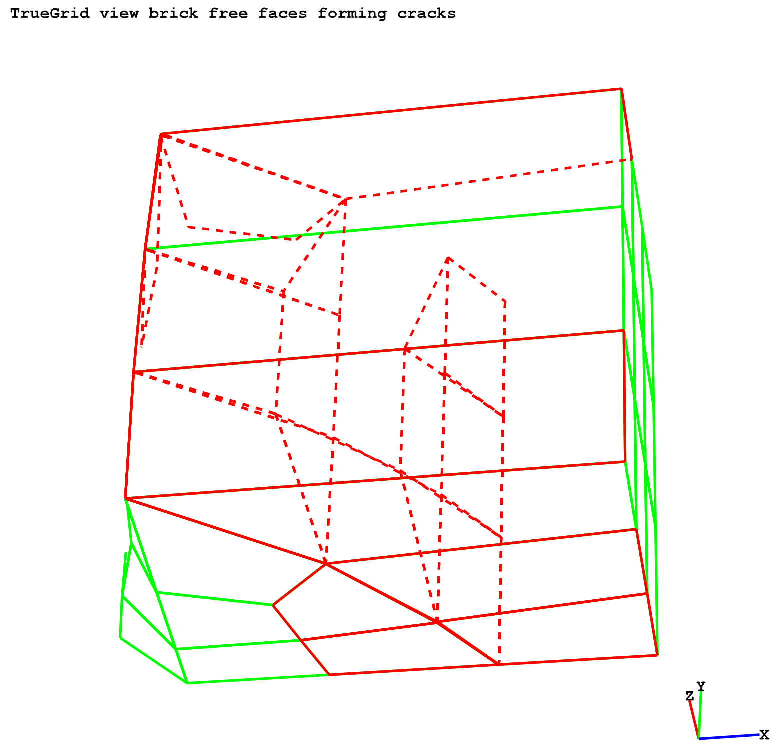


Orthogonal test

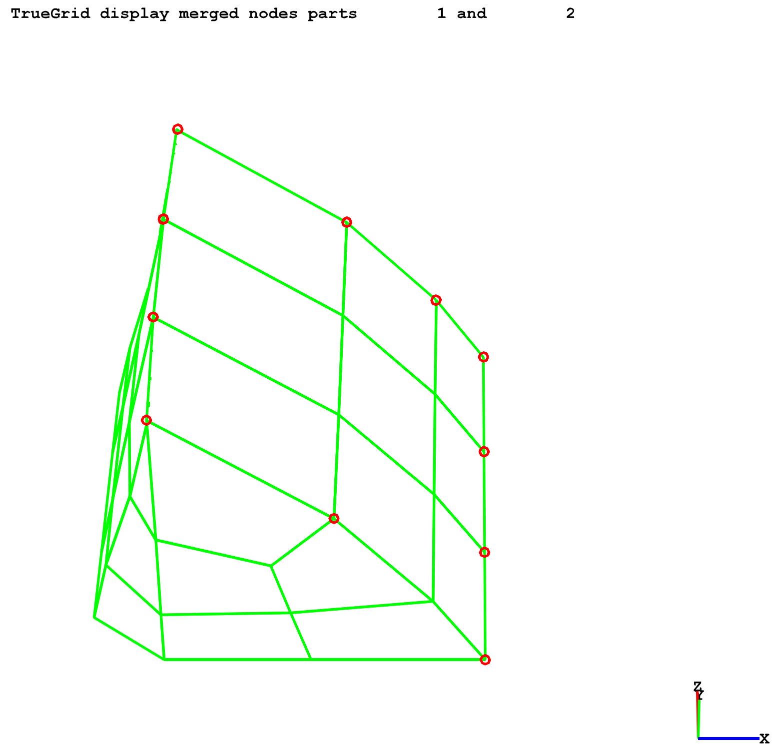


Jacobian test

The closeup of this model shows a problem in the mesh which is detected using the orthogonal, triangle, smallest, or aspect diagnostics (**mea** command). This example produces illegal elements where orthogonal and triangle will show a range starting at -91 degrees deviation. The smallest and aspect options show these elements as -1. These illegal elements can be shown with the **elm** command by including these numbers, respectively, in the range of the **elm** command and can be isolated by selecting this value only (e.g. **elm** -91 -91). The Jacobian test is useful in detecting hour-glass elements.

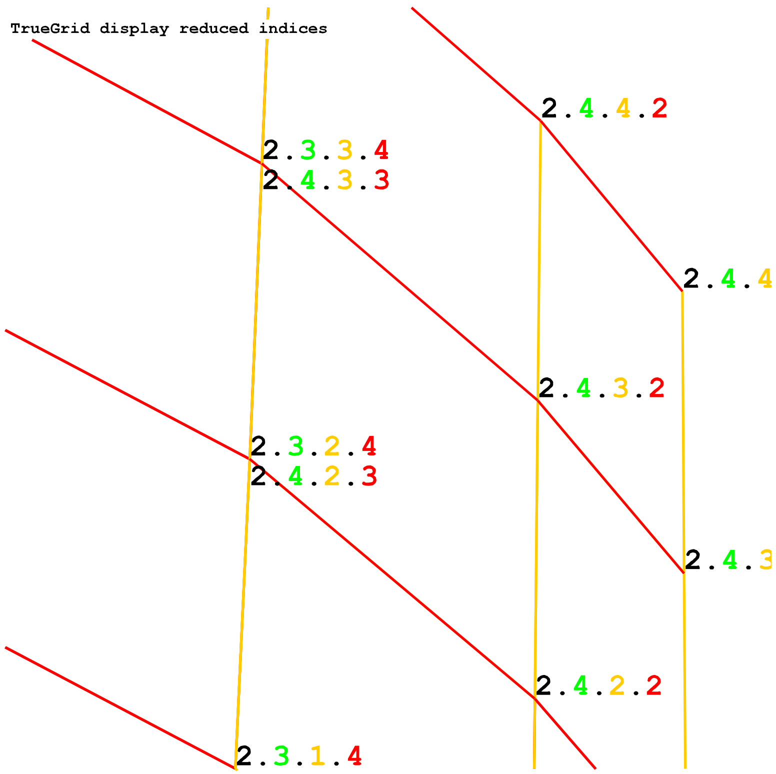


labels cracks 5



labels tol 1 2

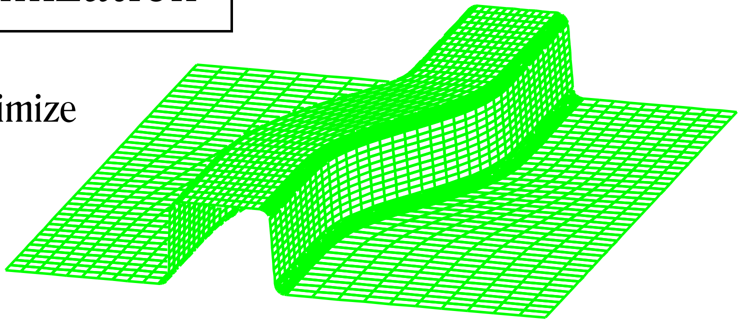
Cracks show that there are interior merging problems. This is further indicated by using the tol option. The best method is to use both cracks and free faces to detect problems between blocks and parts. Check the entire model for cracks. Check each part for free faces.



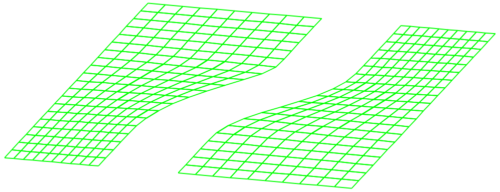
labels ijk2

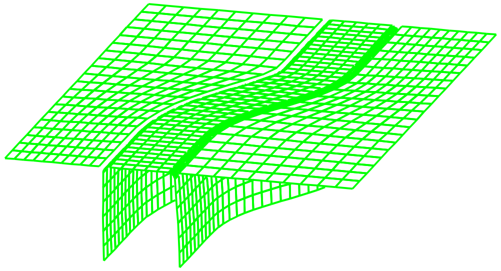
Before returning to the part phase to fix the elements, use the ijk2 option of **labels** to determine the reduced indices of the problem area. This will prove very useful in the future with the re-entrent part. Also, when restarting to return to a part, the errmod 2 command can be very useful. If a syntax error is encountered in batch mode, **True*Grid*®** will not stop.

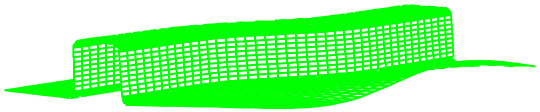
NUMI - Parametric Optimization

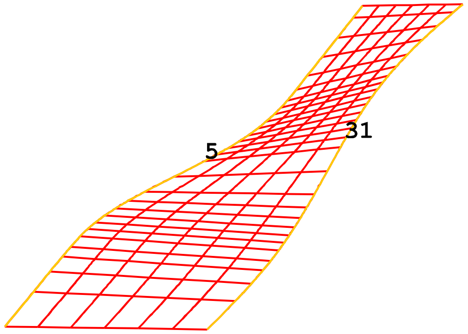


Four parameters are used to modify a metal forming die surface to optimize a die design. The parameters are the *z*-coordinates at four points along an edge of the punch. The four points are used to create a spline curve which, in turn, is used to create the new die surface.









```
c numi
lsdyna keyword
include numi.geo
 if (%max1.gt.0.) then
   para del1 [-%max1];
 endif
 if (%min1.lt.0.) then
   para del1 [%min1-%max1]
        del2 [%min1];
 endif
 if (%min1.lt.0.and.%max1.lt.0) then
   para del1 [min(%min1,%max1)]
        del2 [%del1];
 endif
para delta [abs(%del2)] ;
c ********************** part 1 mat 1
************ blank
block 1 51; 1 41; -1; -80 80 0 250 -1
pb 2 2 1 2 2 1 xyz 131.99998 250.0 -1.0
pb 1 2 1 1 2 1 xyz -31.999992 249.99998
-1.0
pb 2 1 1 2 1 1 xyz 81.999985 -3.815E-06
-1.0
sfi 1 2; 1 2; -1; sd 30
edge 2 1 1 2 2 1 30.3
edge 1 1 1 1 2 1 30.2
lct 1 mz 1 mz [%del2];
lrep 1;
mate 1
endpart
c ********************** part 2 mat 2
************ left binder
block 1 11; 1 21; -1; -102 -25 0 250 -2
pb 2 2 1 2 2 1 xyz 24.998093 260.00293  0.0
pb 1 2 1 1 2 1 xyz -83.998436 259.99966
0.0
pb 1 1 1 1 1 1 xyz -83.99707 -10.004411
0.0
pb 2 1 1 2 1 1 xyz -25.003876 -10.00009
0.0
edge 2 1 1 2 2 1 11.2
sfi 1 2; 1 2; -1; sd 13
lct 1 mz -1 mz [%del1]; lrep 1;
mate 2
endpart
c ********************** part 3 mat 3
************ right binder
block 1 11; 1 21; -1; 25 152 0 250 -2
pb 2 2 1 2 2 1 xyz 134.00607 259.99783  0
pb 1 2 1 1 2 1 xyz 74.999817 259.98672  0
pb 1 1 1 1 1 1 xyz 25.002228 -9.9894829  0
pb 2 1 1 2 1 1 xyz 134.00259 -9.9896154  0
edge 1 1 1 1 2 1 10.2
sfi 1 2; 1 2; -1; sd 12
lct 1 mz -1 mz [%del1]; lrep 1;
mate 3
endpart
c ********************** part 4 mat 4
************ punch
block -1 6 11 -16; 1 41; 1 7 -12;
 -23.8 %x24 %x25 23.8 -10 260 0 %y23 60
dei 2 3; 1 2; 1 2;
mbi 1 4; -2; 1 3; x 50.1124
edge 4 1 1 4 2 1 2.3
edge 1 1 1 1 2 1 2.1
curs 4 1 2 4 2 2 11
curs 1 1 2 1 2 2 12
curs 4 1 3 4 2 3 13
curs 3 1 3 3 2 3 15
curs 1 1 3 1 2 3 14
curs 2 1 3 2 2 3 16
sfi -1 -4; 1 2; 1 -3;sd 2
lct 1 mz -61.0 mz [%del2]; lrep  1;
mate 4
```

```
endpart
c ********************** part 5 mat 5
************* die
block 1 11 -16 21 32 -37 42 52;
  1 41; -1 6 15 -20;
  -102 -25 %x2 %x4 %x5 25 %x8 152
  -10 260 0 %y2 %y3 40
dei 1 2 0 4 5 0 7 8; 1 2; 2 3;
dei 1 3 0 6 8; 1 2; -4;
dei 3 6; 1 2; -1;
curs 7 1 1 7 2 1 17
curs 6 1 1 6 2 1 18
curs 6 1 2 6 2 2 19
curs 6 1 3 6 2 3 20
curs 6 1 4 6 2 4 21
curs 5 1 4 5 2 4 22
curs 4 1 4 4 2 4 23
curs 3 1 4 3 2 4 24
curs 3 1 3 3 2 3 25
curs 3 1 2 3 2 2 26
curs 3 1 1 3 2 1 27
curs 2 1 1 2 2 1 28
edge 8 1 1 8 2 1 5.2
edge 1 1 1 1 2 1 6.2
sfi 1 -3 -6 7; 1 2; -1 -4;sd 7
sfi 1 -3 -6 8; 1 2; -1 -4;sd 7
lct 1 mz 1; lrep 1;
mate 5
endpart
merge
lsdyopts endtim [(40+%delta)/1] ;
```

Parametric Topology

In this example, a method is used to insert partitions for a cylinder hole. The size of the plate is set initially. Then the radius and the center of each cylinder is chosen. Everything else is automatic. The key to method is a list of the indices for each of the partitions. Each time another partition is added, this list must be updated. This is a 2D problem, but the technics can easily be generalized to 3D. Only the i and j-indices of the partitions are maintained. This example allows for up to 4 holes. It can be extended by increasing the number of variables in the i & j-list and adding cases to the command files below. For brevity, the parameters are not test for validity.

i-list: i1, i2, i3, i4, i5, i6, i7, i8, i9 (i1 is set to the initial size of the part and the rest set to 0)
j-list: j1, j2, j3, j4, j5, j6, j7, j8, j9 (j1 is set to the initial size of the part and the rest set to 0)

A simple routine is used to insert a partition in the i-direction (iinsert). There is a similar file (jinsert) for inserting a partition in the j-direction. This routine expects that the parameter newi is the index of the partition to be inserted. First a test is made to determine if the partition already exists. Otherwise, the region for the insertion is determined. All of the indices in the i-list which follow the insertion sequentially must be shifted up one in the list. Then the insertion is made. This routine sets the parameter ip to the sequence number of the partition.

```
c check if the partition already exists

if(%newi.eq.%i1)then
 para ip 2;
elseif(%newi.eq.%i2)then
 para ip 3;
elseif(%newi.eq.%i3)then
 para ip 4;
elseif(%newi.eq.%i4)then
 para ip 5;
elseif(%newi.eq.%i5)then
 para ip 6;
elseif(%newi.eq.%i6)then
 para ip 7;
elseif(%newi.eq.%i7)then
 para ip 8;
elseif(%newi.eq.%i8)then
 para ip 9;
else
 if(%newi.lt.%i8)then
  para i9 %i8;
 endif
 if(%newi.lt.%i7)then
  para i8 %i7;
 endif
 if(%newi.lt.%i6)then
  para i7 %i6;
 endif
 if(%newi.lt.%i5)then
  para i6 %i5;
 endif
 if(%newi.lt.%i4)then
  para i5 %i4;
 endif
 if(%newi.lt.%i3)then
  para i4 %i3;
 endif
 if(%newi.lt.%i2)then
  para i3 %i2;
 endif
 if(%newi.lt.%i1)then
  para i2 %i1;
 endif
 if(%newi.lt.%i1)then
  insprt 1 2 1 [%newi-1]
  para ip 2 i1 %newi;
 elseif(%newi.lt.%i2)then
  insprt 1 2 2 [%newi-%i1]
  para ip 3 i2 %newi;
 elseif(%newi.lt.%i3)then
  insprt 1 2 3 [%newi-%i2]
  para ip 4 i3 %newi;
 elseif(%newi.lt.%i4)then
  insprt 1 2 4 [%newi-%i3]
  para ip 5 i4 %newi;
 elseif(%newi.lt.%i5)then
  insprt 1 2 5 [%newi-%i4]
  para ip 6 i5 %newi;
 elseif(%newi.lt.%i6)then
  insprt 1 2 6 [%newi-%i5]
  para ip 7 i6 %newi;
 elseif(%newi.lt.%i7)then
  insprt 1 2 7 [%newi-%i6]
  para ip 8 i7 %newi;
 elseif(%newi.lt.%i8)then
  insprt 1 2 8 [%newi-%i7]
  para ip 9 i8 %newi;
 endif
endif
```

This file is included 2 times. The jinsert is also included 2 times, forming the four partitions for a typical hole. Then a cylinder is created, the region is deleted, and the edges projected to the cylinder. The file name is hole. There are several parameters, besides the afore mentioned i & j-list, assumed to be set for this routine. They are:

xc - x-coordinate of the center of the cylinder
yc - y-coordinate of the center of the cylinder
r - radius
di - mesh dnsity in the i-direction
dj - mesh density in the j-direction
ns - number of the last surface definition

```
c insert partitions in the i-direction

para ns [%ns+1];
sd %ns cy %xc %yc 0 0 0 1 %r
para newi [nint((%xc-%r*%s)/%di)+1];
include iinsert
para ai1 %ip;
para newi [nint((%xc+%r*%s)/%di)+1];
include iinsert
para ai2 %ip;

c insert in the j-direction

para newj [nint((%yc-%r*%s)/%dj)+1];
include jinsert
para aj1 %jp;
para newj [nint((%yc+%r*%s)/%dj)+1];
include jinsert
para aj2 %jp;
```

```
c delete the region inside the cylinder

dei %ai1 %ai2;%aj1 %aj2;;

c move the four edges into position

pb %ai1 %aj1 1 %ai1 %aj2 1 x [%xc-%r]
pb %ai2 %aj1 1 %ai2 %aj2 1 x [%xc+%r]
pb %ai1 %aj1 1 %ai2 %aj1 1 y [%yc-%r]
pb %ai1 %aj2 1 %ai2 %aj2 1 y [%yc+%r]

c project the edges to the cylinder

sfi %ai1 %ai2;%aj1 %aj2;;sd %ns
```

(plate.tg) The top module uses the hole routine to insert various, possibly overlapping, circles.

```
c
c User specified parameters
c
para i1 51    c  maximum i-index
     j1 51    c  maximum j-index
     x0 0     c  minimum x-coordinate
     xx 10    c  maximum x-coordinate
     y0 0     c  minimum y-coordinate
     yx 10  ; c  maximum y-coordinate
c
c Derived parameters - up to 4 holes
c
para ns 0  c  last surface number
s .9  c  scale factor for cylinder
di [(%xx-%x0)/(%i1-1)]  c i mesh density
dj [(%yx-%y0)/(%j1-1)]  c j mesh density
i2 0 i3 0 i4 0 i5 0 i6 0 i7 0 i8 0 i9 0
j2 0 j3 0 j4 0 j5 0 j6 0 j7 0 j8 0 j9 0;
```

```
block 1 %i1;1 %j1;-1;%x0 %xx %y0 %yx 0

relax 1 1 1 2 2 1 10 0 1

para xc 2 yc 2 r 1;
include hole
para xc 6 yc 5.5 r 2;
include hole
para xc 7.5 yc 7 r 1;
include hole
para xc 1.9 yc 8 r .75;
include hole
```