Converting TetGen mesh into format of MooNMD

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Introduction

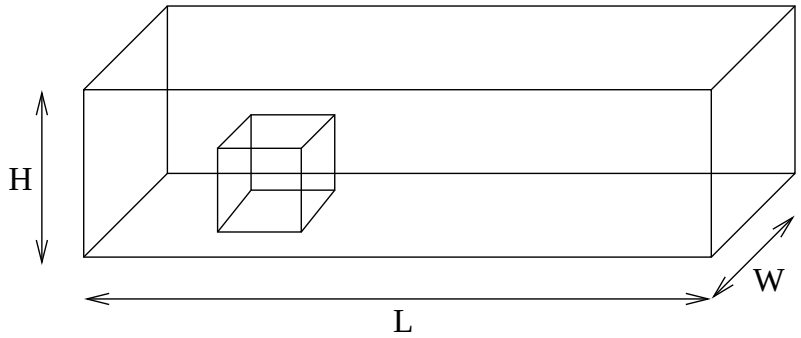
- TetGen generates tetrahedral meshes in three-dimensional domains
- The goal is to create suitable tetrahedral meshes for numerical simulation using finite element and finite volume methods and to convert these meshes into the format of MooNMD

Example 1: Channel with a wall-mounted cube

Channel with a wall-mounted cube

- given a rectangular channel with:

$$
\begin{aligned}
L &= 15h \text{ length} \\
H &= 2h \text{ height} \\
W &= 7h \text{ width}
\end{aligned}
$$



- given a cube of edge length h mounted on the floor centered at (3.5h, 3.5h, 5h) in case h = 0.1

Example 1: Channel with a wall-mounted cube

Set the boundary faces

Rectangular channel

Face 1 1 2 3 4 (bottom)

Face 2 9 10 11 12 (top)

Face 3 1 4 12 9 (left)

Face 4 2 3 11 10 (right)

Face 5 1 2 10 9 (front)

Face 6 3 4 12 11 (back)

The cube

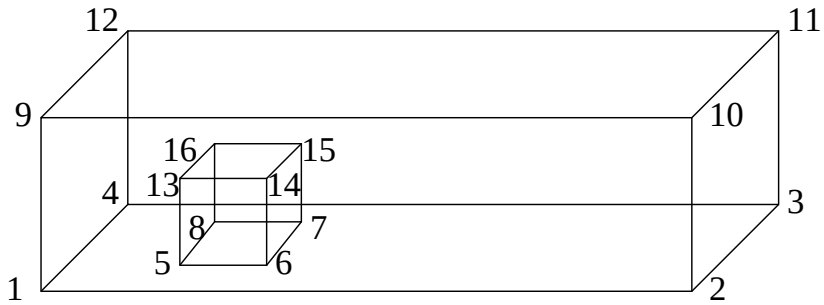
Face 7 13 14 15 16 (top)

Face 8 5 8 16 13 (left)

Face 9 6 7 15 14 (right)

Face 10 5 6 14 13 (front)

Face 11 8 7 15 16 (back)

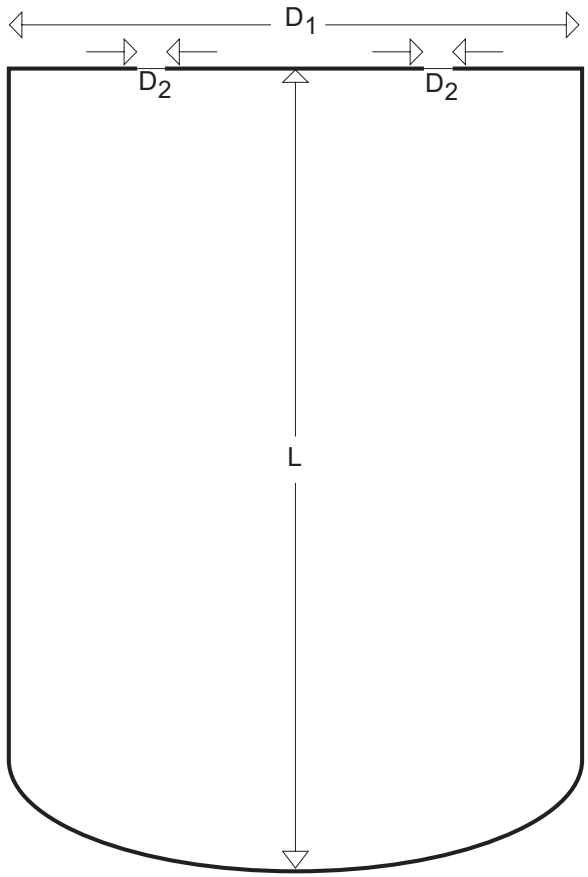


Example 2: Cylinder with a torispherical head

Cylinder with a torispherical head :

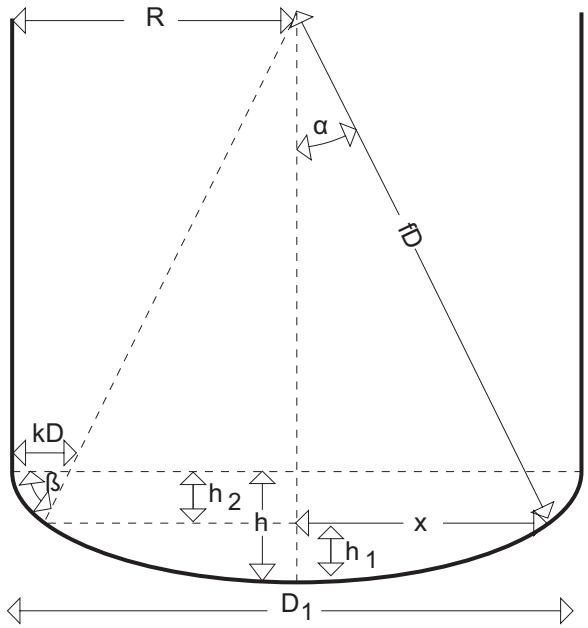
- given a flat flange cylindrical vessel of diameter D_1 with a torisperical head (defined as per DIN 28011)
- dimension of the cylinder with the torispherical head

$$\begin{aligned} D_1 &= 100mm \\ D_2 &= 5mm \\ L &= 140mm \end{aligned}$$



Example 2: Cylinder with a torispherical head

$$
\begin{aligned}
f_D &= D_1 = 100mm \\
k_D &= 0.1 D_1 = 10mm \\
R &= \frac{D_1}{2} = 50mm
\end{aligned}
$$

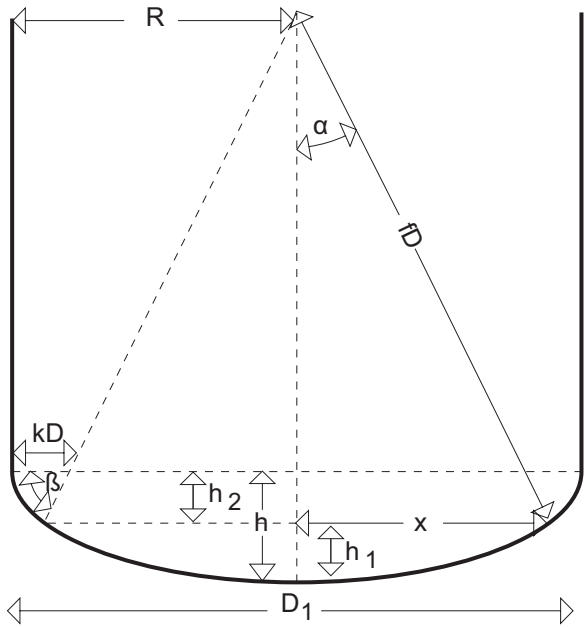


Example 2: Cylinder with a torispherical head

Calculate the others parameters

- apply Pythagorean theorem

$$
\begin{aligned}
(D_1 - h)^2 &= (f_D - 0.1D_1)^2 \\
&- (R - 0.1D_1)^2 \\
\Rightarrow & \\
h &= 19.377mm
\end{aligned}
$$



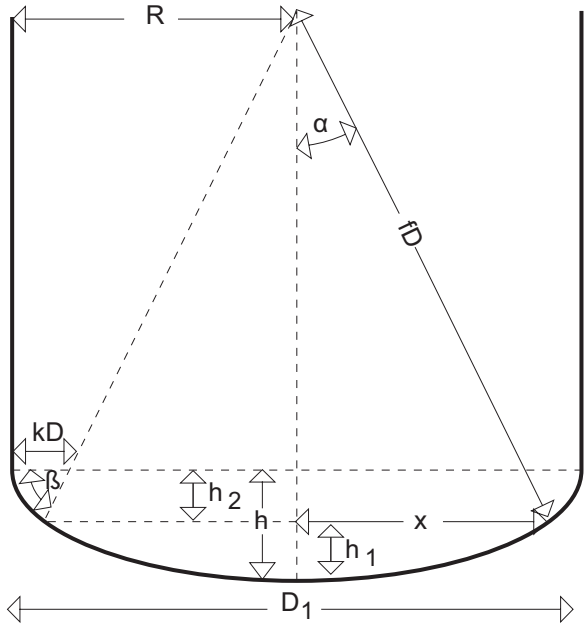
Example 2: Cylinder with a torispherical head

- use triangles similarity

$$\frac{R-0.1D_1}{x} = \frac{f_D-0.1D_1}{f_D} = \frac{D_1-h}{D_1-h_1}$$

$$\Rightarrow$$

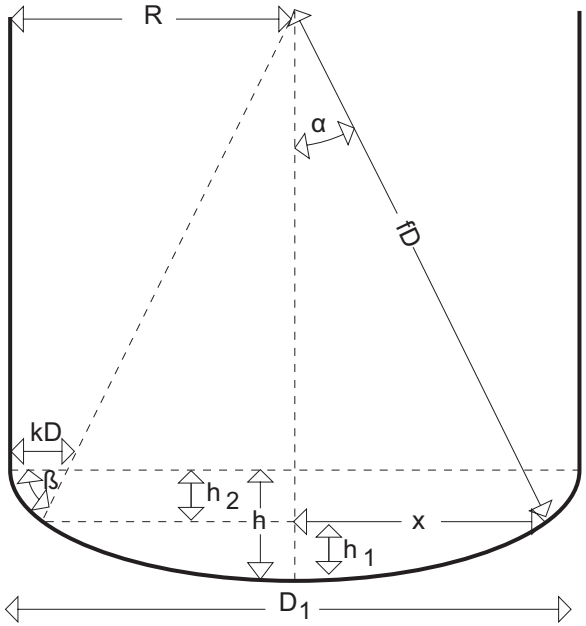
$$\begin{aligned} x &= 44.444mm \\ h_1 &= 10.42mm \\ h_2 &= h-h_1 = 8.957mm \end{aligned}$$



Example 2: Cylinder with a torispherical head

- use elementary trigonometric identities

$$
\begin{aligned}
tan\alpha &= \frac{R - 0.1D_1}{D_1 - h} \\
\Rightarrow & \\
\alpha &= 26.388^\circ \\
\beta &= 90 - \alpha = 63.612^\circ
\end{aligned}
$$

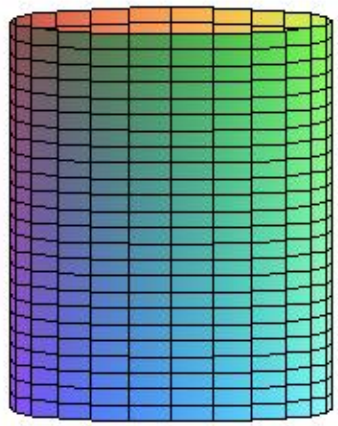


Example 2: Cylinder with a torispherical head

Analytical description

- representation of cylindrical surface with cylindrical coordinates :

$$
\begin{aligned}
x &= r\cos\theta \\
y &= r\sin\theta \\
z &= h_0
\end{aligned}
$$

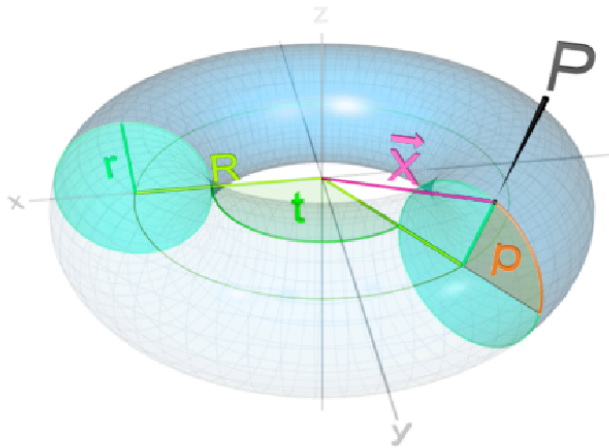


where
$r = 50mm$, $\theta \in \{0, 2\pi\}$,
$h_0 \in \{h, 140mm\}$

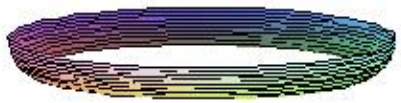
Example 2: Cylinder with a torispherical head

- parametrically representation of torus

$$
\begin{aligned}
x &= [R + r\cos p]\cos t \\
y &= [R + r\cos p]\sin t \\
z &= r\sin p
\end{aligned}
$$



where
$p \in [\pi + 2\alpha + \beta, 2\pi]$, $t \in [0, 2\pi]$
$R = 40mm$ (the distance from the center of the tube to the center of the torus)
$r = 10mm$ (the radius of the tube)

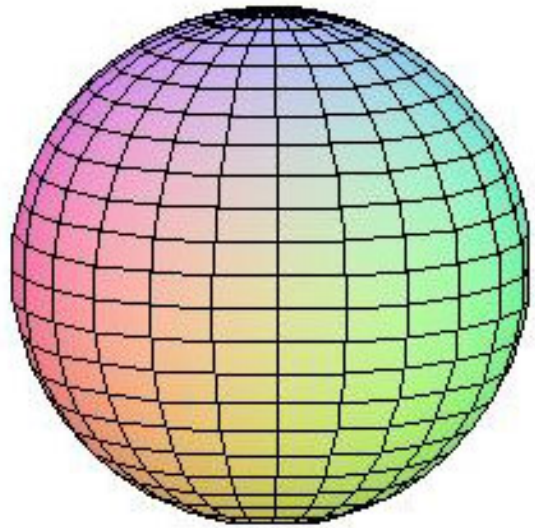


Example 2: Cylinder with a torispherical head

- representation of spherical surface with spherical coordinates :

$$
\begin{aligned}
x &= \rho \sin\phi \cos\theta \\
y &= \rho \sin\phi \sin\theta \\
z &= \rho \cos\phi
\end{aligned}
$$

where
$\rho = 100mm$, $\theta \in \{0, 2\pi\}$,
$\phi \in \{\pi - \alpha, \pi\}$



File formats for TetGen and MooNMD

- the TetGen input file `*.poly` is a simple three-dimensional piecewise linear complex (PLC)
- TetGen requires that the mesh region represented by a PLC should be completely face-bounded
- the `.poly` file format consists of 4 parts

File formats for TetGen and MooNMD

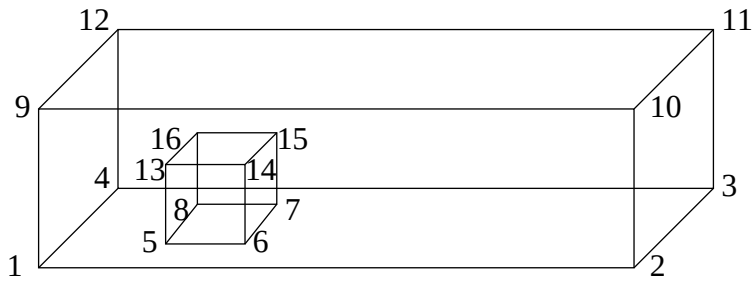
Construct the TetGen file format for the first example:
`wall.poly`

Part 1 -node list

First line:
<number of points> <dimension(3)> < number of attributes>
<boundary markers(0 or 1)>
Remaining lines list number of points:
<point number n> <xn> <yn> <zn>

File formats for TetGen and MooNMD

16 3 0 1
1 0.000000 0.000000 0.000000 5
2 1.500000 0.000000 0.000000 5
3 1.500000 0.700000 0.000000 1
4 0.000000 0.700000 0.000000 1
5 0.300000 0.300000 0.000000 10
6 0.400000 0.300000 0.000000 10
...
...
...
14 0.400000 0.300000 0.100000 7
15 0.400000 0.400000 0.100000 11
16 0.300000 0.400000 0.100000 11



File formats for TetGen and MooNMD

It is important to set the boundary markers for converting the results of TetGen into the format of MooNMD.

File formats for TetGen and MooNMD

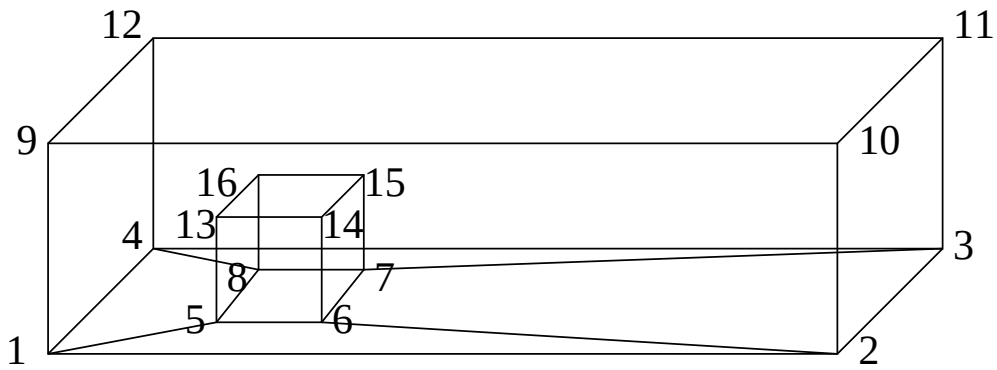
Part 2 -facet list

One line:
<number of polygons> <boundary marker(0 or 1)>

Following lines list number of polygons:
< polygon number > <number of holes> <boundary markers>
<number of corners> <corner 1>...<corner n>

File formats for TetGen and MooNMD

```
14 1
1 0 1
4 1 2 6 5
1 0 1
4 2 3 7 6
1 0 1
4 3 4 8 7
...
...
...
1 0 2
4 9 10 11 12
1 0 7
4 13 14 15 16
```



File formats for TetGen and MooNMD

Part 3 -(volume)hole list

One line:0
<number of holes>
Following lines list number of holes:
<hole n> <xn> <yn> <zn>

0

File formats for TetGen and MooNMD

Part 4 -region attributes list

One line:
<number of region>
Following lines list number of region attributes:
<region n> <x> <y> <z> <region number> <region attributes>

0

File formats for TetGen and MooNMD

Construct the `.prm` file format

NBCT
1 (number of boundary part: always 1 for our example)
IBCT
1 (block for boundary part 1)
NCOMP
11 (number of boundary components, number of planes)
ITYP NSPLINE NPAR
10 0 3
... (11 time)
PARAMETERS (33 triples)
0.000000 0.000000 0.000000 (point in the plane)
1.000000 0.000000 0.000000 (direction vector)
0.000000 0.000000 -1.000000 (outer normal unit vector)
...

File formats for TetGen and MooNMD

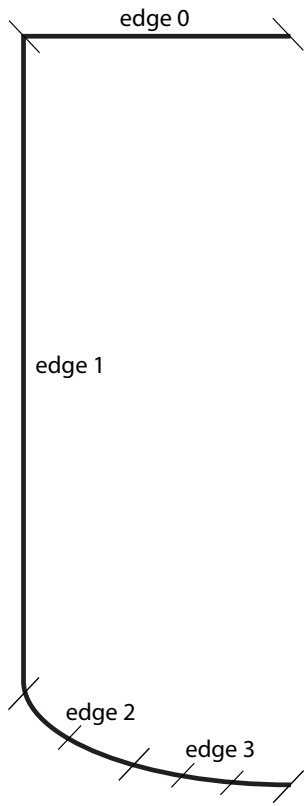
Construct the TetGen and MooNMD file formats for the second example: `torispherical.poly`

- the second example can't be manually operated
- generate the file formats with the help of Matlab programming

File formats for TetGen and MooNMD

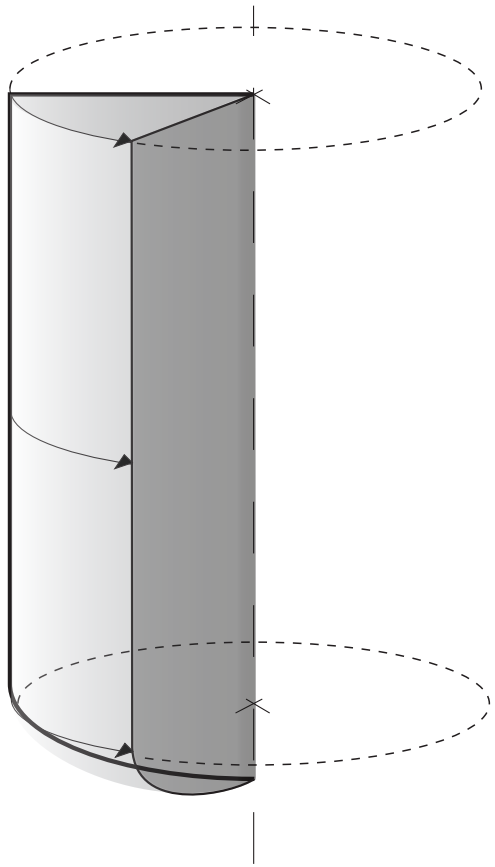
Describe the MATLAB code

- consider the example in 2D
- calculate for the edge 0, respectively edge 1 the first and the last point
- approximatae edge 2 with three points and edge 3 with four points
- rotate the curve to generate the body



File formats for TetGen and MooNMD

- after one rotation will be generated 7 planes
- store for each plane the vertices into format of TetGen
- calculate for each plane 2 direction vectors and then the normals with the help of the cross product(necessary for `.prm` file)
- after the all rotation were done, store the dates in two file: `.poly` and `.prm`



TetGen and TetView

The command line syntax to run TetGen is:

tetgen [-command line option] `file.poly`

The most used command line option in our example

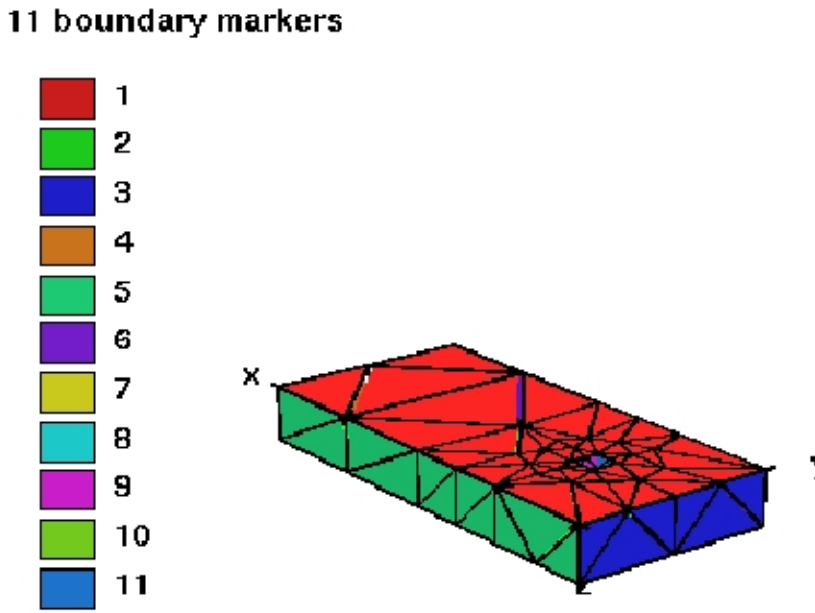
- `-p` option tetrahedralizes a piecewise linear complex (`.poly file`)
- `-q` generates a quality mesh
- `-r` reconstructs and refine a previously generated mesh
- `-i` inserts a list of additional points (stored as `*.a.node`)

TetGen and TetView

Channel with a wall-mounted cube

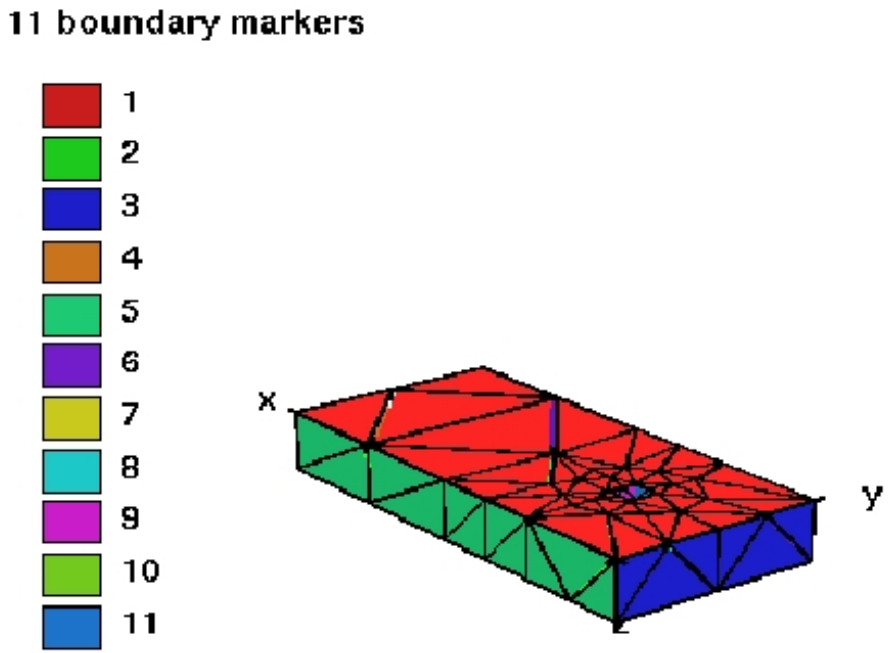
- type tetgen `-pq wall`
- TetGen will read this PLC stored in `wall.poly`
- TetGen will write its constrained Delaunay tetrahedralisation (CDT) to files `wall.1.node`, `wall.1.face`, `wall.1.ele`.
- visualize with TetView

  tetview `wall.1`

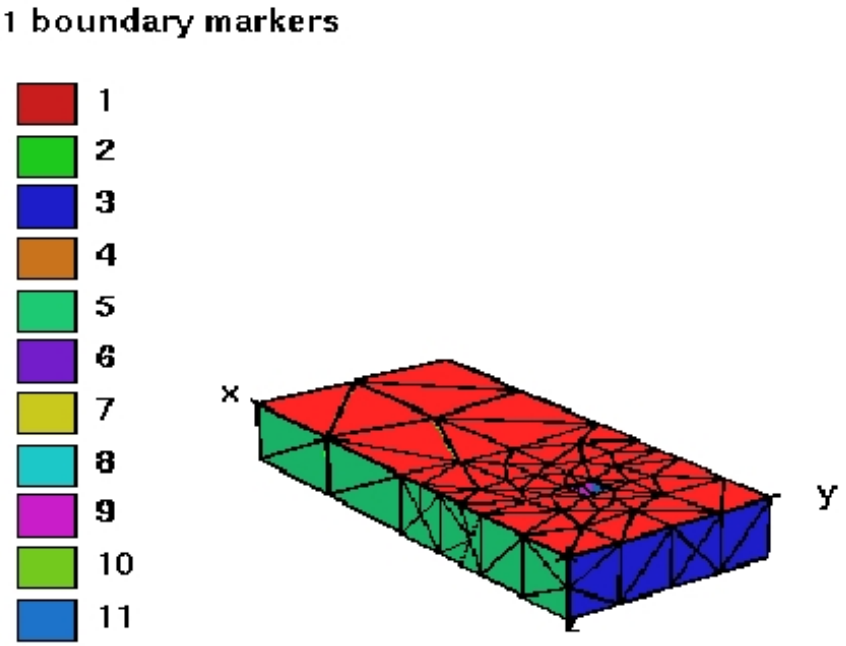


TetGen and TetView

`tetgen -pq wall`



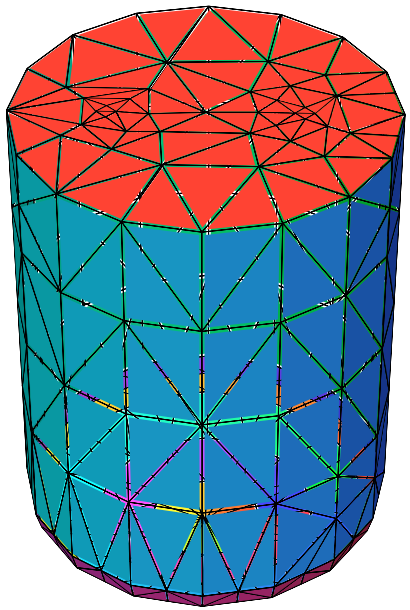
`tetgen -pqr wall.1`

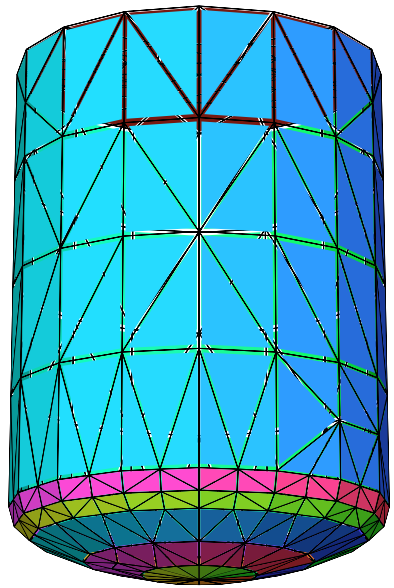


TetGen and TetView

Cylinder with a torispherical head

`tetgen -ipq torispherical`





Converting the TetGen mesh into the format of MooNMD

Generate the .geo file with the help of C programming as follows:

- parametrisation
  NEL NVT NVpF NVpEL NBF
  (number of elements, number of vertices, maximal number of vertices per face, maximal number of vertices per element, number of boundary faces)
- DCONVG (triple)
  number of boundary components, parameter 1, parameter 2
  (for inside vertices)
  x, y, z (for boundary vertices)
- KVERT(tuple)
  for each tetrahedra the 4 vertices

Converting the TetGen mesh into the format of MooNMD

- KNPR is:
  0 : inside vertices
  1 : boundary vertices
- boundfaces (triple)
  for each face the 3 vertices
- FaceParam
  for each side surface:
  element, local number, boundary part, boundary face

Using the output in MooNMD

- after one refinements
- still to be done: automatic adaption to the curved boundary