ME 7120: Project 2

Finite Element Method Applications

Due: December 2, 2016

Team Members:

Hao Li

Jeremy Geaslen

Jay Vora

Single Element Test

* Eigenvalue test

Calculate the eigenvalues of the stiffness matrix of a single brick 8 element, 24 eigenvalues are obtained. Different numbers of gauss points are chosen to calculate the eigenvalues listed in the following table. There are 6 values corresponding to the rigid body motion, which are imaginary numbers close to zero with very small imaginary part. The rest of eigenvalues are all positive. For the case with 4 gauss points, all eigenvalues are real.

Table 1. 24 Eigenvalues with 4 Gauss points for integration

|  |  |  |  |
| --- | --- | --- | --- |
| -6.03E-05 | 6.57E+10 | 1.97E+11 | 3.94E+11 |
| -4.71E-05 | 6.57E+10 | 1.97E+11 | 3.94E+11 |
| 3.80E-06 | 1.18E+11 | 2.63E+11 | 3.94E+11 |
| 3.88E-05 | 1.18E+11 | 3.79E+11 | 3.94E+11 |
| 8.99E-05 | 1.18E+11 | 3.79E+11 | 3.94E+11 |
| 1.30E-04 | 1.97E+11 | 3.79E+11 | 1.21E+12 |

Table 2. 24 Eigenvalues with 5 Gauss points for integration

|  |  |  |  |
| --- | --- | --- | --- |
| 2.66E-05 | 6.57E+10 | 1.97E+11 | 3.94E+11 |
| 7.27E-05 -3.44E-05i | 6.57E+10 | 1.97E+11 | 3.94E+11 |
| 7.27E-05 +3.44E-05i | 1.18E+11 | 2.63E+11 | 3.94E+11 |
| -7.66E-05 -2.64E-05i | 1.18E+11 | 3.79E+11 | 3.94E+11 |
| -7.66E-05 +2.64E-05i | 1.18E+11 | 3.79E+11 | 3.94E+11 |
| 1.01E-04 | 1.97E+11 | 3.79E+11 | 1.21E+12 |

* Uniform stress test

Apply uniform load at one direction with appropriate boundary conditions and loading conditions. Check the displacement to make sure the stress is uniform distribution. Fig. 1 and 2 show the uniform displacement field applying uniform load at x and z direction using WFEM, respectively. The same case for loading at x direction has been applied using ANSYS for comparison. The deformed shape is shown in Fig. 3. The comparison of WFEM and ANSYS for x deflection is listed in Table 1. There is a 0.003% difference for the results getting from WFEM and ANSYS.



Fig. 1. Uniform displacement field at x direction (WFEM)

Fig.2. Uniform displacement field at z direction (WFEM)

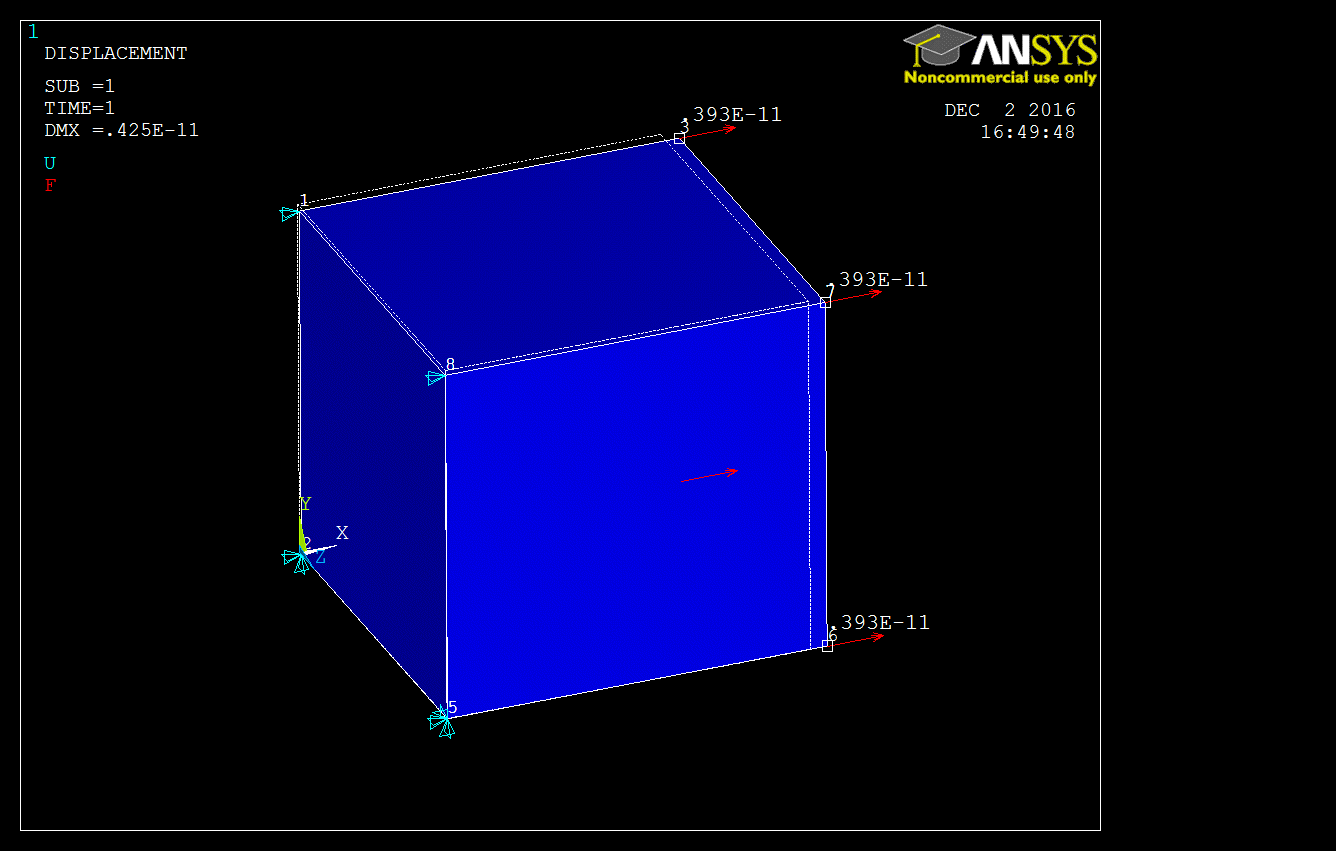


Fig. 3. Deformed shape (ANSYS)

Table 1. Deflection Comparison for x deflection

|  |  |  |  |
| --- | --- | --- | --- |
|  | ANSYS | WFEM | Difference |
| x deflection | 3.93310E-12 | 3.93323E-12 | 0.003% |

* Shear locking test

Three cases are tested in this part. The model is a single brick element with one end fixed and vertical load at the other end, shown in Fig. 4. The first case is to do the analysis using the commercial software ANSYS. The deformed shape is shown in Fig. 4. The second case is to perform the analysis with shear locking fix by WFEM. The third case is to perform the analysis without shear locking fix by WFEM. The deformed shapes are shown in Fig. 5 and Fig. 6. The vertical displacement is compared in Table 2. As it shows, the WFEM code with shear locking fix matches the results from ANSYS. And there is 18% improvement applying shear locking fix. The shear locking indeed makes the element stiffer.

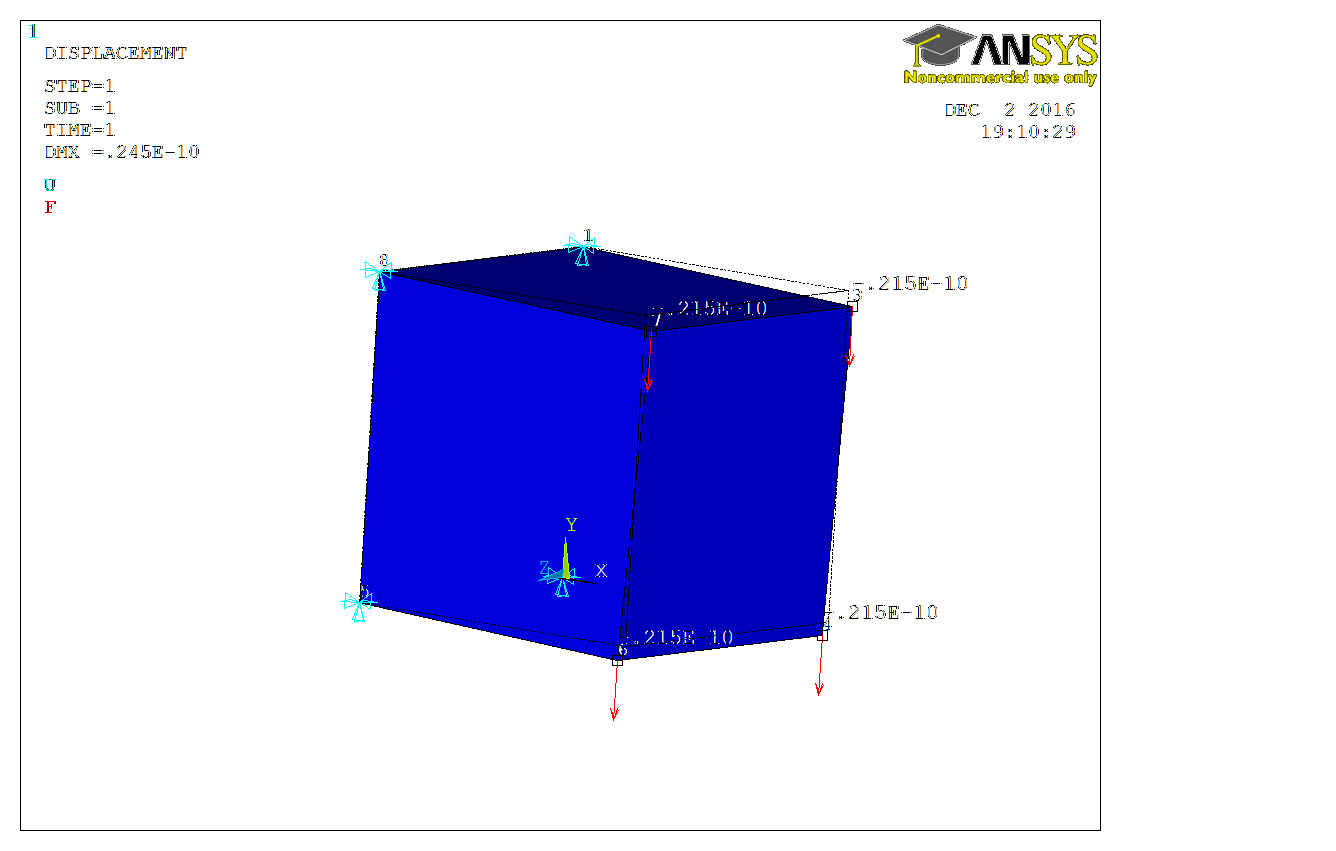


Fig. 4. Deformed shape by ANSYS



Fig. 5. Deformed shape with shear locking fix (WFEM)



Fig. 6. Deformed shape without shear locking fix (WFEM)

Table 2. Comparison including shear locking fix

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | ANSYS | WFEM | | |
| Fix SL | with SL | Diff |
| y deflection | 2.154E-11 | 2.154E-11 | 1.762E-11 | 18.20% |

**Brick Element Comparison**

* **Pyramid**

Table 3. Deflection Comparison for x deflection at tip

|  |  |  |  |
| --- | --- | --- | --- |
|  | ANSYS | WFEM | Difference |
| x deflection | 0.346E-9 | 0.356E-9 | 2.89% |

Results from ANSYS:

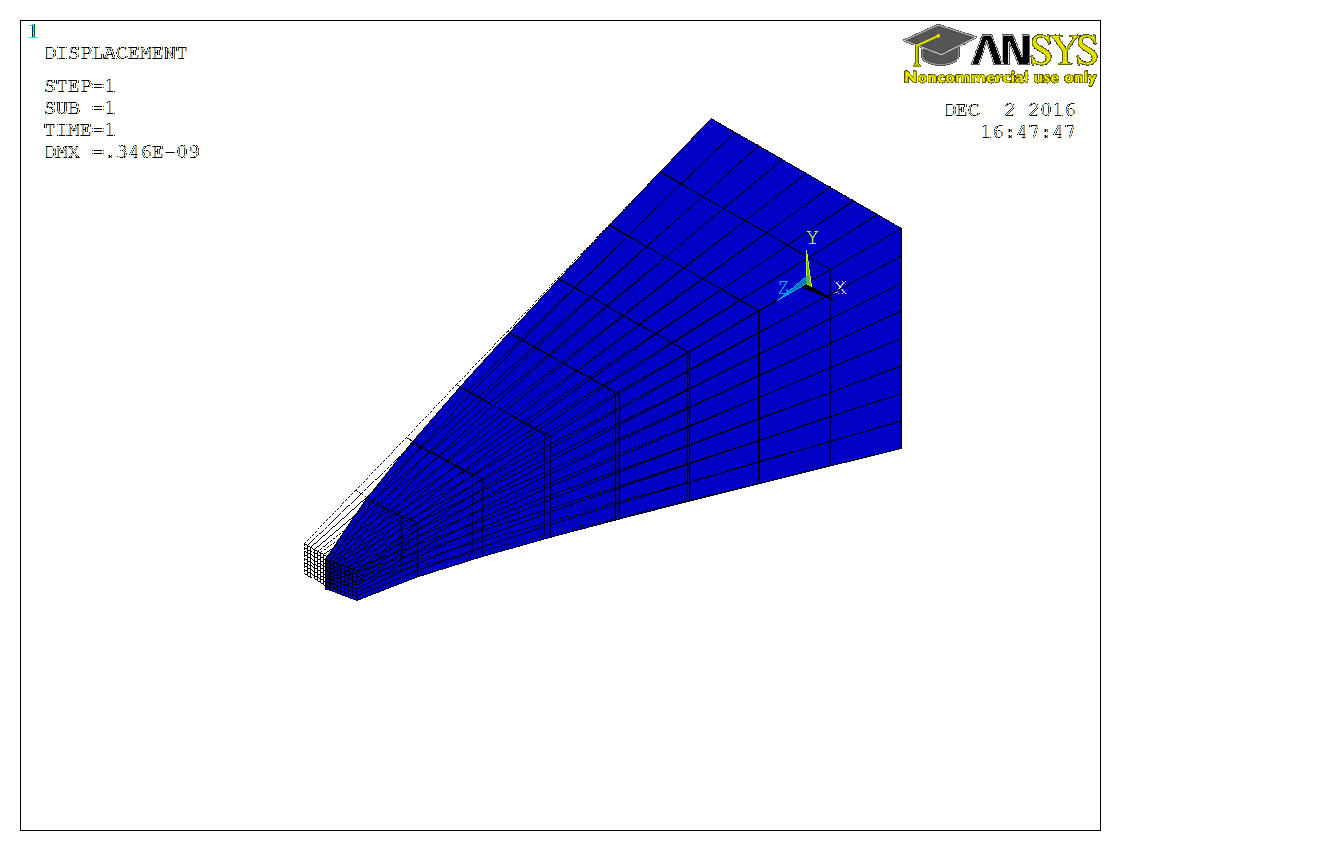


Fig. 7. Deformed shape for Pyramid (ANSYS)

Type of Element: Solid45

No. of Elements: 512 Brick Element

Results from MATLAB:

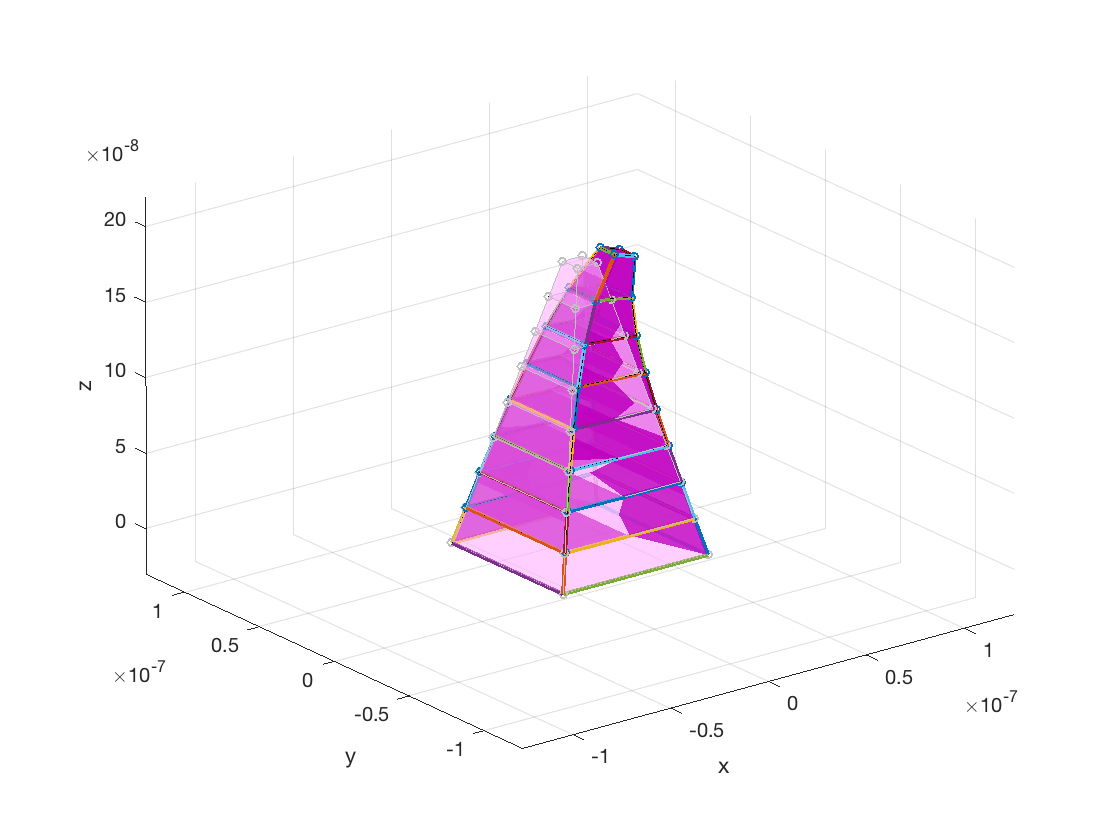


Fig. 8. Deformed shape for Pyramid (WFEM)

Type of Elements: Brick

No. of elements: 8

The results obtained from ANSYS and MATLAB are comparable.

**Brick Element Comparison**

* **CYLINDER**

Table 4. Deflection Comparison for x deflection at tip

|  |  |  |  |
| --- | --- | --- | --- |
|  | ANSYS | WFEM | Difference |
| x deflection | 0.551E-9 | 0.7E-9 | 27.04% |

Results from ANSYS:

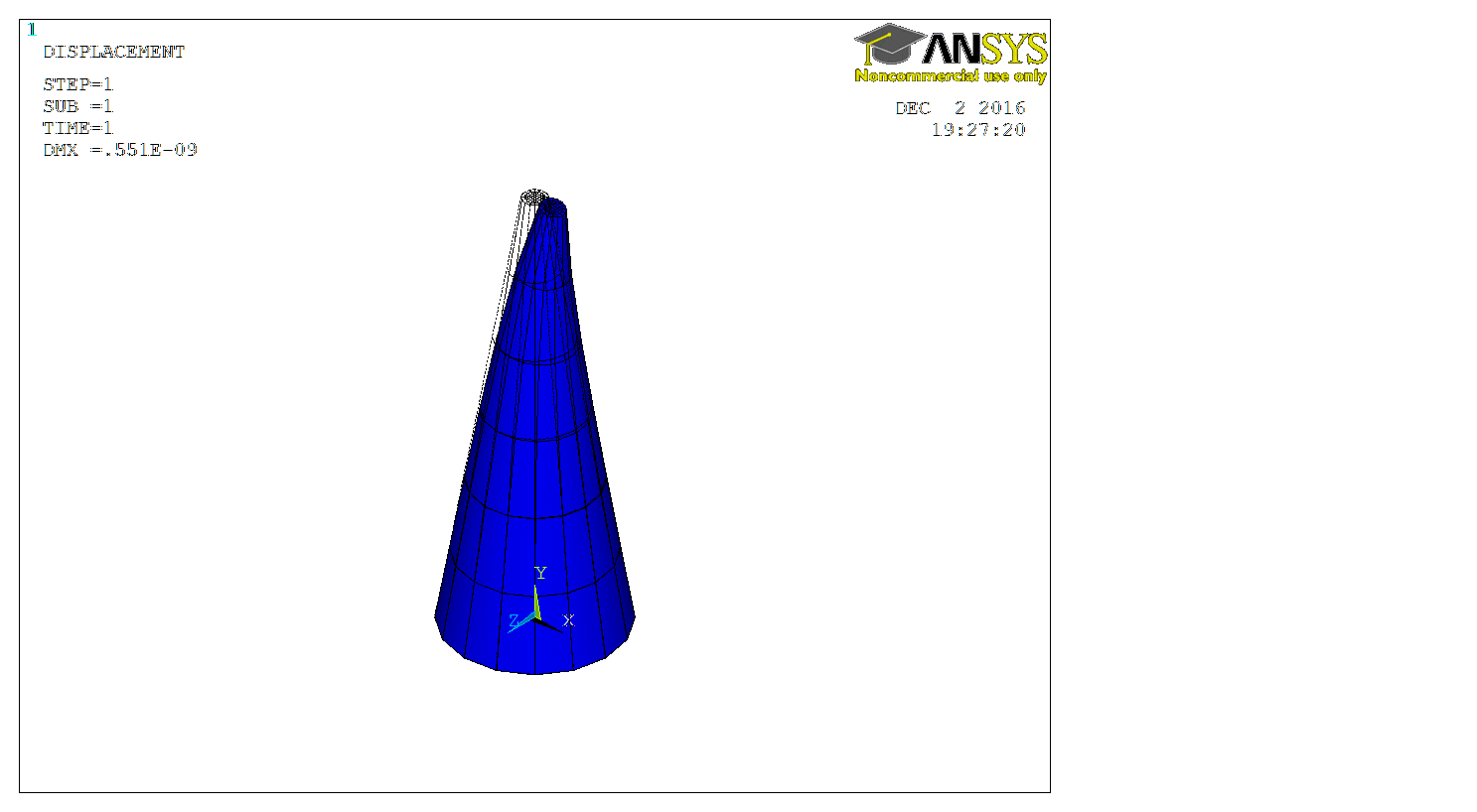


Fig. 9. Deformed shape for Cylinder (ANSYS)

Type of Element: Solid45

No. of Elements: 288 Brick Element

Results from MATLAB (Brick Element):

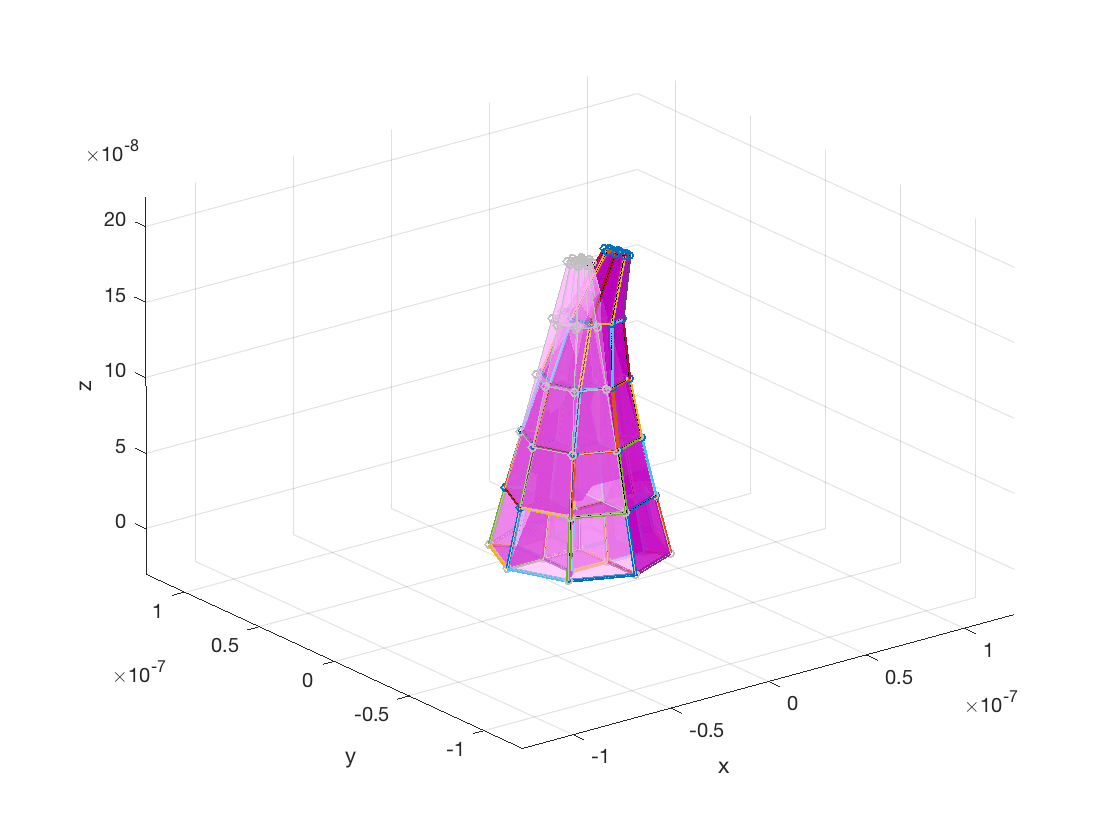


Fig. 9. Deformed shape for Cylinder (WFEM)

Type of Elements: Brick

No. of elements: 60

The Brick Element Structure for the MATLAB file is designed as given in Figure below. There is a total of 5 layers with the same design to give a total of 60 elements

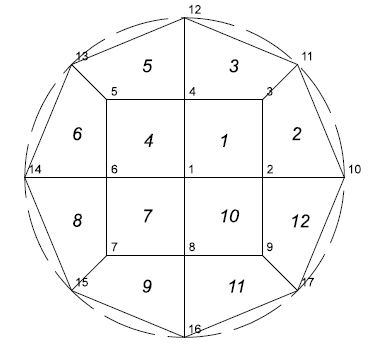


Fig. 10. Nodal Structure for Cylinder (WFEM)

The results obtained from ANSYS and MATLAB show larger difference than expected. This is mainly because we are using more elements in ANSYS, thus helping in defining the true shape.

**VERIFICATION USING BEAM CODE, BRICK CODE AND ANSYS FOR A BEAM STRUCTURE.**

The analysis of the pyramid structure was carried using BEAM ELEMENT code and compared with the previous results.

Table 5. Deflection Comparison for x deflection at tip

|  |  |  |  |
| --- | --- | --- | --- |
|  | ANSYS | WFEM (BRICK) | WFEM (BEAM) |
| x deflection | 0.346E-9 | 0.356E-9 | 0.752E-9 |

There is a significant difference between results obtained using beam element and brick element. The main reason can be because the beam element with the given dimension doesn’t satisfy the Euler-Bernoulli Beam Requirement. Hence the variation in results.

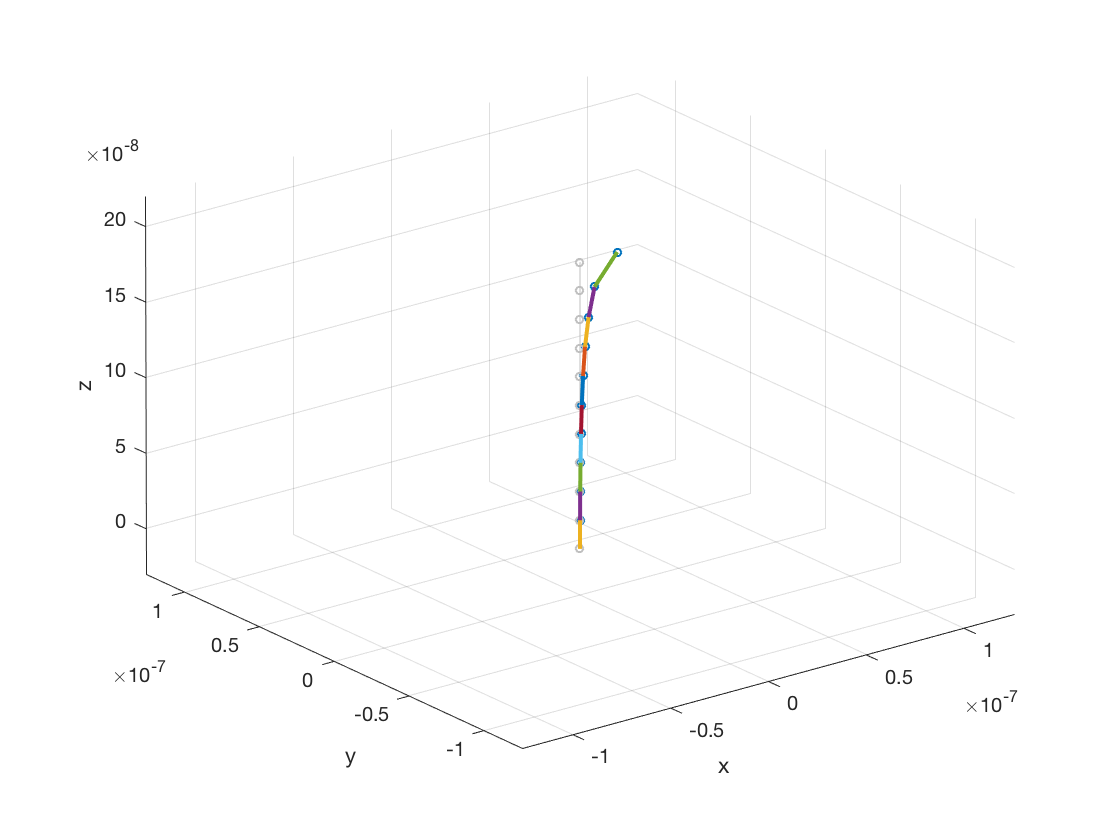


Fig. 11. Deformed shape for Pyramid (WFEM)