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INTRODUCTION

Dumbbell racks are normally subjected to heavy force acted by the dumbbells. This object is commonly found in the gyms or even homes. In order for this object to be safe to use, it must be analyse before manufacturing it to prevent any serious accident or injuries when use.

Figure 1. Dumbbell Rack

For the first part of assignment 2, student are required to study and analyse a component or part of any object. A dumbbell rack was chosen to be the case study for this project. The model was sketched with the real life dimensions so it can be compared to a typical dumbbell rack sold in the market after the analysis. Typically, an old school dumbbell racks are made of steel since this material is strong but it might rusts after some time. Therefore, the material used to construct this dumbbell rack model would be the aluminium since it will not rust and this material is strong enough to handle the stresses exerted by the dumbbells. In ANSYS Workbench, different mesh types and element size were used to analyse the sketched model to obtain the maximum equivalent stress, safety factor and also the average skewness.

1.0 SOLID MODELLING

1.1 Construct

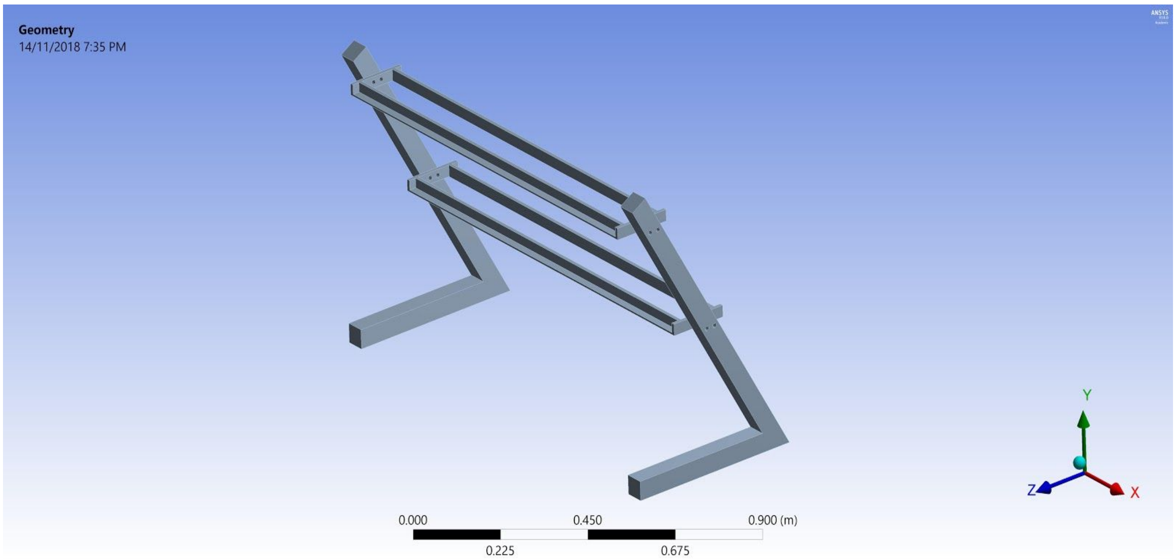

Figure 2. Geometry Figure of Dumbbell Rack

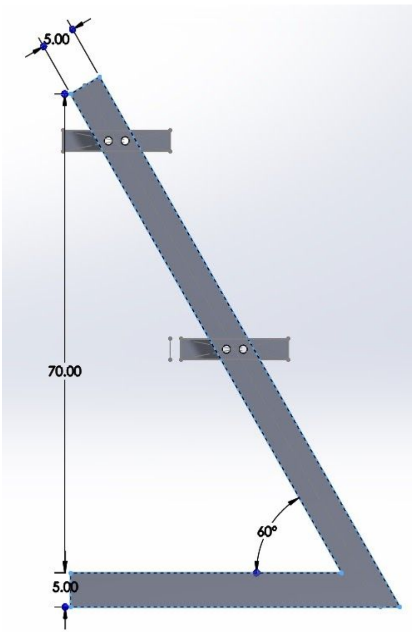

Figure 3. Side View

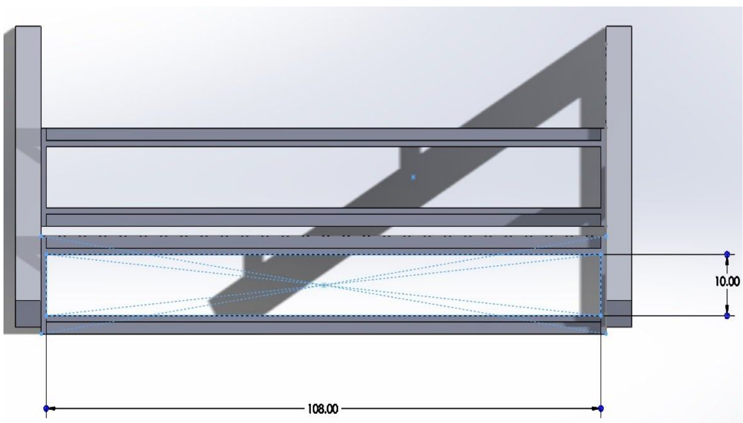

Figure 4. Top View

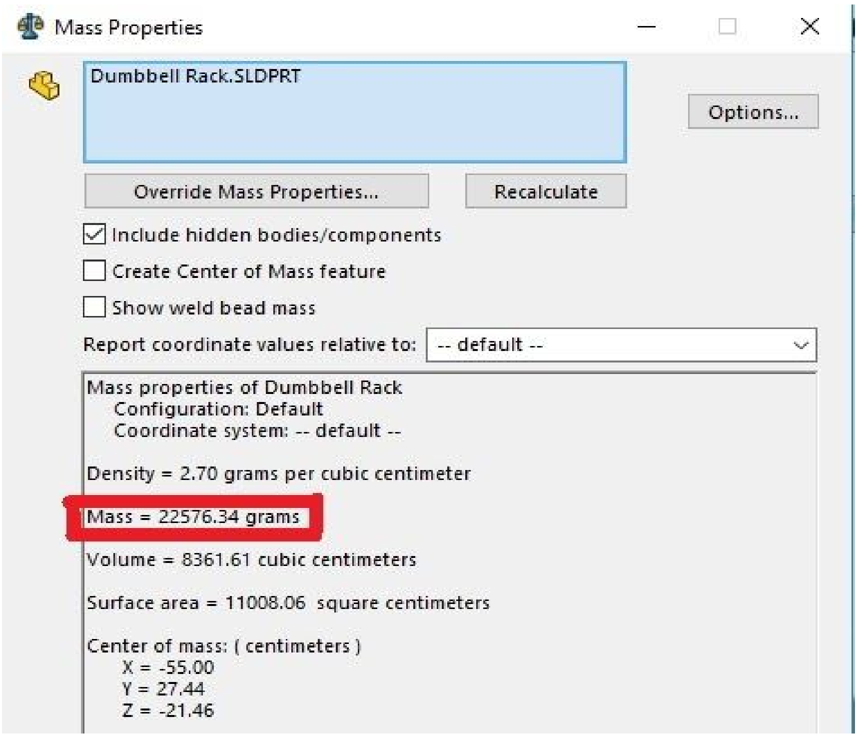

Figure 5. The mass of the Dumbbell Rack

Table 1. Properties of material

Materials	Elastic Modulus (GPa)	Yield Tensile Strength (MPa)	Ultimate Tensile Strength (MPa)	Poisson Ratio
Aluminium	69	95	110	0.334

1.2 Justify

Figure 2 demonstrates the whole figure model of the dumbbell rack which was sketched by using SolidWorks. The material used to construct this model was aluminium which is light and strong to handle the stress. Aluminium was chosen as it will not rust in a long term due to the humidity change of the environment. The dimensions of the dumbbell rack was sketched and designed according to the real life specifications. Based on **Figure 3,** the arm support was sketched with a height of 70 cm and extruded out with a thickness of 5 cm. Based on research found, a typical height of a dumbbell rack range around 70-80 cm to allow user to place the dumbbell easily. The arm support was tilted at an angle of 60 degrees which was inspired by the shape of conventional dumbbell racks in the current market. Besides, a 60 degree angle also reduces the stress caused by the load of the dumbbell comparing to a lower angle which further increases the stress. Based on **Figure 4**, the tray which will be used to place the dumbbells was sketched at a length of 108 cm. This could fit up to 6 pairs of dumbbells in each level of tray. Two screw holes were placed at each end of the tray to fix the tray between the arm support.

After the model was sketched, the complete model was transferred to ANSYS workbench for simulation. By using Ansys, two types of meshing will be carried out which were the tetrahedron and the hex dominant method. Both mesh type were compared by their average skewness to obtain the more suitable mesh type. The maximum equivalent stress, average skewness and safety factor were also obtained.

2.0 MESH ELEMENT & METHOD

2.1 Construct

Table 2. Tetrahedrons Mesh data (before refinement)

tetrahedrons				
element size	elements	max equivalent stress	skewness average	safety factor
0.04	4108	2.21E+07	0.57378	4.293
0.03	5265	2.19E+07	0.51532	4.3356
0.02	13249	2.96E+07	0.4085	3.2057
0.015	25210	3.37E+07	0.31175	2.8201
0.01	79726	4.04E+07	0.28184	2.3492
0.009	111783	4.32E+07	0.25997	2.1973
0.008	155132	4.41E+07	0.25439	1.9686

For tetrahedrons, the best element size chosen was 0.01 m. The skewness average of this element size of 0.01 m is 0.28184.

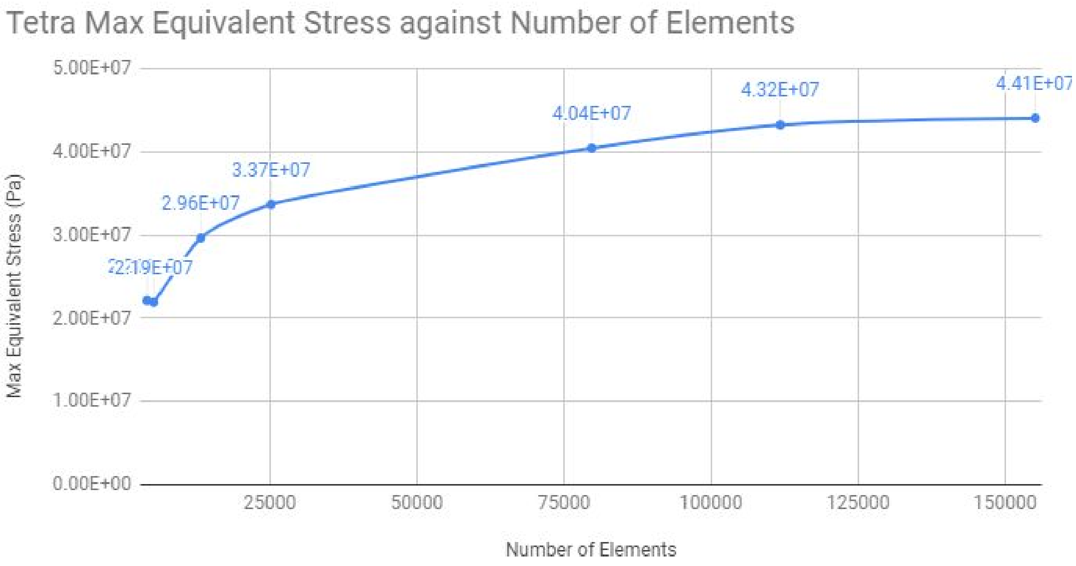

Figure 6. Graph of Tetrahedrons Mesh (before refinement)

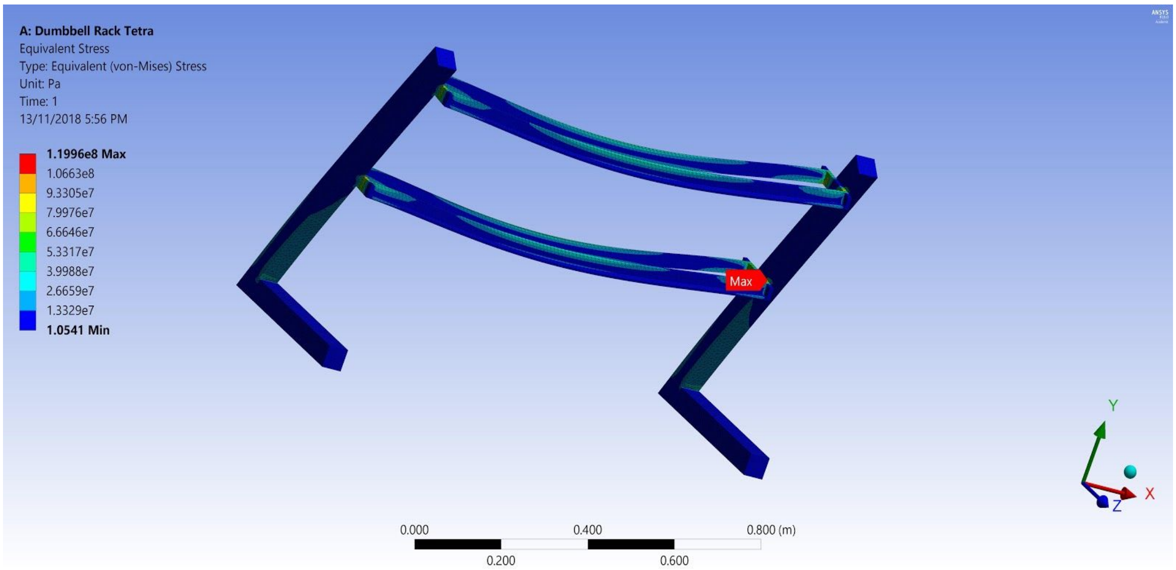

Figure 7. Maximum Equivalent Stress of Tetrahedrons

Mesh Type: Hex Dominant

Table 2. Hex Dominant Mesh data (before refinement)

hex dominant			
element size	elements	max equivalent stress	skewness average
0.01	13520	5.37E+07	0.39831

For hex dominant, the skewness average of the element size of 0.01 m is 0.39831.

2.2 Assess

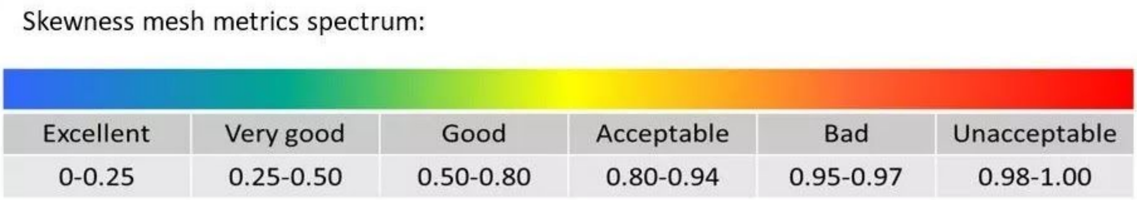

Figure 8. Skewness Mesh Metrics Spectrum

a) Average Skewness

The average skewness for both mesh type were compared with the same element size of 0.01 m. The average skewness for the tetrahedron obtained is 0.28184 while for the hex dominant is 0.39831. The average skewness obtained from both tetrahedron and hex dominant mesh method were in the 'Very Good' column based on **Figure 8** as shown above. Since, the average skewness value for the tetrahedron mesh type is lower compared to the hex dominant mesh type, hence the tetrahedron was chosen to be a more suitable mesh type. This is because the tetrahedron mesh type produce a better quality for this model.

b) Safety factor

According to a reliable source, it was found that the recommended safety factor for the aluminium is 5. On the other hand, the safety factor obtained from the dumbbell rack model after meshing was done only found to be 2.3492 according to **Table 2** above. Although the safety factor obtained was below the recommended general safety factor of aluminium which is 5, the model does not break and could withstand the amount of force generated on it. Further improvements can be made to increase the safety factor closer to the recommended safety factor of aluminium which is 5 that will be done in Part 2 later on. This will be better in a long term.

2.3 Justify

A graph of maximum equivalent stress against the number of elements was plotted based on the mesh data obtained as shown in **Table 2**. The meshing was done by using tetrahedron mesh method. According to the graph as shown in **Figure 6**, it was found out that a more accurate value of the maximum equivalent stress can be found with a smaller element size. Besides, the graph also shows that the maximum equivalent stress increases with the number of elements until a certain point where the trend began to show it is constant. At the point where the gradient decreases and the graph starts to become constant, the element size was taken to refine 3 times to obtain a more accurate maximum equivalent stress.

For the element size of 0.01 m, the maximum equivalent stress was acting towards the vertex which was located between the arm support and dumbbell tray. Hence, the refinement was applied to the vertex of that region as shown in **Figure 7** above.

2.4 Improve

Mesh Type: Tetrahedrons

Table 4. Tetrahedrons Mesh data (after refinement)

tetra 0.01					
element size	elements	max equivalent stress	skewness average	safety factor	
0.01	79726	4.04E+07	0.28184	2.3492	original
0.01	79950	5.06E+07	0.3137	1.879	refine 1
0.01	80237	6.98E+07	0.31448	1.3613	refine 2
0.01	81459	8.18E+07	0.31722	1.161	refine 3

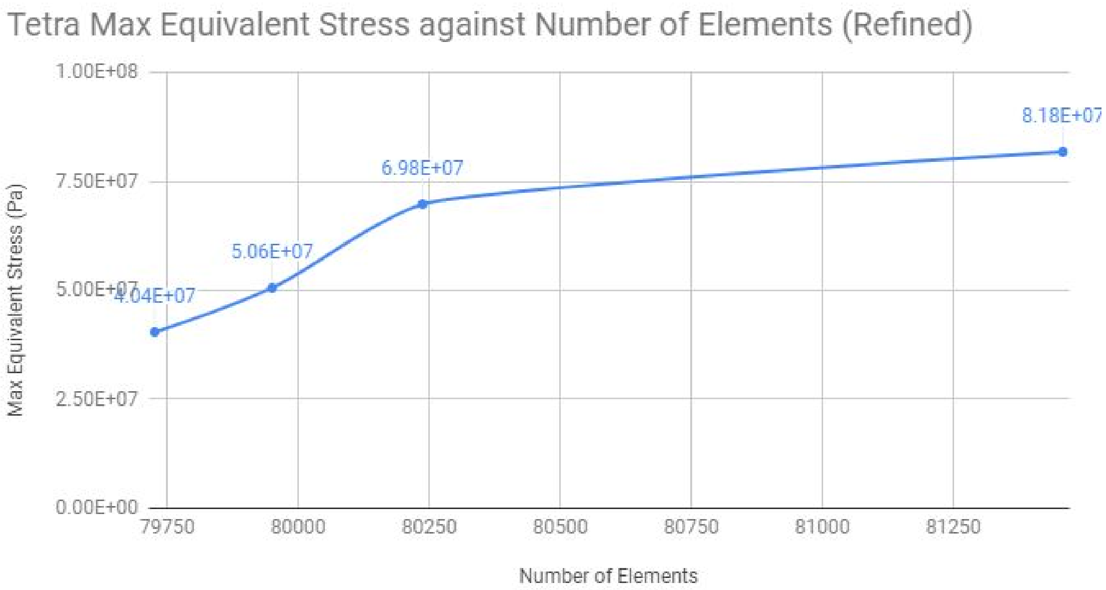

Figure 9. Graph of Tetrahedrons Mesh (after refinement)

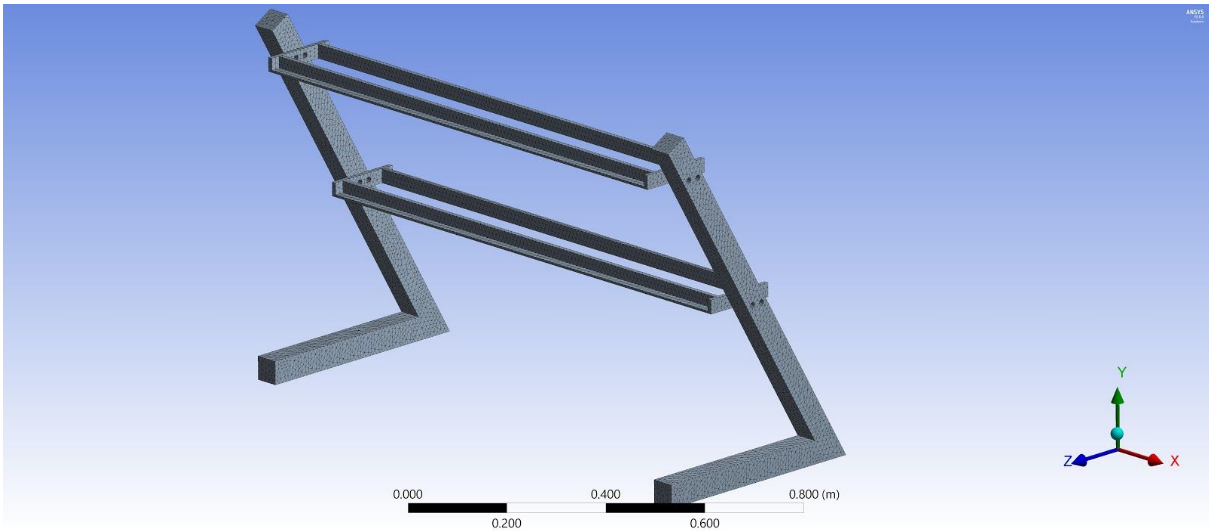

Figure 10. Tetrahedron Mesh (element size 0.01m)

Since the element size of 0.01 m was chosen to be the most suitable, it was refined 3 times to obtain a more accurate maximum equivalent stress. A graph was then plotted as shown in **Figure 9** above. The graph shows that the maximum equivalent stress increases with the number of elements after every refinement was done. Therefore, this also proves that a more accurate maximum equivalent stress was obtained after refinement was done.

On the other hand, the average skewness value increases after every refinement. Therefore, the original average skewness value taken was 0.28184 since this is the lowest compared to other average skewness value after every refinement.

3.0 BOUNDARY/ INITIAL CONDITIONS

3.1 Generate

3.2 Develop

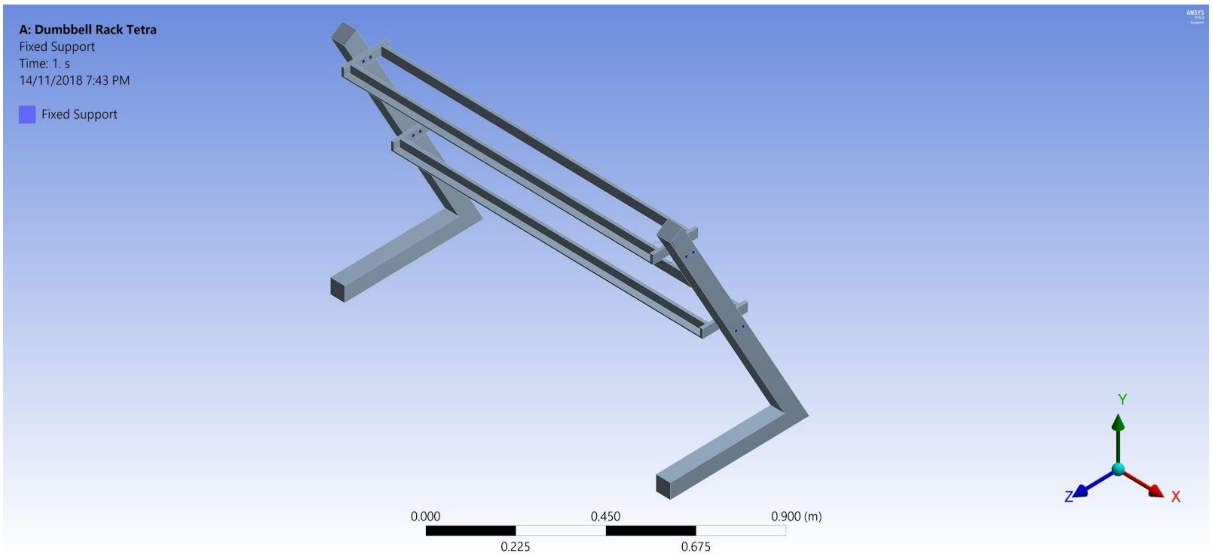

Figure 11. Fixed Support of the Dumbbell Rack

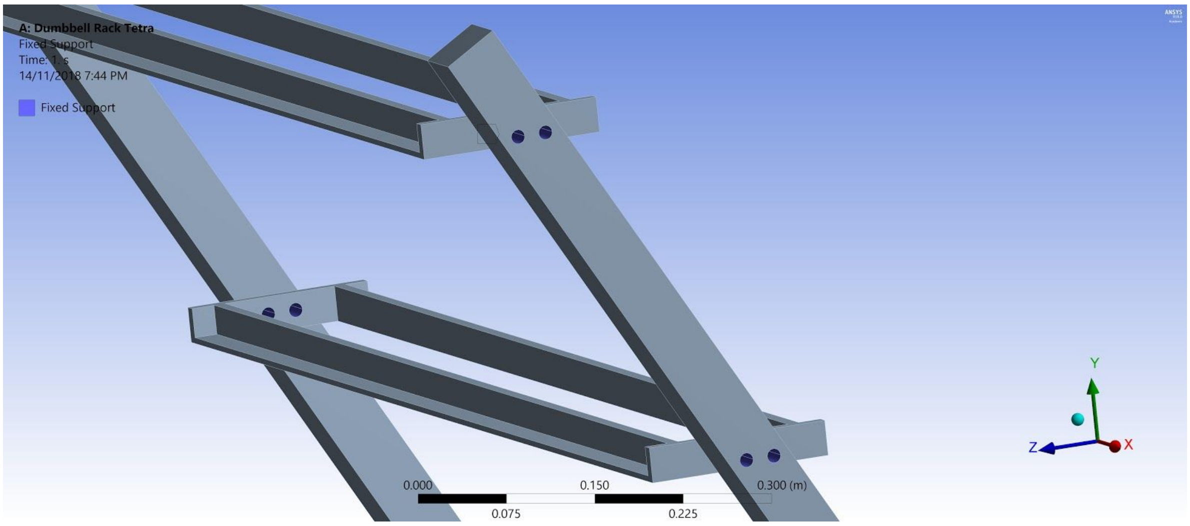

Figure 12. Fixed Support of the Dumbbell Rack (Closer Image)

3.3.1 Justify

The fixed support was applied to the inner faces of the holes of the dumbbell rack support as shown in **Figure 11** and **Figure 12** above. This section was chosen as the fixed support since both of the trays will be supported firmly at this fixed position. Besides, this section was also assumed that they do no move at any x,y,z direction or undergoes any deformation. The trays of the rack will be supported by the two arm supports. This was done by attaching both of them together with screws through the holes.

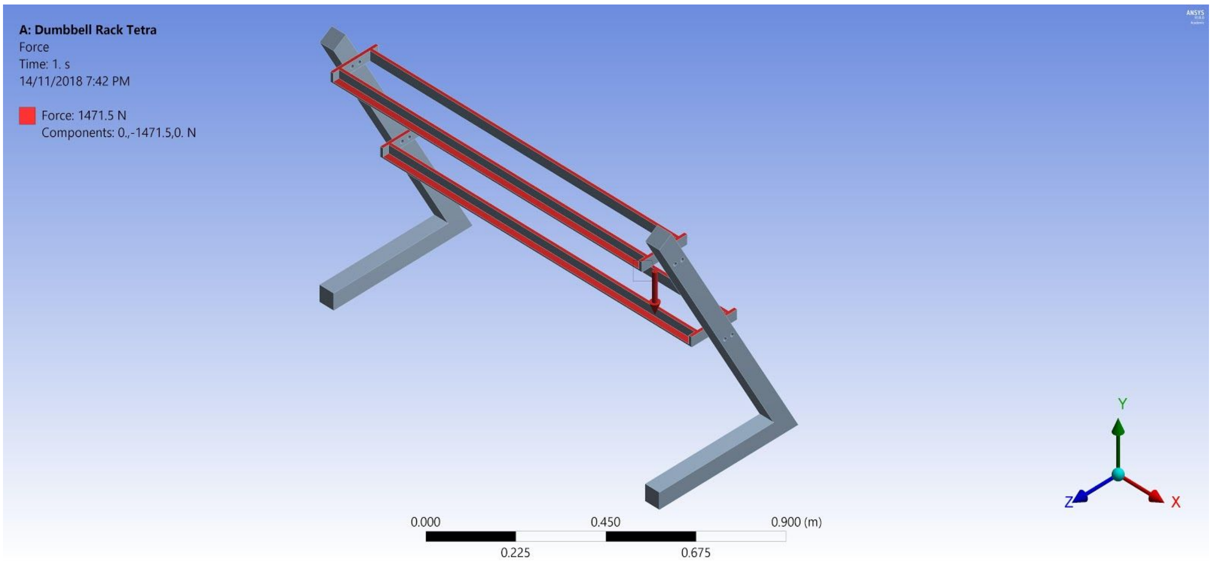

Figure 13. Force Applied on Dumbbell Rack

3.3.2 Justify

The force was applied on the whole faces for both levels of the tray as shown in **Figure 13** above. Assuming a pair of 5 kg,10 kg,15 kg,20 kg and 25 kg of dumbbell were placed on the tray, a total of 150 kg load will be exerted on it. The gravitational force of 9.81m/ s^2 must be taken into consideration since the direction of the force was applied on the y-axis downwards. Therefore, a total force of -1471.5 N was obtained by multiplying the total load with the gravitational force. Since the force is acting in the y-axis downwards, a negative sign was key in with the total force value.