REDUCTION OF VIBRATION OF DRILL BUCKET USING ABSORBER

A Thesis submitted in partial fulfillment of the requirement for the degree of

Bachelor of Science

In

Mechanical Engineering

Submitted By

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June 2023

DECLARATION

This is hereby declared that thesis entitled “**REDUCTION OF VIBRATION OF DRILL BUCKET USING ABSORBER.**” is an authentic report of my study carried out as a requirement for the award of degree B.Sc. (Mechanical Engineering) at Islamic University of Technology, Gazipur, Dhaka, under the supervision of **PROF. DR. MD. ZAHID HOSSAIN**, Professor, Department of Mechanical and Chemical Engineering, during July 2022 to June 2023.

The matter embodied in this thesis has not been submitted in part or full to any other institute for the award of any degree.

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This is to certify that the above statement made by the student concerned is correct to the best of my knowledge and belief.

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Although we have given our best to complete this thesis flawlessly, we sincerely apologize for any mistakes that may have been made.

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ABSTRACT

The drill bucket is the main part of the drill rig which carries the disposed of material after drilling and holds it for a certain time. In the meantime, it also withstands high pressure at the outside wall given by the material it digs into. The drill bucket rotates to dig into a material with a specified speed and accounts for some range of vertical pressure due to its reciprocating motion. A huge vibration is there because of its working procedure. Damping materials and Damping mechanisms are used to compensate for this situation at the top of the bucket head which also faced huge force and becomes outdated these days.

Our work aims to design and analyze new vibration absorber models inside the bucket to reduce the vibration, compare their results and find out the best one with a higher capacity of vibration absorption along with ease of access.

CHAPTER 1

Introduction, Literature review & Objectives

1.1 Introduction

A drilling rig is one kind of construction equipment that is used to build holes inside the surface. They may differ remarkably in structure: they may be of huge sizes or small to be used manually by one person. Drilling rigs can use samples from mineral deposits as well as test the physical properties of rocks, soil, and groundwater. They can also be used to construct underground installations like pipes, shafts and tunnels where drilling rigs are regularly used.

There are very few researches that have been done on the topic of reducing the vibration of a drilling bucket while performing the task of drilling. The main reason for the present vibrations is the digging force that the drill rig presses while entering the surface and the regular reaction force that it faces.

Large drilling rig manufacturers always look for a new design that cut with their perspective works. The drill rig has different parts like the drill head, drill bar, drill traveling block, rotary motors, etc. All of these accounts of vibration which are coming from the interaction between the drill bucket and the materials it dug into. Now, new materials for vibration absorption are coming and also new mechanism of absorption is also introduced to reduce the vibration.

Lightweight materials are very familiar these days, these materials have different types of molecular construction to absorb vibration, and this is itself a good absorber. Also, a combination of absorbers is used in different industries to get very good machine efficiency.

The rotary drill is one of the most prominent machines in construction projects and is also very deprived of getting modern technology. As aforementioned, these new technologies can be helpful to fulfill the gap of new technology adoption shortage of the old heavy-duty machine.

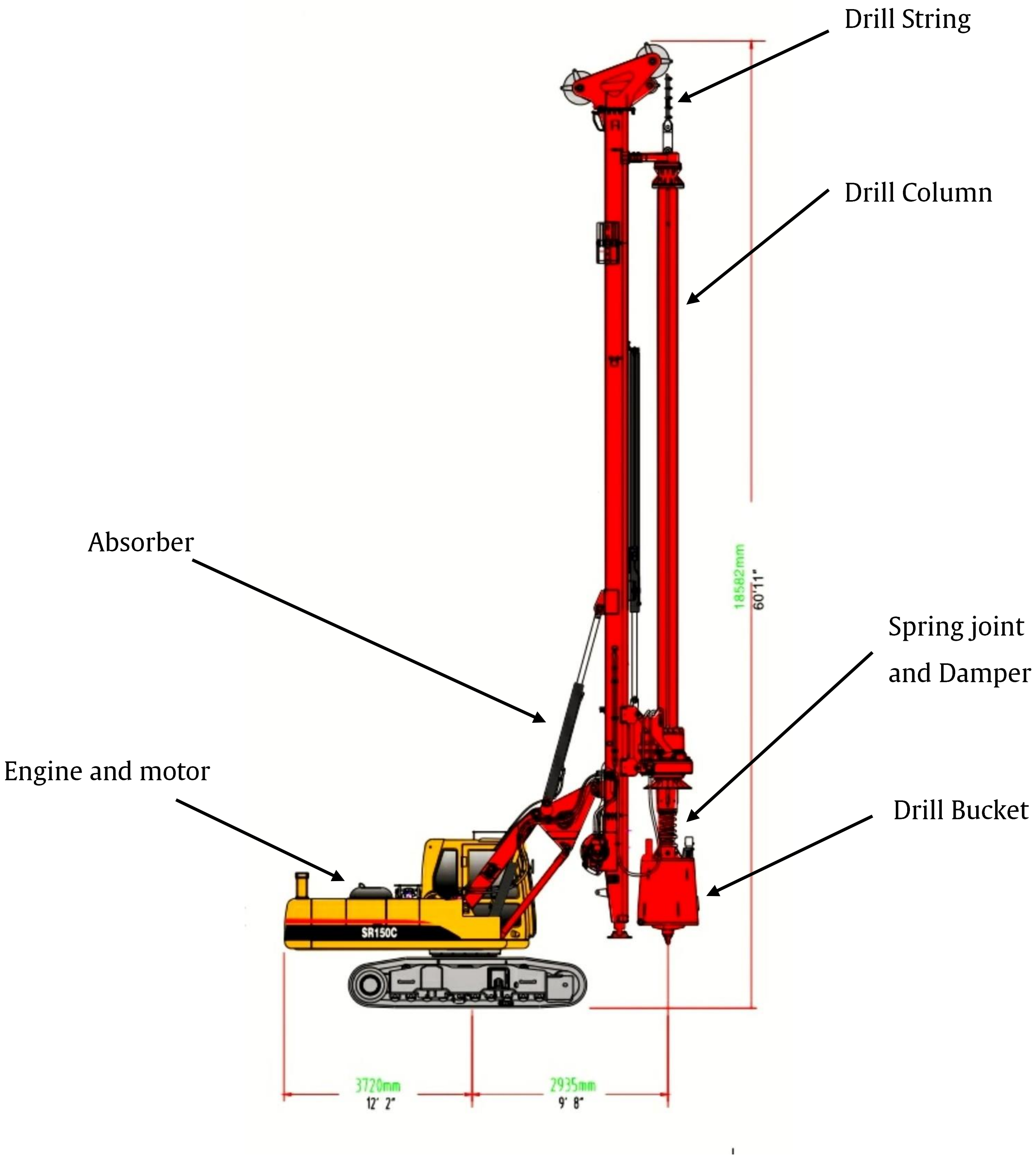


Fig.1.1: Drill Machine with Bucket. [9]

1.2 Literature Review

A lot of research is undergoing on the invention of vibration-absorbing materials but there are not many that analyze the usage of this material on existing content. Now we searched many papers for good fundamental data to start this project. In 2013, Ahmed Ghasolmoonia et al did research on the vibration associated with the drill string of a rotary drill machine. They check the behavior of the drill string when there is an axial load present. They change the power and weight distribution. The coupled axial-transverse vibration behavior of the entire drill string under the effect of a vibration-associated rotary drill tool is investigated. They check their work by comparing the manufactured model with FEM model [1]. Our very own supervisor Dr. Md Zahid Hossain also researched the bucket vibration of the excavator. This paper contains info about the Type of bucket and their modal, harmonic and transient analysis which Helps us to know different material works on vibration reduction. It also suggested how vibration-related simulation is being done [2]. Now we are looking for options that are the materials or absorber mechanism that can be used. A review paper is written by Zhao-Dong Xu, Zheng-Han Chen, Xing-Huai Huang, Chen-Yu show the recent advancement of multidimensional vibration mitigation materials and devices. This paper consists of some mechanisms that gave us ideas about what can be some motivation for our model [3]. Besides the mechanism available in this paper, another paper written by Yiaodang yan et al where it is shown how piezoelectric Ceramics can be used to capture vibration energy [4]. A detailed analysis was done by R. Salazar, M. Serrano, A. Abdelkefi on the energy harvesting of piezoelectric materials on 2020. This paper also defines how the cycle life of a piezoelectric material gets affected by vibration and how this material can be useful [5]. A new type of metal foam is introduced these years and a paper describes how it affected the vibration. This influential research was done by Paolo Albertelli, Stefano Esposito, Valerio Mussi, Massimo Goletti, Michele Monno. It describes the aluminum metal foam′s contribution to vibration damping of a material [6]. Another paper consisting of the damping characteristics of silicon oil is reviewed. This paper was written by Gokce Calis Ismetoglu and Halil Ibrahim Unal. Dynamic viscoelastic data obtained by the oscillation tests showed that viscous behavior was dominant under zero electric field in this paper which also can be material to reduce vibration effect [7]. A comparative study of vibration-damping system is done in a paper. Oshmarin D.A.a*, Iurlova N.A.a, Sevodina N.V.a, Iurlov M.A written paper shows the way of a comparative study of vibration inside two models including mathematical formula generation [8].

By doing and analyzing all the uppermentioned studies, we come to know that still there is some option available for vibration mitigation. Now we will use some attachment and do some modifications on that attachments to get a good result to mitigate vibration and deformation of drill bucket.

1.3 Objectives

The objectives of our study are

- To investigate the vibration of the drill bucket of the rotary drill rig.
- To develop and adopt different absorbers inside the bucket system,
- To analyze and compare the reduction of the vibration using the absorber containing different materials.

CHAPTER 2

Methodology

2.1 Methodology

The workflow of the analysis process

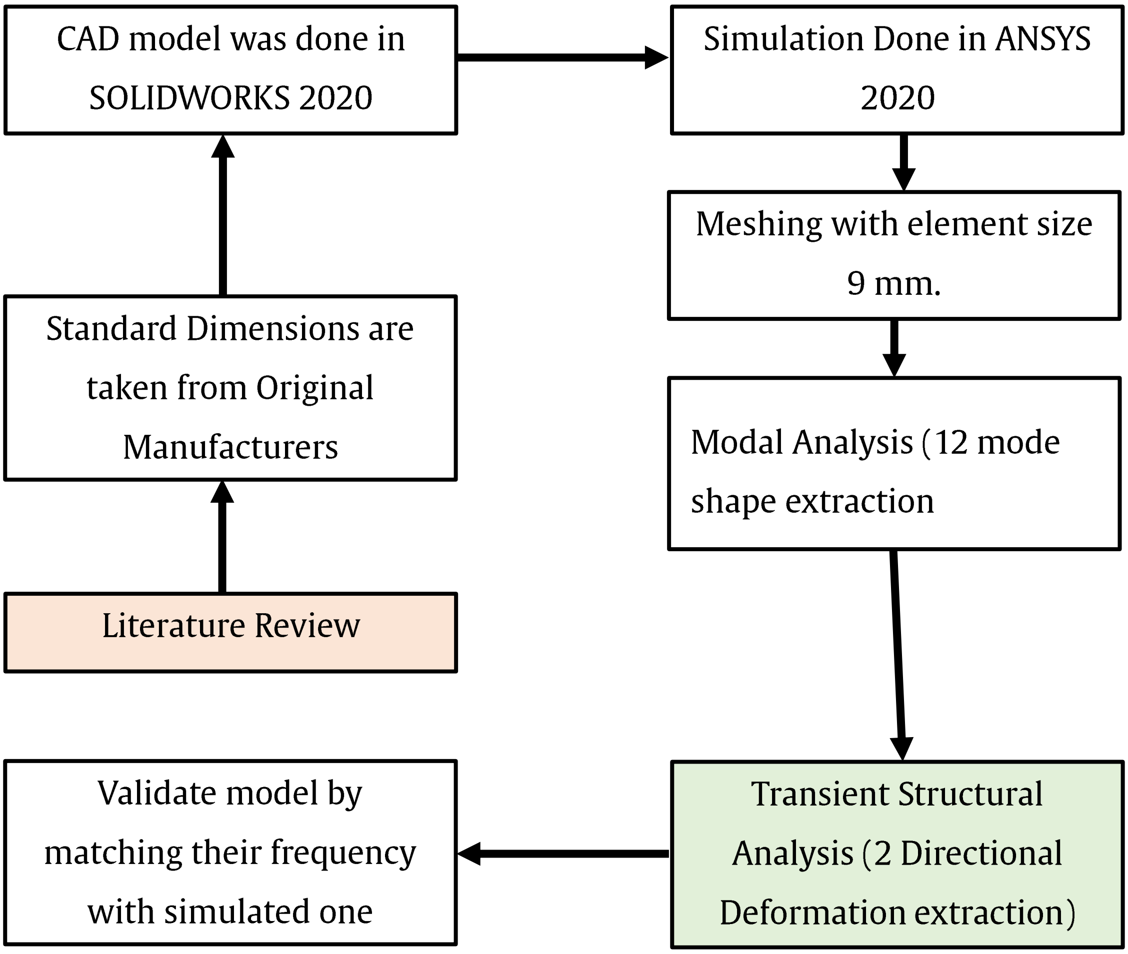


Figure 2.1: Work flow diagram.

For the analysis of vibration, a CAD model of a plain Drill bucket was created in Solidworks 2020 Version. This model is done by taking the measurement from a original working drill bucket model. The model is scaled down into a ratio of 1:100 to match with the model that can be build and run in laboratory for validation of models. STEP file is used in Ansys 2020 for simulations. Modal analysis is done in firsthand. Element size is taken by doing a optimizing test. All natural frequencies are plotted in an excel sheet and look after a more accurate element size in where result is more stable.

Transient Analysis in done for the finding out the deformation in test result and how fast the deformations are mitigated. 2 axis directional deformation results are extracted to see the impact of modifications.

3 modified models are done in solidworks and go through similar simulations. After comparing the result, the best-modified model will be manufactured and physical analysis will be done to validate the modified model.

CHAPTER 3

Design

3.1 Design Specification & Materials

3.1.1 Bucket (without Attachment) Design (Used in Drill Rig)

SOLIDWORKS Model

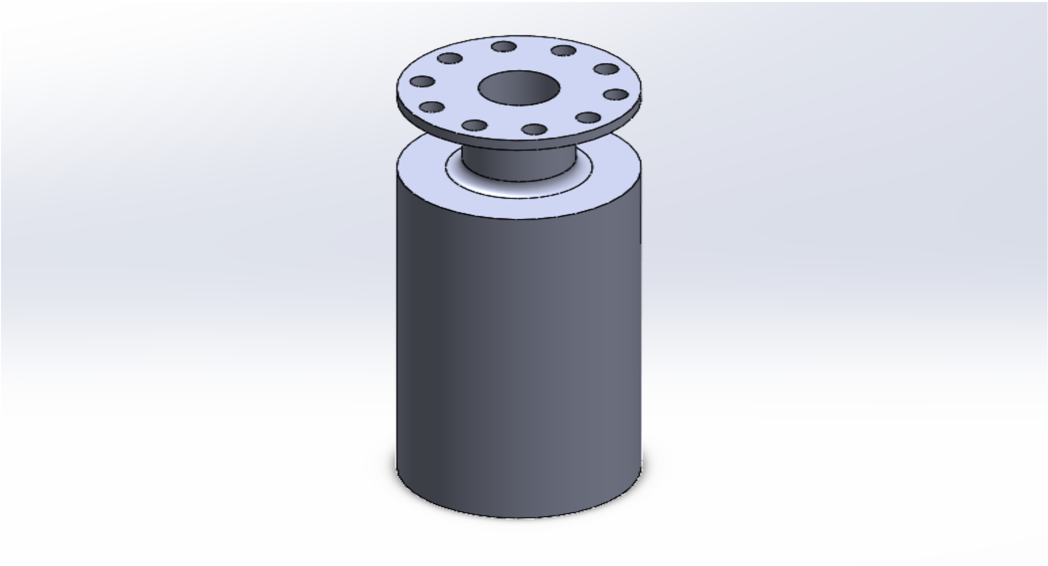


Fig. 3.1: CAD model of Plain Bucket

This model is done in Solidworks taking the measurement from a original Sany Drill bucket. Then this model is scale down into a ratio of 1:100. It is done to fit the model in the laboratory so that the model validation can be done easily.

Design Parameters	
Mass	8143.98 grams
Volume	1057659.74 cubic mm

Surface Area	303701.85 sq mm
Material Name	Mild Steel

Tab. 3.1: CAD model parameters of Plain Bucket

As the model is done in solidworks, there is option for selecting the material of the bucket. Though the original bucket that used in commercial use, that has a combination of material in construction of drill bucket, we used mild steel for the ease of manufacturing and availability.

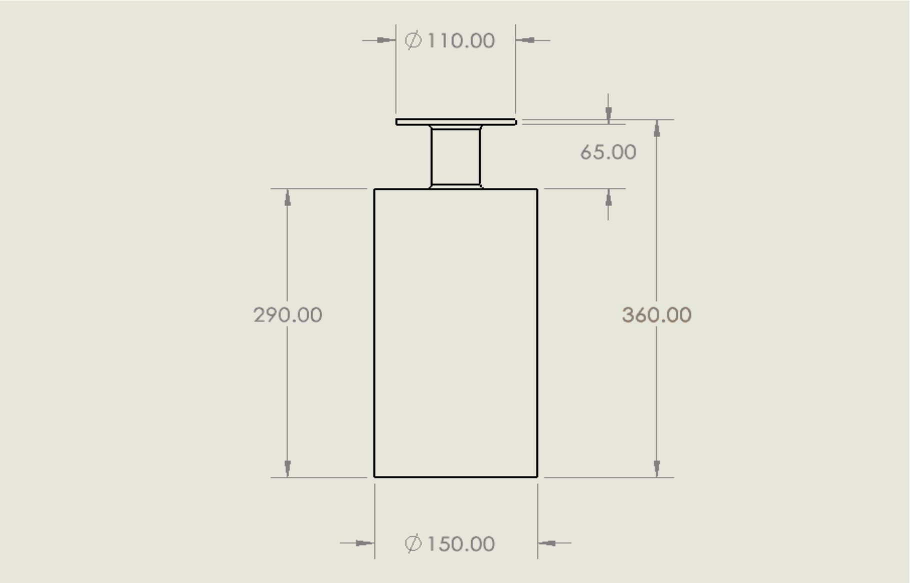


Fig. 3.2: Dimensions of CAD model of Plain Bucket (Side View)

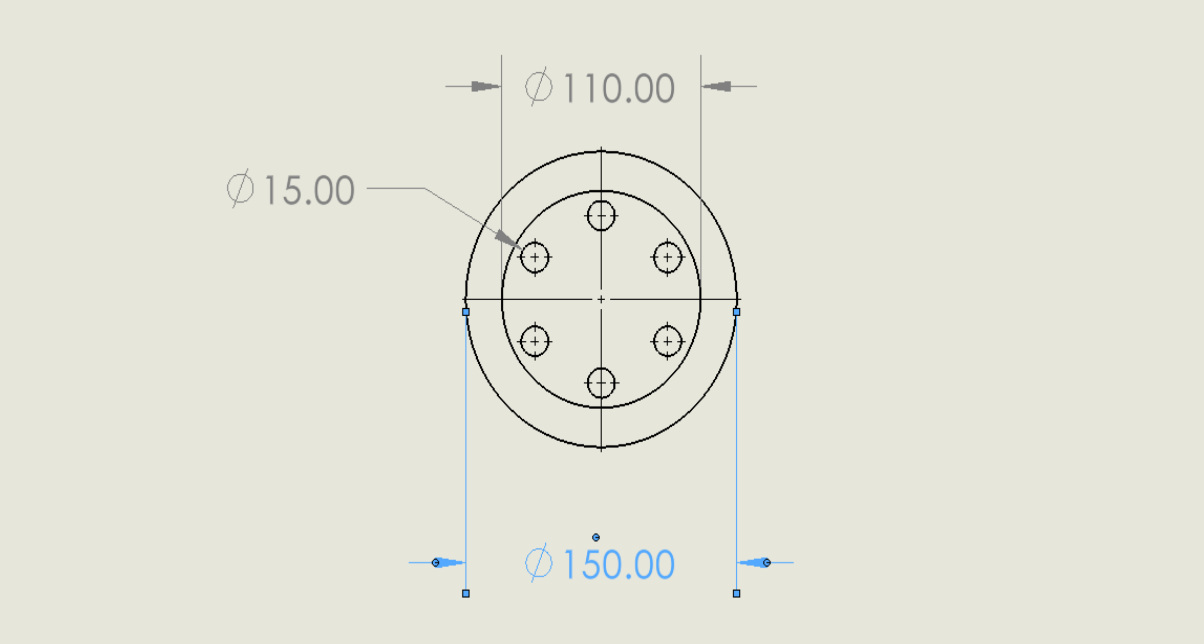


Fig. 3.3: Dimensions of CAD model of Plain Bucket (Top View)

This scale down model has about 360mm height and outside diameter of this bucket is 150mm. the actual bucket contains some attachment outside of the bucket wall which is ignored here to the best possible raw result.

3.1.2 Model 1

Solidworks model

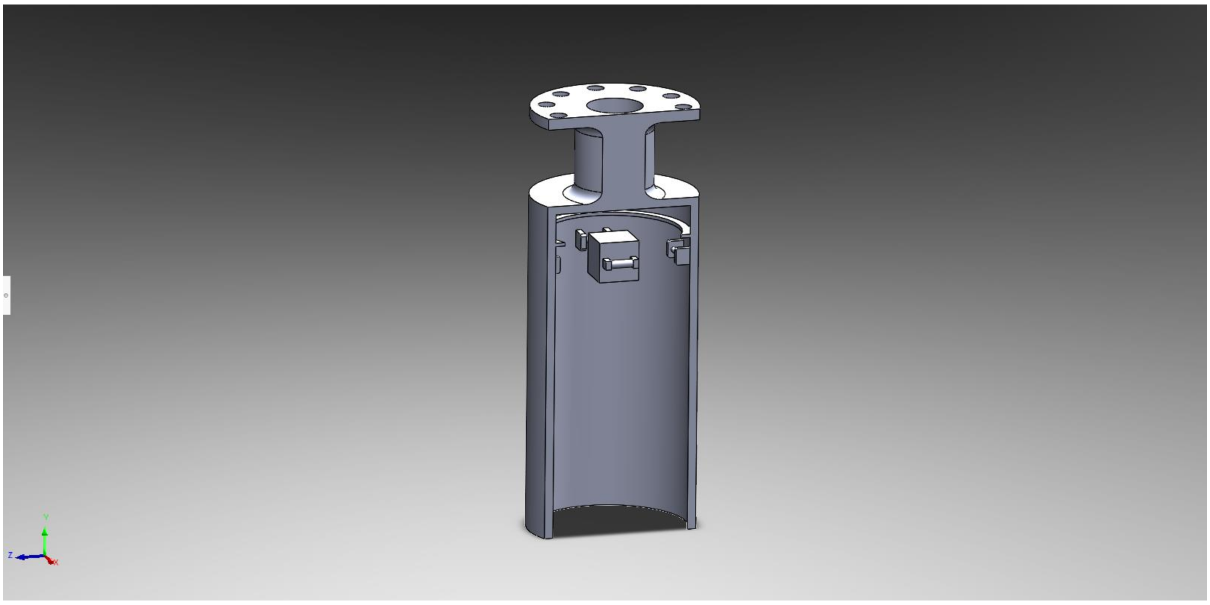


Fig.3.4: Isometric view of the modified model.

This model is done here with a mass attached inside. The mass is free to move in a single axis and no rotation is allowed. Moreover, there are 2 hooks inside the bucket that will hold the mass with the bucket and stop it from the free movement inside the bucket. The mass and bucket are connected with each other with 2 springs. The properties of the spring is pre-defined.

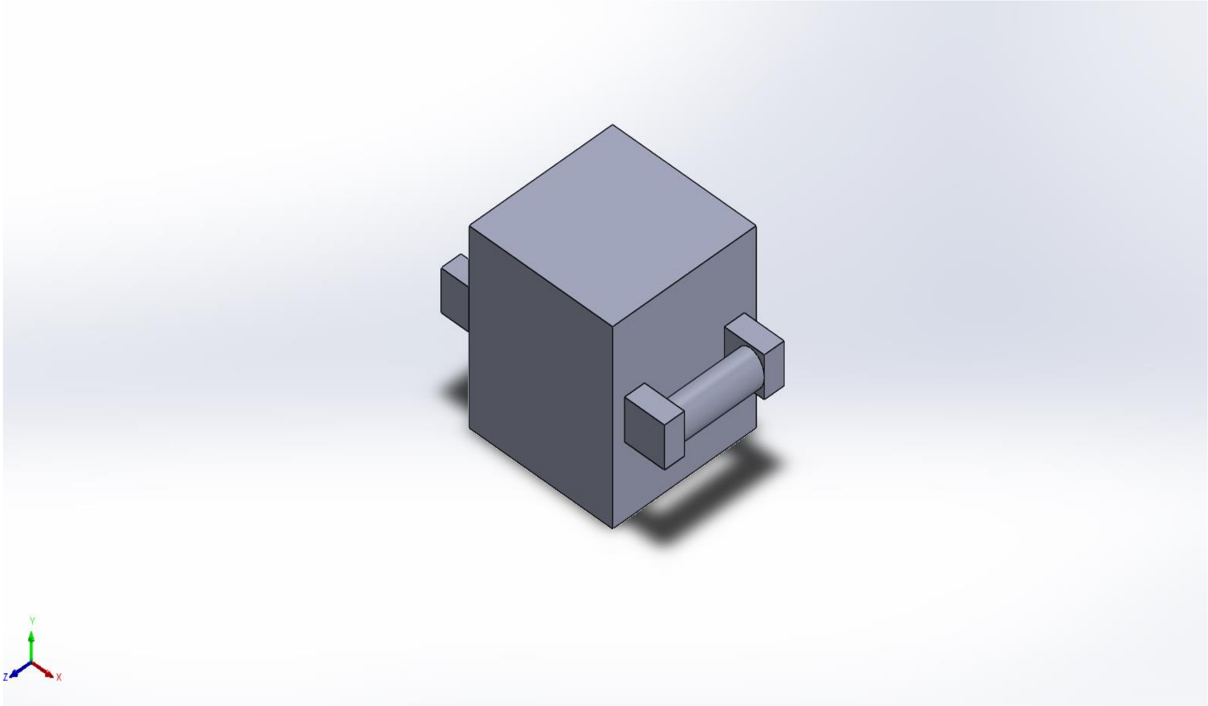


Fig. 3.5: Isometric view of the mass added inside the bucket

Properties of the modified Assembly		
Material	Mild Steel	Mild Steel
Mass (grams)	1408.7	49.08
Volume (Cubic mm)	1408698.13	49795

Tab. 3.2: Properties of Modified Mass.

In this property table, we can see that one column defined the mass and volume of the whole bucket and the other one defined the mass and volume of mass that is used here for testing.

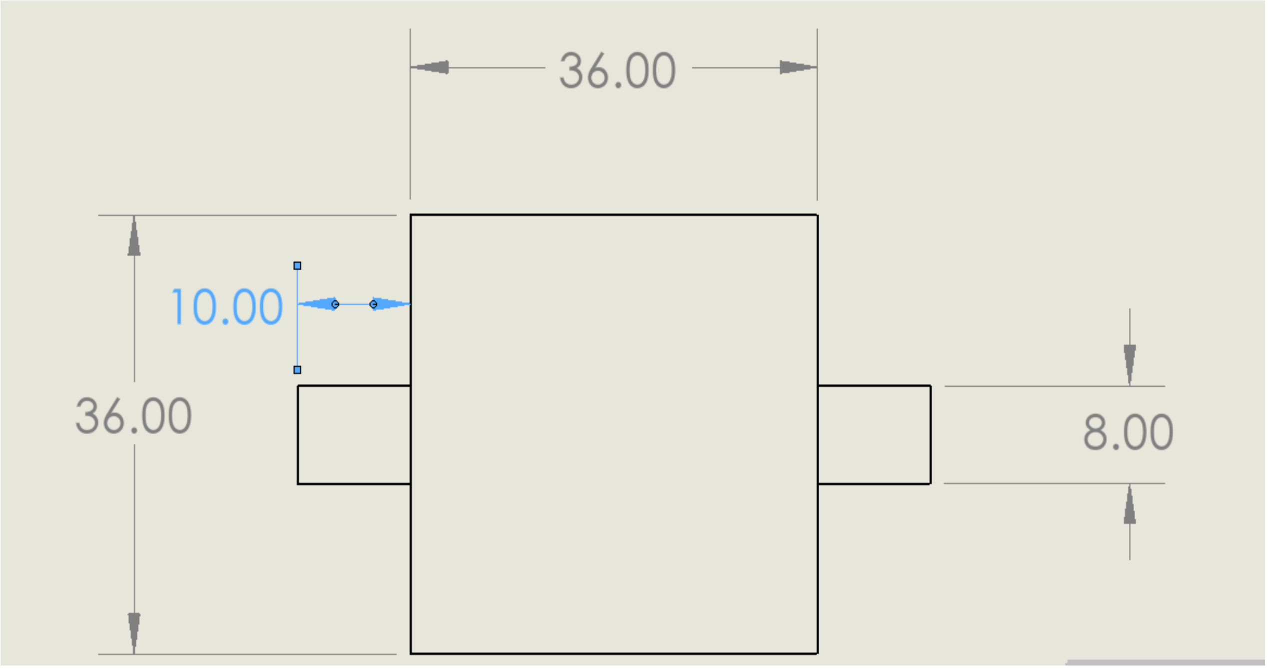


Fig. 3.6: Front View of the mass.

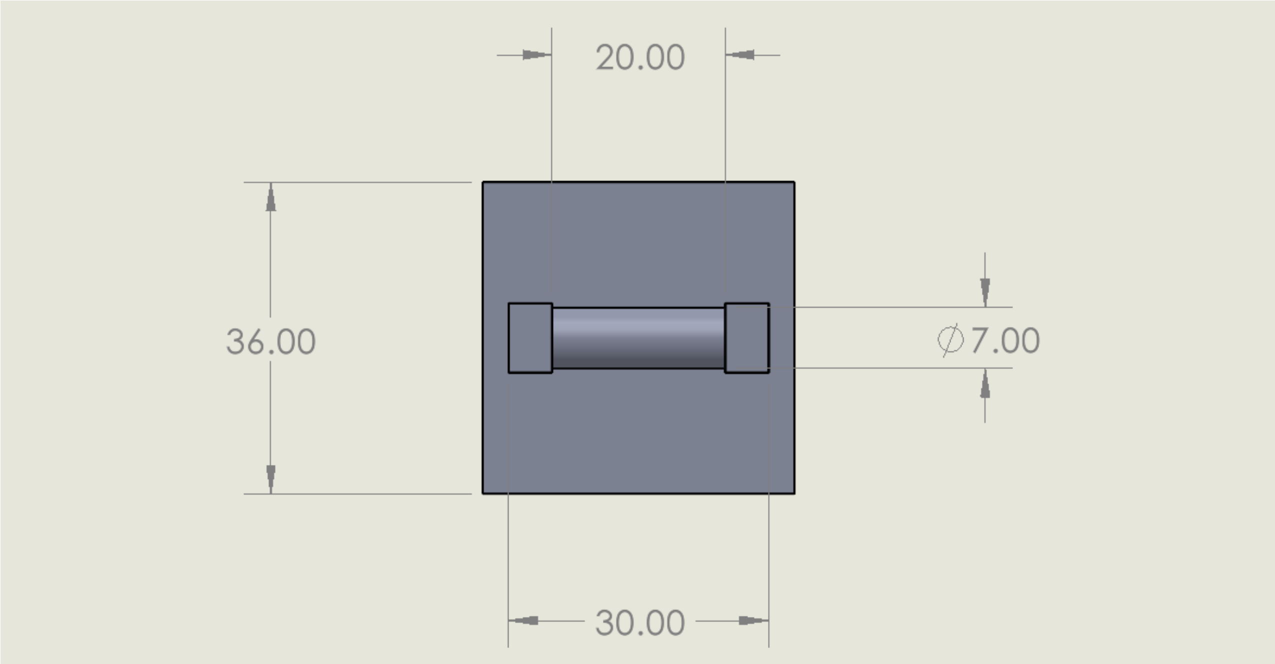


Fig. 3.7: Right View of the mass.

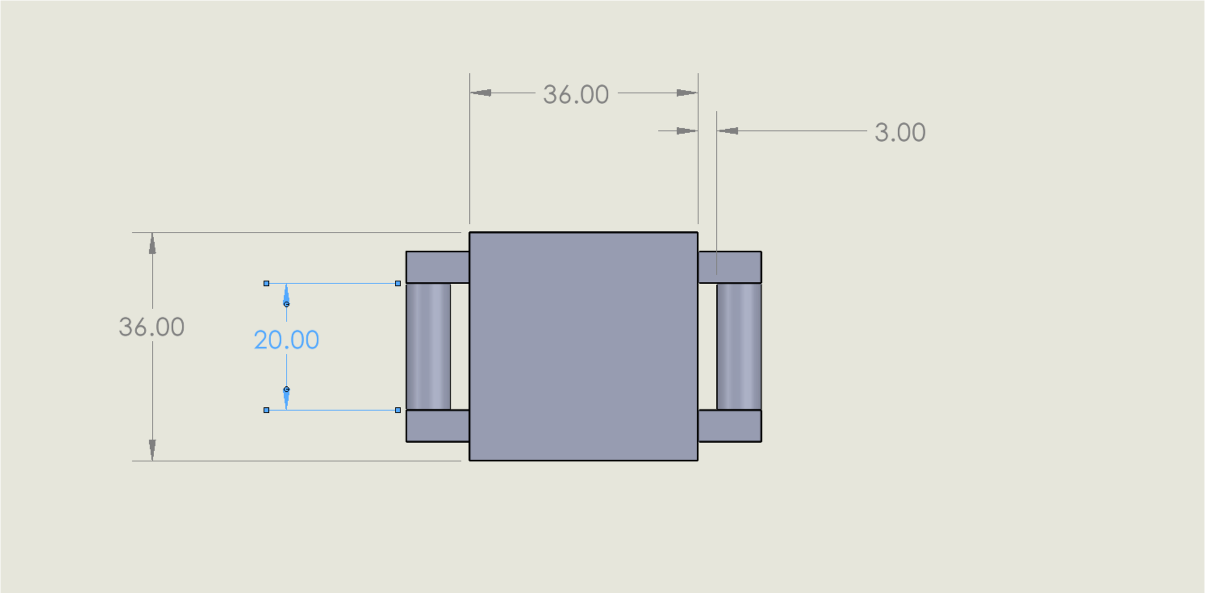


Fig. 3.8: Right View of the Mass.

The mass has a great impact though it′s size is quite bit low in all direction. The hooks that are used here are about 30 mm length altogether and they are enough strong to hold the mass with spring inside the bucket. The mass used here is a cube with 36mm height , width and length in all three directions. 2 hooks are used to hold and give it independence to move in a single direction.

3.1.3 Model 2

SOLIDWORKS Model

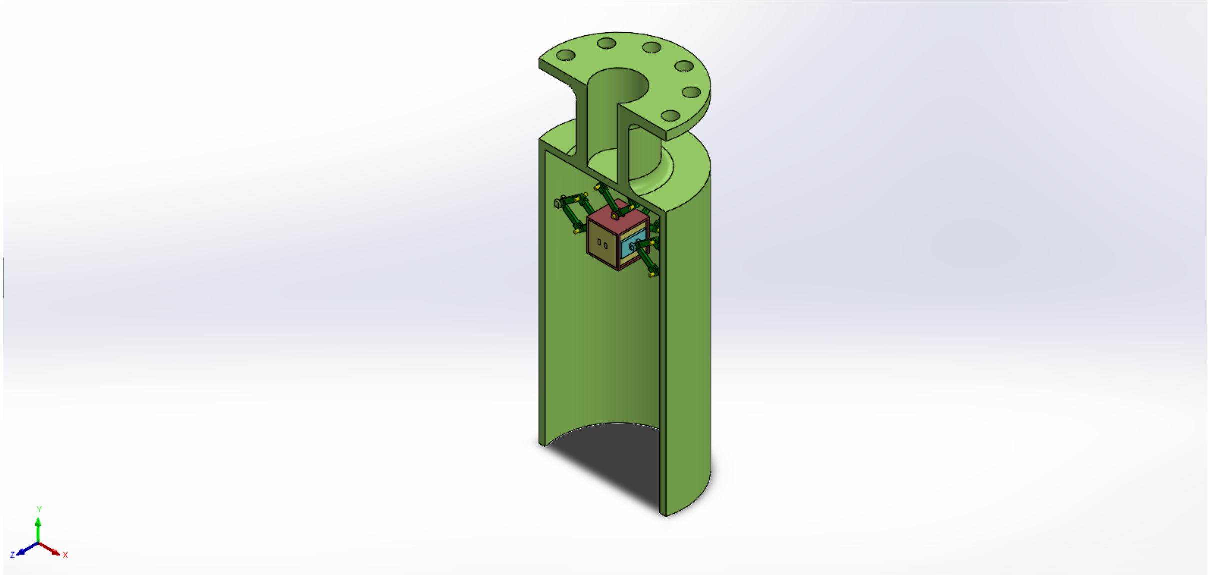


Fig. 3.9: SOLIDWORKS cut view of Second Modified Mass.

This model consist of 6 different parts inside. All these parts are allowed to move in 2 directions. And there is a linkage that used to hold the mass in vertical direction. Different parts are shown here with different colours. Springs are used in vertical direction to allow the movement of this linkage in vertical direction and this allows the movement of mass in X or Z direction.

This modified model consists of about 6 parts

Linkage

SOLIDWORKS Model

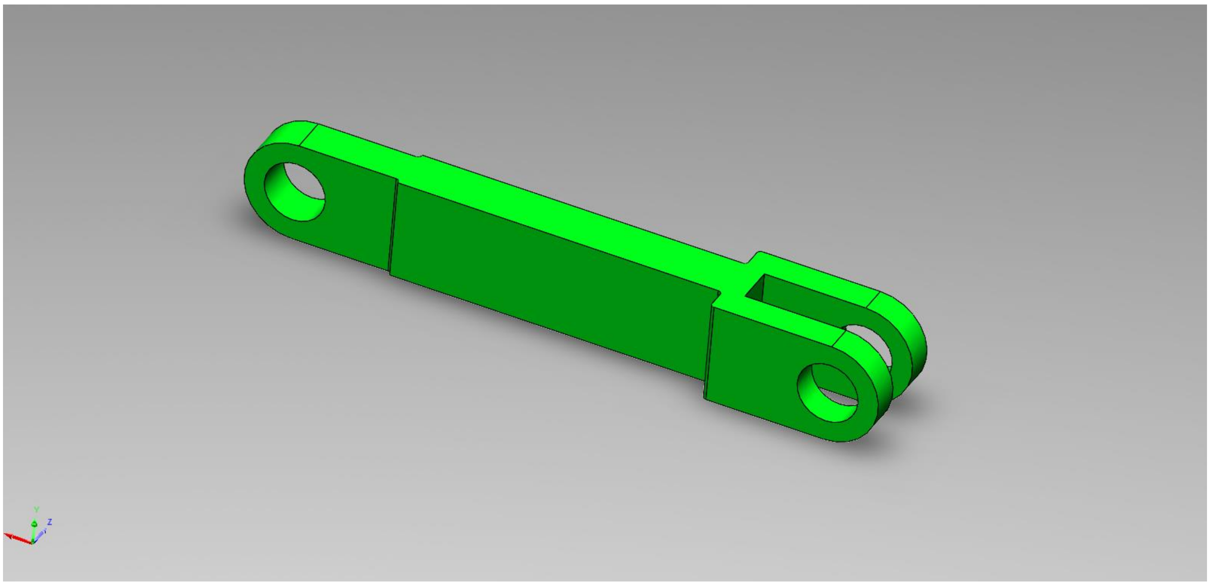


Fig. 3.10: Linkage of modified Design.

There is about 20 this type of linkage used in this modified model. All these linkages are used here are made of mild steel with the same properties of the main bucket.

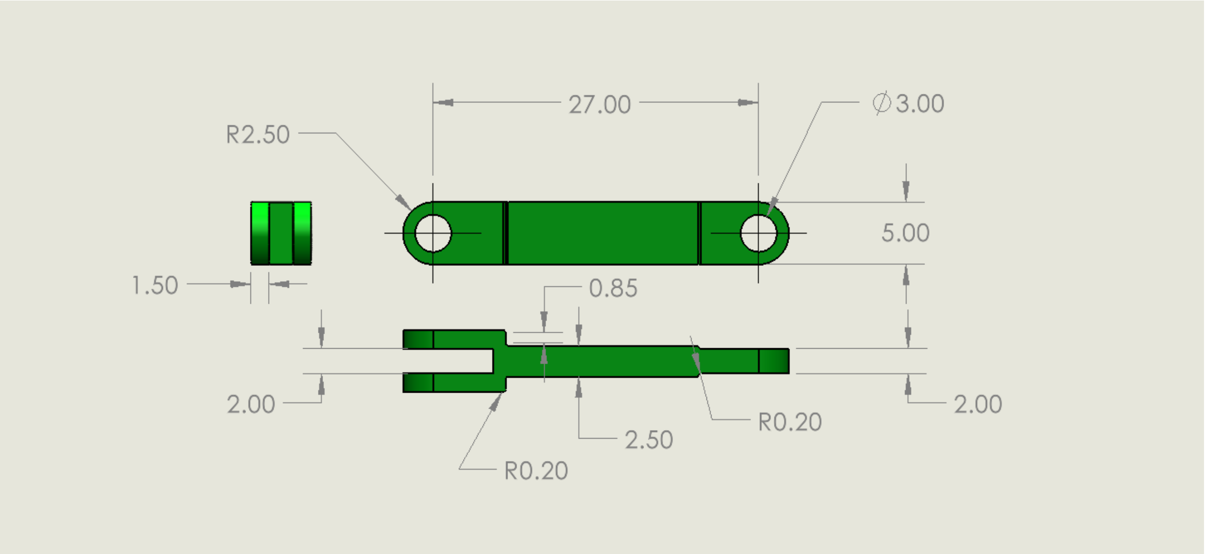


Fig. 3.11: Dimensions of the linkage.

2. Upper Portion of Mass

SOLIDWORKS Model

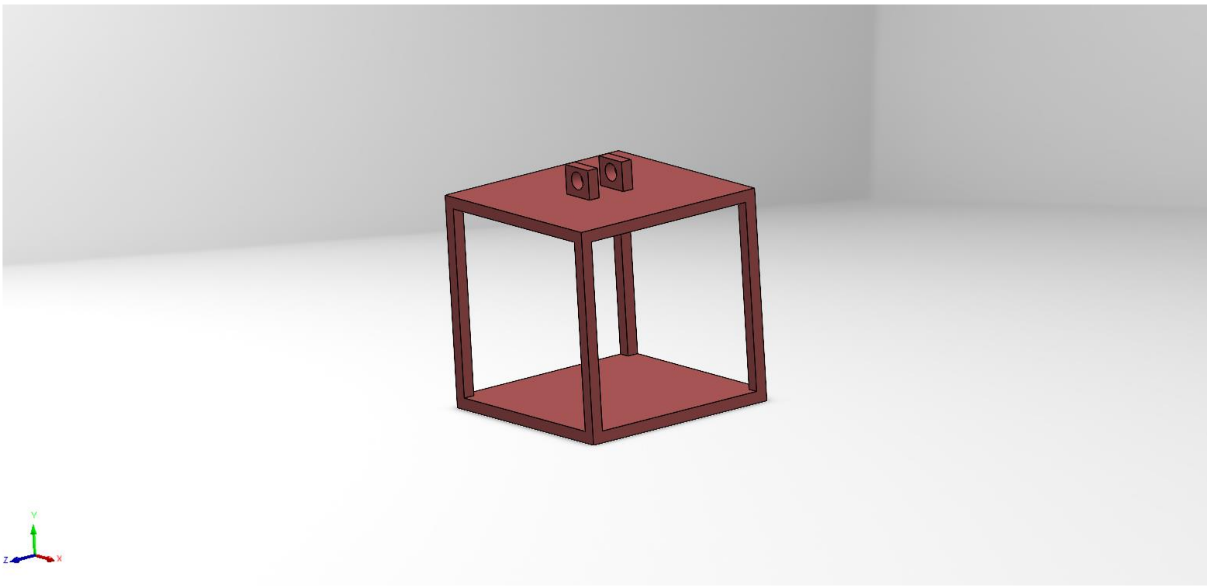


Fig. 3.12: Isometric view of the Upper portion of the Middle Mass.

This mass is used here to hold the other 2 masses that are used to move in X and Z directions. This mass in a hollow and opened in 2 sides. This mass has a hook at the upper portion of the body which allow the linkage to hold this from the top of the bucket.

The main job of this portion is to hold the other 2 masses and give it a friction free movement when the drill bucket work is ongoing

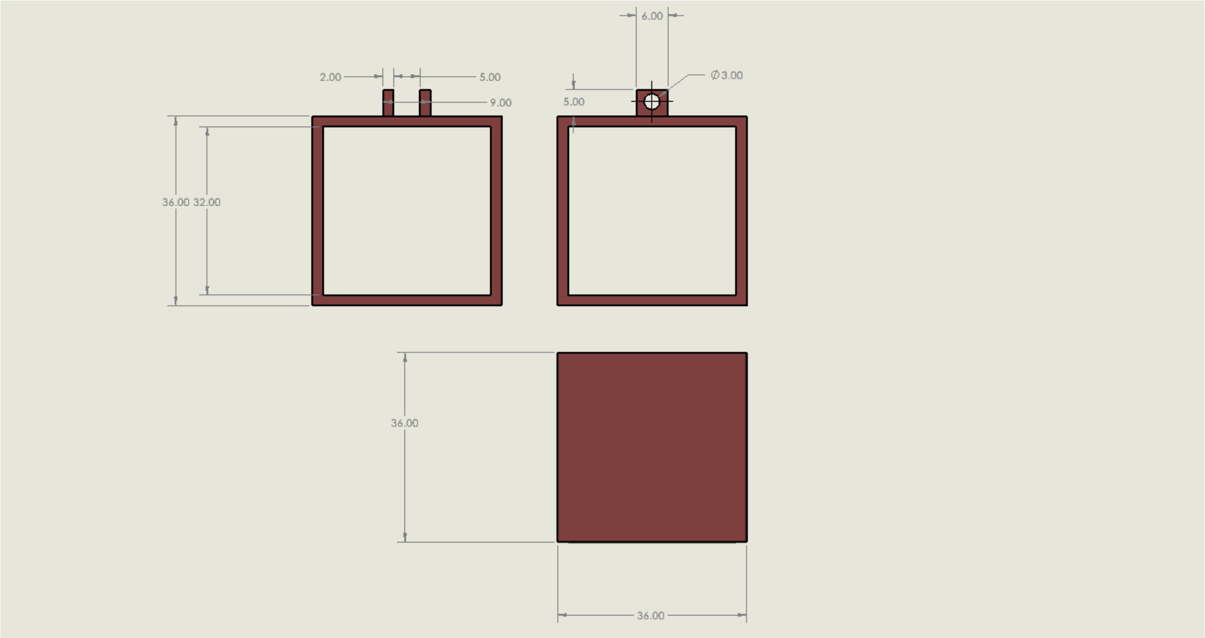


Fig. 3.13: Dimensions of the Upper Portion of the Middle Mass.

3. Middle Portion of Mass

SOLIDWORKS Model

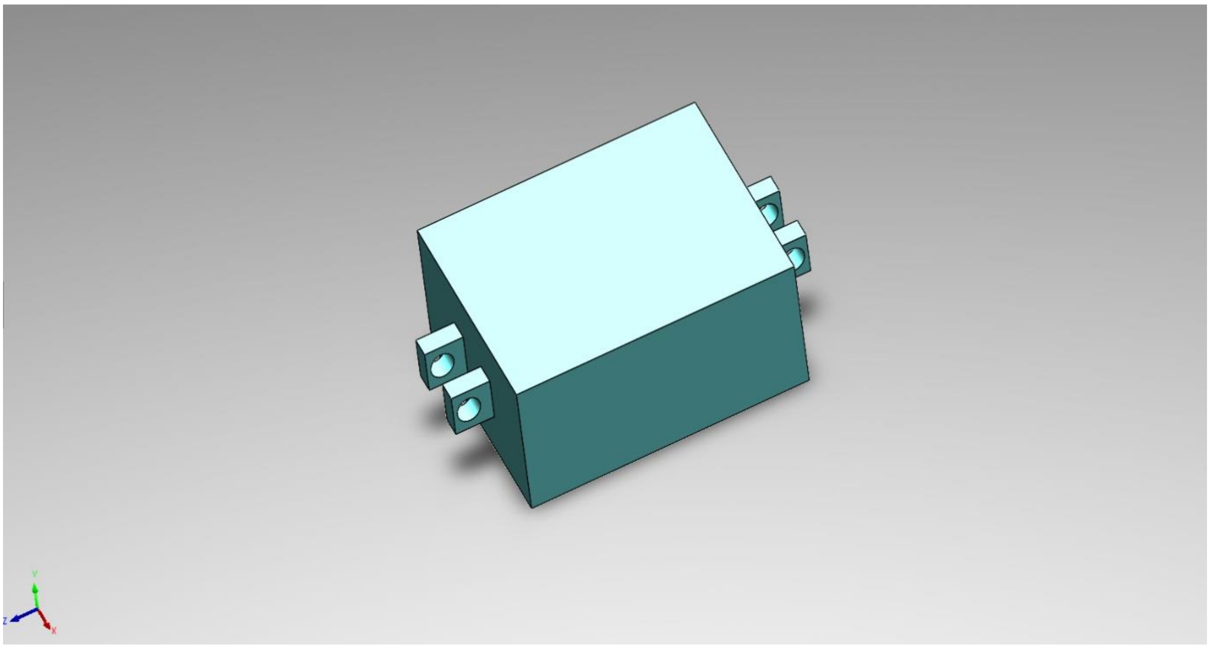


Fig. 3.14: Isometric view of the Middle Mass.

This mass is given a movement of X axis without the vertical movement. This also does not have the permission to rotate or twist.

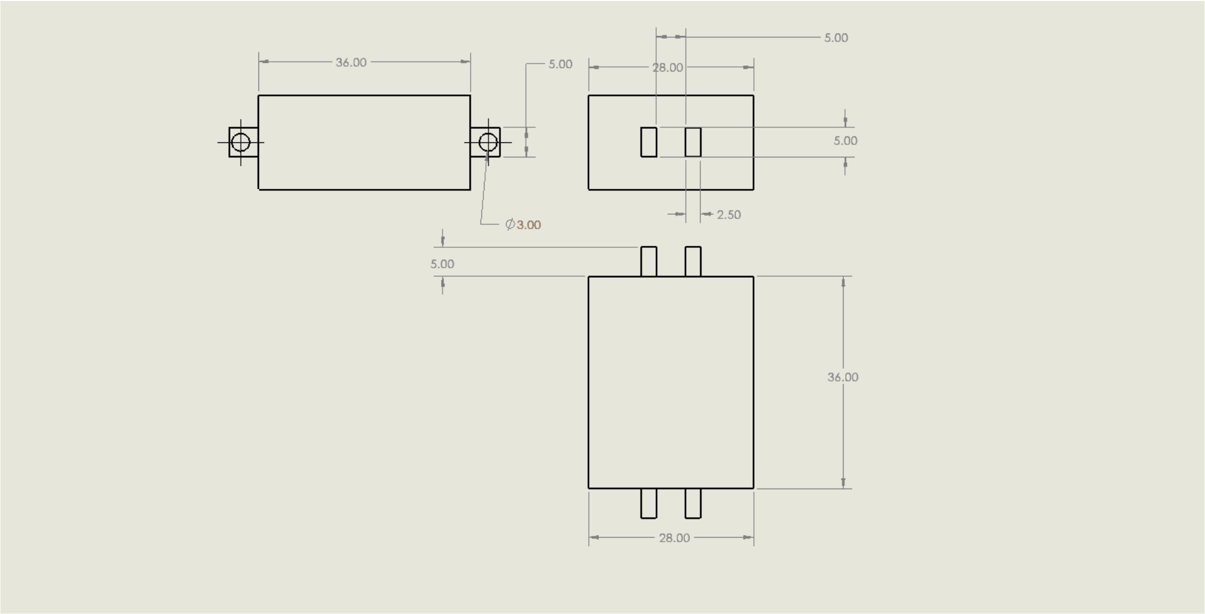


Fig. 3.15 : Dimensions of the middle portion of the Middle Mass.

This model is directly connected with 2 linkage and independent to move in a sigle direction. This is a space between this mass and the yellow one that holds this mass. This one is not directly connected with the mass that is used to hold all the masses and connected with the top of the bucket.

4. Last Portion of Middle Mass

SOLIDWORKS Model

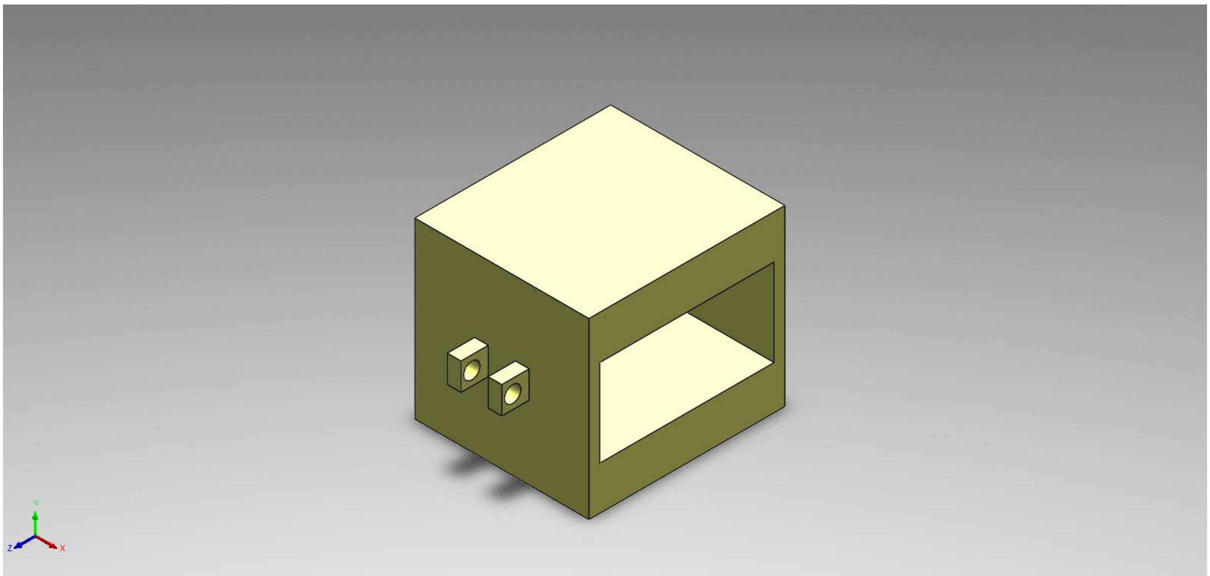


Fig. 3.16: Isometric View of the Last Portion.

This mass situated inside the red mass. This mass directly connected with the red one that hold the total system. Moreover, this holds the sky color one that has a directional motion.

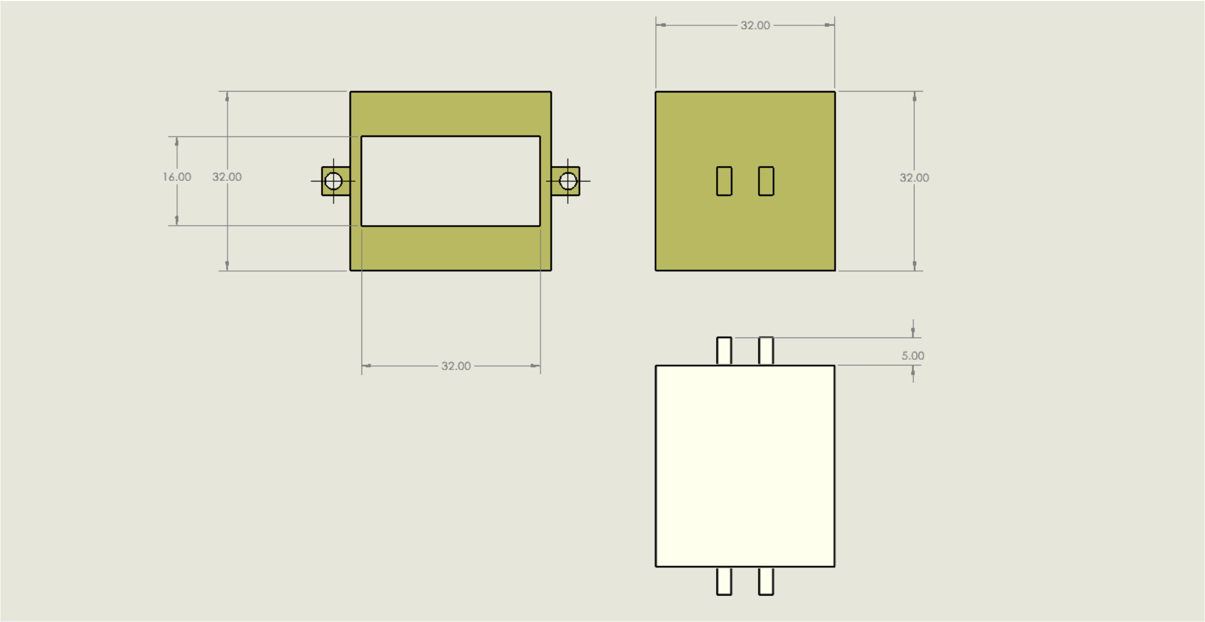


Fig. 3.17: Dimensions of the Last Portion of the Mass.

This mass has a space about 5mm that allow the sky one and the yellow one to move without getting stopped by each other. This mass has also the ability to move in a single direction having a mass inside it which moves totally in a different direction.

5. Pin

SOLIDWORKS Model

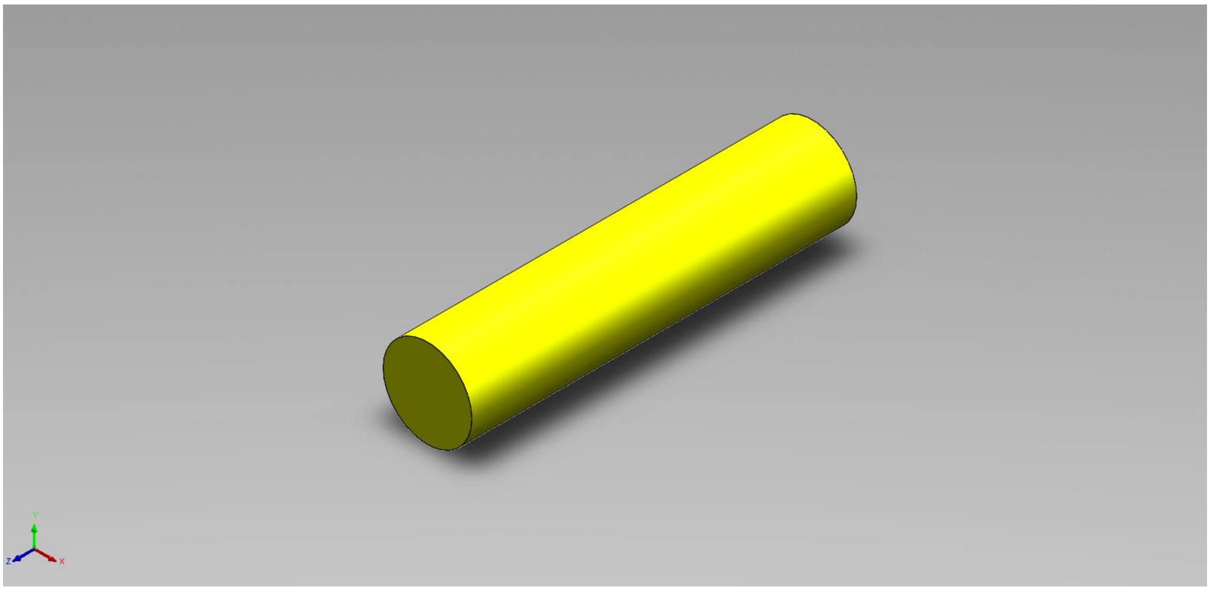


Fig. 3.18: Isometric View of the Pin.

This pin is used to hold 2 linkage together. This used to made by mild steel.

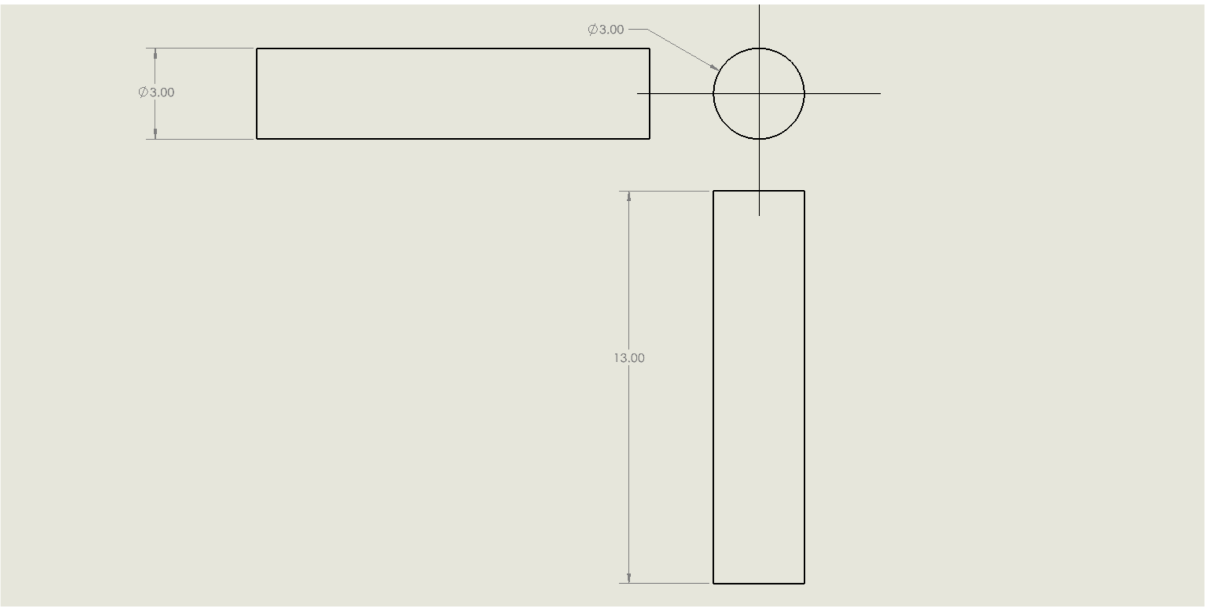


Fig. 3.19: Dimensions of the Pin.

3.1.4 Model 3

Solidworks model

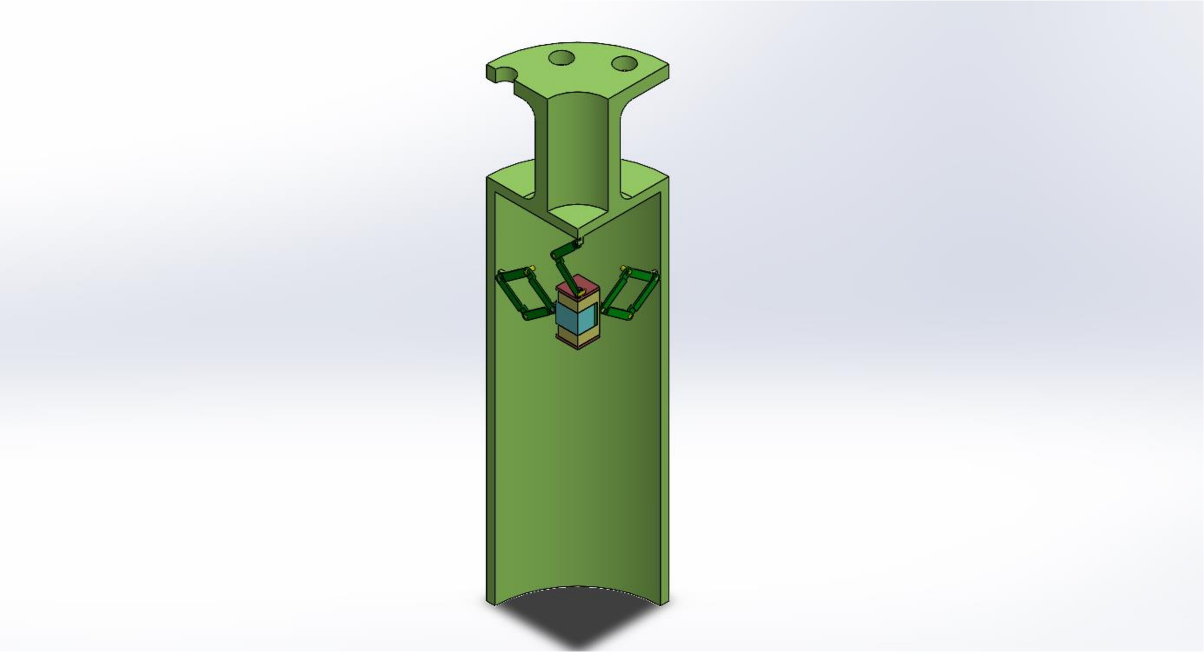


Fig. 3.20: Modified model with rubber attachment.

Here, The model is almost same but as mentioned earlier, there is a space between to moving masses in the previous model. In this modification, we use rubber to fillip the gap. And this small modification of using rubber gives a great impact on vibration mitigation as we see in literature review.

Modified Model with 7 parts: Rubber Part

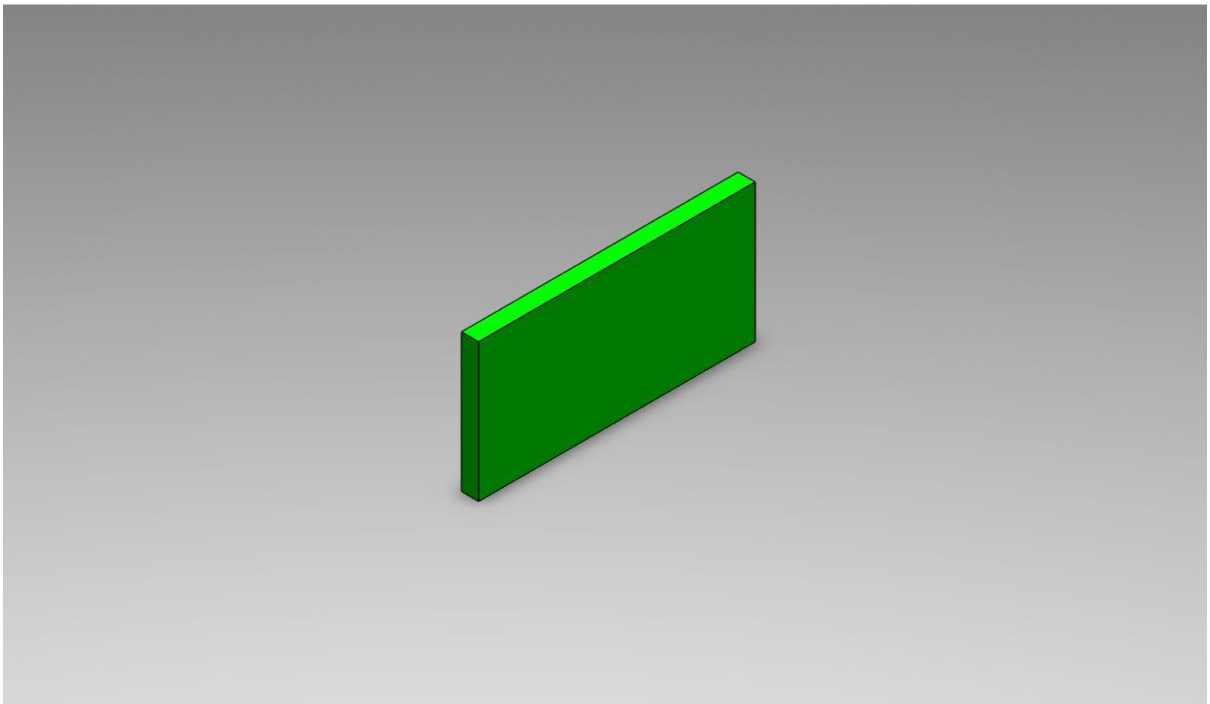


Fig. 3.21: Rubber part.

The piece of rubber is very slick and green in colour as when designed in solidworks

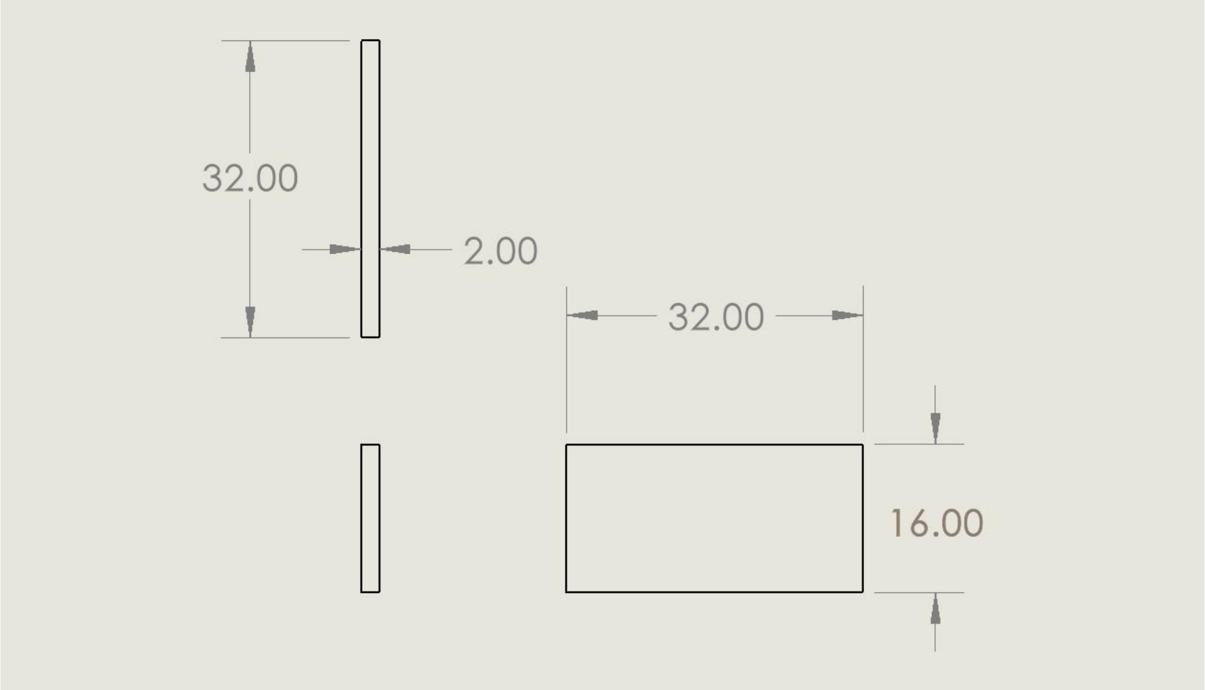


Fig.3.22: Rubber Material Dimensions.

CHAPTER 4

Simulation

4. Simulation (Modal and Transient)

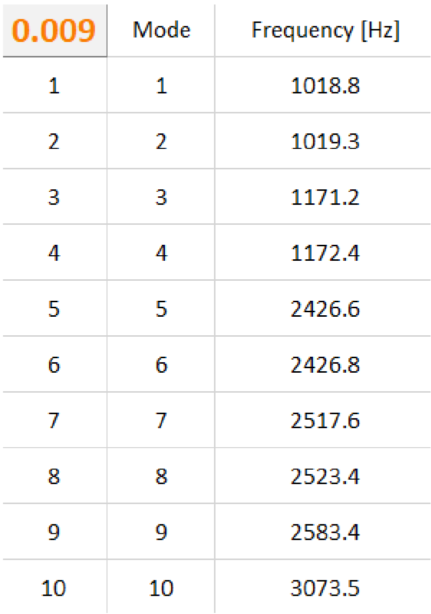
4.1 Modal Analysis

Modal Analysis in done when natural frequency is needed to find out with different mode shapes. But before that a set of things needs to defined. The place where the support will be, the meshing element size, etc.

4.1.1 Element Size

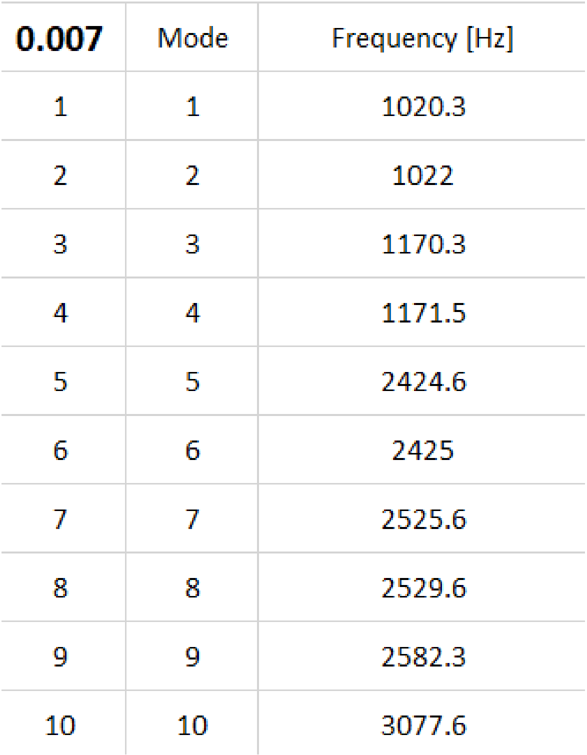
The meshing element size is a great factor to define the accuracy of the model. With accurate and more perfect meshing condition, the result will be more accurate and perfect for use. As simulation result is computer generated, so a validation is required to find out if the model is actually has any real impact or not.

Here we generate frequency with different element size and the element size which comes with more accuracy is 9mm.



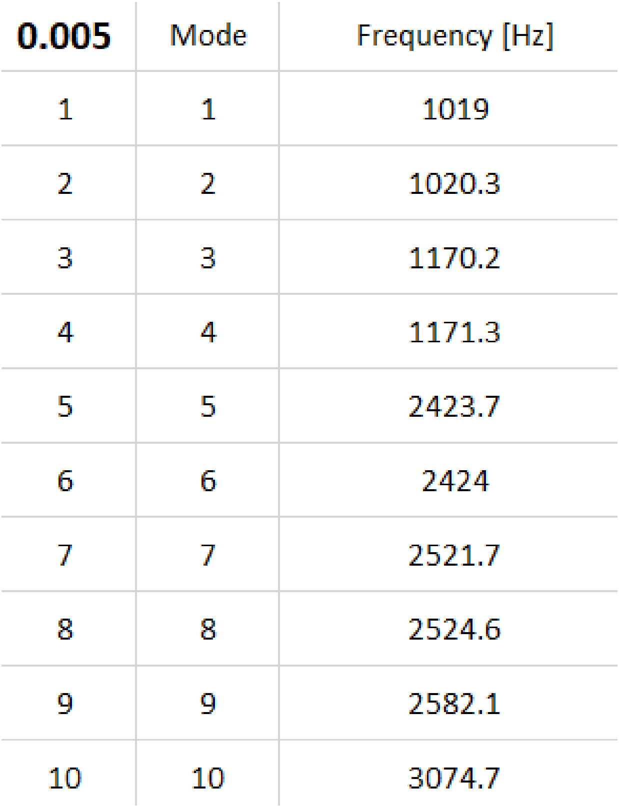
0.009	Mode	Frequency [Hz]
1	1	1018.8
2	2	1019.3
3	3	1171.2
4	4	1172.4
5	5	2426.6
6	6	2426.8
7	7	2517.6
8	8	2523.4
9	9	2583.4
10	10	3073.5

Fig.4.1: Frequency at 9mm Meshing element size



0.007	Mode	Frequency [Hz]
1	1	1020.3
2	2	1022
3	3	1170.3
4	4	1171.5
5	5	2424.6
6	6	2425
7	7	2525.6
8	8	2529.6
9	9	2582.3
10	10	3077.6

Fig.4.2: Modal Freq. with element size 7mm.



0.005	Mode	Frequency [Hz]
1	1	1019
2	2	1020.3
3	3	1170.2
4	4	1171.3
5	5	2423.7
6	6	2424
7	7	2521.7
8	8	2524.6
9	9	2582.1
10	10	3074.7

Fig.4.3: Modal Freq at element size 5mm.

4.1.2 Fixed Support

Fixed support is given to the top of the flange of the drill bucket which defines by the holing point of the drill string.

The violet colour here defines the surface of fixed support. The point of the drill bucket attached to the drill string. In modal analysis, fixed support is given to find out the natural frequency of the modal analysis. It also helps to find out the bending and twisting condition of the bucket.

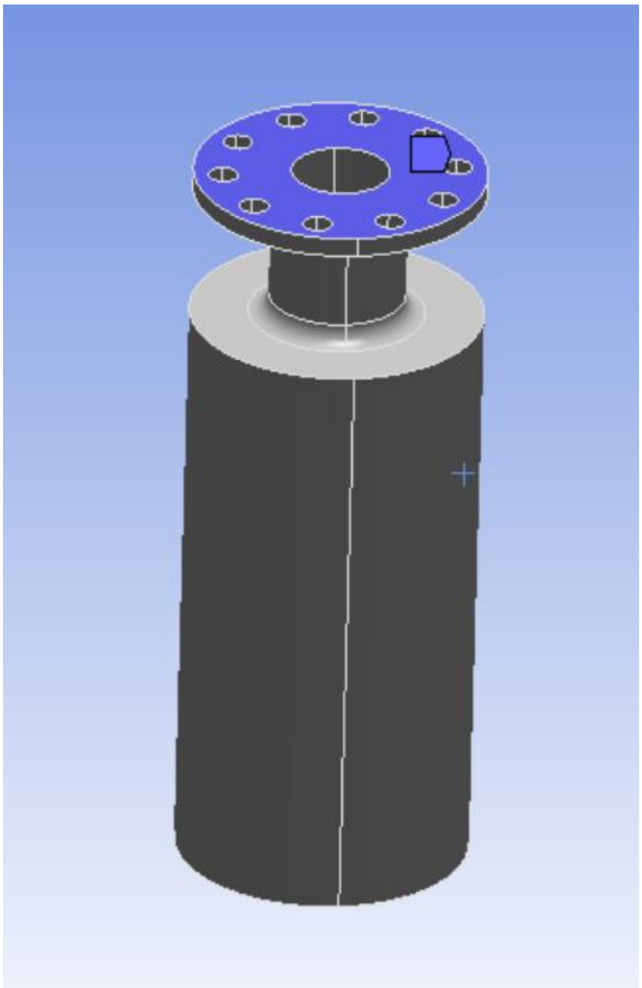


Fig.4.4: Fixed support surface area in modal analysis of drill bucket.

4.2 Transient Analysis

Transient analysis is done to find out the directional deformation which mitigates with time. Here, 2 directional deformation transient analysis is done to find out how fast the deformation is mitigating. A force is given as pressure to the both side of the drill bucket wall which gives a good representation of soil pressure when the drilling operation is ongoing.

4.2.1 Pressure

Pressure is given about 1 milisecond of time at the beginning of the 1 second analysis period. It is given on the both side of the bucket wall. It potrays that the soil pressure given by the earth when the drilling rig is operation under the soil.

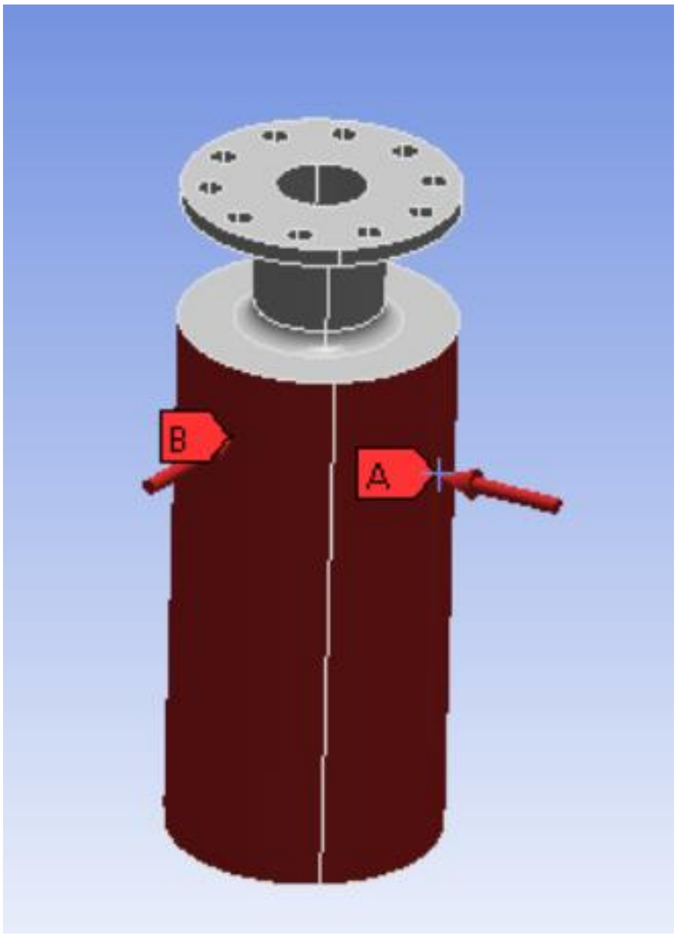


Fig.4.5: The 500 Pa pressure on the side wall of the bucket.

Time Steps and Pressure		
Step no.	Time (second)	Pressure (pascal)
1	0	0
2	.001	0
3	.002	500
4	.003	0
5	1	0

Table 4.1: Table of Force at different times for transient analysis.

Here, from the table we can say that the transient analysis is done for about 1 second of total time. The force which is about **500 pascal** is given at 0.002 seconds and finishes before 0.003 seconds.

A graph is generated to give us a visual representation of the force giving time.

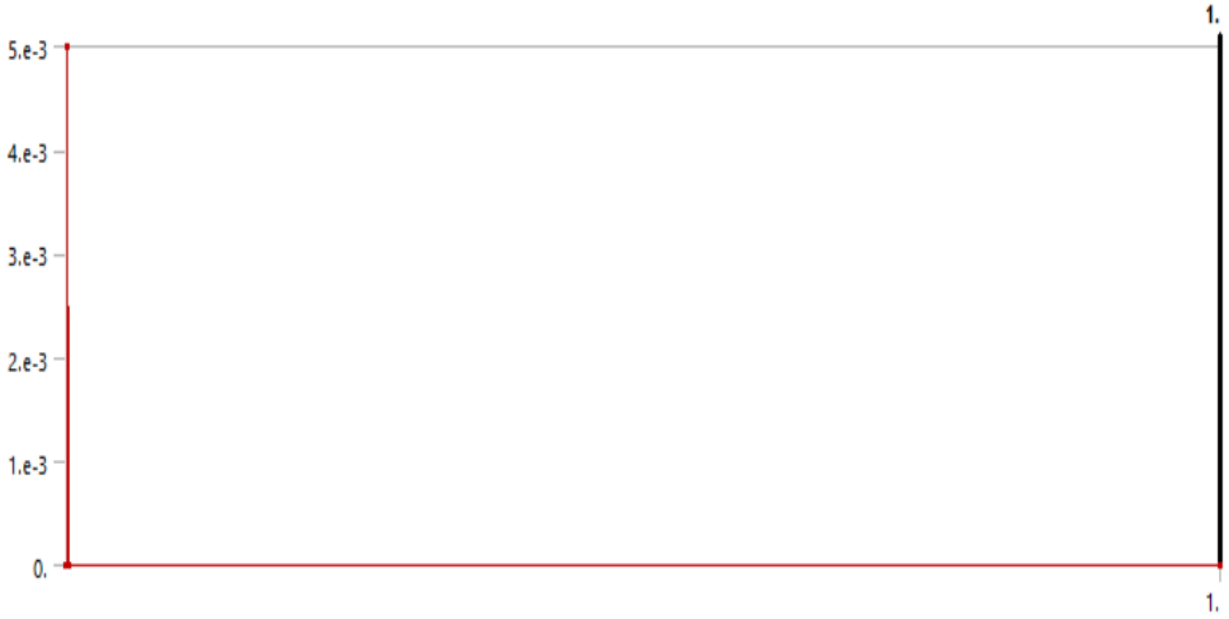


Fig.4.6: Graph of Pressure with respect to Time.

4.3 Model′ s Simulation Setup

A similar property containing spring is used here in all three models with the same damping ratio and stiffness.

The properties of the spring are taken from a company′ s handbook.

The property table is given below.

Spring Properties	
Longitudinal stiffness	11000 N/mm
Longitudinal Damping	0.3 N. s/mm

Table.4.2: Spring properties table.

For model 1, A two Spring setup is used.

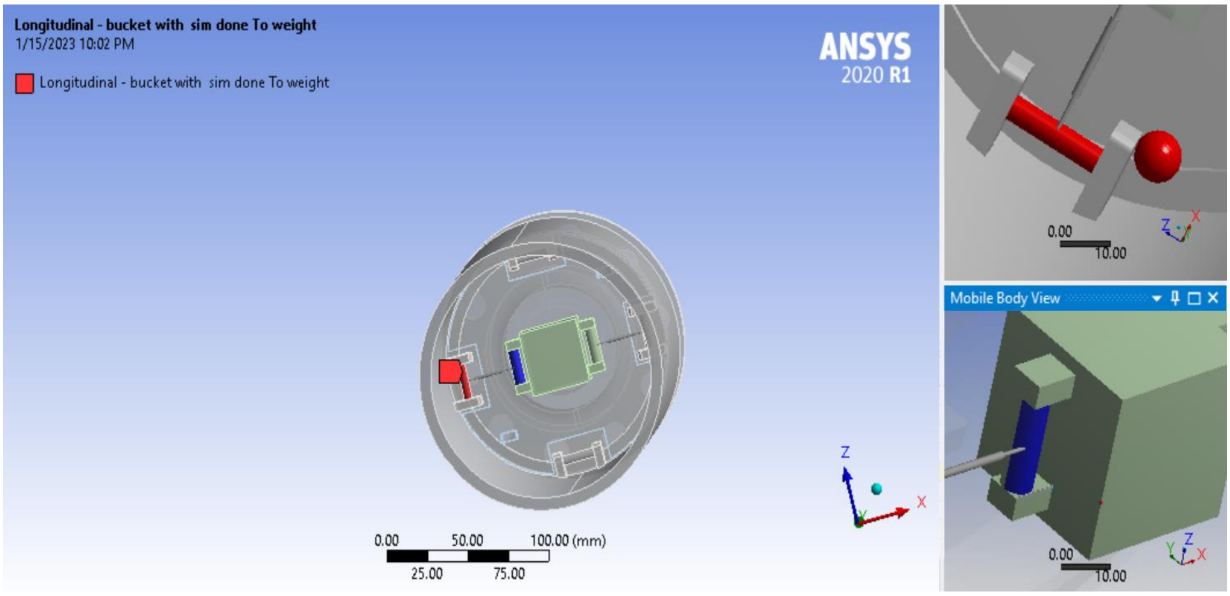


Fig.4.7: 1st model with 2 spring setup.

For Model 2 & 3

The 5-spring setup is used to simulate the model. The main part of the model is connected with the bucket with about 5 spring, 4 for horizontal direction and one for vertical direction.

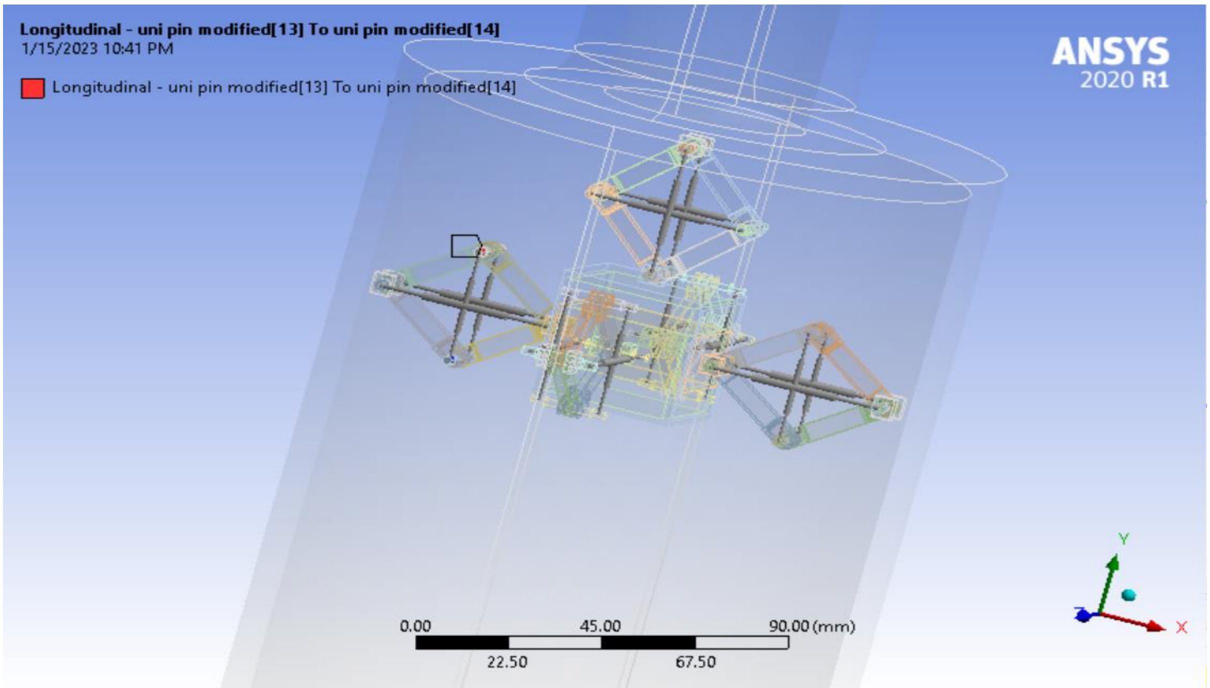


Fig.4.8: 5 Spring setup.

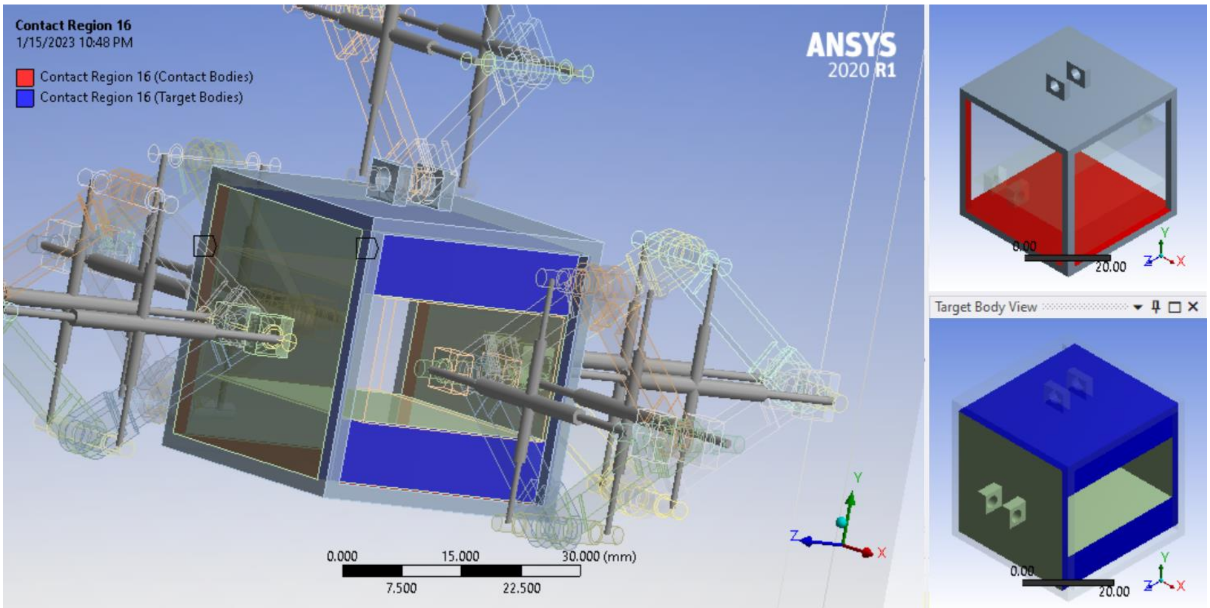


Fig.4.9: Spring setup in 3 direction.

4.3.1 Rubber

Rubber is used in model 3 to fill-up the gap of free space. This introduces a great impact on the result of the model′ s modification. The rubber property is not defined in the Ansys workbench.

The rubber properties used here is taken from a renowned company′ s handbook.

Rubber Properties	
Density	960 Kg/m^3
Young's Modulus	81545 Pa
Poisson's Ratio	0.499
Bulk Modulus	1.359E+07 Pa
Shear Modulus	27200 Pa
Tensile Yield Strength	1.288E+07 Pa

Table 4.3: Properties of Rubber.

CHAPTER 5

Result & Discussion

5.1 RESULT

5.1.1 Modal Analysis

Modal Analysis done only for the Fresh bucket for the validation purpose. Again for the smooth and accurate result of transient analysis, it is necessary of the presence of modal analysis before transient analysis.

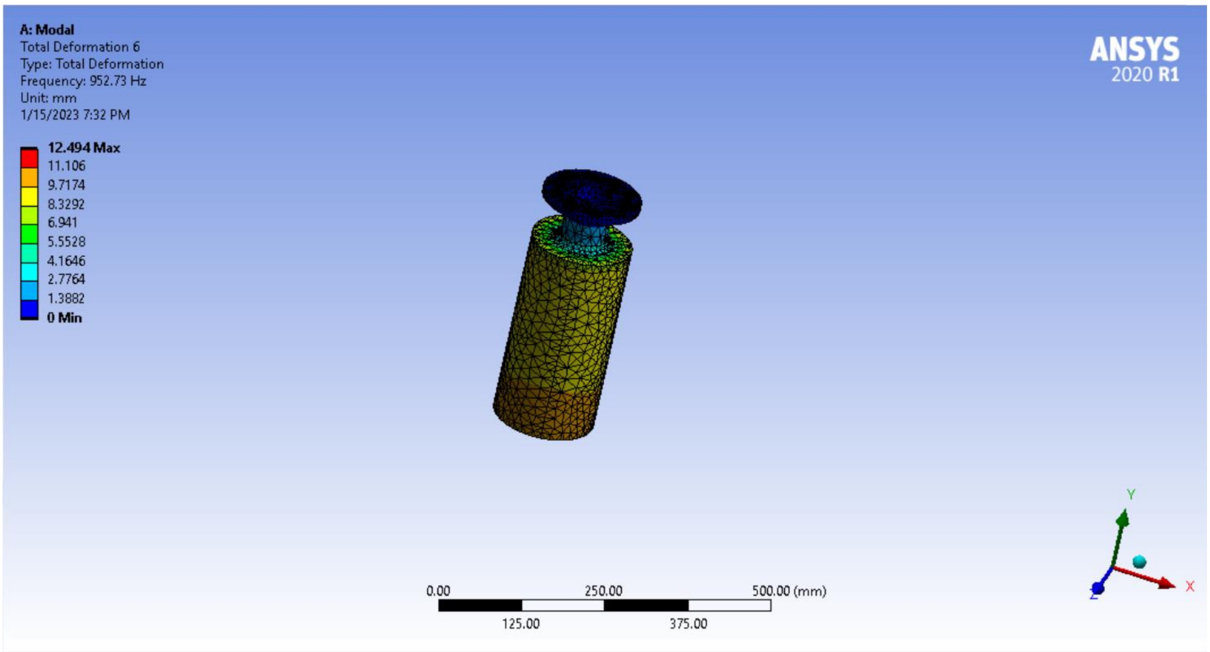
In modal analysis, we extract 12 modal frequencies of the model. The frequencies are given below.

Modal Frequency	
Mode	Frequency
1	222.32
2	222.45
3	918.6
4	918.89
5	952.73
6	1123.9
7	2097
8	2097.5
9	2176.4
10	2177.9
11	2548.4
12	2550.2

Table 5.1: Modal Frequency of Fresh Bucket model designed in Solidworks.

Modal frequencies describe the bending and twisting condition of the bucket model.

Here are some frequency conditions is given.



A: Modal
Total Deformation 6
Type: Total Deformation
Frequency: 952.73 Hz
Unit: mm
1/15/2023 7:32 PM

Fig. 5.1: Mode shape of Plain Bucket (Y-axis Rotation) at 952 Hz.

At this mode shape, it can be said that the bending is happening in the vertical direction. The Y directional deformation is seen here.

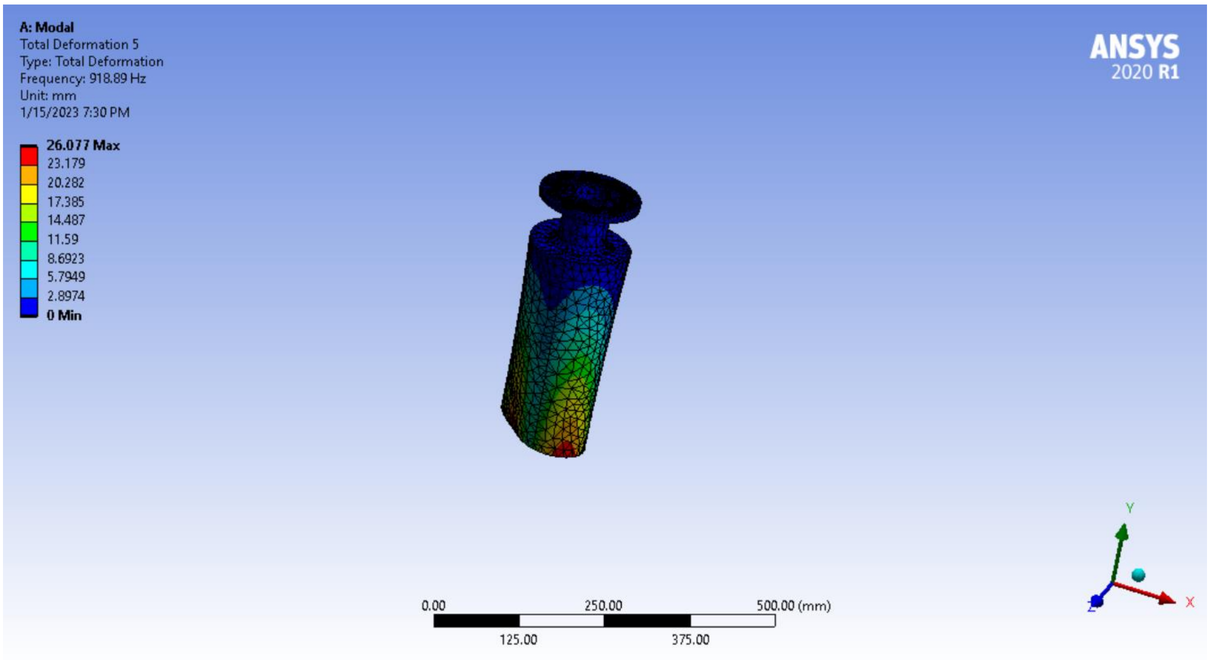


Fig.5.2: Mode shape (Z direction bending) at 918 Hz.

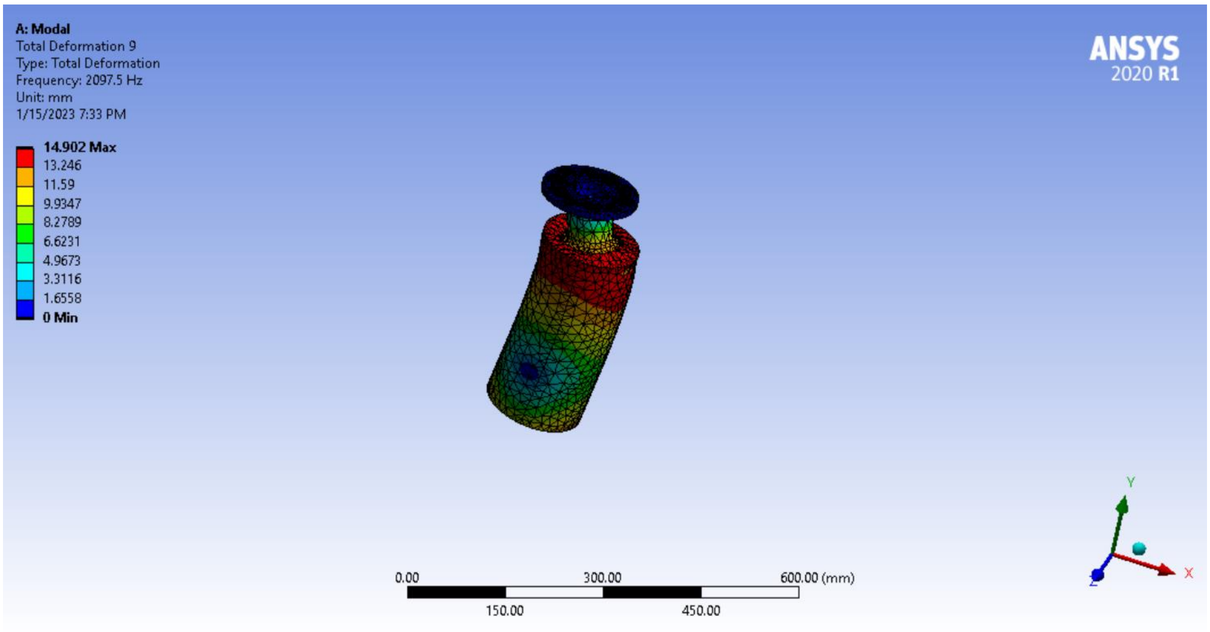


Fig. 5.3: Mode Shape of Plane Bucket (X-Axis bending) at 2097 Hz

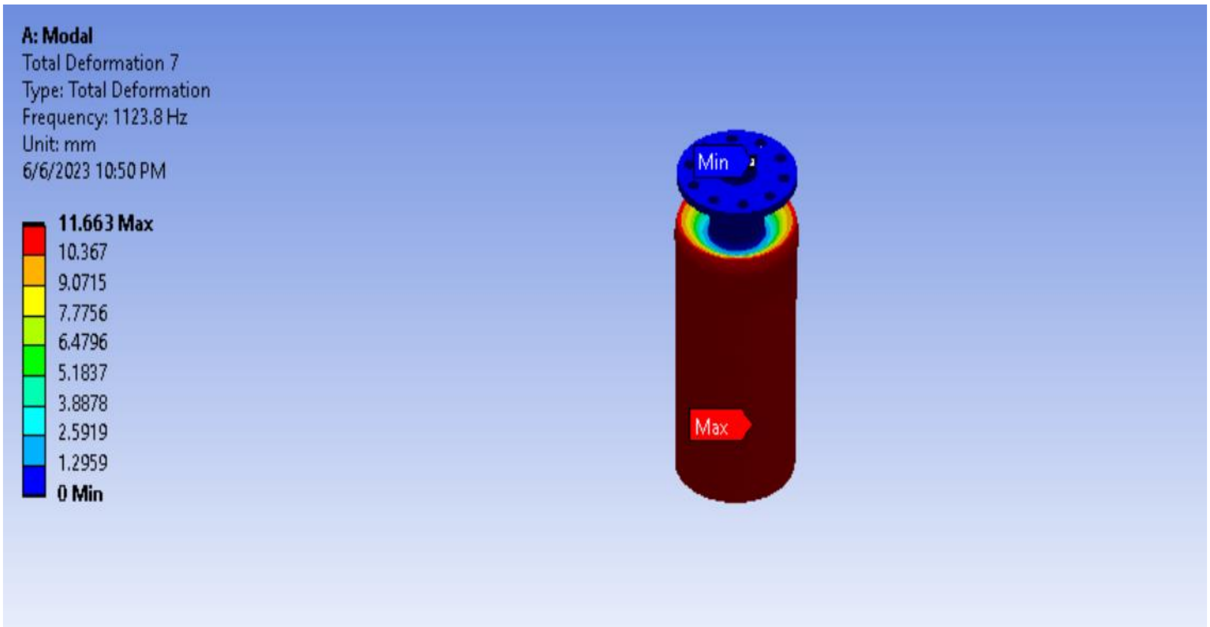


Fig. 5.4: Mode shape of Plain bucket at 1123 Hz (Y axis Rotation)

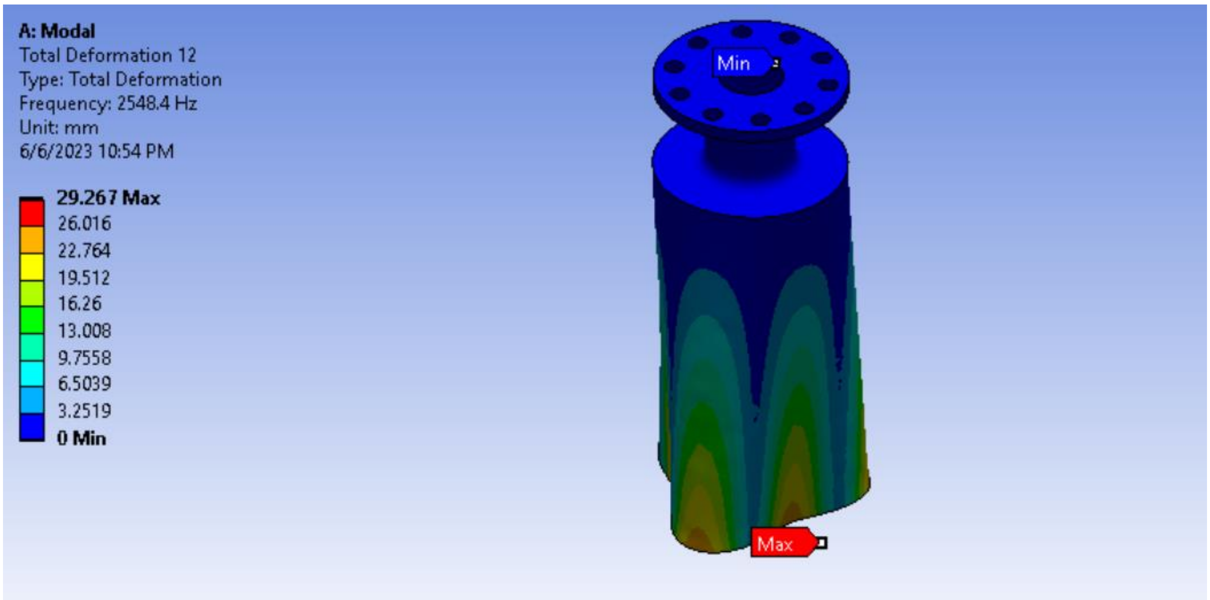


Fig. 5.5: Mode Shape of Plane Bucket (Z-Axis bending) at 2548 Hz

5.1.2 Transient Analysis

We analyze the transient analysis result to find out which model works well and mitigates the deformation with time. 5-pascal force is given to the side wall of the bucket and that is applied for 1 millisecond. The red line shows us the maximum bending in a respective direction.

5.1.2.1 Results of transient analysis for the plain bucket

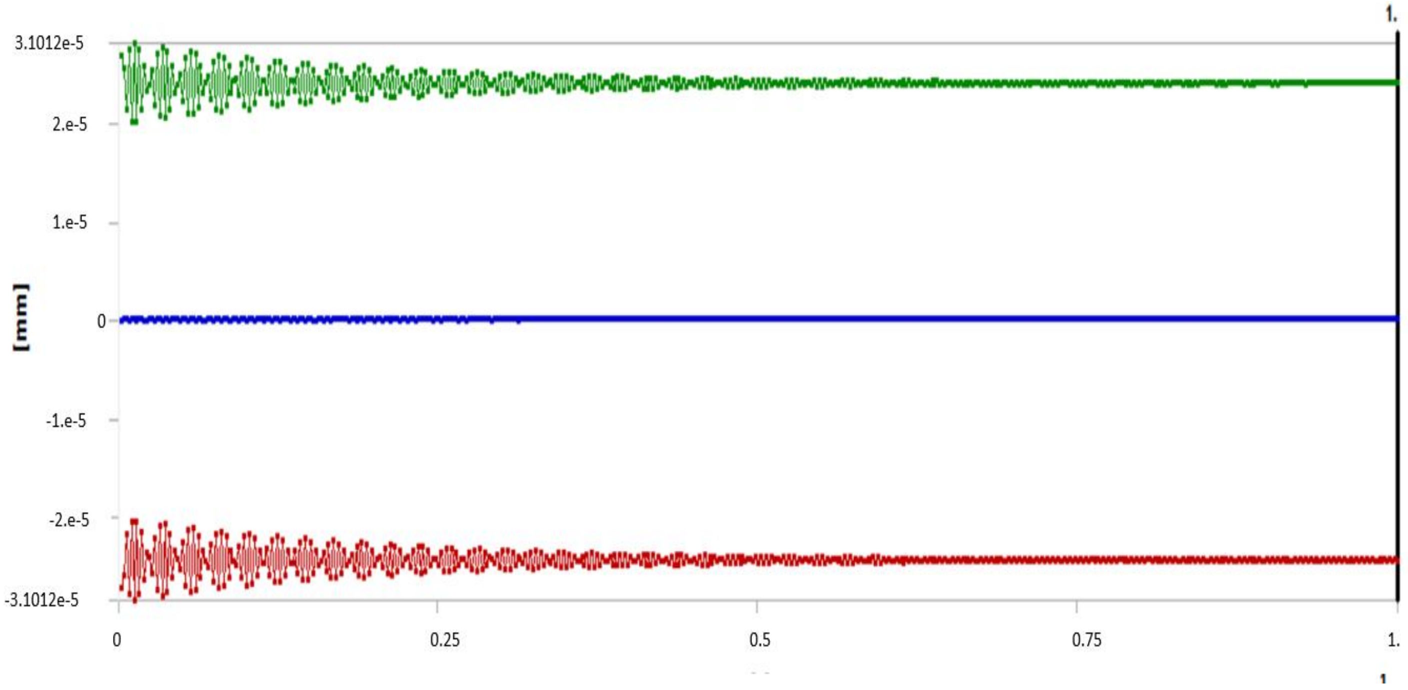


Fig.5.6: Bending in the X direction.

Here, we can see that the after given the pressure for 1 millisecond of time, the deformation happens. The red line pointing out the maximum deformation point and the Green one for the minimum deformation point. And the blue one pointing out the average scenario of deformation. This result is for the X directional bending in Plain bucket model without any attachment. From here, we can say that the deformation will almost mitigate after 0.65 Seconds. A little amount of left after that one.

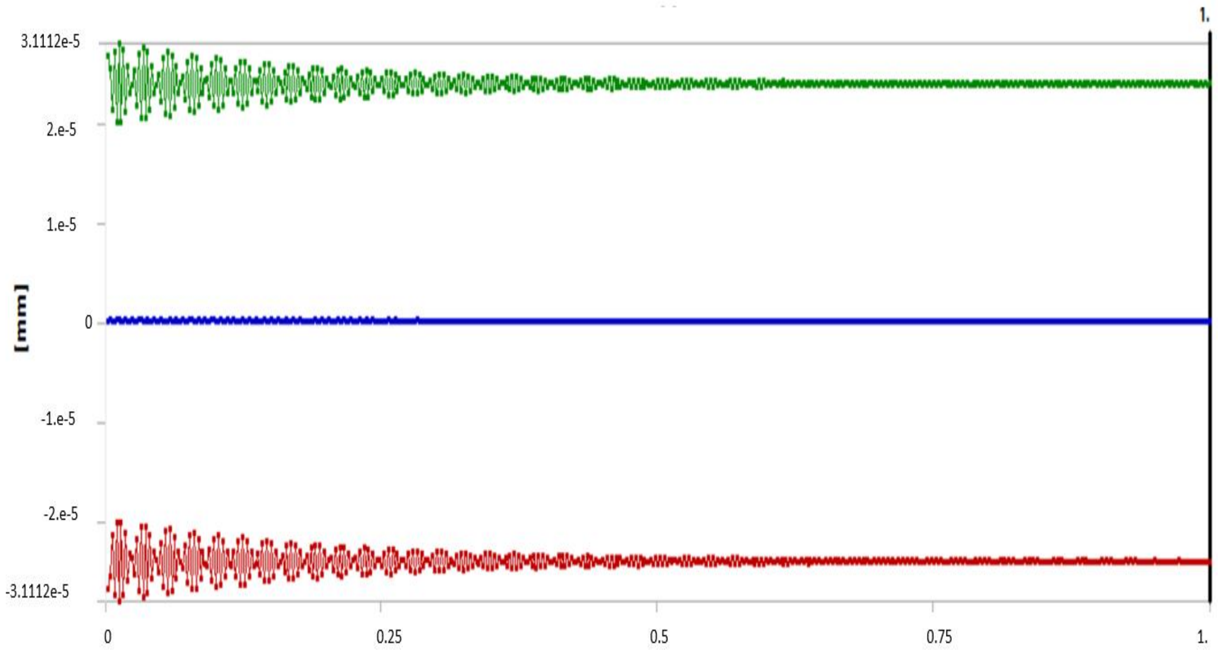


Fig.5.7: Bending in Z Direction.

This one is for the plain bucket in the Z direction. This portrays a different result here, a bit different than X directional one. Here the deformation mitigates after 0.78 seconds.

5.1.2.2 Results of Transient Analysis of Model 1

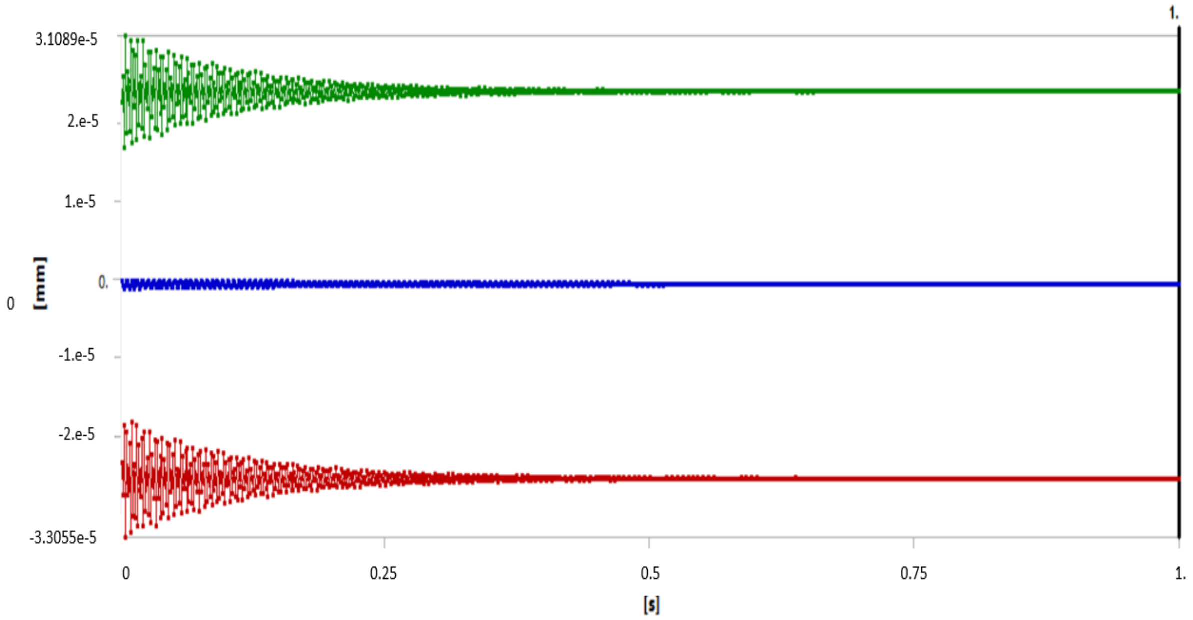


Fig. 5.8: Bending in X Direction.

In this model, we use a mass that only can be moved in X direction. So X directional deformation is taken into account. The amount of pressure and the point is same like the one we did in case of plain bucket. here, the result is still very good. The deformation mitigates just before 0.5 seconds while in the case of plain bucket, it takes about 0.75 seconds to mitigate.

5.1.2.3 Results of Transient Analysis of Model 2

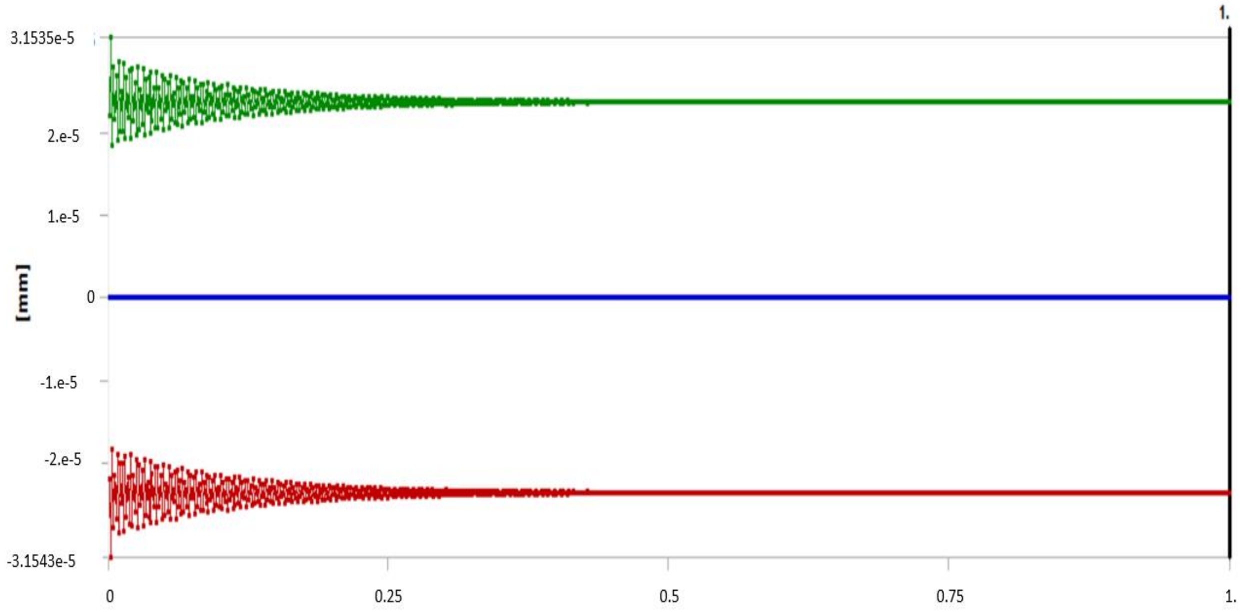


Fig. 5.9: Bending in the Z Direction.

This result is for the model 2 where a several amount of spring is used. A two mass setup is used where each mass can move freely in a single direction. A cage type structure is there is stop the movement of the masses in vertical direction. Here the result is quite prominent. The deformation mitigates about 0.4 seconds. It is even .005 seconds better that the last one.

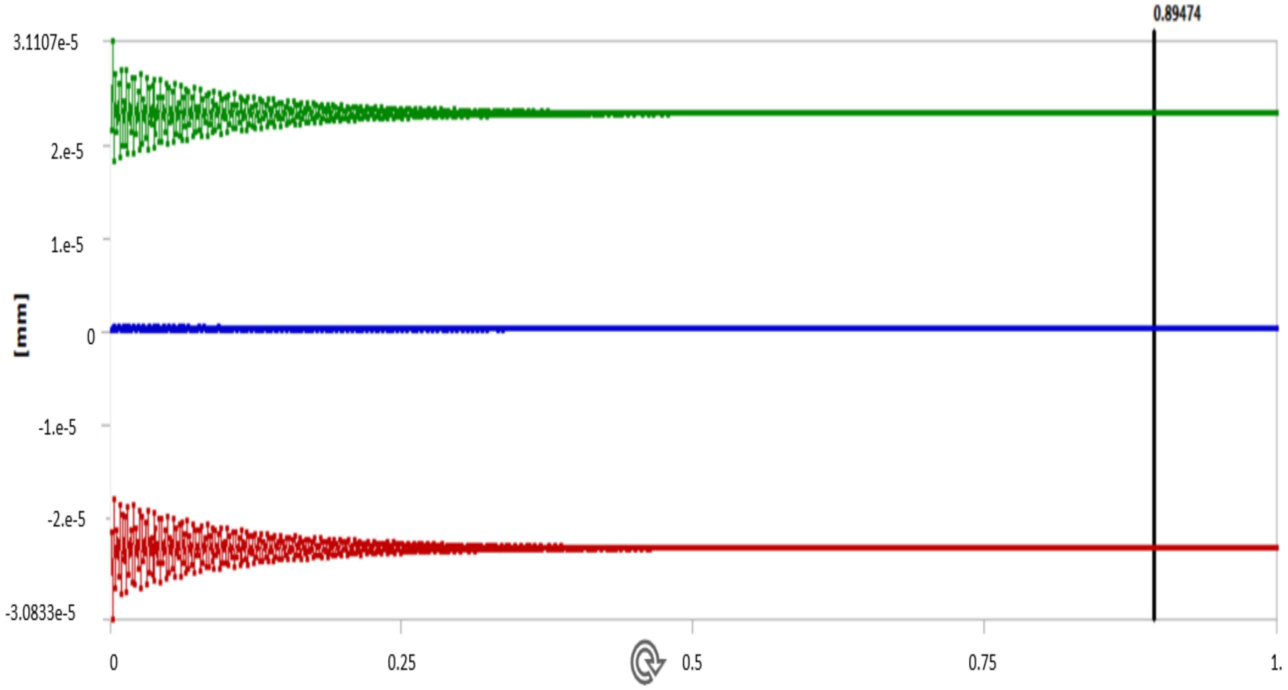


Fig. 5.10: Bending in the X direction.

This one is for the same model, the model 2. This x directional deformation also gives the same as the Z directional one is giving. A slight better result than model one in X direction.

5.1.2.4 Result of Transient analysis of Model 3

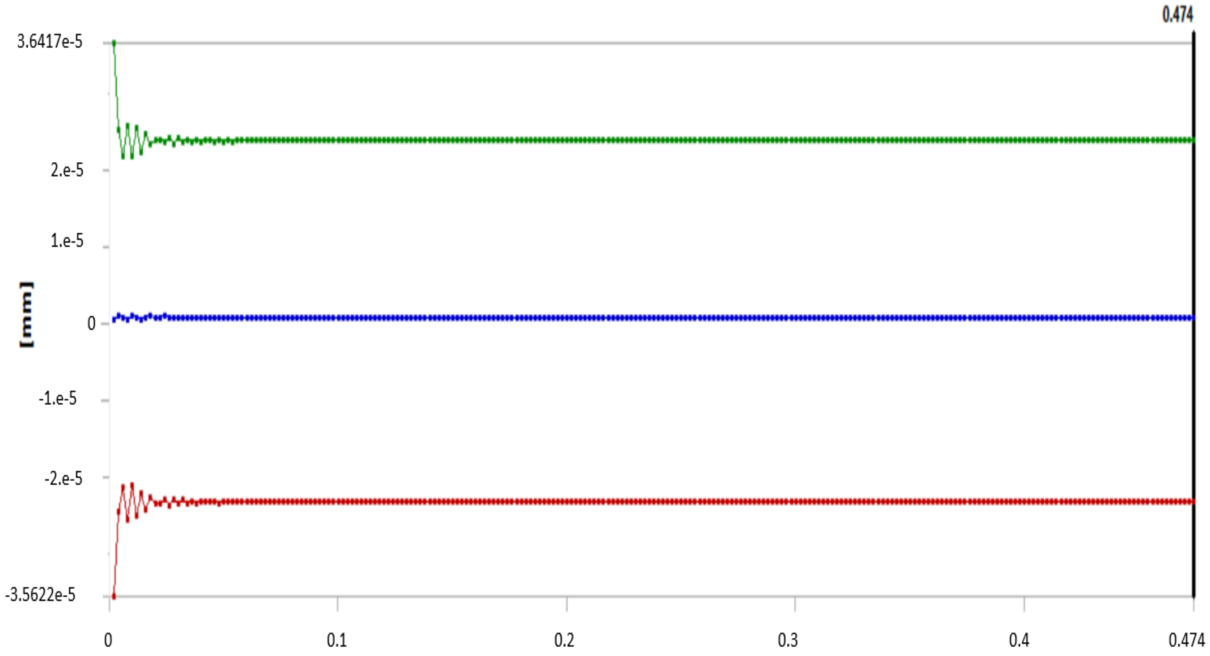


Fig.5.11: Bending in X axis of Model 3.

Now this one a totally different scenario. In the last 2 Modified model, we tried to use mass setup in the middle to mitigate the deformation but here we use a rubber inside the model. And the result is quite shocking. The time steps are always between 1 seconds but after using the rubber, the model mitigates the deformation so fast that it does not even take .01 seconds. Almost after giving the pressure, the deformation vanishes.

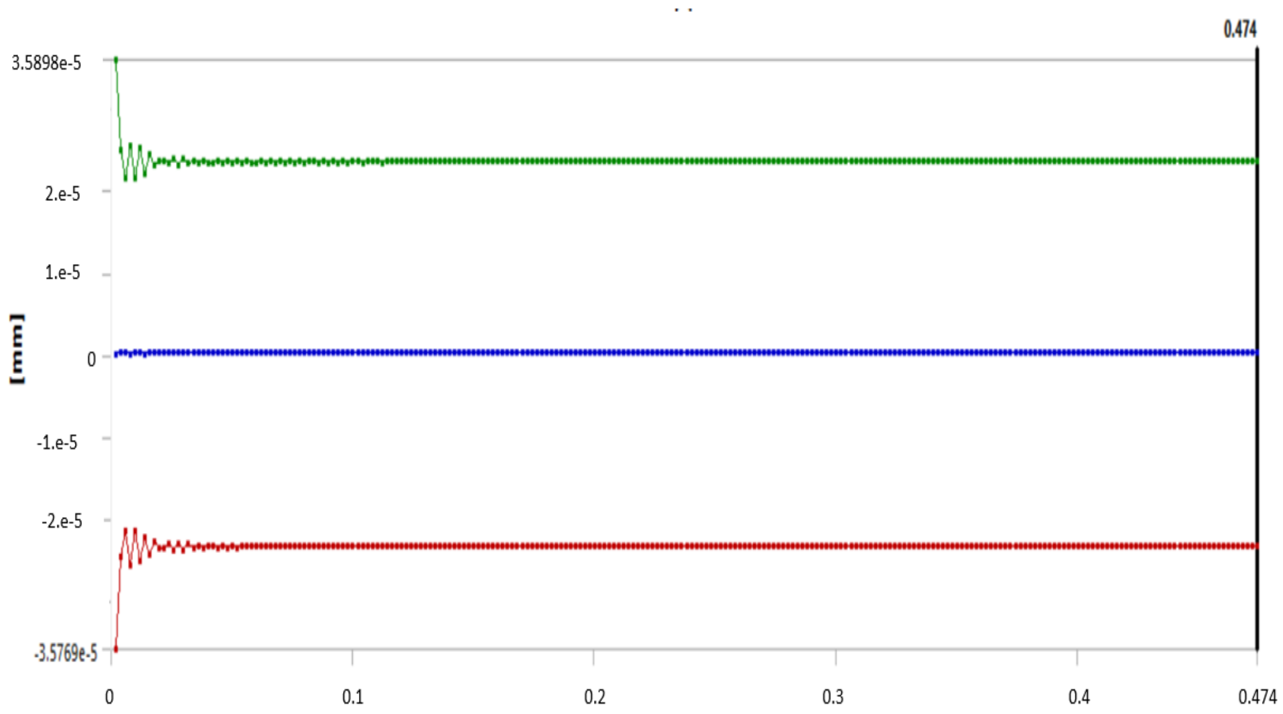


Fig.5.12: Bending in Z axis of model 3.

The result of Z axis is also same as the result of X axis in the case of using rubber in the free space inside the mass setup. In the previous model, the space was not filled and this space is used by the masses to move freely in their respective direction. But when the rubber takes the place, it′s impact on vibration control reaches the pick and mitigate the deformation within milliseconds.

5.1.3 Comparison of 3 results in the same direction

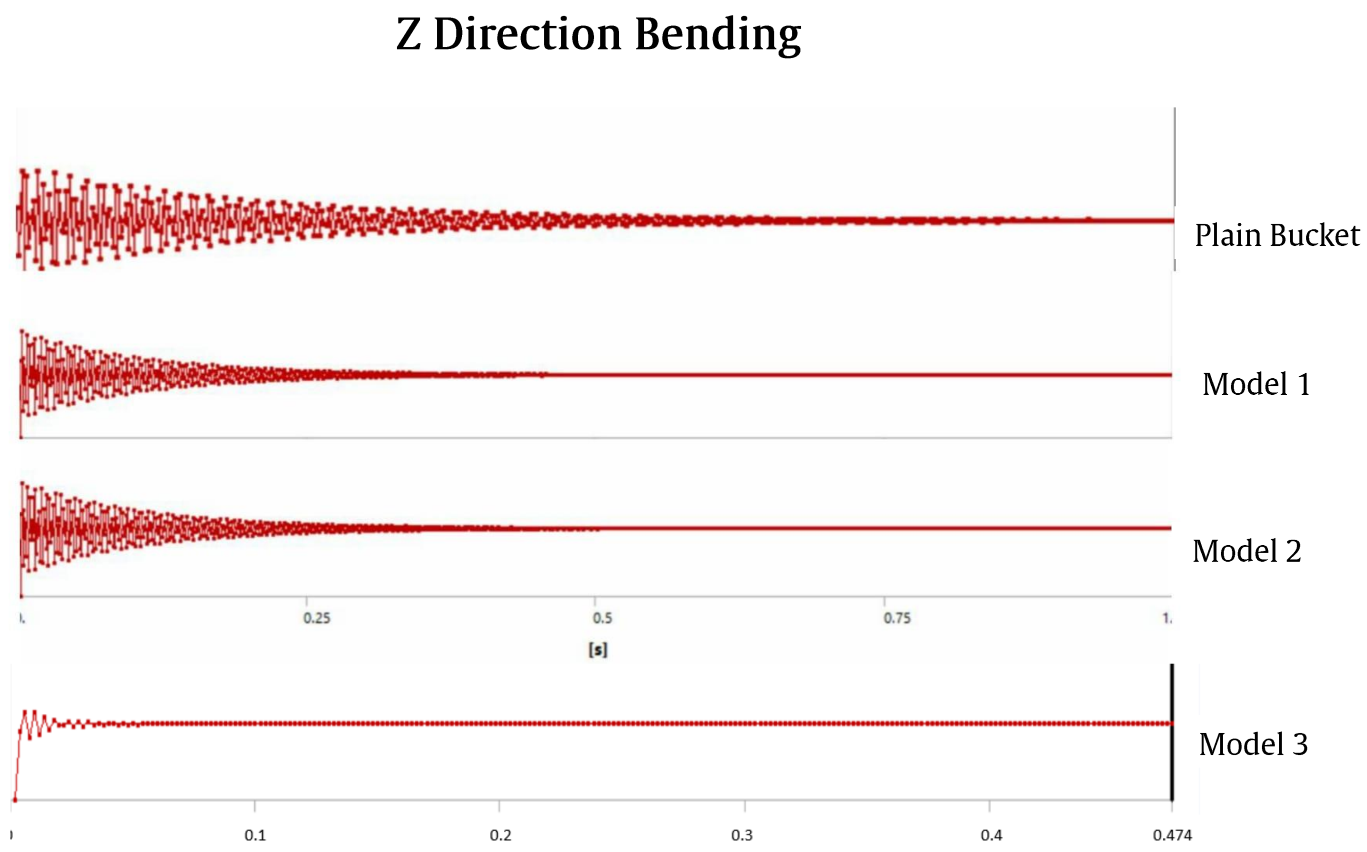


Fig. 5.13: Comparison of bending in Z Direction.

Here we can see that the 2nd modified model gives the best result. It mitigates 90% of bending within 0.3 seconds and fully mitigate the bending within 0.4 second in Z direction. On the other hand, the 1st modified model also gives a good result by mitigating the vibration within 0.43 second which is also good. We can say these results are far better than using plain bucket that takes about 0.9 second to mitigate the bending. The prominent result is given by the model 3 which actually proves the use of rubber in here can change the game.

X Direction Bending

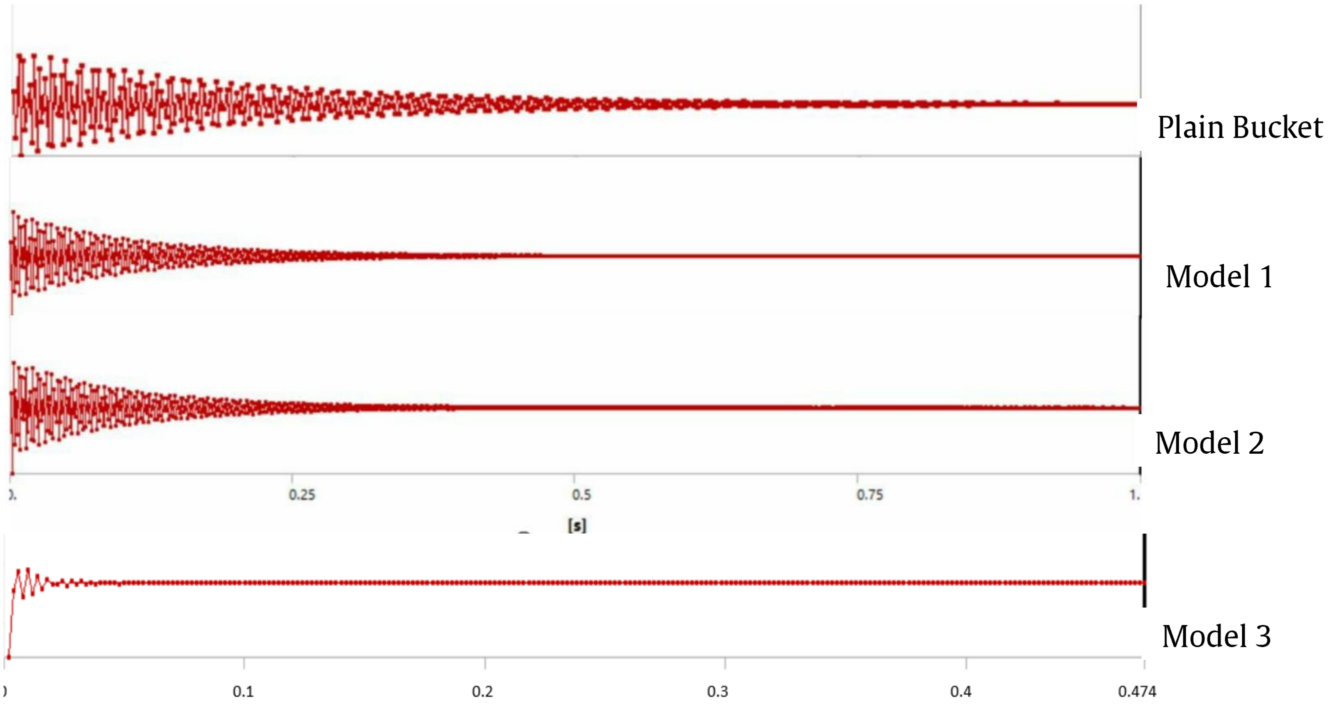


Fig. 5.14: Comparison of bending in X Direction.

In this direction, the result is almost similar. The second model mitigate 100% of the bending within 0.4 seconds while the 1st modified model takes about .48 second. But still both results are far better than mitigating everything within 0.9 second. The time steps changes for model 3 as it takes very less time to mitigate deformation.

5.2 Discussion

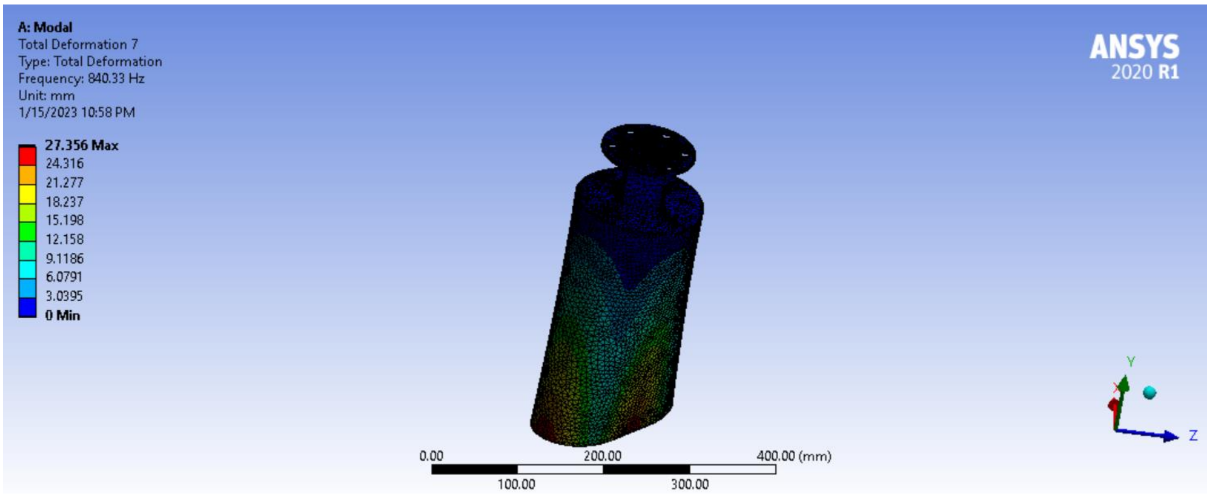
This whole project is done to modify an existing heavy duty workpiece. Modification is done using modern technology. From literature review, the mechanism we got are the tested mechanism for vibration absorption. Now our goal is to mitigate the deformation due the earth pressure at the time of drilling. We extract 2 directional deformation with respect to time. The model 1 is slightly better that the plain bucket. while the 2nd one giving a very good result in comparison with the 1st one. But as we know the rubber material has great property of vibration absorption, we go out for that. The result after using rubber material is quite shocking. Though the 1st and 2nd model are mitigate the deformation very fast even in between 0.4 second after the pressure is applied, the 3rd model mitigate it after 0.05 second. This just prove that how effective the rubber material is. Using the rubber changes result about 78% comparing to first 2 model. As drilling bucket is a very heavy-duty machine, the mechanism that used inside it must be rigid and fail safe. The 3rd model′s mechanism must be under some parametric analysis to find out the exact relationship between the ratio of the size of bucket and the size of mass inside. And we also look for the model if anywhere else the rubber material can be used.

CHAPTER 6

Model Validation

6. Model Validation

As no data is found on any paper, we need to physically manufacture a model, and test it if the data can match the simulated data. Our 1 model is already validated. The Data that is simulated through **ANSYS** is shown here.



A: Modal
Total Deformation 7
Type: Total Deformation
Frequency: 840.33 Hz
Unit: mm
1/15/2023 10:58 PM

Fig. 6.1: Bending in X Direction at 840 Hz.

Modal Frequencies from the Simulation are

1.	222.3
2.	222.44
3.	918.6
4.	918.89
5.	952.65
6.	1123.8
7.	2096.1
8.	2096.6
9.	2176.4
10.	2177.9

TAKING DATA FROM DAQ

Nearest 2 Frequency that are coming

1. 863.2 hz
2. 893 hz

Considering no. 2 with model shape 3′ s frequency 918

Error= ((918.89-893)/893) *100

=2.79%

CHAPTER 7

Future Scope, Conclusion & References

7.1 Future Scope

- New materials like metal foam and piezoelectric material can be used and investigate the vibration-damping condition of these materials,
- Different types of absorbers can be used and attached as a system, which can also work to mitigate the vibration of the bucket.
- Different bucket molding materials can also be used and investigated,
- Investigate if the absorbing system can work in other conditions and in other situations.
- Check if the materials can be used in different projects.
- The addition of fluid can also give a good result in some cases.
- Develop a new model that has fluid Solid interactions.

7.2 Conclusion

This heavy-duty machine needs to operate in very harsh conditions every day. So, a fail-safe design may lead to a revolution in drilling industries. Using new materials and an absorbing system may lead to an innovative new fail-safe design and show this heavy-duty machine, a new era.

Furthermore, experiments and simulations needed to take place simultaneously to find out the best vibration-mitigating model with the help of the absorber mechanism.

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