Garage Door Hinge Mechanism

MENG 3303 REPORT

060-Group 3

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We certify that the narrative, diagrams, figures, tables, calculations and analysis in this report are our own work.

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Abstract

Garage doors come in two types, that being single paneled and multi paneled. The multi panel door is pulled along a guided rail system by a chain. This system cannot always be used in certain areas such as areas near much debris and foliage occurrence. This is due to the rail system being obstructed making it so that the door will not be able to close or open. Due to this the single panel door is used where a six bar mechanism raises and closes the door. The six bar mechanism is meant to be used with or with out power. In this paper the following mechanism will be analyzed where the door will weight in at 125 pounds and will have the requirement of closing in 5 seconds. Based on these requirements the mechanism will have to be analyzed on the main links required speed and reaction moment based on the load from the door itself. The door also will be analyzed for its position displacement, velocity, and acceleration. After the mechanism has been assembled using SolidWorks the following have been results have been surmised based on the plots of **Fig 9** and **Fig 10.** The motor required to turn the main link has been found to have a speed of 6 RPM and the moment of 73.8 pounds * inches. The displacement of the garage door was found to be 35 inches, the velocity was found to peak from 11 inches per second to -13 inches per second, and finally the acceleration peak was found to be at 8 in/sec^2. The analysis allows for one to design the mechanism to following parameters to achieve the goal of having it raise and lower the single panel garage door.

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Introduction

Garage Door Types

Garage doors are doors that cover a vehicle sized opening for a garage. The doors are able to be opened and closed in various ways due the structure of the doors and the mechanisms that lower and raises the doors. There are various types of garage doors, such as solid doors, which are doors that come in one piece, and sectional doors, which are doors that are comprised of multiple rectangles assembled by hinges allowing for the door to bend when transitioning from open to close.

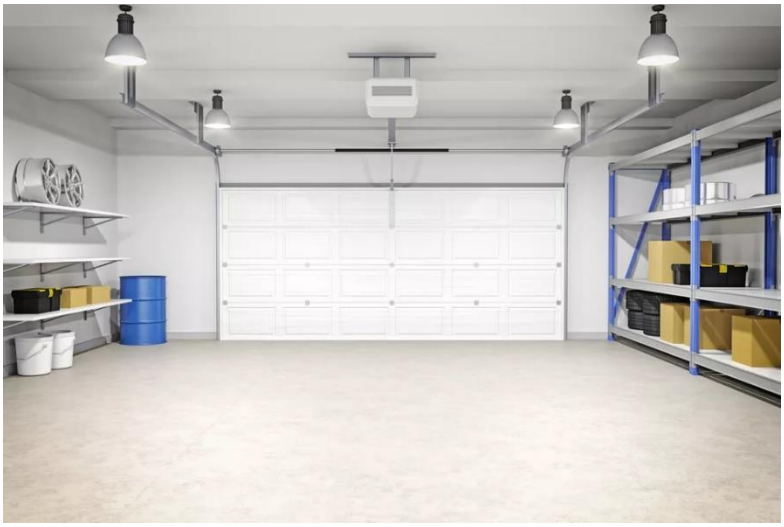

Fig 1. Shows a multi-panel garage door [1].

Multi-panel garage doors work by having multiple sections of a door work in tandem to be pulled while being able to bend at certain hinges allowing for a more flexible movement when being lowered or raised. The panels usually are moved by a rail system for alignment when in transition. They are dependent on the rails and if they are obstructed, they can cause the opening and closing mechanism of the door to fail. Due to this the single panel garage door can be used in areas where foliage and other obstructions may naturally form during usage of the mechanism.

Fig 2. Shows a single panel garage door [3].

In this paper the design that will be used for analysis and improvement will be the single panel garage door mechanism. As shown in **Fig 2.** The door will have weight of 125 pounds, have the length of 9 feet and the width of 8 feet, and will have to move from lower position where the door is perpendicular to the floor of the garage to the ceiling of the garage where it is parallel to the floor.

Six Bar Mechanism

The single panel garage door can be lifted with many mechanisms which can be categorized into two, the first being a central lifting mechanism which operates by being placed in the center, and the second type being one where two mechanisms are placed on either side of the single panel allowing the doors load to be distributed among both mechanisms. The second type of mechanism will work simultaneously with the other mechanism for it to function properly.

In this paper the type of mechanism that will be analyzed will be second type where two mechanisms will be placed on both sides of the garage door to lift and lower it. Since there will be two mechanisms that will operate to lift and lower the garage door the weight of the door will be distributed for the analysis of the mechanism.

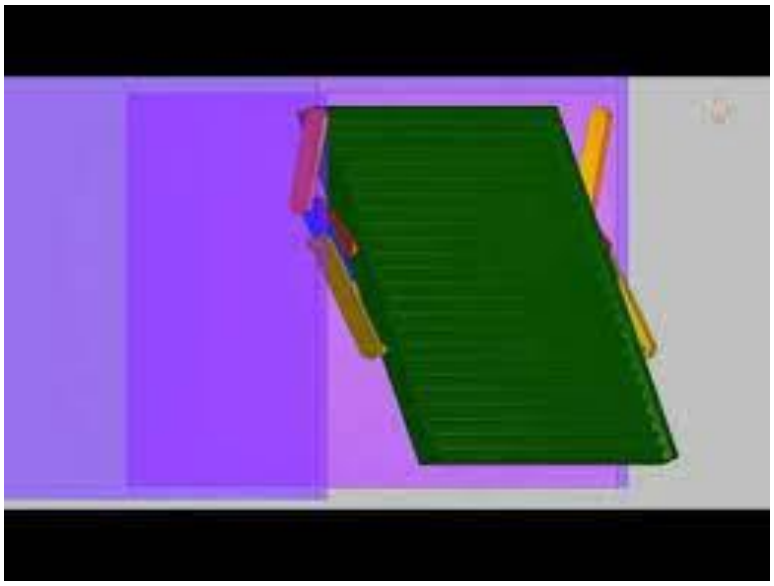

Fig 3. Shows the "Mechanism Design: Garage Door, 6 Bar" [2]

As seen in the figure above, this is mechanism that will be used for the basis of the design in this paper. The design above is a six-bar mechanism which achieves lifting the garage door from a perpendicular state against the ceiling to the ceiling while be rested parallel to the ceiling.

Proposed Design

The motivation for this project is to analyze the six-bar mechanism and show its analysis when it comes to position, velocity, acceleration, and forces enacting on it when it is in operation. This will allow one to find the amount of torque required for the mechanism to raise the garage door to a desired height.

Problem Statement

In designing this proposed mechanism, the following issues must be addressed for it to be able to function with in acceptable means. The first issue that will be assessed is the clearance of the load of the garage door itself, making the positioning of the mechanism when in contact to the garage door to be very important for its functionality. The next part will be the mechanisms range of movement which can be further analyzed in the position analysis, this will be tell whether the mechanism will be able to function while moving its linkages for the garage door to be fully raised. Finally, the next part of design that a problem can arise is finding the correct speed at which the door will be able to transition and rotate, particularly when closing the door since the weight of and speed of the transition can be something of a hazardous to one. This problem will also have to be addressed and an acceptable speed of the mechanism will have to be found for operation.

Objective

In order to have a mechanism that will allow for a single panel garage door to be raised and lower in a convenient position the following six bar mechanism will be designed and analyzed. The design must be able to pass the following criteria to be considered successful so it can be shown to operate. The first part of the designing that will be addressed is how the movement of the first link will for the last link coming into contact of the garage door will allow for the transition and rotation of the door happen simultaneously. The next portion of criteria is as stated above in the previous section having an acceptable speed for the mechanism to move for the garage door to change its state from being raised to lowered and vis versa. Finally, a finite element analysis must be done to find the impact of the distributed load of the single panel on both mechanisms, which are placed on both sides of the door.

Preliminary Literature

In ” Advantages of Single-Panel Garage Doors”, it is stated that a multi panel garage door works by having a mechanism pull and lower its panels, which are connected by hinges, along a guided rail for alignment. The doors are prone to problems since the guided rails can be blocked by foliage and other obstruction causing the rail system to fail [1]. To avoid the article says a garage door that would not have such problems would be a single panel door.

The single panel door is dependent on different types of mechanism as shown in “Mechanism Design: Garage Door, 6 Bar.” The advantages of the mechanisms that are shown in the video are how the links are the only dependent factors for the goal of lowering and raising the garage door. Since the mechanism works entirely only on the links as shown in **Fig 3.** the mechanism will not have the same problems such as having an obstructed guided rail system or having a failing spring system in which a hazardous situation may arise.

In “Position Analysis of Mechanisms”, it shows how the design of the six bar mechanism can be calculated in its positional analysis [4]. This allows one to find the velocity given the speed of the main link based on the time the mechanism is to function, in this case 5 seconds. Since the mechanism also has the garage door to be weighing at 125 pounds, giving the mechanism the distributed load of 62.5 pounds, the torque required of the main link can also be calculated based on the formulas given in the article.

METHODLOGY

In the approach of designing this mechanism, the design concept was to use an existing concept as shown in **Fig 2.**, which exhibits the same simulated outcome of having a fixed mechanism be able to rotate and transition a platform (garage) from it being perpendicular to a floor to parallel to the floor. The mechanism itself is a six-bar mechanism which has two fixed points of links being jointed to a ground link, in this case being the wall.

However, for the existing design a problem arises when having the range of motion of the garage door not having a constraint in how far it can be raised and lowered. In order to combat this problem an implementation of stoppers was used to limit the rotation of certain links allowing for the garage door to have a range of motion for its raised state to be limited.

In order to design this the following dimensions were used for the lifting a garage door with the dimensions of eight by nine feet garage door weighing in about 125 pounds will have to be lowered and raised in about 5 seconds. The door will be lifted by placing the mechanism on both sides of the door. Due to there being two mechanisms being used the weight of the garage door will be distributed to each mechanism making it required to endure about 62.5 pounds.

Now that the parameters for the mechanism have been stated the designing process using the Autodesk inventor software can be started. First in order to make the existing mechanism the ground links must be established based on the height of the garage door and their contacts and the clearance needed for it to transition and rotate. The grounded links are placed vertically 36 inches apart. The next step is to design the links that are used for the mechanism. The first of the links is the main link that has a length of 36 inches is placed on the lower grounded link and connected to the garage door 12 inches from the doors bottom.

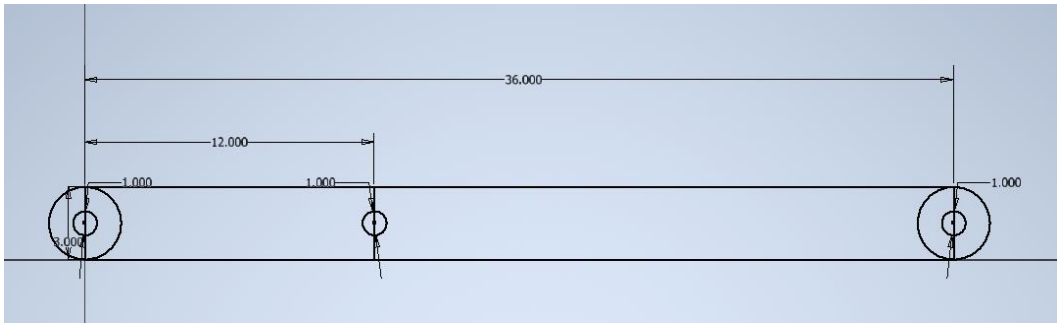

Fig 4. Main link Dimensions has the length of 36 inches.

Now that the outer joints for the main link are in use the inner join is to be connected to another link, otherwise known as the lesser link, and a small link. The lesser link will be connected to the main links inner joint and then connect to another lesser link. The second lesser link is then connected to the upper grounded link. Finally, the small link is also connect to the upper joint of the garage door located 32 inches above the lower joint.

Fig 5. Lesser link Dimensions has the length of 24 inches.

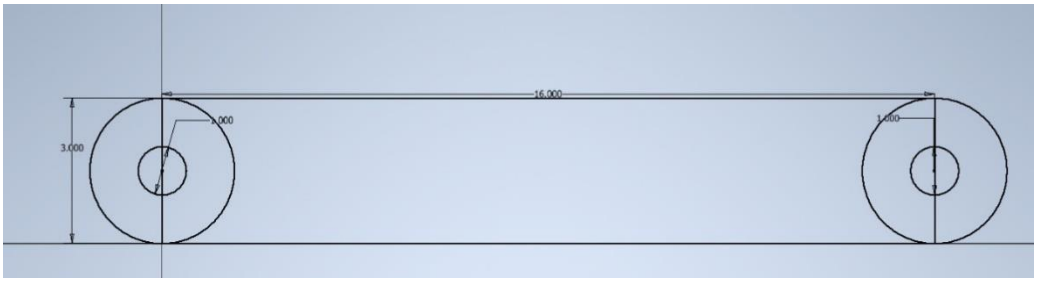

Fig 6. Small link Dimensions has a the length of 16 inches

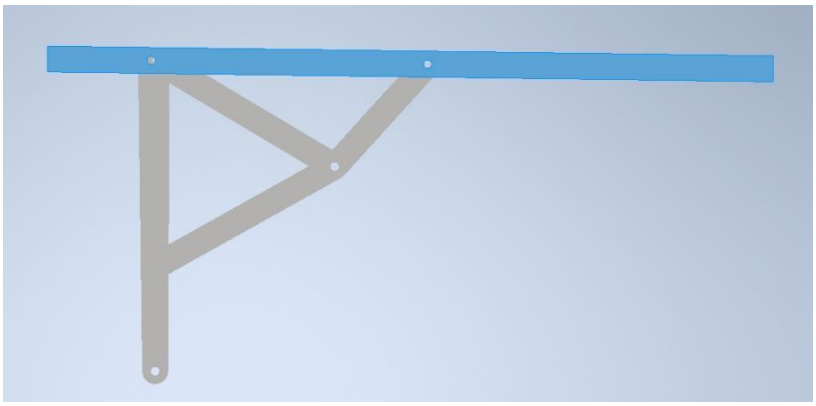

Fig 7. Mechanism assembly in its raised state.

As shown above from **Fig 4., Fig 5.,** and **Fig 6.,** the assembly is made as stated previously and shown in **Fig 7.** Upon further analysis the following figure allows for the angles for all links respect to each other can be found.

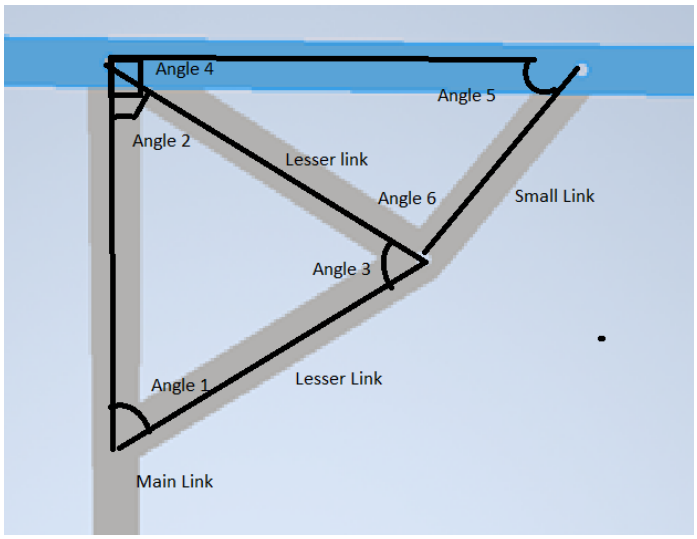

Fig 8. Mechanism assembly free body diagram in its raised state.

Using the lengths of the links, one can find the angles as shown in **Fig 8.** The main link joints are 24 inches apart, the lesser links are 24 inches, the small link is 16 inches, and the garage door joints are 32 inches apart. Since the lengths for the joints of the main link are the

same as the length for the lesser links the angles for angle 1,2, and 3 are all 60 degrees. Using this the remaining angles can be found.

$$angle\ 4 = 90 - 60 = 30$$

Using law of sines for triangles one can also find the remaining angles 5 and 6.

$$angle\ 5 = \sin\left(\frac{24(\sin(30))}{16}\right)^{-1} = 60\ angle\ 6 = \sin\left(\frac{32(\sin(30))}{16}\right)^{-1} = 90$$

This assembly works by having the main vertical link rotate 180 degrees towards its left causing the garage door to be lowered to its closed state. As stated previously the main link will be the driving force that will allow the mechanism to work. Since the garage door is to be raised and lowered in 5 seconds the following rpm for the main link can be calculated as shown below.

Since the main link only has to rotate 180 degrees for the garage door to be raised or lowered the rpm needs to be half of what would normally be required for 5 seconds.

$$\frac{1\text{ half RPS}}{5\ seconds} = \frac{1\text{ RPS}}{10\ seconds} = 6\ RPM$$

The next part of calculations can be done for velocity for the garage door using the 6 RPM, or 15 inches/sec for the main link. The following free body diagram for velocity can be used to determine the following links speed.

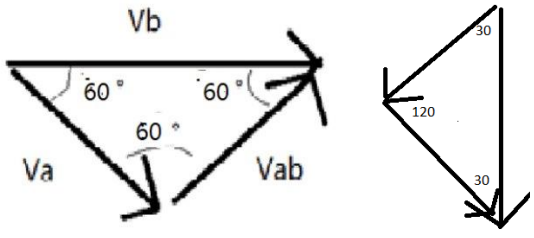

Fig 9. Mechanism assembly free body diagram in its raised state for velocity.

Based on **Fig 9** one can see how all the angles for the following links are the same so that the speed for all the links will be 15 inches/second. Now the remaining speed for the links including the garage door can be determined for the next image in the figure. The following law of sines can be used to determine the vertical speed, which represents the garage door.

$$garage\ door\ speed = \left(\frac{15(\sin(120))}{\sin\ (30)}\right) = 26$$

Now that the required speed is found for the main link has been found the following results for positional displacement, velocity, acceleration, and required torque can be found using the Solid Works motion analysis tool.

Results and Discussion

The next part of the design is to validate the design by analyzing the four categories, that being position displacement, velocity, acceleration, and torque required for the main link. This is done all based on the following parameters of the garage door weighing at 125 pounds and it needing to be raised within 5 seconds where the main link rotates at 6 RPM. Using the motion plot from solid works on the assembly the following graphs of all four categories can be found.

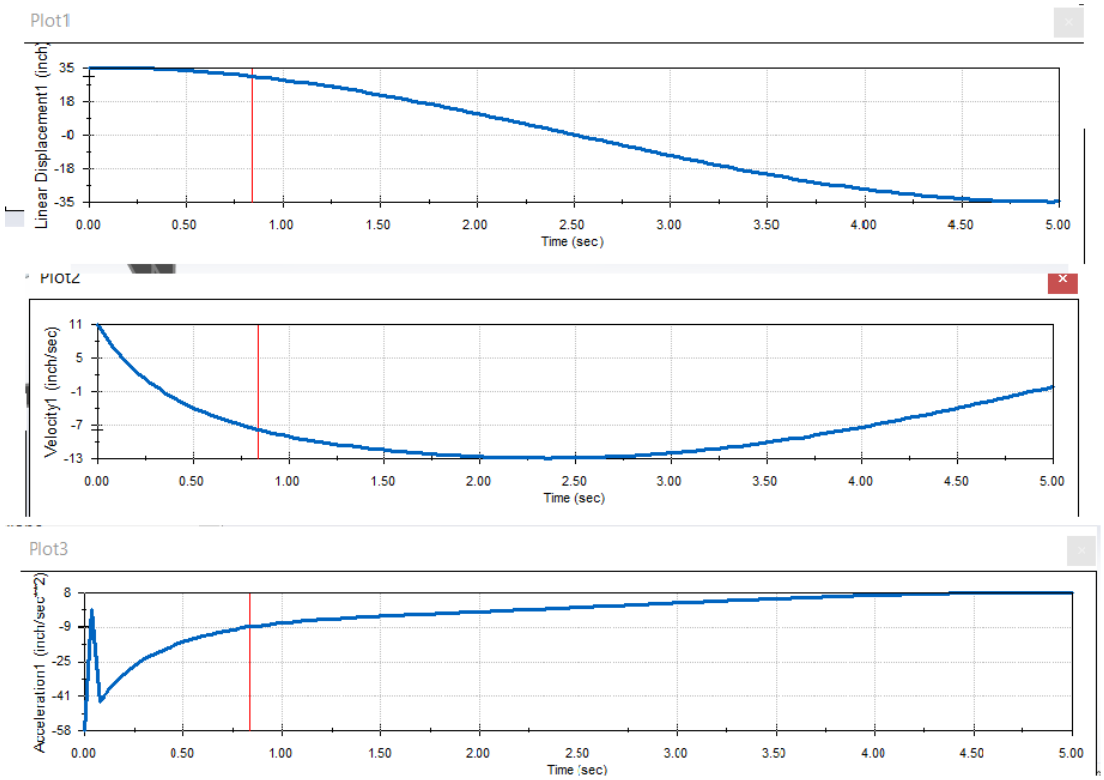

Fig 10. Garage displacement, velocity, and acceleration graphs.

As shown in **Fig 10** the displacement of the garage door was found to be 35 inches, the velocity was found to peak from 11 inches per second to -13 inches per second, and finally the acceleration peak was found to be at 8 in/sec^2. The following show how the impact of the main link moving at 6 rpm on the garage door in these characteristics. When comparing the values of the simulation to the calculated results the velocity is different due to the instance of calculation that was done for the raised state when the main link moves for 6 RPM. This is why the results which take into account of the difference of time.

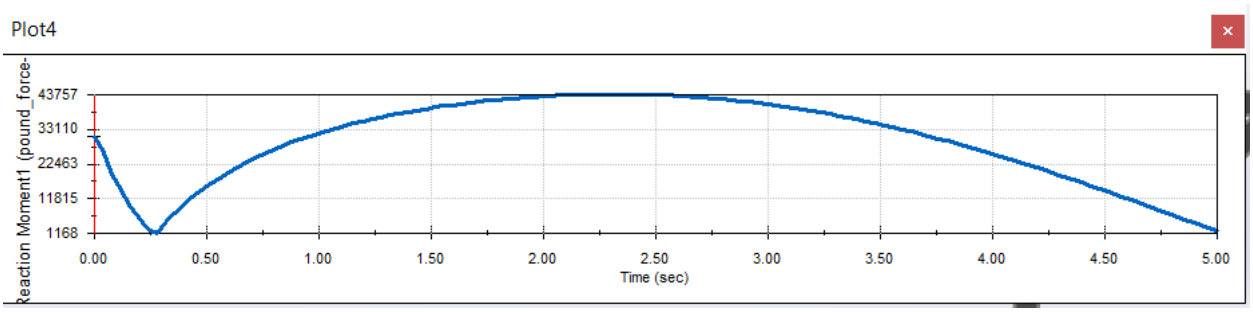

Fig 11. Garage impact on main link giving the moment reaction.

As show in **Fig 11** the moment reaction of the main link based on the impact of the distributed load of the garage door is shown to have 43757 pound force inches squared or 78.3 lbf * inches. With this this value the necessary torque needed to lift the garage door with the main link on both sides when the mechanism is functioning is found to be about 73.8 pounds * inches.

Based on the speed and torque needed for the mechanism to function a motor can be selected where it will spin at 6 RPM and have a minimum torque requirement of 73.8 pounds * inches.

Conclusion

In conclusion the following design for the mechanism allows for the 125 pound garage door to be raised and lowered in 5 seconds by having a motor that has a 6 RPM and have a minimum torque requirement of 73.8 pounds * inches. Also the range of movement for the door is limited so it will not fall backwards by restricting the movement of the main link to turn only 180 degrees and placing stoppers to further stop the garage door from moving further when being raised. The mechanism allows for the transition and rotation of the garage door to a desired position for when it raised and lowered.

References

[1] Mello, Thomas. “Single Panel vs. Sectional Garage Doors.” *The Spruce*, www.thespruce.com/single-panel-vs-sectional-garage-doors-1398094.

[2] MechanismSoftware. “Mechanism Design: Garage Door, 6 Bar.” *YouTube*, YouTube, 9 May 2017, www.youtube.com/watch?v=vWj-XObMujs.

[3] “Wolfram Demonstrations Project.” *Garage Door Lift Mechanisms*, demonstrations.wolfram.com/GarageDoorLiftMechanisms/.

[4] *Position Analysis of Mechanisms*, ocw.metu.edu.tr/pluginfile.php/3961/mod_resource/content/12/ch3/3-6.htm.

Appendix

Appendix A

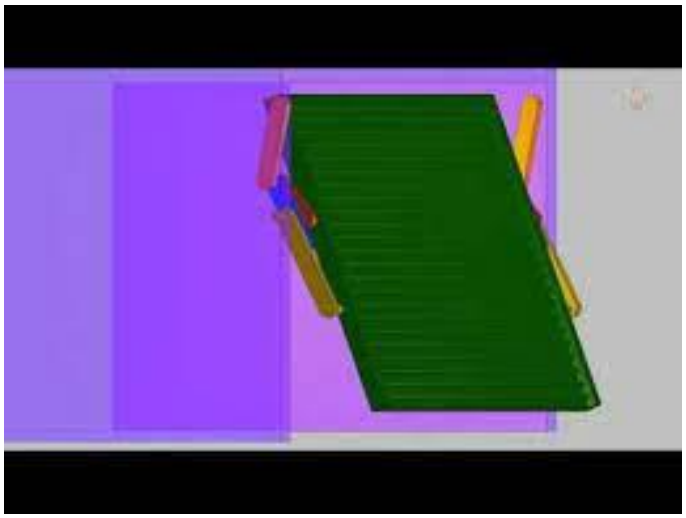

Figure 1. Shows the “Mechanism Design: Garage Door, 6 Bar” [2]

Appendix B

Work Hours of Participation During Zoom Call

Scaffolding 1				
	9-Jun	**10-Jun**	**11-Jun**	**12-Jun**
Usman Akram	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**
Mohammed Waheed	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**
Kenny Padron Aleman	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**
Wendnere Sampebre	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**

Scaffolding 2				
	16-Jun	**17-Jun**	**18-Jun**	**19-Jun**
Usman Akram	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**
Mohammed Waheed	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**
Kenny Padron Aleman	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**
Wendnere Sampebre	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**

Scaffolding 3				
	24-Jun	**25-Jun**	**26-Jun**	**27-Jun**
Usman Akram	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**
Mohammed Waheed	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**
Kenny Padron Aleman	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**
Wendnere Sampebre	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**	**8:40-9:30**