Stewart Platform Report

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May 2023

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Chapter 1

The approach used to analyze the model

1.1 The design process

The design process: before beginning the analysis we designed the model using SOLIDWORKS. As shown in the figures, the model was designed using the 6-6 configuration and the used joints were spherical joints, instead of universal, to reduce the number of needed mates and make the model run more smoothly in ADAMS.

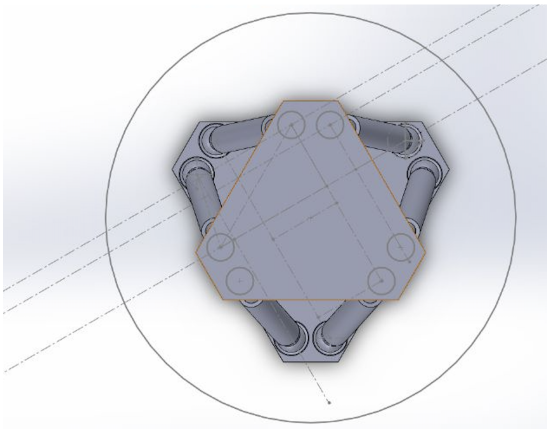

Figure 1.1: SOLIDWORKS design

1.2 The analysis Process

After designing the model successfully we moved to the analysis part in which we do motion analysis and import the model into ADAMS. As shown, the figure captures the top view of the model where we donate each one of the actuated six legs A symbolic name to differentiate it.

1. The legs were assigned the names in table 1
2. Second we came up with a descriptive equation for each type of motion for each actuated leg. In the following sections, we describe these equations in the upcoming subsections.

NOTE: This is the first draft so equations may be not very clear here. to solve this, we have attached a separate Word file containing the equations and graphs in a more organized way:/)

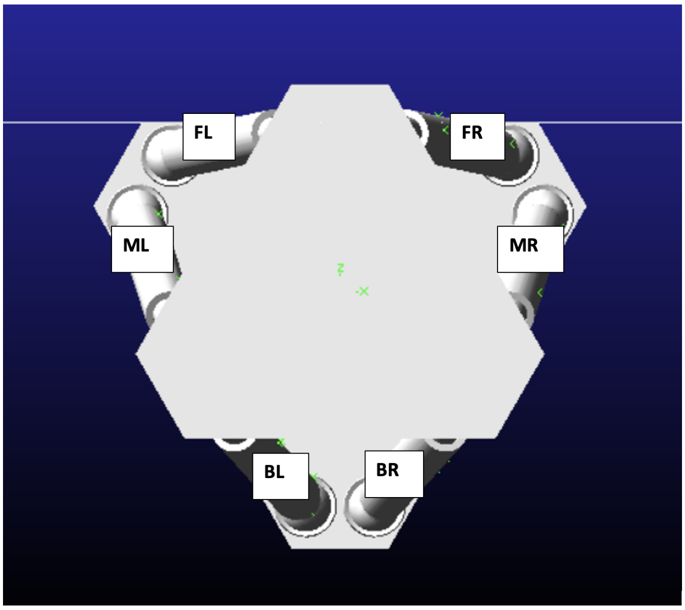

Figure 1.2: Top view for the model from ADAMS

FL	front left leg
ML	Middle left leg
BL	Back left leg
BR	Back right leg
MR	Middle right leg
FR	Front right leg

Table 1.1: Table of actuated legs names

1.2.1 upward and downward motion analysis

In the following motions, the equations for the upward and downward motion were just simply a linear function of time shown in Table 1.2, and Table 1.3.

Table 1.2: upward motion equations

	Equation for each leg		
	Back	Mid	Front
Right	$-0.01 \times time$	$-0.01 \times time$	$-0.01 \times time$
Left	$-0.01 \times time$	$-0.01 \times time$	$-0.01 \times time$

1.2.2 Front planar motion analysis: generating fundamental equations

In this motion, we need the model to move in a planar motion in the X-Y plane along the **x-axis** and keep the z elevation constant. In order to derive the needed equations we have followed those steps:

1. assign each leg a vector
2. describes the norm of each of these vectors in terms of its three coordinates taking into account the changes that happen in the vector's norm due to the motion of the platform.
3. come up with a final function that describes the motion of the leg and the changes in its assigned vector with time

Table 1.3: Downward motion equations

	Equation for each leg		
	Back	Mid	Front
Right	$0.01 \times time$	$0.01 \times time$	$0.01 \times time$
Left	$0.01 \times time$	$0.01 \times time$	$0.01 \times time$

Label	Equation
L_{bR}	$-\sqrt{27005.28342 + (time + 41.64319426)^2} + 152.596115$
L_{bL}	$-\sqrt{27005.28342 + (time + 41.64319426)^2} + 152.596115$
L_{fR}	$-\sqrt{28604.1361 + (time + 11.64)^2} + 152.596115$
L_{fL}	$-\sqrt{28604.1361 + (time + 11.64)^2} + 152.596115$
L_{Midr}	$-\sqrt{25899.98 + (time - 53.286)^2} + 152.596115$
L_{MidL}	$-\sqrt{25899.98 + (time - 53.286)^2} + 152.596115$

Table 1.4: describe equations for the model front motion

using the equations we have generated for each leg, we now have full control over the motion of each leg and we can utilize the superposition principle and combine these equations to generate any type of further motion we will need.

1.2.3 Sideways planar motion analysis

In this section, we will study the planar motion of the platform along the y-axis **(sideways)**. as shown in this

1	B	M	F
R	-SQRT(28604.1361 + (time + 11.64)**2) +152.596115	-SQRT(28604.1361 + (time + 11.64)**2) +152.596115	-SQRT(25899.98 + (time - 53.286)**2) +152.596115
L	-SQRT(25899.98 + (time - 53.286)**2) +152.596115	-SQRT(27005.28342 + (time + 41.64319426)**2) +152.596115	-SQRT(27005.28342 + (time + 41.64319426)**2) +152.596115
2	B	M	F
R	-SQRT(25899.98 + (-time - 53.286)**2) +152.596115	-SQRT(27005.28342 + (-time + 41.64319426)**2) +152.596115	-SQRT(27005.28342 + (-time + 41.64319426)**2) +152.596115
L	-SQRT(28604.1361 + (-time + 11.64)**2) +152.596115	-SQRT(28604.1361 + (-time + 11.64)**2) +152.596115	-SQRT(25899.98 + (-time - 53.286)**2) +152.596115
Superposition	B	M	F
R	-SQRT(28604.1361 + (time + 11.64)**2) +152.596115-SQRT(25899.98 + (-time - 53.286)**2) +152.596115	-SQRT(28604.1361 + (time + 11.64)**2) +152.596115-SQRT(27005.28342 + (-time + 41.64319426)**2) +152.596115	-SQRT(25899.98 + (time - 53.286)**2) +152.596115-SQRT(27005.28342 + (-time + 41.64319426)**2) +152.596115
L	-SQRT(25899.98 + (time - 53.286)**2) +152.596115-SQRT(28604.1361 + (-time + 11.64)**2) +152.596115	-SQRT(27005.28342 + (time + 41.64319426)**2) +152.596115-SQRT(28604.1361 + (-time + 11.64)**2) +152.596115	-SQRT(27005.28342 + (time + 41.64319426)**2) +152.596115-SQRT(25899.98 + (-time - 53.286)**2) +152.596115

Figure 1.3: Sideways motion equations color encoded

tabulated figure, we have defined equations for motion 1 and motion 2 for each of the legs. adding these equations will result in final equations which will give us the desired motion we need.

Note: we have here used algebraic sum to give the superposition needed and give the needed motion effect. This may not be accurate and result in some accuracy errors in the simulation but the errors

are quite small and we are working on solving it.

1.2.4 Circular motion analysis

In this motion, we use the equations we have obtained in the sideways and front motion which represent the motion along the x-axis and y-axis respectively, to obtain circular motion for the platform.

1. we generate front cosine wave motion

Straight Cos Motion	Back	Mid	Front
Right	-SQRT(27005.28342 + (50*COS(time) + 41.64319426)**2) +152.596115	-SQRT(25899.98 + (50*COS(time) - 53.286)**2) +152.596115	-SQRT(28604.1361 + (50*COS(time) + 11.64)**2) +152.596115
Left	-SQRT(27005.28342 + (50*COS(time) + 41.64319426)**2) +152.596115	-SQRT(25899.98 + (50*COS(time) - 53.286)**2) +152.596115	-SQRT(28604.1361 + (50*COS(time) + 11.64)**2) +152.596115

Figure 1.4: Cosine motion

2. we generate sideways sine wave motion

Sideways SIN wave Motion	B	M	F
R	-SQRT(28604.1361 + ((0.5773502692 * 50 * SIN(time)) + 11.64)**2) +152.596115 - SQRT(25899.98 + (-(0.5773502692 * 50 * SIN(time)) - 53.286)**2) +152.596115	-SQRT(28604.1361 + ((0.5773502692 * 50 * SIN(time)) + 11.64)**2) +152.596115- SQRT(27005.28342 + (-(0.5773502692 * 50 * SIN(time)) + 41.64319426)**2) +152.596115	-SQRT(25899.98 + ((0.5773502692 * 50 * SIN(time)) - 53.286)**2) +152.596115- SQRT(27005.28342 + (-(0.5773502692 * 50 * SIN(time)) + 41.64319426)**2) +152.596115
L	-SQRT(25899.98 + ((0.5773502692 * 50 * SIN(time)) - 53.286)**2) +152.596115- SQRT(28604.1361 + (-(0.5773502692 * 50 * SIN(time)) + 11.64)**2) +152.596115	-SQRT(27005.28342 + ((0.5773502692 * 50 * SIN(time)) + 41.64319426)**2) +152.596115- SQRT(28604.1361 + (-(0.5773502692 * 50 * SIN(time)) + 11.64)**2) +152.596115	-SQRT(27005.28342 + ((0.5773502692 * 50 * SIN(time)) + 41.64319426)**2) +152.596115- SQRT(25899.98 + (-(0.5773502692 * 50 * SIN(time)) - 53.286)**2) +152.596115

Figure 1.5: sideways sine equation

3. we superimpose both to get the final circular motion

Superposition Circular Motion	B	M	F
R	-SQRT(28604.1361 + ((0.5773502692 * 50 * SIN(time)) + 11.64)**2) +152.596115 - SQRT(25899.98 + (-(0.5773502692 * 50 * SIN(time)) - 53.286)**2) +152.596115- SQRT(27005.28342 + (50*COS(time) + 41.64319426)**2) +152.596115	-SQRT(28604.1361 + ((0.5773502692 * 50 * SIN(time)) + 11.64)**2) +152.596115- SQRT(27005.28342 + (-(0.5773502692 * 50 * SIN(time)) + 41.64319426)**2) +152.596115- SQRT(25899.98 + (50*COS(time) - 53.286)**2) +152.596115	-SQRT(25899.98 + ((0.5773502692 * 50 * SIN(time)) - 53.286)**2) +152.596115- SQRT(27005.28342 + (-(0.5773502692 * 50 * SIN(time)) + 41.64319426)**2) +152.596115- SQRT(28604.1361 + (50*COS(time) + 11.64)**2) +152.596115
L	-SQRT(25899.98 + ((0.5773502692 * 50 * SIN(time)) - 53.286)**2) +152.596115- SQRT(28604.1361 + (-(0.5773502692 * 50 * SIN(time)) + 11.64)**2) +152.596115- SQRT(27005.28342 + (50*COS(time) + 41.64319426)**2) +152.596115	-SQRT(27005.28342 + ((0.5773502692 * 50 * SIN(time)) + 41.64319426)**2) +152.596115- SQRT(28604.1361 + (-(0.5773502692 * 50 * SIN(time)) + 11.64)**2) +152.596115- SQRT(25899.98 + (50*COS(time) - 53.286)**2) +152.596115	-SQRT(27005.28342 + ((0.5773502692 * 50 * SIN(time)) + 41.64319426)**2) +152.596115- SQRT(25899.98 + (-(0.5773502692 * 50 * SIN(time)) - 53.286)**2) +152.596115- SQRT(28604.1361 + (50*COS(time) + 11.64)**2) +152.596115

Figure 1.6: Superposition circular motion

To obtain the motion we have relied on the equation governing the motion of a point on a circle such that given a unit circle with radius = 1 :

$$sin(\theta)^2 + cos(\theta)^2 = 1 \tag{1.1}$$

1.2.5 Helical motion analysis

To generate this motion we have used the generated circular equation superimposed with the upward motion equation. Using these two combined motions we have obtained the helical motion for the mechanism with high accuracy. Using superposition we can further manipulate this motion, for example, to generate a tornado-like motion.

Superposition Helical Motion	B B	M M	F F
R	-SQRT(28604.1361 + ((0.5773502692 * 50 * SIN(time)) + 11.64)**2) +152.59611[illegible] SQRT(25899.98 + (-(0.5773502692 * 50 * SIN(time)) - 53.286)**2) +152.596115- SQRT(27005.28342 + (50*COS(time) + 41.64319426)**2) +152.596115 - 5 *time	-SQRT(28604.1361 + ((0.5773502692 * 50 * SIN(time)) + 11.64)**2) [illegible]96115- SQRT(27005.28342 + (-(0.5773502692 * 50 * SIN(time)) + 41.64319426)**2) +152.596115- SQRT(25899.98 + (50*COS(time) - 53.286)**2) +152.596115 - 5* time	-SQRT(25899.98 + ((0.5773502692 * 50 * SIN(time)) - 53.286)**2) +152.596115- SQRT(27005.28342 + (-(0.5773502692 * 50 * SIN(time)) + 41.64319426)**2) +152.596115- SQRT(28604.1361 + (50*COS(time) + 11.64)**2) +152.596115 - 5 * time
L	-SQRT(25899.98 + ((0.5773502692 * 50 * SIN(time)) - 53.286)**2) +152.596115- SQRT(28604.1361 + (-(0.5773502692 * 50 * SIN(time)) + 11.64)**2) +152.596115- SQRT(27005.28342 + (50*COS(time) + 41.64319426)**2) +152.596115 - 5 * time	-SQRT(27005.28342 + ((0.5773502692 * 50 * SIN(time)) + 41.64319426)**2) +152.596115- SQRT(28604.1361 + (-(0.5773502692 * 50 * SIN(time)) + 11.64)**2) +152.596115- SQRT(25899.98 + (50*COS(time) - 53.286)**2) +152.596115 - 5 * time	-SQRT(27005.28342 + ((0.5773502692 * 50 * SIN(time)) + 41.64319426)**2) +152.596115- SQRT(25899.98 + (-(0.5773502692 * 50 * SIN(time)) - 53.286)**2) +152.596115- SQRT(28604.1361 + (50*COS(time) + 11.64)**2) +152.596115 - 5 * time

Figure 1.7: Helical motion equations

1.2.6 Cosine motion analysis

	Position		
	Back	Mid	Front
Right	$-50 \cdot \cos(time)$	$-50 \cdot \cos(time)$	$-50 \cdot \cos(time)$
Left	$-50 \cdot \cos(time)$	$-50 \cdot \cos(time)$	$-50 \cdot \cos(time)$

Table 1.5: Equations for Back, Mid, and Front

1.2.7 Sine Motion analysis

	Position		
	Back	Mid	Front
Right	$-50 \cdot \sin(time)$	$-50 \cdot \sin(time)$	$-50 \cdot \sin(time)$
Left	$-50 \cdot \sin(time)$	$-50 \cdot \sin(time)$	$-50 \cdot \sin(time)$

Table 1.6: Equations for Back, Mid, and Front

Chapter 2

Graphs

In this section, we represent the graphs for position, velocity, and acceleration associated with each generated motion.

1. Upward motion graphs
2. Cosine motion graphs
3. sine motion graphs
4. front motion graphs
5. Sideways motion graphs
6. circular motion graphs
7. helical motion graphs

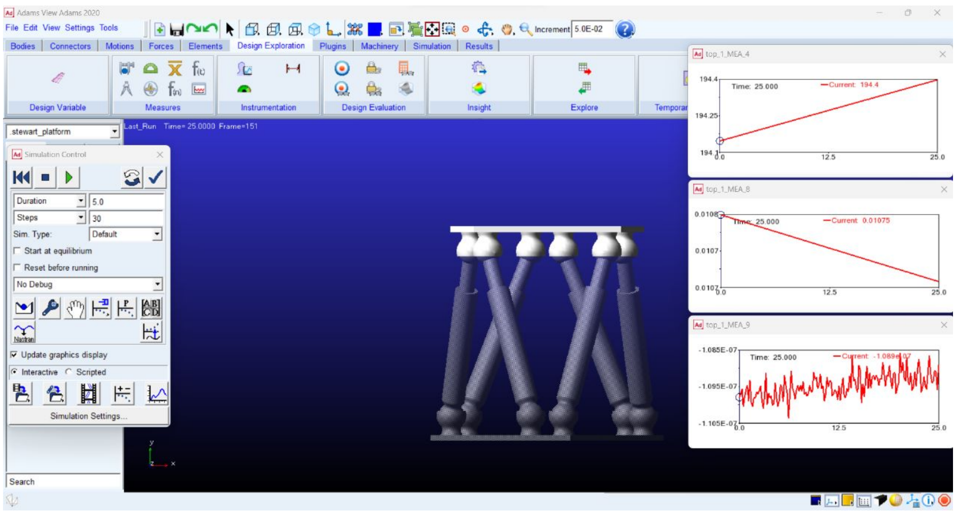

Figure 2.1: Upward motion graphs

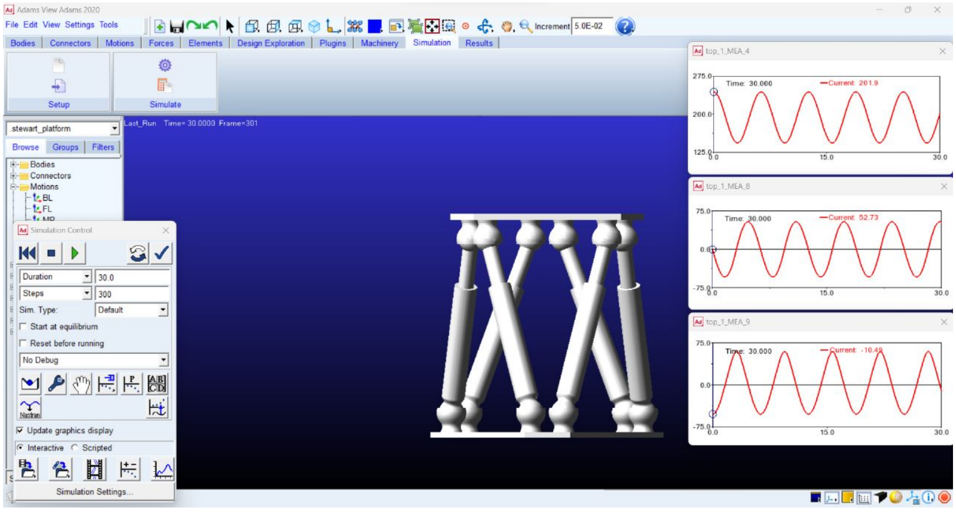

Figure 2.2: Cosine Motion graph

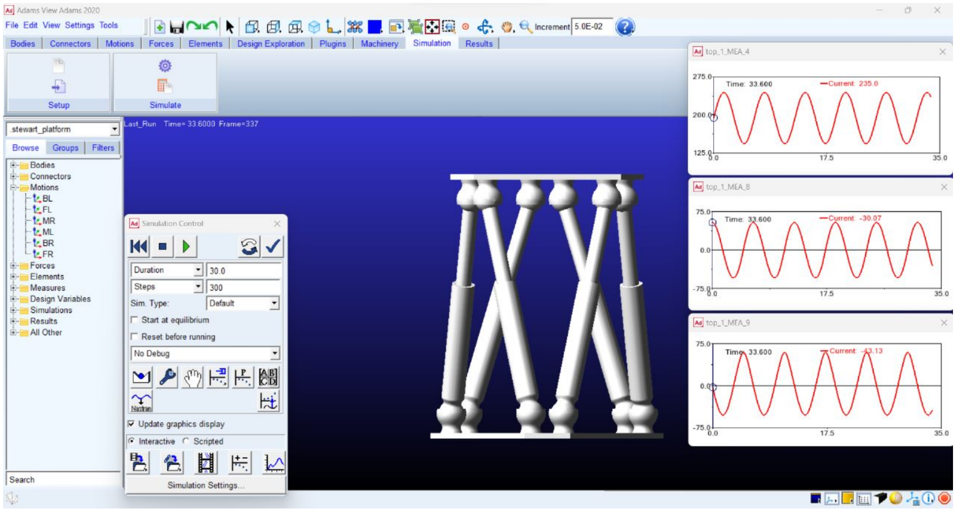

Figure 2.3: sine motion graphs

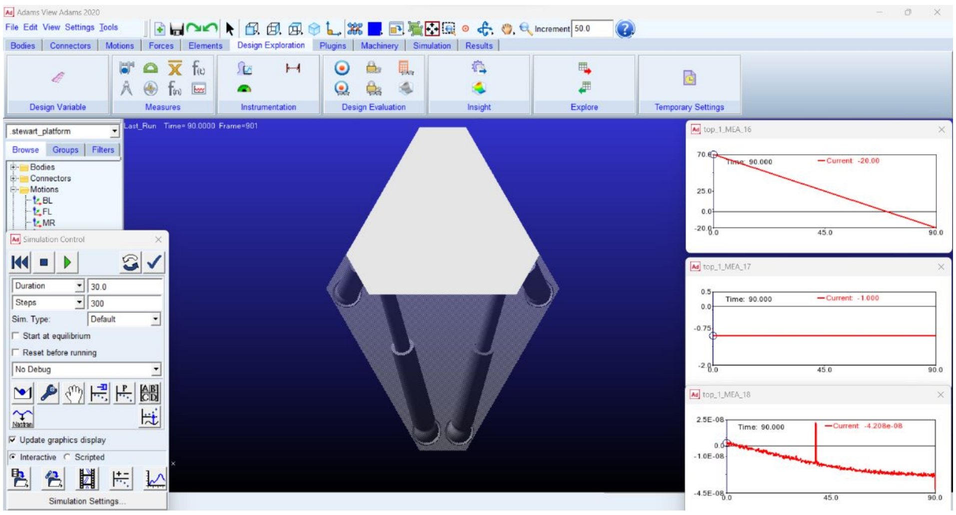

Figure 2.4: front motion graph

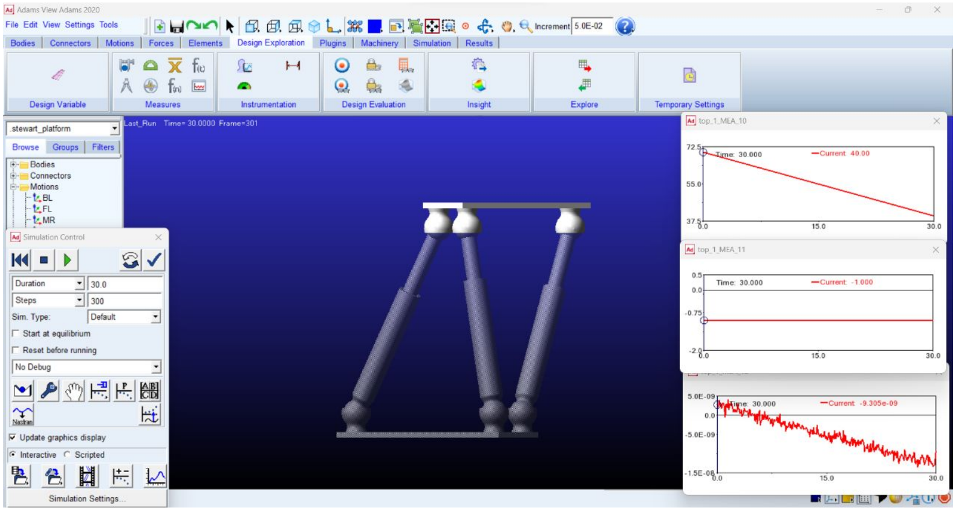

Figure 2.5: Front motion graph 2

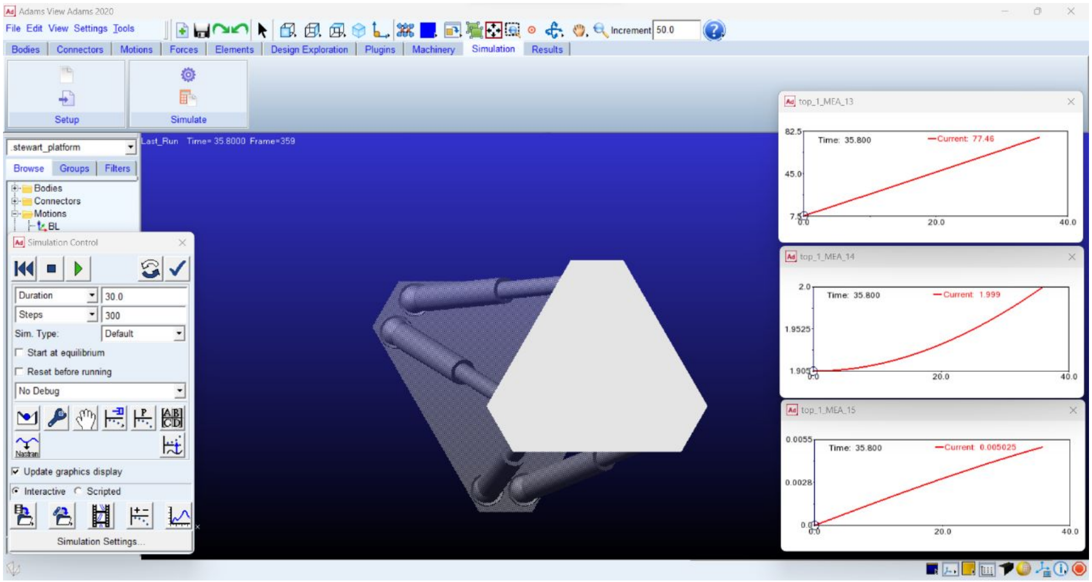

Figure 2.6: Sideways motion graph

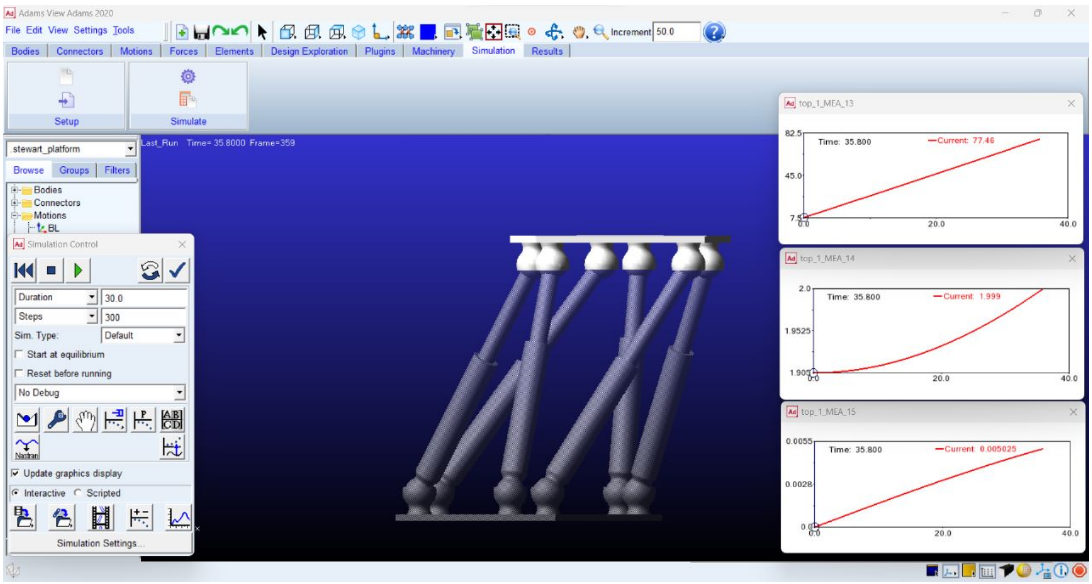

Figure 2.7: Sideway motion 2

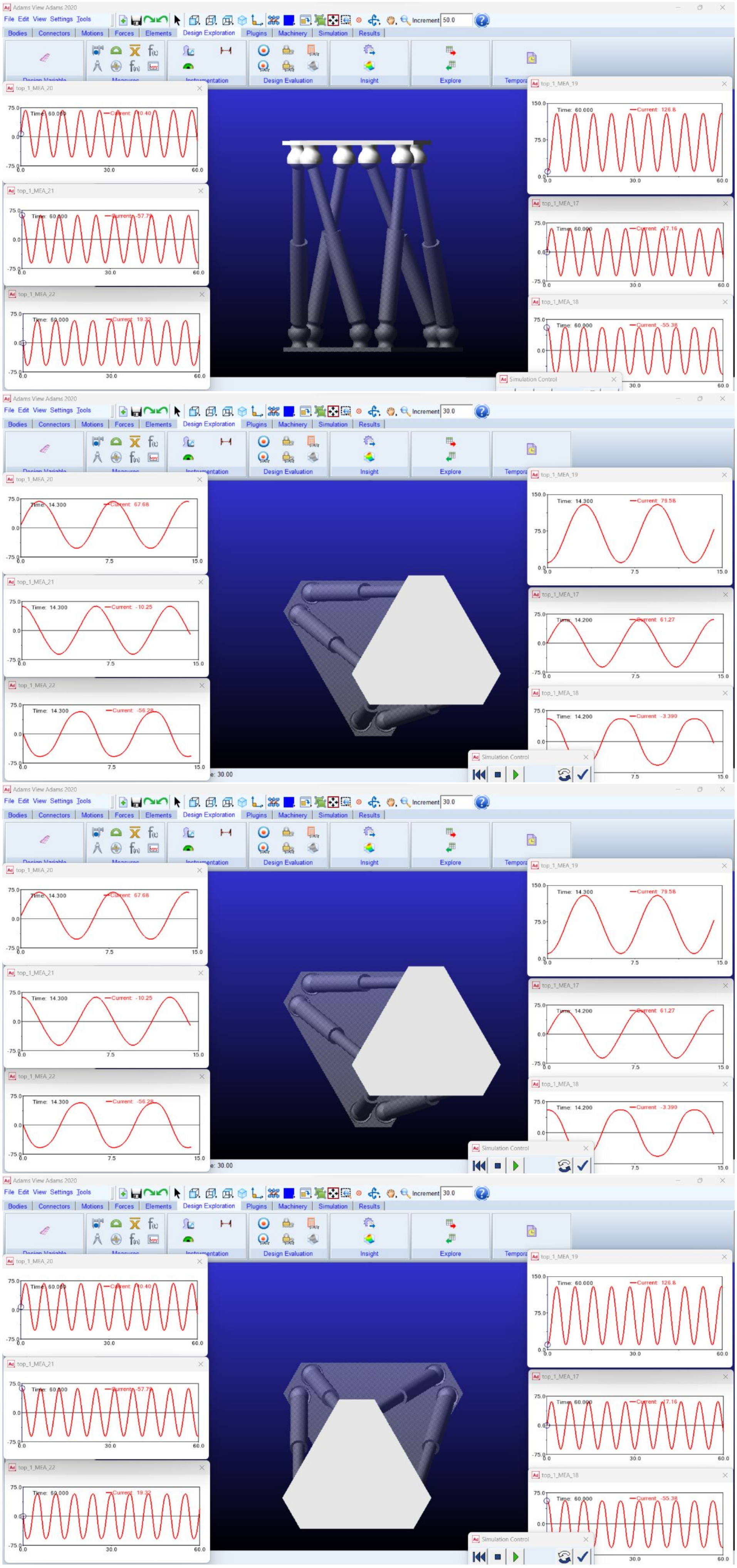

Figure 2.8: Circular motion graphs

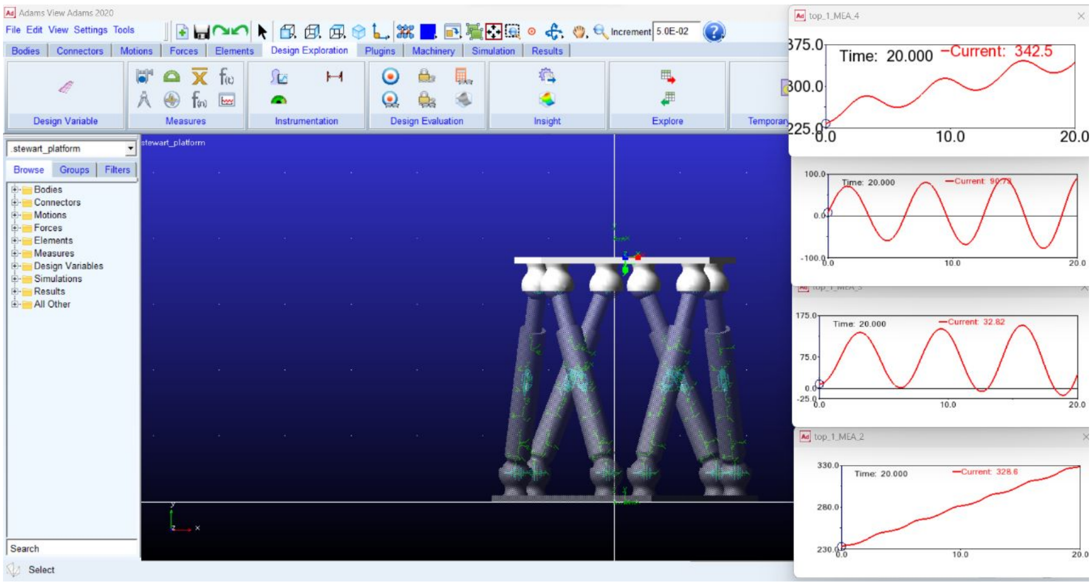

Figure 2.9: helical motion graphs

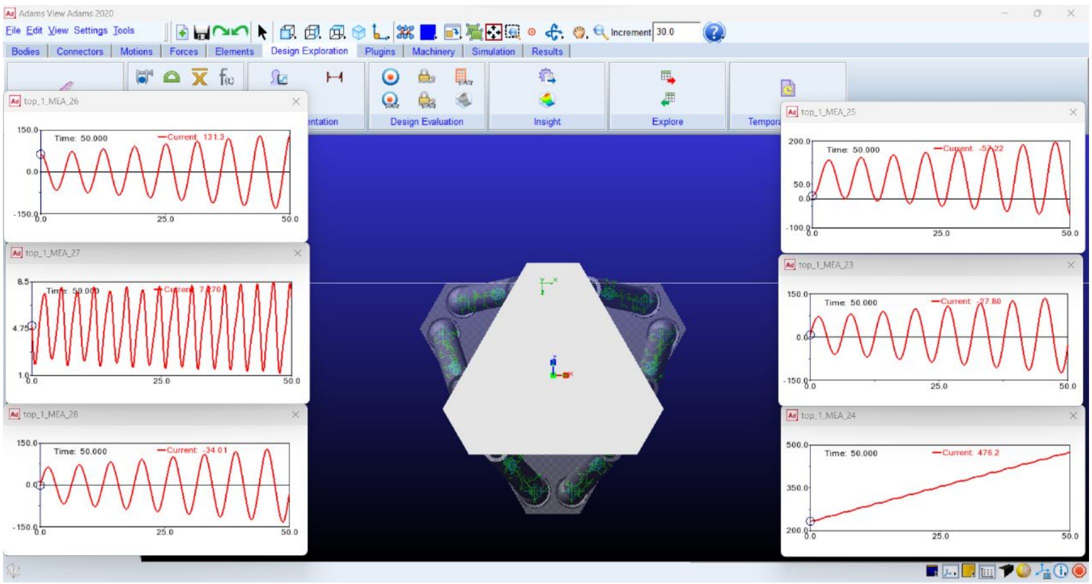

Figure 2.10: taper helical motion graphs2

Chapter 3

Conclusion

To conclude our work, we have used an analytical approach to produce parametric equations in which we can use all of the possible motions for the mechanism like :

1. front planar motion (x-axis)
2. sideways planar motion (y-axis)
3. circular motion
4. helical motion
5. sine and cosine motion along three axis

The generated equations give us full control over each actuator in the mechanism and allow us to produce the mentioned motions with high accuracy and minimum errors.

NOTE: This is the first draft so equations may be not very clear here. to solve this, we have attached a separate Word file containing the equations and graphs in a more organized way :)