MOTION ANALYSIS REPORT

4 Bar Linkage

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ME 357 A2

4/21/2022

ABSTRACT

In this report, I'll be discussing the 4 bar linkage I've created. The 4 bar linkage was designed using SolidWorks with a theme of "childhood" as the linkages reminded me of youth when I used to play with them as a toy. When I reflect back on my childhood, traveling comes to mind since I'd often tag along to my dad's business trips. I tried to symbolize these childhood memories by putting visuals I associated with each of my favorite countries–Denmark, Tokyo and Hawaii–on my 4 bar linkage. I also wanted to implement the idea of childhood in the motion of the 4-bar linkages itself. My dad had always told me that I'd grab, pull and rotate his arms whenever I saw something intriguing on these trips since I'd always wanted to share that experience with him. I decided to attempt recreating this motion of me pulling my dad's arms with the four bar linkage. In order to do so, I made 2 out of the 4 bars much shorter to represent my arms, and two others longer to represent my dad's arms. The purpose of this report is to understand the level of success I had in accomplishing the motion I hoped for. Overall, I believe I was successful, however, there are few minor changes I could've made to make it more reflective of the actual motion of the arms. Through the analysis, I'll elaborate on how the combination of different lengths of the bars I chose work together to contribute in creating a unique motion.

SET UP

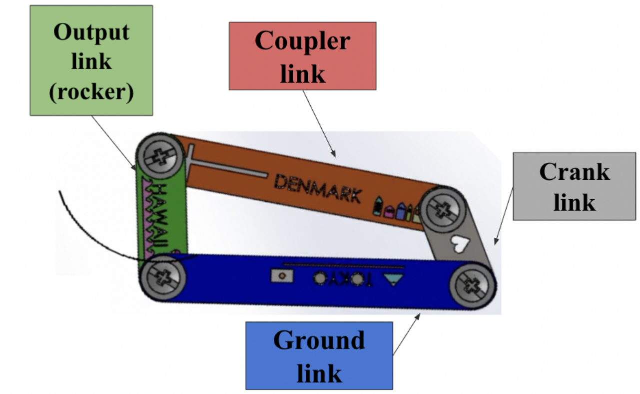

Figure 1: labeled CAD 4 bar-linkage front view

As seen in **Figure 1**, the planar quadrilateral linkage, or 4 bar linkage, consists of 4 bars–base, crank (input) link, output link and a coupler–connected to a loop by four joints in which the crank can rotate a full 360 degrees. The output link is the green bar, the coupler link is the red bar, the crank link is the gray bar and the ground link is the blue bar. I created the bars of the four bar linkage using SolidWorks. Other external components I used include 18-8 stainless steel screws for binding barrels, 18-8 stainless Steel Binding Barrel, and 316 Stainless Steel Washer. The lengths of the bars in the linkage assembly, or distance between pivot points are 70 mm (blue bar), 30 mm (green bar), 75 mm (red bar) and 20 mm (gray bar). As seen in **Figure 1,** due to the position of the shortest link, or the crank link, being adjacent to the fixed link, or the ground link, I determined this linkage to be a crank-rocker. Crank-rocker mechanism is one that "shortest link rotates fully while the other link pivoted to the fixed link oscillates" (Team). The trace curve seen in **Figure 1** was created using the output point of one of the edge points of the pink wave design on the green bar (Hawaiian bar). Since all the 4 internal angles are less than 180 degrees, no 2 links cross over each other, and length of 1 diagonal increases if the other decreases, this is a convex 4 bar linkage.

Figure 2: 8.5x11 (in) Motion Boundary of 4 bar linkage

As seen in **Figure 2**, the motion had a constraint of 8.5x11 motion boundary and I was able to successfully keep the motion under this constraint.

GRASHOF

$$S + L \leq P + Q \tag{1}$$

S = length of shortest link

L = length of longest link

$P,\ Q$ = length of remaining links

In order for the 4 bar linkage to fully rotate, it must satisfy the Grashof condition, shown in equation (1).

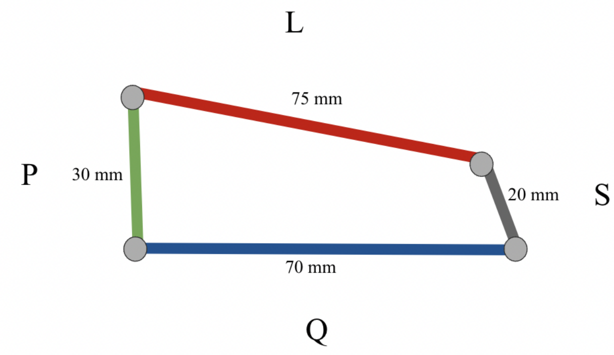

Figure 3: labeled 4 bar linkage for grashof condition equation

Using equation (1) and the corresponding lengths for the variables shown in **Figure 3**, my 4-bar linkage satisfy the grashof condition:

$$20 + 75 \leq 30 + 70$$

$$95 < 100$$

The behaviors of the linkage can be determined using the transitions functions below:

$$T_1 = Q + L - P - S \tag{2}$$

$$T_2 = P + Q - L - S \tag{3}$$

$$T_3 = L + P - Q - S \tag{4}$$

S = length of shortest link

L = length of longest link

$P,\ Q$ = length of remaining links

Using my values of the 4 bar linkage shown in **Figure 3** and plugging the values into the equations (2), (3), and (4), I obtained the following values:

$$T_1 = Q + L - P - S = 70 + 75 - 30 - 20 = 95 \text{ mm}$$

$$T_2 = P + Q - L - S = 30 + 70 - 75 - 20 = 5 \text{ mm}$$

$$T_3 = L + P - Q - S = 75 + 30 - 70 - 20 = 15 \text{ mm}$$

T_1	T_2	T_3	Input α	Output β
+	+	+	crank	rocker
0	+	+	crank	π-rocker
-	+	+	π-rocker	π-rocker
+	0	+	crank	0-rocker
0	0	+	crank	crank
-	0	+	crank	crank
+	-	+	π-rocker	0-rocker
0	-	+	crank	crank
-	-	+	crank	crank

Table 1: Types of 4 bar linkage assembly

Since the values of T_1, T_2 and T_3 I obtained were all positive, using **Table 1,** I determined the configuration type to be a crank rocker, which is shown in the very top row of the table ("Dynamics").

RESULTS

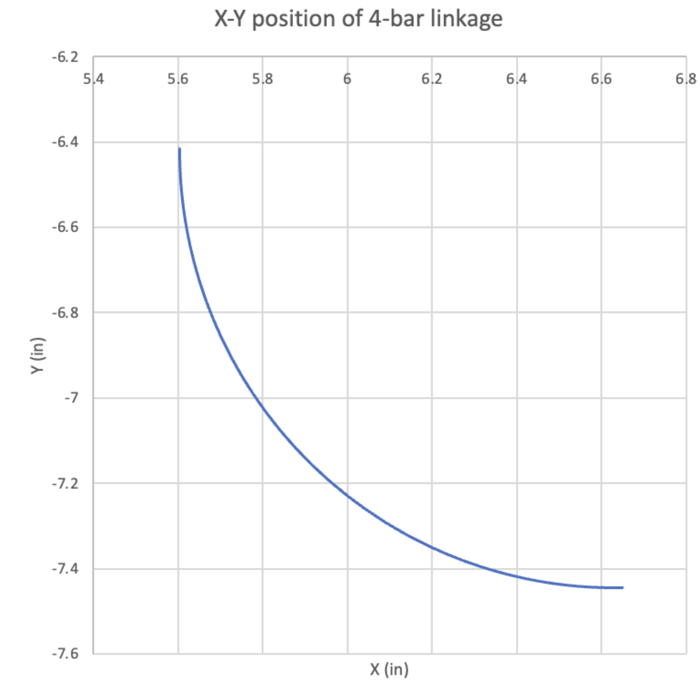

Figure 4: Trace Curve (X-Y position) of 4 Bar Linkage output point (in)

As seen in **Figure 4**, the largest incremental X displacement turned out to be 1.047 inches, while the largest incremental Y displacement turned out to be approximately 1.031 inches. These incremental displacements were calculated as follow:

Largest incremental X displacement: 6.65122083- 5.60431294 = 1.04690789 inches

Largest incremental Y displacement: -6.41457156-(-7.4452765) = 1.03070494 inches

CONCLUSIONS

Overall, I believe that the creation of this 4 bar linkage was successful since it created the motion I had hoped for. In a crank rocker 4 bar linkage that I had created, the shortest link, or the crank, rotates 360 degrees, while the other links oscillate, which is a perfect motion in reflecting the childhood motion I had hoped for. The crank is similar to my arms in that it fully rotates, showing excitement in what I have to show to my father. On the other hand, the other links oscillate and do not rotate completely, which is a perfect representation of my dad's arms as he didn't necessarily want to see what I had to show him at times and often hesitated and resisted my forces. If I were to go through the same process of making 4 bar linkages, there are few changes I would make. One of the things I would change is the size. I made the lengths of the 4 bars very small, using millimeters, due to the concern I had that the linkage could go over the 8.5 x 11 inch boundary. However, my four bar linkage turned out to be very small compared to the boundary, so next time, I would want to challenge myself in finding the maximum combination of the length I can have that's still inside the boundary. Other improvements that I would make is the usage of the washers. To ensure that the components didn't interfere with each other while moving, I had to attach additional washers to increase the height or level of some of the bars. To reduce the cost of these extra washers I had implemented, I could use fasteners with a different height or add in spacers for some parts instead to make sure that it levels and doesn't interfere next time.

Works Cited

“Dynamics.” *Four-Bar Linkages*, https://dynref.engr.illinois.edu/aml.html#aml-sl.

Team, Editorial. “Crank Rocker Mechanism: Theory of Machines.” FreeAptitudeCamp, 27 Dec. 2019, https://www.freeaptitudecamp.com/crank-rocker-mechanism/.