1 PT-014 Chassis Folding System

Artifact ID	Artifact Title	
PT-014	Chassis Folding System	
Team	**Revision**	**Artifact Date**
BYU Mars Rover	2.0	02 Dec 2021
Prepared by:		**Checked by:**
Dallin Cordon		Kyle Rippstein

1.1 Revision History

Revision	Date	Made by	Checked by	Description
1.0	18 Nov 2021	Rock Kim	Joe Liechty	First Draft
2.0	02 Dec 2021	Dallin Cordon	K. Rippstein	Revised System Overview, added Development section

1.2 Purpose

The purpose of this artifact is to describe the folding system for the chassis. The folding system uses two movements to decrease the size of the rover. 3D CAD files can be found in the BYU Mars Rover J-drive.

1.3 System Overview

The main objective of the folding systems is to permit the Mars Rover to meet the 2022 URC dimensional requirements. The system modifies the old chassis design rather than creating a completely new chassis.

There are two major components to the prototype folding system. The first folding system rotates the wheel-base 180 degrees around the x-axis such that the legs are inverted (z-direction). This system reduces the rover's vertical height by eliminating any space between the bottom of electrical box and the ground. As such, the rover will rest on its electrical box rather than on its wheels for weigh in.

The second component folds the normally forward-facing section of the rocker link about the y-axis (i.e. in plane with the rest of the wheel base). A Variloc adjustable locking rotary hinge purchased from Adjustable Locking Technologies LLC accomplishes the folding motion. This system reduces the rover's overall length (x-direction). This length reduction was initially designed to be accomplished through a telescoping system. Information regarding the move from telescoping to folding is found in the next section.

These changes make the rover able to meet the size requirements for the competition.

1.4 Development

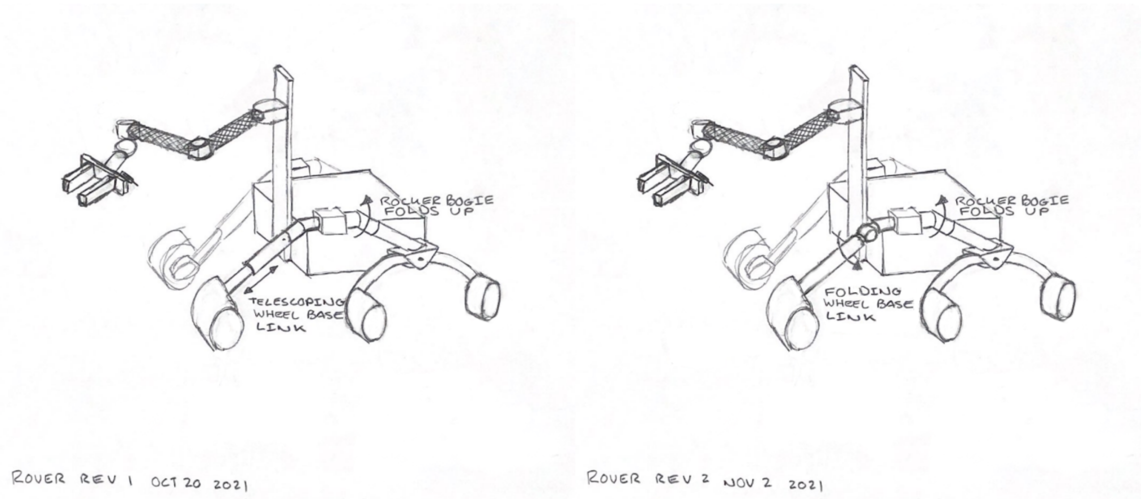

Figure 1: Comparison of initial telescoping concept (left) and implemented hinge concept (right).

Telescoping Links to Folding Hinge

Initial concept selection for size reduction of the rover implemented a combination of the rotation of the entire wheel base 180 degree and telescoping rocker-bogie linkages allowing for size reduction in height and length, respectively.

Upon further inspection, the telescoping design did not achieve the size decrease required. Additional concerns included the time to manufacture a new set of linkages, matching tube curvature and diameters for slop-free sliding tolerance, avoidance of wire pinching during the telescoping motion, methods of securing the tubing to ensure no relative motion of parts during nominal rover operation, and the need to re-manufacture connection points between the linkages and the wheel motors.

A few solutions to the above concerns were discussed. Those included the following:

- Replacing curved, metal piping with straight, carbon fiber tubes built specifically for telescoping. This would eliminate the difficulty of accurate pipe bending and implementing appropriate tolerances. While carbon fiber manufacturing is no easy task, companies like Rock West Composites sell pre-made telescoping carbon fiber tubes and we considered buying from them directly. The carbon fiber would be strong and would have the added benefit of reducing weight. However, the connection point between link and wheel motor would still need to be considered.
- To ensure no relative motion of parts during nominal rover operation, plans were derived to use clevis and cotter pins to hold the linkages in place.
- To avoid pinching wires, a bulkhead, cap, or plate was proposed to be placed on the end of the inner telescoping tube. This plate would have a hole in the center through which wiring

would be fed. The idea was that, if the wiring passed through the center of the tube, it would be less likely to interact with the sliding interface and get caught.

While not impossible to implement, given time constraints and the issue of URC size requirement non-conformance, the telescoping link concept was abandoned in favor of the folding links. This may yet prove to be a valid idea that could be implemented by later teams.

In place of telescoping, an aluminum locking adjustable rotary hinge was purchased from Adjustable Locking Technologies LLC (Fig. 2). To actuate the hinge, one presses the black button in its center which disengages the locking mechanism. The components are then free to rotate. The hinge has a 220 degree range of rotation and can lock every 10 degrees. According to Adjustable Locking Technologies, "Once locked, the hinge becomes an absolutely rigid joint, able to withstand 500 inch-lbs of torque (5:1 safety factor)."

Figure 2: Modified image of medium duty aluminum locking hinge taken from the Adjustable Locking Technologies LLC product page.

The hinge-end diameters are smaller than the inner diameter of the rocker-bogie tubes. To accommodate this, current prototype design requires a spacer to be placed between the outer diameter of the hinge and the inner diameter of the tube. Currently this spacer is 3D printed using PLA. However, due to heat-tolerance concerns, the final design is intended to be either 3D printed from ABS or machined from Delrin (acetal plastic). This will only be required for one side due to the nature of the hinge-sleeve connection on the other side. This connection can be seen in Fig. 7.

The hinge has the following weight and material properties as specified from the company website: body: 7075-T6 aluminum, anodized; pins: 416 stainless steel, heat treated; release button: black thermoplastic; weight: 5.8 oz.

Rocker-Bogie Clamp

The first folding system (mentioned in the System Overview section above and hereafter referred to as the ‘rocker-bogie clamp‘ or ‘clamp‘), underwent thorough discussion before finalizing the prototype concept selection. Our design needed to be secure (to avoid rotation at any time other than weigh in), easy to use (for quick implementation from standing to folded), light-weight, and simple.

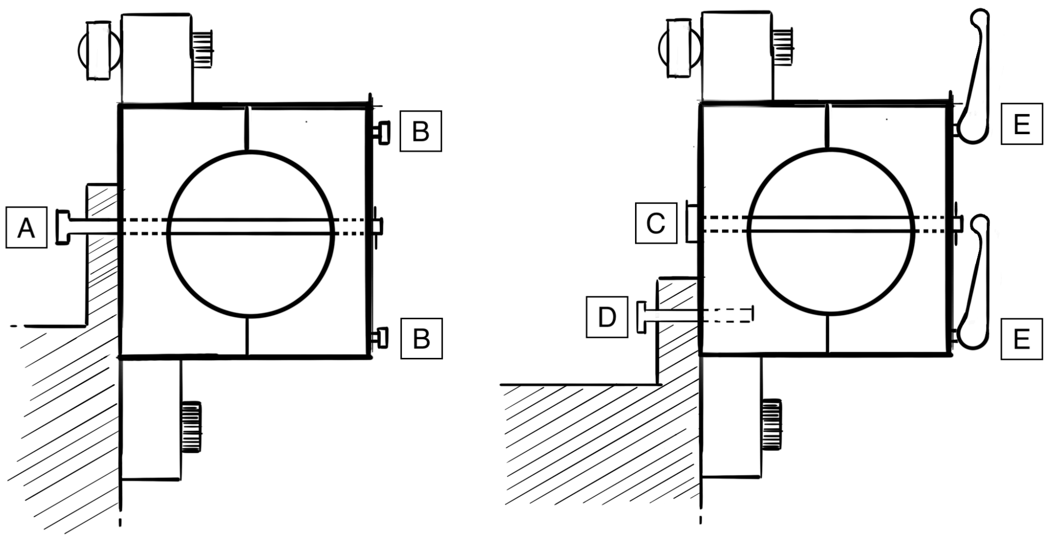

Figure 3: Comparison sketch of current rocker-bogie clamp (left) and implemented clamp concept (right) as seen from the front of the rover.

The preexisting rocker-bogie clamp had a single pin that secured the clamp against the face of the rover's electrical box, prevented rotation of the rocker-bogie linkages, and provided hard limits as to the extent to which the clamp could rotate about its bolted pivot point (this is accomplished by means of a channel cut into the wall of the electrical box wherein the pin resides). This pin can be seen at location A in Fig. 3. While essential, this pin was intended to be a semi-permanent solution and interferes with desired folding.

As such, the new clamp prototype replaces this single clevis pin with two clevis pins (marked as C in Fig. 3) and an additional shoulder bolt (marked as D in Fig. 3). The two clevis pins prevent premature link rotation but can be quickly removed, allowing the rocker-bogie to be rotated 180 degrees. The pins can then be reinserted to maintain the wheel-base in its upright position. The new shoulder bolt is threaded directly into the clamp and secures the clamp against the face of the rover's electrical box. The shoulder bolt fits in the same channel that provides mechanical limits to the extent the clamp can rotate about its bolted pivot points.

The preexisting clamp provided clamping force via bolts shown as B in Fig. 3. The new prototype uses the same principle however, standard bolts are replaced with quick release pins used for bicycle seat posts (E in Fig. 3) thus increasing the speed at which the desired folding can occur.

The current clamp design makes direct, aluminum-on-aluminum contact with the electrical box. In order to reduce wear and friction, 1/32" thick PTFE sheet with 3M 300LSE industrial strength self-adhesive backing is placed both on the electrical box and the clamp resulting in a PTFE-on-PTFE contact surface.

The prototype clamp was optimized through Altair Inspire software. Results of the optimization process were used to redesign the clamp pieces to maintain stiffness while reducing weight. A glimpse of this process can be seen in Fig. 5.

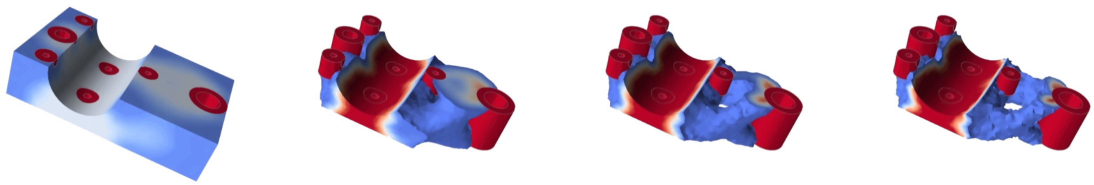

Figure 4: Demonstration of Altair topology optimization process used for weight reduction in clamp design. Shown above is the back clamp whose surface contacts the electrical box. Note that, though not shown, the front clamp half likewise underwent a similar topology optimization process.

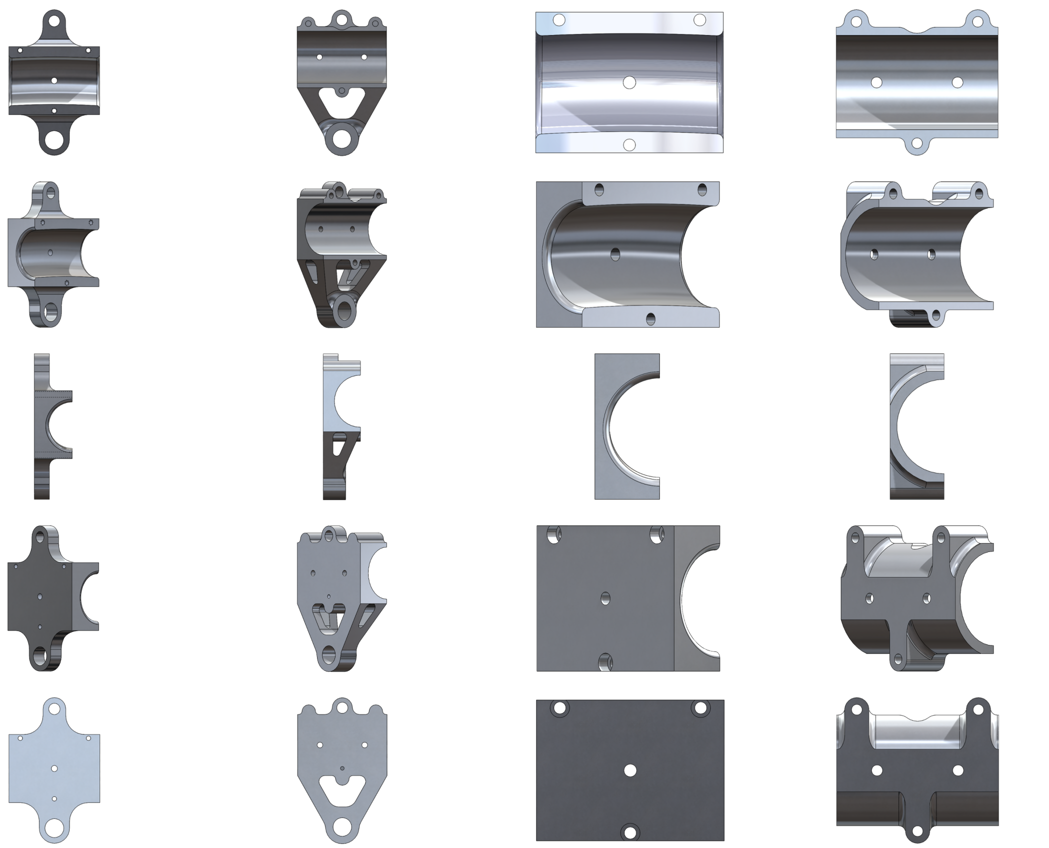

Figure 5: Comparison of preexisting clamp designs (front and back) with prototype clamp designs. The columns are, from left to right: preexisting back-half, prototype back-half, preexisting front-half, prototype front-half.

Clamp-Sleeve Design

The curved rocker-bogie links became an issue for the clamp prototype. The current clamps have curved openings that match the curvature of the links but further prevent rotation. Making the clamping channel with no curvature would permit rotation, but minimize clamping effectiveness. This issue is illustrated by Fig. 6.

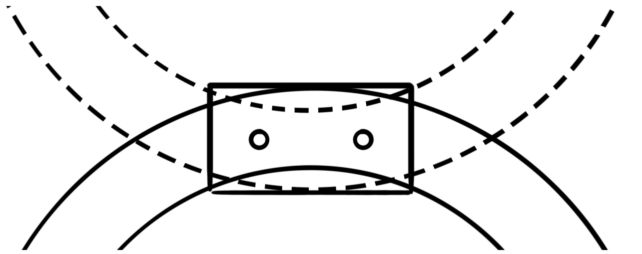

Figure 6: Demonstration of rocker-bogie rotating in a straight channel. Note that, for any given orientation, there are only three points of contact between the clamp and the rocker-bogie.

A number of designs were considered to account for this. Among them were cutting the link and welding a straight section in between, manufacturing a new link that accommodates a straight portion, sliding a larger straight section of pipe over the curved area and welding it in place, and creating a sleeve which would fill all available space between the curved link and the straight channel. Initially the sleeve concept was selected. The sleeve would be fitted over the rocker-bogie link and would rotate inside the clamp. The sleeve was intended to be 3D printed given its geometric complexity. However, following the advice of the project sponsor, Dave Laws, the 3D printed sleeve design was rejected in favor of a new design that favors robustness and ease of manufacturing.

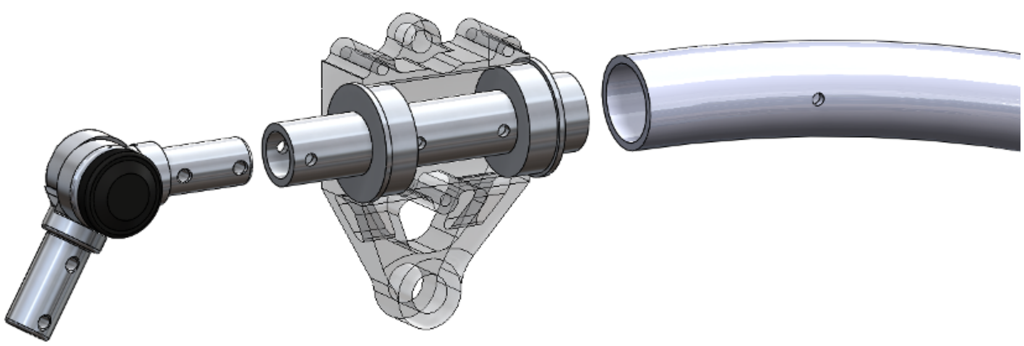

Figure 7: CAD assembly of revised sleeve design consisting of the following components from left to right: hinge, sleeve, clamp (transparent), and rocker tube. Note: Front half of clamp is not shown.

Rather than accommodate the curved link passing through the clamp, the rocker link will be cut. One end (Fig. 7, right) will be welded to a straight aluminum sleeve (Fig. 7, center) which rotates freely in the clamp (Fig. 7, center, transparent) while the other end will first attach to the Variloc hinge (Fig. 7, left) which, in turn, is fastened to the other end of the sleeve. The sleeve has holes whose diameter and location align with those made in the clamps for the clevis pins as seen in Fig. 3 C thus eliminating premature rotation.