Buggy Spring for Jeep Cherokee

by

BRIAN WATSON

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Certified by

Accepted by

Mechanical Engineering Technology

Janak Dave, PhD,
Thesis Advisor

Muthar Al-Ubaidi, PhD, Department Head
Mechanical Engineering Technology
BUGGY SPRING SUSPENSION FOR JEEP CHEROKEES

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BRIAN N. WATSON
ADVISOR: JANAK DAVE
ABSTRACT

The Jeep Cherokee, also known as the XJ, can be a practical dual-purpose vehicle, used for on-road daily routines and off-road recreational duties. A lack of rear wheel travel, however, limits the off-road performance of these vehicles. Alterations need to be made to the rear suspensions of Jeep Cherokees in order to increase wheel travel and allow Cherokees to traverse uneven terrain without sacrificing safety while driving on-road during those daily routines. This report introduces some possible design modifications that can be made to gain greater wheel travel from the standard leaf-spring rear suspension of Jeep Cherokees. Three possible designs are introduced and the best design selected to be fabricated. Cherokee owners who use their vehicle for off-road use were contacted through a survey to determine what they are looking for in a rear suspension design for better off-road performance. Some important features that drove the selection of the final design were the amount of wheel travel gained, convertibility for both on and off-road duties, safety, cost, ease of installation, and being able to remove any alterations without permanently damaging the vehicle.
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INTRODUCTION

Since the introduction of the Jeep Cherokee XJ in 1984, it has grown in popularity with the off-road crowd. Live solid axles, coil spring front suspension, good power to weight ratio, a strong transfer case, and a torquey motor have all contributed to this vehicle’s popularity for off-road use. Unfortunately, while the Grand Cherokee and Wrangler models have been upgraded with front and rear coil spring suspensions, the Cherokee XJ has kept its original rear leaf-spring suspension. Leaf-springs are simple, cheap, and can handle heavy weight, however, they do not offer the comfort or wheel travel that coil springs provide in the newer Jeeps models.

Wheel travel is one of the most important aspects of a good off-road vehicle. The problem being addressed by this project is that the design of the rear leaf-spring suspension found on Jeep Cherokee XJs, in stock form, does not offer the wheel travel that it is capable of. Wheel travel is the amount a wheel can move vertically from spring compression to full extension. It is important for an off-road vehicle to have enough wheel travel in order to keep all the tires in contact with the ground while traveling across uneven terrain. This does not only help in traction to keep the vehicle moving but also help safety. The following picture shows how dangerous a stiff leaf-spring suspension with minimal wheel travel can be while driving over large rocks. Notice how high the rear tire is above the ground. This particular vehicle is a CJ-7 which has leaf-springs both in the front and rear suspensions. The standard shackles and leaf-springs do not allow the wheels to move enough to stay in contact with the ground. Because of the stiff suspension, the axles stay in line with the body of the vehicle. In order for the tires to try
to keep contact with the ground, the body of the vehicle moves with the terrain. This can shift the weight of the vehicle and cause the vehicle to rollover.

![Fig. 1 – CJ-7 with stiff leaf-spring suspension](image)

This next vehicle, which happens to be the test vehicle of this project, has a suspension that will allow the wheels to move more than the CJ-7 and stay in contact with the ground. Because of more wheel travel than the CJ-7 shown, the axles are able to move away from the body of the vehicle. The tires, wheels and axles follow the terrain instead of the body of the vehicle to keep the vehicle’s center of gravity centered. This Cherokee is much more stable while driving off of this same rock ledge.
Fig. 2 – Jeep Cherokee with almost 24 inches of wheel travel

This Cherokee has approximately 24 inches of rear wheel travel over the 12 inches of wheel travel that the CJ-7 has. Below is a picture of how coil springs in the front suspension allow the axles to twist to gain more wheel travel to keep the tires in touch with the ground.
Notice how level the vehicle is in this picture. Even though the vehicle is driving across a deep washout in the trail, the body of the vehicle stays horizontal while the axle is allowed to move to follow the terrain. This kind of wheel travel is not only achieved by coil spring suspensions. A leaf-spring suspension can create this much axle articulation if modified to do so. With the proper modifications, the rear suspension of this vehicle can produce as much wheel travel as the front suspension and greatly enhance the vehicle’s stability while traversing uneven terrain.

Below is a drawing of the original leaf-spring design of the rear Cherokee suspension. This is the passenger side of the vehicle. The left side is the rear of the vehicle.
The blue area is the frame of the vehicle. The gray section is the leaf-spring pack. The spring mounts solidly to the frame on the front side of the spring. The rear end of the spring pivots on a shackle, the green part, which then attaches to the frame. The shackle allows the needed movement in the system. As the spring compresses and extends, the shackle pivots at the frame to allow the needed forward and backward movement of the leaf-spring.

There are many different ways to enhance the wheel travel of this leaf-spring design. This report intends to introduce three possible solutions that would help the original leaf-spring rear suspension gain greater wheel travel. These solutions will be devices that will be added to the leaf-spring suspension, not a replacement for the leaf-spring suspension. Three possible solutions will be introduced and of the three possible solutions, one device will be chosen to be designed in detail, fabricated, and tested on the vehicle.

The main intended purpose of this device will be to add 4 inches of wheel travel to the rear suspension of an XJ. Safety is a major concern also. Stopping a vehicle with large amounts of wheel travel can be dangerous. As the weight shifts forward during braking, the rear springs will extend to try to keep the tires on the ground. The extended
springs are not as stable as springs that are positioned at normal ride-height and the rear end up the vehicle can be hard to control. With a standard leaf-spring, the spring will allow the rear end of the vehicle to raise during a sudden stop as far as the spring can extend. Once the spring extends, the vehicle would have to lift the weight of the rear axle, tires, wheels, and suspension parts to raise any higher. With a suspension with more suspension travel, the rear end of the vehicle will raise higher than a stock vehicle before reaching the full extension of the spring. This places more weight on the front brakes of the vehicle. This device will take this into account and will not increase braking distance by more than 10%. Another important characteristic of this device is that it should be easily installed and removed, if need be. There should be no cutting or welding of the vehicle’s frame in order to accept the new device. Drilling of some holes will be the only acceptable modification to the frame.

The “Technical Discussion” section of this report will cover, in detail, the alternative designs, selection process of the preferred design, and detailed design of the selected system that will help give a Jeep Cherokee 4 inches more wheel travel at the rear wheels.
The off-road market continues to grow and more and more companies are manufacturing suspension components to improve off-road prowess. Just in the last six years major aftermarket suspension companies have begun selling suspension kits for Cherokees. Such companies as Rubicon Express, Tera-Flex, TrailMaster, Superlift, BDS, Rusty’s Off-Road, and many others have realized the potential that these vehicles possess to become great off-road vehicles. While most of these companies target the front coil-spring design of the Cherokee to enhance wheel travel, few address the rear leaf-spring design. Most aftermarket suspension companies offer stiffer springs, add-a-leafs, or lift blocks for off-road use. These devices only hurt the wheel travel of the leaf-springs. Tera manufacturing company, owners of Tera-Flex suspensions, is one company that does see a potential in the rear suspension of the Cherokees. They have developed two alternatives to help wheel travel in the rear end of Cherokees.

Their first design is called a Revolver Shackle. This can be added to the existing suspension of Jeep Cherokees. This device replaces the stock shackle that attaches the spring to the frame. The Revolver Shackle is actually two shackles combined. One half of the shackle lies horizontally while the other half stays in the vertical position like a stock shackle. During normal driving, only the vertical half of the shackle is in use. When the vehicle drives over terrain which calls for more wheel travel, the horizontal half of the shackle pivots at the frame to unfold, allowing the spring to drop further away from the frame. Below are some pictures of the Revolver Shackle in its folded position, extended position, and mounted on a vehicle.
Fig. 5 – Revolver Shackle in Extended (unfolded) Position

Fig. 6 – Revolver Shackle in Folded Position

Fig. 7 – Revolver on vehicle in extended position
The Revolver Shackles perform to give Cherokees added rear wheel travel but there are two major design flaws of this device. The first design flaw is the most important and addresses safety. There is nothing on the Revolver Shackle to keep itself from unfolding except for the weight of the vehicle and the ground pushing up against that weight. During braking the vehicle tries to continue its normal path of driving. This is why the front of the vehicle dives down and the rear-end of the vehicle rises until the end of suspension travel. The Revolvers will unfold to try to keep the tires on the ground whenever the rear-end rises. Since the Revolver Shackles allow more wheel travel, they will also allow the rear-end of the vehicle to rise even higher than normal. This takes weight off of the rear brakes and transfers it up to the front brakes, causing a longer time to come to a complete stop. A suspension with more resistance to unloading would help keep the rear-end of the vehicle down, resulting in more weight on the rear brakes, instead of relying on the front brakes to stop. These shackles can also unfold while turning sharp corners, allowing one side of the vehicle to rise higher than normal. This can shift the center of gravity of the vehicle to a dangerous area, possibly enough to roll the vehicle.

The second design flaw in the Revolver Shackles is in their durability. The center section of these shackles is a small cylinder that allows twisting as well as unfolding to gain more wheel travel. There were 14 cases recorded last year on NAXJA’s (North American XJ Association – a national Cherokee club) on-line discussion forum of Revolver Shackles breaking in this center section.

Other suspension companies make folding shackles similar to the Revolver Shackles. Glen Wakefield of Rocky-Road Outfitter’s has a patent pending on his
Missing Link Shackle. He does not currently manufacture a missing-link shackle for Cherokees but he claims that one is “in-the-works” and is to be out on the market soon. Below is a picture of his missing-link shackle (while extended) installed on a Suzuki Samurai.

![Fig. 8 – Missing link folding shackle](image)

Tera-Flex offers another solution to the lack of wheel travel in Cherokee’s leaf-spring design. They offer a complete replacement rear suspension using coil springs. This is a very complicated suspension requiring professional installation. Two other suspension companies, Black Diamond (formerly owned by Warn Industries) and Rusty’s Off-Road have attempted to develop rear coil-spring conversions for Jeep Cherokees. Due to complications and cost, Black Diamond pulled their kit off of the market within a
year and Rusty’s design never even got to market before he determined it as too complicated for most Cherokee owners.

The Tera-Flex suspension is the only one still available on the market at this time. This kit costs approximately $3000.

Below is a picture of just the rear components needed for the coil conversion.

![Rear coil spring conversion kit](image)

Fig. 9 – Rear coil spring conversion kit

Tera-Flex continues to sell their Revolver Shackles even though they have their problems mainly because this is the easiest, cheapest, most available device available at this time to gain more wheel travel for Jeep Cherokees. The Revolver Shackles currently cost approximately $185 plus shipping per pair.

Internet research on the coil conversions and patent searches on these and the folding shackles were reasons to avoid these designs. In order to determine just what Cherokee owners are looking for a survey was conducted. The survey was posted on several off-road website message boards. One such website is [www.NAXJA.org](http://www.NAXJA.org), the North American XJ Association. This is an Internet based off-road club exclusively for owners of Jeep Cherokees and their pick-up truck version the Jeep Comanche. This club
has over 300 members who are eager to help people needing advice and information on modifying Cherokees for off-road use. This forum delivered the most response to the survey with 28 of the total 34 responses. Other Internet based forums used were www.Jeepin.com, www.dirtroad.com, and www.off-road.com to get as many responses as possible. The survey was also given to local Jeep Cherokee owners who use their vehicles for off-road use. The survey that was given can be found in the “Appendices” section of this report.

After reviewing the results from the survey, the customer and the customer needs were obtained. This device would be targeted towards those in the difficult to hardcore classification that use their vehicles frequently off-road and do not mind giving up some on-road handling for off-road prowess. Braking distance was the main concern during on-road use. The system should be an addition to the existing suspension for simple installation and lower cost. Information from the survey and personal fabrication skills created the following important characteristics that would drive the design selection.

- Amount of wheel travel
- Road manners (handling and braking)
- Amount of modifications needing to be performed on vehicle to take advantage of enhanced suspension
- Adjustability (being able to switch from an on-road mode to and off-road mode and being able to adjust the device to handle different springs and shackles)
- Cost to customer
- Downforce on axle from device to enhance traction
- Ease of installation
- Coolness Factor (uniqueness)
- Cost to manufacture
- Ease of fabrication
- Patent avoidance

From these characteristics the requirements of the system were defined to be:

- Will help give a Jeep Cherokee 4 inches more wheel travel at the rear wheels.
- Device will not increase braking distance by more than 10%.
- It will require only some drilling of the frame for installation.
- The analysis, design, and construction of a prototype will be completed by May of 2002 at a budget of less than $300
- These devices will be added to the leaf-spring suspension, not a replacement for the leaf-spring suspension.
TECHNICAL DISCUSSION

From the surveys that were filled out on this subject, the targeted audience wants simple, inexpensive, safe, non-permanent alterations to the current rear suspension to gain improved off-road performance in the way of greater wheel travel. For simplicity and low cost, designing add-on components to enhance the existing suspension would be the best method. This could be done in a number of ways. The three designs that were studied are described below.

Some possible additions to leaf-springs that would help articulation are a folding shackle or a ¾ elliptical spring (often referred to as a “buggy spring”). A folding shackle is basically two shackles bolted together. One shackle lies flat along the frame of the vehicle and the other drops down and acts as a normal shackle. As the suspension flexes, the top shackle will pull away from the frame and the pair of shackles will unfold until straight. Folding shackles have been used on many leaf-spring suspensions other than just those found on Cherokees. They are a proven design. Cherokees do not have a separate frame and body. They are composed of a unibody. The shackle mount on the subframe is a cup that is attached to the side of the frame rail. This design cannot support a folding shackle. The proposed design is a bracket that reinforces the stock mounting location so that a folding shackle can be used without fear of damaging the unibody chassis of the Cherokee.

A ¾ elliptical suspension consists of the standard leaf-spring pack, a shackle, and another leaf spring. The leaf spring pack on bottom attaches to the frame at one end, the axle in the middle, but then instead of connecting to a shackle that is connected to the frame, it connects to a shackle that is connected to an inverted ½ of a main leaf-spring.
This ½ leaf-spring then attaches to the frame solidly. When looking at this spring set-up, it looks like ¾ of an ellipse. As in the folding shackle, the ½ spring will pull away from the frame to give the suspension more articulation. The ½ spring is considered the buggy spring. See figures 10 and 11 below for diagrams of a buggy spring suspension.
The standard leaf spring pack attaches to the frame at the forward end just as normal. The red part is a bracket that would hold the buggy spring (the small gray spring). The two springs would be connected by a shackle (green part). This would move the pivot point of the suspension from the end of the shackle to the mounting point of the ½ spring on the frame. Buggy springs suspensions are nothing new to the off-road world. Like the folding shackles, there are companies that manufacture buggy spring suspension components for vehicles, just not Cherokees yet.

Below are photos of a Jeep Wrangler YJ with a buggy spring front suspension manufactured by Mountain Off-Road Enterprises. The YJ is flexing its suspension on an RTI ramp.

Fig. 12 – Jeep YJ with buggy spring front suspension
Below is a close-up shot of the buggy spring that is used on Yjs.

![DO NOT ADD ANY SPACERS OR PADS](image)

Fig. 13 – Buggy spring for YJ

Due to the unibody construction of the Jeep Cherokee and the fact that the shackle cup is offset to the side of the frame, a support bracket would be needed in order to use a buggy spring suspension.

A third possible alternative would be completely unique. There are no manufacturers making anything that resembles this kind of suspension. It would be similar in design to the buggy spring system in that the lower spring would connect to a shackle that is not directly attached to the frame. Instead, the shackle would be attached to a bar horizontally perpendicular to the spring. That bar would cross the vehicle and attach to the opposite framerail. This would create a pivot point for the suspension on the opposite side for a large increase in wheel travel. The bars for each side would cross in the center of the vehicle. This design is very complicated but, if it could be done, would be expected to give more wheel travel than either the folding shackle or the buggy spring system.
Once the three designs were proposed, they were run through the selection process of a weighted objectives method using the selecting characteristics derived from the survey. For each design, each characteristic was evaluated and multiplied by the weight of the characteristic. The more crucial the characteristic, the higher the weight. Once all the scores were calculated, they were totaled for each design. The design with the highest overall score would be selected for detailed design and fabrication. Figure 14 below shows the spreadsheet used to calculate the scores for each design to determine to best design.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Weight</th>
<th>Folding Shackle</th>
<th>Buggy Spring</th>
<th>Transverse Bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of wheel travel</td>
<td>10</td>
<td>2</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>Brake performance</td>
<td>9</td>
<td>1</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Ease of installation</td>
<td>7</td>
<td>5</td>
<td>35</td>
<td>4</td>
</tr>
<tr>
<td>Amount of modifications</td>
<td>6</td>
<td>5</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>Road manners</td>
<td>5</td>
<td>3</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>Adjustability</td>
<td>7</td>
<td>2</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>Cost to customer</td>
<td>6</td>
<td>5</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>Coolness Factor</td>
<td>3</td>
<td>2</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Downforce on axle</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Cost to manufacture</td>
<td>6</td>
<td>5</td>
<td>30</td>
<td>4</td>
</tr>
<tr>
<td>Ease of fabrication</td>
<td>5</td>
<td>5</td>
<td>25</td>
<td>4</td>
</tr>
<tr>
<td>Patent avoidance</td>
<td>9</td>
<td>2</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>237</strong></td>
<td><strong>317</strong></td>
<td><strong>257</strong></td>
</tr>
</tbody>
</table>

Fig. 14 – Weighted objectives table

The characteristic weight was determined based upon the survey discussed in the Survey of Technical Sources section of this report. The survey itself can be found in the Appendix. The scores given to each design were from 1-5 with 1 being the least desirable and 5 being the most desirable in that category.
Through the weighted objective method it was determined that the buggy spring suspension was the best solution to the problem at hand. The main traits that make the buggy spring the best choice are the amount of wheel travel available, ability to be pinned for street use so that braking performance is unharmed, it is a proven design for other vehicles, can be produced for under $400, can be installed and removed from the vehicle easily, and the buggy spring forces the tire to the ground as apposed to gravity pulling the axle down.

Due to the unibody construction, design of the buggy spring suspension started with studying the frame and existing suspension of the Cherokee. The longer the buggy spring can be, the more wheel travel can be obtained from the system. Solid mounting points needed to be determined on the frame to support the suspension. The rear end of the bracket would be simple. To keep from relocating the springs, the stock shackle mount cups would be used as mounting points. These mounts are designed to handle the loads of suspension work so strength would not be an issue. There are three holes in the bottom of the framerail just inside the shackle mount cups. These holes are designed to hold the bumper and receiver hitch to the frame. Using these existing holes meant now there are two solid, strong mounting points which do not require alterations to the vehicle. Moving to the front of the bracket, some problems occurred. The gastank lies close to the framerails on both sides just forward of the shackle cups. A molded cross member lies approximately 20 inches forward of the shackle cup. There is a bend in the frame 2 inches before the crossmember. The original design was to mount the bracket directly above the axle using a buggy spring of 28 inches. Due to the bend and crossmember, the length had to be shortened. The bend in the frame was determined to
be the best location for the front mounting point. The bend helps to clear the gastank and is far enough away from the shackle cup to result in a buggy spring length of 16 inches. An eccentric plate was cut to fit the dimensions of the frame. The drilled hole in the frame required for the front frame mount on the bracket can be seen (circled in yellow) in the picture below.

![Fig. 15 – Bracket mount drill hole in frame](image)

All of the main features of the bracket can be seen in appendix 2.
DESCRIPTION OF DESIGN

The plate is seven inches wide at the rear and 7.5 inches wide in the front. For all dimensions see CAD drawings in Appendix 1. The taper appears on the frame side to follow the bend of the frame. To get the buggy spring as long as possible for the most wheel travel, the frame mount on the front end of the bracket was designed to fit along the bend in the frame. Angle braces were introduced to keep the bracket from bending under load. These span from the top of the front frame mount down to the outside edge of the bracket. There is one on either side of the spring bolts. When the bracket is attached to the frame, the outside edge of the bracket is in alignment with the outside edge of the existing shackle cup mount. This allows the buggy spring to be positioned directly above the main leaf-spring pack. Under the bracket contains the important features for the buggy spring. The spring is attached to the bracket via two bolts and a sandwich plate. Two four inch long by three-quarter inch deep locator bars are positioned to help locate the sandwich plate. The buggy spring is placed between the bracket and the sandwich plate. The two ½” grade 8 bolts with nylon lock-nuts hold the pieces together. The locator bars keep the spring from twisting or sliding sideways which would cause stress on the spring and bolts. The other two small tabs hanging down in the rear of the bracket are the retaining pin tabs. These tabs help the spring to slide back into its normal position during suspension cycle. They also have a 3/8” hole drilled through them. A 3/8” retaining bolt with a cotter pin, when inserted through the tabs, keeps the buggy spring against the bracket. This causes the system to act as a normal leaf-spring pack and shackle suspension. While pinned, this system does not allow anymore wheel travel than the standard spring and shackle suspension. Since the buggy spring is
contained and cannot unload, it does not affect driving characteristics at all. Corners can be driven at normal speed without worry of the buggy spring opening and causing a rollover. Braking distance also is not affected because the buggy spring is not allowed to unload. When the vehicle is ready for off-road use, the owner can simply pull the cotter pin and slide the retaining pin out of the tabs. Now that there is nothing holding the buggy spring to the frame but the two bolts at the front end, the spring is allowed to drop away from the frame if needed for increased wheel travel. The following is a construction picture of the bracket. The frame mounts have been welded on and the location of the spring bolts are being placed.

![Fig. 16 – Bracket construction](image)

The buggy spring used for this particular application was a stock Wrangler YJ rear main leaf-spring cut down to length. Wrangler rear leaf springs have a slightly higher spring rate at 150 #/in as apposed to Cherokees 140 #/in. The added spring rate helps to push the axle down when the buggy spring unloads. The forcing of the axle down helps traction and creates a smoother cycle of the suspension than a system that simply relies on gravity to pull the axle down.
The original design used a standard Wrangler YJ shackle for the connection between the leaf-spring pack and the buggy spring. On the next page are some pictures of the bracket installed on the Cherokee with the YJ shackle.

![Image of bracket with YJ shackle](image)

Fig. 17 – Bracket installed with YJ shackle. Buggy spring in extended position. View from the rear of the vehicle.

In this picture, the buggy spring can be seen pulling away from the bracket when the axle is allowed to drop. The YJ shackle worked well for increased wheel travel. The shackle in this picture is almost 5 inches below the bracket. The axle was resting on the floor-jack and could not be lowered any further and the buggy spring was not even completely extended yet. The next picture clearly shows how well the YJ shackle allowed the system to flex. The vehicle is in the same position as the picture above.
Even though the YJ spring worked better than intended in allowing the system to extend, it could not be used. The following pictures show why. When the floor-jack was engaged to push the axle back up to normal position, the YJ shackle inverted on the buggy spring. This could have been very dangerous. If the weight of the vehicle had been resting on the springs instead of the jack stands, the force would have possibly broken the leaf-springs in the position they ended up in.
Fig. 19 – YJ shackle inverted. Buggy spring in extended position. View from the rear of the vehicle.

Fig. 20 – Inverted YJ shackle front view
The inverted shackle was an unforeseen problem. There was a simple solution to the problem though. An anti-kickback shackle needed to be used in order to keep the shackle from inverting. There are suspension companies that sell these special shackles but at a cost of approximately $80 for a pair. Because of the retaining pin tabs, these shackles would need to be modified. Instead of buying new shackles and modifying them, a new shackle was designed specifically for this buggy spring system. Instead of the typical rectangular plates with a one inch square tube welded between them, like a standard shackle, triangular plates were used. Two 1” square tubes were welded between the plates. One in the normal position and another at the point of the triangle. When the shackle rotates now, the tube that crosses at the front of the triangle hits the buggy spring and keeps the shackle from inverting. The following picture shows the anti-kickback shackle clamped together and ready to be welded.

Fig. 21 – Two triangular plates and two 1” square tubes make up the anti-kickback shackles.
The following picture is of the anti-kickback shackle after installation. This is pre-modification to clear the retaining pin and tabs. The shackle in this case is almost to full rotation. If a rock or log was to hit the bottom of the shackle, it would cause the shackle to want to invert.

Fig. 22 – Anti-kickback shackle installed

The next picture is the anti-kickback shackle under load. The shackle is rotated completely up to hit the buggy spring. Once the load was removed, the system returned to normal without any damage.
The anti-kickback shackle was a success. It worked flawlessly. Below is a picture of the shackle after being modified to clear the retaining pin and tabs.
TESTING

The two most important characteristics of the buggy spring suspension are the wheel travel and braking ability. In order to prove the design works, the suspension must pass testing on both the added wheel travel and the braking ability of the vehicle.

Wheel travel is measured by the vertical movement of the tires from spring compression to spring extension. To measure this, the vehicle must be driven over terrain uneven enough to fully compress one rear spring while fully extending the other rear spring. The vertical distance from the top of one tire to the top of the other tire is the wheel travel. The test Cherokee measured 18 inches of wheel travel at the rear wheels. The intended wheel travel increase for the rear suspension was four inches. As long as the buggy spring suspension can meet or beat 22 inches of wheel travel, the design would pass this portion of the testing process. With the retaining pin removed, the buggy spring suspension obtained a total wheel travel of just under 24 inches. This beat the intended goal of 4 additional inches by almost 2 inches.

The second test involved the braking ability of the Cherokee before and after the buggy spring suspension was installed. The testing would be performed by driving the Cherokee to a constant speed of 40 mph. As the Cherokee reached a set marker the brakes were applied in a steady rate until the vehicle reached a complete stop. The intended result was a braking distance with the buggy spring suspension that was no longer than 10% longer than the Cherokee prior to the buggy spring installation. The testing was performed three times by the designer and three more times by Andy Biggs, an off-road enthusiast who is familiar with off-road vehicles. The original suspension had an average stopping distance of 63 feet from 40-0 mph. The Cherokee was able to
stop from 40-0 mph in 63.5 feet with the buggy spring suspension installed with the retaining pin connected. The maximum distance the vehicle was allowed to stop in to pass this test was 69.3 feet. Again the buggy spring suspension passed the test. It is not recommended to drive the vehicle over 20 mph with the retaining pin removed so no braking tests were performed without the retaining pin installed. The 6 inch added length in the braking distance between the two suspensions is acceptable. The retaining pin keeps the buggy spring from unloading and allowing the rear end of the vehicle to rise up during braking. The retaining pin is positioned approximately 3 inches in front of the shackle. The actual pivot point of the system can occur at the retaining pin due to the 3 inches of buggy spring bending. This is a very small amount and can be considered negligible. Six inches over 63 feet is just an increased braking distance of 0.8%.

One test of the buggy spring suspension that was never intended was a durability test. Since the installation of the buggy spring suspension, the Jeep Cherokee has been driven more than 7000 miles. Approximately 200 miles of this is off-road use. This suspension has been used to help the Cherokee navigate some of the toughest trails in Moab, Utah, an off-road haven. The suspension has been tested in the mud and rocks of southern Kentucky and northern Tennessee also. The following pictures are examples of the terrain that this suspension helps the Cherokee to traverse.
In the picture above, both the front and rear suspensions have reached their limit if wheel travel. Due to driver error, the rear-passenger side tire slipped off of the rock wall and fell into the ravine. Without adequate wheel travel, this slip could have caused the front-driver’s side tire to rise into the air. This would have caused a shift in the center of gravity of the vehicle, possibly enough to roll the vehicle onto its passenger side. Because of the added wheel travel of the buggy spring, the axles were allowed to follow the terrain and keep the body of the vehicle horizontal and the center of gravity in a safe location. The picture on the following page is of the rear buggy spring suspension extended while the vehicle is in the same position as in Fig. 25.
Fig. 26 – Extreme wheel travel from buggy spring

This is a rare case in that the driver’s side tire is so high on the rock that the axle is forcing the passenger side tire down as much as possible. The anti-kickback shackle on this spring is working as it should. The front crossbar of the shackle is touching the buggy spring, not allowing it to become inverted. This particular case gave the most wheel travel increase seen to date on this suspension. In this particular location, the wheel travel of the buggy spring suspension was measured at just over 26 inches. This is double the intended wheel travel increase that the suspension was designed for. Notice the amount of space between the gold shackle bolt and the retaining pin tab that can be seen hanging down. The picture on the next page shows the test vehicle crossing the famous Golden Crack in Moab, Utah. This is one obstacle that usually takes a highly modified suspension to cross without lifting a tire off of the ground. While crossing this crack in the Earth, only the front passenger-side tire left the ground about 4 inches. The
buggy spring suspension adhered to the terrain very successfully and did not allow either rear tire to leave the ground.

Fig. 27 – Crossing Golden Crack
This suspension does not only work on the terrain in Utah, it was field tested in Kentucky also.

Fig. 28 – Driving off Table-Top rock without lifting a tire (Natural Bridge, KY)

Fig. 29 – Same position as Fig. 28, front view.

Table-Top rock in Natural Bridge, KY is approximately 40 inches tall and has rolled many vehicles that do not possess enough wheel travel.
CONCLUSION & RECOMMENDATIONS

Through official testing the buggy spring suspension proved that it increases wheel travel on the rear suspensions of Jeep Cherokees. The intended goal of the suspension was 4 inches of additional wheel travel. The actual product increased wheel travel in the rear suspension by almost 6 inches.

With the retaining pin intact, the braking distance of the vehicle was not significantly increased.

This system has proved itself to be a true dual-purpose suspension.

As well as this suspension works, both on and off-road, it is not free from problems. The biggest problem with the suspension is when the retaining pin is removed and hard acceleration is needed. Under hard acceleration, the buggy spring wants to unload due to the torque applied to the axle. This torque rotates the axle backwards which bends the leaf-spring pack into an s-shape. The leaf-spring fights back to keep a normal arc-shape. In doing so, the spring will snap back into shape violently. This is a common occurrence in leaf-springs called axle-wrap. When the leaf spring bends into the s-shape, the buggy spring will pull away from the frame, allowing the leaf-spring pack to bend even more than normal. This causes an even harder snap back into normal shape. In order to tame axle-wrap a traction bar is needed. This is a linkage that attaches from the top of the axle to the frame with a shackle similar to that used on the leaf-spring. Since the linkage is attached to the top of the axle, when the torque is applied, the traction bar redirects that rotational force down to a vertical force that forces the axle down instead of backwards. Another problem that the traction bar would remedy is rear-steer
during extreme wheel travel situations. When a buggy spring pulls away from the frame to increase wheel travel, the suspension follows a circular path. As the axle moves down it will also pull forward. The causes the axle to twist horizontally and can actually turn the rear of the vehicle, hence the name rear-steer. Below is a picture of rear-steer.

![Fig. 30 – Rear steer](image)

This is the same location as Fig. 25 and 26. The added wheel travel saved this vehicle from rolling onto its side but experienced some rear-steer in the process. Notice how the tire is not centered in the wheel well anymore. It is pulled towards the front of the vehicle. A traction bar would allow the vertical movement of the axle but would not allow the tire to move forward like the tire shown in Fig. 30.
RESOURCES

Personal interviews:

Jesse Myers – owner Mudder Trucker’s Off-Road shop
Roy Carl – owner Performance Off-Road
Chad Adams – co-owner BAR Off-Road
Tim Rettig – co-owner BAR Off-Road
Jerry Blair – co-owner BAR Off-Road
John Paulsen – owner Big Off-Road

Internet resources:

www.off-road.com
www.dirtroad.com
www.NAXJA.org
www.Jeepin.com
www.MADXJ.com
www.rubiconexpress.com
www.tera-flx.com
www.rustysoffroad.com
www.jeepsunlimited.com
www.rockyroadoutfitters.com
APPENDICES

1. Buggy Spring bracket and spring dimensions
2. Buggy Spring bracket and spring features
3. Buggy Spring bracket and extended spring – various views
4. Stock Spring Suspension in normal position Bottom-Left Iso View
5. Stock Spring Suspension in normal position Bottom-Right Iso View
6. Buggy Spring Suspension in compressed position Bottom-Left Iso View
7. Buggy Spring Suspension in compressed position Bottom-Right Iso View
8. Buggy Spring Suspension in extended position Bottom-Left Iso View
9. Buggy Spring Suspension in extended position Bottom-Right Iso View
10. Proof of Design
11. Customer Survey
12. Schedule
13. Budget
Stock Spring Suspension in normal position
Bottom-Left Iso View
Stock Spring Suspension in normal position
Bottom-Right Iso View
Buggy Spring Suspension in compressed position
Bottom-Left Iso View
Buggy Spring Suspension in compressed position
Bottom-Right Iso View
Buggy Spring Suspension in extended position
Bottom-Left Iso View
Buggy Spring Suspension in extended position
Bottom-Right Iso View
PROOF OF DESIGN

- This system (while un-pinned) will increase overall wheel travel at each rear wheel of a Jeep Cherokee by 4 inches resulting in better articulation and ability to keep all four tires in contact with the ground while traversing uneven terrain.
- This system (while pinned) will not increase braking distance by more than 10%.
- The system is to require minimal modifications to the frame of the vehicle.

The stationary vehicle will be tested for wheel travel for both the original suspension and for the modified suspension using a jack and a tape measure. The two measurements will then be compared to prove that the modified suspension has at least 4 inches more wheel travel at each rear wheel.

Testing of the braking will be done by obtaining a standard braking distance by driving the vehicle (in both current and modified condition) at 40 mph and measuring the distance it takes the vehicle to come to a complete stop once the brakes are applied in a strong and steady manner without lock-up. The testing will be performed by two individuals multiple times to obtain accurate and unbiased results.
SURVEY
Directed to Jeep Cherokee drivers that use their vehicle’s 4 wheel drive system.

1) How often do you take your Cherokee off-road?
   A) A couple times a year
   B) 5-8 times a year
   C) once a month
   D) At least every other weekend

2) What kind of off-roading do you do?
   mild - use of a stock vehicle is sufficient.
   advanced – 2-4” lift, up to 32” all-terrain type tire needed.
   difficult – at least 4” lift, 33” mud terrain tires, at least a rear locking differential needed.
   hardcore – over 6” lift, 35” or larger mud terrain tires, locking differentials in both axles, full skid-plates, total disregard for body damage.

3) Do you drive your Cherokee on a daily basis or is it primarily a trail-rig?

4) What is the current RTI score of your Cherokee?

5) Would you like to have more flex out of your current rear suspension?

6) If you answered yes to #5, How much extra flex are you looking for?
   Based on RTI numbers: 50 more, 100 more, 200 more, 300+

7) Would you be willing to sacrifice on-road manners for improved off-road performance?

8) If you said no to #7, what on-road manners are most important (braking, handling, etc.)?

9) Would you be willing to pay more for a system that creates better off-road performance yet performs like a stock suspension while on-road over a system that just improves off-road?
   If so, how much more: 10%, 20%, 50%, 100%

10) What do you find wrong with the current products on the market for increased flex? (amount of increased flex, cost, installation, safety, on-road manners, etc.)

11) Would you rather have a complete new suspension or add-on parts that can be used with your current suspension?

12) Is adjustability important to you? (would you rather just bolt it on and go or be able to tweak the system to your liking?)
13) Would you be willing to change other parts on your vehicle in order to use the new suspension? (some changes that might be needed: longer brake lines, longer vent hose, longer shocks, longer driveshaft, transfer case slip-yoke yoke eliminator, etc.)

This survey was taken by 34 Jeep Cherokee drivers. The following were the most common answers to the above survey. This is the targeted audience for this design.

1) C
2) toss up between advanced and difficult
3) daily drive – dual purpose vehicle
4) about 700 with aftermarket suspension upgrades
5) yes… unanimous
6) 100 - 200
7) most said yes but to a point (it still needs to be able to get them to work safely)
8) braking and emergency maneuvers
9) 20 – 50%
10) road manners and cost
11) most that responded to survey already have aftermarket suspension kits and do not want to start over with a whole new suspension, they want add-on parts.
12) about half and half on this one. The more the vehicle has already been altered seemed to set a trend. The more it was altered already, the more the person surveyed wanted adjustability. The more low-key vehicles just wanted something to bolt on and forget about. Most of the more hardcore Cherokee owners had no problem with changing shocks, brake-lines, driveshafts, etc. The Cherokees used mainly on-road with occasional off-road adventures would rather not get that involved.
## Time Schedule

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*if suspension lift of at least 4" has previously been performed, these modifications should have taken place already. Even longer shocks and an even longer brake line may be the only modifications needed.
CALCULATIONS

Calculations were made in order to determine the thickness of the metal needed for the plate. The bending force exerted on the bracket from the buggy spring is the worst case scenario. The thickness of the metal plate used for the base of the frame bracket is sized to this force and this thickness will be common to all metal parts on the bracket. Sizing the metal for the worst case scenario leaves a safety factor over all other pieces of the bracket. Using a common thickness makes ordering material in bulk much easier. Weight is not as important as strength, cost, and ease of fabrication. Sizing each individual piece of metal to handle just enough load not to break, is not necessary and would just take time and make ordering and fabricating material more difficult. The test vehicle weighs approximately 3,800 pounds. Each buggy spring bracket would normally only see about a quarter of this weight but due to the terrain that this suspension is designed for, it may be possible that all the weight of the vehicle could rest on just one bracket. A safety factor of 2 covers minor impurities in the material and some minor dynamic loading on the bracket. Almost all of the dynamic loading on the bracket will be dampened by the buggy spring. ¼ inch cold-rolled sheet metal was determined to be more than sufficient even with a safety factor of 2 to hold the weight of the vehicle without failure.