Design of a Rear Suspension for a Serious Downhill Mountain Bike Racer

ABSTRACT

Our task was to design a rear suspension for a serious downhill mountain bike racer. An attempt was made to design a new drive system that would limit *po-going*, allow 7 inches of rear wheel travel and be strong enough to support our customer's needs.

INTRODUCTION

The rear suspension was designed for a competitive downhill mountain bike racer. The desired customer specifications, in order of importance, include increased travel and durability of the frame which including all links and shocks. Using these requirements the goal throughout the conceptual and actual design stages was to design a rear suspension system that will obtain optimum travel while maintaining the structural integrity demanded by today's serious downhill competitor. Several different bicycle manufacturing companies were researched in order to get a clear understanding of past and current rear suspension systems. The comparative benchmarking included companies such as GT, Cannondale, and Specialized. Samples of their designs are shown in figure (1) The goals for the design include increasing the maximum travel to 7 inches, eliminating energy loss due to po-going, and eliminating *bump-pedal feedback*. All of these aspects will give a smoother, more competitive ride for the cyclist.

MAIN SECTION

The hypothetical customer was assumed to be a person, 5 ft 9 inches tall, approximately 160 lbs. All of our hypothetical customer's measurements will be known. Cost will not be an issue because the design is for a serious downhill biker who is unconcerned with cost, were it can be assumed that the customer would purchase a bike designed exclusively for their measurements.

DESIGN LIMITATIONS

There are many existing bikes on the market with competitive rear suspension designs. The following is a condensed list of the major ideas that have been patented over the years.

- A suspension assembly for coupling the rear wheel to the frame with the pivot point above the crank that moves in a forward direction when the rear wheel moves in an upward direction
- A damping apparatus for use in a bicycle fork includes two telescoping legs, a rebound piston, and a compression piston
- A device for locking and unlocking a bicycle suspension system that attaches to the main frame and restricts the movement of the swing arm
- An electronically controlled suspension that manipulates the spring constant of a bicycle rear wheel suspension system
- A friction damping system for use in a system having at least one of a pair of sliding elements
- A suspension assembly that is formed of an essentially horizontal swing arm which is pivotally attached at one end to the underside of a bicycle frame by a pair of short links and which carries the rear wheel at an opposite end

After looking carefully at these design limitations we decided that we were within our legal limits with the design we chose.

PIVOT POINT PLACEMENT

An elevated pivot point, located above and ahead of the bottom bracket, was chosen for the swing arm connection to the frame. Using an elevated pivot point benefits the design by increasing the travel of the rear wheel. The chosen position allows for a longer swing arm at an angle relative to the ground. A longer swing arm will allow more travel for a given angular displacement, and more of the resultant forces from bumps will be absorbed by the shock with this design. Figure (2) shows that there is a larger reaction force normal to the swing arm when the swing arm is at an angle to the ground.

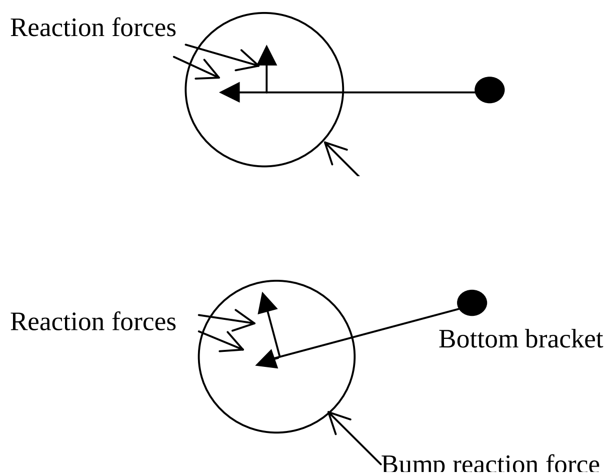

FIGURE 2: Reaction Forces

Pivot Point Design

The pivot point proved to be a design problem because it was necessary to incorporate both the motion of the swing arm and the rotation of the front sprocket on the *secondary drive system* at the same point. In order to do this it is necessary for the drive shaft and swing arm pivot to be located at the same point. The design of this joint is beyond the scope of this project.

RIDER CENTER OF GRAVITY

In order to keep steady control of the bike, the center of gravity of the rider must remain in a near fixed position and not significantly bounce or move around as he hits bumps or dips. The location of the center of gravity also contributed to the decision of where to place the pivot point. The location of the pivot point is almost directly under where the rider's center of gravity will be. This gives minimal movement of the center of gravity of the rider.

DRIVE SYSTEM

The drive system consists of three crank sets instead of the ususal two (see definitions) because the secondary drive sprocket is located at the pivot of the swing arm. See figure (3). These locations were chosen chosen because it was believed that the chain tension would vary the least. This location made the distance ensures a constant distance between the front to rear secondary drive sprockets. This is also why a guide sprocket was added to keep the top of the chain going through the pivot point at all times. It was thought that this would, in effect, reduce or eliminate any slipping or tightening of the chain due to increased or decreased tension. However, according to Fig (4), the guide sprocket was found to a problem. Unfortuntaly this problem was not relized until late in project, an unfortuate error.

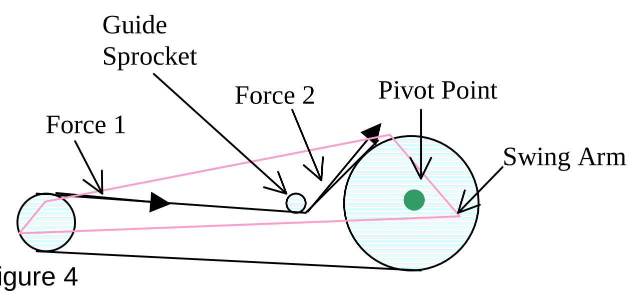

Figure 4

The moment caused by Force 1 cancels, however Force 2 created a new moment about the pivot acting on the swing arm. Thus the guide sprocket does not cancel the rider-induced moment about the pivot.

Possible Solutions

- **Solution 1:** (Figure 5) Remove the guide sprocket from the design.
    - Removes the bend in the chain so the losses associated with the chain bending would no longer be present.
    - The design will essentially have the same moment but it will have a significant po-going effect and bump-pedal feedback compared to the competitive benchmarks.
- **Solution 2:** (Figure 6) Mount the guide sprocket as a spring loaded arm on the frame
    - The forces applied at the guide sprocket would not cause a moment around the pivot point because the sprocket is attached to the frame and not moving with the swing arm. This will lessen the effects of po-going as opposed to a bike without the guide sprocket.
    - The chain will tighten and loosen as the bike goes over bumps so the effects and this will

increase the effects of the bump-pedal feedback.

- A positive moment results if the bike hits a bump and negative moments if the bike goes in a hole, giving the swing arm the tendency to always return to it's equilibrium position. This results in the rear wheel maintaining more sufficient contact with the ground.

SWING ARM

Using measurements from an existing bicycle frame on the market resulted in the following assumptions: The lower portion of the frame climbs from the bottom bracket at an angle of 53°, relative to the ground the angle of the swing arm is 16.4 degrees from the horizontal, and the length from the center of the rear wheel to the bottom bracket is 17 inches. The pivot point of the swing arm will be located 8 inches from the bottom of the existing piece of the frame. Using trigonometry resulted in a swing arm length of 22.75 inches. By constructing a cardboard model it was determined that the wheel would have a vertical travel of 7 inches. Choosing a triangular swing arm gave several benefits. The primary benefit of this design decision is that less material is used while still preserving the integrity of the material. The swing arm in this design uses more material than most because in downhill racing strength of the material dominates over the weight factor.

SHOCK PLACEMENT

After finding the length of the swing arm, the position of the shock on the swing arm and the bike frame was found using vector position analysis. The resultant position on the swing arm from the bottom bracket is 6 inches to the left and 2.3 inches in the vertical direction. The position on the frame relative to the bottom bracket is 2.5 inches to the left and 8.25 inches in the vertical direction. For the complete list of vector analysis and which design parathose already patented.

CONCLUSION

Through investigation it was found that an elevated pivot point would be desirable to increase travel. The previous design has a pivot point that is above and ahead of the bottom bracket to attempt to get the most travel while still having a shorter shock. It was also found that locating the sprocket at the pivot point would eliminate significant change in length between the drive sprocket and rear cog. If a drive chain consisting of initial and secondary drive systems is used, constant distance between the rear wheel center and the pivot point can be attained. Upon review that proved to be too late to change for this presentation, the previous conclusion of locating a guide sprocket on the swing arm in order to reduce the moment about the pivot point proved to be a false one. In order to maintain the best contact with the ground, the guide sprocket must be mounted on the frame of the bike itself so as to produce moments that will bring the rear tire to it's equilibrium position. However when this is done problems including bump-pedal feedback and testing the strength of the chain itself still remain. This preliminary design could still prove to be a useful tool in the design of future rear suspensions. Theoretically, the three crank drive system could improve the stability of the rider while traveling downhill because the center of gravity will remain close to constant and the there will be no difference in the tension of the chain. Losses due to friction of the guide sprocket while travelling down steep and bumpy terrain at 50 miles per hour, are not as important as keeping the rider's center of gravity constant and keeping the rear tire in contact so as not to lose control.

REFERENCES

1. Burke, Edmund R. PHD, High-Tech Cycling ©1996 pg. 62
2. www.calpoly.com
3. www.cannondale.com
4. www.downhillspecialties.com
5. GT Bicycles (1998-1999) Brochure
6. www.GTBicycles.com

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ADDITIONAL SOURCES

Personal Contact with Fox Shock Engineer, Dennis.

The Ski Rack Bike shop in Bangor, Maine.

Interview with Downhill Racer Dustin Sysko.

DEFINITIONS, ACRONYMS, ABBREVIATIONS

Initial Drive System:
The sprocket system from the bottom bracket to the secondary drive sprocket. Separated into upper and lower initial drive sprockets.
Secondary Drive System:
The drive sprocket from the pivot point to the rear cog. Separated into front and rear drive sprockets.
Guide Sprocket:
Sprocket initially mounted on swing arm to help control the moment caused by pedaling and reduce the effects

of po-going and bump-pedal feedback. There are some problems with this initial idea, see report section DRIVE SYSTEM.

Bump-pedal feedback:

When a bike with a rear suspension strikes a bump with the rear wheel, and the bump is large enough to cause the suspension to deflect, some rear suspension geometry will tug on the chain, producing a very noticeable slowing or acceleration of the pedals.

Drive Shaft:

The shaft connecting the upper initial drive sprocket, through the frame, to the forward secondary drive sprockets.

Po-going:

When a rider pushes on the pedals of a rear suspension bike, the chain compresses the suspension system by creating a torque that makes the suspension close, making the bike squat.

Travel:

The vertical distance the rear wheel moves while traversing a bump.

Hypothetical Customer:

Man, 5'8" tall, 160lbs, with a hip to knee length of 20 inches, knee to ankle is 16 inches and ankle to ball of foot is 7 inches.

APPENDIX OF FIGURES