DESIGN AND DEVELOPMENT OF MOUNTAIN BIKE REAR SUSPENSION FOR ALL MOUNTAIN RIDING STYLE

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ABSTRACT

This report discuss about the design and development of mountain bike rear suspension for all-mountain riding style. The objective of this study is to design and develop a proper geometry of rear suspension system for mountain bike, and to study the motion mechanisms of rear suspension system. This study deals with the path analysis (PA) of a wheel axle and pivot position determination for the crank set of mountain bike. The results show that the new developed rear suspension base on Monolink type have a suitable frame geometry that give a great horizontal and vertical travel for improvement of pedalling efficiency. In addition the crank set position for the Monolink rear suspension also helping for a smooth ride resulting from the less chain growth and chainstay lengthening. These research uses AutoCAD, Autodesk Sketch Pro and SolidWork to design and analyze the path analysis in terms of displacement of "x" and "y" axis of the developed rear suspension. The results are compared between another several types of rear suspension mechanisms.

ABSTRAK

Laporan ini membincangkan tentang merekabentuk dan pemajuan sistem suspensi belakang “Mountain Bike” untuk gaya tunggangan “All-Mountain”. Objektif kajian ini adalah untuk merekabentuk dan memajukan system suspensi belakang yang baik untuk “Mountain Bike” dan mengkaji mekanisme pergerakkan system suspense belakang. Kajian ini berkaitan dengan analisis laluan gandar tayar dan penentuan kedudukan pangsi untuk set engkol “Mountain Bike”. Keputusan menunjukkan suspense belakang baru yang telah dimajukan berdasarkan jenis “Monolink” mempunyai geometri bingkai yang menghasilkan pergerakan melintang dan menegak yang baik untuk penambaikkan kecekapan kayuhan. Tambahan lagi, kedudukan set engkol untuk suspense belakang “Monolink” juga membantu dalam penunggangan yang lancer hasil keputusan daripada pemanjangan rantai dan penyokong rantai. Kajian ini menggunakan perisian AutoCAD, Autodesk Sketch Pro dan SolidWork untuk mereka bentuk dan menganalisis laluan yang dilalui oleh gandar tayar suspense belakang yang telah dimajukan dari segi perubahan axis “x” dan “y”.Keputusan analisis kemudiannya dibandingkan dengan beberapa jenis suspensi belakang yang lain.

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LIST OF ABBREVIATIONS

MTB	Mountain Bike
PA	Path analysis
WA	Wheel axle
OC	Outer circle
IC	Inner circle

CHAPTER 1

INTRODUCTION

1.1 Overview

Mountain bikes are also known as trail bikes that can be classified as the most extreme category of bikes. For all-mountain riding style the mountain bike is built to face almost everything a biker could run in a full day of riding. They are designed to climb hills efficiently,generally heavier and a bit stout or larger than the typical cross country mountain bike. With the futuristic design, they can handle a lot rougher terrain andobstacle as well. They are an excellent balance between efficiency, comfort, and control.Even the size is big, all mountain bikes are light and efficient enough to get biker to the top of the hill, it have soft enough suspension to keep bikerremain from rough terrain, and have enough travel to overcome the bigger hits.

The quality of mountain bikes depends on the decision of the rear suspension and a fork. As for an all-mountain riding style bike, it focus on its rear suspension that will help the movement to be smooth ride even in a rough terrain. Accordingly, this suspension help in many ways, it allows the bike rear body to move up when the wheel encounters a bump, and quickly move back down after the wheel passes the bump.The rear suspension consists of spring that can be a coil of steel, or it could be a cylinder containing pressurized air.In either case, the further the spring it is compressed, the more force it takes to compress it. This is the exact way in maintaining a good ride for all mountain bike journeys.

Available mountain bike rear suspension, however, are typically not working well since some of the manufacturers are trying to attract consumers nowadays with trick designs. Some product of rear suspensions that should give a good performances for all-mountain bike riding style do not work well, even decrease the effectiveness.

Basically, there are several types of suspension that can be developed or choose for all mountain riding style such as single pivot, virtual pivot, monolink, horstlink, soft tail, four-bar and unified rear triangle. Each of these suspensions has their own advantages and disadvantages.

1.2 Problem statement

During climbing up a hills or coasting through a rock garden, the poor suspension performance causes an unbalance to the biker,directly affect the pedalling power and finally slowing down the speed.Pedal kickback occurs when the rear axle moves further away from the bottom bracket. The top run of chain is getting longer which called chain growth, such that the tension of the chain decrease and make problem when it turns backward. Besides, the high-frequency trail vibrations and heavy-hitting compressions impact while riding have greatly influence to the suspension perfomance.

Certain positions can compress the suspension, such as brake squat or extend it, brake jack. Braking causes the biker weight to move forward, extending the shock. So, squat can be useful to maintain even geometry to counterbalance this effect, but it can also make the suspension feel harsh and lose traction, while a net extension may upset the geometry but increases the available traction. With well-constructed suspension may help to stabilize geometry of the rider even if the bike hit a big or small bump.

Besides that, all-mountain bike riding style countered bigger forces as it moving through many extreme terrains. A poor rear suspension may be defect. The stress and strain analysis has to be done to make sure the chassis and rear arm of the mountain able to withstand the forces.

1.3 Objectives

The objectives of this study are:

i) To design and develop a proper geometry of rear suspension system for mountain bike.
ii) To study the motion mechanisms of rear suspension system.

1.4 Project Scopes

This project will focus on design, develop and analysis of the rear suspension of all mountain bikes to optimize its uses. The parameters that would be studied in this project are:

i) Wheel path
ii) Chain growth

This project also focuses on the methods and software used which are AutoCADand Autodesk SketchBook Pro in order to sketch and construct the design of the rear suspension. All of the methods that used in this project were aimed to evaluate the best and optimum parameter stated above. Other than that, the material selection is also one of the project scopes, in order to analysis all mountain bike that can withstand the obstacle while riding.

Besides, SolidWork 2011/2012 is used in developing the rear suspension, in order to obtain the data of applied load. All of the methods that used in this project were aimed to evaluate the best and optimum parameter stated above. SolidWork, SketchBook Pro and AutoCAD could simultaneously satisfy requirementsofa good MTB rear suspension system both quality and as well as productivity with special emphasis on reduction of. Besides, the study of rear suspension vertical travel can be done using Solidwork motion application.

1.5 Thesis Organization

This thesis consists of five chapters that will explain about the design and development of mountain bike rear suspension for all mountain riding style. The first chapter is about the proposal of this study including of overview, problem statement, objectives and project scopes.

In chapter two, there is a literature review, discuss about the mountain bike rear suspension. The main propose of this literature review is to get the information about the project from the reference books, magazines, journals, technical papers and web sites.

Then in chapter three, it will describe about the overall process of methodology in this study from beginning until end. For chapter four, it is about the results and discussions. All the data and result from analysis is collected and then used for discussion.

Lastly, the conclusion and recommendation for this study is stated in chapter five.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Mountain Bike is a bicycle that is celebrates the challenges and spirit of technical riding through rough course or downhill where free rider have pushed the limits of what is possible on a bicycle (Blumenthal T, 2004). It is diverse riding style that demands the most from riders and equipment. This mountain bike is aimed at increasing durability and improving performance in rough terrain.

2.2 Full Suspension

An All-Mountain Bike usually consists of a full suspension system. Full suspension simply refers to a mountain bike with both front and rear suspension. It operated for many advantages such as increase pedal efficiency and rider comfort. Aside from improved comfort, other performance benefits include diminished rider fatigue, improved braking, cornering, line holding, and higher downhill speeds (Anon,1992).A full suspension system provides potential benefits of reduced fatigue, better traction for both up and downhill cycling and the ability to control the bicycle at faster downhillspeeds. Focus for the rear suspension, it is a rear joint with several part including swing arm, coil spring or damper. The accepted suspension components used on most production bicycle is a coil spring and oiled damper combination (Padilla,1996).While the mountain bike with a hardtail consist only a front suspension. **Figures 2.1** and **2.2** shown the different between hardtail and full suspension system.

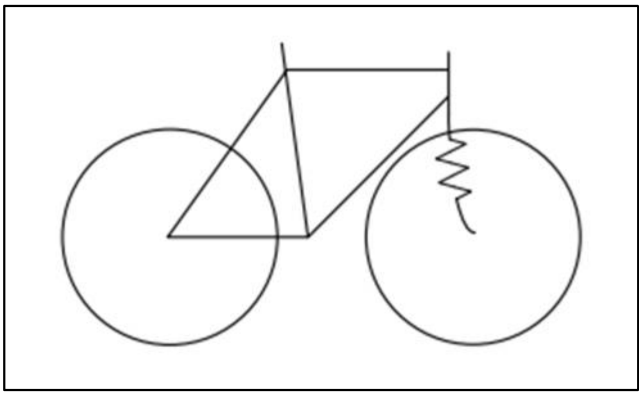


Figure 2.1: Hardtail suspension system

Rear suspension for MTB comprise of shock absorber system which is various type of spring/damper or any shock absorber devices and a pivot system that control the path of the rear wheel upon the impact that cause by the uneven ground surface. Usually a basic bicycle rear suspension, each design has a main pivot and some of it called rocker located at the main frame of the bicycle and with the other end connected to rear frame which is known as swing arm. This type of rear suspension pivotally moves in its circular path with a constant radius about a single axis of rotation which is fixed relatively to the main frame.

There are many type of rear suspension which show a complex linkage systems, such example are soft tail, unified rear triangle, single pivot, linkage driven single pivot, high single pivot, split pivot, horst link, short link four-bar, virtual pivot point, DW link, Giant Maestro, switch link, trek full floater, floating drive train, Equilink, Independent Drivetrain, Monolink, and Pendbox. For this project, the linkage system is more likely have an innovation based on the Monolink rear suspension system which provide a simple linkage system but give a maximum efficiency when pedaling through a garden of rock or bumps.

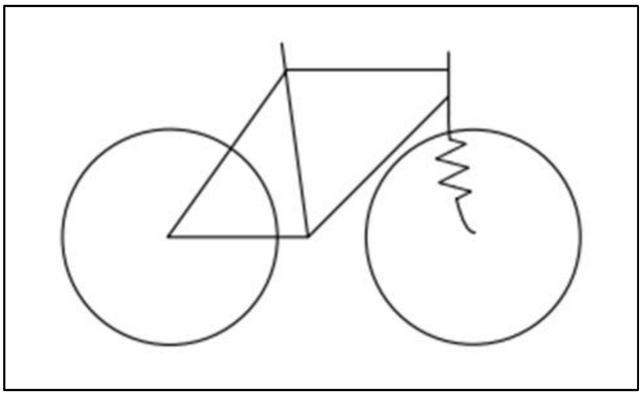


Figure 2.2: Full Suspension System

2.2.1 Design

To design is either to formulate a plan for the satisfaction of a specified need or to solve a problem. If the plan results in the creation of something having a physical reality, then the product must be functional, safe, reliable, competitive, usable, and marketable. Common to all MTB facilities should be sustainability, consideration and cohesion with its environment and technical features that are suited to the specific MTB discipline that the facility is catering for. For this design of the rear suspension, it is aim for development considering wheel path and chain growth effect.

2.3 Existing rear suspension

Nowadays, there are several type of mountain bike rear suspension been developed and each of the rear suspension has their own advantages and disadvantages. The types of suspension are Mono Link, Horst Link, Single pivot, Virtual Pivot, Four Bar and Unified Rear Triangle suspension system. In this section each of the suspension system is explained in simple way.

2.3.1 Mono Link Suspension

Mono Link is a clever new design that came out of the hands of engineers from Maverick Cycles. It is so unique and simple that it requires its own page. It is so proprietary that it must use a modified one a kind air shock that is mounted statically to the rear triangle. Usually the shocks used in suspension designs have two mount points that frame components may rotate on. Refer to Figure 2.3, the shock is permanently coaxial to the bar CG.

The program that was used to make these diagrams is incapable of calculating the wheel path, and has been edited in. As per a video released by Maverick Cycles, the wheel path is significantly more movement about up and back than every other design. This allows less energy to be lost in forcing the wheel out of the way by irregular terrain.

The bottom bracket is mounted roughly in the middle of the link FG, allowing minimal chain growth but just enough to limit pedal bob. Brake-induced lockout will be a very limited issue here because force vector from the brake caliper is perpendicular to the movement of the system's components.

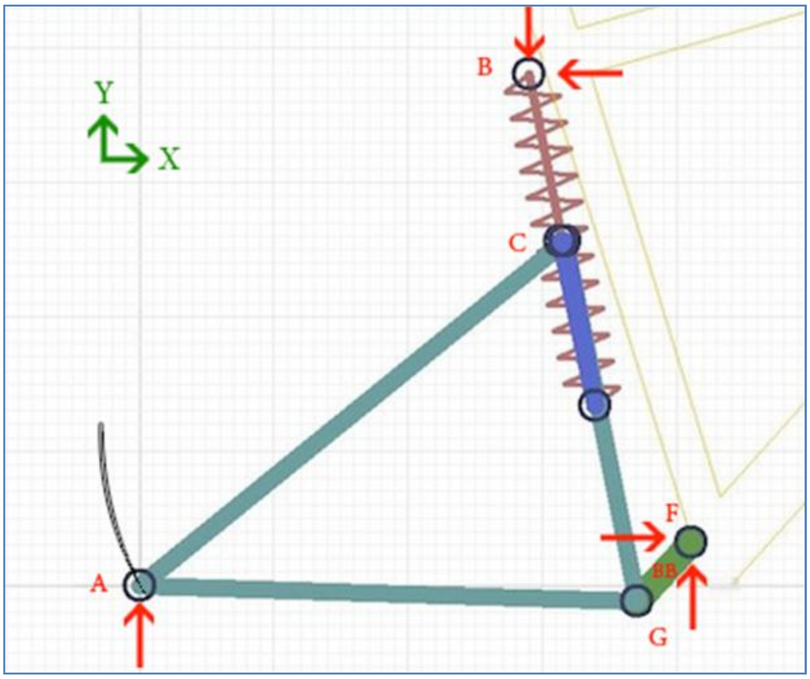


Figure 2.3: Mono Link Suspension System.

2.3.2 Horst Link Suspension

The design of the Horst link Suspension systems, is displayed in Figure 2.4. This is one of the oldest designs and is an attempt to veer from the traditional pivot-concentric wheel path. One could consider this having a 'virtual pivot point', which would be located just behind the point F, but it is more appropriate to categorize it as a four bar because of the linkage design. The advantage to this path is that the slope of the wheel path when there is no compression, which has a smaller slope, less vertical than a single pivot design, and allows for a more active suspension over small bumps.

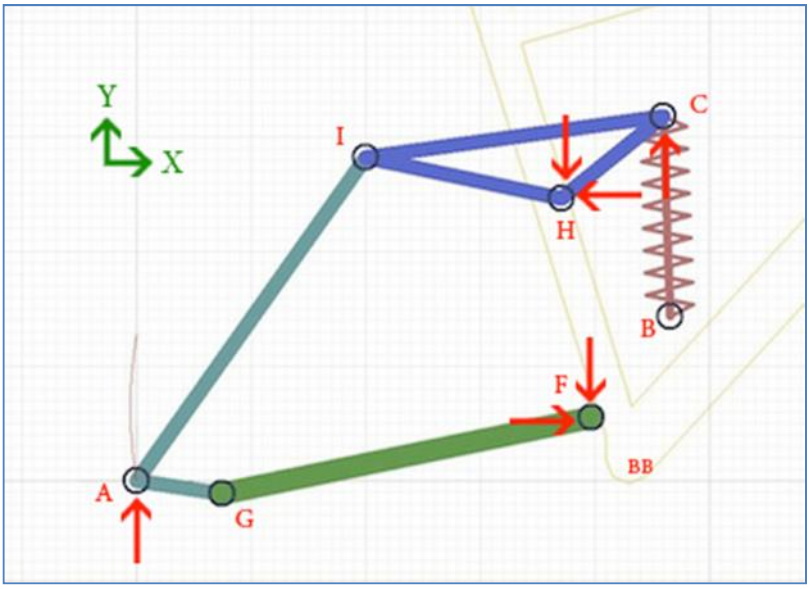
s 

Figure 2.4: Horst Link Suspension System

From the figure it shown thatthere is difference between this system and a real virtual pivot setup on the virtual pivot system. Again, as the Split Pivot design does, the Horst Link has an issue with brake-induced lockout because the rear brake caliper is attached to the seat stay.

2.3.3 Single Pivot Suspension

The Single Pivot is the most widely used method to include rear suspension in bicycle frame design. If built correctly, this system will have the highest rigidity, durability, and versatility of any design currently on the market.

Single pivots were the first type of suspension to become widely available for a bicycle. It is simple, elegant, and requires very little maintenance, the epitome of an engineered solution. The only design parameters necessary besides building it strong enough is the location of the main pivot which is point D in Figure 2.5, both shock mount positions at points C and B, and the length of the swing arm.

As can be easily seen, the suspension works by using a large triangle which is the swing arm transfer upward forces from the wheel to lateral forces into the shock. The amount of travel, at-axle spring rate, wheel path, pedal-jack, and brake jack depend on the dimensions between all of the above points.

The forces on the swing arm are marked in red arrows at the points that make up the triangle. The wheel places a positive torque at length AD. The shock will provide an opposing negative torque. The forces from the main triangle on the pivot point at Point D will have a negative vertical component and a positive horizontal component.

The spring constant will be concave up, allowing for a buttery smooth ride regardless of where the suspension is at in its travel.The wheel path here is concentric to the pivot at Point D. Because the pivot is above the bottom bracket, marked BB in Figure 2.5, the wheel path will have an up and rearward path early in the suspension path, and will become vertical deep into the travel. Bump feedback is an issue here, and the rider will feel an ease in pedaling as the suspension absorbs a bump.

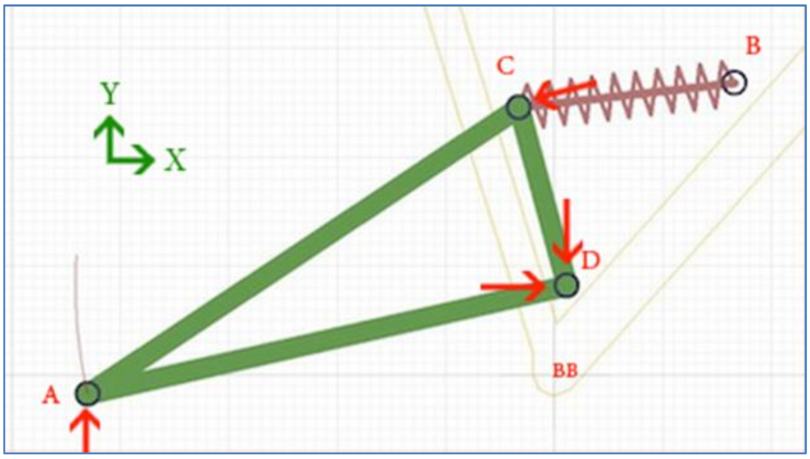


Figure 2.5: Single Pivot Suspension System

2.3.4 Virtual Pivot Suspension

Virtual Pivot Point technology has put into the hands of engineers endless possibilities to manipulate the wheel path of rear suspension. The most optimal path is the S-shaped curve. This is the technology that made this possible.

The design is called the DW-link, and is patented by the same person, Dave Weagle who designed the Split Pivot displayed on the Four Bar Suspension. It is hard to see, but there is an S-shaped curve here, as mentioned with this design. Unfortunately, there is a drawback to this method of suspension: High forces in a centralized region.

The area of the frame near the bottom bracket will be supporting the forces of the suspension at points F and H. This leads to an extremely high stress point. Because this design is more tailored to downhill cyclists and bikes, the extra material required is not a problem. Some of the bikes with this design are found will weigh over forty pounds.

Refers to Figure 2.6, the way it works is as the point A moves up, the triangle AGI will rotate clockwise about its own center, as well as rotating about a center up near the front wheel. The link IH will rotate clockwise with point H attached to the frame. Rocker GCF will rotate clockwise about the mounted point F.

The advantages of this technology are endless, and are often untapped. It is possible to adjust the wheel path to make whatever one whishes. The wheel path in the DW-link looks concentric around a point somewhere near the bottom bracket, or maybe about point I. But if it looks closely, noticed that its concavity becomes smaller, deeper into the suspension. Engineer chose this path so that the wheel travels up and back in the beginning of the travel, and will loop back and straighten out deep into the travel. This allows a more active suspension design while under both high and low compression.

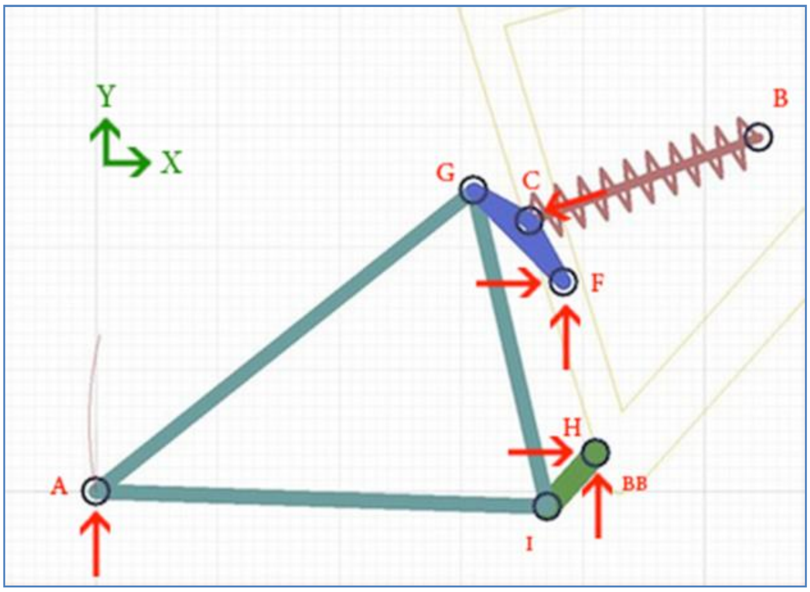


Figure 2.6: Virtual Pivot Suspension System.

2.3.5 Four-Bar Suspension

The Four-Bar design is a very widely used strategy that allows a large amount of adjustment of spring leverage ratios. The four-bar linkage design was the next step in the evolution of bicycle suspension. It was a lighter, more versatile design that, if built well, is a rock-solid choice for manufacturers. The main idea is the linkages and components represent a four-sided polygon: the chain stay, seat stay, rocker, and seat tube. The design is similar in principal to independent front suspension common in vehicles. There are different versions of this design, and each varies ever so slightly. But, each has their own patent filed with the US Patent Office.

The only difference is where the pivot is mounted near the axle. If the link is above or behind the axle, with the axle attached to the chain stay, it is considered a Bona Fide Single Pivot with cool linkages according to Figure 2.7. If the pivot combines the seat and chain stays at the axle, it is called the Split Pivot. If the pivot is directly in front of the rear axle, with the axle attached to the seat stay, it is called a Horst link. The way this design works is similar to most independent front suspension designs in a car. Referringto Figure 2.7, the wheel is mounted at Point A, and the chain stay pivots around point D. The rocker which is the triangle made up by points C, F and G is pivoted around point F. This is the device that transfers vertical movement by the rear axle to the shock.

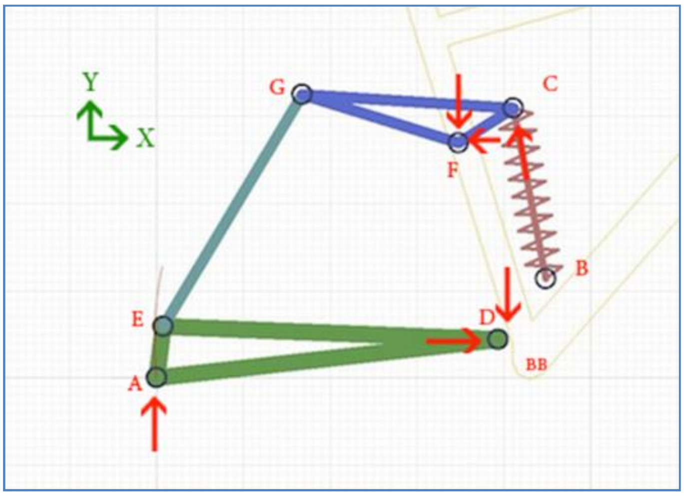


Figure 2.7: Four-Bar Suspension System.

This Four-Bar Suspension System is widely used and has a difference name. The first type is shown in Figure 2.7. The rear pivot is above the axle referring to Point E, with the axle attached to the chain stay Point A, and has the same exact wheel path as a single pivot design. The only difference is that it may be more reactive to bumps because it is lighter. Brake-induced lockout will be an issue if the rear caliper is attached to the seat stay instead of the chain stay.

The second design, called the Split Pivot, is where the pivot is coaxial with the wheel axle. It is in where the points A and E become the same. It is claimed by designers to eliminate brake-induced lockout because the braking forces are isolated from the suspension. This is a lie and is simply a marketing tool. Anyone with even a mild physics background is aware of Newton's third law about equal and opposite reactions. One cannot simply make a clever linkage design and have a braking force magically disappear. The energy must go somewhere, which happens to be in increasing the apparent spring rate at the wheel.

2.3.6 Unified Rear Triangle Suspension

Although this design has lost its appeal to the modern market, it remains a clever way to address the issue of chain growth. From the Figure 2.8, the only difference between the single pivot and the unified rear triangle is that the bottom bracket is attached to the swing arm here. This means that while the suspension compresses, the distance between the wheel axle and the bottom bracket will not change, resulting in no suspension activity from the chain tension, or vice-versa. Granted, pedal bob still exists due to the rider's bouncing up and down while pedaling, but there is no bump feedback at all because the chain remains the same length throughout travel.

Furthermore, the pedal bob will be increased because the bottom bracket is mounted on the swing arm. Any torque provided at a pedal, being on the end of a crank arm will be clockwise in the direction of suspension compression, thus further compacting of the suspension.The unified rear triangle design will have a similar wheel path and forces to the single pivot.