The Chopper Builders Handbook

The Builder Series

How To Build Girder Forks

By Gary Weishaupt

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The Cover

When the on-line version of the Handbook first went public in 2002 we only had a few hundred visitors but out of this group there were four individuals who jumped in with both feet and helped me rediscovered the joys of the garage-built Chopper.

My heartfelt thanks goes to these four, Ken Venus, John Stewart, Glen Hughes and Joe McGlynn who helped to spread the word and keep our obscure little site alive in the vast wasteland of chopper cyberspace.

They have motivated me tremendously to continue in my endeavors to explain the basics of Chopper building and the latest results of this ongoing work with respect to building Girder forks is shown on the cover in progress pictures.

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Section 3 – Drawings

The large-scale and full-scale 30”x42” drawings are included as separate and individual Adobe Portable Document Files (pdf’s) in the CD. They may be accessed using Adobe Acrobat Reader.

Terms and Conditions of Use

Motorcycle design, construction, fabrication, modification and assembly of various component parts can have dangerous consequences for the rider if the work is not done in a professional manner by skilled technicians and tradesmen. If the reader of this manual is in doubt about their skills they should solicit the help and advice of trained professionals skilled in their respective trades to assist in the fabrication of the bike and its components especially the suspension forks and related accessories.

The information contained in this manual and on the Chopper Builders Web Site is based upon information that has not been 'engineered' or 'stress-tested' but is instead founded in the experience of the author and other custom chopper builders going back over forty years. In the legal sense the technical information you will be reading is based upon what is called 'empirical' knowledge; information gathered through trail, error and experimentation by hundreds if not thousands of motorcycle builders for the past ninety years. In many cases historically, an assembly that 'looked good' from an engineering standpoint simply didn't stand up well in actual use so if anything most cycle frames and components are significantly 'over-built' today.

Since the author and the publisher cannot control, supervise, observe, assist or insure the quality of the materials or the quality or standard of the work being used in the development of the readers particular project or bike modification we cannot accept any liability for the results of using the information contained herein or on the Web Site.

For this reason readers are advised that use of said information is done so at their entire risk.

All information contained in this manual and on the Web Site is presumed to be accurate as of the date of publication. Wherever possible we have verified information but we assume no responsibility for errors of fact or omissions.

Use of the words Harley-Davidson and various H-D model names and designations are provided for reference and application information only. There is no affiliation between Harley-Davidson, Inc. and this publication.

Acknowledgements

I have been very fortunate over my working lifetime to have been an apprentice to a wide variety of highly skilled craftsmen who spent their lives building Hot Rods, Dragsters and Choppers. Unfortunately almost all of these old-timers are long gone and even more sadly none of them left behind any printed works that described their work techniques or their design philosophies so I've taken on the task of preparing this Handbook as a way of passing along the information these craftsmen gave to me many years ago.

All of these men had particular talents, strengths and weaknesses but they all worked together when they had to get something done and they weren't afraid to let you watch them work or to teach you something if you asked. They were masters of improvisation, tool making, and creative inventiveness, able to recycle almost anything to make a part for somebody's putt.

I'd like to acknowledge Ed 'Big Daddy' Roth who was kind enough to let a snot-nosed kid from Kansas hang around his shop in Maywood doing odd jobs one summer and Denver Mullins who may have been the first to really understand that Choppers had to look good as well as go fast.

I'd also like to acknowledge the crew over at the Chopper Builders Handbook Discussion Forum who have contributed so much to keep garage-based chopper building alive and well. Members from all over the world participate and pass along a wealth of knowledge.

This book is dedicated to the spirit of independent chopper builders everywhere and most especially to my wife, Beverly, whose untiring patience has made it possible.

Photo Credits

Over the years many visitors to our web site have submitted photographs, diagrams and drawings of their shops, welding jigs, fixtures, frames, forks and bike projects that we've included on the site and here in the various books in the Builders Series of the Chopper Builders Handbook. The following individuals are just a few of those who have helped to illustrate the many aspects of building choppers and we thank them for their support.

Some have participated rather anonymously through the discussion board and we only know them by their login names while others have been regular correspondents over the years. Many of you will no doubt recognize some of these 'Handles' from other sites on the Internet, as they are a pretty active group of builders, designers and fabricators.

Mark Sweet (a.k.a. Knuckle)
James Van der Kroon (a.k.a. Klever Kiwi)
Dan Woosley (a.k.a. Budoka
Scott Pennebaker (a.k.a. Concrete Guy)
Al Wilkerson (a.k.a. Big Al)
Ken Venus (a.k.a. Blaksmith)
Joe McGlynn (a.k.a. jmcglynn)
John Stewart (a.k.a. Hose_Drager)
Craig Irish (a.k.a. Irish)
Glen Hughes (a.k.a. Boner)
Mark Foran (a.k.a. Indian mark)
Brad Wilson (a.k.a. Brad_56)
Weyland Smith (a.k.a. Weyland)
Mark Van der Kwaak (a.k.a. Dbbp)
Michael Fleury
Lynn Avants (a.k.a. Guitar Lynn)
Jim Sawyer (a.k.a. Jim)
Nick Stringer (a.k.a. Sparks)

This list represents only a handful of the people who helped to make the Handbook a great gathering place for independent bike builders but my thanks goes out to all who participate in this craft.

Other webmasters have also consented to allow us to post pictures from their web sites.
Among those have been:

http://www.indianchiefmotorcycles.com/
http://www.bitterendchoppers.com/

How to Use the Electronic Version of the Handbook

Over the years we've looked at a wide variety of ways to both publish and format the Chopper Builders Handbook. Of course most writers of conventional material typically use standard 'book' formatting and publication methods but for the type of material we were presenting this method seemed very limited. With this approach the material could easily become outdated over time as new products, techniques, tools and documents became available to the readers.

Our original concept for the Handbook involved making the entire manual a continual 'work in process' that could be easily updated and added to as new material became available. A newsletter format was considered but the shear quantity of the material we wanted to distribute made this scheme somewhat impractical.

Eventually we began publishing short summarized sections of the manual online in the form of the Chopper Builders Handbook web site that many of you are already familiar with. The Internet has it advantages and disadvantages and the largest disadvantage is bandwidth considerations on both the sending and receiving ends of any given session. We found that we had to capsulate and condense both the descriptive text and photographs in order for the site to be practical.

We gained a wealth of experience running both the web site and it's related discussion board and through the feedback received from visitors we added answers to almost 235 unique technical questions we received in emails that weren't addressed in the original contents of the site materials. As a result we feel the material we're now presenting is probably the best and most complete that's ever been published on chopper building.

One concept that seemed best suited for our purposes involved printing the material in loose-leaf 'binder' or 'notebook' format. Using this method a reader could add their own notes and references, or even entire articles from other documents or magazines thereby creating a completely customized Handbook that suited their unique personal needs and requirements and this is what we've decided to do.

In the binder format each 'Section' of the manual is meant to be a stand-alone document in its own right that can be updated without making the other sections obsolete. Those who purchase the Handbook will basically become subscribers and can download new updates and supplements directly from the website or use what will eventually be a digital version of the materials maintained in a separate section of the site.

While this may sound like a complicated system it actually provides many benefits to the end user. By integrating both hardcopy print and digital media we can continually update the material, provide large format color photographs that are to expensive to issue in print and keep the material from becoming outdated and static.

Section 1 - Fundamentals

Introduction

Back in the sixties the main bread and butter money for most shops that did big twin bike work was raking necks on factory frames and adding ‘slugs’ to stock hydraulic forks to make them longer. The more aggressive shops also got into extending old factory Springers by using pieces cut from Ford radius rods. Both radius rods and old Springers were cheap and plentiful. Other shops used to extend old Indian Girders and this eventually became my personal area of expertise.

By the time the mid sixties arrived many shops were already doing custom forks that included radically extended rigid setups, Springers and Girders. Several outfits actually set up businesses specifically dedicated to front ends.

For instance many people today instantly recognize the name of Buchanan’s because of their spoke and wheel services but few remember that they started out as a frame and fork business and in the sixties built custom extended Springers from modified stock forks.
There was also A.E.E. Choppers, Ron Finch, Ed Roth, and Dick Allen just to name some of the better-known customizers and makers.

For every legitimate business however there were hundreds of small shops and literally thousands of owners who built their own front ends or modified factory units. It was just something that you did if you wanted to customize your bike. In fact building a set of forks back then was just about as common as bolting on a set of new pipes is today.

There was no shortage of information back then like there is today. Long before the mainstream magazines began doing tech articles the small obscure little chopper publications like ‘California Chopper’ and ‘Chopper Magazine’ were printing little booklets describing in detail how to rake frames and build forks. Even Buchanan’s did an article back in 67 in one of Roth’s special booklets. A set of forks was typically the first ‘big’ project people tackled since they totally redefined the look of the bike.

By 1971 custom forks were becoming less popular as more and more mass-production companies go into the act and started selling cheaper units that looked almost as good. That was also about he same period in time when people quit extending stock Springers.

As a result much of the old information about fork building has been lost and one of our goals is to resurrect as much of that information as we can. Hopefully once people understand how easy it is to build a nice set of custom forks the art will once again become commonplace.

I did a significant amount of research for this series of articles by going back through literally hundreds of very old chopper rags and little booklets, which was the most fun I've had in years. I'd find myself constantly chuckling as I read some of the 'old wisdom' and wondered how so many of us made it through those early years in one piece. In one very old article from a 65 booklet about modifying frames the term 'rake' wasn't even being commonly used yet as the writer referred to the act of raking a stock neck as just changing the bikes 'caster'.

At the same time I also noticed a trend that was somewhat disturbing in that much of what we know about chopper history today comes to us through the eyes of the 'mainstream' media that didn't 'discover' chops until the very late sixties and early seventies. In some ways you can say that 1970 represents the birth of chopping from the perspective of the media who even today seem amazing ignorant of everything that took place in the field prior to that date. For instance the modern chopper media credits Dick Allen with the invention of the custom Springer front end but Dick didn't begin making these units until 70. Prior to that time he just extended stock forks like everybody else. In fact Allen actually preferred Girders and used to modify stock Indian forks for use on Harleys. There were several people who began making complete custom Springers as early as the mid sixties so history isn't always to well documented by the magazine publishers.

I also noticed that after 1970 there was virtually no coverage of any black bikers or bike builders in the mainstream rags but prior to that date the small periodicals had a lot of coverage, including a lot of cover photos. Few people realize the contribution black builders have made to the chopper especially with respect to what they look like today. I've written about this glaring historical omission in more detail in the main section of the Handbook.

This peculiar mindset, where the mainstream media began to define what a chopped bike and what a chopper owner/builder were supposed to be like coincided with a very rapid decline in people continuing to build their own bikes and parts and turn instead to mass consumption of mass produced and heavily advertised components that were pushed in the new generation of so-called tech articles. Everybody and anybody who didn't fit the new mold or build the 'right' types of bikes was completely ignored and in some ways erased from history.

This may be why we received so much ill will from the so-called 'industry' when we started the Handbook website. We were bucking a well establish trend and according to some sources publishing 'dangerous' or 'secret' or 'patented' information that was not to be available to the general public. The media especially, until only recently, has had a big problem with the Chopper Builders Handbook and what it is that we are trying to do. In fact you will never see any reference whatsoever in any magazine about the Handbook except for Chopper Build.

It's kind of ironic that Bikers were considered social outcasts by mainstream society and now about sixty years later 'mainstream' Bikers and 'media hounds' consider us independent thinking Chopper builders as outcasts. It's amazing to see how the pecking order has changed over the years as 'socialized' Bikers have become amalgamated into media based society.

Home-based chopper builders are a very nonconforming bunch of people and they can't be lead around by the nose. That's why we try to build what we ride instead of buying something from an advertisement.

It started with frames and now we're going to learn how to build forks again which is something every biker should be free to know.

There is a mindset out there shared by many people that is somewhat socialist in nature that holds that information needs to be controlled and disseminated by the 'experts' and the appropriate 'pundits' as the 'amateurs' don't need access to certain things since they might hurt themselves in an attempt to have some small inkling of personal expression. The so-called 'safety' can-opener is a good example of this type of thinking. Of course the thing didn't work worth shit but it kept us from getting cut since it didn't open cans to well to begin with.

Building Choppers isn't rocket science and it is dangerous. In fact riding one of these weird art forms is extremely dangerous and that's why we do it, just to be able to say that's it's possible and more importantly it is fun. It is even way more fun if we built the creation with our own two hands to begin with.

Some of our detractors say that we promote 'death-machines'. I guess that statement is open to debate. Ironically that phrase first appeared on the 'Horse' magazine discussion board about five years ago posted by a Internet chopper 'expert' who had 'issues' with what it was that we were doing since we weren't a 'manufacturer'. To me the words 'Chopper' and 'Manufacturer' can't be put into the same sentence but it is true, that today, there are, what some people would call 'Chopper Manufacturers'. In reality these types of concerns are 'Semi-Custom Bike Manufacturers'. There is no way that they build real Choppers as a chopped bike has to be built by an individual and not a company.

The reason I seem to be on a tirade here is because we've had more negative press on the various discussion boards about our forks plans than anything else we've ever published. The bad comments about our frame plans died off pretty soon after people started posting their own frames at most of the boards. Eventually most of these sites copied our plans and now have them in their own download sections.

This hasn't been the case with the fork plans for some strange reason. Maybe fewer people want to build forks as opposed to frames. It seems strange that we've had so much negative press about the forks since they are so simple compared to the frames we've posted. Over the past five years I've responded to posted questions about our

forks as opposed to our frames at a 5 to 1 ratio which is a huge puzzlement and one of the reasons we've prepared this more detailed material about forks which I always thought were pretty self-explanatory from the plans.
As you read through the material keep in mind that there are dozens of different ways to build almost anything so what we've illustrated is just one way of building forks. As you begin your own project you will eventually develop you own unique methods and procedures and in fact even create new and better designs of your own.

Remember the old adage that says that if you don't build you own ride it'll always belong to somebody else. This is even truer today, in the era of 'canned' bikes, than it was back in the old days.

You can ride a Custom Bike that looks like a Chopper or you can ride a real Chopper. There is a world of difference between the two machines.

Gary (Smiley) Weishaupt
Napa, 2008

Front Forks

This part of the handbook is not about which forks to use for the salad but which forks to use on your motorcycle. To a huge extent this decision is usually based upon an economic limitation more than anything else. It is not at all unusual to spend more money for your forks than you did for your frame, which explains why so many people hold off buying forks until the bike is almost complete.

If you have an existing bike that you're working on the decision about fork selection is a lot easier to make since you've at least got something to start from and in most cases the question is what length tubes are needed to get the frame sitting properly after you've raked the neck and/or stretched the down-tubes.

If you're building a bike from scratch however things can get more complicated since you have control over more variables.

There are basically five different types of forks available today which are:

- Rigid
- Telescopic (hydraulic)
- Springers
- Girders
- Spirders (Spurders)

You don't see to many rigid forks today except on show bikes but at one time they were pretty popular because they could be built quickly and cheaply. Outwardly they resemble a girder except there are no suspension links since the side rails or tubes are just bolted solidly to the yokes or trees. At one time we were building rigid forks over sixty inches long that actually functioned fairly well since they were very flexible but in order to provide effective cushioning rigid forks need to be on bikes having extreme amounts of rake with relatively low steering neck heights.

Girders have also been around about a hundred years and like Springers first appeared on bicycles but the style most typically adopted for chopper work is derived from the design first used on the old Indian motorcycles of the thirties.

Figure 1 - Indian Style Girder

There is no such thing as a 'perfect' front end for a chopper and no matter how radical the frame is configured or what type of forks are used there will be proponents and detractors for each configuration. What is 'acceptable' riding and handling characteristics for one rider will be totally unacceptable for another. To complicate matters a bikes handling characteristics are also affected by a variety of things that have nothing to do with the fork system being used. Some of these factors are tire and wheel size, neck height, wheelbase, total weight, and weight distribution just to name a few. An old Springer for instance may work wonderfully on one particular chassis configuration and not another. A certain amount of experimentation will always be needed and that's why used front-ends are so easy to find.

I am no fork expert by any stretch of the imagination but over the years I've logged a lot of miles on various bikes having a wide variety of fork systems so I think that I'm at least a little qualified to make some general observations but I urge the readers to seek out the advice of professional fork builders before just going out and slapping any old eBay bargain to the front of their bikes.

There are some facts and then there are also some myths about front-end systems that just don't ever seem to die. One myth is that Springer's are sloppy and ill handling and this is simply not the case unless the rocker bushings are shot. Another myth is that hydraulic forks don't work to well on radically raked front ends and this is true. Once you get beyond a 38-degree rake angle or so the effectiveness of hydraulic forks starts to diminish rapidly and they start behaving more like a 'flexible-beam' system where the fork tubes are taking the entire load by flexing.

Out of all the fork systems I've ever owned my personal favorite has been the Girder design and many racing frame engineers seem to agree, as you'll usually see some type of girder design on cutting edge racing frames. Girder designs are adaptable to virtually any chassis configuration and they can be made to provide excellent handling characteristics over a broad range of steering neck rake angles and trail can be manipulated very easily to suit specific requirements. A Girder can be made very strong but also very light in weight and in general a properly designed Girder pound for pound will deflect less than any other type of fork system. The only reason that Girders are not more popular than they are is because they are more complicated and hence more expensive to manufacturer and they really need to be custom made for a specific frame configuration. Whenever you hear somebody bad-mouth a girder it's usually because the particular set of forks in question were designed for a specific bike or frame and then adapted, unmodified, to a new frame that has slightly different geometry. You can't just add a set of stock Indian forks and trees to a Harley chopper frame and expect the bike to handle well.

Unfortunately since forks in general are a relative high-dollar item and fairly easy to mass produce the field is populated by both good, and less than good, manufacturers so it pays to ask around and investigate a fork suppliers background and reputation before buying anything. Your life depends on your forks regardless of the style, type or design you finally select.

Always remember to take anything you see or read in a chopper magazine with a grain of salt. I am amazed at the number of times I've seen pictures in a chopper rag of some bike that was supposed to have 16 over forks when it was obvious that they could not possibly have been much over 6 inches at the most. Sensationalism seems to sell and builders love to feed the baloney to uninformed writers.

The table below shows the length of various stock fork configurations that you can use for reference. All of these lengths are taken with stock tree offset already factored in and are measured parallel with fork leg from the bottom of the lower bearing cup to either the rocker pivot hole or the front wheel axle centerline on bikes equipped with stock wheels and tires in an unloaded condition.

Table 1.1

Stock EL, UL, WL, FL Springer	19.50”
Stock Xa Springer (rare)	21.00”
Stock FL Series Glides 1949-1976	20.50”
Stock FL Series Glides 1977-1983	20.75”
Stock FLST 1984-1999	22.25”
Stock FXWG 1980-1983	24.75”
Stock FXWG, FXST 1984-Up	24.25”
Stock Sportster 1957- Up	23.00”

Table 1.2 lists the tube length, not fork length, for the most popular bikes using hydraulic forks.

Table 1.2

Heritage Softail/Fat Boy 86-99	41mm	22.875”
FXWG,FXST,FXSTC, and Dyna Wide Glide 84-99	41mm	24.250”
FLT,FLHT,FLHS and Road King 85-99	41mm	20.875”
FXWG and FWDG 80-83	41mm	24.875”
FL, FLH, FLHS 77-84	41mm	20.875”
FLT, FLHT 80-83	41mm	20.875”

FL, FLH 49- early 77	41mm	20.500”
Sportster and FXR 87-05	39mm	23.375”
Sportster and FXR 86-87	35mm	23.250”
Sportster 79-82	35mm	25.250”
Sportster 75--83	35mm	23.250”
Sportster 73-74	35mm	23.500”

Use these figures for reference but please don’t rely on them for ordering forks. We’ve been doing this a long time and have yet to find any kind of published charts, graphs or tables that accurately provide correct fork length data for the average chopped cycle. Do a good complete accurate mockup of your bike, take into account the offsets and then consult with your supplier, manufacturer or fabricator. Buy a quality product if at all possible. Measure many times before you make a final decision and remember that it’s better to be over than under in your estimates.

You’ll notice the center column of Table 1.2 shows the diameter of the fork tubes used on the various bike models. Over the years the Harley factory has produced hydraulic forks in three different configurations typically referred to as being the ‘Wide-Glide’, Mid-Glide’ and ‘Narrow-Glide’. These designations refer to the center-to-center spacing of the forks legs as measured on the triple-tree. The narrower spaced forks had smaller diameter fork legs.

The ‘official’ factory spacing dimension for these various forks is:

Wide-Glide – 9.875” between fork tube centers.
Mid-Glide – 8.875” between fork tube centers.
Narrow-Glide – 7.000” between fork tube centers.

Be warned however that aftermarket tree makers have taken considerable latitude with respect to these dimensions and it’s not unusual to find differences as great as .5”, plus or minus, from one manufacturer to the next with respect to the bore hole centers on trees.

Today the de facto standard that most makers use as a baseline for their designs is the FXWG (Wide-Glide) fork assembly which is supposed to be made with 41mm tubes, 9.875” apart, on centers, with a length measured from the bottom of the upper tree to the axle hole of 31.75 inches (24.75” for Springer measurement from the lower bearing cup). These dimensions take into account the increased up-stretch of modern frames as opposed to the original rigid frames.

Girder Forks

As mentioned elsewhere Girder forks are probably the best front-end suspension system ever invented. In fact many experts believe that Girders, or their derivatives, will eventually be the ideal front suspension design used on all cycles in the future. For some insights into this future we encourage readers to examine the works of Foale and Britten but in the mean time we have to keep this section of the manual focused on the older or more traditional interpretation of Girder forks as found on most choppers.

Girder forks took their name from the classic structural shape of the Girder Truss or Girder Beam used primarily in bridge or roof construction since the fourteenth century but perfected during the late 1800's. This shape represents the most fundamental engineering application of 'triangulation' as seen in Figure 2 below.

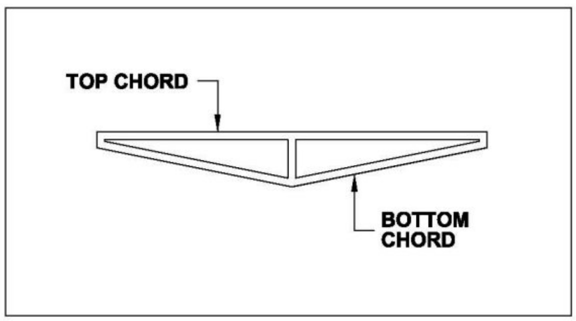


Figure 2

In such a structure the bending forces on one of the spans that puts it in compression are resisted by the spans on the opposite side that are then placed in tension. Such structural elements resist forces that can come from either side and can be arranged horizontally, as in a bridge, or vertically, as in a tower.

Basically the assembly is comprised of a single compression member and one or more tension members with struts connecting the members at midpoint. You can actually build a girder truss with a rigid compression member, represented by the 'top chord' in the diagram above, and wire cables as the tension members, represented by the 'bottom chord'.

An excellent example of modern day girder trusses in action can be seen in sailboats where the mast is the compression member and the wire rope side stays are the tension members. The very same engineering principals that keep these masts from bending apply to motorcycle forks.

A truss or girder can be hundreds of times lighter than a solid structural member intended to resist the same forces. It was the invention and perfection of steel girders that made structures like the Eiffel tower possible back in 1889.

Figure 3

Not coincidental is the fact that almost all bicycle makers immediately adopted the 'triangulation' method for frame and fork construction at the same period in history.

The girder truss by itself however was only part of the solution for both early bicycle and motorcycle makers who initially used the design but only on a rigid set of forks. In 1909 the second part of the system was patented as shown below.

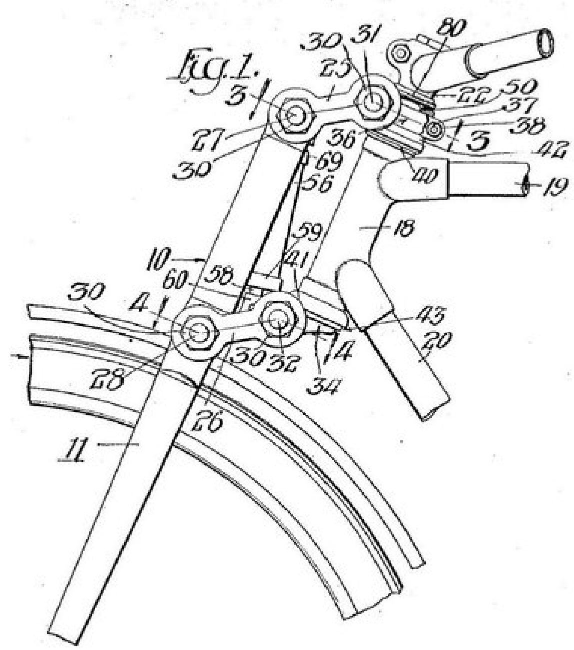


Figure 4

This invention was the Levedahl link suspension, which combined with the trussed fork, became the classic Girder style adopted by virtually all cycle makers except Harley-Davidson who held steadfast to their old bottom-link Springer concept.

Ironically Harley eventually did use a Girder on the 1948-S when they needed a good light weight high-performance set of forks for their little 170 pound sport bike.

The biggest advantage of a Girder, for chopper applications, as compared to Springers or telescopic forks is that Girders can be both extremely light and extremely strong at the same time. They are relatively inexpensive to build and can be constructed in a very wide variety of shapes and sizes to suit individual tastes. In fact there are very few if any design constraints so the limits of a Girders appearance is only restricted by the builders imagination.

While this is a blessing to many talented fabricators it is also a hindrance to the average home-based bike builder as it is this very flexibility of design that makes Girder layout relatively complicated compared to Springers for instance.

Where one can pretty much build a ‘universal’ Springer design that will work on a wide variety of frame types most good Girders are custom engineered and fabricated for particular frame geometry. This is the reason that almost all ‘mass-produced’ Girders that have been on the market over the past thirty years have had little appeal to the public since they usually didn’t work well on most bikes and many people had very bad experiences with poorly setup Girders that simply didn’t suit their particular bike. On the other hand those rare few who just happened to have frames that matched the geometry of the fork makers master-frame had nothing but praise for the handling quality of their front-ends. It was a hit or miss proposition and the vast majority of buyers were unwilling to take a gamble so Girders took a back seat to Springers for most custom builders. Even today with some new mass-produced Girders on the market the same situation still exists.

My first introduction to girders involved building rigid forks out of angle iron that could be used on ‘rollers’ in a shop that did a lot of custom work. We’d just hack together crude rigid girders and yokes to the appropriate lengths so the fabricators could move uncompleted bikes around the shop and the owners could at least have a better visual ideal of what their rides would look like. Some of these lash-ups actually saw the road under power before the final fork selections were made.

Girders appeal to many builders since than can take on so many different shapes and styles, just a few of which are illustrated below in figure 5.

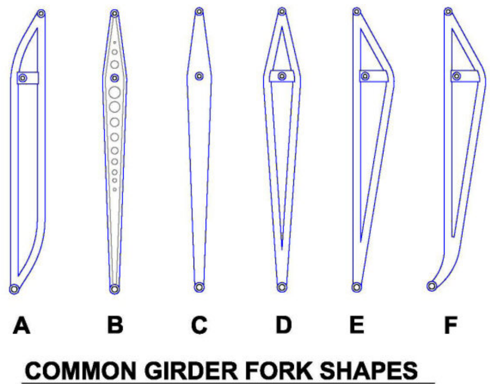


Figure 5

As mentioned above Girder forks are inexpensive to build. It is entirely possible to buy all of the materials and components for a first class set of forks for under $250 in most parts of the country. Depending upon the techniques and methods of construction very few special tools or equipment are needed and improvisation can lead to many creative solutions to bypass the need for expensive machine work if you're on a really tight budget. There is also tremendous opportunity for those out there who have access to aluminum casting equipment and some imagination. The sky is the limit as to what a person can come up with.

Figure 6 is a series of advertising scans sent in by site visitors taken from magazines of the sixties and seventies.

Figure 6

Many of these old Girders were made from bent solid stock and were pretty poorly welded with extremely crude link connections, which certainly didn't do anything to help with user acceptance of the basic design. To make matters worse backyard builders just copied these old crappy 'off the shelf' designs to the point that almost all people came to believe that a Girder was just about the last type of front-end that you wanted on a bike.

What makes Girders complicated isn't the design of the Girder Beams themselves but the geometry of the trees, links and attachment points which can be almost infinitely arranged to provide all types of trail and affect other elements of handling such as anti-dive and anti-squat to name only two. Some have said that Girder forks are an engineers 'heaven' but a builders 'hell'.

People who don't care for Girders to begin with are very quick to point out that on a well-designed Girder the trail will change by a whole 3/16 of an inch when the forks are cycled from maximum compression to maximum extension for about 3.5" or more of total suspension travel. Detractors cite this as a horribly dangerous characteristic of Girders.

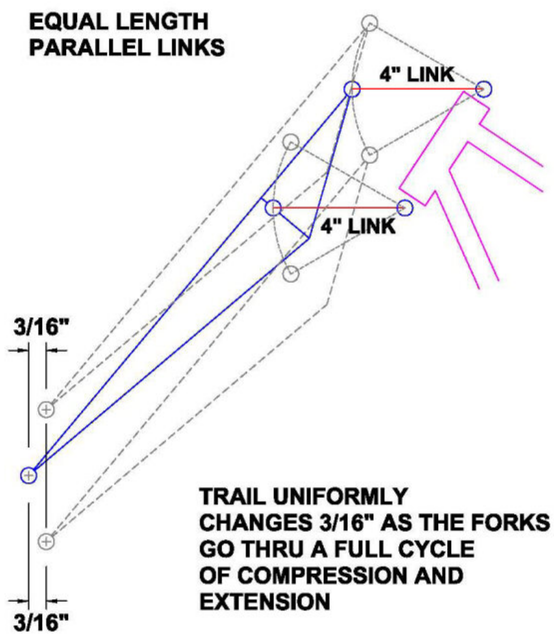


Figure 7

What they forget however is that trail change, on a well-designed set of hydraulic-telescopic forks as they move through 3.5" of travel is a whopping 2"or more! This is why most serious road racing engineers are looking to girders instead of trying to improve hydraulic forks. This also shows that most people commenting about fork geometry don't know what they're talking about in the first place.

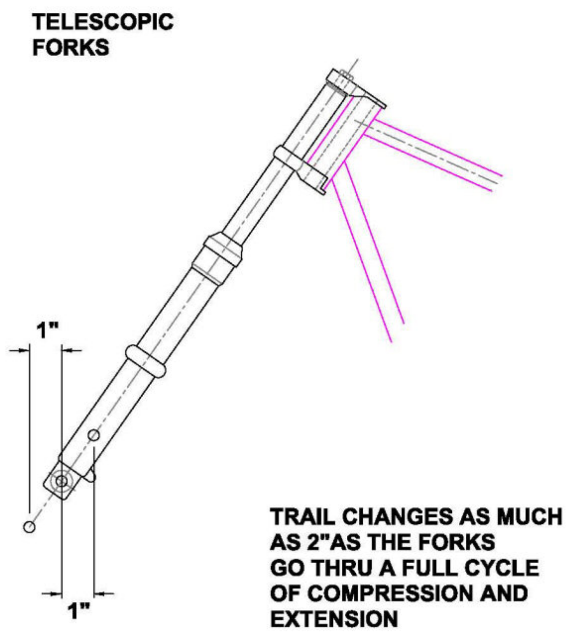


Figure 8

The above paragraphs of course refer to static changes in trail. The dynamic changes in trail as the frame dips and rises in response to suspension travel are of course more dramatic as the effective rake angle is dynamically changing but even then the Girder is far superior in performance.

Plain and simple, Girders handle better than any other fork style you could possibly use; if properly designed and constructed. Poorly designed or poorly built Girders however can be a real nightmare.

Unfortunately this section of the manual can't tell you how to build a 'perfect' set of Girder forks since a well-designed set is truly custom tailored to a particular bike but it can get you started in the right direction and save some wasted time in your development efforts.

All of the data and design information that follows concerns designing and building a set of forks that are intended to be used on frames having geometry very similar to our so-called 'standard' designs. In other words, for frames with a neck height of about 33" and a neck rake of about 40 degrees. The diagram below illustrates the key dimensions needed to start designing a typical Girder fork. If your bike is within plus or minus 2" or plus or minus 2 degrees of these specs our published Girder plans will work with only minor customization. If your bike is above or below these tolerances you'll have to do some experimentation. Believe me it's well worth it to get a good set of girders on your ride. Once you've had the experience you'll never use any other type of forks again.

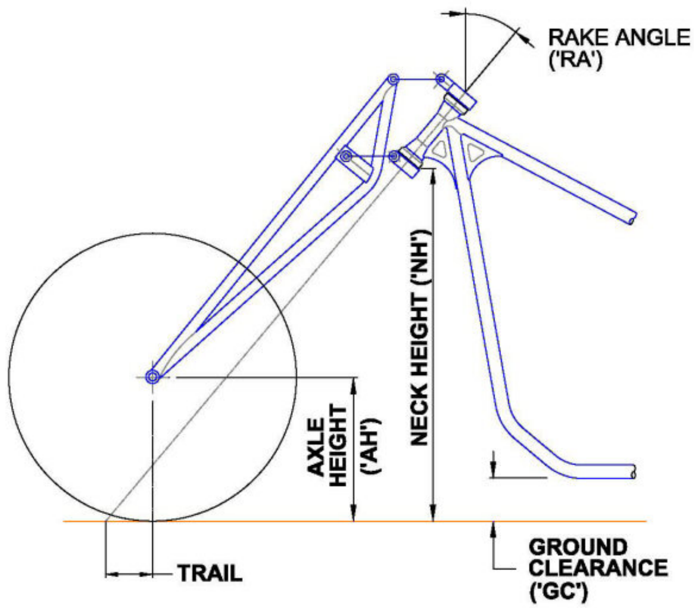


Figure 9

Before we go any further I'd like you to understand that it is impossible for me to know how much your particular bike weighs or how much you yourself weigh. I cannot know what the spring rates will be for the shock you eventually decide to purchase or what size wheel and tire you'll eventually be running. For this reason I strongly suggest that you assemble your entire front end with only tack welds until you can actually mount it on your personal frame. Once the forks have the final weight on them you can adjust the location of the shock mounts and link lengths to optimize the geometry for your unique setup.

This 'cop-out' turns many away from building a Girder since they immediately think that the project will simply be to complex to be feasible but this is false reasoning. A lot of builders put together complete fork mockups from plumbing pipe, conduit and even wood or angle-iron before deciding on the final connection and attachment points for a good custom-designed front-end. Nothing 'good' is 'easy', and building a 'good' set of forks will always require a lot of work. Those looking for the quick fix can buy a set of $1500 hydraulics and be riding on crap all day long not having any idea of what good forks are really like. As they say 'ignorance is bliss'.

Link Attachment

There are at least three schools of thought about how to attach the links to the upper and lower yokes and forks on Girders. Old-school folks like to use the method where the yokes and forks each have a long 'pin' or 'shaft running through the yokes and forks in bushings and the links attach at each end of this shaft. In this setup the shaft rotates in the bushings and the links are rigidly attached to the shafts.

The more modern approach, though not to say a better approach, is to replace the shaft with shoulder bolts or machined 'pins' and have the links themselves pivot in bushing on the rigidly mounted pins or bolts.

A low-cost way to fashion 'pins' or 'studs' is to plug weld a section of solid drill rod of a suitable diameter inside a piece of DOM tubing. You leave enough of the drill rod exposed on each end for the bushed links to slip on to and then thread the last half-inch or so for a nut and washer.

The third approach involves building the links and cross-members as an integral unit where the left and right fork legs are separate components and then the entire assembly is tied together with continuous shafts at the upper and lower fork pivot points. This hasn't been a popular construction method in the past but I personally think it has the greatest potential for 'modern' chopper forks and is possibly the strongest assembly.

All three of these basic methods work just fine and it is largely a matter of what you personally prefer and what equipment you have on hand to do the machine work that makes the final determination on which way you decide to go.

Regardless of what style of attachment you decide to use it must be understood that in all girder designs the weak link in the system, structurally speaking, is in the attachment point of the suspension links with the pivot points. More specifically it is the diameter of the pivot shafts or the shoulder bolts that you have to be concerned with.

The weakest point of any threaded shaft is where the threaded portion meets the unthreaded area and most engineering manuals publish the shear strength of this junction for various types of material.

In the case of girders the shaft material is usually mild steel with a tensile strength of around 36,000 pounds per square inch and the shear strength for various shaft diameters is as follows:

3/8" shaft shear strength in the shaft proper = 10,280 psi
3/8" shaft shear strength at the thread neck = 3,970 psi

1/2" shaft shear strength in the shaft proper = 18,350 psi
1/2" shaft shear strength at the thread neck = 5,985 psi

5/8" shaft shear strength in the shaft proper = 28,785 psi
5/8" shaft shear strength at the thread neck = 11,140 psi

3/4" shaft shear strength in the shaft proper = 41,515 psi
3/4" shaft shear strength at the thread neck = 17,800 psi

It's pretty obvious that the larger diameter shaft and thread is the way to go if you want to build strong front-ends but there is a 'practical' limitation where you run up against 'looks' vs. 'build-ability' and in the world of Choppers 'looks' pretty much overrides other engineering constraints.

You also run up against the wall of 'engineering impossibility' where an engineer will tell you a particular design idea will fail mathematically but the very same design has been in actual road use for decades without any problems. So who is right?

In the world of choppers we very often have to fall back upon empirical knowledge gleaned from years of trial and error experiments to find the correct answers to many questions. History has shown us that the typical maximum 'normal' load imposed on most motorcycles (catastrophic crashes excluded) is about ten times their dry weight with a 'safety factor' of three. Of course this an old handed-down 'rule-of-thumb' that is probably extremely conservative.

If you look at the loads on a girder, or even a springer, from an engineering standpoint based upon the rule-of-thumb above it appears as if the minimum bolt or shaft diameter needed is .75" for typically encountered maximum road impact (failure) loads but in the real world thousands of bikes have been riding the pavement with .5" shafts and bolts for decades with no problems.

From where I stand today, based upon the average weights of choppers being built in this decade I would be willing to say that a minimum solid shaft or shoulder bolt diameter should be .625" for either springer rockers or girder linkages which equates to a .5" threaded segment diameter at the minimum.

For a girder application this means using a shaft or shoulder bolt with a .625" diameter that terminates in a .5" diameter threaded portion at the connection point. This will give you a breaking strength of 5,985 psi at the intersection of the shaft and the thread neck, (which is the weak juncture) at each connection point, of which there are four.

Is this a 'safe' assumption? Well let me say that there are perhaps thousands of old girders out there riding around using .5" shoulder bolts or pivot shafts that only have .375" threaded studs and as far as I know none have failed to date in regular road use. Some of the old 640-pound Indian Chiefs had .5-inch shafts bend and the factory switched to 9/16" and they had no more problems. If you have a habit of hitting curbs or doing wheelies you're probably at risk even using the larger diameter specifications. Each and ever builder has to fabricate his or her components to their own personal level of safety and sanity. What we specify herein works for our own level of what I consider 'average' road conditions which may be different than your own interpretation so in the end the fabricator has to be the final judge as to what is safe and what is not. To be very honest I personally have no problem riding rather long Girder forks using only .375” studs and half-inch shafts but I know my limitations. We have to remember that under ‘normal’ riding conditions, whatever those are, that the forks will seldom encounter much more than 700 pounds of load at any given point in time unless something gets in the way of the wheel or you’re doing wheelies.

There is another very important point we have to bring up however and that is exactly how the loads are to be placed on any particular shaft, shoulder bolt or regular bolt for that matter. The forgoing paragraphs assumed that the fasteners in question had loads applied in what’s sometimes called a ‘single shear’ scenario. Imagine for a moment that you screwed a big lag bolt into one of the wall studs in your garage so that half of the shaft was sticking out of the wall and then you gave a downward blow with a hammer right on top of one of the flats of the hex head. In effect you applied a ‘load’ at the head of that lag bolt and the ‘shearing’ point was where the screw met the stud. The wood stud supported half of the bolt and the other half of it was unsupported, just hanging out in the air. This is the ‘single-shear’ installation. Now imagine another situation where you screwed the bolt into two studs that are about 6” apart so that both the threaded tip and the hex head itself are completely embedded in the wood. Now in this instance if you whack the bolt right in the middle of it’s length, in the space between the two studs, it will resist the force of the blow at both ends and have twice the resistance to breaking. This is called a ‘double shear’ installation.

If you look at a typical clevis and pin you will see a good example of a ‘double-shear’ engineering application. The pin is supported at both ends and the load has to be applied right in the middle. This is exactly the same type of connection method you should endeavor to use in building the link connections for a pair of girder forks.

Link Length

There really aren’t any limitations on how long Girder links can be. Some sport bikes with cutting edge technology use links that are almost 18” long. Old Indians used links that ranged from 4 to 4.75 inches. 60’s era ‘customs’ had links that were in the neighborhood or 5 to 5.5 inches long. I personally think that shorter links handle better and try to keep my designs in the range of 4 to 4.5 inches center to center of the attachment points.

Link length is closely related to not only the diameter of the shock you select but also the effective travel length of the shock. The links have to be long enough to provide clearance for the shock while at the same time permitting the forks to cycle completely through the shocks full range of motion, which is usually in the area of 3.0 to 4.0 inches of total travel from maximum compression to maximum extension.

Keep in mind that just like Springer rockers the Girder links act as levers and have a significant impact on ‘perceived’ spring rates. Long links have a lot of leverage and can use much stiffer springs than shorter links. The relationship of the lower shock pivot point and link length is crucially interconnected from a design standpoint.

In an attempt to correct problems with trail encountered by many riders who happen to have a set of improperly designed girders on their bikes some have resorted to using upper and lower links having different lengths. It is true that using unequal length links can be used to advantage on specially design fork geometries but it is a poor system to use on the vast majority of bikes. Some ‘unexpected’ and ‘unwanted’ handling characteristic may result if you don’t know what you’re doing. Just to give one simple example of a common situation, note that in the figure below, the lower links are 5” long and the uppers of 4” long. You’ll see this quite often in the real world. What you don’t see however is the rather radical changes in trail that occur as such links cycle through full shock compression and extension that can easily change the trail a full 3” every time you hit a bump.

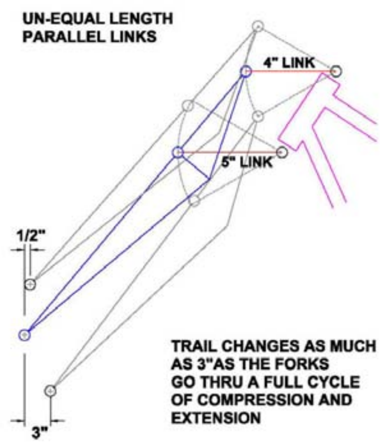


Figure 10

In general almost all unequal length parallel link configurations will ‘bind’ at certain points in the travel arcs and even though the rider is unaware of it every time the links overcome one of these binding points the forks and links bend to compensate which eventually leads to stress fatigue of the components.

Using unequal length parallel links that don’t have the pivot points properly arranged can also lead to a catastrophic situation where one of the links can go ‘over-center’ and actually lockup the entire fork assembly.

Equal length parallel links will always give the best handling characteristic on typically driven street choppers and it’s my personal opinion that experimentation with unequal length links be left for your road racer where you really do want certain changes in geometry at specific points in the suspension travel.

This last statement may lead people to believe that the links themselves have to be straight and parallel to the ground but in reality it is only the link ‘pivot point’ that have to be equal and parallel to one another. The links can be almost any shape or configuration imaginable including 'L's', 'U's', swords, spears, lightening bolts, boomerangs etc., etc.

Shock Absorbers and Springs

Unfortunately advertisers on Madison Avenue invented the phrase 'shock-absorber' and in reality the Brits have a far better term to describe what the modern day 'shock' really is and that's a 'damper'.

The only role that a shock plays in the world of suspensions is to 'dampen' spring oscillation and not to 'absorb' impacts from the pavement. You can easily drive a car or a bike without shocks but if you hit a bump you'll have a roller-coast ride until the springs get through doing their thing. On the other hand you can't drive a car or a bike without springs since you'll just destroy the shocks when you hit the first bump in the road.

In the old days Girders had a central spring, usually progressively wound, and a pair of friction shocks mounted on either side of the lower pivot points. Even back then most builders realized that the friction shocks 'sucked' to say the least so when newer hydraulic shocks appeared on the scene they were quickly adapted. The Vincent builders placed a hydraulic shock up between the links and added long, narrow shielded springs to the forks as seen in figure 11 below. Their set up was called a 'Girdraulic fork".

Figure 11

Fortunately nowadays we've got dozens of coil-over shock combinations to choose from. Unfortunately most don't fit in between the narrow constraints of chopper forks to well since the diameter of the coils are simply to large to clear the steering neck and the fork cross-members.

A full eighty percent of all of the effort you will put into building your Girder forks will be in selecting an appropriate coil-over shock (or shocks) and then deciding on the ideal mounting points for that particular shock between the top yoke and the lower fork cross-member.

You will have to experiment with various spring rates over time until you come up with the ideal solution for your particular bike. No two bikes are alike and depending upon the location of the center of gravity for your particular ride you might need a shock with a spring rate as low as 70 pounds to as high as 300 pounds.

Over the years I've become pretty suspicious about 'published' spring rates from various shock manufacturers so take anything you get from spec-sheets with a grain of salt. For example one popular mountain bike shock supplier has a unit with a so-called 180 pound spring rate but if you look at the little .25" diameter coils that are almost 2" on center vertically compared to the much beefier Koni with .375" diameter wire stock at 1 inch on center for the same 'published' rate you just have to wonder who's closer to the fact of the matter.

We bought a very narrow shock from Italy that was rated at 150 pounds with 3.5" of travel all in a package that was only 1.75" in diameter but when we received it the real rate was more like 8 pounds since we could easily compress it to full bind with just body weight alone.

I'm sorry to say it but as to shock selection you're completely on your own as we've bought and tried several dozens of units from various makers and to date I'm still not completely satisfied that we've found a starting point that we can recommend.

For those wanting to experiment we want to remind readers that spring 'rate' is expressed in the terms of 'X' pounds needed to compress the spring at it's unloaded (free) height by one inch in length. For example if we have a spring with a rate of 100 pounds it will take a weight of 100 pounds to compress it one inch in length or height and a weight of 200 pounds to compress it two inches in length or height and so fourth. If we have a spring that is 10 inches long having a 'rate' of 100lbs./in. with no weight on it and we put it in a set of forks bearing 200 pounds of the bikes weight it will compress two inches under static load leaving only eight more inches to use for real suspension.

Unfortunately however very few springs have nearly this much effective range before they 'bind', or reach the point where the coils stack up against one another and in effect become a solid mass. In shock salesman terms this is the 'coil bind' position or point of maximum compression. Keep in mind however that springs 'stretch' as well as 'compress' so what we're looking for, ideally, is a spring that will compress around 1" when the front weight of the bike is on it (about 2/5th the bike total weight actually) but still gives us around 2.5" more compression before binding. Such a spring will also stretch 2.5" (probably significantly more) at full extension. In other words we're looking for a spring with fairly small diameter coils having a rate of around 200 pounds that has at least 2.5" of compression room before the bind point for a light chopper.

Don't bother looking at car coil-overs for possible Girder springs since they are usually far too large in overall diameter to fit between the forks and the steering stem. Instead look at small coil-overs for ATV's, golf-carts, motor scooters (Vespa), mountain-bikes and rear shock units for small displacement imported swing-arm bikes. Right now one of the old rear coil-over shocks on my Honda 750 is looking pretty good but it's really about one inch to long for what I really want.

(Upon daily inspection however it seems to be shrinking in anticipation of the inevitable moment of experimentation).

For those who want specifics before they start a design project we've found that coil-over shocks having an overall (fully extended) length approaching 11.5" are a good starting point. At load condition these units typically are near 10" in length and shorten to around 8.0" at maximum compression giving you about 3.5" of 'effective range of motion'. You can fit almost anything you find however by playing around with the location and angles of the shock mounting tabs so don't be discouraged if you can't find the 'ultimate' unit for your particular application right from the start. Sooner or later you'll stumble across a unit that'll be perfect.

Keep in mind that girder shocks can take of advantage of unequal valve rates and that you need more dampening on the extension stroke than on the compression stroke for a smoother 'perceived' ride. This is just the opposite of what you'd normally expect. Always keep in mind that the spring is really doing the suspension work and that the shock is just dampening the spring, which seems to be a hard fact for many Americans to grasp after fifty years of brainwashing about shocks.

Dual shocks look cool but they double your costs and believe me when I say you'll never find two identically performing units unless you pay a premium for a so-called 'balanced' or 'matched' pair. Normally only one of the units is really doing the work and the other just follows along playing catch-up. If you just have to have multiple shocks why not try to run four ultra-mini coil-overs in some unconventional mounting position that nobody's done yet.

Fork Tube Size

The tubing you decide to use is based exclusively on how long the forks have to be. Whatever you do please don't use solid rod in a set of girder forks. On the one hand it's over-kill as to weight but under-kill as to strength.

Short forks, less than 26" in overall length can be constructed from stock as small as .75" O.D by .095" wall. Forks up to 30" in overall length can be safely constructed from 1" tubing with a .120 wall. Forks 31 to 32" in overall length need to be 1" O.D. by .134" wall. Forks 32 to 38" in overall length need to be 1" O.D by .156" wall material. For forks over 38" in length you really need to go to 1.125x.156" tubing at least for the front or primary legs. These suggestions are based upon not having any unsupported (non-gusseted) single spans over 28” in length. Of course these suggestions also assume that you’re building a lightweight chopper. If you’re building one of the new-age 680 pound sleds some folks call a chopper then I can’t possibly give you a starting point as to tube sizes. Short wheelbase heavy bikes need more beef in the forks as more weight is on the front end. Long chops with the motor well aft of the midpoint of course need less meat up front since the center of gravity is further to the rear.

If you keep the unsupported lengths of tubing short you can very easily build forks up to six feet long from stock as small as ¾ diameter x.083 wall and they will be incredibly stiff and strong. An example of such construction is shown below.

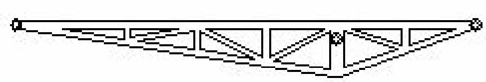


Figure 12

One of the weak points in girder forks is the inability to adequately resist torsion forces that are applied in a line perpendicular to the steering stem axis. If you can visualize your bike parked with the tire wedged in between two huge concrete blocks while somebody pulls on a twenty-foot cheater bar welded to the fork tree you can understand what I’m talking about. Under extreme road conditions the wheel axle acts like a long lever and wants to ‘twist’ the two fork legs in opposite directions. Of course such forces can be easily resisted if we had tension members that ran down the ‘outsides’ of the fork legs but we usually don’t. Instead we have to rely on having the main compression members (front fork tubes) large enough in diameter or thick enough to resist twisting as well as bending.

Common sense and experience has to come into play when you are building any type of fork system. The fabricator has to be responsible for putting together something that is both safe and effective at the same time.

In this era of the ‘lawyers’ many builders have fallen back on building massive over-kill solutions for chopper front ends which is why we’re seeing Springer and Girder forks with 1.5” diameter tubes which is simply ridiculous and we all know it. I personally think that if a person is afraid of his or her own capabilities and personal judgment then they shouldn’t be messing around with chops in the first place.

Can you possibly imagine some guy walking into an insurance company or a local law firm and saying " I'm a custom chopper builder and I want to build cutting edge, balls-to-wall death machines but I don't want to be liable for anything".

Of course when he leaves the office his fully sanctioned, approved and safe frame specs for a chop is 2" diameter .25" wall frame tubing and 2" diameter .25" wall fork tubes. Do you want one of his bikes? If you want safety and sanity don't mess around with choppers to begin with and don't come crying to me for recommending something that broke down the line. You're going to be the 'builder' so use your own judgment and build to you own personal levels of safety and sanity.

Choppers are pieces of mechanical art, not appliances that need the 'Good Housekeeping Seal of Approval'.

Handlebar Risers

Before starting to layout the design of your upper tree or yoke it's a good idea to give some thought as to how you're going to mount the handlebars with respect what type and size risers you're going to use. Today there are basically two ways risers on mounted to trees. One method of course is to just drill a couple of nine sixteenth-inch holes, spaced 3.5" apart and just bolt the risers through the tree with ½-inch by 13 socket head cap screws. A refinement on this method involves milling a slight recess, having a diameter that matches the diameter of your riser, about 1/4-inch deep into the upper surface of the tree. This makes for a little tighter and cleaner installation. Beware that not all risers have the same base diameter and in fact some are elliptical, not circular, in cross section.

One problem with the methods outlined above and variants thereof is that the handlebars don't have any type of vibration isolation and this bothers some riders. If you want isolated bars then you'll have to use the big ugly rubber, or fancier polymer isolation bushing that set in big holes bored through the tree. The disadvantage of the isolators is that the risers have to be set further forward on the tree to allow clearance for the little dust covers and the steering stem dust shield so the whole tree is therefore larger than it would have been otherwise.

Of course the ultimate girder risers would be integral with the trees; that is welded into position, with nice graceful sweeps back to the handlebar collars.

We typically leave enough 'meat' in our standard tree drawings and patterns so you can build them for either solid or isolated risers. You can tighten-up the patterns a lot if you do away with the isolation mounts.

Trees or Yokes

I personally prefer to call fork 'Trees' by the term 'Yokes' when speaking about Griders or Springers but I think everybody understands the particular pieces I'm talking about.
For Girder forks a person can build Yokes that range from the incredibly 'crude' up to incredibly 'cool' depending upon the amount of time and money they're willing to invest.

Both extremes of design sophistication will get the job done so again it's a matter of personal desire, machinery available and budget that determines what you'll eventually come up with.

Stock Yokes on old bikes were pretty crude castings, many of which you can still buy from various restoration suppliers if you're doing a 'retro' bike but the trend today is to use a 'composite' or 'combination' approach where the yokes are fabricated from both pieces of plate stock, and round or square tubing, or solid bar stock.

If you access to a lath and a milling machine you can build Yokes in 'billet' fashion but for the cost of materials and the amount of work involved most people prefer to fabricate the Yokes using the 'built-up' technique.

Simply stated the 'composite' or 'built-up' method involves using pieces of cold-rolled plate or wide strap stock to construct the main segments of the Yoke and then welding-on tube spacers for thickness, if needed, and sections of DOM tubing or solid bar stock for the link pivot points. You can easily see examples of the composite fabrication method in the pictures above.

There is no cut and dried system, formula, technique or pattern for building Yokes out of separate pieces. Every builder will invent their own unique design based largely upon available materials and the equipment on hand.

For instance you could simply weld a piece of thick plate stock, drilled for the steering stem, to a piece of DOM tubing or sold rod for the pivot carriers. Another method might involve building up plate thickness by using multiple pieces of thin sheet stock into a thick 'stack' cut every-other plate about one quarter inch undersized and you have a 'ribbed' looking Yoke to weld to the pivot shaft tube or rod. Another method uses a semi-billet approach, where the main flat portion of the yoke is milled from thick steel or aluminum plate and then welded to a pivot shaft or pivot tube. The possible fabrication combinations are numerous.

Keep in mind that Girder Yokes are very different than Springer or Hydraulic fork trees in that on Springer and Hydraulic systems it is the lower tree that takes the vast majority of the structural loads and the top tree is, in a way, just going along for the ride from a strength standpoint. On Girders both yokes are usually loaded very nearly to the same levels and have to be comparably identical structurally.

Copper or brass yokes and even forks are easy to do with Girders for those wanting something out of the ordinary.

Yoke Geometry

Older bikes usually adopted yoke geometry where the lower link pivot tube or pivot shaft ran at right angles to the neck and backbone immediately below and on the centerline of the steering stem. The upper link pivot tube on the top yoke was placed about 1 to 1.5 inches forward of the stem nut. This configuration is about as close as one can get, with a girder, to the equivalent 'zero offset' found on Springers or hydraulic fork systems. In effect this configuration is usually considered the baseline for girder fork yoke geometry. It is possible with a little creative machining and welding to get both link pivot tubes centered exactly on the steering stem but from a handling standpoint nothing is to be gained by doing this although it looks pretty good.

Our current yoke design for use with standard H-D handlebar vibration isolators has 2.75" of offset in the upper and 1.5" in the lower and I personally can't perceive any difference in the way this setup handles compared to an earlier design I used to run that had near zero offset.

One advantage of a girder over other fork systems is that you can run a significant amount of offset to make a short bike look longer and you can offset either of the link pivot points on the yokes to make changes in trail or to make a bike with a shallow rake look like it has a long front-end. In fact with a girder you can build trees that actually have the link pivot points 'behind' the steering stem axis and it will handle just fine.

Having said of all this however I do have to qualify my statement by saying that 'offset' as we are accustomed to thinking of it as applied to hydraulic or springer forks has no real comparable 'function' with respect to yoke design on a girder since the forks themselves are actually offset by the link length.

It is extremely hard to describe just how 'open' girder suspension really is to experimentation, artistic expression, easy of fabrication and low costs. Girder forks simply cannot be compared, at any level, with other suspension systems.

One of the 'sticking' areas however to building a true 'low-cost' girder system is that sooner or later you're going to be faced with making a custom steering stem for your yokes and unless you have access to a lath you're going to have to pay somebody to do the work on your behalf. This isn't an item to cut corners on as your life depends upon the integrity of this small and seemingly insignificant piece of steel.

The actual dimensions of the stem will depend entirely upon the dimensions of your particular neck-bearing-yoke combination and it's a very good idea to haul all of these pieces down to your local machine shop. You have to trust your machinist, not the Internet chopper 'experts' with respect to the material selected for the stem piece.

The Internet 'experts' will tell you to use threaded chromo tubing since it'll save you 0.01 pounds of weight and it's just the 'trick' thing to do on a custom chopper. Other experts will say that the stem has to be stainless steel or titanium with all kinds of special heat treating, etc, etc.

Nine chances out of ten your local machinist will have the right material on hand to make up a nice solid stem that has just the right amount of surface hardness and tensile strength to do the job without fracturing somewhere down the line. My guy likes 1040 mild steel and his partner likes 303 stainless. We haven't tried the stainless yet. Your own guys will have their own ideas but if you don't have 100% confidence in your machinists then shop around until you find a guy you trust more than your own doctor. Your life depends on it.

There are two ways to mount the stem on or into the lower yoke. One way is to simply drill a hole in yoke, cram the stem into it and then weld the stem in place from the bottom. The other way is to drill and tap the yoke to accept threads placed on the lower end of the stem, screw it all together and then tack weld the stem in place. It's six one way and a half-dozen the other. The important thing is that when assembled, the stem is at exact right angles to the yoke, in other words perfectly perpendicular to the lower bearing surface of the yoke. There should not be any room for error whatsoever.

General Configurations

The overall assembly of the individual parts of a typical Girder suspension system can be quite varied. For example the links can be situated on the 'inside' or the 'outside of the main fork legs. The links themselves can be fabricated from tubing or from flat bar stock or from castings. It's not uncommon to see more than one link attachment method used on a single girder. You'll sometime run across units that use continuous pivot shafts in the forks but rigid link pins on the yokes and vice versa. You'll also see units where the upper links may be mounted inside the fork legs while the lower links are mounted outside. On some customs you'll see forks with only one central upper link and two lowers or one central lower and two uppers. Occasionally you'll find a fork where the shock or shocks are mounted below the lower yoke and attach to the rear legs in a modern adaptation of the old Vincent configurations.

Folks are finally catching on to the fact that a good mono-shock mounted lower in the forks reduces the height of the bikes center of gravity and permits one to use very short links while cleaning up that area ahead of the steering stem.

Hardware and Connections as to Appearance

Earlier we alluded to the fact that in the realm of chopper building there are often trade-offs, adjustments and compromises made that create a balance between strength, practicality, form, function and simple appearance considerations until just the right balance of critical factors, tempered with artistic judgment result in a final design concept that not only 'works' but also looks good at the same time.

All of us at one time, or another, have walked through a bike show and seen machines that defy the imagination. We've also made mental notes about which particular bikes were really 'roadworthy', or could actually be driven on a daily basis and which one's were pure 'eye-candy'.

If you decide you want to build Girders your design talents will be pushed to the limit since I cannot possibly imagine where artistic judgment and good engineering sense are put more to the test than in building one of these front ends that will not only handle the real road on a daily basis but look good while doing it.

From my personal perspective I rank fork system strength and functionality foremost and try to figure out a way to make it all look attractive and proportional with the rest of the bike secondarily. To be able to do this you have to have the raw materials and other components in hand to make valid decisions based upon not only sound engineering principals but also artistic visual comparisons of various potential assemblies. In other words you have to be able to actually see, feel and 'experience' the parts you want to experiment with. You just can't pick parts from a catalog and expect anything to look proportional. You've got to have the stuff in your hands before you begin the design and fabrication process. As much as I like 'plans' this is the one area where real parts will far outweigh anything you see on paper.

Fortunately buying a lot of parts for a potential Girder project isn't all that expensive and to start with you really only need a single 'example' of each item for each component assembly you're planning to experiment with and you don't need fancy top of the line parts to start with during the planning and mock-up stage.

To give you an example of what I'm talking about try this little experiment. Take two sections of 1" tubing about 36-inches long and polish one to a bright luster. Paint the other one with black paint, to simulate powder coating, and put them side-by-side. The polished tube will look considerably 'narrower' or smaller in diameter than its painted counterpart. If it were chromed it would look even thinner. In this instance if you were after a certain 'look' for a set of forks that were to be powder-coated you would have selected slightly smaller tubing, 7/8" DOM for instance, so it would have the same visual 'weight' or 'size' as a skinny looking piece of chromed 1" tubing.

Section 2 - Construction

How To Builder A Set of Girder Forks

This is a Girder building segment that takes up from the section in Volume I of the Handbook that discussed design, geometry and other issues and involved with Girder Forks and the reader is urged to re-read that section before starting on the fabrication of the forks.

The pictures used to illustrate this section have been accumulated over the past three years and involved several different projects that sometimes used different design parameters. As a result the various snapshots and parts shown herein may not be specific to this particular build project. Where there is an obvious difference I will specifically point it out otherwise the reader can safely assume the part or procedure shown is applicable to this specific set of forks.

Before we go much further you need to know that I'm not some kind of race bike Girder engineer and I'm certainly no expert on the subject of Girder design or building but I do have some experience.

I built my first Girder forks a bicycle when I was around 13 or 14 years old and over the past forty-five years or so I've probably built and ridden on around 100 Girder forks. I've done a huge amount of restoration and rebuilding on old English and Indian Girder forks and I have actually drawn plans that other people have successfully used to build Girders of their own. In my opinion this past experience gives me at least a few qualifications.

On the other hand the reader needs to be aware that several 'experts' from the various discussion boards have stated that my designs are "death-traps", "impossible to build" and a host of other things. You as the reader need to make up your own mind about the suitability of what follows with respect to your own project. You can believe what I've written or you can believe the 'experts'.

Keep in mind that none of 'experts' who downgrade my designs or my advice have ever actually built many Girders even though they like to talk about them. Some of the 'experts' have never actually built anything at all but for some reason they are still considered to be an 'expert' for some reason.

Use your own judgment and proceed by reading the material that follows and add to your knowledge base by reading the material published by other knowledgeable people in the field. Don't pay to much attention to 'experts' if you really want to build choppers.

The biggest problem in building a set of Girder Forks is getting the raw materials to begin with. The fabrication itself is relatively simple and easy.

Unfortunately the bits and pieces of tubing and steel plate needed for a Girder are not commonly found at most small fabrication shops or local steel supply houses so you may have to do some pretty creative scrounging to come up with what you need. If all else fails however you can buy the material at full retail from almost any of the larger steel retailers but you'll have to pay accordingly and probably have to buy far more stock than you actually need. You will pay a premium but you can always buy from the online metal suppliers but even then the raw materials cost should be under $200 for everything including all of the fasteners and bushings. Girders cost very little to build compared to other types of forks.

Figure 13 illustrates almost all of the various components and steel stock you'll need to build a nice set of Girder forks. By comparison this is about half as many materials and parts needed to build a comparable Springer.

Figure 13

For starters you'll need enough 5/8" thick by four inch wide steel strap to cut out the upper and lower yokes. A section about 16" long is more than adequate. This seems like something pretty simple to find until you start making some calls and find that very few shops, even the big ones, have a need to stock anything this thick at anything over 2 inches in width. I ended up having to buy a 10-foot 'drop' for this particular build-up article and I have all kinds of contacts in the steel business that I was hoping could provide just a small segment from the scrap pile.

For the links you'll need about two feet of 1/2" thick by 1.25" wide steel strap and this is actually pretty easy to find almost anywhere.

For the fork legs you need to round up about 16 feet of 1" diameter by .134" wall DOM or ERW tubing. The DOM is preferred and surprising easier to find than the cheaper ERW. Usually you'll end up having to buy a full 'stick' of twenty feet but you'll find uses for the left over portions pretty fast in a typical Chopper garage. For this particular project I'm using 1x.125" DOM but the forks are only 39 inches long and they are going on a lightweight bike.

If you're building from the CBH plans the cover sheet contains an itemized list of parts and fittings but most people make a lot of substitutions and alterations. It's a good place to start nonetheless.

We talked about tubing in general in previous sections but as we were in the process of cutting materials for this article we ran across something that we're started to see over the last few years in the quality of materials you might purchase.

Figure 14

Figure 14 shows a snapshot of two sections of DOM tubing. The one on the left is 1"x.125" and the piece on the right is 1"x.083". Both are common sizes used in Girders. The thinner wall material of course is for lighter forks on drag bikes and Bobbers and the heavier material is for heavy street bike applications.

If you look closely at the end sections of these two pieces you'll notice that the internal bore or hole is slightly offset with respect the exterior surface perimeter of the tubes. It's much more noticeable in the smaller wall sample but it exists in both samples.

According to the 'official' industry specifications for DOM tubing neither one of these samples is even close to being within tolerances and in fact should have never been sold in the first place. Unfortunately we've been seeing a lot of this substandard tubing over the past few years and when you get it, if you do, then just throw it away as you have no way of knowing where the thin spots will be in a long section of tube.

We've actually found that regular old CREW tubing from almost all suppliers is much better in overall quality and uniformity than the much more expensive DOM most suppliers are pushing.

On the thick wall tubing it's still fairly usable up to a point since even at the thin spots it's still just slightly less than .120 inches but the thin wall .083 material is only .0627 at the thin spots which is like building with cardboard.

Tools

If you frequent the typical Internet Chopper Forums you'll find all kinds of people trying to tell you that you need a full-blown milling machine to make the upper and lower yokes for the Girder but in reality all you need is a good 'Saws-all', a chop saw or even a small saber saw with metal cutting blades. If push comes to shove you can even use a regular old hacksaw but it'll take some time. Don't discount flame cutting the parts. This seems to be lost art nowadays but at one time this is how everybody cut parts. You just have to make dimensional allowances depending on how good you are with the torch.

It's a real shame that many people today seem to put down the old traditional methods of building stuff and try to look for 'high-tech' solutions for their fabrication solutions even thought the old methods still work just as well. I personally suspect that a lot of people, especially the Internet crowd, are looking for excuses as to why they can't build something for the lack of some 'special' tool or equipment.

As an example of being adaptable, imaginative and working on a tight budget Dan, who logs into several of the discussion boards as 'Budoka', cut out all the parts, including the 3/4" thick trees, for his extremely nice Springer front end using only a hand grinder. He photo-documented the project at the CBH discussion board. The Springer parts are far more complicated, shape-wise, than Girder parts so if he could do it then you can do it just as easily.

No matter how you eventually end up cutting the parts from the steel blanks, even if they are cut with a water jet, you'll still need a belt sander to dress the edges to get a smooth surface for chrome or powder coating.

It's a good idea to invest in a couple of common taps and dies if you plan on doing a lot of girder work but most of my designs are fairly standardized around 1/2-13 fasteners and you can buy this size at almost any hardware store.

The building sequence that follows isn't necessarily presented in any particular order, as each individual will develop his or her own unique method of approaching the project. I've laid it our here in a series of steps that basically follow the least complicated, and hence least expensive, processes first and then progressing in both costs and complexity to the final product.

Cutting the Materials

Ever time you cut a piece of steel for any kind of part you always want to cut it slightly oversized so you have enough meat around the edges to dress it down smoothly to the final dimensions. This even holds true for parts you might have cut with a water-jet machine. I typically allow at least 1/16-inch over even on parts cut in a milling machine. Sanding and final buffing and polishing can actually take off a lot of material.

I prefer to do all cutting operations at one sitting and as long as I'm going to be making a big mess I like to cut out 'extra' parts for a variety of future projects until I've exhausted the supply of steel on hand.

Figure 15 illustrates some of the major components of a typical Girder ready to be cut along with some links that have already been roughed-out and area ready for shaping.

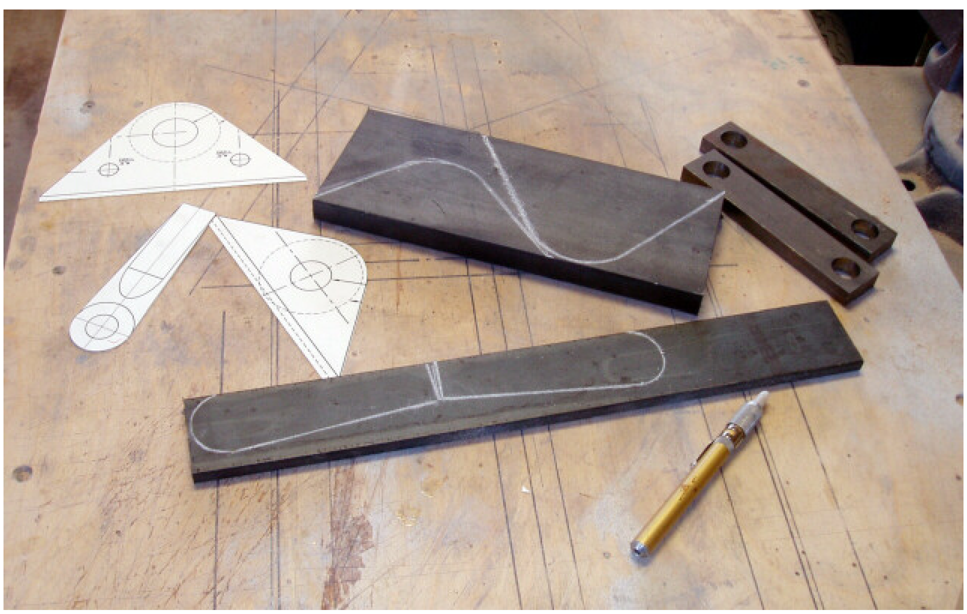


Figure 15

The paper patterns were taken from the CBH plans, cut with some scissors and then traced around with soapstone onto the steel plates.

The trees in the picture are going to be made from 3/4-inch thick material since nobody in my area had any 5/8" stock on hand when I needed it.

There are nine basic ways to cut steel starting with the most expensive which is to use a water-jet. Following down the ladder in cost comes plasma cutting, oxy/acetylene cutting,
metal-cutting band saws, abrasive cutting wheels, hand-held band saws, saws-all, saber-saws and finally the good old hacksaw method. All of these methods work just fine and if care is taken the quality of the finished product will be equally as accurate and pleasing to look at no matter how you do the cutting.

For most home based builders working on a tight budget the last four methods are most readily available.

Figure 16

Figure 16 depicts using an abrasive chop saw to rough-cut the 3/4" steel tree material. This method works fairly well if you have a big 14" saw but with smaller blades you'll have to reposition the stock periodically to keep the edge of the disc at the proper approach angle to make fast clean cuts.

Figure 17 shows the axles plates being cut using a regular saber saw. This method is excellent on most materials up to half and inch in thickness.

Figure 17

For thicker material there is no substitute for a reciprocal saw, generically referred to as a 'Saws-all'. This handy saw will cut through just about anything and it's what I used to make the final cuts on the 3/4" tree material.

The secret to using a saber saw or a Saws-all is in selecting the right blade. Buy good Lenox bi-metal blades and shoot for a tooth count that will leave 3 to 4 teeth inside the cut. For instance, if cutting 1/2" material the proper tooth-count would be 8 teeth per inch. A very common mistake is to buy blades that have a higher number of teeth thinking that it will cut faster, cleaner and easier.

On this particular project all I had on hand was a cheap, and already well used, Ace Hardware blade having 10 teeth per inch and it did make 3 nice clean 5-inch long cuts in the 3/4" material before it finally got to dull to continue.

I actually kept track of the time spent in cutting out all of the various pieces for the Girder and working at a leisurely pace with some beer time the clock showed just under twenty minutes had elapsed.

Those 20 minutes are worth a lot of money if you compare my 'free' labor time against having to pay for a one-time setup on a water-jet or CNC plasma machine. My local fab shop wanted $160 just to do the cuts if I supplied the materials and I'd get the parts in about a week.

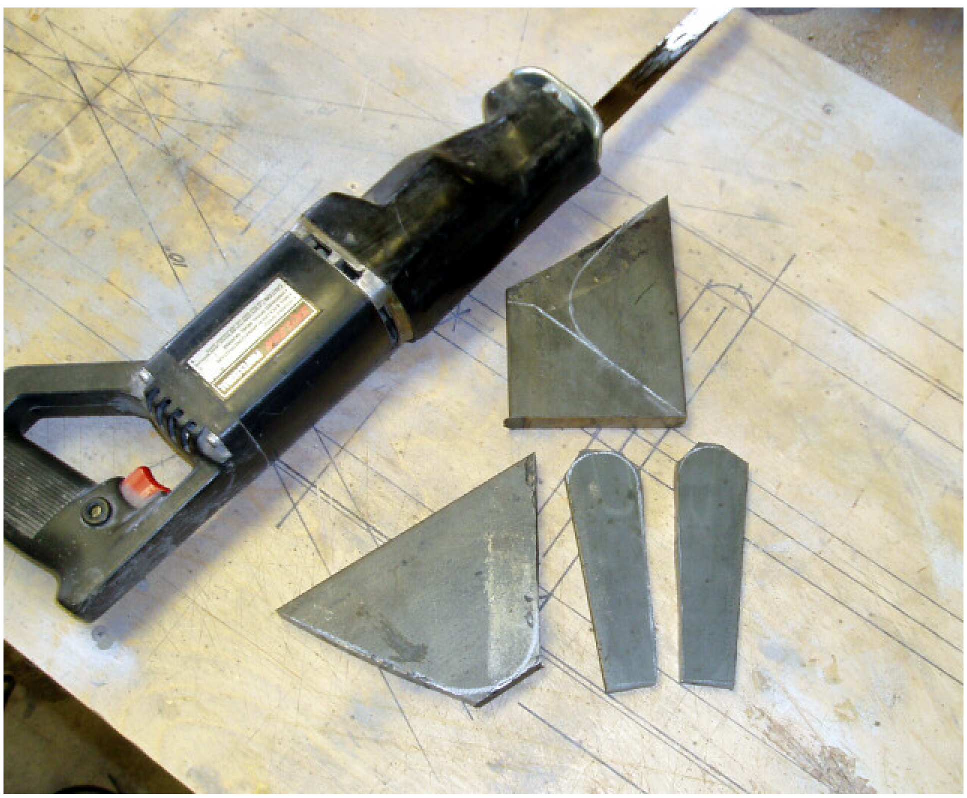


Figure 18

Axle Plates

Keep in mind when you're building your girder that you have several options as to the configuration of the axle mounts and the axle itself. You can fabricate mounts as we show on the plans made from short 1.5 inch sections of 1.25 inch DOM tubing or you can build mounts from plate stock as we show on the Leafer plans.

Regardless of which direction you decide to go it's a very good idea to buy or build your axle before making the mounts. In fact it's a good idea to have not only the axle but also the wheel hub and brake components at hand so that you've got the actual hardware to measure instead of guessing at dimensions.

As to the axle there are several possible choices and different attaching methods.

Old traditional girder axles were usually only .625" in diameter with a stationary lug or nut on one side and then a threaded portion on the 'fixing' side that was typically only a half-inch in diameter. The 'glide' front ends today still use a similar configuration except that they're larger in diameter. As a result one of the holes in your axle plates or tube lugs will be larger than the other if this is the type of axle you'll be using. I bring this up because it's a potential 'gotch-ya' if you make both mounts identical. If you've already drilled both holes the same diameter and end up with an axle having one end smaller you can always bush down one of the holes as needed.

You can buy axles ready-made from a variety of sources since girder axles for all practical purposes are exactly the same as any other axle that you'd use on a Springer or even some hydraulic front-ends. You can also have axles custom made from several of the people and shops that you find on the various chopper discussion boards so there's not a whole lot to say about this particular piece of hardware. Look in the Paughco catalog for several suitable axles before you go to the trouble for having one custom made.

Keep in mind that even today most brake-less narrow 'spool' type wheel hubs used on choppers still use the small 5/8-inch diameter axles. Fortunately the hub design on the new generation of spools allows you to simply change the bearings if you need to upgrade to a larger ¾-inch axle.

For this particular project we're going to be using axle plates made from flat steel stock in lieu of the tubing type axle mounts shown on the plans. These are cheaper and easier to make but they also give the builder some latitude in doing more creative design work.

We start out with some 3/8" thick by 2" wide flat steel bar stock. Even though the widest part of the axle plate is only 1.5-inches you need the extra width provided by the wider bar to leave some extra meat for the final shaping, sanding and polishing.

Figure 6 shows the plates we've cut for this particular Girder. The one on the left is shown in the 'rough-cut' condition. Note that when cutting with a scroll or reciprocal saw you don't actually try to make the cuts 'curve' to follow any contours in the pattern but rather make a series of 'straight' slashes that only approximate a true curve. The final shaping of any contours is actually done with a grinder or sander.

The plate on the right is shown as it's in the process of final shaping. Note that the radius on the end is almost fully formed and we're just beginning to flatten out the right hand edge of the rough saw cut.

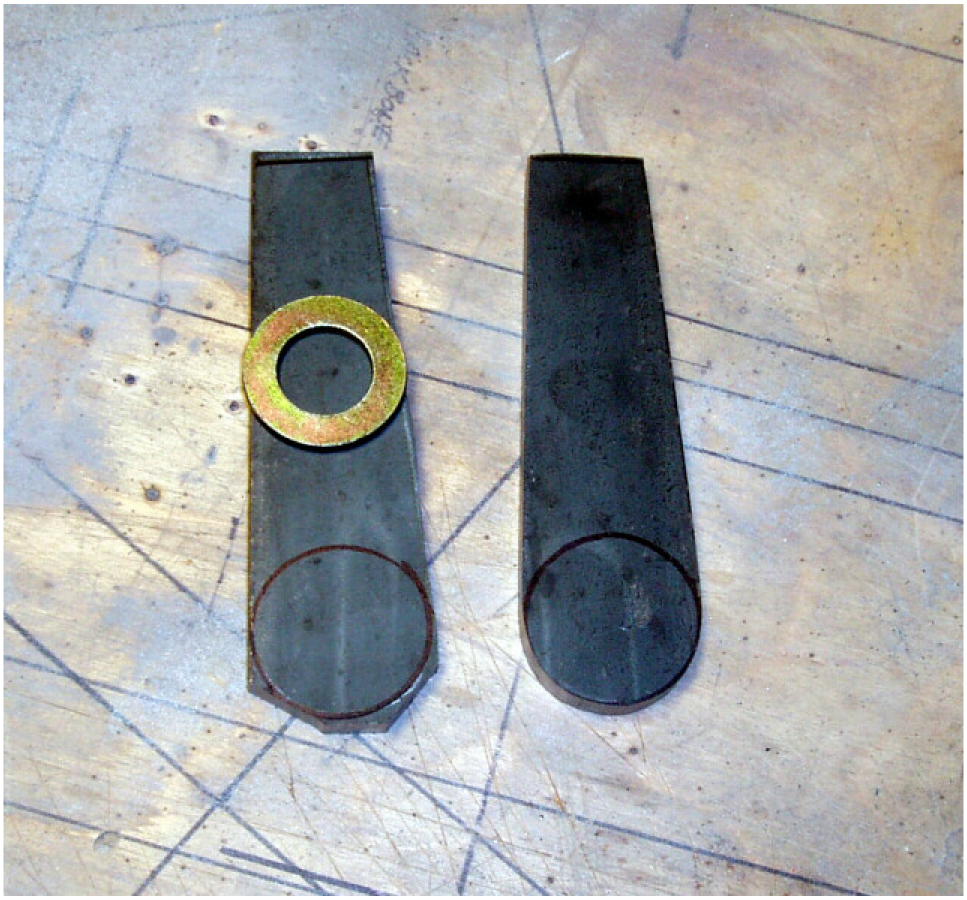


Figure 19

In the old days I used to use both bench mounted and hand held grinders to do the majority of shaping work but modern abrasives have made belt sanders a much better choice for both shaping and later the final sanding and polishing.

If you're lucky you have enough money for a relatively cheap combination belt/disc sander. Two Years I bought a very affordable Ryobi on sale at Home Depot. It's almost all plastic and I expected to last a few weeks at the most. I bought it for a specific frame project and would have been more than happy if it had simply lasted for the duration of that build but it's two years later and it's still going strong.

Figure 20

Figure 21 is another snapshot of the axle plates this time showing the edge of the plate that is being shaped. In this particular picture the edges are being brought down to what I call the ‘rough shaping’ stage using 60 grit belts. The objective is to remove any irregularities from the rough saw-cuts and to keep all edges straight all sides at a perfect 90-degree angle to the surface faces. Up close the piece at this stage looks almost as if it had been cut using a water-jet.

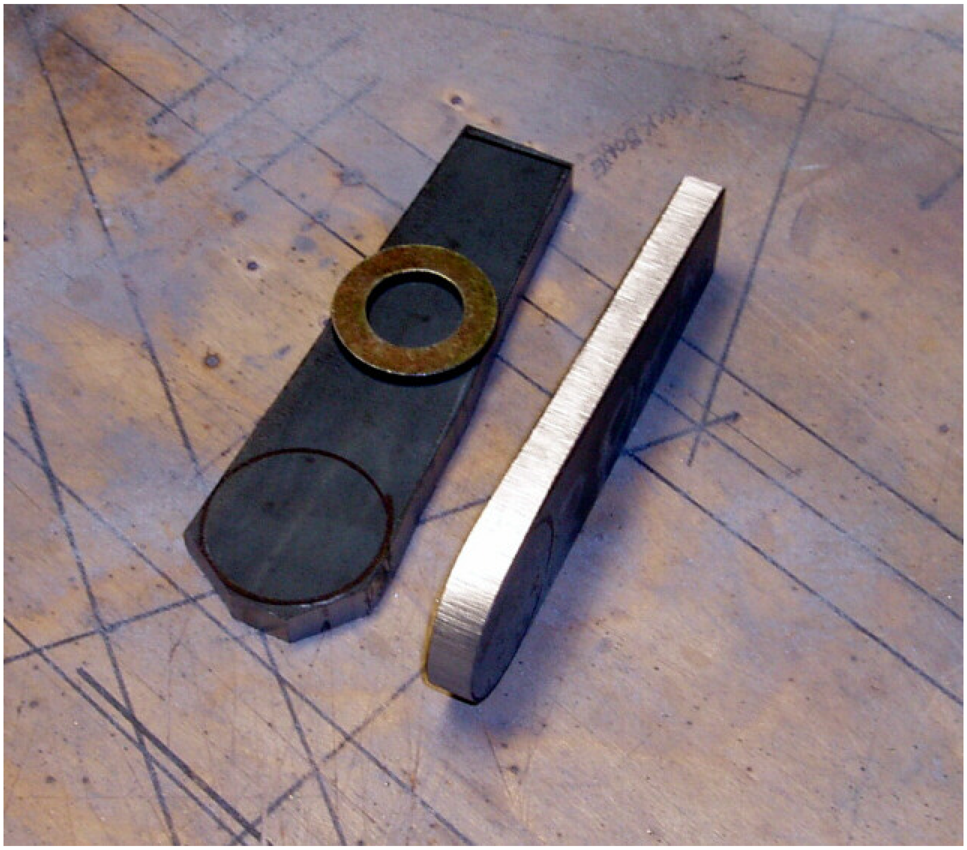


Figure 21

The same quality of shaping can be done without the expenses of a bench mounted sander by using a combination of drill mounted sanding drums and a jury-rigged hand held belt sander as seen below.

Necessity is the mother of invention. The little sander shown below is another ‘cheapy’ made almost entirely from plastic and it’s seen a huge amount of hard use and still works just fine but not usually clamped to the bench like this. This arrangement produces results that are just as good from a quality standpoint but it takes a little longer compared to using a larger more expensive machine.

The big trade off in using low-tech gear and rather primitive fabrication techniques is that it simply takes a lot longer to do the work. The benefit is that the work gets done very economically. The quality of the parts, whether you use expensive equipment or crude equipment, is proportional to the time and care you personally put in to making them. Costly gear doesn’t automatically produce quality products on their own accord nor does primitive gear produce poor parts on their own accord. It’s the equipment operator, the fabricator, behind the gear, that determines the final output.

There is nothing wrong with fancy machine tools but don’t let the lack thereof become an excuse for not starting your own project. If you can afford the sophisticated equipment then buy it and learn how to use it well but if you can’t raise the cash then go ahead with alternative methods of fabrication to at least keep your dream alive.

Figure 22

The axle plates we're using for this build are a very simple straight type that can be adapted for use on Springers and Leafer forks as well but the reader is urged to keep in mind that artistic creativity is always welcome.

Figure 23 shows a simple idea for a fancier plate with a little curve in it. The curve will change your trail by about a half-inch but sometimes, especially on a chopper, exact technicalities aren't necessarily adhered to.

The sky is virtually the limit as far as 'design' goes when it comes to custom bikes so please keep in mind that what we're building here is just one type of Girder design and only one way of doing things. The variations and possibilities are almost endless.

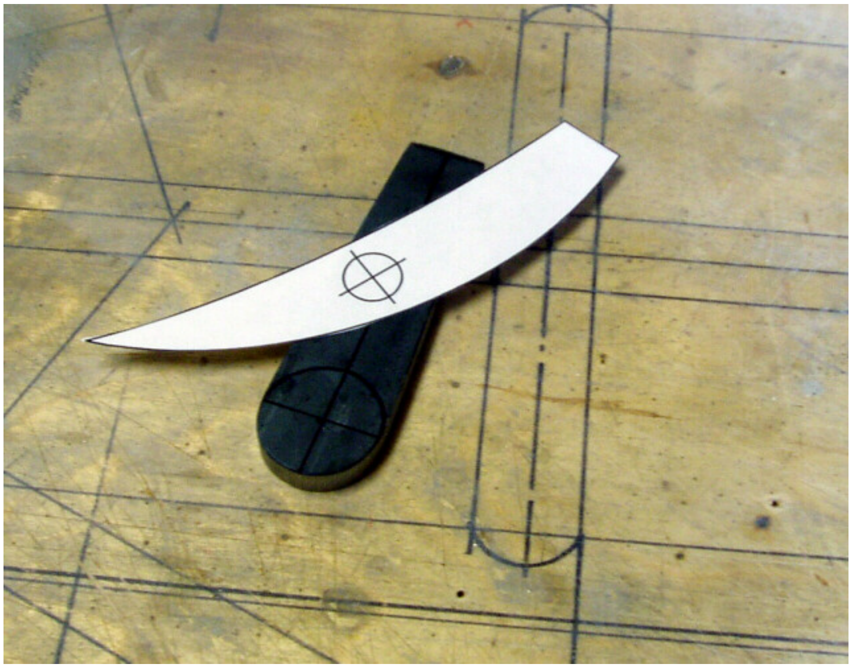


Figure 23

Figure 24 and 25 show the axle tabs in further stages of shaping. Note that we've drilled the axle holes and are using a section of ¾" drill rod to hold the plates in alignment.

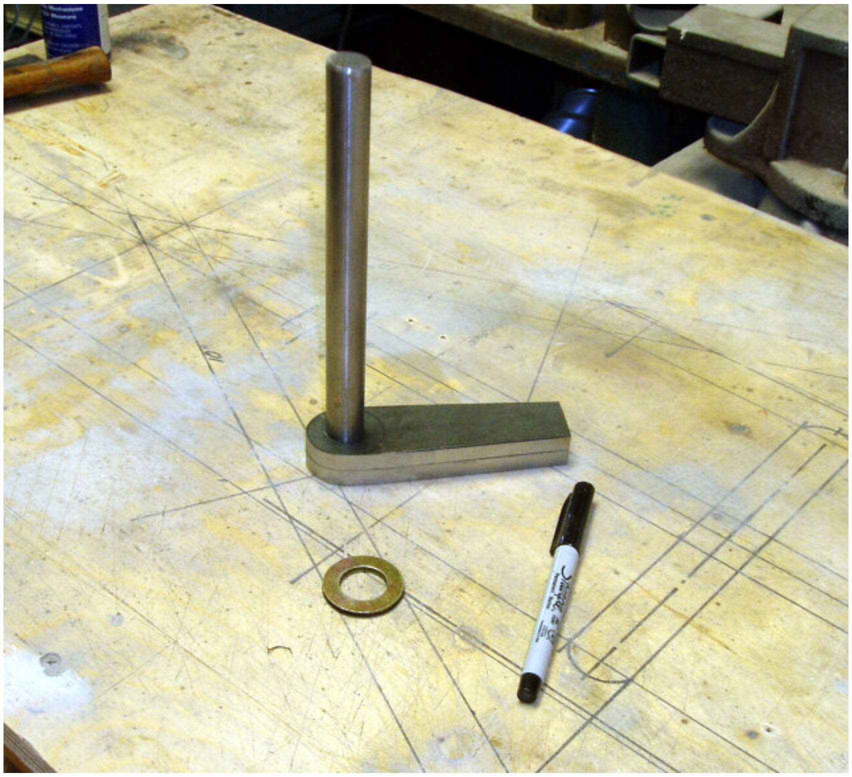


Figure 24

Figure 25 shows the opposite side.

The objective is to continue shaping each piece so that they are identical in every respect.

The washer is what I'm using as a template to smooth the large radius on the ends. It slides over the drill rod when the pieces are being sanded or ground and then I work up to the edge.

Figure 25

At any time during the course of the work you can de-scale the surfaces of all flat parts. I usually do this before even doing any of the layout work, pattern tracing, cutting and drilling but I've found that the shiny surfaces don't show up as well in the photographs. If you use cold-rolled material this isn't much of a job.

Figure 26

I usually do this finishing on the belt sander but you can use almost any sander so long as it has a nice firm and flat sanding surface and not a foam pad of some kind.

It's hard to see in the picture above but even after some fairly vigorous sanding there is still some mill scale down in the small pores of the metal. I like to use acid for the final step. Metal-prep is the old standby. Make sure you don't get any of this stuff into the bored holes. If you need to lather it on plug the holes with a waxed cork or waxed wood dowel rod of some kind.

Suspension Links

Girders use a series of suspension links that connect the forks to the steering stems. In the geometry segment we talk about their lengths and angular relationships but for now all we're concerned with is building some.

Most of my designs use links that are fabricated from 1/2" thick steel bar stock that is 1.25" wide. That thickness isn't really required for strength as much as it's needed to get the proper amount of bearing surface in the bushings. For this reason I'll often make links from 5/8 or even 3/4" thick material to get a much longer bushing installed.

I also like to use links that are fabricated entirely from tubular stock so there is great latitude with respect to both the design and the fabrication of links in general. For this project however we're going to keep things simple and basic.

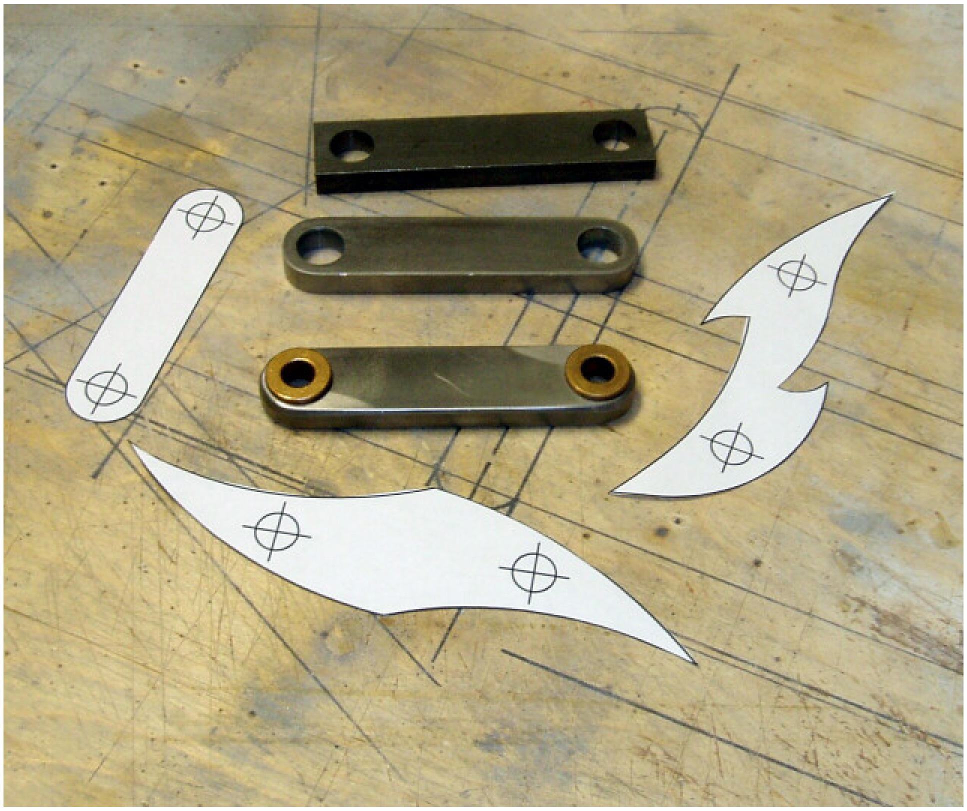


Figure 27

Figure 27 illustrates several possible design patterns for some alternate link designs. All of these are based on a center-to-center pivot spacing of 4.5-inches, which is what we're using for these specific forks.

The links in the center of the snapshot from top to bottom show the rough-cut link drilled for the pivot holes. The next link has been rough-shaped to radius the ends and the lowermost link is in the process of having the edges chamfered and surface sanded smooth. The bushings are trial fit into the bores. These should be a firm and snug fit requiring very light taps with a plastic or wood mallet to become fully seated.

For those of you interested the plywood shown in the background having the frame layout lines on it is the same one we used five years ago to illustrate the old school build-up article. It's become my favorite workbench and I've never had the heart to sand off the frame patterns or paint over them. I hope the lines don't confuse readers who might imagine that they have something to do with the Girder design, which they don't.

Figure 28 shows a pair of tubular type links. These are in the process of having the miters fitted and dressed.

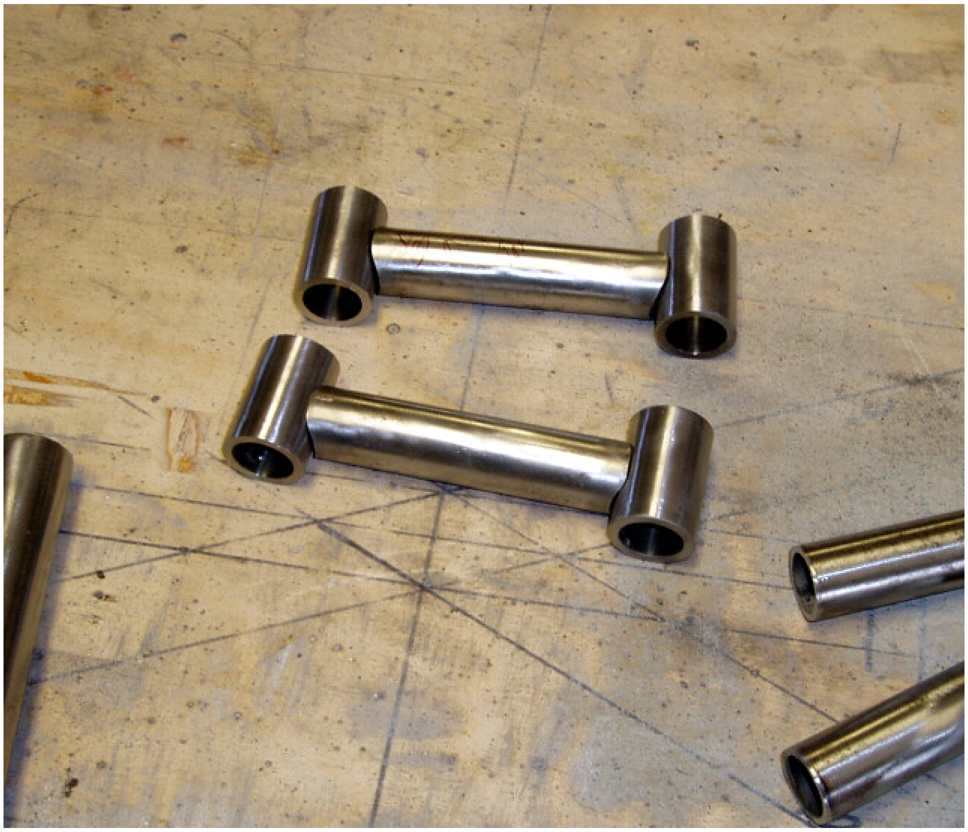


Figure 28

They are just lying loose on the table so it doesn't look like a very good fit-up but once they're clamped it looks normal. The tubing for the link is 7/8" diameter and the bushing sleeves are 1". When people were still building lightweight choppers I preferred 7/8" material for Girders, even on the legs, but I'd be hesitant to recommend that anymore with the weight of bikes increasing almost daily.

Drilling

Having to bore the links brings into play having to drill holes in relatively thick steel and later on into really thick steel when we need to drill the trees so it's time to talk about the various ways of doing this task on a budget.

Even a small shop needs a good heavy-duty drill press but sometimes this just isn't economically feasible. Sometimes you can compromise and buy a relatively moderately priced press like those made by Sears Craftsman. I have a small 10-inch model and it does about 85% of my work just fine. Occasionally I wished it had a greater depth of cut and a 5/8" chuck but that's not to often.

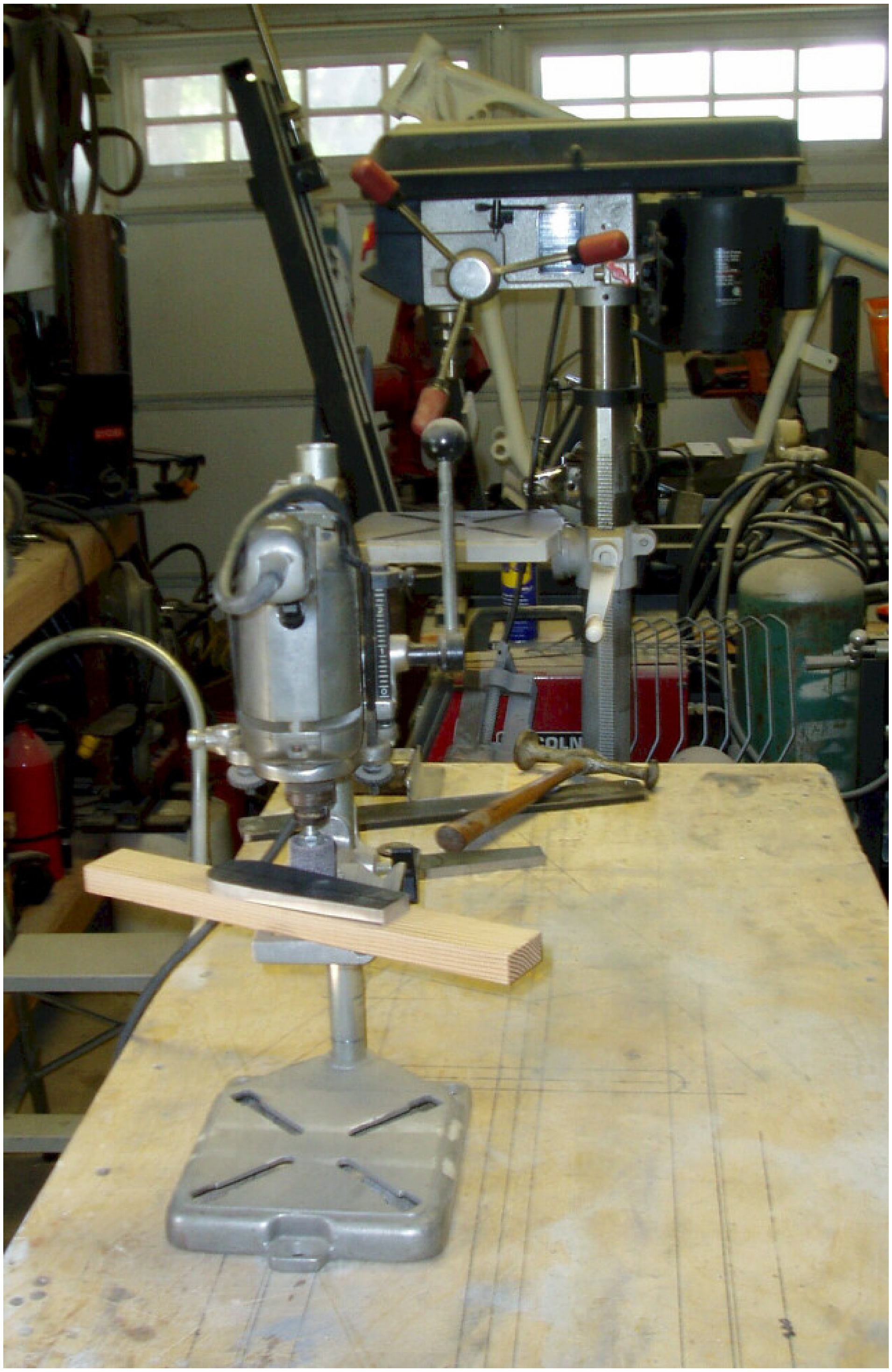


Figure 29

Figure 30 shows one option and that's one of the small presses made by a variety of companies that allow you to mount a hand drill. The Craftsman press is in the background.

This particular drill-motor press is a very old one made by Sears back in the sixties. I imagine that its still made today, perhaps 'improved' with a lot of plastic parts.

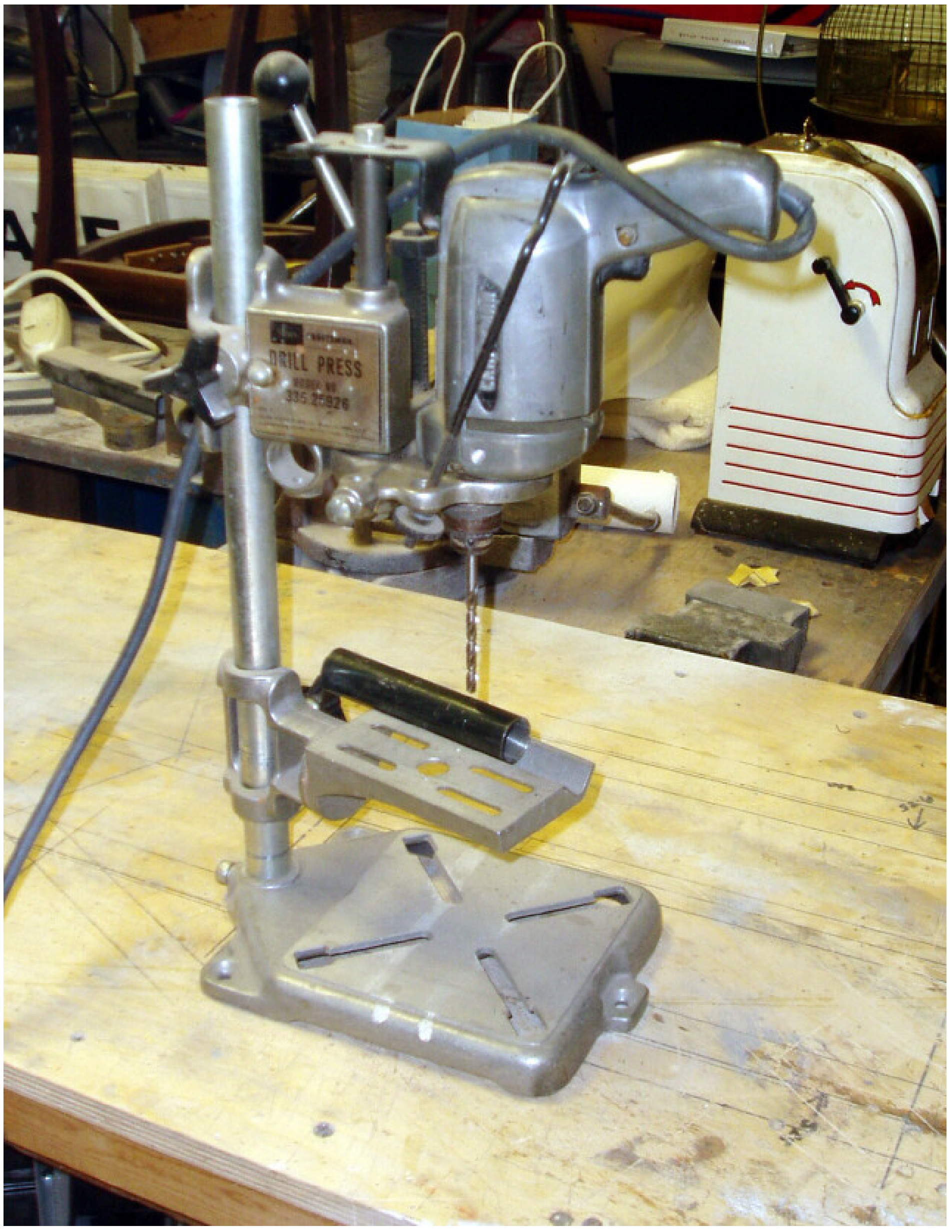


Figure 30

Here's another shot of it from another angle. I actually still use this thing quite often for a variety of 'specialized' types of work. The drill is probably 20 years older than the press itself and has been abused horribly over the years but keeps on spinning. The insulation on the cord is actually brittle and falls off in chunks.

Don’t ever try to drill any holes ‘freehand’ using a hand drill. If you can’t even afford one of these little units then please make friends with somebody who’ll let you use their press.

Anyway the equipment isn’t actually critical but the holes and the bits are very important.

Wherever possible try to always bore all holes slightly undersized and ream them to the final dimension you need for any particular fitting. Of course non-critical holes like mounts for headlamps, brake brackets, fender mounts, handlebar risers and the like can be bored using regular bits sized to the ‘nominal’ bore needed for the application. The holes for the bushings, steering stem, stem locknut and cap-nut should be a perfect reamed fit with no ‘slop’ whatsoever.

I prefer to use the ‘adjustable’ reamers. These can be purchased at McMaster-Carr and you really only need one for one-inch holes and one for 1.25-inch holes. They are very expensive so unless you’re going to be making a lot of forks it’s probably cheaper and faster to take the parts down to your local machine shop.

It is best to do all of your drilling operations while the steel blanks are still uncut so you have some nice 90-degree edges to use for measuring, layout and clamping operations. I should do this all the time but as you’ll see I often violate my own rules.

I get a lot of mail from people who are on ultra tight budgets and can’t afford the larger diameter drill bits not to mention reamers and machine-shop time so my suggestion is to simply use cheap hole-saws to bore your ‘special’ holes. Most metal hole-saws are made to very tight tolerances, especially the Milwaukee brand, but even house brands are very good. ‘Experts’ have told me that you can’t bore steel that’s much thicker than 3/8” stock, which is an old wives tale. You can bore almost any thickness of material up to the cutting depth of the saw itself and in many cases the hole is cleaner than you’d get with a conventional drill bit.

Good quality hole saws come in 1/16” increments but most shops only stock the ‘common’ sizes so you may have to order over the Internet.

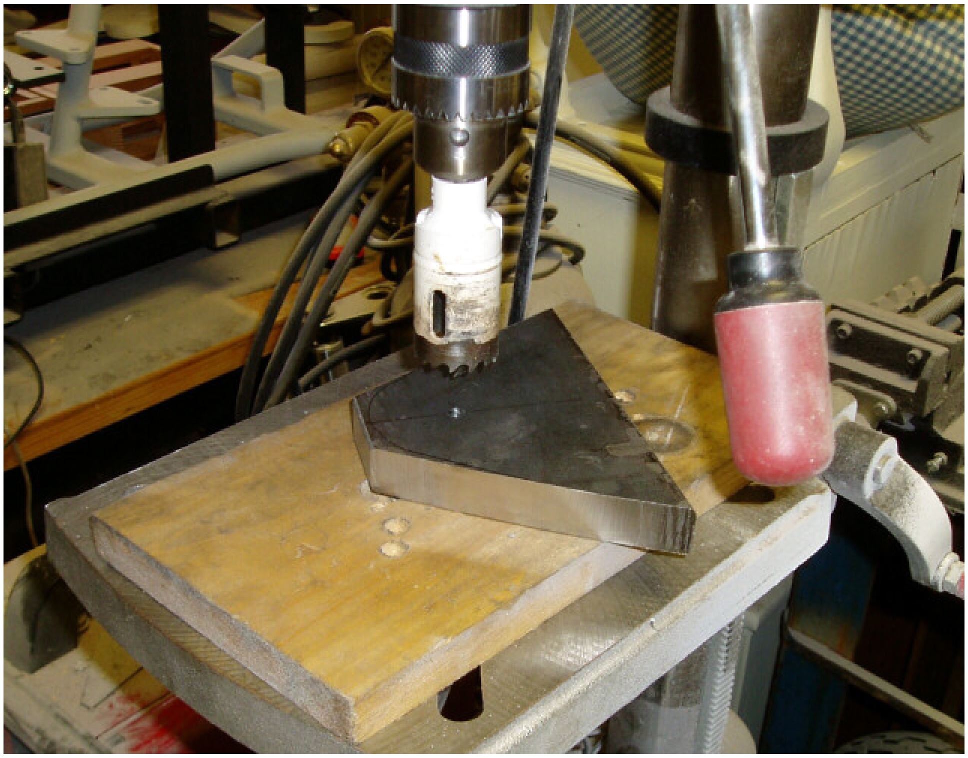


Figure 31

Just to show what's possible we chucked up a well-used twelve-dollar Ace hardware saw to drill the 3/4" thick trees for the Girder. I generally drill a quarter inch pilot hole first so that the pilot drill inside the saw actually doesn't have to do any cutting and just acts as a guide.

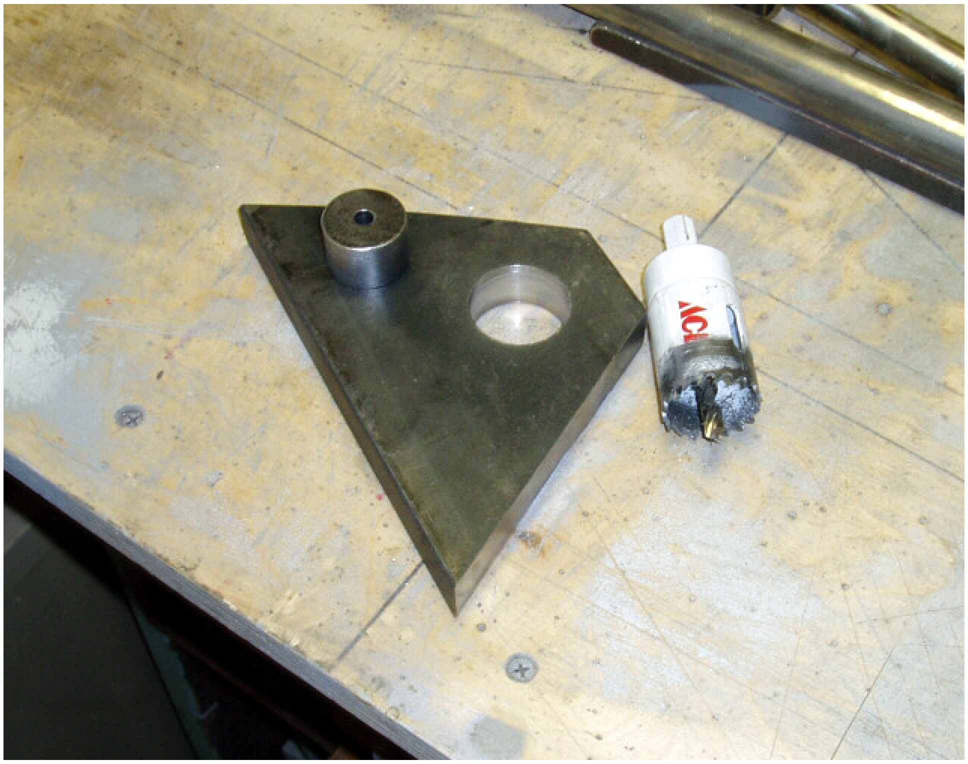


Figure 32

It took about 10 minutes to get through the material running the drill at around 500 rpm and the final bore is very clean and measures exactly 1.25 inches. I save all of those slugs by the way. They can come in handy for building a variety of stuff.

Just for kicks I measured up some stock trees I had laying around and found the top bores to vary from 1.24 to 1.265 and one import was up to 1.28 inches.

I also measured several styles of stem cap nuts and found that the shoulders that fit down into this bore range from 1.2 to 1.24 inches.

The tree pictured hasn't been shaped yet which is why it still has the sharp corners in the rear portion.

The holes for the handlebar risers can of course be drilled with a conventional bit and the 1-inch hole in the lower tree for the steering stem can also be bored with a hole saw if you can't lay your hands on a one-inch bit.

More parts

Somewhere along the line I'll start to cut the tubing to length. We've already described elsewhere in the handbook about how to determine the length of your forks so I typically start with front legs on a girder and cut these just slightly longer than I need. The 'extra' sections of tubing will eventually become the link pivot shaft barrels.

Figure 33

While you're at it you can also do the bends in the rear legs. I typically leave a lot of extra length on each side of the bend at this stage so I have a lot of material to work with during the final fitting.

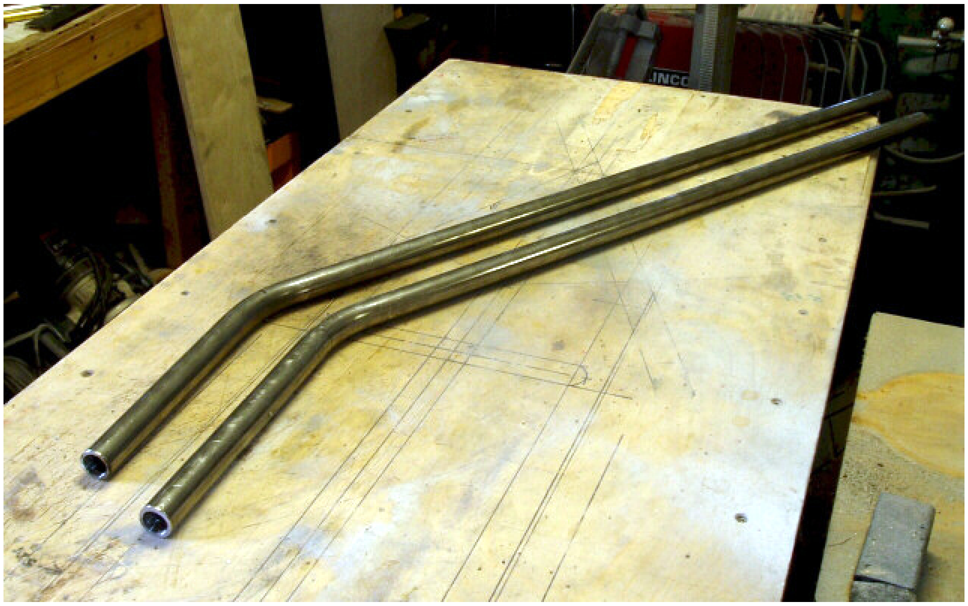


Figure 34

Keep in mind that the bend angle on these legs varies relative to the length of the forks so it's a good idea to do a full-sized layout on cardboard or plywood before you start cranking the bender handle. For most chopper applications the bend will range between 30 and 40 degrees so it's an easy one to do. This bend angle isn't super critical so if you're off by a degree or two or even three, don't worry about it. If you don't have a bender I would imagine that most shops in your area might charge you a six-pack to do something this complicated. If they want more than that then I'd find a real chopper shop somewhere that knows what they're doing and knows what chopper building is all about.

Link Attachment Methods

We talked about the various types and styles of Girders in Volume I of the Handbook but we're going to digress a little and discuss the three most common methods of attaching the links to the forks and trees.

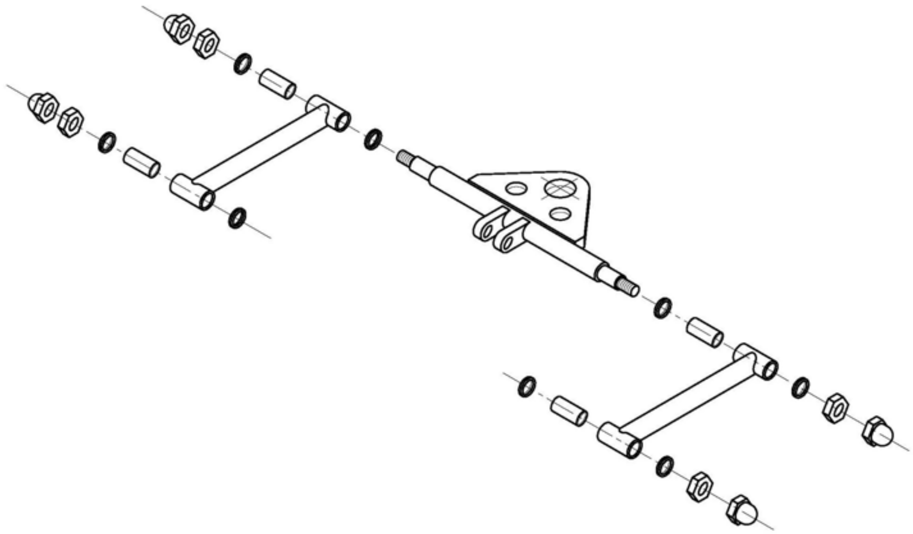


Figure 35

Figure 35 illustrates one of the most common methods of mounting the links to the trees.

In all of the illustrations that follow we have omitted the lower tree and the fork itself for purposes of clarity but I think the reader will still understand the concepts we'll be discussing.

In this scenario a threaded shaft is either welded inside a sleeve barrel or the shaft is machined from a billet with threaded portions on each end. The barrel is welded to the tree. The links slide onto the bushed shaft and are secured with jam nuts and cap nuts. This is a very strong assembly and relatively economical to fabricate. It is slightly superior to the method shown in Figure 36 that follows and only slightly more complicated to build.

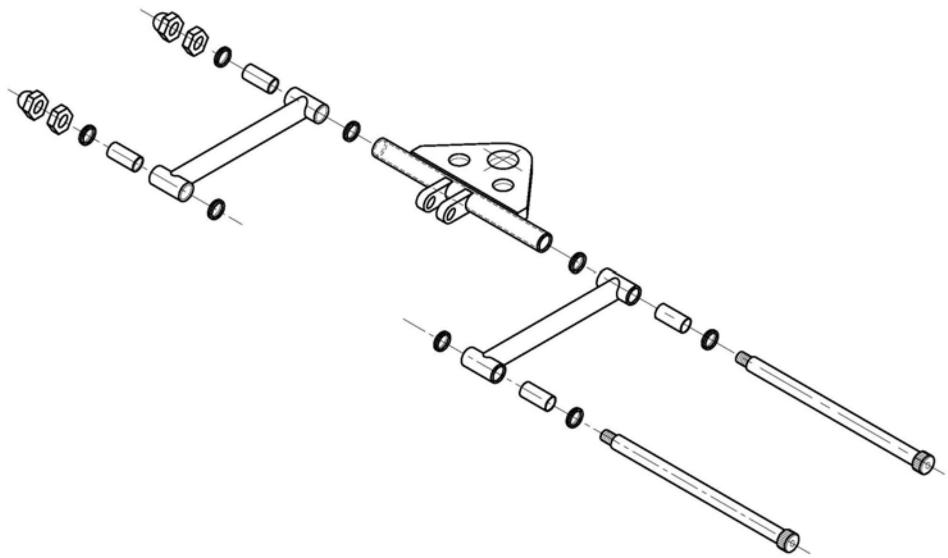


Figure 36

Figure 36 depicts one of the older methods of link attachment. In this scenario a long bolt or shaft threaded at both ends passes through the tree 'barrel' which houses the bushings. There are definite advantages of using this method as the links themselves can be secured to the shaft, either by keyways in the shaft or clinch bolts in the links. This creates a monolithic link/shaft assembly that insures that each link on opposite sides of the tree move in unison. This is an extremely strong attachment method and as a result the shaft itself can be made much smaller in diameter, 1/2" is not uncommon though I prefer to use 5/8" diameter material.

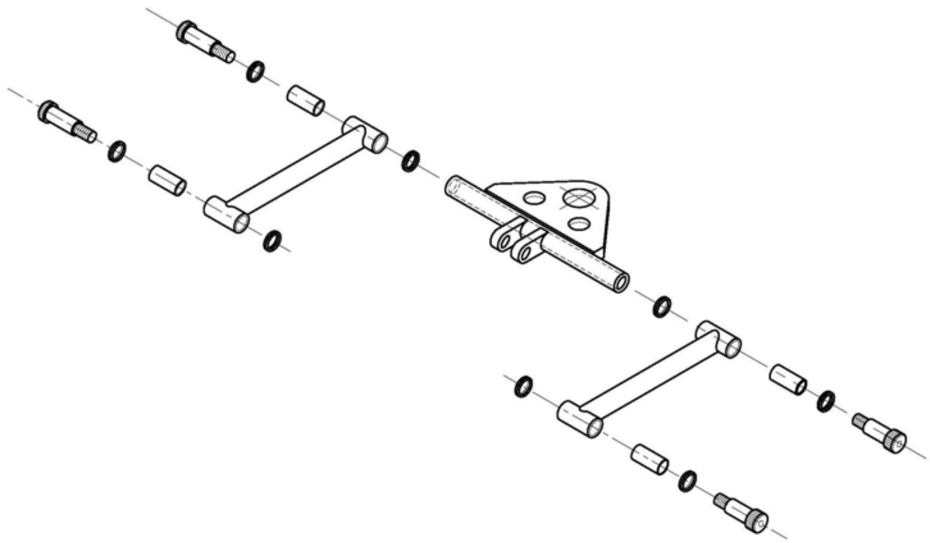


Figure 37

Figure 37 shows one of the more modern methods of link attachment that you'll often see on so-called 'custom Girder plans' sold on the Internet. In my personal opinion this is the least desirable way to build a Girder as all of the stresses are placed on the smallest section of the shoulder bolts that are designed to thread into a tapped recess in the tree link barrels. In some cases the 'barrel' itself is omitted and the shoulder bolts simply thread directly into the trees themselves. In this scenario the threaded portion of the shoulder bolts take the entire load and this is not a good thing to rely on. It's cheap and easy to build which is why you still see people doing it, even a lot of so-called professionals.

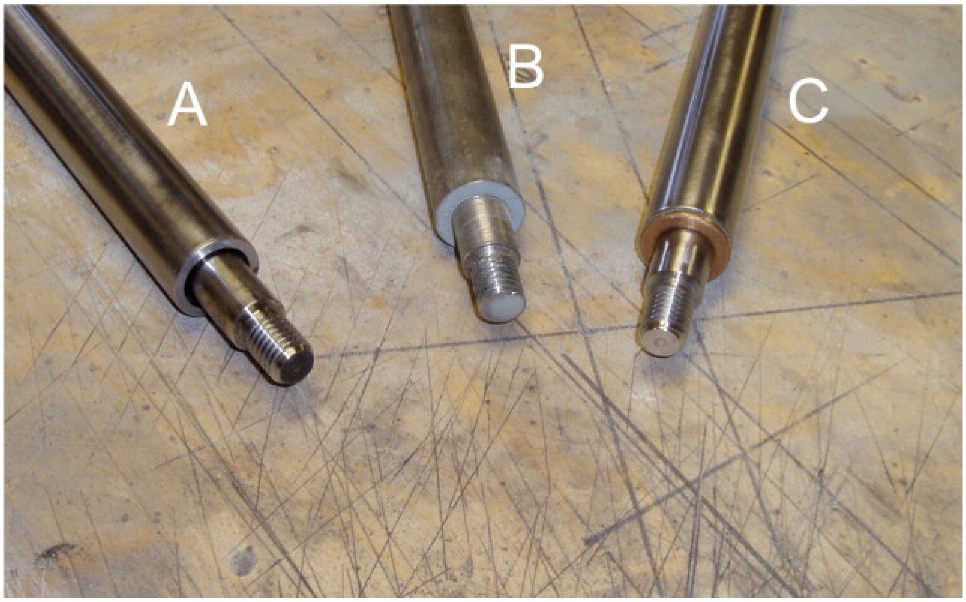


Figure 38

Figure 38 is a close-up of the various shaft configurations. On the left is a machined link shaft that has been plug-welded into a section of DOM tubing as described in the basic CBH Girder plans. The shaft shown in the center of the picture is machined from a one-piece billet of 1-inch stock so that the shaft and barrel are a monolithic unit. On the right is a traditional bushed barrel containing a continuous machined shaft as used in Figure 18 shown above.

Note that if you're using method 'C' with a continuous rotating shaft you really need to use links that incorporate cinch bolts as on the old original Indian forks. Figure 39 depicts one of these link types.

Figure 39

I personally prefer to use continuous shafts that rotate inside bearing sleeves or barrels as I think it is a strong method and more evenly distributes the load to the links.

Figure 40 illustrates a typical bushed sleeve with a continuous shaft.

Figure 40

Figure 41 depicts an optional method of running a continuous shaft inside of separate bosses as you'll find on two-piece girders or girders using one-piece links.

Another advantage to the continuous shaft method is that it eliminates any machine work which is a plus for the home builder as these shafts can be purchased ready-made from a variety of sources including Graingers, Mcmaster-Carr and Ace hardware to name just a few.

Prices range from around twenty dollars to fifty-five for precision high quality, high strength shafts. Shafts are generally available in lengths of 6, 8, 10 and 12 inches so they are perfect for both Girder pivot shafts and even axles. Common diameters are 3/4 and 5/8", again perfect for our applications. With the more expensive products you also have a wider range of threads and shoulder sizes.

Figure 41

These are but three methods out of perhaps dozens that you'll see incorporated into various types of Girder forks but these common methods are the easiest for the home-based builder to adapt to his or her specific project.

On this particular project we'll be using the attachment method shown in Figure 38B with one-piece billet shafts and barrels provided courtesy of John Stewart (Hose Dragger).

Tube Notching

We're about at the stage of starting to need some notches in the tubing. There is an entire section on notching in Volume I if more information is needed but for Girder work there are few complicated miters that need to be made. I usually just do all of my copes using a hand-held disc grinder or die grinder. On these small diameter tubes it is easier and faster. You can use the free 'Tube-Miter' program available on the web site to create patterns for the various miters that you'll need.

For simple cuts you can always use one of the several different types of 'Joint-Jiggers'.

Figure 42

The notcher pictured above costs around $40 when they go on sale at Harbor Freight Tools and they're pretty good if you ignore the horribly inaccurate built-in protractor.

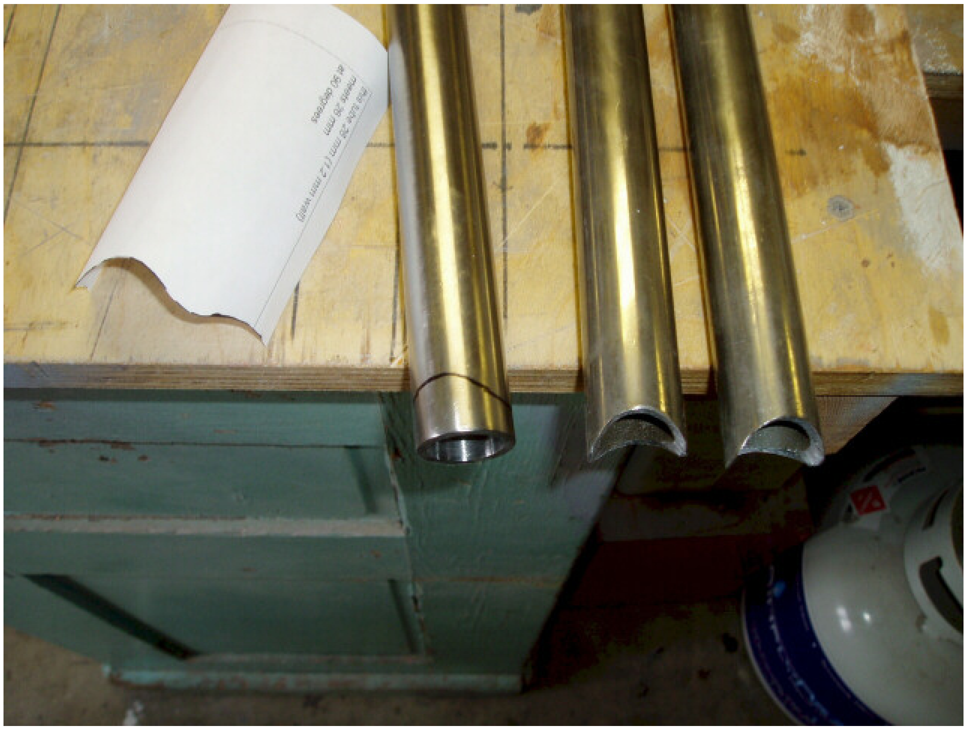


Figure 43

Figure 43 shows some typical notches. The two on the right were made in the Joint-Jigger. The white paper on the left is a pattern from the Tube-Miter program and you can see the ink outline on the tube next to it. It's very easy to make these small copes with a grinder. Of course these are the simple cuts that adjoin the fork cross-members at a 90-degree angle. They will get more complicated as we go along.

Welding Jigs and Fixtures

One of the biggest mistakes I eve made was to publish plans and pictures of frame welding jigs as all it did was make people believe that they had to invest thousands of dollars into a jig to only build three or four frames. We've tried to dispel this myth over the years and have done fairly good explaining the whole concept of jigs and fixtures.
Building forks is not much different than building a frame except there is a lot less tubing involved, far fewer welded connections and far less complicated bends.

For this reason one can make-do with a minimal system for use as a fork jig and its fixtures compared to a full-fledged frame jig.

If you only going to be building three or four sets of forks a good wood jig will serve every bit as well as a steel jig so long as it's equally as strong with respect to resisting distortion during the welding process.

The key element in jig design is to make sure, first of all, that's it's accurate and secondly, stiff enough to resist bending or deflection during the welding of the assembly. The style, arrangement, design concept, fixtures and sub-fixtures can be of almost any conceivable arrangement and execution that suits the nature of the work to be performed.
All you need is some type of structure to hold the parts in their proper position for welding, nothing more and nothing less. How you decide to accomplish this simple task really makes no difference. For this reason we're not going to go into describing the construction of a fancy production-line type of fork jig but rather explore primitive but effective ways for the home-based builder to get the job done at minimal cost.

In the original edition of the Handbook I mentioned that every time I go to a yard sale or into a tool store I look for manufactured items that I can adapt to chopper building. One of these items is a simple angle clamp made under the trade name of 'Pony'. Pony makes all kinds of clamps but these bottom of the line little clamps are great for welders since they are cheap and actually well made. This entry-level angle clamp is typically available at almost any hardware store for about twelve dollars, sometimes much less.

Figure 44

In the picture above you see a setup with two Pony clamps used to hold tubes at right angles to an intersecting tube. You also see that something isn't quite right with this picture. The width of the tube legs is much wider than the Girder pivot pin cross member.

A little grinder work on the cheap aluminum clamps and we have the setup shown below which looks a whole lot better and took about five minutes.

Figure 45

You can spend an entire day and twenty dollars worth of steel building a fixture that helps to weld up another just another fixture to put on a welding jig that does exactly the same thing as these cheap little clamps do.

Figure 46 shows the opposite end of the legs where we've made a set up to clamp the axle bosses in place. The spools in the center, within the clamp jaws are just spacers that hold the 3/4" drill rod in place so the bosses are properly centered on the rear tube legs.
Shaft collars would be used to make sure the bosses don't move laterally during welding.

Of course it goes without saying that even if you use the clamps you will still have to do some tweaking and shimming and maybe some grinding to be certain all angles are exactly 90 degrees. We found them to be remarkably accurate right out of the box.

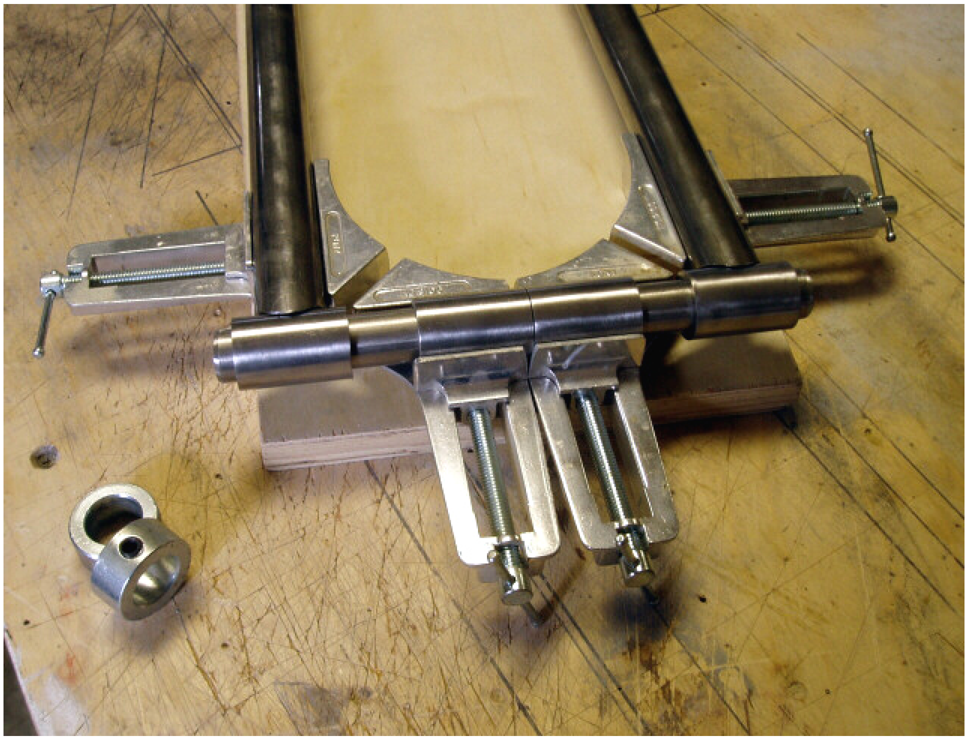


Figure 46

For a few forks the cheapie clamp option is great but or a production operation you do have to build something more substantial. I don't think I need to say much more about this particular example as I think you get the drift of where I'm going. Improvisation, imagination and ingenuity are the keys to good time/cost effective fabrication.

Just keep in mind that your jig can be as fancy or as simple as you decide to make it.

For those on an ultra-tight budget we're going to build what I call the 'Twenty-Dollar' jig since that's about what it cost to build one. This is very similar to the type of jig I build for special or unusual prototype projects. It's quick and dirty but can be extremely accurate and surprisingly strong.

To start out you need to get a good straight and flat piece of 3/4 or 1-1/8" plywood at the local lumberyard.

Figure 47

Saw this down to a strip that's about 48 inches long and 8 inches wide.

Figure 48

I usually saw it just a tad wider than needed and plane it down to the final 8-inch width. The objective is to have a perfectly square and flat piece of board. The width is determined by the distance between your link bosses at the pivot points, so if you're building a wide Girder then adjust the width accordingly.

To make sure that the board stays flat during welding we need to add some strong-backs to one side. These strong-backs can either be wood or steel. It really makes little difference.

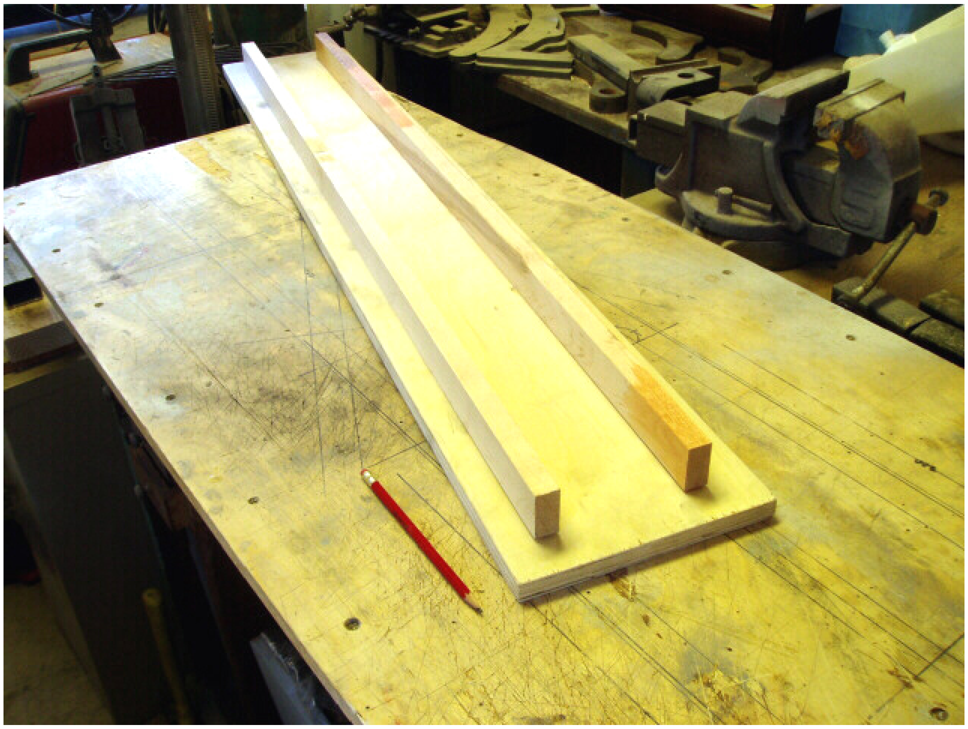


Figure 49

I usually place them well inside the outside perimeter of the board so that I have room for clamps around the edges.

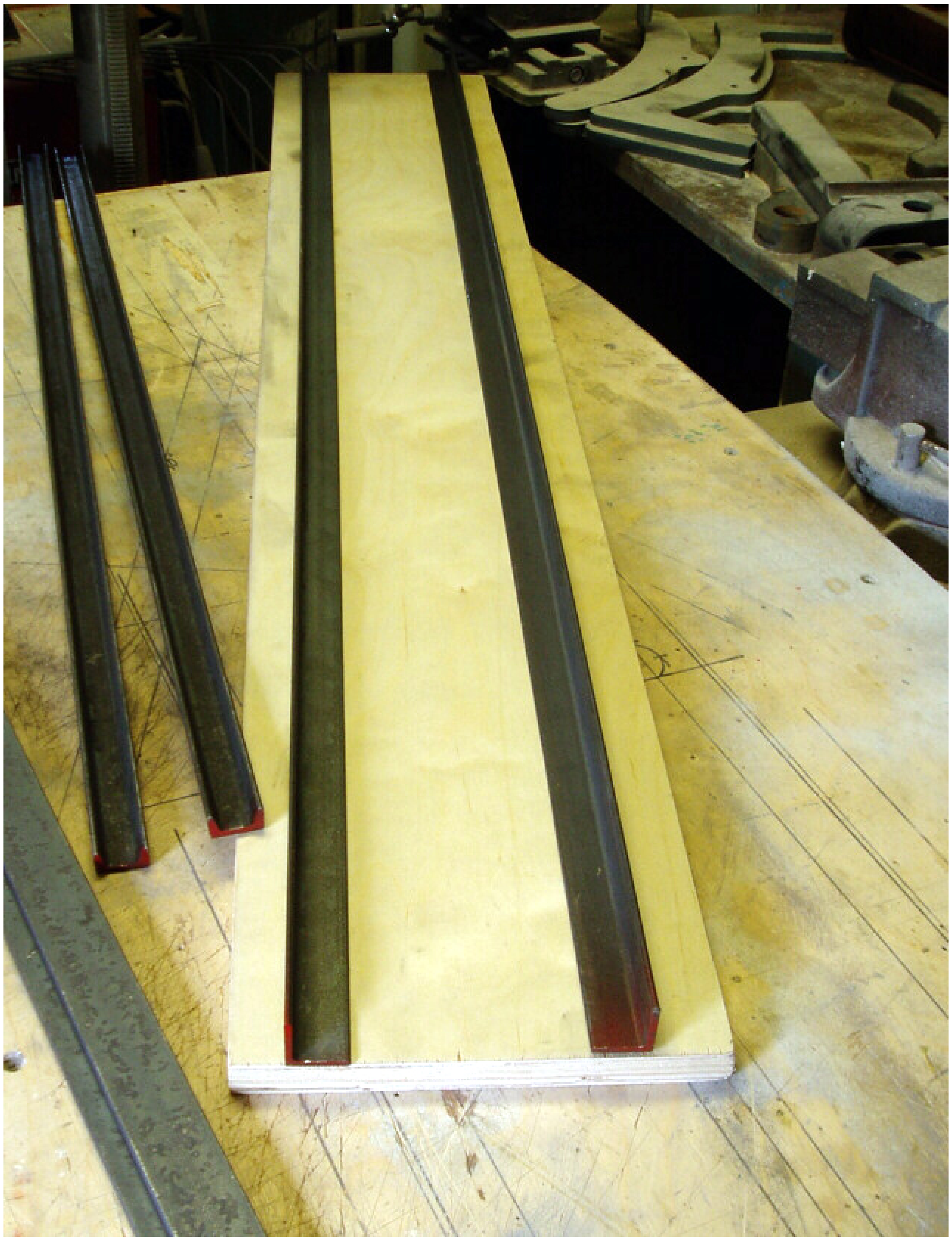


Figure 50

Before permanently installing the strong-backs we need to cut some notches in the plywood so that we can eventually weld from both sides of the jig. There is no magic about the size of the notches. I like to have at least an inch and half clear around all joints and connections but that's just a personal thing.

Figure 51

Figure 51 shows the direction we're headed for. Here the notches have been cut and the strong-backs installed. In this particular case they are made from 1-1/2" maple that I had around the shop already.

Next we're going to install the most critical piece that will become the fixture used to hold the upper link pivot barrel or shaft bosses.

Figure 52

It doesn't look like much but it works. That little piece is made from 1" by 1/2" steel channel which you can buy almost anyplace. The best material is clearly marked 'Canada' and it is very accurately formed and of good steel.

I use this stuff constantly in jigs and fixtures because it's the perfect size to hold tubing and bar stock from 3/4" up to 2" in diameter and it's about a 100 time easier to use than angle iron for building fixtures. Two pieces together are the perfect tube clamps.

What we've done in Figure 52 is to align that little section of channel at a perfect 90-degree angle to one side of our jig board. I always only work from one side of a jig, the side that I know is perfectly perpendicular to any ends or cross-members.

You can see that I've drilled countersunk holes in the channel and simply screwed it down onto the layout board.

We install a similar piece at the opposite end of the board. The distance between the two pieces should be about 2 inches longer than the longest forks you ever expect to build.

At this stage you want to be constantly checking that everything is square and plumb and to be sure that the distance from you work table to the center of both the pivot barrel and axle bosses are identical in every respect. Measure everything three times and then check them again.

Don't be to concerned with specific dimensions. I use 'story-boards' to check that distances are equal. The dimension isn't even checked, just that both sides are exactly equal. An eighth or a sixteenth in overall fork length isn't going to matter so long as everything everywhere is perfectly equal, square and plumb. I can't overemphasize how important this is.

Figure 53

Figure 54 illustrates how these little pieces work in application. The lower section of channel is screwed into the jig board (or welded if you're making a steel jig) and then another small section is placed on top of the pivot pin barrel and the a C-clamp creates a solid stable clamping pressure holding the part in the proper position.

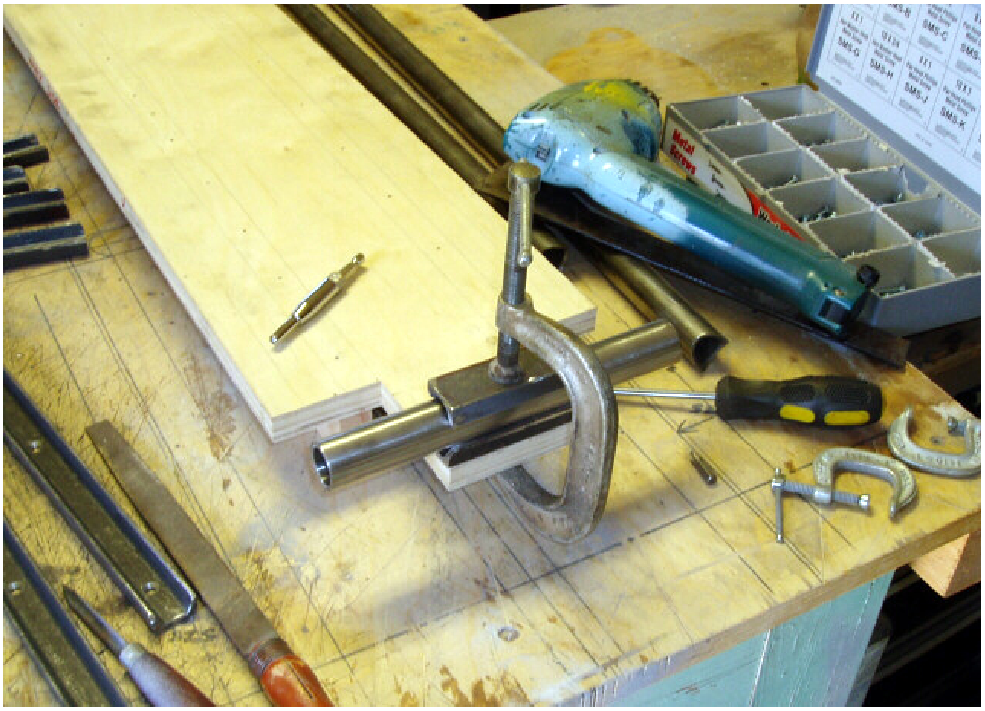


Figure 54

Keep in mind that during this jig mock up we're only showing short sections of channel clamps and only one C-clamp. When you're ready to weld you want to use sections of channels that are as long as possible and still give some room around the weld point. Also you want to use at least two clamps on every run of tubing, more on the long runs.

The next thing we want to install is what I call the bed rails. These are just a couple of long sections of channel that the front legs of the girder fit into for welding into the head barrel and axle bosses.

Figure 55

These pieces don’t really need to be much more than 16-inches long but they have to be installed at perfect right angles to the pieces of channel that hold the upper pivot barrel or shaft and the axle bosses or axle plates.

Once this is done we have a very cheap but very accurate and strong fork jig less some of the fine points at this stage, but a good foundation to work with as we go along.

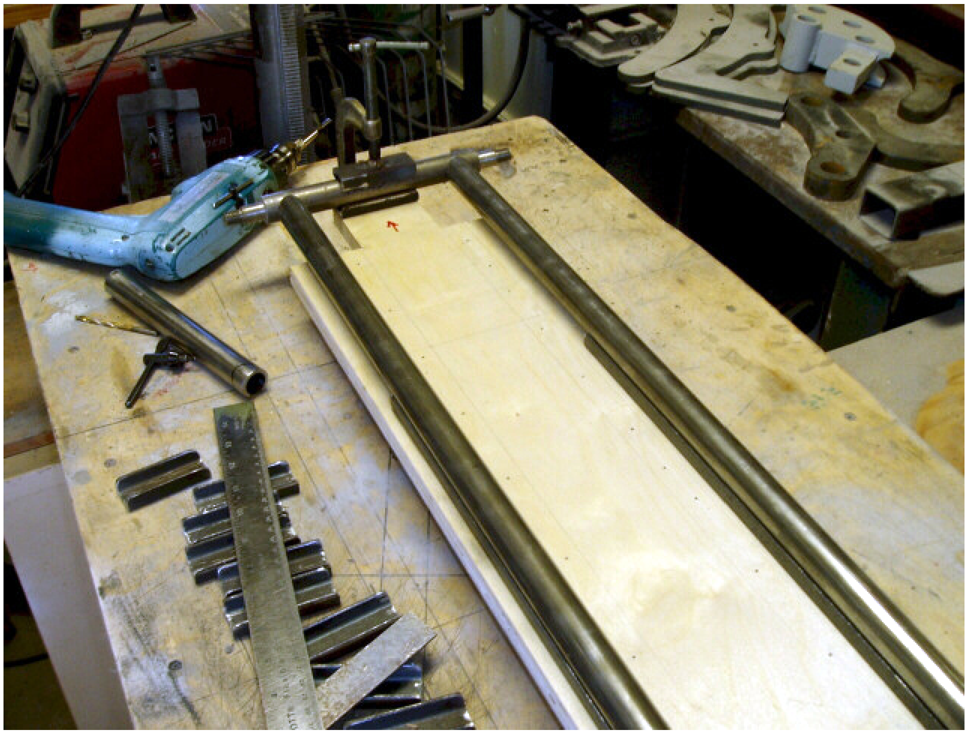


Figure 56

Figure 56 shows our front legs and upper pivot shaft in position lying down in the channels runs we've installed.

This is actually an amazingly strong little 'quickie' jig. The channels act as additional strong-backs so the entire structure is very stiff, probably just as stiff as an all steel jig but it cost about one fourth as much and can be built in about two hours from materials that are readily available. I don't necessarily expect you to follow this pattern exactly but hope that what we've shown gives you some ideas can explore yourself.

By the way that gray dust you see on everything in my garage is primer residue since I don't have the luxury of having a spray booth. When it gets to be about a quarter inch thick on the floor I do a big 'cleanup' day. I'm sometimes amazed at all of the things I find buried under this dust.

I hate so-called 'adjustable' jigs and fixtures of any kind. To my way of thinking anytime you make something 'adjustable' or 'movable' with respect to welding jigs, you're probably making a mistake that will come back to bite you in the ass someday.

One way to ad little adjustability with this type of jig is to simply add extra sections of channel stacked up against one another as shown in the next figure.

Figure 57

This particular setup is on the 'bottom end' of the jig and allows fast adjust for the length of the main legs in one-inch increments.

We've got enough of a jig built at this point to start cutting, coping and laying out the various tube runs. Figure 58 is a snapshot of the upper pivot pint shaft clamped into the fixture at the top end of the jig and the two front legs, mitered earlier set into position inside the two runs of channel iron.

The other shaft, shown leaning up against a lead duck I use to keep stuff from rolling around is the lower pivot point. You can see that we're building the forks from the front, 'upwards' towards what will be the backside when we're finished.

Figure 58

Our plans show the distance, measured on the horizontal, between these two shafts as being 8.375 inches. This works out to the shaft centers being on an 8.5" radius, which is about right for most choppers. The exact measurement however depends on the total installed height of you steering neck, with all bearings, seals, dust shields, jam nuts and trees and this can vary anywhere from 7.25 to as much as 9.5 inches on various bikes.

Figure 59 illustrates a typical arrangement with a spare neck sitting on top of the lower tree over the lower bearing and dust shield. On top of this goes the upper bearing, dust shield, stem bearing adjuster nut, lock washer and then the upper tree. Another type of combination dust shield and jam -nut is shown on the tabletop along with the cap nut.

You can just barely see the shoulder on the jam-nut and cap nut that fits down inside the 1.25" stem bore of the upper tree.

The point being is that you really do need to measure the assembled neck on your particular bike and make any adjustment as needed in the distance between the upper and lower pivot shaft location. If you don't then it is likely that you won't be able to get your links to actually run parallel to one another.

Figure 59

If you're unsure of how the various components of the neck assembly go together take a look at the exploded view diagrams in the factory shop manuals. Even Harley has revised the exact arrangement of the parts over the years. Use one that best suits your particular situation.

Rear Truss Legs

We've already bent the rear truss legs as described earlier and now it's time to start getting them mitered to fit the front legs.

I usually cut all pieces extra long so it's easier to work down into the miters for these connections without worrying about accidentally taking off to much material. The miter at the upper connection to the front tube legs is pretty straightforward and can be cut using a notcher as we described for the notches in the front legs where they meet the pivot shaft.

Figure 60

I still cut most miters with a grinder so to establish a base line I just chop off the ends of the truss legs in the chop saw along a line that runs parallel with the angle of the front legs as shown above. Be sure that you leave enough extra length to actually cut in the miter notches.

I make a similar flat cut on the lower end of the leg. The angle of this cut is so steep that the chop saw is pretty much out of the question. The alternative is to grind it in or cut it in using a small hand-held grinder.

Note the felt-pen line on the tube that is just an eyeball approximation of the depth of the cut to be made. This can be determined by just sitting both the front and rear leg into their proper positions and then scribe a mark there the two tube intersect. Like always, make this cut on the long side so you have enough meat to do the final miter notch.

Figure 61

Once you have the two tubes cut at the approximate proper angle you can use the free 'Tube-Miter' program to make some patterns for the final fish-mouths.

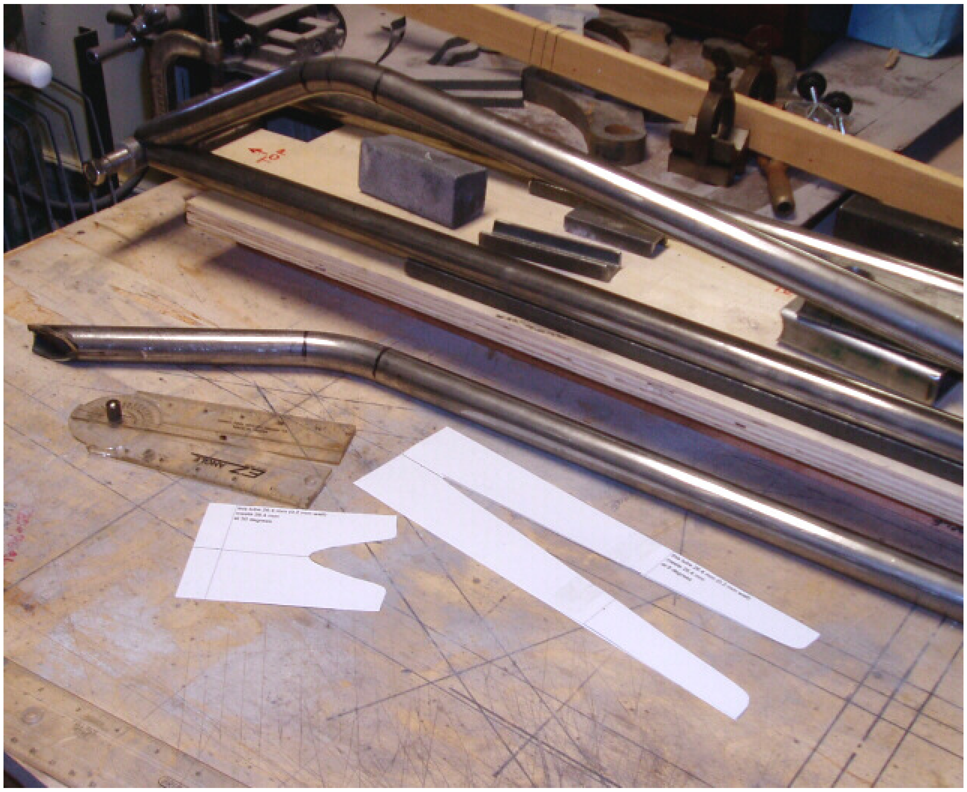


Figure 62

The figure below illustrates the miter pattern wrapped around the tube for the upper notch. As you can see I was pretty conservative with my eyeballed rough-cut but better safe than sorry.

Figure 63

The next snapshot depicts the pattern for the lower cut wrapped around the leg tubing.

Figure 64

If you look closely you can see the felt pen outline for the cut as I actually want to start it. As you can see my estimation of the notch is significantly different than the so-called 'perfect' pattern created by the computer program.

These various software packages for notches and tube bending in general are all fairly good to use to generate close approximations for actual fabrication work but more often than not they can lead you down the wrong road if you're not careful and conservative.

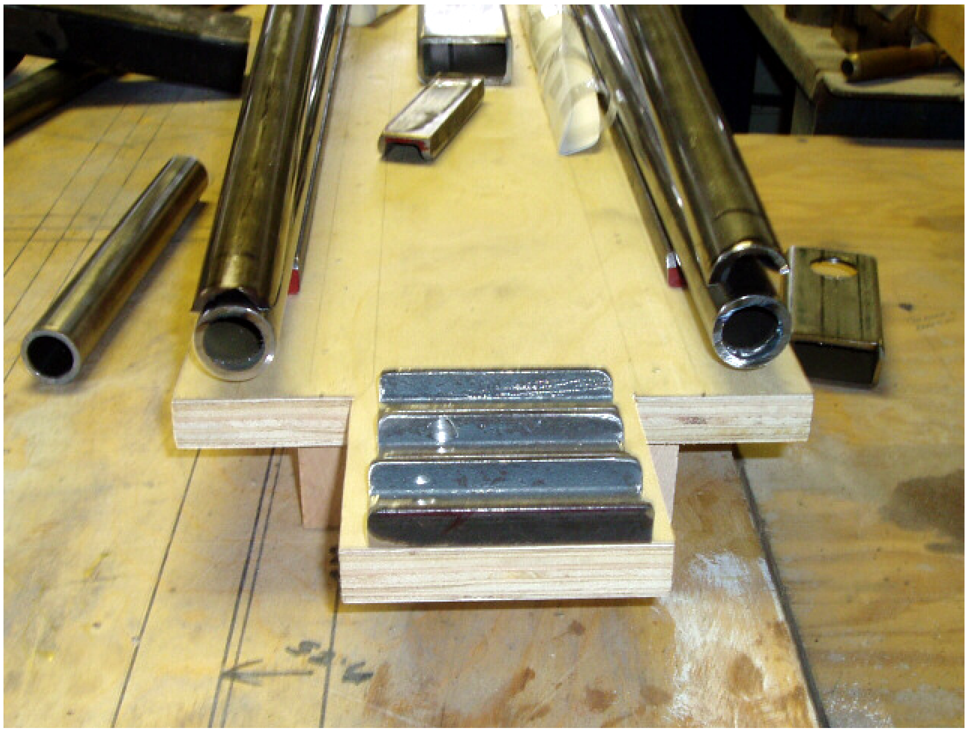


Figure 65

In figure 65 we can see the connection points at the bottom end of the Girder legs. The tube on the left side of the shot has the notch almost fully formed. The tube on the right has just had the initial rough cut made. Note how high it sits.

The process of fitting these four tubes can be tedious but it's important to take the time to work each notch a little at a time with constant trial fits along the way.

Keep in mind that as the notches are deepened the tube become shorter in length, which is the reason to cut everything slightly longer than is actually needed.

Figure 66

You can see in the snapshot above that the rear truss tubes, the ones with the bends, are about 1/4" longer than the straight front legs. As theses long miters are being formed that extra length will gradually disappear. The reason I'm trying to emphasize the importance of this simple fact is that because so many people make the mistake of cutting the tubes to the exact length before starting to shape the notches. This ends up creating a situation where the rear tubes look awkward and out of place in comparison to the fronts.

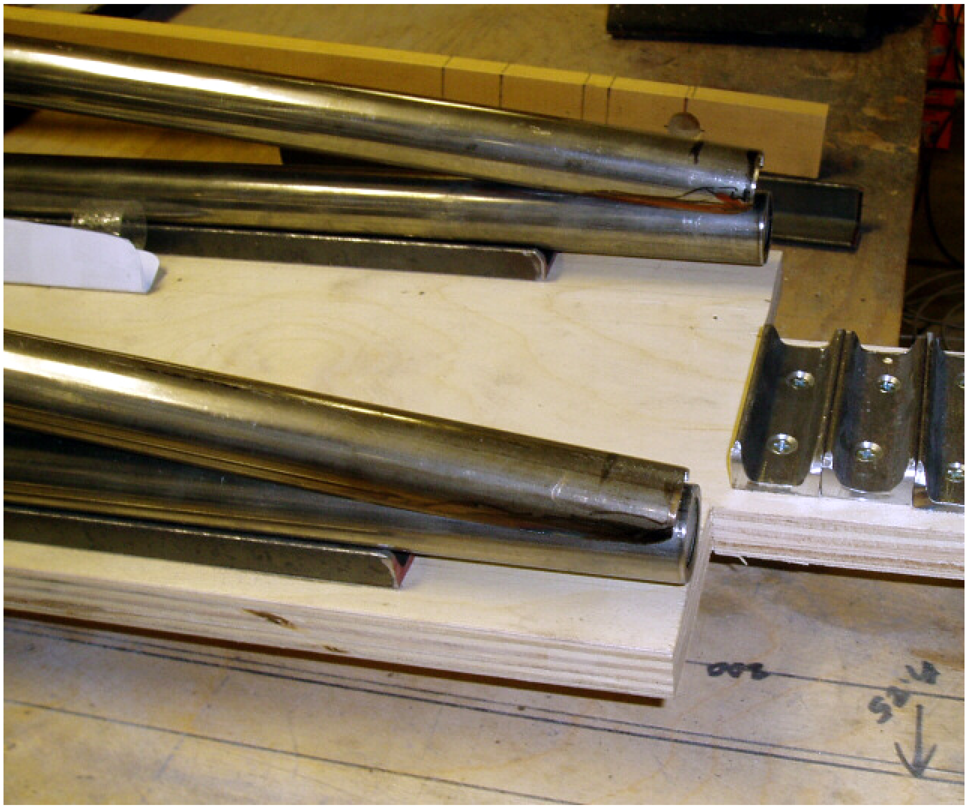


Figure 67

In can see in the figure above, taken as we're deepening the miters that almost an eighth of an inch has already disappeared from the length of the rear legs.

Keep working on the miters at each end of the tube until it starts to sit down perfectly over the top of the front leg.

I didn't have any Dye-Chem on hand for these photos so I just used a magic marker as a spotting compound. Lay down a coat of ink in the notch and using a piece of 100 grit paper wrapped around a spare section of tubing give it a few strokes to reveal the high and low spots in the area of the cut. You can get almost surgical precision if you want to.

Figure 68

Don’t make the mistake of trying to get a knife-sharp featheredge at the sides and edges of the fish-mouth since such fine edges will just burn away when you try to weld them.

Figure 69

In the photo above the tube in the upper portion of the shot is almost completely finished while the one in the lower section of the image is still in the fitting stage. Note that on the finished tube the raw edge is just under a eighth of an inch in thickness. This is needed for a good solid weld. The bead itself will create the smooth transition from the upper tube to the lower surface.

We're getting pretty close to making the first welds but there are still a few more parts to make and at this stage of development we need to fabricate the lower fork pivot shaft gussets that run between the front and rear legs on each side of the fork.

I typically make these from sections of 1"x2"x.120 wall rectangular cold rolled steel tubing as shown in the rough-cut condition below.

Figure 70

There is nothing to say that you can't substitute some half-inch plate stock if you wanted to. Keep in mind however that if you do decide on using solid stock these gussets should not be welded into position bearing right exactly on the middle, or centerline of the tube legs. Any and all gussets should be positioned so that they bear tangentially to the tubing, in other words, just to one side or the other of the tube.

The size and shape of these gussets isn't very critical. Try to allow at least a half-inch of material around the perimeter of the pivot shaft barrel.

The cardboard pattern below is something rough to give you idea about the possible shapes for the gussets. It hasn't been trimmed yet to follow the contour of the rear leg.

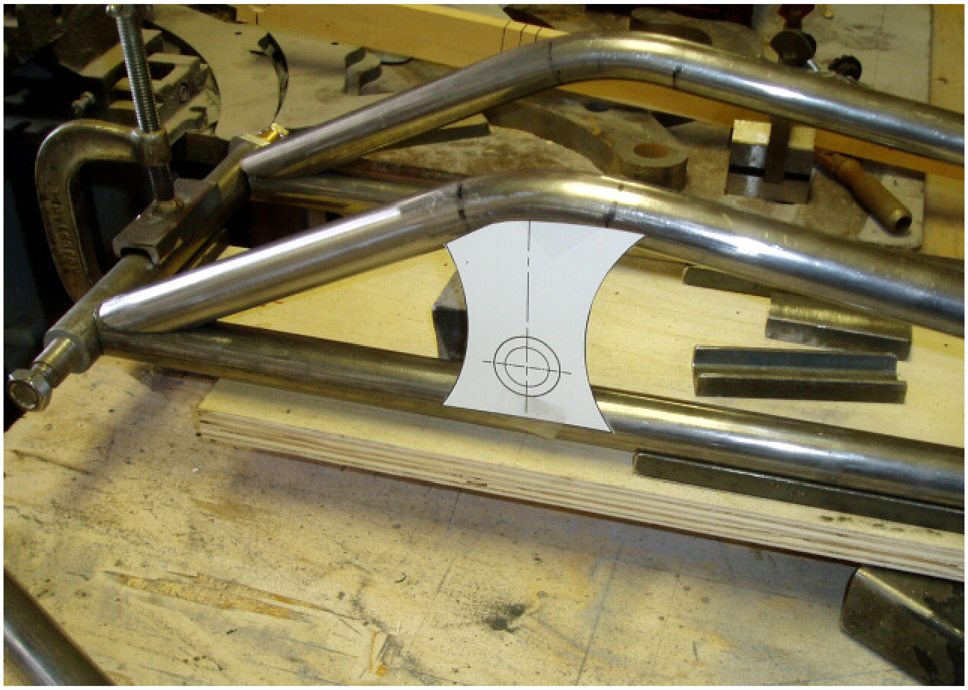


Figure 71

I think that for most lightweight choppers that these gussets could be made using 3/8” plate stock but I still prefer 1/2” material.

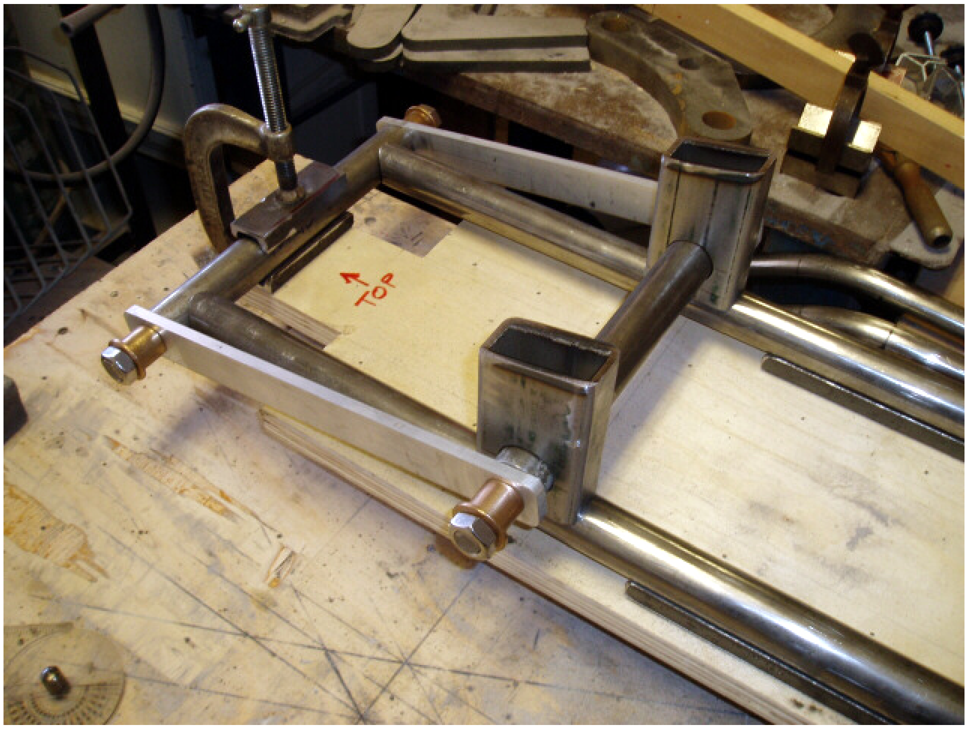


Figure 72

Figure 72 shows the rectangular tubing type gussets as they are being shaped to fit the bent rear truss legs.

Note the use of the two pieces of aluminum strap stock that holds the lower pivot shaft square to the upper pivot shaft. These straps should be drilled at the same time to insure that the holes on each one are identical. In the case of this particular Girder the dimension between the holes is 8.5 inches.

These straps really should be made form 1/4- inch steel to insure that they don't buckle but I had these lying around from another project. You can make an identical set of straps that bolt to the outside of these and run to the front axle shaft. By doing so you're sure that all of your shafts are in perfect alignment from top to bottom.

Figure 73

Figure 73 shows the left side shaft gusset being shaped to fit the radius of the rear truss leg. The opposite gusset has been rough shaped but the fish-mouth hasn't been cut yet.

Rear Truss Leg Fitment

There are two schools of thought about how to fit the rear truss legs to the main front tubes. One school holds that's it's better to weld the two leg sections, front and back, together in a separate jig or fixture with the parts arranged horizontally, or flat on the table so to speak as seen below.

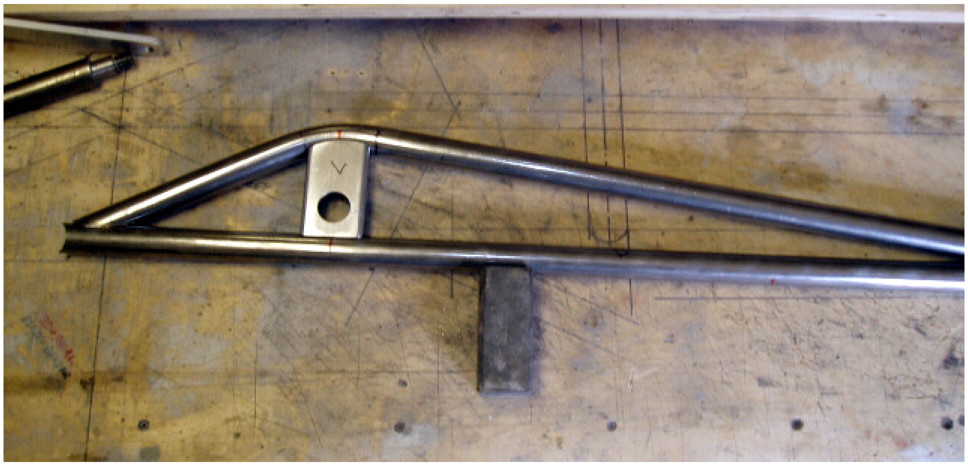


Figure 74

I've deliberately designed my truss legs so this can be accomplished, as the bent rear legs do not weld directly into the axle slugs or the upper pivot shaft so the two separate halves can be welded up as assemblies if desired.

I personally think that this makes it much harder to keep the lower pivot shaft gusset and the top and bottom pivot points in alignment with the axle shaft slugs. I prefer the method expounded by the second school of thought that is to weld the rear tubes while the entire assembly is in the jig as seen below.

Figure 75

Figure 76 shows a snap of the two options for comparison purposes.

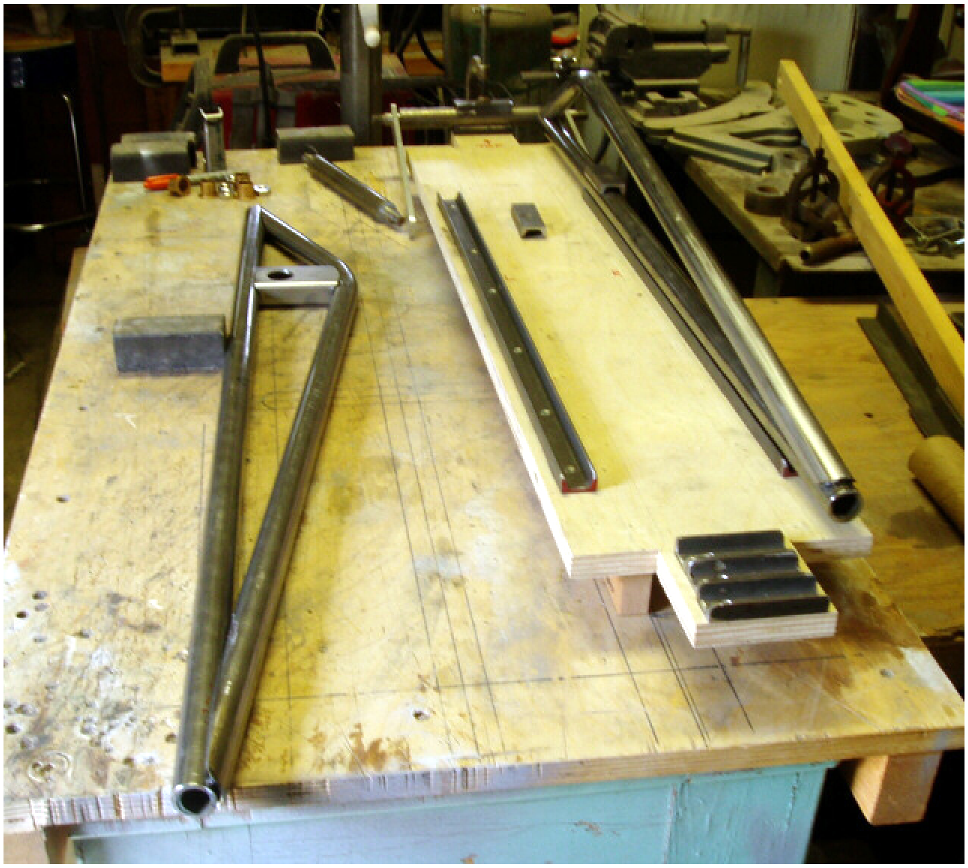


Figure 76

It's a very good idea at this stage of fabrication to check and see if the bends in the rear truss legs are shallow enough so that the bulge doesn't interfere with the lower tree pivot shaft as the legs move up and down in suspension travel. This is easy to do by just bolting on your lower links and run a piece of shaft between them. There should be at least 3/8 of an inch clear between that shaft and the bend in the legs at the nearest point as the suspension link is rotated as it would in normal operation.

I have a dimension on the plans as to how far out the bend is supposed to be but apparently many people don't think it's critical but it is.

To hold the axle plates in position we use a modification of the same system used when adding the axle plates to a frame as see below.

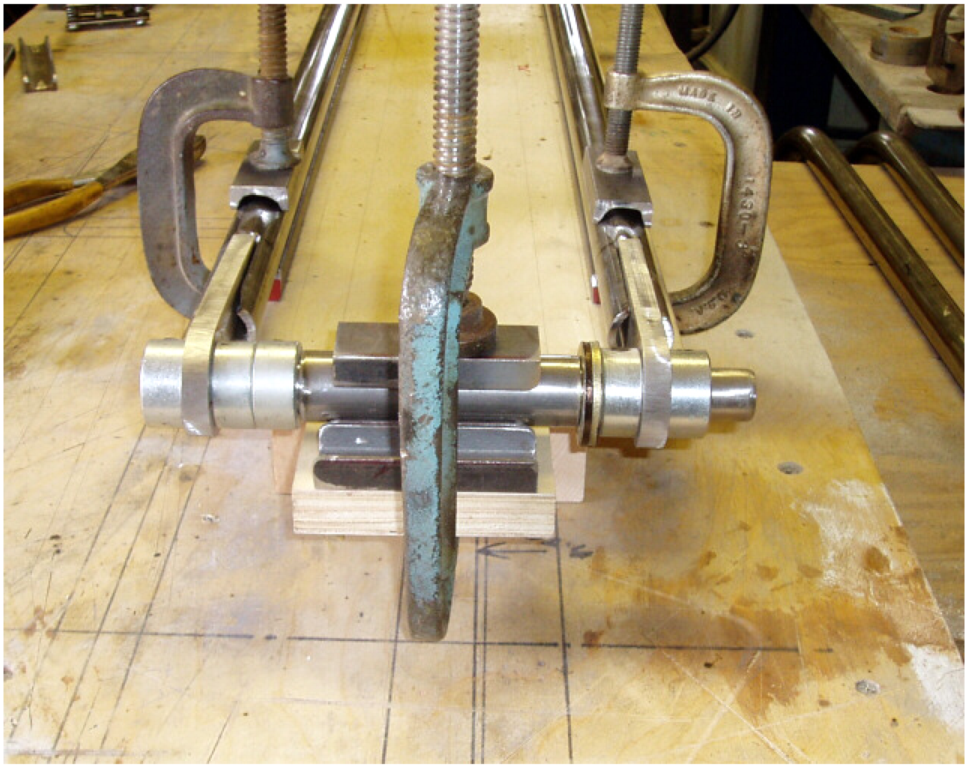


Figure 77

This is just a section of 3/4” drill rod run through the axle plates, which are held square by shaft collars.

Welding

Once all of the miters are finally dressed and have been beveled for welding there isn’t much left to do but grab every clamp you have on hand to hold all of the various parts in their proper positions to be tack welded. I generally make very deep and somewhat long tacks at every connection point alternating from side to side and from front to back to minimize distortion. I do the final welding outside of the jig but others prefer to do all of the welding while the parts are stilled clamped in position. I’ve tried both methods and can see no difference so it’s up to you to develop your own technique.

Figure 78 shows the forks tacked and out of the jig ready for the final welding.

Figure 78

As in all welding of tubular space frames the welds will cause the materials to shrink and as a result there will be bending in the long runs unless you account for this during the ‘fit-up’ of the parts. To keep your tube runs perfectly straight after welding you have to deliberately factor in some ‘bend’ when the parts are placed in the jig to begin with. This will be most noticeable in the long run of the front tube legs so I put small shims in the channel sections prior to clamping to put a slight (1/8-inch) reverse bow into these pieces. When the rear trusses are welded into place they shrink and in so doing pull the slight bow out of the front legs so that they end up perfectly straight.

If you’re not a skilled welder yourself I strongly urge you to have the final welding done by a professional. The welds on a set of forks are far more critical than the welds on a frame and there is literally no room for error with respect to the integrity of each and every connection point.

Many people are surprised to find that there are so many welded connections on a simple Girder. On our basic model there are 16 junction points with short welds averaging from 1 to almost 8-inches in length so in total there is about eight lineal feet of bead to lay down and all of it has to be as close to perfect as possible.

If you want to tackle the final welding yourself set aside an entire day where you’re sure that you won’t be interrupted. Remember that each separate weld has a ‘perfect’ setup with respect to positioning and direction so approach each connection as if it was the only one in existence. Go slow; take all the time you want but concentrate on each individual weld as if it was the only one in the world. If it doesn't take you at least six hours to finish all of the connections then you've taken shortcuts or hurried too much.

Temporary Steering Stems

When you're building a new frame and a set of forks you rarely have the bearing cups installed in the neck until its time for painting so I usually create a dummy steering stem so I can mount the forks to the frame and check the motion and geometry before adding the shock mounts.

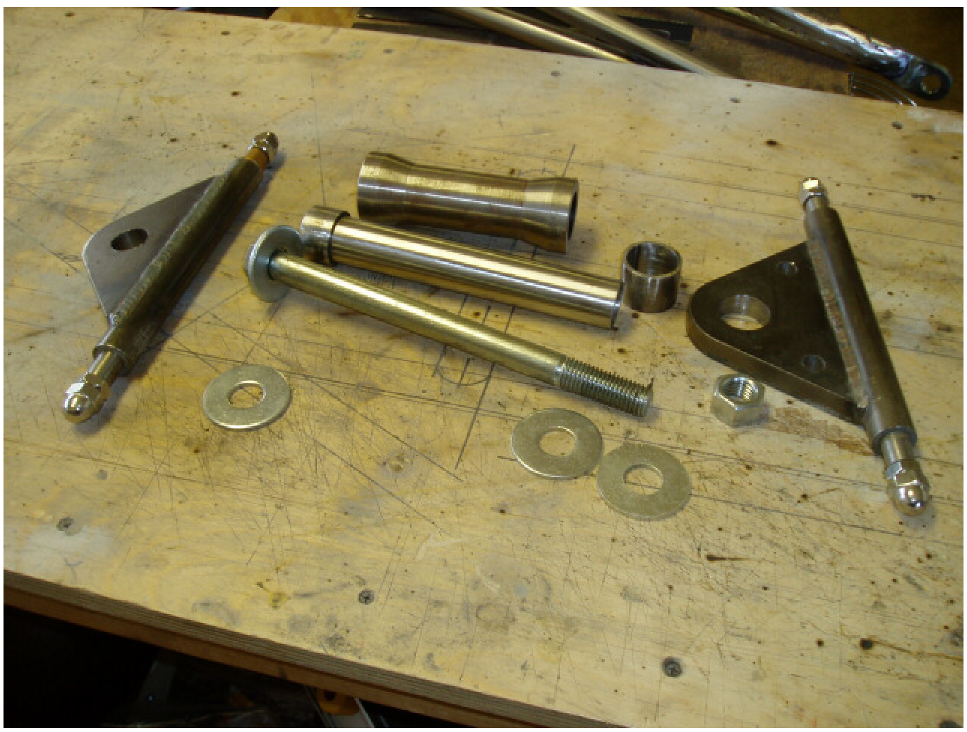


Figure 79

Figure 79 shows one version of this lash-up with a more or less standard Harley steering neck in the background for reference.

In essence the unit consists of a 1" O.D. section of .120 wall tubing slipped inside a section of 1.25" O.D. by .120 wall tubing. On one end I've welded on a 1" high section of 1.5" O.D. tubing that acts as a temporary neck cup and bearing. On the other end I have a section of 1.5" O.D. tubing cut 1.375" long that acts as the upper bearing cup, bearing and jamb nut. The whole thing is held together with a 9" long 3/4" bolt.

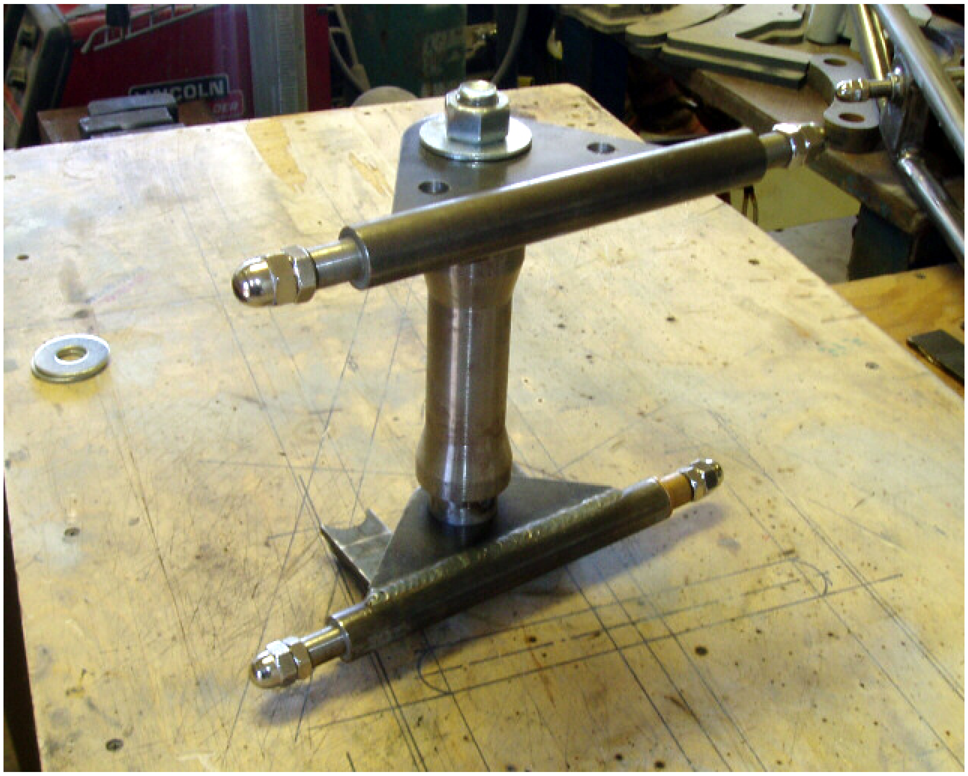


Figure 80

You can see it assembled in the snapshot above but in reality of course the steering neck would actually already be welded to the bikes frame.

You can shim the overall height of the assembly with washers to make it match your final neck height perfectly. The 1.25” tubing fits snuggly in the upper tree that’s been bored to receive a standard Harley cap nut and the innermost section of 1” tubing also fits snuggly in the lower tree hole bored to receive the final steering stem.

It doesn’t look like much but it works well and is very tight. You could probably actually test-ride a bike for a short distance with this setup installed.

While we’re talking about steering necks and stems you might want to decide if you want to use internal or external fork stops. I’ve never had very good lucky with internal stops lasting very long and prefer externals. Regardless of which method you prefer it is important to remember that stops set up for 45 degrees of rotation, as on stock bikes, can be dangerous on raked choppers. For this reason I usually try to limit fork turning travel to 35 degrees in either direction.

Shock Mounts

About the last parts to cut are the tabs used for the shock mounts. I usually wait until I actually have the shock in hand but when I was writing this article my shock ended up getting lost in shipping somewhere.

If you're planning on running double coil-overs you can get by making the mounting tabs from regular old 1/4" cold-rolled strap stock but for a single shock application I suggest tabs made from 3/8" material.

Based on past experience I knew that the worse case scenario I could expect to have once I received the shock was a mounting distance of 2" maximum between the center of the pivot shaft and the center of the shock eye so I used that value to rough cut blanks as seen below.

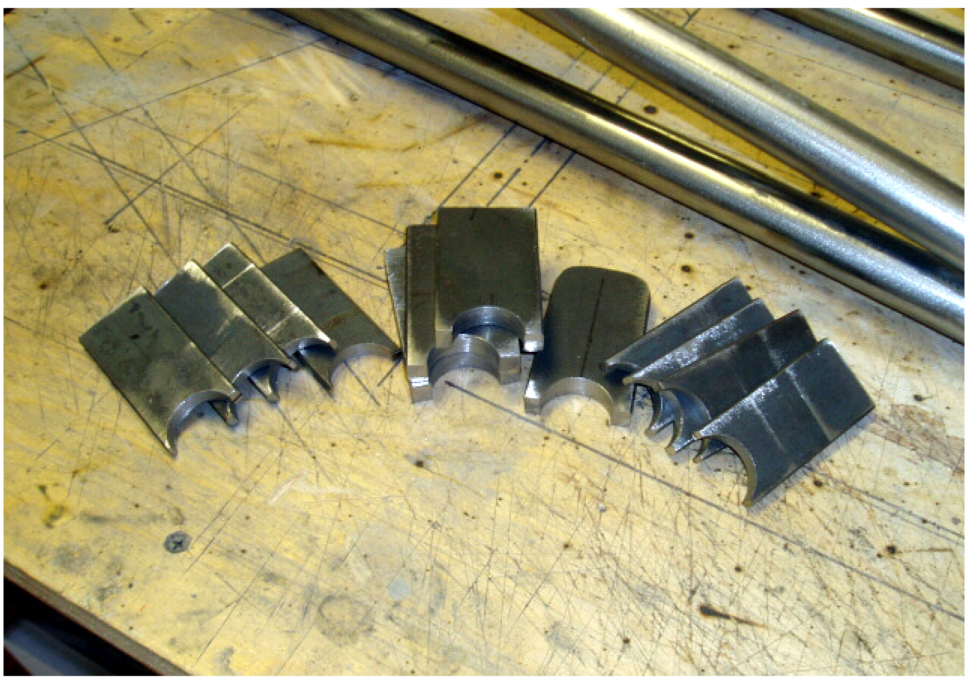


Figure 81

The four in the middle are from 3/8" stock and the other eight are from 1/4" material. As I mentioned before, once I get set up to do a particular type of operation, like drilling and cutting, I try to use up all of my stock on hand just in case I want to build another unit later on down the road.

Keep in mind that once these tabs are welded into position that it will be almost impossible to get a drill bit aligned so that you can modify the boltholes if you decide to change shocks someday. For this reason it's a good idea to bore the shock mounting holes oversize and then sleeve them down to fit the particular fastener that matches the shock or shocks you finally decide to mount.

Coil-Over Shock Absorbers

The coil-over shock is one of the greatest inventions of mankind. Had they been around decades ago you would have seen Springers and Girders take off in radically different ways from what we see in the old antique pieces we're all familiar with.

Today there are literally dozens of different manufacturers making shocks in all types of sizes from almost miniature to gigantic units. For most Girder work smaller shocks work better but they're harder to find. If you're searching on the Internet try to look for shocks designed for Golf-carts, midget-racers, motor scooters, small ATV's or snowmobiles and smaller motorcycles. Prices range from nineteen dollars to as much as five hundred dollars depending on the quality of the component. Good midrange name brand chrome plated or polished aluminum coil-overs should set you back about one hundred and sixty dollars.

A cheap Asian ATV shock selling for twenty bucks on eBay will do until you're ready to get the bike on the road. In fact there are a large number of Girder owners still riding around today with their cheapo shocks installed. The overall quality of the units only come into play over the course of time or how much you abuse the assembly. There are some fairly good products coming from China in the fifty to sixty dollar levels but below that price barrier you start to find products that range from marginal to unimaginably horrible.

Keep in mind that most imported shocks will need to be mounted with a metric bolt to insure a good tight fit in the mounting eyelet sleeve so don't drill your bolt holes in the tabs until you determine the proper fastener size to use.

The overall length of the shock is dependent on the overall length of your frame neck with the trees installed. On this particular design it ended up that a shock having a fully extended dimension from eye to eye of 12-inches was what we needed. In the fully- compressed condition the length distance was slightly over 8.25 inches so we needed a shock with nearly 4-inches of total travel.

I've used Koni, Hagon, Empi, Aldan and Ikon shocks in the past but lately I've been using units made by QA1 Precision products (Carrera Shocks) which are extremely well made and far more affordable than the others, about one third the cost in fact. Their 92 series aluminum shocks for Quarter Midgets and the 82 series for larger racers are ideal for Girder applications.

Springs for coil-overs are usually sold separately since there are many different rates to select from. I don't have any way of knowing how much your particular bike will weigh but for most choppers a spring rate of around 200 pounds is a good starting point. If you have an adjustable shock you can go slightly softer to begin with. Of course if you're running dual shocks you cut that rate in half for each unit.

I've had Girders running with single shocks with as little as a hundred and twenty pounds of spring rate and I've also had similar bikes running with as much as 250 pounds so there are no hard and fast rules that you can follow. There are dozens of variables such as rake, bike weight, fork length, road conditions, tire pressure, tire size and it goes on so sometimes you just have to make an educated guess. Fortunately springs aren't too expensive and they're easy to change. You won't be to far off target if you start with 200 pounds to begin with divided up by the number of shocks you're running.
One of the problems with the smaller imported shocks is that they will have a very limited range of travel. For racing bikes a travel distance of 1.5–inches from full extension to full compression might be adequate but on a street bike much more range of movement is needed, something on the order of 3 to 4-inches.

There is a relationship between the length of your suspension links and the travel length of the shock that somewhat limits how much 'effective' suspension travel you can have before the springs start to hit the lower tree pivot shaft. In general you'll find that about 3.5-inches will be the maximum effective range attainable on most chopper forks. Anything between 2.75 and 3.5-inches of total effective travel seems to be just about right for most Girders, even on sport bikes.

Shock Mounts

We talked briefly about making the shock mounts but it should be understood that there are numerous alternative shapes and mounting positions for these pieces and you may have to do some creative thinking if you're not using typical components.

One of the most common problems is not checking for interference between the outer perimeter of the springs and the pivot shafts on both the trees and the forks as the Girder moves through its complete range of motion.

In general there are few problems but one that does raise its ugly head is shown below.

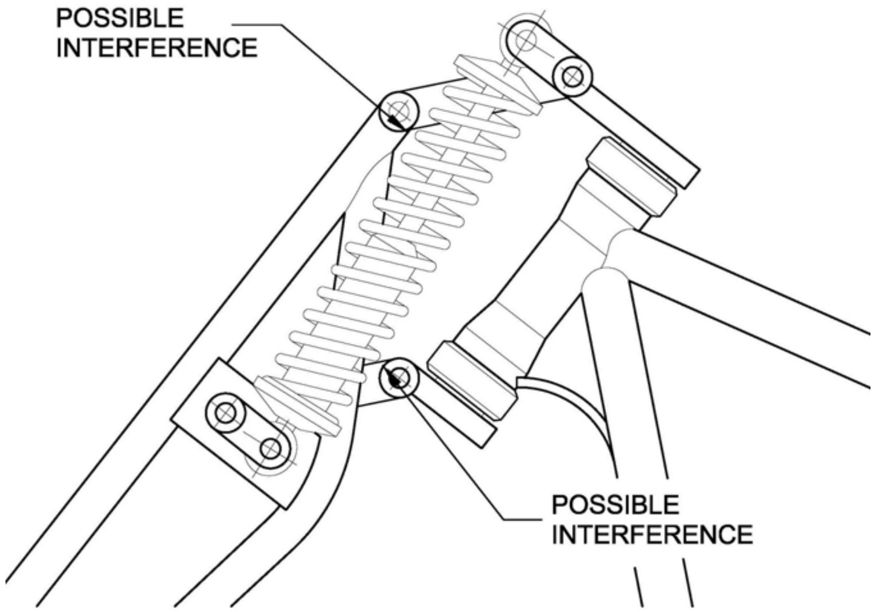


Figure 82

This sectional sketch above depicts the forks when there is no weight on them and the shock is at its maximum full extension.

Note that there are two points where the coil might interfere with the pivot shafts. This is not usually a problem if you're using shocks with small diameter springs but if you're running one or two of the better quality coil-over shocks with larger diameter spring it can be problematic. A similar situation can occur when the forks are at maximum compression but this is not nearly as common.

A quick check can be made during the mockup phase by just trying to pass a spray paint can between the shafts when the forks are in their 'relaxed' position. It just so happens that rattle cans are almost exactly the same diameter as racing coils. A beer-can will make do in a pinch but it's slightly smaller in diameter. If you do find that you've got a problem at least you can drink the beer and think about what to do next.

Ride Height and Link Geometry

I like to set my Girders up so that the links, when the bike is sitting normally at the curb, with me and my gear on board, point slightly upwards where they connect to the forks. For most applications this means that you set the shock mounts so that the links are exactly parallel with the ground when the shock is fully extended and there is no load on the forks. In other words take the weight off of the forks by sitting the front of the bikes frame on a block about 1-inch higher than normal ride height and then prop up the girder until the links are level with the ground and then mark where you need to weld in the shock mounting tabs to install the shock when it is fully extended.

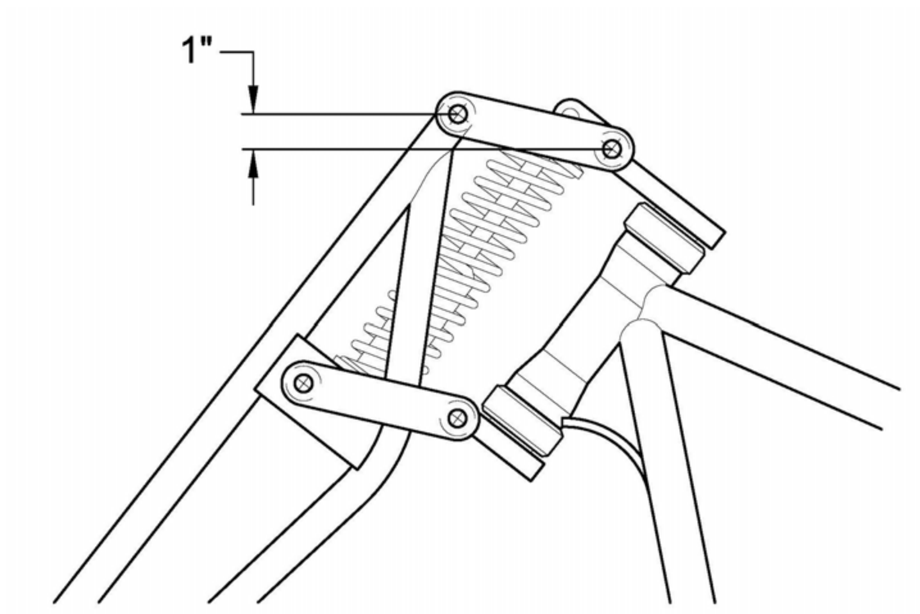


Figure 83

Figure 83 illustrates what the best attitude should look like when the bike is fully loaded. By arranging the links in this manner you will also better optimize the full range of motion the shock is designed for. To get that 1” offset the links are set at a 10 to 12 degree angle from the horizontal.

What you don’t want to end up with is a configuration like that shown in Figure 84 which is far to common on home-built Girders for some reason.

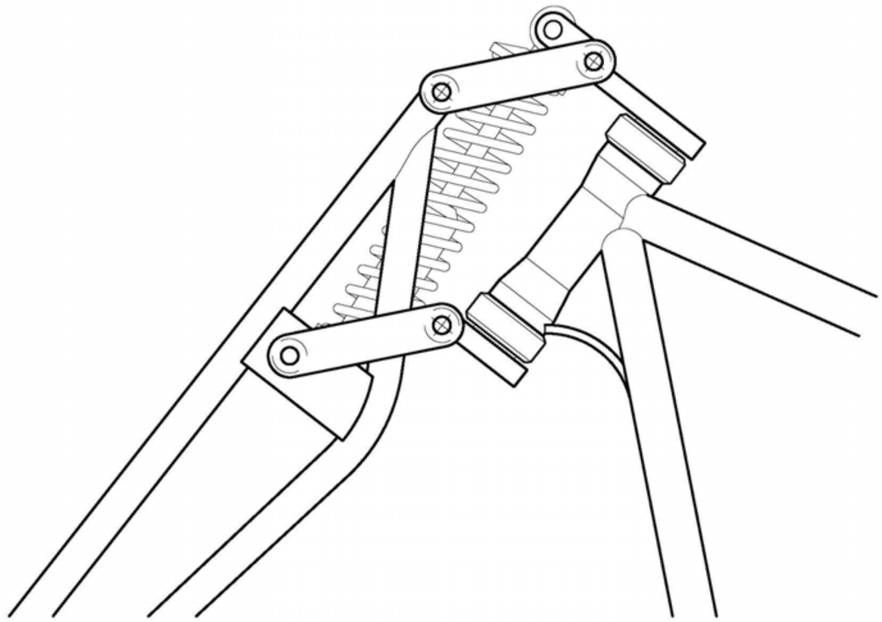


Figure 84

This is the attitude the forks should be in at maximum extension of the shock, not at rest. An equally poor situation is shown in Figure 85.

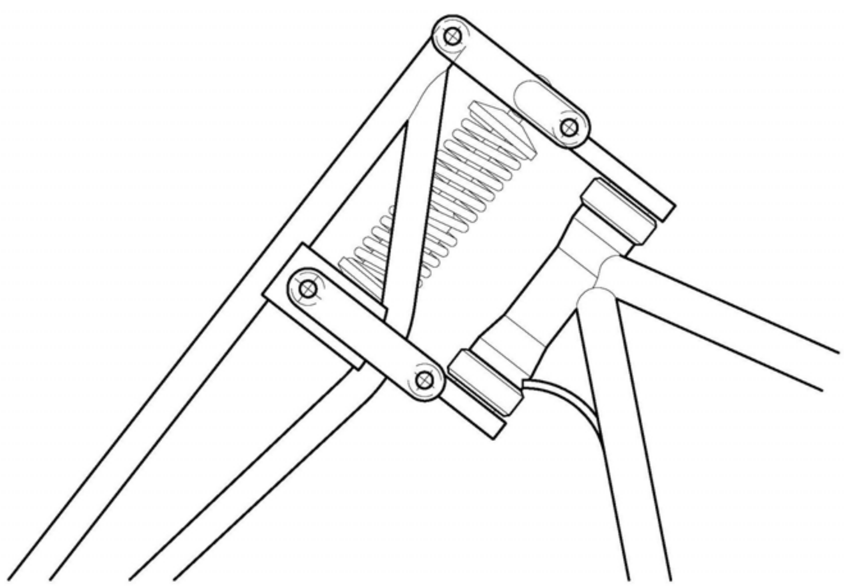


Figure 85

This should be the attitude of the links when the shock is at full compression and the spring is virtually bottomed out.

Prototyping vs. Production

In my personal opinion anytime you build something for the first time, even if it's an exact duplicate from a set of good plans, it's going to be a prototype since you'll always want to mess around with it to suit your personal taste. For this reason I always try to build what I call 'one and one-half' of any particular design or assembly.

In other words I try to cut 'extra' critical parts for some project, the parts I'm pretty sure I won't mess around with much as I refine a design.

I build the 'intended' design and test it as you do with any prototype and if I don't like it and have to do major modifications I've got enough 'spare' bits and pieces to build what I call the 'production' version. This isn't to mean that you're going into mass-production but that you've got an assembly you're completely satisfied with.

This doesn't mean that the original prototype was a failure. It's still probably going to be a nice set of forks but you refined it into something even better. This is always a win-win situation. You've got two sets of forks and a whole lot of valuable experience. Just keep this in mind for future reference.

Starting your first project with a simple jig, even a wood jig, will let you prototype the jig itself and eventually refine it into something perfectly suited to your particular fabrication techniques. Always try to think and plan on a long-term basis, as you'll never know how many forks you'll build over the years. It may be one or it may be hundreds.

Bushings

There are two basic ways to bush the links and shafts. The first method involves the use of a regular so-called 'sleeve' bushing, also called 'sleeve bearings' with an associated bronze washer. The second method involves using what are called 'shoulder bushings' or 'flanged bushing or bearings' that have an integral shoulder or flange on the outside perimeter so the washer is not needed. Both methods work just fine. Bushings come in several different materials, including some space-age plastics but regular old plain bronze bushing work just fine on forks. If you want something a little more special you can get SAE 841 bronze, which is generically referred to as 'Oilite' since the bearing material is impregnated with 30-weight motor oil. You can go even further upscale and get high-temp bushings and super hard bushings but almost anything works on a girder. Even with the Oilite bushings I still use lubrication. Any of these can be purchased through McMaster-Carr.

Girder Steering Stems

Our free girder plans show the dimensions and specifications for a custom made steering stem and as mentioned above there are several sources for this item but if you're on a budget I suggest cannibalizing an old stem from a glide lower tree that you can usually pick up pretty cheaply on Ebay or at a swap meet. Paughco still sells a stem for use on wide-glide forks that is relatively inexpensive and can be modified pretty easily. Look for part number 170T in their catalog. The stem is probably the single most expensive thing you'll have to acquire when building a custom front end of any type.

Weight

A well designed and well built Girder will weight about half as much as a comparable Springer or Glide type front end and they are far less expensive and much less complicated to build. In my opinion they are the perfect solution for somebody building a bike from the ground up who has limited tools and a limited budget. The big 'plus' is that they 'ride' and 'handle' almost perfectly and don't have nearly as many inherent 'handling' problems as other fork arrangement you might be contemplating for a chopped bike.

This particular Girder weighed in at 21.75 pounds and it is heavy-duty by most standards. The lightest 4-inch over comparable Springer we weighed came in at 39.5 pounds and a 4-over FXWG hydraulic fork was the heaviest at 43.25 pounds.

It might not seem like much of a weight savings but every pound you save is like adding more horsepower to the motor.

Finishing

Before you start to do the final welding it's a good time to anticipate what kind of finish you're going to want on the forks because to some degree it determines exactly how you want to do the welding.

We've talked about the various welding processes in Volume I of the Handbook and briefly touched on the added aspects of what I call 'cosmetic' welding using the Esab rod material as a 'filler' or conventional brazing over the welds but most people will usually opt to use conventional body filler to blend in all the tube junctures.

If you intend to simply paint the forks then almost any automotive body filler will work but if you intend on having the forks powder-coated then you'll have to use one of the electrically conductive fillers like 'Alvin Lab-Metal' or an equivalent product.

If the forks are to be chromed then you are forced to use real metal materials to give the weld beads a pleasing appearance and this is why brazing can be so important as a filler material.

If you want to keep the welds exposed but still looking ‘pretty’ then you’re pretty much limited to using Tig or a ‘drag’ type electrode but the key thing to keep in mind is to never try to grind down the weld beads to make them look good. Grinding a weld bead down into a nice concave or filleted appearance actually destroys about 75% of its strength. Beads can be successfully dressed down a little bit however but just a very tiny bit and only where needed.

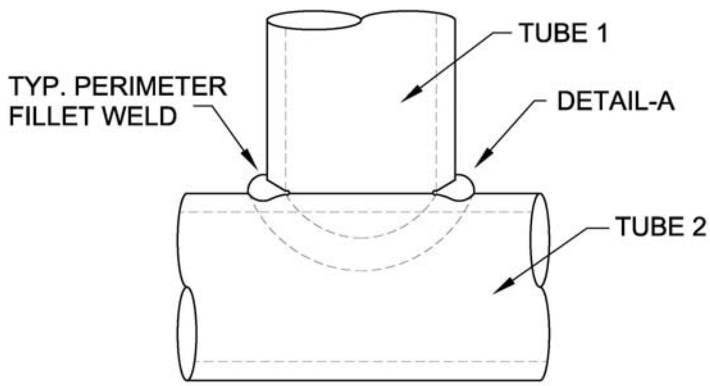


Figure 86

Figure 86 is a stylized illustration of a typical welded tube junction where the intersecting tube has been properly beveled and the weld fully penetrates the wall material. If properly done the penetration also deeply eats into the shell of the tube that runs through the intersection so that for all practical purposes both pieces of tubing become monolithic.

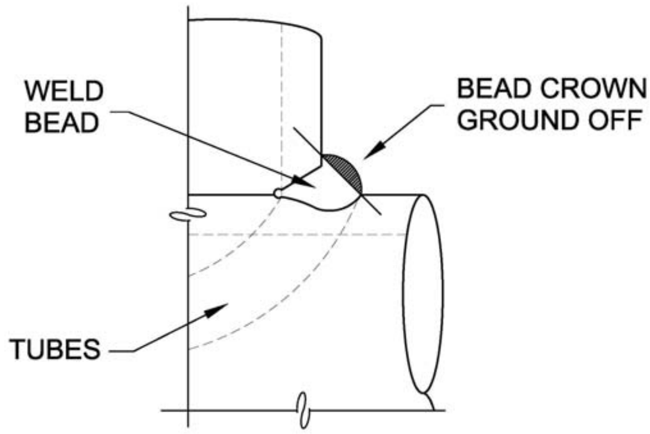


Figure 87

Figure 87 is an enlarged section of the tube intersections shown above and it depicts that portion of a typical weld bead that is not contributing to the strength of the weld itself. That portion is determined by extending an imaginary line from the extreme outermost edges of the bead at a 45-degree angle. The resulting portion, labeled the 'crown' above can be safely removed by grinding without weakening the weld or the connection.

If you make the mistake of trying to grind deeper in an effort to make the bead actually appear to be concave you've pretty much destroyed the connection and need to weld it again.

A much better method and a much older method of 'shaping' welds is to build up a decorative fillet over the top of the structural weld as seen below.

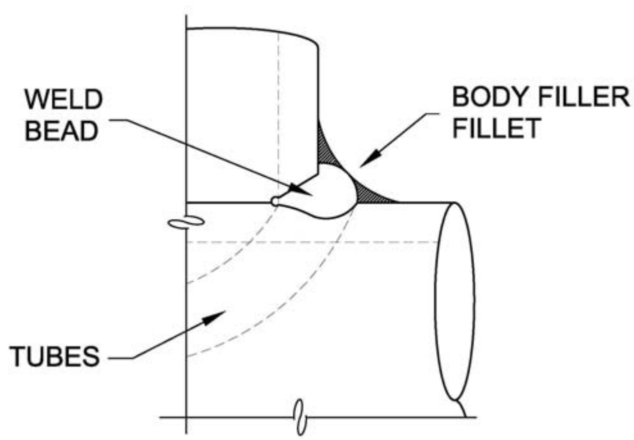


Figure 88

In this illustration we call out body-filler but the same effect can be achieved with brazing or even soldering but filler is much easier and much faster. With today's modern formulations of filler materials this is a very strong and long lasting way to give all welded connections a nice clean appearance without damaging the weld in any way.

In the old days this was called 'molding' and it got a bad name because we all did it in excess. Today the objective is to do a minimal amount of filling, just enough to blend the bead into the adjoining tubes, not completely conceal it, just make a smooth transition.

There is simply no reason whatsoever to do more than take the few obvious high spots off of a weld bead with very minor grinding and dressing.

Adaptability

The whole secret to building a bike on a tight budget is to be imaginative, adaptable and flexible. If you have an assortment of bits and pieces that you've acquired for a project and they don't quite 'fit' with the plans then it's a good idea to modify the plans to 'fit' what you've got on hand. Always 'go' with the hardware and not anybodies drawings, even mine. You'll be way ahead from a cost standpoint if you remember this simple concept.

Budget

When we were finished with the project I actually added up all the receipts for materials and supplies. It was more than my original estimate but in many cases I had to buy far more material than I actually needed. With the exception of tubing I have enough steel to build a second set of trees, links, axle plates and gussets plus I've still got a little over 5-feet of tubing left.

Tubing (1.0"x.134 DOM)	62.00
4 Threaded Pivot Shafts	110.00
Axle	27.00
3/4" Steel for Trees	31.00
1"x2"x.120 rectangular Tubing	6.00
3/8"x2" Plate for Axle Plates	8.00
5/8"x1.25" Steel for Links	15.50
Steering Stem	45.00
½-13 Stainless Steel Jam Nuts	11.90
½-13 Stainless Steel Acorn Nuts	41.90
Bushings	47.12
Grade 5 Washers	7.76

Precision Washers	12.60
Hole Saws	22.50
Sandpaper	5.62
Grinding Discs	9.75
Lacquer Thinner	12.00
Flapper Wheels	8.50
Grinding Points and Burrs	12.23
Primer	9.96
Welding Jig (complete)	29.73
Total Girder Fork Project Costs	536.07

This is not bad considering the extra materials we had to buy and the fact that we have a lot of miscellaneous supplies saw blades, grinding wheels and other stuff left over for another project. In fact we had to buy enough materials to actually build two jigs and two sets of yokes.

For this reason I'd say that our 'hard' cost for one set of forks was very close to $350.00 and that included high quality bushing and polished stainless fasteners. This expenditure could have spread out over time since in the mock-up stage cheap bushings and zinc plated fasteners could have been used and bar stock with shaft collars could have substituted for the pivot shafts and axle.

I good scrounger can cut these costs significantly and you can also save money buy building more than one set at a time so some quantity discounts kick in during the project.

Design Considerations

In the introduction we mentioned some of the fundamental design configurations but in the world of Girders there are thousands of possibilities. As already stated this is one reason they have not become more popular for the masses since a prospective builder does have to develop a specific Girder design for a specific bike. A single design will not fit all bikes no matter how hard you try.

Is it worth the small amount of effort to sketch out some full-sized patterns to check for trail and suspension geometry? Ask any Girder owner. It's more than worth it since these forks, when well executed, are about as perfect as one can get and to top it off they are relatively inexpensive and easy to build.

I strongly suggest that a good way to start a prospective project is to make a bunch of quick and dirty sketches of several Girder alternatives.

First decide on whether you want a one-piece fork assembly or a two-piece assembly.

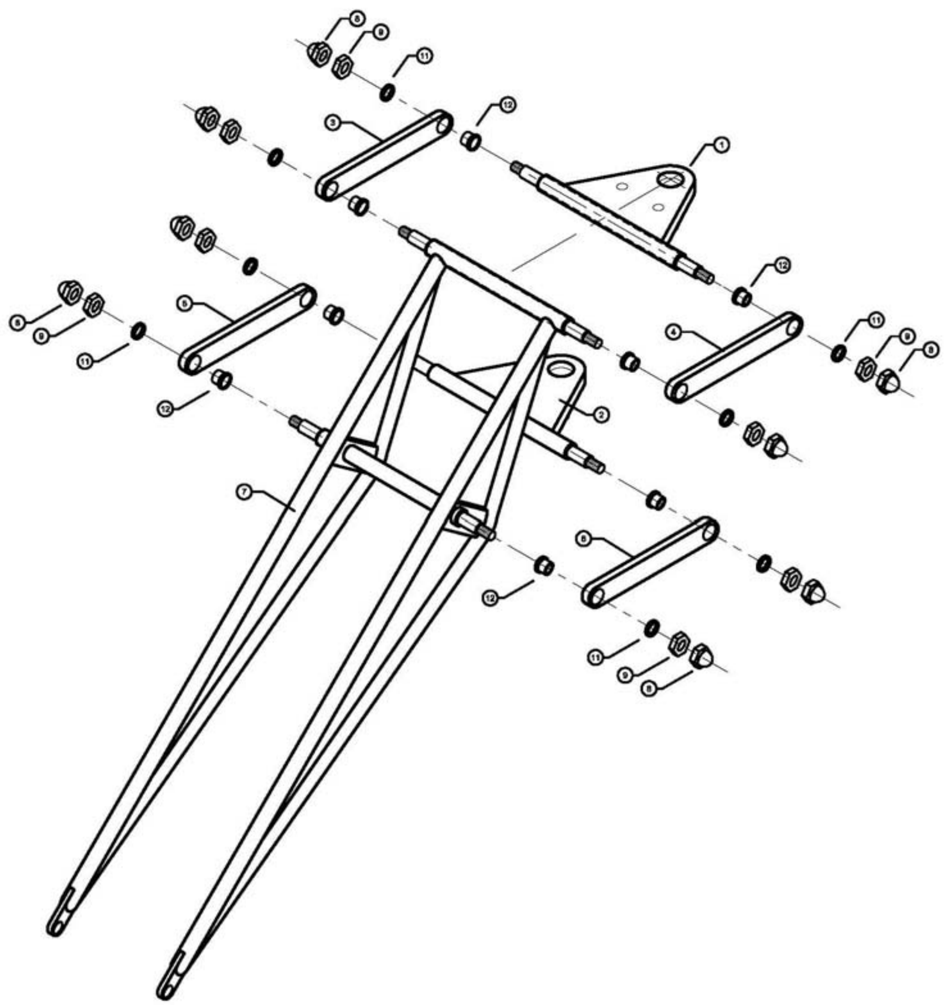


Figure 89

Figure 89 illustrates a typical one-piece assembly, which seems to be more common with chopper builders since it is very easy to fabricate.

This arrangement however does limit the range of visual design possibilities but you can still get pretty creative and keep things relatively simple.

The two-piece fork assembly, seen in Figure 90 is the type commonly seen on high-performance racing bikes. It looks complicated but in reality is not much more complex than a simple one-piece set of forks.

The two-piece fork opens up a huge range of design options, especially in the configuration of the trees and the links. In practice it is built following the same procedures we outlined for a conventional Girder.

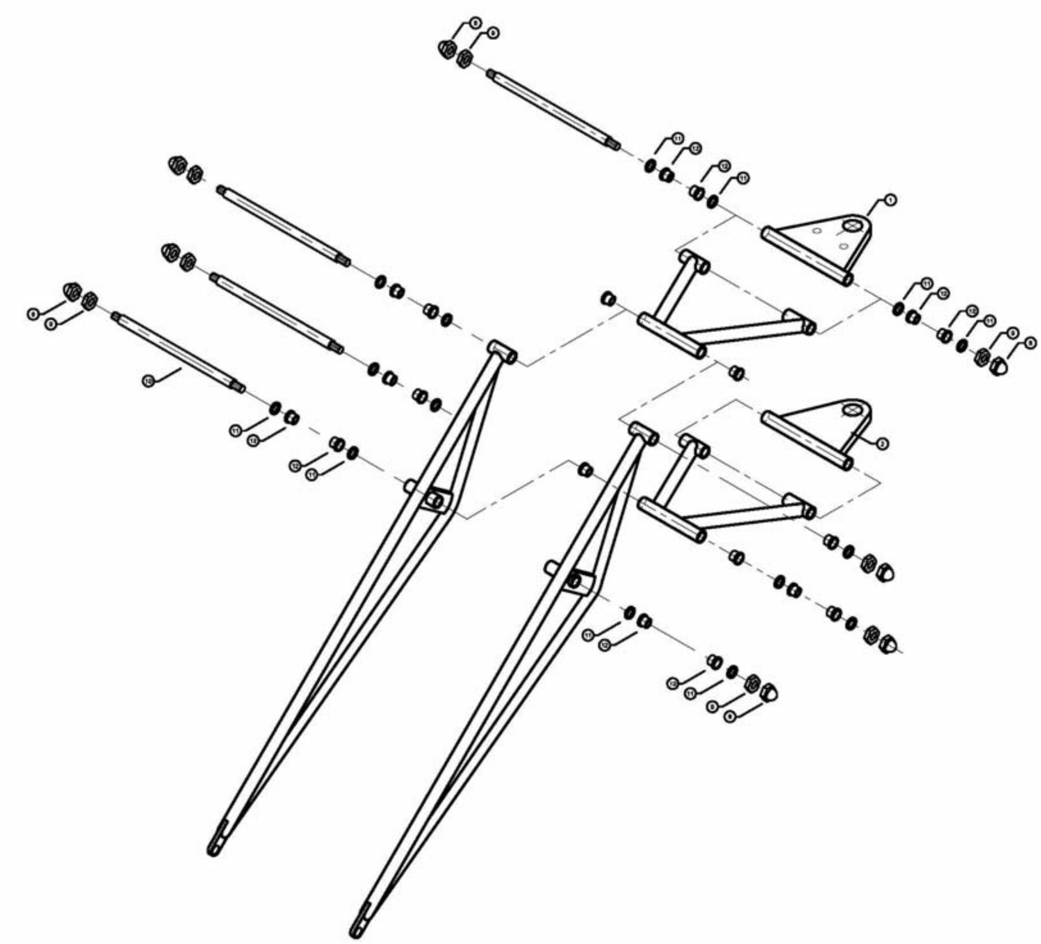
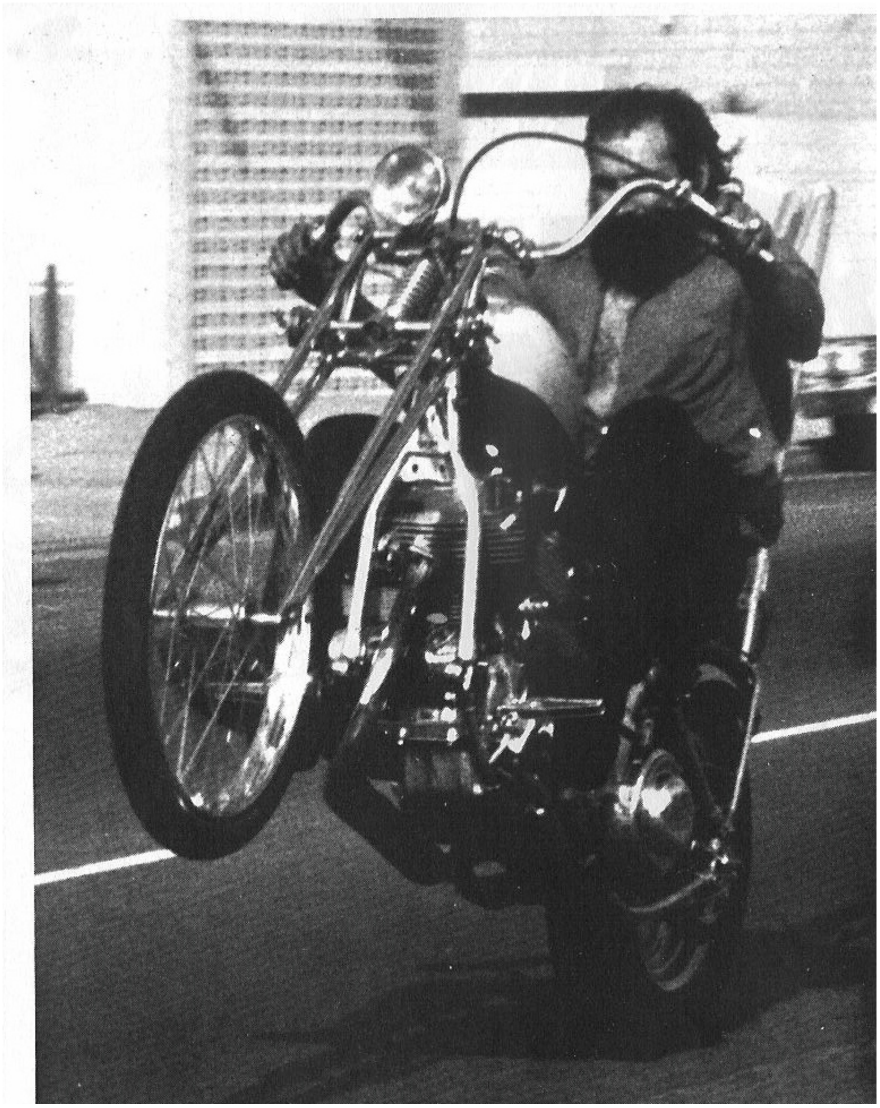


Figure 90

The stylized two-piece fork shown here of course is the most basic design configuration but by comparing the two different types you can get a good idea of which direction best suits some of your design ideas.

The very modern Donnie Smith Girders being sold through catalogs today are of the two-piece design but built to look more like an old original one-piece units made from bent 3/4" solid rod.

You know that when the cutting-edge race bike designers are looking towards Girder forks for performance improvements that there has to be something inherently superior in the basic function that a Girder provides compared to other types of forks. Even people who have become famous for building other types of forks prefer mounting a girder to their own personal rides. Dick Allen who became famous with his extended custom Springer's in the sixties and early seventies still opted for a Girder for his personal ride, the 'Wheeler Dealer', a bike that was notoriously fast in it's day.



Dick Allen - 1968

He was just as famous for extending stock Indian Girders as he was for the Springers but many people don't remember his full range of capabilities.

Many people have undertaken their own Girder projects that they have posted at the discussion board but since not everybody has visited the site I thought that this would be a good place to show a few of these projects. If you spend a few hours at any of the tech sites you can find literally scores of project pictures that will provide both inspiration and design ideas since Girders are finally becoming popular once again. In some small way I hope that our site and our plans have played a role in this resurgence. As far as I know nobody else has publicly posted any Girder plans on the Internet, which seems very odd to me since so many custom builders are using them on show bikes.

Scott Pennebaker, known to most of us as 'Concrete Guy', was one of the early adopters of a Girder for his project bike. I think he's now building the second set.

Figure 91

This is really an old picture of his project but to me it's one of his best since it gives you a real feel of what goes into a hand-made chopper as compared to a kit bike. I can almost feel the emotion that has gone into this project and to my eyes the proportions are perfect. The best part is that it's 100% original like the stem below.

Figure 92

Another guy who went out on a limb was Brad Wilson, who we know from the site as Brad56. He built the classic diamond leg configuration but updated it by mounting the shocks on the outboard side of the links, which is the first time I'd seen this type of installation.

Figure 93

Another shot of the project shows the extent to which Brad has gone on this completely custom bike.

Figure 94

I think that you're probably getting the drift by now. A real Chopper with a set of hydraulic forks is a pretty 'nerdy' bike to be riding since 'chopping' by definition means to modify a stock configuration. In the old days the first stock thing to get tossed into the junk pile was a set of hydraulic forks.

Figure 95

Figure 95 is a set of what we call 'composite' Girder forks made up from a combination of milled billet sections and weldments of tubing and flat stock. James Van der Kroon made these particular forks for his project.

You simply can't get to this level of design creativity with Springers, Leafers or hydraulic fork systems so if you're serious about doing true custom work then Girder forks simply have to be in your future.

Conclusions

I think the particular Girder design used in this build-up article, which is elementary, is ideal for the first fork project somebody decides to build. It is simple, economical, light and takes very few special tools or jigs and it can be fabricated from start to finish in about three weekends.

Figure 96

It is a good departure point for somebody who wants to refine the basic concepts of Girder suspension, design styles and the more exotic types of 4-link geometry. As it is in even this very simple form it still makes for an outstanding front end on any Chopper.

Girder design and fabrication is a part of the craft that has to be learned a little at a time but it is well worth the effort put forth to do experimental and prototyping work until you develop a unique personal scheme that you’re comfortable with.