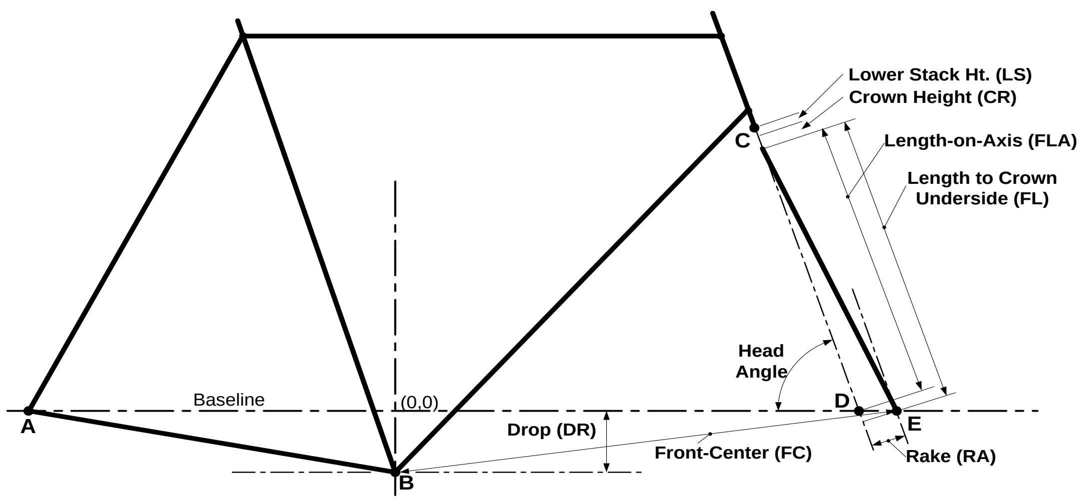
Fork Re-Raking and Head Angle Change

Summary: Following a recent surge in the appreciation of the handling characteristics of low-trail steering geometry on road/sport bicycles, the subject of increasing the rake of existing steel forks has appeared in various bicycle forums. Owners of a quality frameset have asked about the potential for increasing the fork's rake. Posted responses usually have been either stern notes of caution about secondary geometry changes, or accounts full of encouraging anecdotal evidence. Generally absent, however, is a complete discussion on the elements of frame/fork interaction, and a quantitative method to estimate the impact of a re-raked fork on the frame/steering geometry. This document provides this missing resource, with a review of fork re-raking from a frame design perspective, and a simplified graphical tool for use in estimating the resultant change in the frame/steering geometry. As shown here, the mechanics of re-raking a fork requires care so as not to diminish a desired brake reach and tire clearance, and installing a re-raked fork will change the frame's head angle by a small, but possibly significant, degree.

Rake and Fork Length-on-Axis: A bicycle frame is supported by its fork. Understanding the nature of this support, and exactly how it changes, is key to evaluating how a frame's head angle changes with a different and/or modified fork. The easiest way to understand the underlying geometry is to look at it from the perspective of frame design.

The design of a frame begins with the fork, defined by length and rake. In this discussion, the fork length is measured along the steering axis, from the underside of the crown to the point where a perpendicular line intersects the axle center, as shown by the "FL" dimension in the diagram below. (The height of the fork's crown sometimes is included in a stated fork length, but it is considered to be a constant in this discussion.) Fork rake is measured on a line perpendicular to the steering axis.

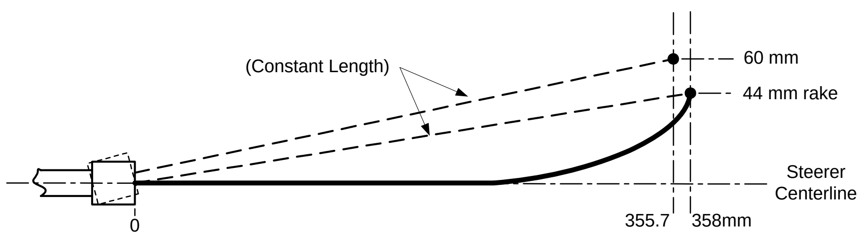
From the designer's perspective, the front end of a bicycle frame is located in space by the distance along the steering axis from the lower end of the head tube (point C) to a baseline drawn through the axles. As shown in the diagram below, this distance along the steering axis is the sum of the fork's length-on-axis "FLA" plus the fork's crown height and the headset's lower stack height. Again, the crown and headset are considered to be constants in this discussion. This leaves us with an evaluation where the key variable, length-on-axis (FLA), is calculated directly as a function of the fork length (FL), the fork rake (RA), and the head angle.



Increasing only the rake tends to effectively "shorten" a fork, and increase the head angle of an existing frame. Consider a replacement fork with a greater rake, but built using a length (FL) identical to that of the original fork in order to preserve the original brake reach and tire/fender clearance. At the original head tube angle, this fork will have a shorter length-on-axis (FLA). To see this, first put your finger on the axle point E. Increase the rake by moving your finger to the right along the line perpendicular to the steering axis, keeping the fork length (FL) constant. Note how, in order to return this new point E back down onto the axles baseline, you must drop the whole fork, which then shrinks the fork's length-on-axis. When this larger-raked fork replaces the original fork, the frame will rotate around the rear axle as the lower end of the head tube settles onto the shorter length-on-axis. As this settling increases the head angle, the fork's length-on-axis also increases slightly. When the frame and fork converge on a unique geometric solution, the head angle will end up being steeper than it was with the original fork.

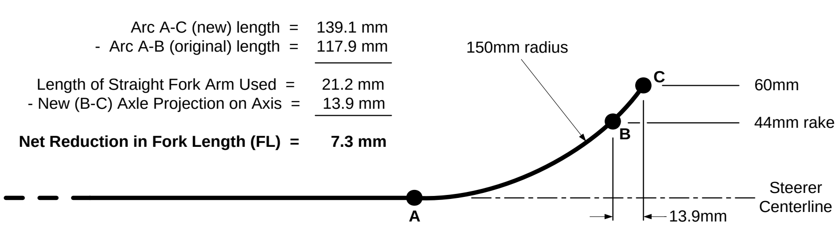
Re-Raking and Fork Length: The act of re-raking a fork is constrained by the manipulation of a fixed length of existing material in the fork blades. When a fork's blades are bent to increase the rake, the fork length (FL) is shortened. How much shorter depends on the shape of the bend, and where on the blade it occurs. This is critical when considering how brake reach and tire clearance will be altered. And, this is something that cannot be predicted without knowing the specifics of the blade bending tooling, and how the operator intends to use it. There are, however, some conceptual boundaries which may be calculated as points of reference.

- The <u>smallest</u> reduction in FL results from cranking (reorienting the sockets) the fork's crown, without altering the curve of the fork blade, as depicted in the diagram below. You can visualize an imaginary line, of constant length, between the crown and axle. This line is rotated counterclockwise, away from the original axle point, until the new rake is achieved. For rake increases in the range of 10-20 mm, this method will reduce the original FL value by about 2-3 mm, respectively. This type of manipulation requires deliberate care to not bend the fork blades, and an understanding of the potential for damage to the fork crown.



Reduction in Fork Length (FL) = 2.3mm

- The <u>greatest</u> reduction in FL results from re-raking by following an original small radius bend located just above the dropout, as depicted below. Continuing an original 150 mm radius bend to increase the rake by 10-20 mm will reduce the original FL value by about 5-10 mm, respectively. (Think of winding string up on a reel.) Continuing, or creating, a larger radius bend situated farther up the fork blade would yield a smaller, but still quite significant, reduction in the FL. A key point here is that this seemingly proper continuation of the fork blade's original curvature profile can, in fact, produce an undesirable outcome by shrinking the brake reach and/or tire clearance enough to void the usage of the intended brakes, tires, or fenders.

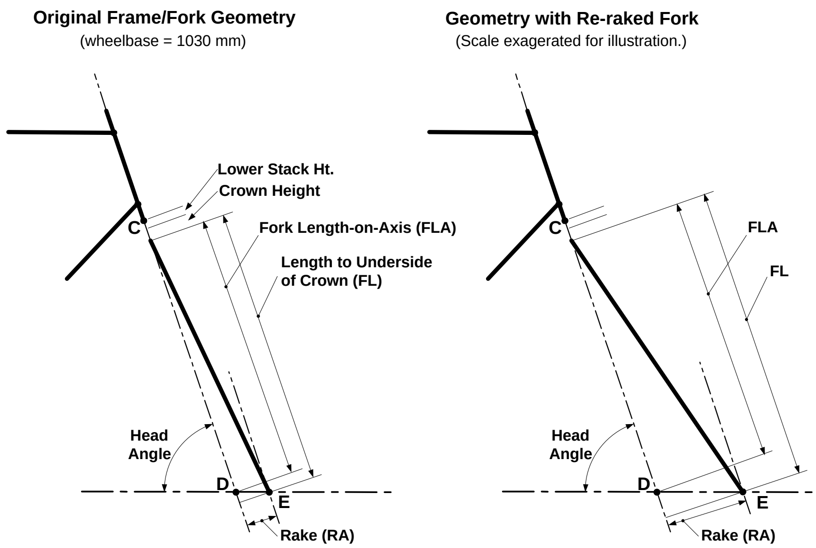


Two conclusions are clear. First, the inescapable reduction in fork length (FL) as the result of this manipulation will combine with the effect of the increased rake to further reduce the fork's length-on-axis (FLA). As a result of the steeper head angle, less rake than initially figured will be adequate to provide the target value for trail. And second, the process of re-raking a fork can be done well, or it can be done poorly when it comes to preserving tire clearance and brake reach.

Examples: In the case study shown below, a road/sport frame's original fork is re-raked in an attempt to yield the type of low-trail steering geometry currently of interest. The original rake of 44 mm is increased to 60 mm. These evaluations were calculated using a numerical frame geometry model, designed to solve on the new head angle when the fork length and/or rake are changed.

The configuration shown in the left panel is the original frame and fork geometry. The original fork length (FL) of 358 mm is characteristic of a fork designed to use a standard (47-57 mm) reach caliper brake, with the pads at the bottom of the slots. The calculated fork length-on-axis establishes the location in space of the lower end of the head tube. The rest of the frame design defines the dimensions of the rigid structure which will pivot around the rear axle as the fork design changes.

Three re-raked scenarios are listed in the right panel. The first results column shows how installing a fork of the same length, but with a greater rake, changes the head tube angle. The second and third columns show the resultant change in head angle with a re-raked fork where the fork length (FL) dimension has been reduced by 3 mm and 7 mm, respectively.



Fork Length (FL), mm	**358**	**358**	**(-3) 355**	**(-7) 351**
Rake (RA), mm	**44**	**60**	**60**	**60**
Fork Length-on-Axis (FLA), mm	**344.6**	**340.0**	**337.1**	**333.4**
Head Angle, degrees	**73.0**	**73.26**	**73.41**	**73.62**

As demonstrated above, a typical attempt to re-rake a fork easily may result in a head angle increase on the order of one-half degree. As a consequence, the steering geometry with this re-raked fork will provide less trail, and produce less wheel flop, than what would have been anticipated by simply using the bicycle's original head angle. All things considered, this is not necessarily bad, just different than what you may have expected. If the target trail value is highly important in your re-raking exercise, then you will want to reduce the new rake by a few millimeters to compensate for the steeper head angle.

We haven't mentioned the seat tube angle, This will, of course, mimic the change in the head angle. For riders who fine tune their saddle-to-pedals relationship, the steeper seat tube angle with a re-raked fork will call for moving the saddle back a bit. The magnitude of the saddle movement is small, but this is just one more thing to consider if you are already near to the travel limit on the saddle rails with the existing saddle/post combination.

How about building a new fork that will have the desired larger rake <u>and</u> enough length to preserve the bike's original head angle? You can, but not without extending the original brake reach. In the example above, a new fork with a 60 mm rake would have to be built with a length (FL) almost 5 mm longer than that of the original fork, in order to preserve the original 73° head angle. In situations where the brake pads already were close to the bottom of the slot, this much additional fork length would increase brake reach beyond the capability of the existing components.

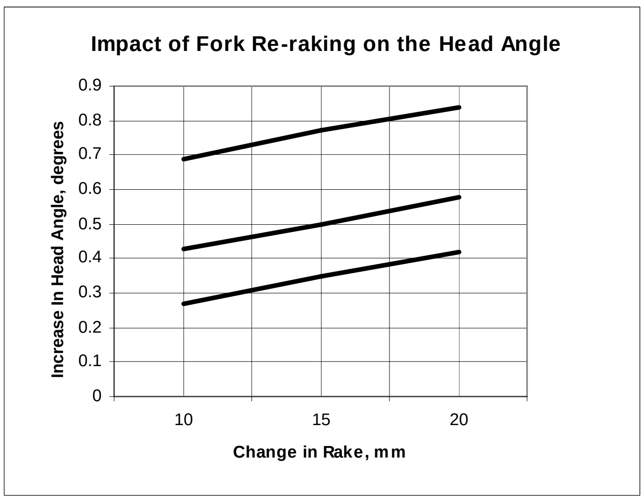
A Simple Graph: Having a numerical geometry model designed specifically for this topic is great, but I wanted to create a simple, convenient, and reasonably accurate graphical method. Running a large set of cases through the geometry model has demonstrated that this topic can be reduced to a basic graph, with an accuracy level suitable for the general discussion of head angle change.

The graph below defines the increase in head angle as a simple function of the increase in the rake and the reduction in the fork length.

This plot is suitable for the following conditions:

- Original fork length (FL) from 350-370mm (most 700C through 26" wheeled frames),
- Original fork rake from 40 mm to 55 mm,
- Original head angles from 72° to 74°, and
- Original wheel base values in the range from 990 to 1070 mm.

The three curves are drawn for parameter values at the midpoints of the respective suitable ranges. At the ends of these ranges, some of the variables introduce a bit of variance, which may be counteracting. For most real world cases, however, this graph probably should be considered to have a variance band of no more than ± 0.03° in the projected increase in the head angle.



In this plot, the three lines represent different levels of reduction in the fork length (FL), as a consequence of the re-raking process.

Upper line = 10 mm reduction in FL

Middle line = 5 mm reduction in FL

Lower line = 2 mm reduction in FL

Example: 15 mm increase in rake,
5 mm reduction in FL,
Head angle increases by 0.5 degrees.

In Summary: For the bicycle owner contemplating having a fork re-raked, understanding the issues described here will assist in deciding if that frameset really is a good candidate for the modification, and in communicating effectively with the framebuilder who will perform the task. Better to be educated in advance, than to be disappointed afterwards.

Under the right conditions, a well executed fork re-raking may be a viable technique to convert an existing bike into a low-trail steering geometry. If your fork already has marginal clearances for tires and fenders, it is not a good candidate for re-raking. On the other hand, if you have generous clearances, and if your brake pads are near to the bottom of the slot, a careful re-raking of the fork should pose few problems. Just make sure that you discuss with the framebuilder how the act of re-raking will shorten the fork and shrink these clearances and the brake reach. And, when figuring the new rake-and-trail relationship, remember to factor in the small increase in head angle that is a side effect of the re-raking process.

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